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TuberLog and Co. – measuring behavior of artificial fruits in laboratory

Artificial fruits are used for measuring mechanical load in order to detect critical points in harvest and following processing lines. For realistic measurement of impact acceleration the measuring devices should have similar physical properties as the real products. Results are presented of drop experiments and measurements in a laboratory processing line. Therefore, different acceleration sensors with plastic cover and a sensor which is implanted in a potato tuber were used. The measuring systems TuberLog, IRD and Mikras are in a similar manner appropriate for detection of critical points in a processing line according to this study. Measuring with synthetic devices results in an overestimation of impacts onto firm material compared to measuring in a real product.

Keywords
Impact acceleration, impact force, potato, mechanical damage

Abstract

Landtechnik 68(4), 2013, pp. 259–264, 5 figures, 2 tables, 9 references

Mechanical loads during harvest and processing cause severe superficial as well as internal damage to agricultural products, e.g. black spot disease of potatoes which is externally not visible. Since about 30 years so-called artificial fruits are applied in harvest and processing lines in order to detect critical impact points. Changes of machine settings or application of drop chutes and soft impact material enable a risk reduction of produce damage during their transportation.

Artificial fruits measure mostly triaxial impact acceleration. They have been developed with different shape and size in order to imitate real products. Some are shaped as spheres like onions or apples (IS 100, Techmark, USA) [1], some are longish-shaped like potato tubers (PTR-200, SM Manufacturing, Denmark; TuberLog, Esys, Berlin) [2]. One has been developed with a small spherical form (Ø 2,5 cm) like berries (Berry Impact Recording Device, BIRD, USA) [3]. Some systems are available with different shapes in which the impact sensor is embedded (IRD, Techmark, USA) or the user can chose different covers for inserting the sensor (Smart Spud, Sensorwireless, Canada) [4]. A miniaturized sensor Mikras (Esys, Berlin) has been developed in order to consider beside the shape as well the tissue properties of the produce when impacts are measured. It can be implanted in variable products as potato tuber, apple, carrot or pickling cucumber [5;6].

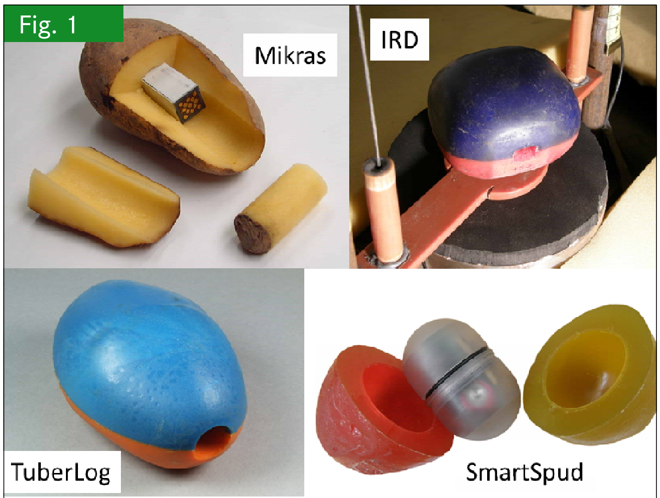
The aim of this study was the comparison of impact acceleration, which has been measured using the electronic fruits TuberLog, IRD and Smart Spud and the implanted sensor Mikras under defined conditions. This comparison enables a better evaluation of the measuring results obtained with the respective systems. The experiments have been carried out using a drop simulator for free-fall tests onto steel or PVC and a processing line simulator.

Material and Methods

For the comparison of triaxial acceleration measurement the systems here presented have been used (**Figure 1**):

- Mikras implanted in real potato tubers
- Mikras implanted in a synthetic potato dummy from Grimme company (Landmaschinenfabrik, Damme) (not pictured)

Fig. 1



Artificial fruits for measuring impact acceleration in processing lines of agricultural products (Fotos: ATB)

- IRD (Impact Recording device)
- Smart Spud with a casing fabricated by Grimme company instead of the original casing
- the acceleration logger TuberLog

Table 1 presents the technical data of the devices and the specific settings for this study. The systems differ in the parameters shown in the table and also in their mode of data recording. All systems allow an attribution of the measured impact values to the time elapsed. Mikras and IRD provide all impact acceleration values related to the time in the directions of three axes. The IRD system registers additionally the velocity change which indicates whether impacts cause produce damage according to preset boundary values. Smart Spud or TuberLog record only the peak acceleration values of the time related impacts.

