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Effect of genotype and storage on textural parameters in potato tubers

Влияние на генотипа и срока на съхранение върху параметрите на текстурата в картофени клубени

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ABSTRACT

Potato lines bred by intraspecific hybridization of *Solanum tuberosum* L. were evaluated on their textural properties in two consecutive years. The plants were grown under mountain conditions at 1610 m altitude and were harvested at the end of September. The cutting test was performed using a Warner-Bratzler blade of texture analyzer (TA) for obtaining the maximum force to shear the tubers. Textural parameters were analysed right after harvesting, 3- and 6-month storage under ambient conditions (2-8 °C and 70-90% Rh) in unheated storehouse. It was found out that the values of all investigated physical parameters decreased during the storage. Higher influence of the storage duration than the genotype was recorded on the dynamic of yield force, modulus of deformation, deformation work and rupture force. Based on the studied physical qualities line E 1096 was selected as the most appropriate for long-term storage because of the slightest softening of the tubers and the most homogenous parameters of the texture at the end of the storage. The observed correlations indicated that the yield force may give the best information about the quality of raw potato texture.

Keywords: correlations, deformation work, modulus of deformation, rupture force, *Solanum tuberosum* L., yield force

РЕЗЮМЕ

В две последователни години са оценени параметрите на текстурата на линии картофи (*Solanum tuberosum* L.), създадени чрез вътревидова хибридизация. Растенията са отгледани при планински условия на 1610 метра надморска височина и са реколтирани в края на месец септември. Тестът за разрязване е проведен с текстурен анализатор (TA) с помощта на нож Warner-Bratzler за получаване на максимална сила за срязване на клубените. Анализът е извършен непосредствено след реколтиране, след три и шестмесечно съхранение в условията на неотопляемо складово помещение при температурен диапазон 2-8 °C и 70-90% относителна влажност на въздуха. Установено е, че продължителността на съхранение оказва по-голямо влияние върху динамичната сила на поддаване, модула на деформация, работата за деформация и силата на разрушаване в сравнение с генотипа. Стойностите на всички изследвани физични параметри намаляват по време на съхранението. Линия Е 1096 е най-подходяща за дългосрочно съхранение поради най-слабото омекване на клубените и най-хомогенни стойности на параметрите на текстурата в края на съхранението. Въз основа на наблюдаваните корелации може да се заключи, че силата на поддаване би могла да даде най-добра информация за качеството на текстурата на непреработените картофи.

Ключови думи: корелация, модул на деформация, работа за деформация, сила на поддаване, сила на разрушаване, *Solanum tuberosum* L.

INTRODUCTION

Potato breeding at Maritsa Vegetable Crops Research Institute in Bulgaria started more than 40 years ago. Some of the selected cultivars have preserved their valuable properties and importance for the development of the potato production up to the present. However, the modern requirements for potato crop force the cultivation of special new type of varieties with good potential for long-term storage (Bhutani and Khurana, 2005; Nacheva, 2009).

Potatoes are usually kept in storage before supplying the market or processing. Undesirable storage conditions lead to physical and chemical quality loss in stored potatoes which affect their consumer acceptability (Nourian et al., 2003). The softening of potato tubers depends on the storage temperature and on the relative humidity of the storage chamber. Studies on the extent of those changes under different storage conditions are valuable for minimizing the deleterious effect on product quality (Thybo et al., 2007; Alvarez et al., 2002).

Textural parameters are important potato traits during the storage. Relations between mechanical properties determined instrumentally such as stress, strain and moduli and sensory quality are only occasionally treated in literature (Diehl and Hamann, 1980). There are studies for investigation information which concerns the prediction of texture properties of cooked potato from the similar parameters of raw potato. Thybo and Van den Berg (2003) found that good predictions for most of the texture attributes on cooked potatoes can be obtained from uniaxial compression on raw potatoes. The most of the information is found around the fracture point (yield point) but the analyzing of the full uniaxial compression curves give better predictions. According to Solomon and Jindal (2005) there is an apparent correlation between the elasticity and viscosity parameters of raw and cooked potatoes irrespective of the storage conditions. Such relationships led to the estimation of textural parameters of cooked potatoes directly from textural measurements of raw potatoes. For this reason, potato breeders pay attention to the mechanical properties of the tubers after long-term storage in order to guarantee high quality raw material for the processors.

