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Impact Detector for Implantation into Perishable Fruit

Significant criteria for evaluating damage risks for perishable fruit are necessary to improve quality management. Currently used certification instruments for fruit production systems do not contain methods and means suited to satisfy the specific requirements for fruit quality and safety. A newly developed innovative impact detector for implantation into perishable fruit and for real-time data transmission and processing could be helpful in overcoming present difficulties in evaluating mechanical impacts according to specific fruit properties.

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Keywords

Mechanical load, perishable fruit, impact detector for implementation

Potato tubers, carrots, bulb onions as well as apple fruit undergo numerous mechanical impacts during handling from harvest to packaging for retail market. It is well known that single mechanical impacts but also the sum of mechanical impacts contributes to reduction of quality and last to appreciable economical losses. However, the detailed evaluation of mechanical impacts concerning fruit specific effects is very difficult. For practical application of the wide knowledge on causal relation between mechanical impacts and damage of perishable agricultural products, the presently available guidelines for certification of production systems do no contain well suited methods and means [1].

The state-of-the-art means for acquisition of mechanical impacts on perishable fruit is the produce dummy ("electronic fruit"), i. e. an electronic instrument simulating the size and - to some extent - the shape of real fruit, and enabled to acquire data on impact acceleration or pressure load [2, 3, 4, 5]. However, these electronic instruments currently used in agriculture are not sufficiently adapted to actual fruit properties, and therefore, the obtained data cannot be directly transferred to real fruit. An additional drawback of currently available commercial produce dummies is that the costs for practical use of are relatively high.

Adaptation through "implantation"

An approach to solve this problem is to miniaturise the electronic data acquisition unit as far as possible to fit and to implant into the real produce like a potato tuber, a carrot or an apple fruit. For this purpose, a common research and development project was carried out by ATB Potsdam-Bornim and two small enterprises (deka Sensor+Technologie und teleBITcom).

In practical harvest and postharvest technology for agricultural products, for instance potatoes, mechanical impacts are the dominant mechanical load. Therefore the objective of the data acquisition was specified: acquisition of mechanical impacts by using tri-axial acceleration measurement with a

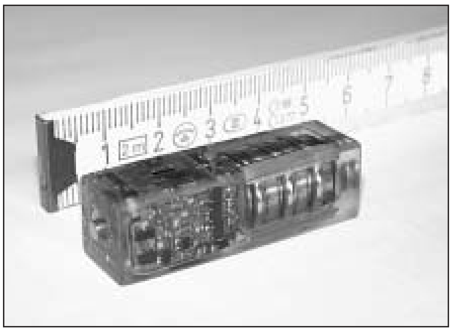

Fig. 1: Data transmitter for implantation (all parts are cast integral in an epoxy resin block; right the button cells, left the PCB's, and left outside one of the two charging connectors are visible)

sufficient high sampling rate, and radio transmission of the data in real-time.

The objective of miniaturisation of electronic circuitry could be achieved by using conventional SMD technique, i. e. a cost-saving manufacturing was possible. Finally the implant had to be protected against mechanical and chemical influences.

Specific radio transmission technique

The final system consists of two components: an autarkic data transmitter with acceleration sensor, and a slight hand-held data receiver. Size and weight of data transmitter were, as provided in the objective, small enough to fit with size of apple fruit, potato tuber or carrot (*Fig. 1*). The dimensions are smaller than those of a Mignon battery (R6). The power supply of data transmitter was built based on rechargeable NiMH button cells with capacity sufficient for several hours duration of operation. Tri-axial acceleration data are acquired with high sampling rate. The measuring data of the three axes are digitised and transmitted online by reliable radio contact to the data receiver. There they are available for real-time monitoring and additional more detailed evaluation. The parameters of the data acquisition and transmission system are shown in *Table 1*.

Drop test with potato tuber

The implantation is done by removing a piece with suited size and shape from the real produce, and replacing it by the data transmitter. Because of the relatively higher density of the data transmitter, the implantation procedure leads to an increase of the

