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# FACTORS AFFECTING THE CHEMICAL COMPOSITION OF STRAWBERRY FRUITS

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K e y  w o r d s: strawberry, fruit quality, chemical composition.

A b s t r a c t

Strawberry fruits (*Fragaria x ananassa* Duch.) are valued by consumers for their high nutritional qualities, taste and visual values. In this work the literature review was made about the influence of different factors on sugar, organic acids, vitamin C, poliphenols and antocyanins content in strawberry fruits.

It was found, that selection of strawberry cultivar combined with agricultural practices have the essential meaning to obtain the required yield parameters.

## CZYNNIKI WPŁYWAJĄCE NA SKŁAD CHEMICZNY OWOCÓW TRUSKAWEK

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S ł o w a  k l u c z o w e: truskawka, jakość owoców, skład chemiczny.

A b s t r a k t

Owoce truskawki (*Fragaria x ananasa* Duch.) są cenione przez konsumentów dzięki wysokim wartościom odżywczym, walorom smakowym, a także wizualnym. W pracy dokonano przeglądu piśmiennictwa na temat wpływu różnych czynników na zawartość cukrów, kwasów organicznych, witaminy C, polifenoli i antocyjanów w owocach truskawki.

Wykazano, że niezbędnym warunkiem zapewnienia wymaganych parametrów jakościowych plonu truskawek jest dobór właściwej odmiany i lokalizacja pola w połączeniu z odpowiednimi zabiegami agrotechnicznymi.

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## Introduction

Strawberry (*Fragaria x ananassa* Duch.), a well known berry-bearing plant, was created by crossing Chilean strawberry (*Fragaria cgiloensis*) with Virginia strawberry (*Fragaria virginiana*) in the 18$^{th}$ century. Significant progress concerning cultivation of this plant and breeding highly productive varieties took place only in the 20th century (REJMAN 1994, PIEGRZA, SZCZYGIEŁ 1999). Strawberry is cultivated on a large scale in all countries of moderate climate and in cooler regions of subtropical countries (REJMAN 1994). The largest producers of strawberries include USA, Spain, Poland, Morocco and China (KUBIAK 2001). The most intense region of strawberry cultivation is California. Due to its specific climatic conditions, strawberries bear fruit there for 4–6 months a year, giving an average yield of 40–60 tones per 1 ha. For comparison, average yields of strawberries obtained in Poland amount on average to 6 tones per 1 ha. In recent years, as a result of the increasing requirements of food consumers, greater attention has been placed on yield quality. This aspect particularly concerns strawberries, which are characterized by high nutritive and health properties. Strawberry fruits are a valuable component of the diet, since they are of low calorie content and contain easily assimilable sugars, as well as many vitamins, pectines and fibre. As regards the content of iron and phosphorus, strawberries rank the highest among berry-bearing plants. They are also a good source of potassium, magnesium and calcium (HAKALA et al. 2003). Vitamins found in large amounts in strawberries include: vitamin A, B1, B2, C and PP. Their contents vary for different cultivars (REJMAN 1994). In terms of abundance in vitamin C in berry fruits, strawberries are second only to black currants. Strawberries are also valued for to their antioxidant content (SKUPIEŃ and OSZMIAŃSKI 2007). On the other hand, high water content in fruit determines their juiciness and refreshing taste.

One of the threats resulting from an intensive production of strawberries is the risk of contaminating the yield by harmful chemicals, like pesticides or fertilizers. Although monitoring research conducted in Poland does not show harmful amounts of residues of plant protection products, nonetheless, a detection of trace amounts in even 44.8% of the samples analysed should be considered alarming (NOWACKA et al. 2010). Insignificant amounts of pesticide residues in strawberries were also found in research conducted in Finland (HAKALA et al. 2003).

Factors related to the choice of cultivars, growing technology although harvesting and fruits trading are of crucial importance for ensuring quality parameters of the yield. Cultivars can be classified into traditional

varieties (short day cultivars) – early, medium-early and late, and everbearing (day neutral cultivars) – bearing fruit in elongated period of growing season). Generally, native cultivars are better adopted to the local environment, giving the best yield and fruit under the conditions in which they have been grown. The number of strawberry cultivars throughout the world already exceeds 2.000 (ŻURAWICZ 1997). In 2011, the register of orchard plant varieties in Poland contained 45 cultivars of strawberry (*Odmiany wpisane...* 2012).

