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SENSORY QUALITY OF EGGPLANT FRUITS (*SOLANUM MELONGENA* L.) AS AFFECTED BY CULTIVAR AND MATURITY STAGE

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Sensory quality of eggplant fruits harvested at three stages of maturity was examined. Eggplant cultivars: ‘Impulse’ F_1, ‘Epic’ F_1 and ‘Cubanita’ F_1, which differ in fruit shape, were chosen for the experiment. The quality of the fruits was evaluated by the panel of trained assessors and a quantitative descriptive analysis (QDA) was used for that assessment. Nineteen descriptors for fruit quality were chosen in an expert panel. Consumer preference test was also performed. Results showed that both cultivar and maturity stage significantly affected some sensory properties of fruits – sharp odour, odour of steamed potatoes, flesh colour, number of seeds, flesh firmness, flesh fibrousness, skin hardness, bitter taste, pungent flavour and overall quality. Overall sensory quality score was the highest for cv. ‘Impulse’ F_1 and for the fruits harvested at the earliest maturity stage. The correlation between consumer preference and QDA results was significant. Linear multiple regression models were constructed for the prediction of overall quality scores and overall preference.

INTRODUCTION

Eggplant (aubergine) is a cold-sensitive plant which is widely grown in the Mediterranean Sea region. In Polish climatic conditions it can be grown successfully in glasshouses or foil tunnels only [Gajewski, 1997; Gajewski & Gajc-Wolska, 1998]. However, popularity of this vegetable in Poland has been increasing during the last few years. Eggplant cultivars grown in Poland are mainly of Dutch origin. Fruits of these cultivars are oval-shaped or elongated, with black violet skin. According to EC quality standard [Anonymous, 1981], eggplant fruits are harvested for consumption at a physiologically non-mature stage – they are already developed, but seeds are still soft. Eggplant fruits have a specific spicy flavour and are eaten usually after roasting – as a single dish or as a component of vegetable dishes. They have been reported to decrease the LDL level in human blood due to hypolipidemic effect of some flavonoids [Kashyap *et al.*, 2003]. However, there are no reports concerning sensory characteristics of eggplant fruits.

Sensory evaluation of vegetables brings very valuable information on their quality characteristics. Sensory traits of vegetable are usually the main factors determining consumer’s satisfaction [Abbott, 1999]. Among various sensory evaluation methods reported in literature, the QDA method (quantitative descriptive analysis) is often applied for detailed description of the sensory characteristics of a product. In this method, an assumption is accepted that sensory quality is not a single attribute but it is a complex of many descriptors which can be individually estimated by a panel [Meilgaard *et al.*, 1999]. As a result of the analysis, profiles of sensory characteristics are obtained. The QDA results can be elaborated statistically with Anova or PCA methods [Baryłko-Pikielna *et al.*, 1986; Chabanet, 2000]. For the unification of sensory evaluation methods international standards were approved, based on ISO recommendations [Anonymous, 1996, 1998, 1999].

The aim of this work was to examine the influence of eggplant cultivar and maturity stage of fruits at harvest time on their sensory quality and consumer acceptance. An approach was also made to explain which sensory descriptors of eggplant are the most important for consumers as well as to construct regression model for sensory quality of eggplant fruits.

MATERIAL AND METHODS

The experiment was carried out at the Department of Vegetable and Medicinal Plants of Warsaw Agricultural University. Eggplants were grown from transplants, planted out in the middle of June to the unheated plastic tunnel, on the natural mud soil of pH 7.0. The plants were trained, with three stems left, and tied to the strings. The fertilizing was applied according to soil analyses results. Plants were chemically-protected against pests and diseases and watered regularly. Fruits were harvested systematically. The fruits for sensory evaluation were harvested in the middle of September, at three maturity stages.

Factors of the experiment:

Factor A: cultivar – ‘Impulse’ F_1 (black violet fruit, elongated), ‘Epic’ F_1 (black violet fruit, oval-shaped), ‘Cubanita’ F_1 (black violet fruit, oval-shaped);

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Factor B: maturity stage of fruits at the harvest time - M-1, M-2, M-3.

The characteristics of maturity stages of fruits: M-1 – physiologically non-matured fruit, with glossy violet black skin and non-ripened seeds; M-2 – fruit few days older than M-1, but still physiologically non-matured, with slightly mat violet black skin and non-ripened seeds; M-3 – fruit few days older than M-2, but still physiologically non-matured, with mat skin, the colour of which begins to change from black violet to light violet, and with semi-ripened seeds.

