

Potato Breeding Lines Suitable For Production of Frozen French Fries

Y. GEGOV¹, G. PEVICHAROVA², E. NACHEVA² and V. SLAVCHEV²

¹ *Regional Centre for Scientific-Applied Service, BG - 4002 Plovdiv, Bulgaria*

² *Maritsa Vegetable Crops Research Institute, BG - 4000 Plovdiv, Bulgaria*

Abstract

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Results of two-year-old study for twelve new Bulgarian potato-breeding lines suitable for productions of frozen semi-fried French fries are presented. Complex of sensory, physical, chemical and agrobiological characters was analyzed. General evaluation was made by "rank sums" method and the most appropriate breeding lines for freezing and frozen storage were revealed.

Key words: sensory properties, chemical components, agrobiological characters

Introduction

Potatoes are significantly important products which value of food properties is only exceeded by wheat (Metlickii, 1971). Their energy value is determined by carbohydrates (generally starch) with average content of 15-19%. They are a source of several chemical components providing good health like vitamin C, thiamine, riboflavin, thiacyne and salts of Ca, Fe, P and K (Desrosier, 1977).

Predominant part of potato harvest is a raw material for processing industry in The USA, Russia, Germany, England, Poland, The Netherlands and France. Rapid development of frozen potato production has been a clearly-expressed

world trend for the last years. Frozen semi-fried French fries occupy the first place with over 60 per cent among frozen potato products (Smith et al., 1997). French fries represent 2/3 from all frozen vegetable crops in The USA (Mallet, 1993).

Potatoes for frozen products should meet certain requirements about taste properties (colour, aroma, texture), morphological characters (uniform size and shape, smooth surface, number and depth of eyes, lack of defects in the flesh part) and certain components especially dry substances (starch) and reducing sugars (Gruboi, 1990; Pshechenkov and Davidenkova, 2004; Love et al., 1998), as well as stable structure and colour during the frozen storage (Lambrev, 1994). Pro-

ductivity and disease resistance are also very important characters (Love et al., 1998). Different varieties have different behaviors during separate producing processes including blanching, frying, freezing and fridge storage (Postolski and Gruda, 1978; Kumar et al., 2004).

Dry matter content of potatoes for French fries determines at great extent their technological value. Increase of the dry matter content of tubers leads up to improving of the qualitative characters of the product: structure (including crispness), colour, low content of absorbed fat during the initial frying, energy consumption, ready-made product yield (Metlickii, 1970; Kita, 2002; Smith et al., 1997). Potatoes with dry matter content with range of 20-24 per cent (Pshechenkov and Davidenkova, 2004; Mallet, 1993), 21-22 per cent (Smith et al., 1997), over 20 per cent according to Bulgarian State Standard (1970), 22-25 per cent (Metlickii, 1971) and 21.2-25.6 per cent (Love et al., 1998) are recommended for frozen French fries production.

Potatoes with lower dry matter content (17-20 per cent) absorb more fat during the frying, have weaker structure than preferred one and are produced by bigger energy consumption (Smith et al., 1997). Reverse, potatoes with higher dry matter content (over 26 per cent) become colourless along the slice edges after frying and obtain starch texture (Postolski and Gruda, 1978).

It is proved that significant variation of dry matter content during the individual years keeps variety ratio which appears to be strongly determined variety character (Metlickii, 1970). Late varieties contain more starch than the early ones (Almashi et al., 1981). Principally, longer vegetation makes higher dry matter con-

tent (Love et al., 1998).

Colour is the most important property of the fried potato products (Hayes and Thill, 2002; Henryka and Zimnock-Guzowska, 2004). Content of reducing sugars determines their dark colour during the frying. Formation of dark-coloured compounds is as a result of sugar and amino acid melanoido-formation reactions (so called mayard reaction) (Almashi et al., 1981). Reducing sugars and dry matter content depend on the variety and at great extent on the vegetation conditions (Metlickii, 1970; Smith et al., 1997). The initial content of reducing sugars recommended in scientific articles ranges not over 0.4 per cent (Postolski and Gruda, 1978), 0.5 per cent (Kriuss, 1963), 0.25-0.5 per cent (Mallet, 1993), below 0.25-0.35 per cent (Smith et al., 1997), 0.23-0.30 per cent (Pshechenkov and Davidenkova, 2004) and 0.05-0.15 per cent especially for American varieties used during the last 10 years (Love et al., 1998).

Besides darkness, high content of reducing sugars leads to a friable texture during the frying (Kriuss, 1963). Potatoes containing over 2 per cent reducing sugars are counted for unsuitable for French fries (Almashi et al., 1981).

Nowadays it is assumed that only reducing sugars participate in the darkness process. Sacarose may affect only after reduction during the frying due to butyric acids in the frying fat. Its effect on coloration could be entirely eliminated by use of controlled storage conditions and harvest at completed technological maturity (Desrosier, 1977).