Free-fall experiments

A drop simulator was used for dropping the devices (ten times each) from 10 cm height onto steel or onto PVC foam of 5 cm thickness, which can be fixed on the steel plate [6]. Therefore the devices have been placed manually into a circular hole (diameter 40 mm) in a free-movable sliding carriage on two vertical guide wires. The devices dropped after the free-fall in the middle of their flat side onto the impact material. The drop simulator was fitted with a piezoelectric force sensor below the impact plate, which measured the impact force related to the time with a scanning rate of 10 kHz. The Mikras sensor was implanted in a round shaped potato tuber of cultivar Karlena from storage during 4 month.

Run in a processing line simulator

For comparison of the impact detection the devices run each 10 times through a continuously moving processing line simulator (**Figure 2**). The produces were conveyed with three belts (2 conveyor belts in horizontal position and one drag conveyor belt with ascending slope of 30.5°). The line has a total length of 5.2 m with conveyor speed between 0.19 m s^{-1} and 0.35 m s^{-1}. The products run over 4 drop steps and 2 small chutes during each course through the line. For the measurements with Mikras potatoes of the cultivar Karlena with round shaped tubers and of

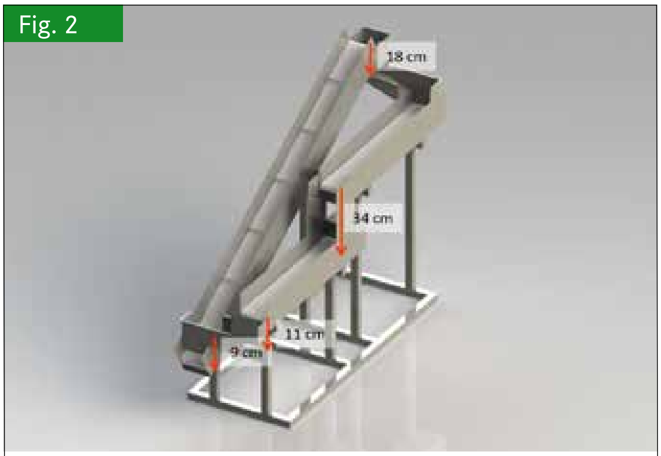
Table 1

Impact acceleration measuring devices with selected specific settings for the application in this study

	Mikras	Mikras	IRD	Smart Spud	TuberLog
Form/*Shape*	in Kartoffelknolle implantiert *implanted in potato tuber*	in Dummy implantiert *implanted in dummy*	flach, kissenförmig *flattened sphere*	eiförmig *egg-shaped*	knollenförmig *like potato tuber*
Hüllmaterial *Skin material*	Kartoffelgewebe *potato tissue*	Kunststoffdummy *plastic dummy*	Kunststoff *plastic*	Kunststoff *plastic*	Kunststoff *plastic*
Masse/*Mass*	14 g + Produktmasse *14 g + mass of real product:* Kartoffelknolle/*potato tuber* 203 g (Fallversuch/*free-fall test*), 170 bzw. 245 g (Test in Förderstrecke/*processing line simulator test*)	14 g + Produktmasse *14 g + mass of real product:* Dummy/*dummy* 213 g	270 g	314 g	200 g
Größe/*Dimension*	Implantat/*implant* 42 x 13 x 13 mm Kartoffel/*potato* Länge/*length* 81 mm, Durchmesser/*diameter* 59 mm	Dummy/*dummy* Länge/*length* 97 mm, Durchmesser/*diameter* 66 mm/53 mm	Länge/*length* 90 mm Durchmesser/*diameter* 79 mm/52 mm	Länge/*length* 108 mm, Durchmesser/*diameter* 75 mm	Länge/*length* 90 mm, Durchmesser/*diameter* 65 mm/50 mm
Härte/*Hardness*	nicht bekannt *not specified*	90° Shore A	nicht bekannt *not specified*	90° Shore A	80–85° Shore A
Messparameter *Measuring parameter*	Triaxiale Gravitationsbeschleunigung/*triaxial gravitational acceleration*				
Abtastrate *Scanning rate*	3 kHz	3 kHz	4 kHz	nicht bekannt *not specified*	3 kHz
Messwertschwelle *Threshold for triggering measurement*	30 g[1)]	30 g[1)]	30 g[1)]	nicht bekannt *not specified*	30 g[1)]
Messbereich *End of measuring range*	200 g[1)]	200 g[1)]	500 g[1)]	nicht bekannt *not specified*	250 g[1)]
Auflösung/*Resolution* Genauigkeit/*Accuracy* (Herstellerangabe/*Manufacturer*)	~ 1 g[1)] nicht bekannt *not specified*	~ 1 g[1)] nicht bekannt *not specified*	~ 2 g[1)] 3 %	nicht bekannt *not specified* nicht bekannt *not specified*	0,1 g[1)] +/- 1 g[1)]