Based on the study of Hiller and Jeronimidis (1996) the cutting test has the advantage of being easy and rapid to perform in order to assess the fracture behaviour of potato tuber parenchyma in different (fresh vs. flaccid) turgor states. From the other hand the cut (shear) test is expected to relate to the force required for the incisor penetration into a food, (i.e., planar penetration) (Kim et al. 2009).

The present study aimed to characterize newly created perspective potato lines by their mechanical characteristics and to evaluate the influence of genotype and storage duration on the textural properties of raw tubers.

MATERIALS AND METHODS

Field design: The investigation was carried out at Maritsa Vegetable Crops Research Institute, Bulgaria in two consecutive years (2016-2017). Potato lines D 112, E 1096 and E 1110 participated in the experiment. The plants were grown by the technology for late production cultivation (Ganeva et al., 2014) and under the typical conditions of Pashaliytsa surrounding area in the Rhodope Mountains at 1610 m altitude. The field experiment was carried out by the block scheme with 4 replications, 100 plants per replication, 70/25 cm. During the crop period standard agronomic practices such as fertilization and plant protection were utilized. The tubers were harvested at full maturity at the end of September.

Physical characteristics: Textural parameters were studied right after harvesting, 3- and 6-month storage under ambient conditions (2-8 °C and 70-90% Rh) in unheated storehouse. Laboratory tests were conducted on ten whole potato tubers from each line by Stable Micro Systems TA.XT.Plus Texture Analyser, with a "Warner-Bratzler blade" probe (Figure 1 left). The force-deformation curves were analyzed for yield force (1st force maximum), modulus of deformation (slope up to 1st maximum), deformation-work (area under the curve up to 1st maximum) and rupture force (force maximum) (Figure 1 right).

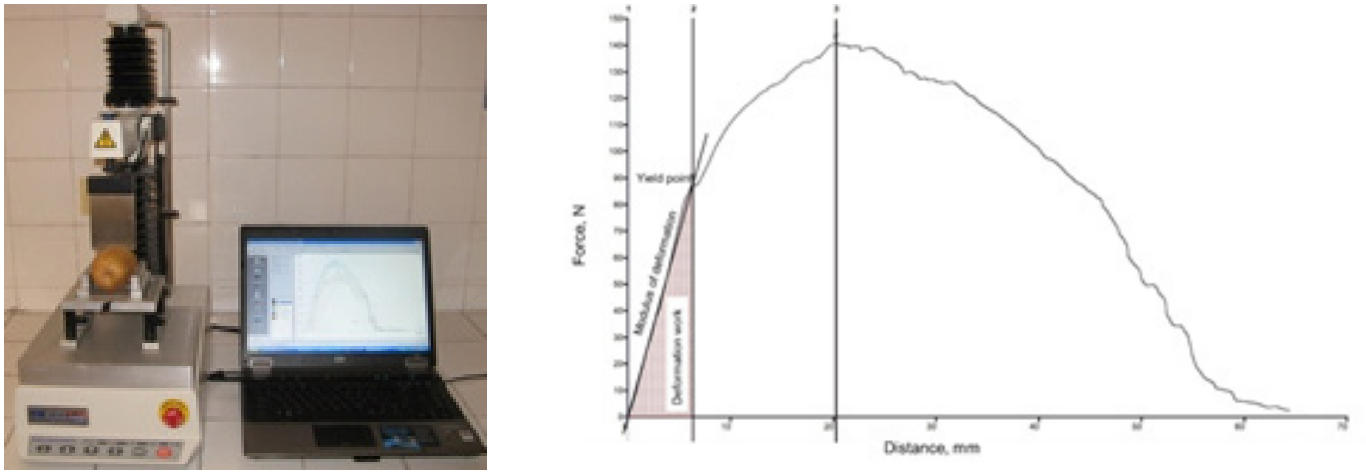


Figure 1. Stable Micro Systems TA.XT. Texture Analyser with a "Warner-Bratzler blade" probe (left) and a typical cutting curve with the investigated parameters (right)

The instrument was set at a test speed of 1 mms^{-1} and a travel distance of 80 mm. The dry matter content was measured using the same ten fresh potato tubers from each studied line. The tubers were chopped, ground and dried in oven at 100 °C for 10 minutes and at 50 °C until a constant weight was achieved.