The dominant cultivar in Poland is 'Senga Sengana', originated in Germany, particularly because of its good adaptation to prevailing climatic conditions and high yielding (ŻURAWICZ et al. 2005). Currently, the most demanded cultivars are dessert varieties, the fruits of which are tasty, well formed and are characterized by distinctive size, colour, high firmness and lower susceptibility to fungal diseases causing fruit rotting. Therefore, it is necessary to increase the market supply of strawberry cultivars that meet consumers' expectations and satisfy producers (MASNY et al. 1996).

This study has a review character. The aim of this work is to summarize researches data about the quality of strawberry fruits.

## Strawberry yield quality parameters

### Sugar content

Sugar content is one of the main parameters considered in the evaluation of the nutritive value of strawberries. Moreover, yield quality factors are included in the characteristics of cultivars registered in Poland. As demonstrated by some researchers, high sugar content was found for the 'Senga Sengana' cultivar (ROLBICKI and RZEKANOWSKI 1997, SKUPIEŃ 2003, KOSZAŃSKI et al. 2006). Low sugar content in fruits was determined for such cultivars, like: 'Pandora', 'Vicoda', 'Purpuratka', 'Dange', 'Saulene', 'Ydun' (REJMAN 1994, SKUPIEŃ 2003, KOPYTOWSKI et al. 2006, KOSZAŃSKI et al. 2006]. As regards accumulated sugars, particular attention should be given to: fructose, glucose and saccharose occurring in significant amounts in strawberry fruits (KALLIO et al. 2000, CORDENUNSI et al. 2002). The proportions of their content slightly varies, depending on the cultivar and agricultural conditions. The content of individual sugars within the cultivar seems to be inherited and independent of environmental conditions (OGIWARA et al. 1998) and thus it is important to cultivate and popularize varieties characterized by high sugar content, which will transfer this feature to subsequent generations (OHTSUKA et al. 2004). Sturm et al. (2003) also distinguish xylose, which is

found in trace amounts in strawberries. Its relatively high content was observed in fruits of the 'Northhaester' cultivar and it was very low in the 'Miss' cultivar. Literature data concerning sugar content in strawberries of individual cultivars are divergent depending not only on the cultivar, but also on many cultivation conditions, such as irrigation (which is particularly important in blossoming phase and fruit setting phase), fertilization (mainly nitrogen, phosphorus and potassium – NPK), as well as the health condition of the plantation (SKUPIEŃ 2003, OHTSUKA et al. 2004, KOSZAŃSKI et al. 2005]. The time between the harvest and fruit chilling also plays a significant role – a longer interval results in the greatest losses in nutritional value of strawberries (NUNES et al. 1995). Additionally, the period of storage frozen fruits affects the reduction of saccharose content (CORDENUNSI et al. 2003, SKUPIEŃ 2003). The research by KOSZAŃSKI et al. (2005) demonstrated that the 'Elsanta' cultivar contained lower amounts of sugars after the application of 2 NPK fertilization (40 kg of nitrogen, 80 kg of phosphorus and 100 kg of potassium $ha^{-1}$) and irrigation as compared to control objects. Different results were noted by CHEŁPIŃSKI et al. (2010), where fruits of cultivar 'Kent' contained more sugar after fertilization on 150 kg $ha^{-1}$ NPK level. STURM et al. (2003) determined the highest total sugar content for the 'Mohawk' cultivar, depending on the degree of fruit maturity (mature fruits for processing purposes were characterized by lower sugar content than fully ripe fruits). Differences in sugar content can be also related to various factors occurring during the fruit ripening phase. TREDER (2003), after ROLBICKI and RZEKANOWSKI, demonstrated that drip irrigation had a significant effect on lowering sugar content in strawberries of the 'Senga Sengana' cultivar.