[1)] Vielfaches von g (Erdbeschleunigung)/*Multiple of g (gravitation)*.

Fig. 2



Processing line simulator for conveying agricultural products after harvest

the cultivar Ludmilla with longish shaped tubers have been used, respectively 5 tubers of 170 ± 10 g and 5 of 245 ± 10 g mass.

Results

Free-fall experiments

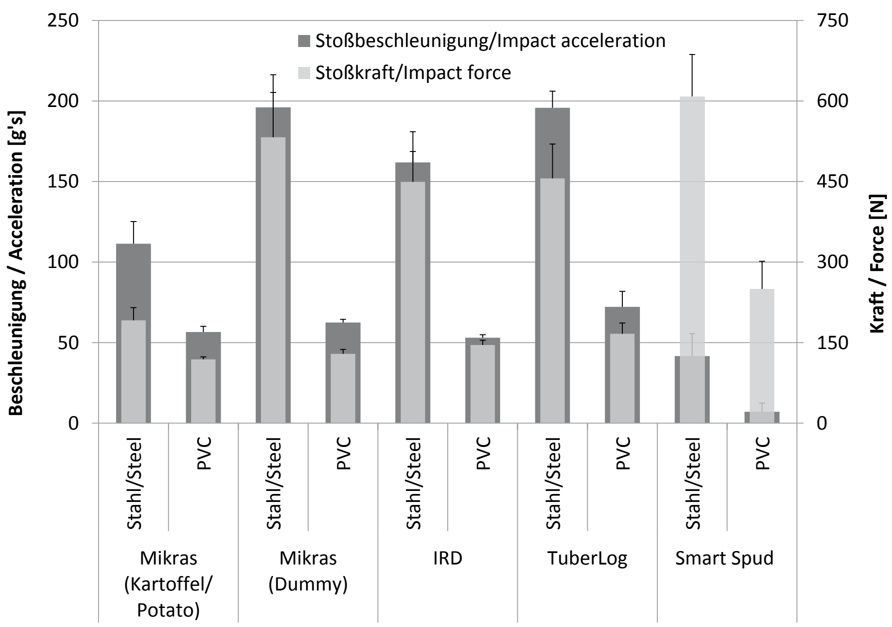
Mikras implanted in potato tuber recorded an average peak acceleration of 110 g's when laterally dropped from 10 cm onto a steel plate (**Figure 3**). The peak acceleration was almost doubled with Mikras implanted in a synthetic potato dummy. Also IRD devices and TuberLog each recorded high acceleration values of nearly 200 g's. One reason is probably that the devices with synthetic casing are more firm than the stored real potato. Using turgescent freshly harvested tubers of higher firmness the difference in peak accelerations might be less extreme for falls from the same height. In past free-fall experiments we observed a reduction of peak force values of 10 % to 20 % in potatoes during storage period. Overall the repetitive test falls of electronic fruits produced consistent impact acceleration values, which was shown by low standard deviation of their peak measurement values up to 14 g's.

When falling from 10 cm onto PVC foam the average peak acceleration was similar about 50 ± 20 g's for all systems, except Smart Spud. Measurements with Mikras during a potato harvesting process resulted in similar impact acceleration values when using a real potato tuber as well as the synthetic dummy [7]. Most likely the recorded impacts of the harvest processes occurred after dropping onto soft materials (e.g., soil, other tubers, cushioned conveyor belts) rather than on a firm material like steel.

In spite of similar hardness of the casing Smart Spud recorded much lower peak acceleration values than the other systems. Also other authors observed a lower sensibility of Smart Spud when detecting impacts, e.g. compared to IRD [8].

