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Mechanical Impact on Carrots during Mechanised Packaging

Washed carrots are mechanically harvested, transported, graded and packed. During these handling processes they undergo intensive mechanical impact that can decrease quality and shelf life. In particular, packaging in foodtainers is one of the processes with very high mechanical impact. In order to quantify it, an impact detector was implanted directly into a single carrot to determine mechanical impact accelerations occurring during transport through the packaging machine. By analyzing the impact data, the frequency and magnitude could be measured, and critical aspects of each technical section identified. The impact data recorded can be used to reduce mechanical impacts during mechanical handling in the future.

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Keywords

Mechanical load, perishable fruit, impact detector for implementation

By using combination weighers, the packaging process for carrots consists of several sections: feeding, stringing, decollating, weighing, aligning, and punnet filling. When passing single phases like stringing and decollating, the carrot bulk is scarified by excitation of vibration, i.e. multiple small forces act on the carrots. Different transfer points between the phases are necessary to assure an effective transportation. Depending on the design of transfer points and on the evenness of carrot flow, the single carrots drop or swim, and they undergo mechanical loads due to impacts. Therefore, each transfer point represents a critical point.

Measurement by using an implanted sensor

To detect the mechanical impacts on carrots during packaging, a data transmitter with impact sensor has been implanted into a carrot [1]. This data transmitter has a length of 42 mm and cross section of 13 mm • 13 mm. The sensor acquires triaxial accelerations with a sampling rate of 8 kHz per axis, and the measuring data are transmitted wireless online to a portable data receiver.

Two carrots (no. 1 and no. 2) with diameter of about 30 mm but different length were selected for the tests. To place the data transmitter into one of these carrots, a cylindrical hole with a diameter of 15 mm was driven about 60 mm deep into the carrot. Thereafter the data transmitter was plugged in this hole. The remaining hole was filled with a suited part from the top of a second carrot. The implanted parts were protected against undesired displacing by means of adhesive tape. Simultaneously, this coloured tape provided a useful marker for visual identification of the carrot with implanted data transmitter within the carrot flow. This carrot was used to investigate the mechanical impact of carrots during packaging in 1 kg punnet (*Fig. 1*). The carrots no. 1 and no. 2 selected before were used to test two types of packaging machines (types A and B) manufactured by different companies. Carrot no. 1 was used for both machines, carrot no. 2 only for type B.

Parameters of mechanical impact

A single impact event is analysed based on the time characteristics of impact acceleration or impact force and derived parameters such as peak value and impulse (= integral of impact force over time). The high sampling rate of the acceleration sensor is useful to acquire impacts with duration of a few milliseconds (*Fig. 2*).

Normally, the peak value is the crucial factor for the damage risk of a carrot due to a single mechanical impact. That means, if the peak value exceeds a specific threshold value, then produce damage is expected to occur. The knowledge on the threshold value is necessary to evaluate the risk of produce damage.

Besides the magnitude of a single impact, the total number of impacts occuring during the run through machinery affects the risk of produce damage [2, 3]. During run through harvest and postharvest processes, the carrots undergo a multitude of mechanical impacts. Many of them are caused only by mechanized packaging (*Table 1*).

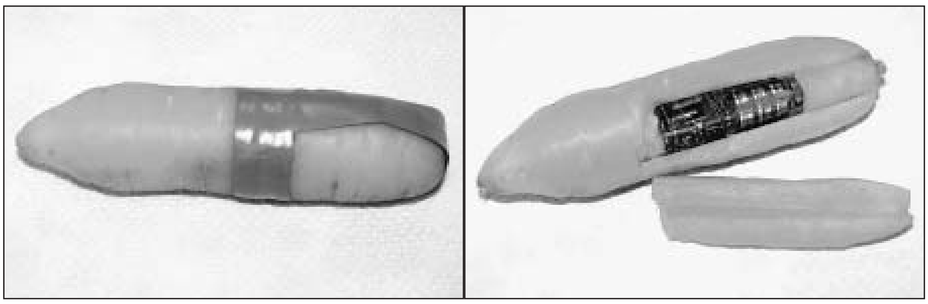

Fig. 1: Carrot with implanted data transmitter (left: carrot ready for measurement, right: carrot opened after completing measurements)

Results of impact measurements

The number of mechanical impacts recorded during the run of a carrot through each of the both types of packaging machines was in average above 100, particularly for type A above 200. Predominantly, high numbers of impacts occurred in the first sections from feeding to weighing. It should be mentioned that only mechanical impacts with peak value above 12 g's were considered (dimension g's means the multiples of the gravity g = 9.81 m/s^2). This high number of impacts was recorded particularly in the section of feeding and stringing of carrots, and there the number of impacts was subjected to high fluctuations. The reason for that could be the inadequate high feeding rate on packaging machine type A.