For better estimation of fruits maturity, their colour was measured instrumentally with a HunterLab spectro-colorimeter and expressed in CIE L*a*b* system [Anonymous, 1976], where L* – lightness (from 0 to 100 units), a* intensity of red (a* > 0) or green (a* < 0), b* – intensity of yellow (b* > 0) or blue (b* < 0). Colour coordinate values for fruits at different maturity stages were as follows:

– for M-1 fruits: L*=24.0–26.0, a*=1.0–3.0, b*=0.0–3.0;
– for M-2 fruits: L*=26.1–29.0, a*=3.1–5.0, b*=3.1–5.0;
– for M-3 fruits: L*=29.1–31.0, a*=5.1–6.0, b*=1.0–6.0.

The trained panel consisting of 12 staff members of the Department, previously selected and trained according to ISO guidelines [Anonymous, 1996], carried out the sensory analysis. The assessment was conducted in a laboratory equipped according to ISO guidelines [Anonymous, 1998]. At the first part of QDA procedure 'brainstorming' sessions were run to select sensory attributes for eggplant fruits evaluation. The panelists received samples of fruits varying in sensory properties and individually generated a set of descriptors for odour, colour, texture and flavour of roasted eggplant fruits. After generating and agreeing the descriptors (Table 1), the quantitative descriptive analysis (QDA) was used for the evaluation of the samples prepared. Every assessor was given randomized samples of fruits. The analysis was performed in separate booths, equipped with a computer system for data acquisition. For the assessments, whole fruits were roasted in special foil bags for 30 min at a temperature of 180°C and then they were cooled to a room temperature. Samples of the fruits (1 cm-thick slices) were put to coded plastic boxes covered with lids and then served to the assessors. The assessments were marked on 10-cm non-structural line scales shown on the monitors. Each scale was appropriately marked at both sides (low intensity – high intensity), showing the continuum being measured. The results were converted to numerical values (from 0 to 10 units) by a computer. The analysis was performed in two independent sessions, in two replications.

During semi-consumer assessment, a level of consumer overall preference for eggplant fruits was investigated using the same type of scale as above. The preference was expressed as 'liking' the sample, within the range of: fruit unacceptable – highly acceptable. Twenty persons participated in that session. For coding samples and for initial processing of the numerical data, the program Analsens was used. For the analysis of variance, Anova program was applied and HSD Tukey's test was used to show which values differed significantly at p=0.05. Principal component analysis (PCA) and regression analysis were also applied for data elaboration.

TABLE 1. Definitions of sensory descriptors used in the analysis.

No.	Descriptor	Definition	Anchoring points
Odour descriptors			
1	Sharp odour	Pungent, spicy odour	None – very intensive
2	Odour of steamed potatoes	Characteristic odour of steamed potatoes with skin	None – very intensive
3	Odour of boiled fungi	Characteristic odour of boiled fresh fungi	None – very intensive
4	Odour of hay	Characteristic odour of long stored hay	None – very intensive
5	Odour of plum jam	Sweet fruity odour, characteristic of plum jam	None – very intensive
6	Odour of boiled vegetables	Characteristic odour of boiled root vegetables - celeriac, carrot	None – very intensive
7	Off-odour	Untypical odour of eggplant fruit	
Appearance descriptors			
8	Flesh colour	Visual evaluation of flesh colour	Light – dark brown
9	Number of seeds in the flesh	Flesh visual evaluation in respect of number of seeds	Few – many
Texture descriptors			
10	Flesh firmness	Degree of force needed for chewing the flesh	Firm – soft
11	Flesh juiciness	Amount of liquid released when the sample is chewed	Not very juicy – very juicy
12	Flesh fibrousness	Mouthfeel of flesh homogenousness	Smooth – very fibrous
13	Skin hardness	Degree of force needed to bite the skin	Hard – soft
Flavour and taste descriptors			
14	Sweet taste	Basic taste	Not very intensive – very intensive
15	Flavour of boiled fungi	Characteristic flavour of boiled fresh fungi	None – very intensive
16	Flavour of a roasted fruit	Characteristic flavour of roasted apples or plums	None – very intensive
17	Bitter taste	Basic taste	None – very intensive
18	Pungent flavour	Flavour which gives an impression of burning on the tongue	None – very intensive
19	Off-flavour	Untypical flavour of eggplant fruit	None – very intensive
Overall quality			
20	Overall quality	General sensory quality impression	Low quality – high quality fruit