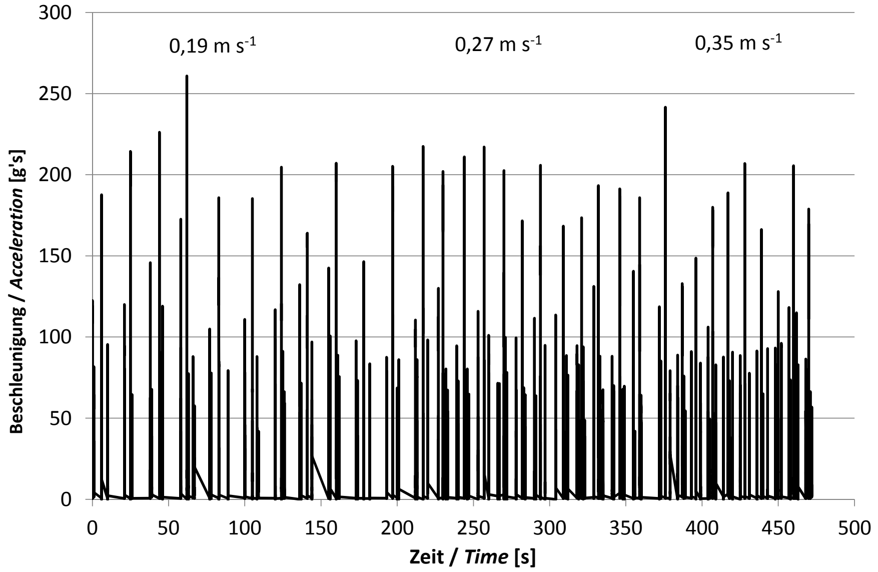
The peak force values which have been recorded by the force sensor at the drop station for falls from 10 cm height onto steel were much lower for impacts of potato tubers than that of the other devices such as tuber dummy, IRD, TuberLog, and Smart Spud. The reasons are higher firmness and mass of the electronic fruits. The relationship of the force values and the acceleration values measured with Smart Spud deviated considerable. This means that the impact intensity is measured insufficiently with this acceleration sensor.

Fig. 3



Peak acceleration measured from different electronic fruits (lateral drop, height 10 cm, onto steel or PVC) and peak force measured by a sensor in the drop simulator

Fig. 4



Measurement of impact acceleration with Mikras implanted in a potato Karlena (170 g) running through the processing line simulator (3 conveyor speeds, each ten runs)

The drop experiment shows that both the material of the sensor casing and the impact material influence strongly the peak acceleration and the peak force measurement values. During a fall onto soft material an important part of the impact energy is absorbed and not converted into rebound energy [9].

Run in a processing line simulator

Exemplary **Figure 4** shows the impacts related to the time of a potato (Karlena) in which Mikras was implanted for several runs through the processing line (at 3 conveyor belt speeds of 0.19 m s^{-1}, 0.27 m s^{-1} and 0.35 m s^{-1}, each 10 runs). The highest impact acceleration values have been measured at the high drop step of 34 cm height (**Figure 2**).

During 10 runs in the processing line simulator the number of recorded single impacts was very different for the tested electronic fruits with threshold setting of 30 g's. TuberLog registered the highest number of impacts of all electronic fruits where Smart Spud recorded the least impacts (**Table 2**). Beside the recording modes or different levels of sensor sensitivity also the shape and the cover material of the devices might influence the number of recorded impacts. For example, the egg-shaped Smart Spud rolls easier compared to flattened or potato-shaped devices.

Increasing the conveyor speed resulted in a higher number of impact measurements for all tested devices except Mikras. The frequency of slight impacts between 60 and 100 g's increased and at the same time the number of strong impacts decreased. The faster movement of the conveyor may cause an attenuation of the impact intensity at the high drop step (data not shown).

According to previous tests only impacts with acceleration > 60 g's were relevant for produce damage. Therefore the frequency distribution histograms do not consider impacts with lower peak acceleration (**Figure 5**). The peak acceleration measurements of Mikras implanted in the dummy, IRD, and TuberLog during the runs in the processing line at 0.35 m s^{-1} conveyor speed result in a similar frequency distribution (**Figure 5**, A). Smart Spud did not record any acceleration values > 100 g's.