The resulting average peak values did not show significant differences between both types of machines. The maximum and minimum values in *Table 1* indicate the range of variation of maximum impact recorded in a single measuring run considering all measuring runs. Accordingly, the maximum impacts reached approximately the upper limit of the measuring range of the acceleration sensor.

For analysis of mechanical impacts it is useful, to consider the relation between motion and acceleration of elastic bodies under impact conditions. During impact of a carrot (M) against a fixed plate (U), the impact acceleration a depends on the impact speed v_M and the mass m_M of the carrot as well as on the elastic properties of both the carrot and the plate. When the elastic properties are described by the spring constants k_M and k_U, then the relation can be written in simplified way as follows

$$a = v_M \cdot \sqrt{\frac{1}{m_M} \cdot \frac{k_M \cdot k_U}{k_M + k_U}} .$$

From this relation, the most important influencing factors for reduction of mechanical impacts can be derived. These are the impact speed v_M and the spring constant k_U of the plate, where the carrot is hitting on. High impact speeds are due to big drop heights but also due to high differences in the transport speeds and directions of the conveying units before and after the transfer point. High spring constants stand for hard materials of the plate, and therefore for high impact accelerations.

By using this equation it is possible to explain a little higher peak values of impact acceleration recorded with carrot no. 2 that has lower mass than carrot no. 1.

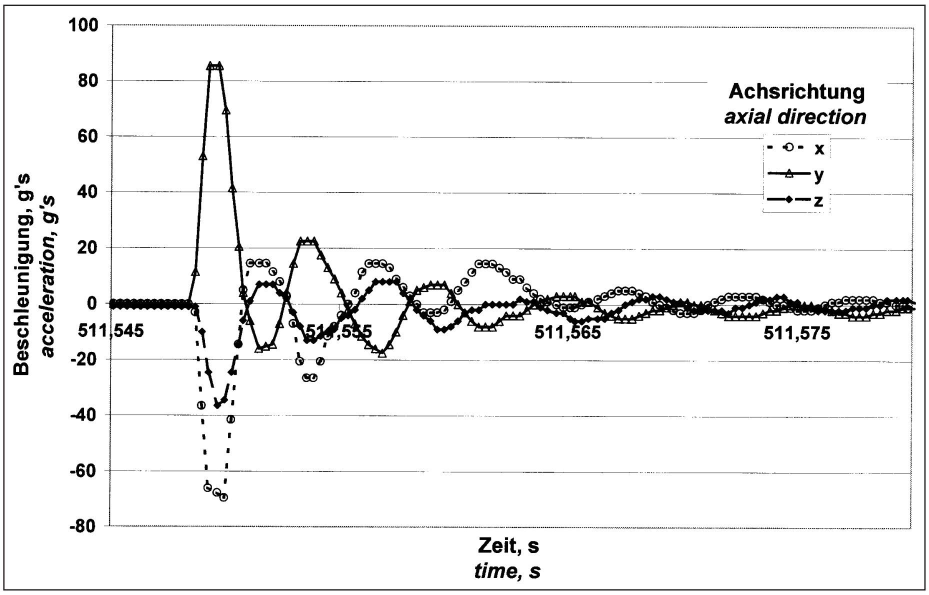

Fig. 2: Record of accelerations in the three axial directions during an impact event over a period of 35 ms (data transmitter implanted in a carrot with weight of 152 g and length of 170 mm)

Evaluation of mechanical impacts

The relation between on the one side the number and the magnitude of mechanical impacts and on the other side the deterioration of produce quality (produce damage) is not constant. It is highly affected by genetic, physiological and environmental factors, and the determination is very expensively. To obtain an economical assessment of mechanical impacts it is recommended to take into account also the intended use of the product, and the relevant quality properties. Therefore, different approaches for risk assessment are possible.

For instance, a risk index was calculated based on the results of impact data acquired during measurement of several runs through the section of production technique. This index is defined as product of average magnitude (peak value) of impacts and average number of impacts [4]. A similar index was introduced for an elliptical-shaped electronic potato, and consists of the sum of impact energies calculated from the acceleration data [5].

If the first risk index is applied to the impact data of carrot packaging, then the index value of type A is 7215, and the index values of type B are 4269 and 4826, respectively. These index values are suited to compare the both types of packaging techniques, but they do not provide any conclusion on the quantity or the economic relevance of caused deterioration of produce quality.

Table 1: Measuring results of mechanical impact on carrots in two different packaging machines by using the implanted impact detector

	Carrot 1 (m = 152 g, l = 170 mm)				**Carrot 2 (m = 71 g, l = 117 mm)**	
Type of machine (number of measuring runs)	A (n = 27)		B (n = 29)		B (n = 21)	
Parameter	**Number of impacts**	**Peak value g's**	**Number of impacts**	**Peak value g's**	**Number of impacts**	**Peak value g's**
Average	237	30	117	36	127	38
Standard deviation	165	20	35	28	30	28
Maximum	646	276	223	254	183	297
Minimum	69	110	51	85	57	118

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