It could claim that the frozen French fries quality is as higher as the reducing sugar quantity is lower before processing (Love et al., 1998). The initial content of the raw material correlates positively with

quality of ready-made product after storage.

Requirements for French fries colour have been formed by consumption traditions. Thus potatoes with white colour tubers that become white-yellow after frying are widely used in North America. Those are so called Irish potatoes. Fried potatoes with intensive gold-yellow colour are preferred in Europe therefore varieties with yellow flesh are used (Gruboi, 1990; Kita, 2002). French fries flavour generally depends on the flesh texture of ready-made product and on the untypical aroma and taste (Nacheva and Pevicharova, 2003). French fries production requires varieties with rather starch than friable and moist texture.

The oval and oval-elliptical tuber shapes are preferred for frozen French fries production (Smith et al., 1997). They provide maximum slices length that is an important part of high quality. Diameter size over 4.5-5 cm (Almashi et al., 1981) or over 5 cm (USSR Standard, 1978; Smith et al., 1997) and lengths over 55 mm (Gruboi, 1990), 62-87 mm (Mallet, 1993), 50-70 mm (USSR Standard, 1978) and over 76 mm (Smith et al., 1997) are recommended in the scientific articles. Smooth peel and small number shallow eyes are factors for decrease of the waste during the mechanized peeling.

High genetic potential for yield is a total valid requirement for potato varieties in spite of producing direction (Nacheva and Pevicharova, 2003; Heselmans et al., 2004). The negative correlation between productivity and starch content, i.e. dry matter occurs like a breeding problem. That needs to cultivate number of varieties (over 75 to be accepted 10-15 (Desrosier, 1977) in The USA) and a large number of hybrid populations.

The references show that the list of potato varieties for different producing directions is mainly determined by quality of the final product and productivity. The aim of current work was to be assessed breeding potato lines for frozen French fries by sensory, chemical, physical, technological and agrobiological properties.

Materials and Methods

The investigation was carried out at Maritsa Vegetable Crops Research Institute, Plovdiv and Centre for Scientific-Applied Service, Plovdiv during the period 2003-2005 (two subsequent years). Twelve breeding potato lines selected by interspecies hybridization of *S. tuberosum* L. with different vegetation periods were included: early: E 112, E 292; mid-early: E6, E68, E766; mid-late: E24, E28, E100, E136, E199 and late: E16, D68. Mid-early variety Sante - official standard for Bulgaria - was used as a control. Potatoes were grown by accepted technology for mid-early production and under typical conditions for our main producing regions - Pashaliytsa area in the Rhodopes Mountains with altitude of 1500 m.

Three agrobiological characters of the breeding lines - tuber diameter (cm), eye depth (a scale from 1 to 9) and standard productivity (kg/da) - were included. These characters are close correlated to quality of ready-made product and per cent of potato processing waste according to the reference and our preliminary studies. Dry matter content by weight, starch calculated by Reyman and reducing sugars by Shoorl-Regenbogen (Genadiev et al., 1968) was estimated on average sample of 20 tubers.

The colour of fresh tubers was measured by colorimeter Colorgard system

2000 of Byc Gardner Inc., USA in the colour systems - Hunter Lab and SIE Lab. The colour parameters L and b were used for evaluation. The third colour parameter - L+b was evaluated as informative one for yellow colour zone (analogically with Richev, 1971).

The initial potato processing for French fries (about 4 kg for each line) was done by technology close to the industrial one which was corresponded to the laboratory conditions and was ensuring maximum equal parameters for each sample. The processing included: preliminary washing, hand peeling and temporary storage in a container with tap water; cutting into prisms with section of 12x12 mm, washing for 5 min, quick water cooling, soaking for 5 min in 1% solution of potassium metabisulphite, straining, washing of its waste by water, straining and filling into polyethylene bags, sticking and storage for twenty-four-hour period at 0 °C as an absolute colour stability was guaranteed (checked by Gardner colorimeter).

The final processing on the next day included: frying into semi-liquid palm oil at 172 °C for 2.5 to 3 min until one and the same level, straining of the fried oil, freezing in a single layer at -37 °C with air speed of 2.7 m/s passing through the layer for 10 min, packaging into bags and storage at -18 °C.

The panel test (scale from 1 to 5 with step 0.25) of French fries was performed on the traits: colour, aroma, taste and texture. The total sensory evaluation was formed on the basis of the complete perception, but not as an arithmetic average from evaluation of individual sensory traits. One and the same expert-panelists (7 for 2003 and 5 for 2004) participated during both experimental years. Sensory analysis was made immediately after freezing

and after 3 and 6 months of frozen storage. For that aim they were refried without preliminary unfreezing at 172 °C for 3.5-7 min till full readiness for consumption. The fried potatoes were preserved for a short time in thermostat at temperature about 50 °C till taste panel performance. They were tasted warm, all samples simultaneously.