## Organic acids content

The content of organic acids is a very important indicator affecting the taste of fruits, which influences both their consumer and processing value. This feature is variable and depends on the cultivar, weather conditions, as well as agricultural factors and regional differences between the studies conducted (SKUPIEŃ 2003). The content of organic acids in strawberries does not usually exceed 3%. The most important organic acids determined in strawberries include citric acid and apple acid (KALLIO et al. 2000), and the total acidity of fruit is determined on the basis of their content. The research by this author proved that the content of apple acid in strawberries fluctuated on a level that was 2–3 times lower than the level of citric acid. Similar results can be found in BASSON et al. (2010) research. Their studies showed that citrate content decreased slightly as the berries ripened, and sugar-to-acid

ratio increased during ripening. The highest values of total acidity were found for 'Aura', 'Dange' and 'Senga Sengana' cultivars (KOPYTOWSKI et al. 2006). STURM et al. (2003) demonstrated that fully ripe fruits were characterized by lower content of organic acids than technologically ripe fruit. In research by KOSZAŃSKI et al. (2005), the content of organic acids in the fruits of 'Senga Sengana' cultivar increased for objects fertilized with a double dose of NPK. Therefore, the acidity of strawberry fruits is not a constant feature of the cultivars under examination. It can change depending on many environmental parameters occurring during the cultivation and to a large extent depends on agricultural factors.

## Content of biologically active compounds

In recent years, particular attention has been placed on the occurrence of biologically active compounds in strawberry fruits, such as vitamin C and antioxidant-type compounds, which include phenolic acids, flavonoids and anthocyans. A particular importance is attributed to the second group of compounds because of their anti-cancer, anti-inflammatory, neutron protective and anti-atherosclerosis properties (MILLER et al. 2008, KILLIAN et al. 2009, ROUSSOS et al. 2009). The accumulation of phenolic compounds is consistent with the proposed protective roles of these substances as antimicrobial metabolities (GIL et al. 1997).

## Vitamin C

The content of ascorbic acid in fruits and vegetables is affected by many factors, such as genotypic differences, climatic conditions, cultivation and fruit ripening conditions and the time of storage (LEE and KADER 2000). In this regard, the research proved, for instance, the unfavourable effect of extending the period of fruit exposure to high temperature between the harvest and chilling (NUNES et al. 1995). HÄGG et al. (1995) reported that vitamin C content in the fresh mass of various cultivars of strawberry cultivated in Finland ranged between 56 and 99 mg% in 1992. Noticeable changes in content of vitamin C were noted between organic and conventional strawberry farms (REGANOLD et al. 2010). Fruits from organic farms contained more ascorbic acid. CORDENUNSI et al. (2002) found that all from studied cultivars showed increase in total ascorbic acid content from the early stages of development to full maturity. KAZUYOSHI et al. (1999) found that ascorbic acid content among the cultivars varied much during harvest. The first changes in vitamin C

content can already be observed in the period of supplying fresh fruit to the market (RUSSEL et al. 2009). Even short storage of frozen strawberries deprives them of a substantial amount of ascorbic acid (CORDENUNSI et al. 2003), but those changes are much more noticeable during long-term storage of frozen strawberries (SKUPIEŃ 2003). It was found that even subjecting strawberry fruit to irradiation does not prevent vitamin C losses during storage (GRAHAM and STEVENSON 1997). As results from the research conducted by KOPYTOWSKI et al. (2006), the highest content of this component was found in 'Saulene', 'Senga Sengana' and 'Aura' cultivars. The accumulation of vitamin C in vegetables, according to JABŁOŃSKA-CEGLAREK (1989), depends on the level of irrigation as well as on climatic, agricultural and varietal factors. KOSZAŃSKI et al. (2005) demonstrated a reduction of vitamin C content under the influence of irrigation and high levels of NPK fertilization.

