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Mechanical harvest of pickling cucumbers

Spreewald region is the second largest pickling cucumbers producing region in Germany with a processing capacity of around 40 000 tons per year. Up to now pickling cucumbers are picked by hand supported by so called cucumber flyers. The main problems to keep pickling cucumber production in Germany are the high labour costs. In order to position the cucumber cultivation to be able to cope with future demands and challenges, an innovative mechanical harvesting technology was developed. Analyses of the mechanical load during the harvesting process, measured by an acceleration sensor, are presented and accompanied by product quality studies and results.

Keywords
Mechanical harvest, pickling cucumber, 3D-acceleration sensor

Abstract
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The internationally well established and protected brand name „Spreewald“ as well as the intense regional cooperation between vegetable growers and canning industry ensured a further successful development of the cucumber production in Spreewald region. Current production methods are, however, burdened by the very cost- and labour-intensive harvest of cucumber fruit. The cost pressure is further steadily amplified by imported canned vegetables. This trend may lead to a shift of the cucumber production to low-wage countries. The competitiveness of the entire production chain is under the pressure of seasonal employment. For this reason, there is a demand to employ the available workforce efficiently and to further develop the harvesting technology. The introduction of advanced mechanical harvesting technology for pickling cucumbers can be an attractive solution. This vision has now been realised by a collaboration of agricultural practice, processing and mechanical industry and scientific support. The project ”Mechanical harvesting of pickling cucumbers under the conditions of Southern Brandenburg” has been supported by the European agricultural fund for the development of rural areas ELER and the Federal State of Brandenburg in the years 2009 to 2013. The cooperation partners are Gurkenhof Frehn, Biohof Schöneiche, the fruit and vegetable processor “Spreewaldkonserve” Golßen GmbH in cooperation, and the Leibniz-Institut für Agrartechnik Potsdam-Bornim e.V. (ATB).

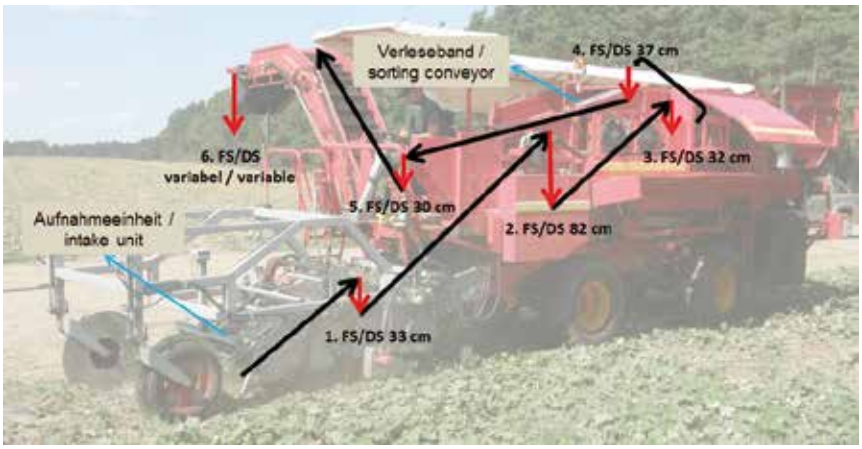
The aim of this project is to develop a technique for cultivation and mechanical harvesting of pickling cucumbers under the local conditions of Southern Brandenburg and to efficiently coordinate harvest with logistics and processing. Selection and testing of suitable cultivars and development of suitable cultivation techniques for mechanical harvested cucumbers were first emphasised in the project. This paper further focuses on the analysis of the technical process and the optimisation of the harvesting technology. Besides the technical challenge, mechanical harvest of pickling cucumbers also results in physiological quality loss [1]. It has been shown [2; 3] that mechanical stress (e. g. high drop steps) leads to a rise in metabolic reactions in pickling cucumbers. To examine the extent of mechanical stress on produce quality, intensity and effects of impacts during machine harvesting were recorded by an acceleration sensor implanted in single cucumbers.

Current state of harvesting technology

Currently, cucumber harvesting is supported by so-called cucumber flyers. Up to 38 employers are lying prone next to each other on “wings”, fastened right and left-hand side to the tractor pulled cucumber flyer. Facing the opposite direction, they are checking plants for ripe fruit, harvest them and put them on a conveyor belt that transports the cucumbers to a trailer. The advantages of this procedure are high product quality, harvest of small cucumber sizes, reliable removal of the stems, no damage to the plants and minimal technical work. However, this activity requires a pronounced practical know-how and the willpower to endure this rather awkward position for several hours. Depending on the prevailing temperatures, the crop is harvested at intervals of few days.

