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Yielding mapping with potatoes

In Europe so far there is no commercial solution offered on the farm machinery market for yield mapping with potatoes. An important part of yield mapping is the throughput measurement technique. For this, the applied measurement principles are radiometric measurement, weight cell, optical measurement and impact plate. Because of their precision, the optical measurement and the impact plate were studied closer and evaluated. The resultant measurement errors lay in the areas which mean that yield mapping accuracy demands can be met.

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Yield mapping is technological state of the art nowadays as a precision farming aid with grain combines. However the same does not apply to other harvesting equipment. In research, a series of solutions are being investigated which are not yet, however, available on the implement market.

Yield mapping systems comprise main components throughflow measuring system, displacement transducer, satellite supported navigation system (DGPS), on-board computer with software and, where necessary, sensors for the working width, moisture content and other content material. The throughflow measurement takes a key role in the yield mapping system in that it has a decisive influence on the yield determination.

The following measurement principles are known for the throughflow measurement with potatoes (*fig. 1*):
- radiometric measurement [1]
- weighing cell in the continuous conveyor belt [2, 3]
- optical measurement with photo evaluation [4], and
- deflection plate [5].

Through measuring the weakening of the radiation intensity, the throughput could be calculated radiometrically. The radiometric measurement can take place as early in the process as the area of the sieving webbing in the harvest material flow comprising soil, stones and potatoes. This enables potatoes and other material to be recorded separately – achieved through the application of two separate radiation sources of different wavelengths (Am-241) and Cs-137).

In the case of the second measurement system, a support roller with weighing system was fitted under a webbing conveyor. In addition, the potatoes produce a reaction force which, with regard to the conveying speed, allows a continuous throughflow measurement. Potato harvesters with this sort of measurement system are already in the market in the USA.

In the following report, further measurement principles from figure 1 “optical sensor” and “deflection plate” are looked at in closer detail with regard to their measurement precision and principle characteristics.

Optical sensor

Available is an optical sensor (Agrisort from AGEC AB, Sweden) which is already on the market. The optical sensor is so arranged that the potatoes are recorded immediately after they leave a webbing conveyor. The camera can analyse 200 to 250 objects per se-

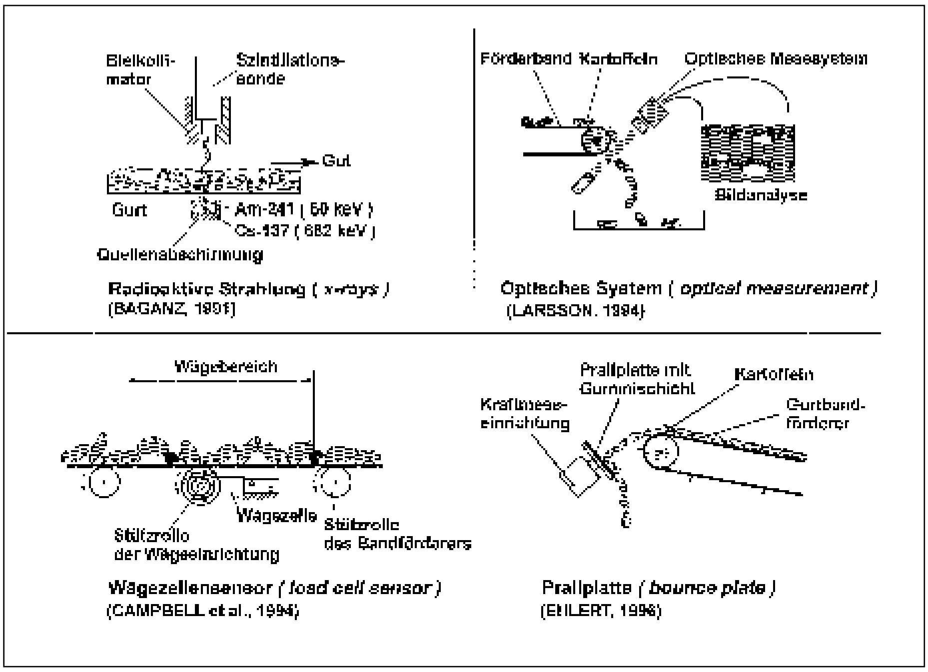

Fig. 1: Principles of through put measurement in potatoes

Potato variety	Average weight	Minimum	Maximum	Standard error
Bintje	106	101	116	3
Asterix	108	104	114	3
Kardal	106	96	124	4
Elkana	108	100	120	3
Saturna	111	106	118	3
Lady Rosetta	106	100	114	3

Tab. 1: Relative sensor values versus weighing check in % (weighting check = 100 %)