RESULTS AND DISCUSSION

Sensory evaluation of eggplant fruits showed that cultivars differed significantly in some sensory descriptors. Maturity stage of fruits also affected their sensory characteristics. Tables 2–4 show the influence of the two investigated factors (cultivar and maturity stage of fruits) on all sensory descriptors. The smallest differentiation between fruit samples was noted in the case of odour descriptors (Table 2). It was however found that cv. 'Epic' F_1 fruits had the most intensive sharp odour and fruits harvested at M-2 stage of maturity had the most intensive odour of steamed potatoes. Flesh colour of cv. 'Impulse' F_1 fruits as well as flesh colour of fruits which were harvested at M-1 maturity stage were scored as the brightest ones (Table 3). Fruit of cv. 'Impulse' F_1 had significantly less seeds in the flesh than the two other cultivars and its flesh was additionally the most firm and the most fibrous. The skin of cv. 'Impulse' F_1 fruit was scored as the softest. Hardness of skin depended on maturity stage of fruits and the skin of M-1 fruits was evaluated as the softest (except for cv. 'Cubanita' F_1 fruit). According to Gajewski [2002a], the firmness of eggplant fruits, measured instrumentally with a penetrometer, increases with fruit development and for M-1 fruit the firmness shows the lowest values. On the contrary, firmness declines during storage of fruits [Gajewski, 2002a; Jha &

TABLE 2. The results of sensory analysis of eggplant fruits – odour attributes (scale 0–10).

Factors		Odour						
		sharp	of steamed potatoes	of boiled fungi	of hay	of plum jam	of boiled vegetables	off-odour
Impulse	M-1	1.49	3.86	2.40	1.16	1.59	2.96	0.00
	M-2	1.37	4.99	2.55	1.61	1.44	2.41	0.05
	M-3	1.58	4.31	3.06	1.61	1.53	2.44	0.00
Epic	M-1	2.71	4.98	3.04	1.67	1.22	2.67	0.11
	M-2	1.85	4.69	3.05	1.57	1.94	2.68	0.08
	M-3	2.69	2.90	2.79	1.98	1.87	2.03	0.17
Cubanita	M-1	1.99	3.59	2.68	1.68	1.57	2.41	0.06
	M-2	1.98	4.82	2.96	1.46	1.33	2.12	0.00
	M-3	2.82	4.72	2.93	1.93	0.82	2.41	0.12
Means for cultivar(A)	Impulse	1.48^{a}	4.38^{a}	2.67^{a}	1.46^{a}	1.52^{a}	2.60^{a}	0.02^{a}
	Epic	2.42^{b}	4.19^{a}	2.96^{a}	1.74^{a}	1.68^{a}	2.46^{a}	0.12^{a}
	Cubanita	2.27^{ab}	4.37^{a}	2.86^{a}	1.69^{a}	1.24^{a}	2.31^{a}	0.05^{a}
Means for maturity stage (B)	M-1	2.06^{a}	4.14^{a}	2.71^{a}	1.50^{a}	1.46^{a}	2.68^{a}	0.06^{a}
	M-2	1.73^{a}	4.83^{b}	2.85^{a}	1.55^{a}	1.57^{a}	2.40^{a}	0.04^{a}
	M-3	2.36^{a}	3.98^{a}	2.93^{a}	1.84^{a}	1.41^{a}	2.29^{a}	0.10^{a}
LSD AxB (p=0.05)		n.s.	1.66	n.s.	n.s.	n.s.	n.s.	n.s.

Note: mean values for factors, which do not differ according to HSD Tukey's test at p=0.05 are marked with the same letters; n.s. – interaction non-significant.

TABLE 3. The results of sensory analysis of eggplant fruits – colour, number of seeds and flesh texture (scale 0–10).