The data from the panel test and the colour measurement were processed using variation and correlation analyses (Lidanski, 1988) as well as Duncan's (1955) and Sheffe's (1958) multiple range tests.

The total evaluation was made by the "method of rank sums" (Lambrev, 1994). The mean rank evaluations obtained from two or more multipliers were corrected by such called "calculated ranks" method.

Two types of characters - 4 for quality and 3 agrobiological, each of them with corresponding weight coefficient - were included, determined expertly as follows: sensory evaluation - 0.20; colour of raw tubers-0.07; dry matter content - 0.13; content of reducing sugars - 0.10; standard yield - 0.30; tuber diameter - 0.10; eye depth - 0.10. We accepted the ratio of two groups of indexes to be fifty-fifty.

Results and Discussion

Results obtained from 6 panel tests of potato French fries for both experimental years are shown in Tables 1 and 2. The mean evaluation (between 4 and 5) for four characters of the sensory analysis as well as the calculated one had very close values and occurred in the range characterizing high quality (Table 1). The means for the colour, taste and aroma show that the lines have been well selected with respect to gustatory properties. The lower

Table 1
Sensory traits of the frozen French fries

Line		Colour	Taste	Aroma	Texture
early	E 112	4.28	4.15	4.26	4.09
	E 292	4.33	4.25	4.32	4.18
mid-early	E 6	3.85	4.1	4.13	4.14
	E 68	4.58	4.42	4.37	4.33
	E 766	4.25	4.26	4.33	4.21
	Sante	4.29	4.17	4.22	4.13
mid-late	E 24	4.32	4.21	4.28	4.21
	E 28	4.08	4.24	4.25	4.21
	E 100	4.43	4.3	4.29	4.22
	E 136	4.44	4.28	4.24	4.24
	E 199	4.07	3.89	4.17	3.97
late	E 16	3.98	4.03	4.09	3.97
	D 68	4.07	4.28	4.14	4.25
Coefficient of influence		0.35	0.25	0.1	0.3
± sd		4.23 ± 0.21	4.20 ± 0.13	4.24 ± 0.08	4.17 ± 0.11
CV (%)		4.88	3.21	2	2.53

- mean; sd – standard deviation; CV – coefficient of variability

mean value of texture was expected and it was as a result of available damage even if the cell structure, starch and protein complex damages were low due to ice-formation in freezing and re-crystallization of ice crystals during the storage.

The highest mean evaluation was given by panelists according to aroma. The evaluations for the lines and the control Sante were put into groups within the range 4.2 - 4.4 corresponding to typical aroma expressed mainly up to strongly.

Out of this range, there were only four samples but they also had evaluation over 4.0, i.e. with aroma meanly expressed. Obviously, for this character the lines did not differ essentially and the coefficient of variability was the lowest. In spite of

the close values, the line E68 exceeded the others, followed by E766 and E292. Lines E100 and E24 were close to them.

The panelists noticed decrease of the typical potato aroma during the storage which was weakly expressed after 3 months period and notably after 6 months period (Table 2). Only in some performed panel taste for both E16 and E199 lines, a "soil" aroma was recorded which is typical for potatoes grown in the open field and appearing to be a variety property in many cases. Other aroma deviations due to absorption of too much fat in the initial frying and refrying before panel tests did not observe. According to us, the low variation of aroma was due to a bit "masking" of natural potato aroma

Table 2
Total sensory evaluation of the frozen French fries

Line	2003					2004					Mean from both years
	After freezing (I)	After 3 months (II)	After 6 months (III)	Mean for the year	After freezing (I)	After 3 months (II)	After 6 months (III)	Mean for the year			
early	E 112	4.22 cd	4.10 b	4.22 a	4.18 bc	4.21 bcdef	4.42 a	4.03 ab	4.22 abcd	4.20 b	
	E 292	4.54 ab	4.02 b	4.08 a	4.21 bc	4.38 bc	4.33 ab	4.26 ab	4.33 abc	4.27 b	
mid-early	E 6	4.02 d	4.00 b	3.90 ab	3.98 c	3.93 e	4.33 ab	4.00 ab	4.09 bcd	4.04 c	
	E 68	4.78 a	4.58 a	4.21 a	4.52 a	4.78 a	4.30 ab	4.31 a	4.47 a	4.50 a	
	E 766	4.57 ab	4.16 b	4.18 a	4.30 ab	4.12 cdef	4.27 ab	4.20 ab	4.20 bcd	4.25 b	
	Sante	4.49 b	4.19 b	4.05 a	4.24 ab	4.23 bcde	4.12 ab	4.30 a	4.22 abcd	4.23 b	
mid-late	E 24	4.51 ab	4.19 b	4.14 a	4.28 ab	4.18 bcdef	4.33 ab	4.21 ab	4.24 abcd	4.26 b	
	E 28	4.05 d	4.16 b	4.11 a	4.11 bc	4.34 bcd	4.21 ab	4.20 ab	4.25 abcd	4.18 b	
	E 100	4.52 ab	4.26 b	4.23 a	4.34 ab	4.42 b	4.27 ab	4.27 ab	4.32 abc	4.33 b	
	E 136	4.38 bc	4.28 b	4.24 a	4.30 ab	4.36 bc	4.39 a	4.28 ab	4.35 ab	4.33 b	
	E 199	4.15 cd	4.01 b	3.73 bc	3.96 c	3.95 ef	4.33 ab	3.97 b	4.09 cd	4.03 c	
late	E 16	4.10 d	4.18 b	3.55 c	3.94 c	4.07 def	4.02 b	4.09 ab	4.06 d	4.00 c	
	D 68	3.99 d	4.11 b	4.18 a	4.10 bc	4.41 b	4.22 ab	4.23 ab	4.29 abcd	4.20 b	