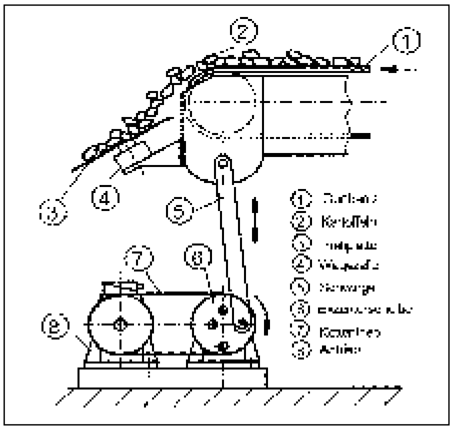

Fig. 2: Bounce plate testing station for static and dynamic conditions; 1 belt conveyor, 2 potatoes, 3bounce plate, 4 load cell, 5 rocker linkage, 6 crank disk, 7 chain transmission, 8 electric drive

cond which represents a throughflow of about 20 kg/s with a movement velocity of about 1 m/s. For checking the measuring system, the recorded potatoes were gathered in a container equipped with a weighing cell. For the calibrating was determined for four classes according to size (diameter 40; 50; 60 and 70 mm) with, in each case, 30 to 100 potatoes the number of photographed pixels and the respective weight of potatoes.

Results

The functional association between potato weight (m_K) and the number of pixels (n_P) was recorded through the exponential function

$m_K = 0.0012\ n_P^{\ 1.421}$

with a coefficient of determination of $R^2 >$ 0.99. The applied digital camera brought, by the chosen arrangement for a potato of 150 g, an exposure of around 4000 pixels.

The check weighing of the container by the weighing cells served as evaluation criteria with regard to the measurement precision of the system. All pairs of values thus determined were calculated with a linear regression application and investigated as the result of the regression equation

$S = 1.083\ W - 1.043$

with $R^2 > 0.99$.

In the ideal case the sensor value (S in t/ha) and the control value achieved over the weighing (W in t/ha) must be the same. With the calculated constants which instead of 1 → 1.083 and 0 → 1.043, the deviation from the ideal performance is characterised.

Because of the measurement principles presented here, it is to be expected that the geometric form, and thus the type of potato, has an influence on measurement precision. For this reason, different types of potatoes were brought into the investigation for the further evaluation of measurement principles (*table 1*).

From the measurement results it can be deduced that through the optical system for all investigated types of potatoes a too high weight of 6 to 11% was recorded. This tendency is especially emphasised with potato varieties which deviate considerably from a round shape.

Impact plate

For the testing and optimising of the control parameters for the measurement principles of the impact plate, a test station was conceived and constructed which used the following influence parameters to investigate the precision of measurement:

- arrangement of impact plate fitting angle and gap width,
- webbing speed,
- oscillation of different frequencies and amplitudes (*fig. 2*).

The test station consisted of a 6 m long conveyor belt with a breadth of 0.5 m arranged horizontally. In order to develop defined oscillations for simulation of driving movements, the delivery side of the conveyor belt was fitted in a swinging block linkage with degree of eccentricity adjustable in steps. The production and halting of the swinging block linkage's causative frequency was carried out by an electric transmission motor, the revolutions of which could be set by a frequency converter. Used as measuring gauge of the eccentric load introduction was a hydraulically dampened weighing cell.

Starting point for the discovery of practical positioning of the impact plate were the fall curves resulting from the conveyor belt speed which could be calculated with the help of the movement equations of a measurement point in -x and -y direction. The fall curves allowed the 20 promising impact plate positions to be recorded and investigated. In all plate positions the conveyor belt was loaded in steps of around 1 kg up to 40 kg. The length of the loading was measured in such a way that a potato throughflow time of around 5.5 seconds resulted.

Results

For the investigation of the most efficient impact plate arrangement for positive and negative positioning, the accuracy degree and the standard error were calculated for all 20 variants with conveyor belt speeds from 0.5; 0.86 and 1.1 m/s without and with oscillation forces (frequency 1.05 l/s, eccentricity 45 mm).

For estimating the imprecision caused by low-frequency oscillations as a result of driving movements, all the measurements recorded with and without oscillations were compared with one another in the form of the calculated standard error. The average of all standard errors without oscillation equalled 0.96 kg and with oscillation 1.24 kg, because of the simulated driving movement the imprecision was increased by 29% under the given trial conditions. If the four variants were compared with the minimum standard error (*table 2*) the average standard error then equalled 0.462 kg based in static reading and 0.498 (dynamic reading). The increase of the standard error through the oscillation application can, with the resultant 7.9% be estimated as minimal. If the static and dynamic standard errors were taken from the average weight on the belt of about 20 kg, then a relative measurement error of 2.3 or 2.5% results.

Adjustment angle in °	Space width in mm	Webbing speed in m/s	Standard error weight in kg		Standard error throughflow in kg/s	
	Working type		static	dynamic	static	dynamic
-30	Min.	0,50	0,412	0,474	0,068	0,079
50	150	0,86	0,599	0,427	0,099	0,072
-30	Min.	0,86	0,456	0,529	0,076	0,008
45	150	1,10	0,383	0,564	0,063	0,094
	Average		0,462	0,498	0,077	0,083

Tab. 2: Measurement errors for suitable bounce plate positions

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