Data analysis: A two-way analysis of variance was applied to evaluate the effect of genotype, storage duration and their interaction on the studied traits. It was performed by Excel software. The data obtained from ten individual tubers for each line were processed by Duncan's multiple range test and correlation analysis using SPSS 14 program. The Duncan's multiple range test was applied because it obtains the statistical significance of the results even if the Tukey's test does not allow (Silva and Azevedo, 2016).

RESULTS AND DISCUSSION

Right after harvesting the uniaxial cutting curves were characteristic of potatoes (Figure 2). After 3-month storage they were situated lower in the diagram keeping almost the same design. The closest curves were reported for line E 1096. This was the indicator for the slightest softening of the tubers and better storage up to this period.

In 6-month storage the design was totally changed. The softening of potato tissue caused the disappearing of the typical peaks. A very good similarity between the two year curves was established.

The values of yield force, modulus of deformation, deformation work and rupture force were reduced in all parameters during the storage (Table 1). The results corresponded to those uncovered by Bentini et al. (2009). Generally, the decrease was stronger from the first to the second reported date than from the second to the third one. The higher values of the coefficients of variability (CV) illustrated that the deformation work was the most changeable parameter. Yield force and modulus of deformation seemed to be more stable mechanical traits.

The results of the investigated textural parameters revealed statistically genotype differences in the potato lines. Right after harvesting line E 1100 possessed the firmest potato flesh. The other two lines had close values of the studied traits. Similar results concerning the genotype reaction toward the texture profile in potato varieties were reported by Jůzl et al. (2008).

Line E 1100 kept the first place in three months in regard to yield force and deformation work whereas line E 1096 had the higher values for modulus of deformation and rupture force. At the end of the storage both lines had approximately equal values but line E 1096 was distinguished by more homogenous textural parameters. The diminution of the differences between the rupture force and the yield force during the storage was due