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

resulted by the frying fat. Because of this fact the lowest weight coefficient (0.10) in the calculated evaluation was given.

Colour is the most important sensory characteristics for French fries. The line E68 met the most completely requirements for an intensive, homogeneous golden-yellow colour without any darker fragments on the slice edges and/or sides. It demonstrated that priority during the first two panel tests (after freezing and 3 months storage) while colour advantage was not well visible after 6 month storage for the both years. The lines E136 and E100 had high sensory evaluations for colour (Table 1). Generally, all investigated lines had the require colour for the highest quality: from golden-yellow (rate of 4) to intensive-yellow (rate of 5).

The coefficient of variability for colour was the highest. This permits us to accept colour as a clear variety property with good information for panelists. Its intensiveness and brightness decreased during the storage.

The predominate part of the lines were close in respect to their taste. The line E68 was notable again, followed by E100, E136, D68 and a group with evaluations from 4.20 to 4.25. Only two lines were with evaluation below 4.0. The coefficient of variability had the second value (after colour), suggesting a comparatively good distinction of the lines.

Immediately after freezing any flavor deviations or defects did not find in French fries. The panelists remarked taste hue and deviation only at the end of 6 month storage as follows: "soil" taste of E16, E24 and E199; a bit bitterness of E6; slight sour taste of D68, E136, E199 and E292. More significant taste hue, dominated by the frying fat, was not remarked during the three panel tests. That suggests a structure suit-

able for French fries which absorbs less fat in frying and less products from its oxidation during the storage.

The texture was the lowest value character and with comparatively slight variation at the same time. Again, the line E68 was given the highest evaluation, followed by D68 and E136 (Table 1). Only two lines have evaluations about 4.0 (moderate crisp). The other lines were estimated higher than 4.0 because of their strongly expressed crispness, formed surface peel, mealy grain flesh of slices with an uniform thickness along all the section and without detaching of peel from the flesh. The last mentioned defect usually appears in immature potatoes with low dry matter content as well as low temperatures of frying available (Postolski and Gruda, 1978). Obviously, these reasons were eliminated with respect to the studied samples.

The texture became weaker totally after 3 month storage. It was more significant at the end of the storage where the peel split from the flesh was observed in some lines: Sante, E28, E292, E100, E112. Absorbing of more fat as a function of a weaker texture was visible only in the line E24 after freezing. Some panelists marked the same defect in lines E199, E112, D68 in panel test after 3 month storage.

The data for the calculated total evaluation from the panel test indicate that the predominant part of lines have a close sensory properties (Table 2). The line E68 was the leader that was confirmed by Duncan's test. In five of six panel tests, it had the highest absolute evaluations and it was a statistically proved absolute leader in 3 of all tests. The lines E100, D68, E292 and E100 had also high calculated evaluations what was observed in all panel tests during the both years.

Duncan's test had the highest selectiv-

ity (the biggest number of groups) straight away after freezing (Table 2). This selectivity decreases during the storage and the number of groups became 2 or 3. That means the physical processes of storage had eliminated the line priorities established after freezing and the most samples became statistically indistinguishable.

The average evaluations for whole experimental period were separated into 3 groups. The line E68 was at the first place and had the best sensory properties. The variety Sante, accepted as a standard for French fries sample and insuring high quality of final product, as well as 8 lines occupied the following group. These lines were with lower quality compared with E68 but better than the following 3 lines: E6, E119 and E16. In view of the organoleptic requirements all tested lines, except the 3 last mentioned, could be recommended for the frozen French fries production.

