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# Changes in quality of selected red beet (*Beta vulgaris* L.) cultivars during the growing season

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## ABSTRACT

Red beet (*Beta vulgaris* L.) may be consumed at all stages of growth, both in the form of small early vegetable during spring and later, during winter, when stored. Therefore, knowledge of the dynamics of changes in the content of individual components in subsequent stages of growth is very important.

The experiment was conducted for two consecutive growing seasons. The study included four cultivars of red beet 'Boro' $F_1$, 'Czerwona Kula', 'Nochowski' and 'Regulski Cylinder'. The aim of this study was to assess the dynamics of changes of selected components during the growing season. Particular attention was paid to the content of components having a positive impact on the quality of red beet, such as: antioxidant activity, the content of betalain pigments, soluble sugars and dry matter.

On the basis of the survey it was demonstrated that the optimal harvest date of red beet roots, with respect to the favorable nutrient and health-related content, falls in the $8^{th}$ and $11^{th}$ week of the growing season depending on the weather conditions in a given year. A significant increase in the anti-radical activity, soluble sugars as well as betanin and vulgaxanthin (2009) was observed between the $6^{th}$ and the $8^{th}$ and also in the $11^{th}$ week of the cultivation. A gradual drop in betanin to vulgaxanthin ratio was observed within the following weeks of the vegetation. On the basis of the research conducted we can conclude that the cultivar recommended for consumption is 'Nochowski'.

Key words: antioxidant activity, betalain pigments, soluble sugars

## INTRODUCTION

Red beet is one of the most popular vegetables in Poland. Individual cultivars differ with respect to the length of the growing season, shape, color intensity of the root and nutritional compounds content (Biegańska-Marecik et al. 2007).

Red beet is characterized by the attractive flavor; it stimulates the appetite and is easily digestible and refreshing. It is beneficial for digestion, improves liver function, lowers blood pressure, reduces fragility of blood vessels and regulates cholesterol levels (Delgado-Vargas et al. 2000) The presence of betalain pigments has significant impact on the value of health benefits of beet roots. They consist of red betacyanins and yellow betaxanthins (Azeredo 2009). The red beets main betacyanins are betanin and izobetanin, which constitute about 95% of all

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betacyanins. Vulgaxanthin I and vulgaxanthin II are the main betaxanthins (Stintzing et al. 2006).

Red beet is often used in cancer prevention. It has been shown that products containing betalains have a high antioxidant potential and have a positive impact on human's health (Re et al. 1999). Red beet belongs to the group of 10 vegetables of the highest antioxidant potential (Vinson at al., 1998, Wettasinghe et al. 2002). According Stintzing and Carle (2004), Mikolajczyk and Czapski (2006) there is a positive correlation between the content of betacyanins in beet juice and its antioxidant activity. However, there is no clear link between the presence of yellow pigments and antioxidant activity (Czapski et al. 2009).

The presence of carbohydrates has an influence on the nutritional value of red beet. High sugar content largely affects the taste, increasing desirability. It has been shown that during the cultivation, content of betalaine compounds and sugars changes. As a result, betacyanins and betaxanthine pigments do not reach their maximum levels at the same time. The maximum level of red pigments is achieved faster while the concentration of the yellow pigments increases throughout the growth period (Stintzing and Carle 2007).

The aim of this study was to assess the dynamics of changes in content of quality ingredients during the growing season of four red beet cultivars. The information received will identify when red beets contain the largest amounts of beneficial compounds, in which period they should be eaten in greatest amounts.

## MATERIAL AND METHODS

The experiment was carried out from 2009-2010 in the experimental field of the Department of Vegetable and Medicinal Plants of the University of Agriculture in Krakow. The experiment was founded in brown soil. The conducted study involved four selected cultivars of red beet, 'Boro' $F_1$ (spherical shaped root, with dark-red flesh and hardly visible rings, Bejo Zaden Company), 'Czerwona Kula' (spherical shaped root, rings are hardly noticeable when it is cut, has dark-red flesh, one of the oldest cultivars available on the market, introduced by), 'Nochowski' (spherical shaped root, with dark-red flesh with scarcely visible rings, introduced by Spójnia Nochowo breeding), 'Regulski Cylinder' (cylindrical shaped root 'Czerwona Kula' cultivar – round in shape, averagely colored flesh with well noticeable rings, introduced by Spójnia Nochowo breeding)

The experiment was begun at the beginning of July (01.07.2009, 01.07.2010, 01.07.2011, 03.07.2012). Before sowing, seeds were treated with the seed coating Funaben T. The spacing was 40 × 10 cm. Thinning was held at the 2-4 leaf stage, about the final space between plants in the row was 8-10 cm. In the middle of the growing season the plants were sprayed with Curzate preparation (20 g of product per 10 liters of water) to prevent *Cercospora beticola*. The experiment was conducted in a randomized block design with 4 replications, where each block was 6 m$^2$, so included about 150 plants.