In the USA, mechanical one-time harvesting of pickling cucumbers has been carried out since the sixties [4]. The modality of cucumber production in the US, however, differs considerably

Fig. 1



Drop steps (DS) of the fully mechanized harvesting machine Pomac (Foto: M. Geyer)

from that applied in Europe. Harvested and processed cucumbers are much bigger, while small cucumbers are economically irrelevant. In contrast, in Germany, small fruit yield the highest sale revenue. According to texture analyses, a sorting size of 6 to 9 cm length is recommend for processing [5]. Besides this, other cucumber cultivars with leathery, rough and nubby skin are cultivated in the USA, which cannot be market in Europe. Moreover, in Germany, cucumber plants are predominantly produced on plastic mulch film to accelerate growth and suppress weed. American harvesting technique was not designed for this technique; the plastic film would be caught by the harvesting machine and would plug it. Harvesting on plastic mulch film is supposed to work with the help of specially developed patented collecting device with rotating cutters [6].

To make mechanical one-time harvesting economical, cucumber cultivars are necessary that provide high yields concerning sorting and quality, that is, plants should evolve tendrils with many small fruit of equal size. In Europe, leading breeders meanwhile have put cucumber cultivars on the market that better fulfil the requirements for mechanical one-time harvest. Breeding process, however, is still taking its time.

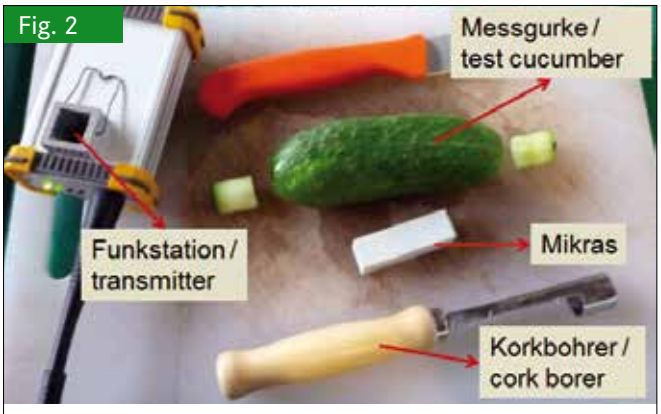
Test run

The tomato harvester Super Cosmo (Pomac Co., Mirabello, Italy) was selected as the basic machine. The first test runs showed that far-reaching modifications were necessary to adapt the machine to the pickling cucumber harvest. The entire intake unit (**Figure 1**) had to be newly constructed. This unit consists of a device to cut the tendrils above the soil surface and the intake unit itself. Together with the fruit, the tendrils are transported onto the intake elevator chain and with the help of elevator chains to the separating unit. However, the separating unit caused heavy damage to the cucumbers (**Figure 1** between 3. and 4. drop step), and, consequently, this unit was also newly designed. In August 2012, after numerous reconstruction measures, first test runs took place. To evaluate weak points in the process of the new harvesting technique, a miniature 3D-acceleration sensor (Mikras, Esys GmbH, Berlin, Germany) was implanted in otherwise intact cucumber fruit. Including memory and power supply, the sensor has the size of an AA battery and a mass of 14 g. Mikras measures impact acceleration with a frequency of 3 000 Hz [7; 8]. By means of a cork borer, cucumbers were hollowed out and the sensor was implanted in the middle of the bore hole. The ends of the resulting core were plugged into the fruit again and fixed with coloured tape (**Figure 2**).

To check the mechanical stress of the cucumbers on their way through the machine, the implanted test cucumber was placed on the intake unit (**Figure 1**) and ran, together with the product stream, through the harvesting machine until dropping on the sorting conveyor (**Figure 1**, drop step 1–4). One test run lasted about 10–14 s, then the machine was stopped. The mechanically harvested cucumbers were collected and visually evaluated according to damage pattern.

In addition, respiration rates of both hand-harvested and mechanically harvested fruit of the same cultivar (sorting size "6/9 cm") were measured in a closed system with an infrared gas analyzer (AMR-Sensoren, Ahlborn, Gelsenkirchen) to evaluate the influence of mechanical load [9].

Fig. 2



Implantation of the 3D-acceleration sensor Mikras into a test pickling cucumber (Foto: J. Surdilovic)

