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Breaking load as quality characteristic of potatoes

Because of their diversity as a food compared with other vegetables potatoes have to fulfil many quality criteria. Compared with conventionally produced food, that which is organically produced is often regarded as of higher quality. An important quality characteristic of potatoes is firmness of tissue. The measurement method presented here allows this characteristic to be objectively determined. The penetrometer test is applied in the DFG research group „Optimising Strategies in Organic Farming" (OSIOL) to test the influence of different trial factors on firmness values.

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Keywords

Potatoes, penetrometer test, potato quality, organic farming

Potato quality is determined neither by legal trade description of eating potatoes nor through sensor sampling of cooked tubers. Ware potatoes are sold raw but eaten cooked. The quality criteria reflect the tubers' complexity and high quality requirements. As part of its mechanical characteristics, the tissue firmness properties of the potato are recognised as important quality factors.

The potato tuber represents a complex biological system with high water content (75 %) and large variability regarding exterior and interior characteristics. Its composition, dry matter content, and tissue structure continually alters during growth, maturation and storage and reacts during these processes every change in environmental factors.

Thus the firmness characteristics of potatoes depend on very many factors, whereby a large proportion of these associations are still not known. This is because the potato represents a complex biomechanical system the reactions of which cannot be described through only a few physical values such as, e.g., steel. Thus, assumptions have to be made relatively often in the mechanical descriptions of the biological material and results reached in this way are only applicable under defined conditions. Despite these limitations, the firmness characteristics of agricultural materials can to a large extent be objectively and reproducibly described through standardised recording methods and their results [2]. One such method is the penetrometer test.

Penetrometer test

This measures the quasi-static effect from penetration of the tuber by a defined object at constant velocity. As a rule, this type of quasi-static load reflects the static stress exerted upon the tuber during storage in bulk stores.

For determination of firmness values, the load-displacement behaviour was recorded using a material testing machine and related software from Zwick The size and form of the penetrating object was defined as a standard [2]. The tuber was laid upon a sandbag for the test and positioned to resist horizontal movement *(fig. 1)*. Preliminary load was 5 N, the penetrator velocity 10 mm/min.

A load-displacement curve typical for potatoes is shown in *figure 1a.* The maximum load as a measurement parameter (F_{max}) was tissue resistance at breaking load or the resistance threshold. This is a value of firmness in material testing of metal as well as agricultural material. The maximum load describes the point of the load-displacement curve where the tuber flesh resistance to the external force breaks down, a reaction associated with the complete destruction of the potato skin and subcutaneous layer.

Evaluation of penetrometer test

In conducting the trial the potato must be so positioned that the circular face of the penetrator stamp is parallel to the tuber surface so that penetration force is equally distributed. Thus, round potato varieties and smaller tu-

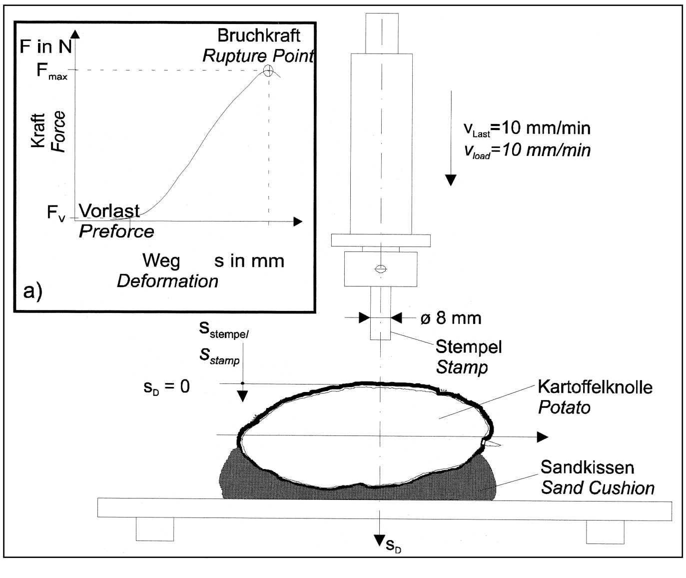

Fig. 1: Scheme of penetrometer test; a) typical force-deformation-curve of potatoes

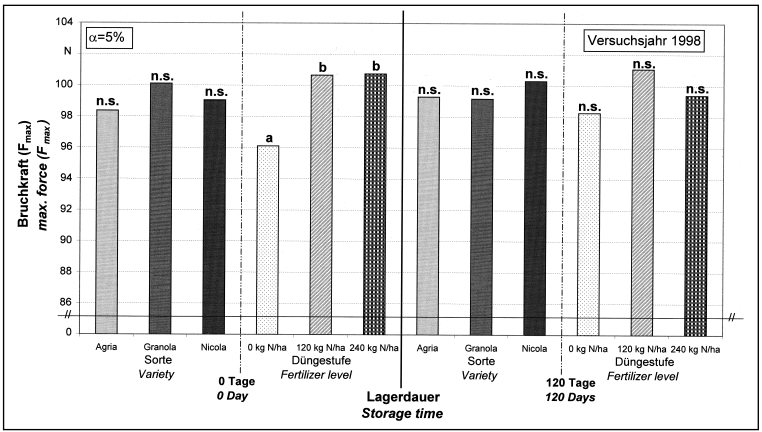

Fig. 2: Maximum force of the penetrometer test, 0 and 120 days of storage, three varieties and three fertilizer level, year of experiment 1998

ber sizes are less suitable for the test as are potato varieties with rough skin because of the associated higher penetration resistance. Other reasons for false measurements can be externally invisible damage or disease.