During the growing seasons the representative samples of 20 storage roots of red beet were collected from the experimental field at 2 weeks intervals. In 2009, the samples were collected in the 6$^{th}$, 8$^{th}$, 9$^{th}$ and 11$^{th}$ week of growing season. In 2010, due to the unfavorable weather conditions, the samples were collected in 6$^{th}$, 8$^{th}$, 9$^{th}$, 11$^{th}$ and 13$^{th}$ and 15$^{th}$ week of vegetation.

The roots were weighed, measured and placed in a freezer at a temperature of -70°C for a period of 2-3 months. Then, successive samples were thawed and the following analysis was performed:

*Dry matter* [%] – the dry matter determination was conducted with the usage of the oven method by Pijanowski at 70$^o$C (Krełowska-Kułas 1993). The pulped plant material was weighed and moved into a weighing dish. The samples were dried in an oven to a constant weight and left to cool in a desiccator. Finally, the content of the dry matter was calculated according to the following formula:

$$X = \frac{M_2 - M_0}{M_1 - M_0} \cdot 100\%$$

where: $M_0$ – mass of the dish $M_1$ – the mass of the dish with the remains after drying, $M_2$ – the mass of the dish with the pulp.

*Antioxidant activity* of the stable radical DPPH (2,2-diphenyl-2-picryl-hydrazyl) (Miliauskas et al. 2004) [%] – 2.5 g tissue was weighed out and mixed with 10 ml of 80% methanol for 5 minutes in a CAT homogenizer. Subsequently the samples were spun in a centrifuge for 15 minutes at 6000 g at a temperature of 4°C. They prepared the DPPH solution with a concentration of 0.1 mmol within 1 dm$^3$ of 80% methanol. The supernatant was moved from the centrifuge dishes into the measuring cylinders and topped up with 10ml of 80% methanol. A measuring solution was prepared from 5.90 ml of the DPPH solution and 0.10 ml of the plant extracts. The absorbance of the solutions was measured at a wavelength of 517 nm after 5 minutes of the sample being stored in the dark. The anti-radical activity was calculated according to the following formula:

$$\% \text{ of DPPH}^{\bullet} \text{ scavenging} = [1 - (As/Ac)] \times 100\%$$

where: As – absorbance of the sample; Ac – absorbance of the control sample

*Betanin and vulgaxanthin* were determined by Nillson (1970) [mg $g^{-1}$ fresh mass] – the plant material was cut in a blender then 3.5 the volume of water was added and finally it was homogenized in a mixer for 10 minutes. The samples were filtered through a filter paper. 0.5 ml of filtrate was taken and diluted with a phosphate buffer to a volume of 50 ml. The absorbance of the solution was measured at wavelengths of 600, 538 and 476 nm. The content of the pigments was calculated by the formula:

$$X = \frac{A \cdot V \cdot R}{\frac{1}{10} \cdot M \cdot E^{1cm}{}_{1\%}}$$

where: A – dye absorbance, V – volume prepared for the measurement, R – degree of dilution of red beets, $E^{1cm}{}_{1\%}$ – factor of the pigment absorption, M – mass of the sample in the measuring solution.

*Soluble sugars* were determined by anthrone method (Yemm and Wills 1954) [% fresh mass] – 2g of the homogenized plant material was weighed then placed in the volumetric flasks and a small amount of alcohol was poured over it. Subsequently they were extracted in a hot water bath for 30 minutes. After cooling, the samples were filtered and the extract was topped up with alcohol to the volume of 100 ml. The samples were placed in cold water and the anthrone reagent was added (0.2 g anthrone in 100 ml 96% $H_2SO_4$). The samples were then heated in a boiling water bath for 10 minutes. After cooling, the absorbance of the solutions was measured on a spectrophotometer at a wave length of 625 nm. The content of the sugars was read from the calibration curve within the range of 0.5-3.0 mg glucose in 100 ml of distilled water.