Results

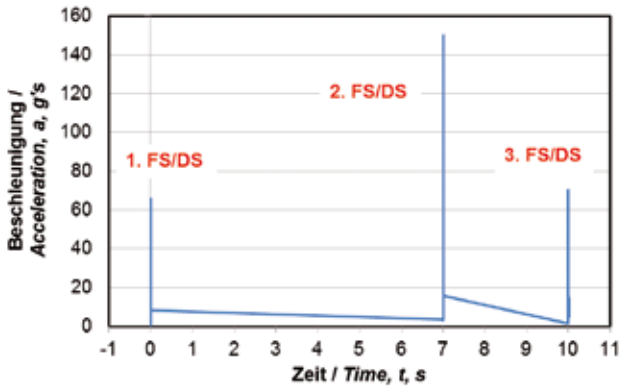
Harvesting in the tested machine includes 6 drop steps (**Figure 1**). At the first, fruit fall on a steel chain from a height of 33 cm. After this step, the tendrils with the cucumbers were transported by a steeply ascending steel chain belt, from which every tenth chain was rubberized. Immediately after the ascent, a second fall followed from a height of 82 cm onto a steel conveyor belt with sharp edges. As a result of the mechanical load measurements with the acceleration sensor, this drop step was considered critically. In the course of the different test runs, impact intensities with accelerations of about 150 g's (**Figure 3**) were measured (dimension unit correlate to multiple of acceleration due to gravity, g's = 9.81 m/s^2). Reaching drop step 3, the tendrils were gripped by the contra-rotating rolls and separated the cucumbers. After that, they fell from a height of 32 cm onto a short steel belt. At the first and the third drop step, accelerations exceeding 100 g's were measured (**Figure 3**). After being redirected at the 4th step, the cucumbers fell onto a long rubberized conveyor belt, which serves as a sorting conveyor. This conveyor transports the cucumbers to an elevator. Here, the fall height is 37 cm. The threshold for the sensor data was set to 30 g's and, therefore, at the 4th drop step no data were recorded by Mikras during all test runs. Hence, the fall onto the soft material was seen as unproblematically for the product. After step 4, the test runs were finished. The sensor was removed from the test cucumber, and the stored data transferred and saved at the transmitter station (**Figure 2**). In the course of the real harvesting process, two additional drop steps follow. At the 5th step, the cucumbers fall from a height of 30 cm onto the conveyor belt of the elevator. At the final 6th step, the cucumbers are transported to a trailer. Depending on trailer`s load, the fall heights vary.

Up to now, the quality of the mechanically harvested cucumbers was not satisfactory. Of all cucumbers (**Figure 4**), 21 % of showed minor to severe damages (n = 446). Of the damaged cucumbers, 15 % were broken. The rest of the damages consisted of cracks and punctual injuries. The reason for the high percentage of damages was attributed to the fall-height at step 2, the sharp plastic edges of the conveyor belt and the contra-rotating separating rollers, which were not installed optimally. They severely injured in particular small cucumbers.

Respiration measurements give information about the physiological activity of the cucumbers after harvest. Compared to hand-harvesting, fruit respiration was 30 % higher after mechanical harvesting (**Figure 5**). After harvesting, pickling cucumbers undergo further processing steps (sorting, packing, transport) during which they are exposed to further mechanical impacts. Therefore, mechanically harvested cucumbers must be processed as soon as possible; at best, within one day.

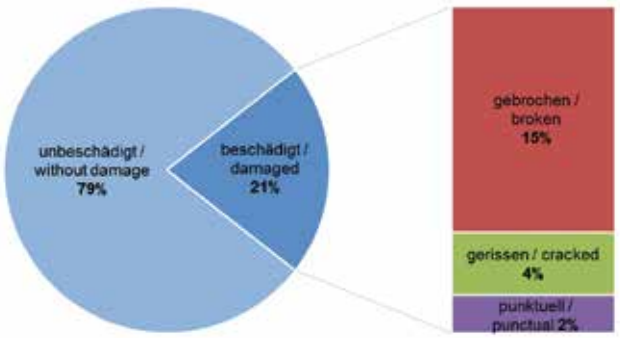
So far, results showed that smaller pickling cucumbers can be harvested mechanically; damages are, however, still much too high. Hence, the machine must be further improved with regard to the mechanical loads at nearly all transfer points.

Fig. 3



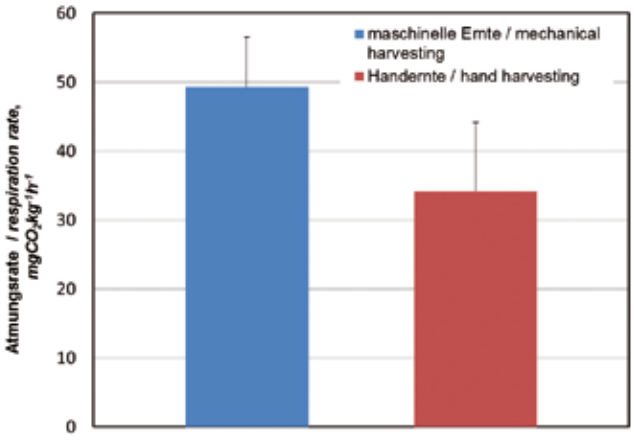
Example of measured impact acceleration with an implanted test pickling cucumber over one cycle from intake unit to sorting conveyor (DS 1–4, Fig. 1)

Fig. 4



Breakdown of damaged cucumbers (visual rating) after the mechanical harvesting process (n = 446)

Fig. 5



Respiration rate after mechanical and hand harvesting, measured 24 h (at 21 °C) after harvesting process (n = 36)

Conclusion

To introduce one-time mechanical harvest of pickling cucumbers in Europe, it is necessary, to further optimise the harvest technique and to breed improved cucumber cultivars that assure high yields of small and consistent sizes. Most possibly, the combination of hand harvesting at the beginning of season and mechanical harvesting at the end could be a solution to obtain optimal sorting and higher yields.

Besides this, the costs for seeds need to be considerably reduced and the growth of weed needs to be controlled by well-directed mechanical and chemical treatments as long as cucumbers are produced without plastic mulch film.

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