The systematic error through constantly selected measurement parameters does not have to be considered in the error observations of the penetrometer test. For determination of coincidental measurement error the investigation was replicated with 20 homogenous tubers. Four consecutive measurements were made on each tuber. The coefficient of variation of the potato mechanical properties lay in general at 25% [3]. The threshold value for the penetrometer test was small at from 2 to 5% for the average coincidental measurement error.

Test factors and parameters

The field tests were conducted in a block system with four replications at Wiesengut experimental farm in 1997, '98 and '99. Varieties tested were Agria (processing variety), Granola (mainly firm when cooked) and Nicola (always firm when cooked). Because of the lower yields in organic production, the effects of increased applications of organic fertiliser on the yield and quality were investigated. Three levels of fertiliser were applied with 0, 120 and 240 kg in the form of composted farmyard manure (FYM). In that the potato is a farm product which is typically stored, the influence of storage duration on flesh firmness values and thus on quality was investigated in the trial. Three dates were chosen for carrying out the laboratory tests – at storage, after 60 days and after 120 days storage. Storage took place at temperatures under 6 °C and at 95 % relative air humidity. Testing occurred at a room temperature of 20 °C and around 50 % air humidity in the materials testing laboratory of the Institute for Agricultural Engineering, University of Bonn. Before the trial the potatoes were kept in this climate for two hours. Thirty spot samples were taken at each factor stage.

Results and discussion

The presentation of results is limited to the examples from two trial years (1998 and '99), three varieties and two storage periods (0 and 120 days). Based on the three trial factors the statistical evaluation took place with a three factorial variance analysis.

Mature potato tubers have a high breaking load at harvest and tissue breaks-down even under limited indentation. Stored potatoes have a smaller breaking load and relatively more tissue flexibility [3, 4]. In other literature, potatoes indicate an increase in breaking load with lengthening storage duration [5, 6].

The composted FYM used as fertiliser was allotted a factor level according to amount applied. However, the availability of the nitrogen for the potato plant remained in question. The release of nitrogen from the organic FYM into the soil and the availability to the potato plant is a factor very difficult to evaluate. Among other aspects, this release is weather-associated [7, 8]. This led to differing results in the trial years.

In 1998 breaking load was barely influenced by variety. The statistically secured difference in FYM levels as quality-influencing factors at storage indicated that breaking load increased tendentially in line with increased Nr. fertilising. This was because the yield rose with the increased dunging, tubers and their cells were larger and could absorb substantially more water. These tubers were more brittle because of this and therefore indicated a higher breaking load during the tests. In 1998 there was no significant difference after 120 days storage *(fig. 2)*.

In 1999 the levels of dung, the varieties and the storage durations could be differentiated. The results are presented in *fig. 3*. Regarding the three dung levels, the recorded tendencies of 1998 could not be reaffirmed. In this case it could be assumed that the dung level factor in this type of trial cannot be differentiated accurately by this measurement method. At storage, the varieties Agria and Granola achieved a significantly higher breaking load than Nicola. Granola has very good storage characteristics, thus the values recorded after 120 days showed little change. Nicola indicated substantially less firmness values with increasing storage duration, a reaction also reflected in the variety's increased sprouting propensity.

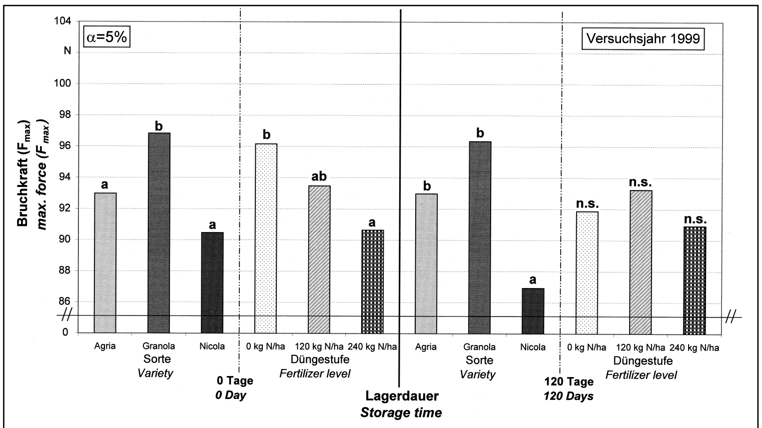

Fig. 3: Maximum force of the penetrometer test, 0 and 120 days of storage, three varieties and three fertiliising level; experimental year (1999)

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