Factors		Flesh colour	Number of seeds	Flesh firmness	Flesh juiciness	Flesh fibrousness	Skin hardness
Impulse	M-1	2.16	3.95	8.04	5.37	5.89	6.91
	M-2	3.67	4.15	6.20	5.24	4.72	4.49
	M-3	4.06	2.54	6.46	4.42	5.87	3.98
Epic	M-1	4.37	5.51	6.57	5.86	5.40	6.11
	M-2	6.04	6.76	3.42	5.29	3.40	2.91
	M-3	5.35	5.56	4.82	4.93	4.86	5.02
Cubanita	M-1	5.70	6.08	4.03	4.66	3.67	3.80
	M-2	4.85	5.23	5.54	5.12	4.82	5.34
	M-3	5.82	5.93	4.52	4.96	4.24	2.62
Means for cultivar (A)	Impulse	3.29^{a}	3.55^{a}	6.90^{b}	5.01^{a}	5.49^{b}	5.12^{b}
	Epic	5.25^{b}	5.94^{b}	4.94^{a}	5.36^{a}	4.55^{ab}	4.68^{ab}
	Cubanita	5.46^{b}	5.75^{b}	4.70^{a}	4.91^{a}	4.24^{a}	3.92^{a}
Means for maturity stage (B)	M-1	4.08^{a}	5.18^{a}	6.21^{b}	5.30^{a}	4.99^{a}	5.61^{b}
	M-2	4.85^{ab}	5.38^{a}	5.05^{a}	5.22^{a}	4.31^{a}	4.25^{a}
	M-3	5.08^{b}	4.68^{a}	5.27^{ab}	4.77^{a}	4.99^{a}	3.87^{a}
LSD AxB	(p=0.05)	1.63	1.63	1.80	n.s.	n.s.	1.61

Note: see Tab. 1

Matsuoka, 2002]. The fruits differed in flesh pungency – cv. ‘Epic’ F_1 fruit as well as fruits harvested at M-1 stage (except for cv. ‘Epic’ F_1 fruit) were scored as less pungent than the other fruits (Table 4). Sweet taste remained unchanged during ripening of the fruits and was scored at the same level for all maturity stages. It seems that increasing the content of sugars in fruits during the ripening process [Esteban *et al.*, 1992; Gajewski, 2002b] does not affect their sensory characteristics. Off-odour intensity was rated low for all fruit samples (scores below 0.25 unit).

Overall quality scores were affected both by cultivar and maturity stage of fruits (Figure 1). The highest score was reported for cv. ‘Impulse’ F_1 fruits and fruits harvested at M-1 or M-2 maturity stage. The same tendency, as was noticed for overall quality scores, was observed for preference ratings (Figure 1). Fruits harvested at the oldest stage of maturity were rated lower in the preference test than the younger ones.

PCA projection of profiling sensory descriptors and fruit samples (*i.e.* for three cultivars and different maturity stages) is presented in Figure 2. The projection shows that

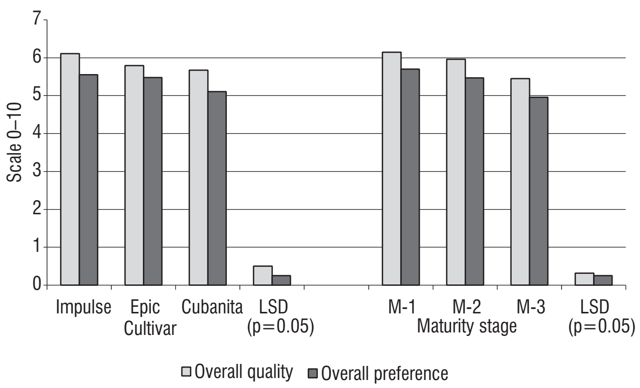

FIGURE 1. Overall sensory quality and overall preference for eggplant fruits as affected by cultivar and maturity stage (scale 0–10).

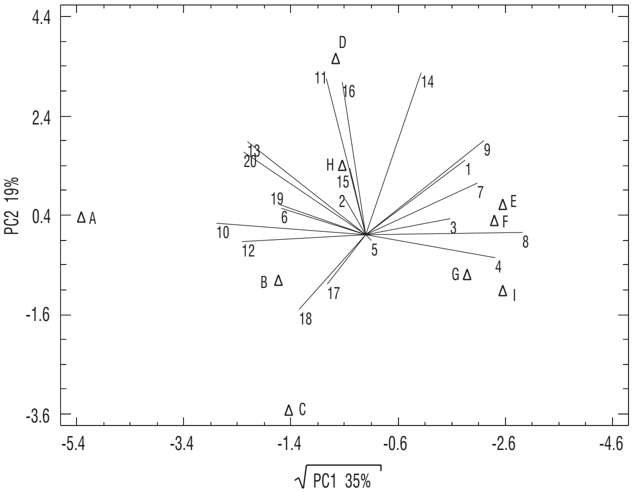

FIGURE 2. PCA projection of sensory analysis of eggplant fruits for sensory descriptors and samples.