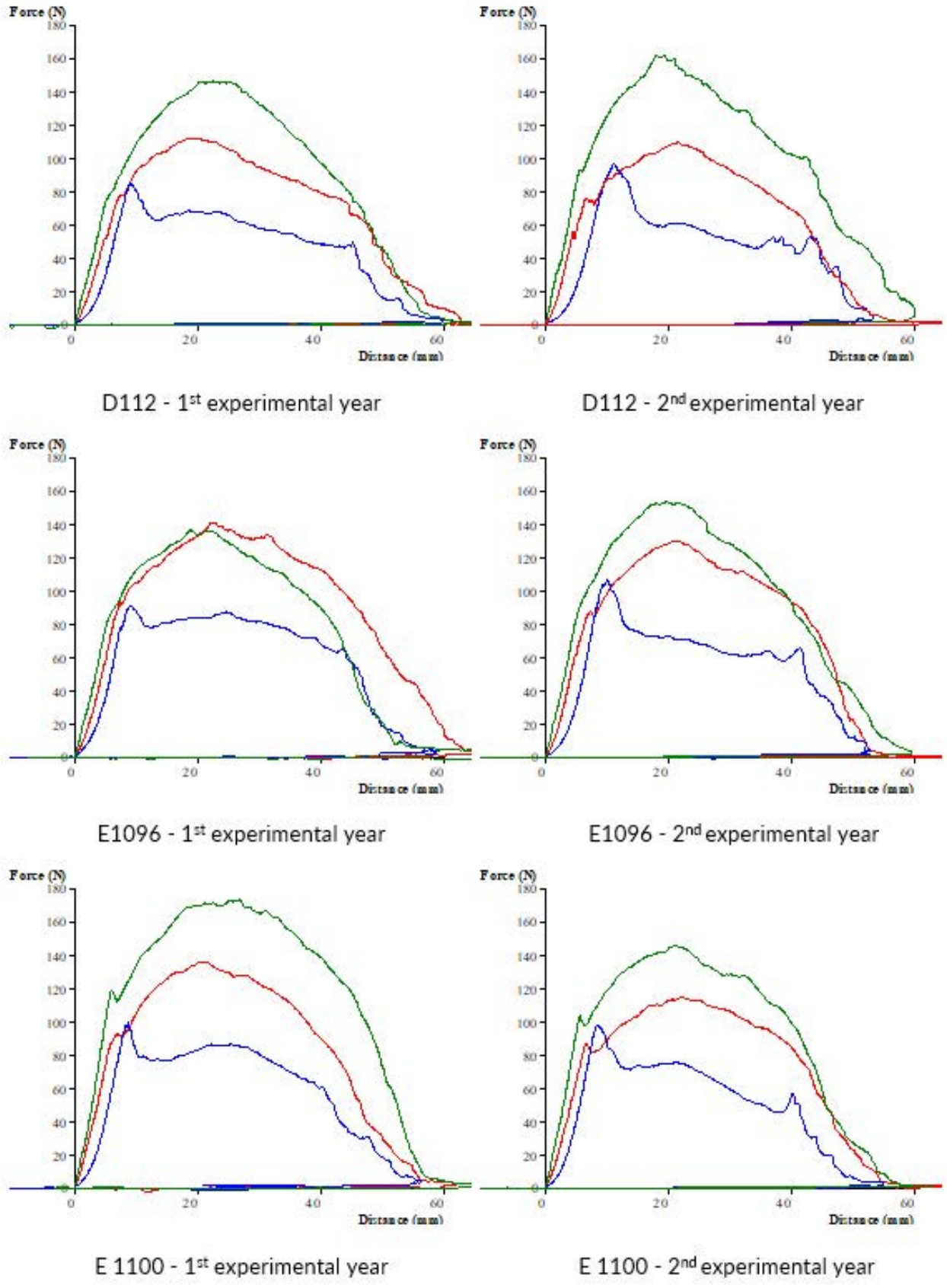


Figure 2. Force-deformation average (n=10) curves for potato tubers after harvesting (–), 3- (–) and 6-month (–) storage

Table 1. Textural parameters of the studied potato lines

Cultivar	Yield force (N)	CV (%)	Deformation work (N.mm)	CV (%)	Modulus of deformation (N.mm^{-1})	CV (%)	Rupture force (N)	CV (%)
After harvesting								
D 112	87.91^{b}	13.48	237.31^{c}	17.26	15.62^{b}	11.99	153.89^{ns}	10.22
E 1096	94.48^{b}	14.70	272.67^{b}	18.89	15.87^{b}	11.86	152.43^{ns}	15.12
E 1110	113.12^{a}	12.18	324.80^{a}	16.11	18.66^{a}	10.79	163.87^{ns}	10.12
After 3-month storage								
D 112	76.19^{b}	16.26	208.02^{c}	30.53	12.12^{b}	15.42	115.20^{b}	11.40
E 1096	83.67^{b}	14.65	236.23^{b}	28.30	14.35^{a}	10.54	135.77^{a}	9.22
E 1110	86.00^{a}	17.72	250.61^{a}	26.26	13.66^{a}	13.07	125.81^{ab}	9.54
After 6-month storage								
D 112	74.34b	17.77	197.03^{ns}	21.43	9.02^{b}	11.66	108.91^{ns}	21.14
E 1096	88.55a	14.86	232.07^{ns}	17.00	11.25^{a}	12.32	110.98^{ns}	12.45
E 1110	86.50ab	18.44	226.61^{ns}	26.92	11.31^{a}	14.21	115.21^{ns}	24.36

a,b... Duncan's multiple range test (P<0.05), ns - not significant

to the softening of the potato flesh. The data were in accordance with reported by Martens and Thibo (2000) deformation at fracture increased after 8 months of storage of potatoes as the rigidity of cells decreases due to weakening of the middle lamellae in the noncooked tissue.

Higher influence of the storage duration than the genotype was recorded on the dynamic of yield force, modulus of deformation, deformation work and rupture force (Figure 3). Among the textural measurements, the storage duration was the most influencing factor on the rupture force. Except for the rupture force the genotype influence was significantly proved concerning the other studied traits. Genotype x storage duration was a significant factor for yield force and modulus of deformation.

Dry matter content is one of the most essential traits of the internal quality of potatoes (Van Eck, 2007). In this experiment line E 1096 was statistically different from the other two studied lines after harvesting, in 3- and 6-month storage (Figure 4).