The correlations between the total sensory evaluations for the 3 storage variants in the different years were from low to moderate ($r_{I/II} = 0.343^{**}$; $r_{I/III} = 0.320^{**}$, $r_{II/III} = 0.196$ for 2003 and $r_{I/II} = 0.060$, $r_{I/III} = 0.169$, $r_{II/III} = 0.433^*$ for 2004). It shows that the total sensory evaluation for French fries after 6 month storage could not be prognosticated on the basis of a sensory evaluation right after freezing or 3 month storage. The suitability for freezing is the most clearly determined by the latest panel test because the different lines suffer the refrigeration at different extent.

The correlation between the total sensory evaluation for both years for the first panel test was moderate - $r_{(I) 2003-2004} = 0.450^{**}$. This confirms the conception that ranging of compared genotypes before refrigeration is relatively conserved and is a variety property (Richev, 1971) never-

theless the different dry matter contents in the years.

Chemical components

The data for the basic chemical components of investigated potatoes are shown in Table 3. Dry matter content ranged from 20.5 to 26.3 per cent in 2003 and from 18.8 to 25.8 per cent in 2004. During the second year the obtained results showed a significant decrease of the investigated components in all lines except E16. The most probable causes for this fact were a bigger amount of rainfalls and lower temperatures during the second year. For both years the predominant part of the lines had dry matters ranged from 20 to 24 per cent that is recommended for French fries. Only the line E16 passed over the upper shown range (about 26 per cent) and was classified at the last place by sensory evaluation. That proves the statement described in scientific articles that very high dry matter values are not a desirable property in French fries production (Postolski and Gruda, 1978).

It should be mentioned that lower dry matters in 2004 affected neither total sensory evaluation (Table 1) nor the range of the samples (Table 2). That confirms that the dry matters are not an absolute character for determining of French fries quality. In 2004, some lines like E68, E766, D68, E199 and E136 with dry matter contents ranged from 19 to 20 per cent were given the highest sensory evaluations. Their classifying was the same for the year as well as for the final estimation.

Starch content ranged from 14.8 to 20.6 per cent for 2003 and from 12.6 to 20.0 per cent for 2004. For the most of potato lines it satisfies the values of 15-17 per cent recommended for French fries (Smith et al., 1997).

Table 3
Basic chemical components of the studied potato lines

Line	Dry matter, %			Starch, %			Reducing sugars, %			
	2003	2004	Mean	2003	2004	Mean	2003	2004	Mean	
early	E 112	23.14 bc	22.32 b	22.73 bc	17.4 bc	16.6 b	17.0 bc	0.17 bcd	0.27 bc	0.22 abc
	E 292	20.88 de	19.50 de	20.19 c	15.1 de	13.8 de	14.4 c	0.07 de	0.28 b	0.18 abc
mid-early	E 6	23.94 b	20.18 cde	22.06 bc	18.2 b	14.4 cde	16.3 bc	0.30 a	0.27 bc	0.29 a
	E 68	21.90 cde	18.80 e	20.35 c	16.1 cde	13.1 e	14.6 c	0.06 de	0.15 cd	0.10 bc
	E 766	21.30 de	19.48 de	20.39 c	15.5 de	13.7 de	14.6 c	0.07 de	0.30 ab	0.19 abc
	Sante	23.21 bc	19.84 cde	21.52 bc	17.5 bc	14.1 cde	15.8 bc	0.11 bcde	0.19bc	0.15 abc
mid-late	E 24	26.29 a	21.67 bc	23.98 ab	20.6 a	15.9 bc	18.3 ab	0.08 de	0.41 a	0.25 ab
	E 28	26.24 a	21.52 bc	23.88 ab	20.5 a	15.8 bc	18.2 ab	0.08 de	0.07 d	0.08 c
	E 100	23.88 b	21.52 bc	22.70 bc	18.1 b	15.8 bc	17.0 bc	0.24 ab	0.26 bc	0.25 ab
	E 136	22.24 bcd	21.14 bcd	21.69 bc	16.5 bcd	15.4 bcd	16.0 bc	0.01 e	0.21 bc	0.11 bc
late	E 199	20.52 e	20.24 cde	20.38 c	14.8 e	14.5 cde	14.6 c	0.21 abc	0.31 ab	0.26 ab
	E 16	25.82 a	25.74 a	25.78 a	20.1 a	20.0 a	20.1 a	0.09 cde	0.31 ab	0.20 abc
	D 68	23.42 bc	22.52 b	20.97 bc	17.7 bc	16.8 b	17.2 bc	0.15 bcd	0.22 bc	0.18 abc