## Polyphenols and anthocyanins

Compounds demonstrating high antioxidant activity against free radicals include polyphenols and anthocyans. The content of those components in strawberries depends on many factors, such as the choice of cultivar, agricultural conditions, light availability, nitrogen content in soil, degree of fruit ripeness and storage temperature (KALT et al. 1999, BOJARSKA et al. 2006, BACCHELLA et al. 2009, ROUSSOS et al. 2009). BOJARSKA et al. (2006) demonstrated that the highest content of polyphenolic compounds in fruits was characteristic for the 'Polka' cultivar, and the lowest was for the 'Kent' cultivar. ROUSSOS et al (2009) observed a reduction in polyphenol content in fruits of the 'Camarosa' cultivar, obtained after previous treatment of plants with gibberellic acid and Fenotiol. Those differences prove the significant influence of the suppressing effect of growth stimulants on the content of antioxidants. FERREYRA et al. (2007) found that the decreasing antioxidant activity of fruit was negatively correlated with anthocyan synthesis. CORDENUNSI et al. (2005) recorded a decrease in the antioxidant activity of strawberries under conditions of lowered storage temperature. SHIN et al. (2007) demonstrated that strawberries revealed the highest antioxidant activity when they were stored at 10°C, regardless of the air humidity. SKUPIEŃ and OSZMIAŃSKI (2007) observed that the antioxidant activity against the DPPH radical grew significantly after applying fertilization with titanium only in fruits of the 'Elsanta' cultivar. For other cultivars, no significant influence of a growth regulator applied on the antioxidant activity of strawberry fruit was observed. In other studies (PANICO et al. 2009) was noted that bioactive compounds content was correlated with type of soil. REGANOLD et al. (2010)

found that strawberry fruits from organic farms had higher antioxidant activity and concentration of phenolic compounds in correlation to conventional ones.

## Summary

The growing of strawberry cultivars distinguished by a high commercial yield, and at the same time rich in nutrients and other valuable components, is a very important aspect of the production of berry-bearing fruits. On the basis of research conducted to date, it can be claimed that between many factors affecting biological value of strawberry fruits, e.g. varietal, agricultural practices, weather conditions, the highest impact has their genotype and origin. Nevertheless, the quality of the yield obtained is conditioned by all factors accompanying the cultivation. It also applies to the production of fruit deprived of the remains of harmful chemical compounds, which is related to the preference of a protection system characterized by a low dependence on pesticides.

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## References

BOJARSKA J.E., CZAPLICKI C., ZARECKA K., ZADERNOWSKI R. 2006. *Związki fenolowe owoców wybranych odmian truskawki*. Żywność, Supl., 2(47): 20–27.

BACCHELLA R., TESTONI A., SCALZO R.L. 2009. *Influence of genetic and environmental factors on chemical profile and antioxidant potential of commercial strawberry* (*Fragaria x ananassa, Duchesne*). EJEAFChe, 8(4): 230–242.

BASSON C.E., GROENEWALD J-H., KOSSMAN J., CRONJÉ C., BAUER R. 2010. *Sugar and acid-related quality attributes and enzyme activities in strawberry fruits. Invertase is the main sucrose hydrolyzing enzyme*. Food Chem., 121: 1156–1162.

CHEŁPIŃSKI P., SKUPIEŃ K., OCHMIAN I. 2010. *Effect of fertilization on field and quality of cultivar Kent strawberry fruit*. J. Entomol., 15(2): 251–257.

CORDENUNSI B.R., NASCIMENTO J.R.O., GENOVESE M.I., LAJOLO F.M. 2002. *Influence of cultivar on quality parameters and chemical composition of satrawberry fruits grown in Brazil*. J. Agric. Food Chem., 50: 2581–2586.

CORDENUNSI B.R., NASCIMENTO J.R.O., LAJOLO F.M. 2003. *Physico-chemical changes related to quality of five strawberry fruit cultivars during cool-storage*. Food Chem., 83(2): 167–173.

CORDENUNSI B.R., GENOVESE M.I., OLIVEIRA DO NASCIMENTO J.R., HASSIMOTO N.M.A., DOS SANTOS R.J., LAJOLO F.M. 2005. *Effects of temperature on the chemical composition and antioxidant activity of three strawberry cultivars*. Food Chem., 91: 113–121.

FERREYRA R.M., VINA S.Z., MUGRIDGE A., CHAVES A.R. 2007. *Growth and ripening season effects on antioxidant capacity of strawberry cultivar Selva*. Scientia Hortic., 112: 27–32.

GIL M.I., HOLCROFT D.M., KADER A.A. 1997. *Changes in strawberry anthocyanins and other polyphenols in response to carbon dioxide treatments*. J. Agric. Food Chem., 45: 1662–1667.

Graham W.D., Stevenson M.H. 1997. *Effect of irradiation on vitamin C content of strawberries and potatoes in combination with storage and with further cooking in potatoes*. J. Sci. Food Agric., 75: 371–377.

