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Effect of Dynamic Impact Load on Black Spot Bruise in Potatoes

A common research project of ATB Potsdam-Bornim and two SME is aimed to develop a modified miniaturized sensor for acquisition of impact acceleration of agricultural and horticultural products during harvest and post-harvest handling [1]. The telemetric data transfer to computer used before shall be replaced by internal data storing. In order to be able to use this sensor for prediction of produce damage such as black spot bruising of potato tubers in practice, the relationship between dynamical mechanical load and produce damage has been studied. The miniaturized sensor can be implanted into real potato tuber and then acquire tri-axial acceleration data. Therefore, it is possible to distinguish between repetitive mechanical impacts on the same location and those on different locations of the tuber surface, and, particularly, to evaluate its effect on tuber damage in relation to practical potato handling.

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Keywords

Mechanical sress, potatoes, blackspot, fall height, fall frequency

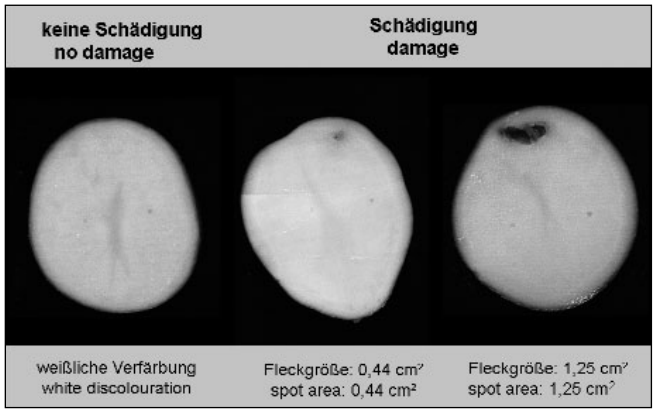

Fig. 1: Rating of internal damage at the impact site of potato tubers

Substantial economical losses in potato production are caused due to mechanical impacts during harvest and post-harvest handling which increase the risk of externally not visible black spot bruising. Particularly, susceptible cultivars exhibit high damage risk, mostly cultivars with high starch content. Additionally, insufficient potassium supply, low temperature during handling (< 12°C) and tall drop height [2, 3, 4] increase the damage risk. The effect of multiple mechanical impacts on the same location of potato tuber is not sufficiently investigated.

Relationship between mechanical impact and produce damage

Potato tubers cv. Afra and Milva were manually harvested from practical field production in the region Brandenburg and used for drop tests in laboratory in November 2007 and April 2008. Three weeks after harvest the starch content of cv. Afra was 17.0 ± 2.2 % and cv. Milva 14.7 ± 1.7 %. The potassium content of cv. Afra was 572 mg K / 100 mg fresh mass and cv. Milva 458 mg K / 100 mg fresh mass.

The potatoes were stored at 4 °C. 24 h before the tests, tubers with mass of 120 ± 30 g were taken from storage and held at test temperature of 12 °C. Drop tests have been carried out by using a fall apparatus. The tubers were oriented with apical end below and dropped from drop height selected before, one time or several times, onto a flat steel plate equipped with an impact force sensor. Thereafter, the potatoes were held 48 h at 33°C and 95 % relative humidity, and rating of internal damage was carried out. According to a computerized image analysis technique of ATB [5], the potato tubers were cut through the centre, an image of the cut surface was acquired. The dimensions of black spot bruises were determined by software Optimas®. The whole cut surface, the distance of bruises from tuber surface and their depth were calculated. Only dark, but not light white tissue discolouration was classified to be damaged (*Fig. 1*).

For both cultivars, repetitive drops from 5 cm up to 60 times did not cause any damage. During tests in November, only small number of tubers was slightly damaged (spot area up to 0.2 cm^2) after dropping 20 times from 10 cm. For drop heights above 25 cm up to 100 cm, the percentage of damaged tubers of both cultivars increased, but those of cv. Milva substantially more at big drop heights of 50 cm and 100 cm. At increasing frequency of drops at the same drop height, mostly the percentage of damaged tubers also increased. During tests in April, the percentage of damaged tubers was doubled at drop heights of 25 cm and 50 cm when frequency of drops was duplicated.

Compared to November, in April the tubers showed higher elastic compliance. Although the average of maximum impact forces were reduced, the percentage of damaged tubers increased in April for most of given test series.

In the present case the impact threshold for emergence of black spot bruise was found to be at drop heights between 10 cm and 25 cm onto steel, approximately ad-

equately to max. force of 200 N (*Table 1*). According to this study, damage due to extremely numerous mechanical impacts, even at small drop height, cannot be excluded.