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

Table 4
Multiple comparison for colour of the fresh potatoes – Sheffe’s test

a) by L* - 2003

Line	E 136	E 199	E 28	E 112	E 16	D 68	E 68	E 24	E 766	E 100	E 292	E 6	Sante
Value	76.5	76.7	76.8	77.0	77.0	77.9	78.0	78.2	78.4	78.4	78.6	79.0	79.4
												a	
												b	
												c	
$\gamma=2.4 (P<0.95)$													

b) by b* - 2003

Line	E 24	Sante	E 28	E 6	E 112	E 100	E 16	E 292	D 68	E 766	E 68	E 136	E 199
Value	39.8	40.4	40.4	43.1	43.8	44.1	44.2	44.5	44.7	46.2	47.4	48.4	48.7
												a	
												b	
												c	
$\gamma=6.7 (P<0.95)$													

c) by L*+b* - 2003

Line	E 28	E 24	Sante	E 112	E 16	E 6	D 68	E 100	E 292	E 766	E 136	E 68	E 199
Value	117.4	117.9	119.8	120.8	121.2	122.1	122.5	122.9	123.1	124.7	124.8	125.4	125.4
												a	
												b	
												c	
$\gamma=7.3 (P<0.95)$													

d) by L* - 2004

Line	E 112	E 199	E 136	E 16	E 6	E 28	D 68	E 68	E 766	E 100	E 24	Sante	E 292
Value	83.6	83.9	84.9	85.3	85.3	85.4	85.4	85.5	86.4	86.4	86.5	87.5	88.3
												a	
												b	
$\gamma=3.7 (P<0.95)$													

e) by b^* - 2004

Line	E 6	E 24	Sante	E 292	D 68	E 16	E 100	E 28	E 112	E 199	E 136	E 766	E 68
Value	40.4	40.8	42.8	44.6	44.7	44.8	45	46.1	46.5	48	48.2	49.7	50
	a												
	b												
	c												
$\gamma=7.57$ (P<0.95)													

f) by L^*+b^* - 2004

Line	E 6	E 24	E 16	E 112	D 68	Sante	E 100	E 28	E 199	E 292	E 136	E 68	E 766
Value	126	127.2	130	130	130	130	131	132	132	132.9	133	136	136.1
	a												
	b												
$\gamma=8.2$ (P<0.95)													

Table 5

Agrobiological characters of the fresh potatoes for processing

Charac-ters	Line													
	E 112	E 292	E 6	E 68	E 766	Sante	E 24	E 28	E 100	E 136	E 199	E 16	D 68	
Standard yield, kg/da	2955	2730	2379	3183	2896	2922	3228	2271	2147	3477	3237	2482	3612	
	abc	abc	bc	abc	abc	abc	abc	c	c	ab	abc	abc	a	
Tuber diameter, cm	5.4	5.7	5.1	6.2	5.5	5.9	6.1	4.6	5.3	6.8	6.2	5.9	6.8	
	bc	abc	bc	ab	bc	ab	ab	c	bc	a	ab	ab	ab	
Depth of the eyes, score	7.5	7.4	7	7.4	8.2	7.7	6.5	6.4	6.1	8	8.4	7.7	8.1	
	bcd	cd	de	cd	ab	abc	ef	ef	ef	f	abc	abc	ab	

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

The established reducing sugar amounts confirmed the good preliminary choice of breeding lines and applied agrotechnical

activities. Its contents ranged from 0.01 to 0.30 per cent in 2003 and from 0.07 to 0.41 per cent in 2004. Relatively higher

reducing sugars in 2004 could be related to the climate conditions. These results are very valuable for Bulgarian breeding -13 from 26 analyses for the both years were below 0.17 per cent, 3 - about 0.3 per cent and 2-about 0.4 per cent. The very good initial and after refrigeration colour of French fries is related to the indicated very low content of reducing sugars (below 0.35 per cent recommended).

Colour measurements

Statistical processing of the 3 colour characters into 2 systems Hunter Lab and CIE Lab (marked with *) showed better information of the second one because of dividing into more levels. This system was preferred for result presentation.

The values of the 3 colour characters in CIE Lab system - brightness (L^*), yellow colour (b^*) and summarized (L^*+b^*) are shown in Table 4. The calculated Kohran criteria indicated that the investigated 13 potato lines were distinguishable according to the mention characters.

For both years, the ranging of samples was practically equal according to L^* index, i.e. colour brightness was a stable and typical character. Predominant part of the samples was indistinguishable. The groups (marked with a, b and c) were wide coverable and statistical differences were recorded only between the ultimate classified samples Sante and E136 in 2003, E292 - Sante and E122 - E199 in 2004. The variety Sante had the highest evaluation for the both years.

The ranging on the b^* index was rather close i.e. the typical colour was relatively unchangeable in the compared multitudes. Potatoes can be divided into 3 groups according to b^* . The lines E68, E199, E136 and E766 had the most intensive colour

without any domination. E24 and E6, in particular Sante and E28 had the lowest estimation. The rest ones had mean values for colour between indicated groups.