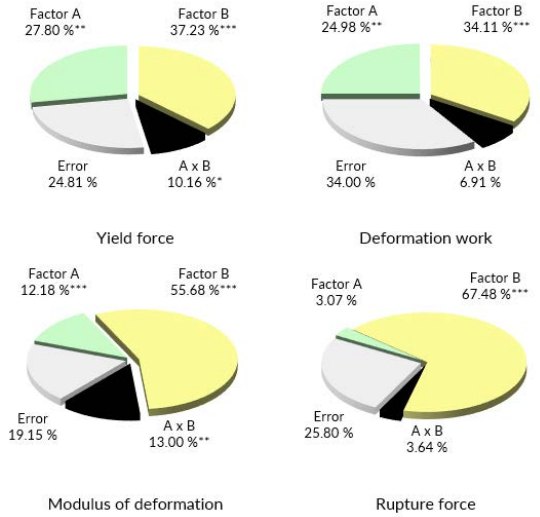
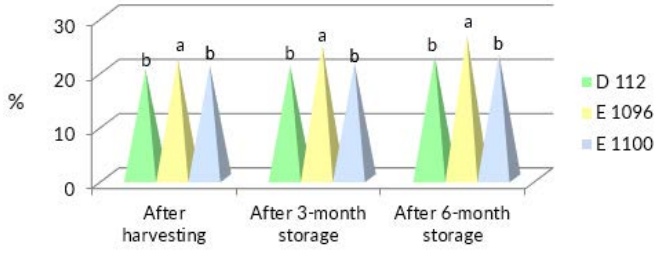


Figure 3. Two-way analysis of variance (factor A – genotype, factor B – storage duration) for the whole experimental period



a, b... Duncan's multiple range test (P<0.05)

Figure 4. Dry matter content of potato tubers

During the whole experimental period it kept values over 22 %. Lines D 112 and E 1100 had close dry matter content approximately two percent lower than line E 1096 in the each of the three periods of the investigation. Similar results for genetically influenced dry matter content of potato were reported by Jansen at al. (2001) and Mohammed (2016).

The dry matter content of potato tubers correlated positively with all the studied textural parameters after harvesting (Table 2). The correlation was high and statistically proved with yield force, deformation work and modulus of deformation.

The results were similar to those obtained by Gupta et al. (2015) who found a significant and positive correlation coefficient between tuber dry matter and texture which indicated that potato varieties with high tuber dry matter possess floury texture.

After 3-month storage a strong positive correlation was observed only with modulus of deformation. In 6-month storage the correlations of the forth textural parameters with the dry matter content measured right after harvesting were moderate and not significant. The lack of high correlations at the end of the storage show that the instrumental traits of raw potato texture could not be predicted by analysing of dry matter content at the beginning of storage.

A very strong significant correlation ($r > 0.918$) was recorded between yield force and deformation work, no matter the storage duration (Table 2). Strong positive correlations of modulus of deformation were found with yield force and deformation work ($r > 0.734$). Right after harvesting moderate correlations were determined between rupture force and the other studied textural parameters. In the next two periods of storage only the

Table 2. Correlations between the studied parameters of the raw potato tubers during the storage

	Yield force	Deformation work	Modulus of deformation	Rupture force	Dry matter
					After harvesting
Yield force	♦	0.984**	0.980**	0.656*	0.823**
Deformation work		♦	0.932**	0.614*	0.794*
Modulus of deformation			♦	0.705*	0.769*
Rupture force				♦	0.335
Dry matter					♦
					After 3-month storage
Yield force	♦	0.918**	0.809**	0.654*	0.335
Deformation work		♦	0.818**	0.376	0.377
Modulus of deformation			♦	0.600*	0.816**
Rupture force				♦	0.432
Dry matter					♦
					After 6-month storage
Yield force	♦	0.970**	0.848**	0.695*	0.366
Deformation work		♦	0.734*	0.770*	0.404
Modulus of deformation			♦	0.388	0.442
Rupture force				♦	0.560
Dry matter					♦

relationship with yield force kept stable and at the same level.

CONCLUSIONS

The production of high quality potato products requires a raw material with appropriate and stable physical properties throughout the storage period. The results from the experiment show that potato breeding is one of the ways to obtain tubers with good potential for keeping hard flesh during long-term storage. The established genetic determination in the textural parameters is a prerequisite for successful selection in the creation of new varieties of potatoes which largely satisfy the requirements of producers and processors.

Long-term storage modifies the physico-mechanical properties of the potato tubers. The values of all investigated physical parameters decreased during the storage. Based on the observed correlations it could be concluded that the yield force may give the best information for the quality of raw potato texture.

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