The dimension of black spot area increased with increasing drop height, up to about 1.5 cm^2 at single drop from 100 cm. Also repetitive mechanical impacts on the same location of tubers of cv. Afra caused extension of the black spot area of damaged tubers in average from 0.3 cm^2 to 0.7 cm^2, if the tubers dropped two times from 25 cm, and eight times from the same height, respectively. Similar enlargement of discolouration in potato tubers is given, if the energy of a pendulum impact is increased from 0.3 J (adequately to 25 cm drop height and 120 g tuber mass) by double up to eightfold [6].

External tuber damage occurred for cv. Milva in the form of very small cracks even at fivefold drop from 10 cm, but for cv. Afra only at drops from 50 cm height.

When repetitive mechanical impacts with constant energy were conducted, e.g. by a pendulum impact tester on the same location of a potato tuber, then initially increasing rebound energy of the single impacts was observed. That was attributed to decreasing energy absorption within the stressed cell tissue, but after several impacts there the balance was redressed [7]. Also the current study showed in average of 20 tubers for repetitive impacts that the maximum impact forces tend to increase due to reduction of absorbed energy. Variations of single test specimens may be caused due to insufficient accuracy of the mean during the drop test (*Fig. 2*).

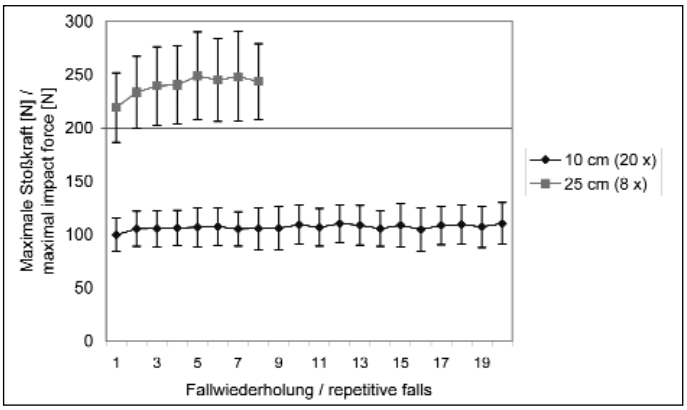

Fig. 2: Maximal impact forces for 20 repetitive falls of 10 cm height respectively 8 repetitive falls of 25 cm height (average of 20 tubers of the variety Milva)

Conclusions for damage prediction by using an implantable acceleration sensor

The future evaluation of measured data impact acceleration in handling lines should be related to the tuber orientation, i.e. the fall direction, considering the impact strength as well as the tuber mass. In the present case single impacts with forces below 200 N (calculated from measured maximum acceleration and tuber mass) had little effect on appearance of black spot bruises. Several impacts on the same location above this threshold led to smaller tuber damage than impacts evenly distributed over the tuber surface. Because of the various dependencies and the variability of damage threshold it is not sufficient to evaluate the risk of black spot bruising through repetitive mechanical impacts only by the sum of maximum forces. For potatoes cv. Afra in April, this sum accounted for 4000 N according to 60 times drop from 5 cm onto steel and did not cause any tuber damage, whereas the sum of 500 N according to a single drop from 100 cm caused damaging of 45 % of the tubers.

Numerous parameters affect the black spot susceptibility of potatoes. Therefore, the evaluation of the risk of black spot bruising through mechanical impacts during harvest and post-harvest handling has to consider not only the data of impact acceleration but also the current susceptibility of the lot of potatoes, e.g. by using a simple impact test and subsequent damage rating.

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Table 1: Percentage of damaged tubers and average maximal impact force for different fall frequency and fall height (sample of 20 tubers)

November											
	5cm			10cm			25cm			50cm	100cm
	10x	20x	5x	10x	20x	2x	4x	8x	1x	2x	1x
Mittlere maximale Stoßkraft [N] Average maximal impact force[N]											
Afra	81	74	128	135	135	236	260	244	383	376	560
Milva	82	77	126	138	141	225	243	250	344	356	507
Anteil geschädigter Knollen [%] Percentage of damaged tubers [%]											
Afra	0	0	0	0	0	0	0	5	20	30	50
Milva	0	0	0	0	20	0	40	15	20	40	80
April											
	5cm			10cm			25cm			50cm	100cm
	40x	60x		10x	20x	2x	4x	8x	1x	2x	1x
Mittlere maximale Stoßkraft [N] Average maximal impact force[N]											
Afra	66	65		118	116	219	212	222	337	352	508
Milva	70	69		104	107	208	238	240	330	354	469
Anteil geschädigter Knollen [%] Percentage of damaged tubers [%]											
Afra	0	0		0	0	10	20	30	25	45	45
Milva	0	0		0	0	5	10	25	35	70	95