Index L^*+b^* repeats the ranging about b^* index at great extent and according to us it is not selective. The both results are completely logical having in mind that the range of L^* 2.9 and 4.7 units for 2003 and 2004, and for b^* - 8.9 and 9.6 units, respectively as the group number into their ranging is 3 or 2. The lines E68 had the highest estimation for the both years which is different from the lines E28, E6 and E24 with the lowest estimations. The rest ones were on one and the same colour level.

Agrobiological characters

The investigated breeding materials were mainly different according to a complex of agrobiological properties (Table 5).

The line D68 possessed the highest standard productivity (3612 kg/da) followed by E136 (3477 kg/da). Both lines exceeded the control Sante (2922 kg/da) with over 550 kg. Seven of the tested lines: E112, E292, E68, E766, E24, E199 and E16 with yield from 2482 kg/da to 3228 kg/da were included into the group of the control variety. The lines E100, E28 and E6 possessed the lowest productivity and together with a relative lower weight (expressed by their cross diameter) of their standard tubers, restrict the possibility for industrial processing in spite of their chemico-technological and flavour properties.

All tested breeding materials meet the eye depth requirements. The lowest percentage of the mechanization peeling of tubers could be expected in E199, E766, D68 and E136 whose rate estimate was over 8.0.

Rank estimate

Mean rank evaluations from the both breeding years according to the accepted characters as well as the rank sums are presented in Table 6. The instrumental evaluation of colour was ranged by the means for the both year values of the parameters L^* , b^* and L^*+b^* .

Two-year test evaluation is shown on Figure 1. The line E136 manifests with the highest values in all studied characters making it the most suitable for freezing (Table 6). The lines E68, D68 and Sante form the following group at the level of rank sums 5. At the next level (about 6)

the line E24 occurs. It can be related to the most suitable lines listed above.

The groups of the next 3 lines: E766, E199 and E112 occupy mean rank level from 7 to 7.5. The line E766 possesses higher than the mean of quality properties but they are lower than the mean level of the standard yield (Table 6). Reverse, the line E199 possesses lower of quality properties but very high agrobiological ones. The line E112 has a typical mean level with 4 characters below and with other 2 upper it. We consider that these lines should be recommended for frozen French fries in spite of their not too many high evaluations.

Table 6**Arrangement of the basic characters and range sums for the studied potato lines**

Line	Characters of the quality				Agrobiological characters			
	Sensory evaluation of French fries	Colour of fresh potatoes	Dry matter content of fresh potatoes	Reducing sugars of fresh potatoes	Standard yield	Diameter	Depth of the eyes	
early	1.E 112	8	8.5	4.5	8	6	10	7
	2.E 292	4	3	13	9	9	8	8.5
mid-early	3.E 6	11	11	6	13	11	12	10
	4.E 68	1	1	9	4.5	5	3.5	8.5
	5.E 766	6	2	10	6	8	9	2
	6.Sante	7	8.5	8	4.5	7	6.5	5.5
mid-late	7.E 24	5	13	2	10.5	4	5	11
	8.E 28	10	12	3	1	12	13	12
	9.E 100	2	5	4.5	10.5	13	11	13
	10.E 136	3	4	7	2.5	2	1.5	4
	11.E 199	12	6	11.5	12	3	3.5	1
late	12.E 16	13	10	1	7	10	6.5	5.5
	13.D 68	9	7	11.5	2.5	1	1.5	3
Coefficient of influence		0.2	0.07	0.13	0.1	0.3	0.1	0.1

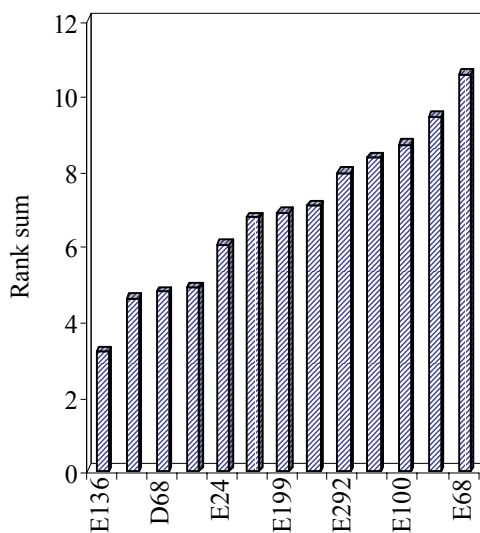


Fig. 1. Rank sums of the studied potato lines

The last group forms by five lines with an increasing rate sum from 8 to 10.5. Two of them E292 and E16 are little suitable and not suitable for production (E6, E28 and E100).

Genotypes, classified at the first 4 places, are the represents of the mid-late, mid-early (2 numbers) and late varieties, respectively. The early lines E112 and E292 are in the second classifying part. Line E68 has the most suitable shape - prologated-oval ensuring the longest slices followed by E136 and Sante, and finally D68 (round shape).