Hakala M., Lapveteläinen A., Houpalahti R., Kallio H., Tahvonen R. 2003. *Effects of varietes and cultivations conditions on the composition of strawberries*. J. Food Comp. Anal., 16: 67–80.

Hägg M., Ylikoski S., Kumpulainen J. 1995. *Vitamin C content in fruit and berries consumed in Finland*. J. Food Comp. Anal., 8: 12–20.

Jabłońska-Ceglarek R. 1989. *Wpływ nawadniania, nawożenia obornikiem, nawożenia mineralnego oraz uprawy po poplonach na wartość odżywczą kapusty białej późnej i selera korzeniowego*. Biul. Warz., XXV: 100–124.

Kallio H., Hakala M., Pelkkikangas A.M., Lapveteläinen A. 2000. *Sugars and acids of strawberries varieties*. Eur Food Res Technol., 212: 81–85.

Kalt W., Forney C.F., Martin A., Prior R.L. 1999. *Antioxidant capacity, vitamin C, phenolics, and anthocyanins after fresh storage of small fruits*. J. Agric. Food Chem., 47: 4638–4644.

Kazuyoshi S., Tatsuya M., Yuji N. 1999. *Variations in ascorbic acid content among strawberry cultivars and their harvest times*. J. jpn. Soc. Hortic. Sci., 68: 1007–1014.

Killian C., Li L., Adams L.S., Chen A., Seeram N.P. 2009. *Strawberry poliphenols inhibit proliferation and COX-2 protein expression in human HT-29 colon cancer cells*. Division of Agricultural & Food Chemistry. The 238th ACS National Meeting, Poster2: http://oasys2.confex.com, access: 24.03.2012.

Kopytowski J., Kawecki Z., Bojarska J.E., Stanys V. 2006. *Ocena plonowania i jakości owoców kilku odmian truskawki uprawianej na Warmii*. Zesz. Nauk. Inst. Sad. Kwiac., 14: 53–60.

Koszański Z., Rumasz-Rudnicka E., Kaczmarczyk S., Rychter P. 2005. *Wpływ nawadniania i nawożenia mineralnego na plonowanie i cechy jakościowe dwóch odmian truskawek uprawianych na glebie lekkiej*. Inż. Rol., 3(63): 251–256.

Koszański Z., Rumasz-Rudnicka E., Podsiadło C. 2006. *Wpływ nawadniania kroplowego i nawożenia mineralnego na jakość owoców truskawki*. J. Element., 11(1): 21–27.

Kubiak K. 2001. *Kierunki produkcji i zagospodarowania owoców truskawek w kraju i za granicą*. Ogólnopolska Konferencja „Intensyfikacja produkcji truskawek". Inst. Sad. Kwiac., 42–61.

Lee S.K., Kader A.A. 2000. *Preharvest and postharvest factors influencing vitamin C content of horticultural crops*. Post. Biol. Technol., 20: 207–220.

Masny A., Laszlovszky-Zmarlicka A., Cieśliński G., Smolarz K. 1996. *Ocena przydatności wybranych nowych odmian truskawki do uprawy polowej*. Zesz. Nauk. Inst. Sad. Kwiac., 3: 37–49.

Miller E., Malinowska K., Gałęcka E., Mrowicka M., Kędziora J. 2008. *Rola flawonoidów jako przeciwutleniaczy w organizmie człowieka*. Pol. Merk. Lek. XXIV, 144: 556–560.

Nowacka A., Gnusowski B., Walorczyk S., Drożdżyński D., Wójcik A., Raczkowski M., Hołodyńska A., Barylska E., Ziółkowski A., Chmielewska E., Rzeszutko U., Giza I., Jurys J., Łozowicka B., Kaczyński P., Rutkowska E., Jankowska M., Szpyrka E., Rupar J., Rogozińska K., Kurdziel A., Słowik-Borowiec M., Kuźmenko A., Szala J., Sadło S. 2010. *Pozostałości środków ochrony roślin w płodach rolnych* (*rok 2009*). Prog. Plant Prot. / Post. Ochr. Rośl., 50(4): 1947–1962.

Nunes M.C.N., Brecht J.K., Sargent S.A., Morais A.M.M.B. 1995. *Effect of delays to cooling and wrapping on strawberry quality* (*cv. Sweet Charlie*). Food Control, 6(6): 323–328.