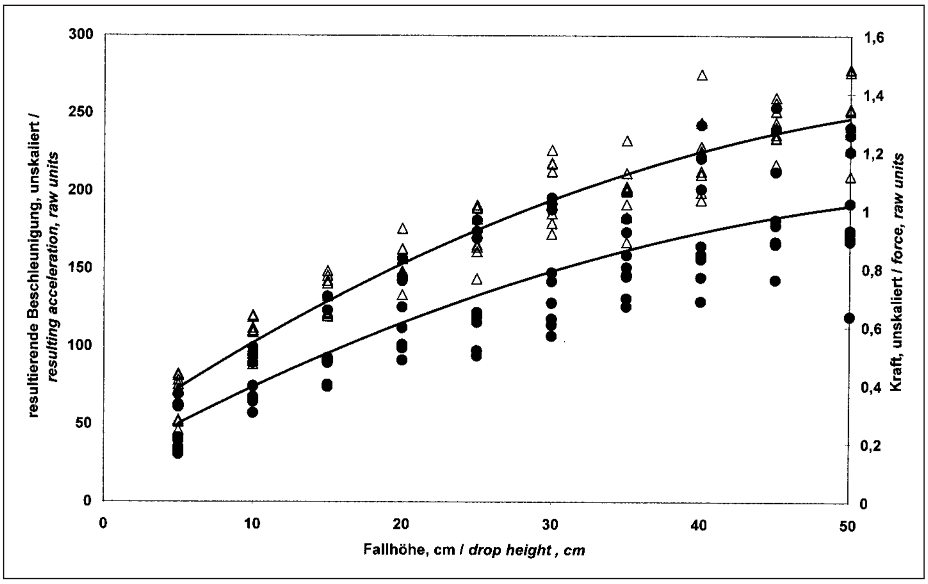

Fig. 2: Acceleration (•) data of data transmitter implanted into a potato in comparison with reference data of measured impact force (∆) obtained during drop test at heights from 5 to 50 cm onto steel plate

produce weight. In the case of a 100 g tuber the weight increases by about 5 %.

To operate the data acquisition system, the data receiver is connected to the USB interface of a PC. The PC and the data receiver are switched on. After the data transmitter is implanted in the produce, a permanent magnet is used to switch on. The operation of the data transmitter is indicated on the data receiver by LED. Then the data acquisition system is ready to measure mechanical impacts.

A laboratory test was carried out with a 160 g potato tuber cv. “Agria”. After implanting the data transmitter and starting the data acquisition, the tuber was dropped each three times with three different orientations from the same drop height onto a steel plate. The drop height was stepwise increased from 5 to 50 cm. Below the steel plate, a force transducer was installed to record the impact force. The maximum of resulting impact acceleration as well as the maximum of impact force were evaluated. Both parameters show significant correlation ($R^2 = 0.86$). The trend lines, i.e. the relationship of both parameters vs. drop height could be approximated by square function (*Fig. 2*).

The measurement of single acceleration data of the three axes provides detailed information on impact direction and also on the corresponding location of the produce surface. Consequently, the impact load characteristics on specific locations of the produce can be analysed and the occurrence of critical situations can be evaluated. A specific software module was developed to visualise the distribution of mechanical impact according to direction and intensity. The software module allows to simulate the shape and size of typical products, and to provide a three-dimensional projection of the distribution of mechanical impacts on the produce surface (*Fig. 3*).

Geometrical and mechanical parameters		
Dimensions	Length / mm	42
(Cuboid with squared	Maximum width / mm	~ 17,5
front face of ~	Volume /cm^3	7
13 mm width)		7
Weight / g		15
Average density / g/cm^3		2,1
Measuring parameters		
Acceleration sensor:	Number of measuring channels	3
	Measuring range/ G (1 G = 9.81 m/s^2)	200
Signal processing::	Sampling rate / 1/s	~ 3200
	Data resolution / Bit (every channel and vector sum)	8
Operation parameters:	Duration of continuous operation / h (with rechargeable accumulator)	> 5
	Operation temperature range / °C	+5 ... 35
Additional features	Waterproof, resistant against fruit acids; cast in epoxy resin	
	Radio transmission range / m	> 15
Data processing:		
Platform	PC (notebook), PIII min. 800MHz, Win2000 or XP, USB interface	
Data presentation	Calibrated acceleration/time diagram (online and offline) , three axes and vector sum	
Data export as ASCII-Table	Table with several columns: clock time, acceleration, time markers	

Table 2: Parameters of the data transmitter for implementation

Future prospects

The implantable data transmitter can be used in the same way like “electronic fruit” for impact data acquisition in production chains of harvest and postharvest handling. After putting in the produce flow of the process to be tested, the run of the produce with implant can be visually monitored. This task is facilitated by using the specific feature of online audio signalisation of occurring impact events by headset. The data receiver is equipped with several keys that can be used to record time markers for signalisation of passing pre-selected points in the production chain. The recorded time markers will be helpful to allocate the recorded impact data and to detect the impact sources in the production chain. After the end of the run through the production chain, the produce with implant can promptly used for further measuring runs.

If suitably calibrated, the actual impact load as well as the location of mechanical impact on the produce surface can be determined. Therefore, the implantable impact detector has high potential to refine the test of production chains. Particularly, the transferability of acquired impact data on the real produce can be improved. That could provide a basis to add more objective criteria to the certification instruments for production chains.

Literature

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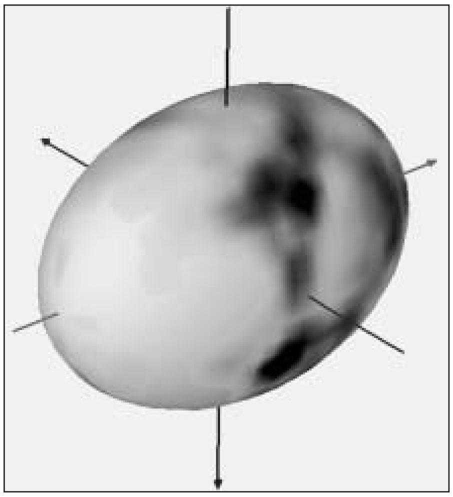

Fig. 3: Example of visualisation of impact load distribution according to direction and intensity