Conclusion

The investigated lines had high sensory quality. The line E68 was distinguished by the highest total evaluations for colour and flavour while the lines E6, E119 and E16 had the lowest ones.

According to the all studied characters

the line E136 had the best complex evaluation followed by E68, D68 and Sante. The lines E292 and E16 were not too suitable for frozen French fries production and E28 and E100 were unsuitable at all.

Refrigeration decreases French fries texture. Freezing suitability of a certain genotype was expressed strongly immediately after the indicated operation and trade quality - after refrigeration. Refrigeration for more than 3 months is undesirable regarding to the structure and expression of taste deviations.

High quality of French fries was provided in a wide range of dry matters from 19 to 24 per cent. Content of reducing sugars below 0.4 per cent guarantees a very good colour of French fries after freezing and storage. Such values of this component under 0.2 per cent are true approached under well-suitable genotype and agrotechnology.

References

- Almashi, E., L. Erdeli and T. Sharoi, 1981. Fast freezing of food products. *Food Industry*, Moscow, 408 pp. (Ru).
- Bulgarian State Standard 2479-70. 1970. Potatoes for industrial processing (Bg).
- Desrosier, N., 1977. Elements of Food Technology. AVI, Westport, 774 pp.
- Duncan, D., 1955. Multiple range and multiple F-test. *Biometrics*, **11**: 1-42.
- Genadiev, A., D. Kalcheva, N. Nenchev, D. Tevekeliev and N. Chavdarova, 1968. Analysis of the food products. *Technika*, Sofia, 695 pp (Bg).
- Gruboi, Y., 1990. Production of frozen products. *Agropromizdat*, Moscow, 336 pp. (Ru).
- Hayes, R. and C. Thill, 2002. Selection for Potato genotypes from Diverse Progenies

- that Combine 4°C. Chipping with Acceptable yields, specific gravity, and Tuber Appearance. *Crop Science*, **42**: 1343-1349.
- Henryka, J. and E. Zimnock-Guzowska**, 2004. Interitance of Glucose Content in Tuber of Diploid Potato Families. *American Journal of Potato Research*, **81**: 359-370.
- Heselmans, G., P. Kerkhoven and H. Barfeld**, 2004. Improving of quality of potato varieties and rights of breeders. *Potatoes and vegetables*, **8**: 27 (Ru).
- Kita, A.**, 2002. The influence of potato chemical composition on crisp texture. *Food Chemistry*, **2**: 173-179.
- Kriuss, V.**, 1963. Industrial processing of fruits and vegetables. Part II, *Pishtepromizdat*, Moscow, 428 pp. (Ru).
- Kumar, D., B. Singh and P. Kumar**, 2004. An overview of the factors affecting sugar content of potatoes. *Annals of Applied Biology*, **3**: 247.
- Lambrev, A.**, 1994. Bases of the engineering experiment with machines and apparatus for food industry. *HIFFI*, Plovdiv, 214 pp. (Bg).
- Lidanski, T.**, 1988. Statistical methods in biology and agriculture. *Zemizdat*, Sofia, 375 pp. (Bg).
- Love, S., J. Pavék, A. Thompson-Johns and W. Bohl**, 1998. Breeding Progress for Potato Chip Quality in North American Cultivars. *American Journal of Potato Research*, **75**: 27-36.
- Mallet, C.**, 1993. Frozen Food Technology. *Blackie Academic & Professional, London*, 340 pp.
- Metlickii, L.**, 1970. Biochemistry of fruits and vegetables. *Economics*, Moscow, 272 pp. (Ru).
- Metlickii, L.**, 1971. Fruit and vegetable raw materials for canning industry. *Food industry*, Moscow, 356 pp. (Ru).
- Nacheva, E. and G. Pevicharova**, 2003. Quality evaluation of potato breeding lines for industrial processing. *Scientific works of the University of Food Technologies - Plovdiv*, vol.L, **2**:306-311 (Bg).
- OCT 18-335-78**. 1978. Fastfreezing ready-to-cook-foods from potatoes. USSR Standard (Ru).
- Postolski, Y. and Z. Gruda**, 1978. Frozen food products. *Food Industry*, Moscow, 608 pp. (Ru).
- Pshechenkov, K. and O. Davidenkova**, 2004. Suitability of varieties for processing in depending on growing and storage conditions. *Potatoes and vegetables*, **1**: 22-24 (Ru).
- Richev, G.**, 1971. Study on the influence of some physical and chemical factors on the technology for production of concentrated peach purees. *PhD Thesis*, HIFI, Plovdiv (Bg).
- Scheffe, H.**, 1958. The Analysis of Variance. *John Wiley & Sons Inc*, New York, 477 pp.
- Smith, D., J. Cash, W. Nip and Y. Hui**, 1997. Processing vegetables, science and technology. *Tecnomomic publishing Co. Inc.*, Lancaster, 434 pp.

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