Vectors 1–20 relate to the descriptors: 1 – sharp odour, 2 – odour of steamed potatoes, 3 – odour of boiled fungi, 4 – odour of hay, 5 – odour of plum jam, 6 – odour of boiled vegetables, 7 – off-odour, 8 – flesh colour, 9 – number of seeds, 10 – flesh firmness, 11 - flesh juiciness, 12 – flesh fibrousness, 13 - skin hardness, 14 – sweet taste, 15 – flavour of boiled fungi, 16 – flavour of a roasted fruit, 17 - bitter taste, 18 - pungent flavour, 19 – off-flavour, 20 – overall quality.

Points A–I relate to samples (cultivars / maturity stages): A – ‘Impulse’ M-1, B – ‘Impulse’ M-2, C – ‘Impulse M-3’, D – ‘Epic M-1’, E – ‘Epic’ M-2, F – ‘Epic’ M-3, G – ‘Cubanita’ M-1, H – ‘Cubanita’ M-2, I – ‘Cubanita’ M-3.

two principal components (PC 1 and PC 2) explain together only 55% of the variation between samples, with the first component alone accounting for 35% of the variation. The relationship between sensory attributes and fruit samples can be seen by their location on the graph. Points E, F, G and I are situated close to each other, which indicates similar sensory characteristics of respective fruit samples – of cv. ‘Epic’ F_1 at M-2 maturity stage, of cv. ‘Epic’ F_1 at M-3 stage, of cv. ‘Cubanita’ F_1 at M-1 stage, and of cv. ’Cubanita’

TABLE 4. The results of sensory analysis of eggplant fruits – flavour attributes (scale 0–10).

Factors		Flavour (taste)					
		sweet	of boiled fungi	of roasted fruits	bitter	sharp, pungent	off-flavour
Impulse	M-1	2.49	2.85	2.00	1.73	1.32	0.61
	M-2	2.58	3.17	1.59	0.71	2.02	0.00
	M-3	2.11	2.90	1.32	1.35	1.53	0.00
Epic	M-1	3.36	3.16	2.14	1.05	1.02	0.14
	M-2	2.94	3.31	1.73	1.03	0.93	0.00
	M-3	3.01	2.86	1.72	0.68	0.99	0.18
Cubanita	M-1	2.72	2.91	1.72	0.89	1.06	0.00
	M-2	3.28	2.93	2.25	0.74	1.62	0.00
	M-3	2.68	2.44	1.82	1.94	1.50	0.23
Means for cultivar (A)	Impulse	2.39^{a}	2.97^{a}	1.64^{a}	1.26^{b}	1.62^{b}	0.20^{a}
	Epic	3.11^{a}	3.11^{a}	1.86^{a}	0.92^{a}	0.98^{a}	0.11^{a}
	Cubanita	2.89^{a}	2.76^{a}	1.93^{a}	1.19^{ab}	1.39^{ab}	0.08^{a}
Means for maturity stage (B)	M-1	2.86^{a}	2.97^{a}	1.95^{a}	1.22^{a}	1.13^{a}	0.25^{a}
	M-2	2.93^{a}	3.14^{a}	1.86^{a}	0.83^{a}	1.52^{a}	0.00^{a}
	M-3	2.60^{a}	2.73^{a}	1.62^{a}	1.32^{a}	1.34^{a}	0.14^{a}
LSD AxB	(p=0.05)	n.s.	n.s.	0.30	n.s.	n.s.	n.s.

Note: see Tab. 1

F_1 at M-3 stage. Fruits of cv. 'Impulse' F_1 harvested at M-1 maturity stage and of cv. 'Impulse' F_1 harvested at M-3 stage differed remarkably from other fruits in their sensory characteristics.

As seen from literature, some approaches have been made to find a relationship between results of sensory and instrumental quality evaluation of vegetables [Fillion & Kilcast, 2002; Gajewski & Radzanowska, 2003]. In this work, to describe the relationship between scores for overall sensory quality and for sensory descriptors, a linear multiple regression model was applied. In this modelling, the assumption was accepted that the relationship is of a linear character. It is a simplification, however, since there are reports on non-linear relationship between the intensity of some sensory attributes and overall sensory quality [Meilgaard *et al.*, 1999].

After eliminating the independent variables, with $p>0.10$, a simplified model was obtained. The R^2 statistics indicates that the model explains 51% of the variability of overall sensory quality (the relationship is significant at $p=0.01$). The equation of the fitted model is as follows:

$$Y_o=3.90+0.18x_2+0.32x_5-0.14x_9+0.25x_{11}+0.16x_{13}-0.24x_{17}-0.20x_{18}-0.25x_{19} \quad (1)$$

where: Y_o – score expected for overall quality of eggplant fruit; x_2–x_{19} – independent variables expressed by scores obtained for sensory descriptors of eggplant fruit, numbered according to Table 1.