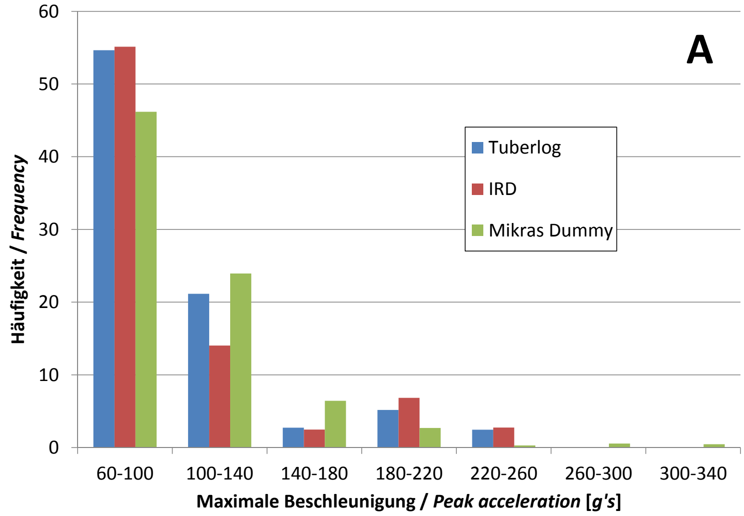
The Mikras sensor in a potato tuber recorded a lower number of impacts in the range of 60–140 g's than the electronic fruits. Using the longish-shaped potato Ludmilla less impacts of 60–100 g's have been measured than with the round shaped Karlena. The reason might be different paths of motion of the tubers on the conveyor belts (**Figure 5**, B).

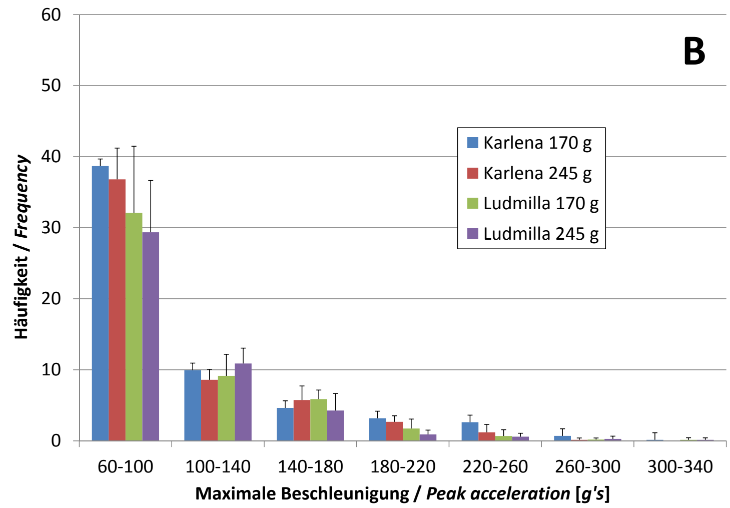
Table 2

Number of impacts detected during 10 runs through the processing line simulator

Bandgeschwindigkeit ***Conveyor velocity***	**Mikras (Kartoffel/*potato*)**	**Mikras (Dummy/*dummy*)**	**IRD**	**Smart Spud**	**TuberLog**
0,19 m s^{-1}	117	136	129	69	163
0,35 m s^{-1}	102	117	139	78	170

Fig. 5





Frequency distribution of impacts with peak acceleration of ≥ 60 g's measured with electronic fruits (A) and Mikras in potato tubers (B) during 10 runs through a processing line simulator (conveyor speed 0.35 m s^{-1})

Conclusions

Elasticity and hardness of the impact material as well the casing materials of the devices influence strongly the peak acceleration values when the devices drop from an uniform height. The high acceleration values measured with IRD, TuberLog and Milkras in the synthetic dummy suggest an overestimulation of the impact intensity compared to Mikras in the potato tuber when hitting a firm material. The casing properties of the electronic fruits are less important for drops onto damping impact material. Therefore a similar evaluation of mechanical load is possible as long as the produces do not drop onto hard materials like steel during the processing line.

A prediction of produce bruising risk based on measurements with an impact acceleration sensor requires a prior determination of relationships between the impact acceleration and the specific produce damage. The systems Mikras, IRD and TuberLog are suitable in a similar manner for determining critical points of mechanical load during processing according to this study. The reason for extremely low acceleration values and the small number of recorded impacts with the Smart Spud sensor is not clear.

The presented devices differ in their possibilities of data evaluation and handling during the measuring operations. Exemplary the practical application of TuberLog system is easy for the user. For research purposes Mikras and IRD are suitable because these systems provide all impact acceleration values in three axes related to the time throughout the entire measuring process.

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