*Odmiany wpisane do krajowego rejestru (KR). Truskawka*, www.coboru.pl/Polska/Rejestr/odm_w_rej.aspx?kodgatunku=TRJ, access: 24.03.2012.

Ogiwara I., Miyamoto R., Habutsu S., Suzuki M., Hakoda N., Shimura I. 1998. *Variation in sugar content in fruit of four strawberry cultivars grown in the field and under forced culture, harvest years, and maturation stages*. J. jpn. Soc. Hortic. Sci., 67(3): 400–405.

Ohtsuka Y., Kibe H., Hakoda N., Shimura I., Ogiwara I. 2004. *Heritability of sugar contents in strawberry fruit in the F1 population using a common pollen parent*. J. jpn. Soc. Hortic. Sci., 73(1): 31–35.

Panico A.M., Garufi F., Nitto S., Di Mauro R., Longitano R.C., Magri G., Catalfo A., Serrentino M.E., De Guidi G. 2009. *Antioxidant activity and phenolic kontent of strawberry genotypes from Fragaria x ananasa*. Pharm. biol., 47(3): 203–208.

Reganold J.P., Andrews P.K., Reeve J.R., Carpenter-Boggs L., Schadt C.W. et al. 2010. *Fruit and soil quality of organic and conventional strawberry agroecosystems*. PLoS ONE, 5(9): 1–14.

Rejman A. 1994. *Pomologia. Odmianoznawstwo roślin sadowniczych*. PWRiL, Warszawa: 603–648.

ROLBICKI S., RZEKANOWSKI C. 1997. *Influence of sprinkler and drip irrigation on the growth and yield of strawberries grown on sandy soil*. Acta Hort., 439(2): 669–671.

ROUSSOS P.A., DENAXA N.K., DAMVAKARIS T. 2009. *Strawberry fruit quality attributes after application of growth stimulating compounds*. Scientia Hortic., 119: 138–146.

RUSSEL L.F., LEBLANC B.I., MCRAE K.B., RYAN D.A.J. 2009. *Losses of vitamin C from fresh strawberries in a commercial supply chain*. Int. J.. Food Sci. Technol., 44(4): 820–828.

SZCZYGIEŁ A., PIEGRZA K. 1999. *Truskawka*. Hortpress Sp. z o.o., Warszawa.

SHIN Y., LIU R.H., NOCK J.F., HOLLIDAY D., WATKINS C.B. 2007. *Temperature and relative humidity effects on quality, total ascorbic acid, phenolics and flavonoid concentrations, and antioxidant activity of strawberry*. Post. Biol. Technol., 45: 349–357.

SKUPIEŃ K. 2003. *Ocena wybranych cech jakościowych świeżych i mrożonych owoców sześciu odmian truskawki*. Acta Sci. Pol. Hort. Cultus., 2(2): 115–123.

SKUPIEŃ K., OSZMIAŃSKI J. 2004. *Comparison of six cultivars of strawberries* (*Fragaria x ananasa Duch*.) *grown in northwest Poland*. Eur Food Res. Technol., 219: 66–70.

SKUPIEŃ K., OSZMIAŃSKI J. 2007. *Influence of titanium treatment on antioxidant content and antioxidant activity of strawberries*. Acta Sci. Pol., 6(4): 83–94.

STURM K., KORON D., STAMPAR F. 2003. *The composition of fruit of different strawberry varieties depending on maturity stage*. Food Chem., 83: 417–422.

TREDER W. 2003. *Nawadnianie plantacji truskawek jako czynnik warunkujący jakość owoców*. Ogólnopolska Konferencja Truskawkowa, Inst. Sad. Kwiac., 88–92.

ŻURAWICZ E., DOMINIKOWSKI J. 1993. *Plonowanie dwu powtarzających odmian truskawki w warunkach Polski centralnej*. Zesz. Nauk. Inst. Sad. Kwiac., 1: 19–26.

ŻURAWICZ E. 1997. *Truskawka i poziomka*. PWRiL, Warszawa.

ŻURAWICZ E., KRUCZYŃSKA D., MASNY A. 2005. *Wartość produkcyjna najnowszych odmian truskawki w warunkach Polski centralnej*. Zesz. Nauk. Inst. Sad. Kwiac., 13: 75–80.