Independent analysis of variance was applied to the collected data. The results have been analyzed with the Tukey HSD test at a significance level p = 0.05. Statistical analyses were performed with a computer program StatSoft Statistica 9.0.

## RESULTS AND DISCUSSION

During the experiment conducted in the second year of the study, the weather conditions were exceptionally adverse, i.e. a very large amount of rainfall throughout the growing season, particularly in the last ten days of July and August, when the field had been flooded for some time. During this period in 2010 twice the rainfall was recorded as the same period in 2009. Temperature was also an important factor. At the beginning of the growing season in 2010 the temperature was significantly higher than in the previous year, but then began to decline dramatically. Also in 2010 a wide disparity in the prevailing temperatures was observed (Fig. 1). Adverse weather conditions in 2010 caused a delay in harvesting the roots of about a month.

A systematic increase in mass and diameter of the tested cultivars was observed during the whole period of vegetation. 2010 reported a lower value of these parameters, certainly due to the adverse weather conditions; lots of rain and major temperature fluctuations. The study showed that at the time of harvest, red beet with a weight greater than 200 g were examined only in 2009, for all analyzed cultivars except 'Regulski Cylinder' of cylindrical shaped root. The cultivar of the biggest roots turned out to be 'Boro' $F_1$ (Fig. 2).