Overall quality and all descriptors are expressed in numerical values from 0 to 10 units.

To describe the relationship between fruit preference from semi-consumer assessment and scores for sensory descriptors, another regression model was obtained following a similar procedure. The R^2 statistics indicates that the model explains 53% of the variability of preference (the relationship is significant at $p=0.01$). The equation of the fitted model is as follows:

$$Y_p=3.10+0.13x_1+0.15x_5-0.14x_8-0.21x_9+0.35x_{11}+0.15x_{13}+0.21x_{14}-0.31x_{15}-0.23x_{17}-0.18x_{18} \quad (2)$$

where: Y_o – rating expected for consumer's preference for eggplant fruit; x_1–x_{18} – independent variables expressed by scores for sensory descriptors of eggplant fruit (see note for equation (1)).

The prediction is not very precise, as linear multiple regression model explains only about half the variability of overall quality and 53% of the preference (overall liking).

The relationship between ratings for consumer preference and scores for overall sensory quality was then calculated. Correlation coefficient value between these two variables is equal to 0.75 (the relationship is significant at $p=0.01$), which indicates a strong relationship. The regression equation for this relationship is as follows:

$$Y_p=0.12+0.90x_o \quad (3)$$

where: Y_p – rating expected for consumer overall preference for eggplant fruits; x_o – score obtained for overall quality of eggplant fruits.

CONCLUSIONS

1. Sensory quality of eggplant fruits is affected both by cultivar and maturity stage of fruits. Especially physiologically-older fruits (harvested at M-3 maturity stage) demonstrate a more firm flesh, harder skin and show more pungent flavour than the younger fruits (harvested at M-1 stage).
2. Fruits of cv. 'Impulse' F_1 show higher overall sensory quality than the fruits of other investigated eggplant cultivars. Simultaneously, fruits of this cultivar are the most liked by the consumers.
3. Overall quality score for eggplant fruits can be predicted with the multiple regression linear model, where the following scores for sensory descriptors are taken into account: odour of a plum jam, number of seeds in the flesh, flesh juiciness, skin hardness, bitter taste, pungent flavour, and off-flavour. For predicting consumer overall preference of eggplant fruits, intensity of sharp odour, odour of a plum jam, flesh colour, number of seeds in the flesh, flesh juiciness, skin hardness, sweet taste, flavour of boiled fungi, bitter taste, and pungent flavour should be taken into account in a regression model.

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JAKOŚĆ SENSORYCZNA OWOCÓW OBERŻYNY (*SOLANUM MELONGENA* L.) ZALEŻNIE OD ODMIANY I STADIUM DOJRZAŁOŚCI

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W Katedrze Roślin Warzywnych i Leczniczych SGGW badano jakość sensoryczną owoców oberżyny w zależności od odmiany (‘Impulse’ F_1, ‘Epic’ F_1 and ‘Cubanita’ F_1) oraz stadium dojrzałości zbiorczej. Oberżynę uprawiano w tunelu foliowym i zbierano we wrześniu. Jakość owoców oceniano w zespole 12 osób przeszkolonych w ocenie sensorycznej. W ocenie wykorzystano metodę ilościowej analizy opisowej (QDA). W ocenie wstępnej przeprowadzonej w zespole oceniającym wybrano 19 wyróżników charakteryzujących właściwości sensoryczne oberżyny. Przeprowadzono również ocenę konsumencką stopnia ogólnej preferencji oberżyny. Wyniki doświadczenia wskazują, że odmiana i stadium dojrzałości zbiorczej owoców wywierają istotny wpływ na niektóre cechy sensoryczne. Najwyższe noty w ocenie ogólnej jakości uzyskała odmiana ‘Impulse’ F_1 oraz owoce zebrane w stadium dojrzałości zbiorczej M-1 (najwcześniejszej) (tab. 2–4, rys.1). Analiza składowych głównych (PCA) wykazała, że pierwsza i druga składowa odpowiadają łącznie za 54% zmienności jakości sensorycznej owoców (rys. 2). Korelacja między stopniem preferencji konsumenckiej a wynikami analizy sensorycznej była istotna statystycznie. Zaproponowano model regresji liniowej wielokrotnej dla prognozowania oceny ogólnej jakości i stopnia preferencji owoców oberżyny, w zależności od wyników oceny dla wyróżników jakości sensorycznej.