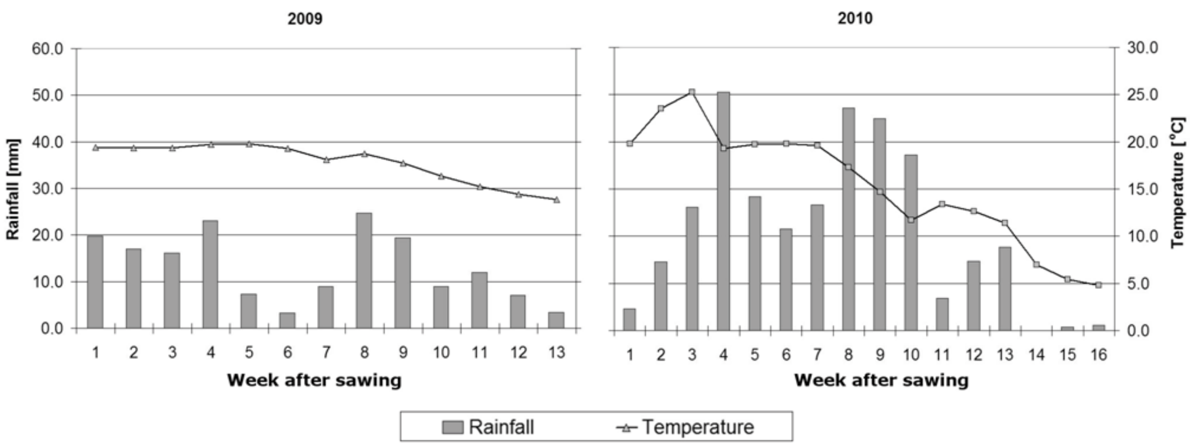


**Figure 1.** Average week temperatures and sum of rainfall in 2009 and 2010

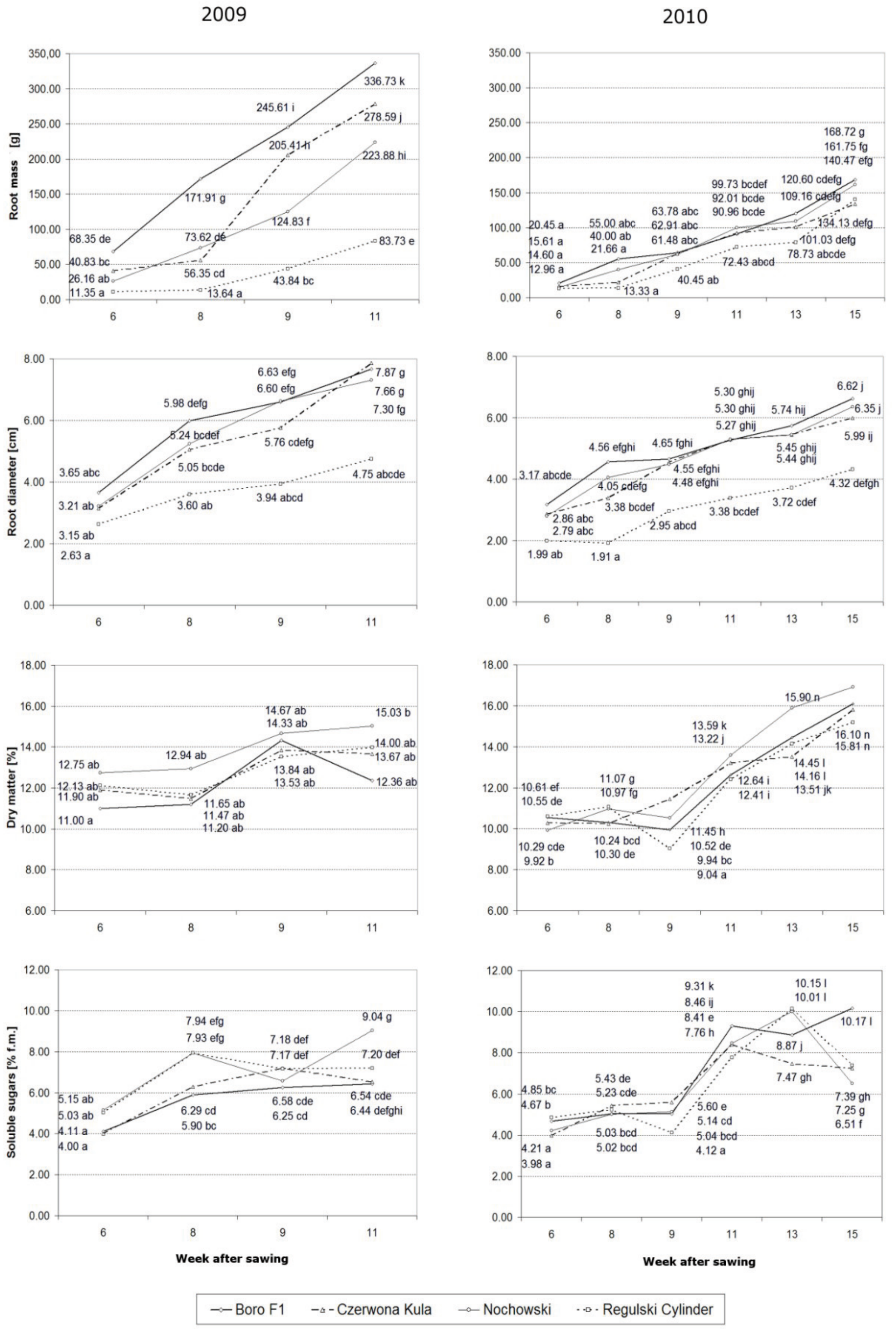


**Figure 2.** Root weight, diameter, dry matter and soluble sugars in the roots of selected 4 cultivars of red beet in particular weeks after sowing

In 2010 it was observed that there is a smaller diversity among particular cultivars. The mass and diameter of the roots of ‘Nochowski’ and ‘Czerwona Kula’ cultivars remained on a similar level. ‘Boro’ $F_1$was characteristic by largest roots. Both in 2009 and 2010 the lowest values were recorded for ‘Regulski Cylinder’).

According to Michalik et al. (1995) the diameter of the root after about 14 weeks of cultivation is within the range of 3-5 cm, after 17 weeks it is 6-7 cm. In this study, after about 11 weeks of cultivation it ranged from 3.38 to 7.87 cm.

In 2009 no significant differences in the content of dry matter were observed between investigated cultivars. In 2010 'Nochowski' contained the most of dry matter (apart from the 6$^{th}$ and 9$^{th}$ week). The lowest content of dry mass was shown for 'Regulski Cylinder' in the 9$^{th}$ week of vegetation In the case of dynamic of changes of soluble sugars content, the situation was analogous to the case of antioxidant activity, in similar periods increases and decreases in soluble sugars were observed.

Both in 2009 and in 2010 an increase in the content of soluble sugars in the roots of red beets occurred between the 6$^{th}$ and 8$^{th}$ week of vegetation. Nonetheless, in 2010 the growth was much lower than in the previous year of the research. Another increase was observed between the 9$^{th}$ and 11$^{th}$ week of vegetation. In 2009 it was largest for 'Nochowski' cultivar. In 2010 the rise of the content of sugars was proved for the three cultivars ('Boro $F_1$', 'Czerwona Kula' and 'Nochowski'), yet there was a fall for 'Regulski Cylinder' cultivar. In the following weeks of cultivation it was observed a growth for two cultivars and a drop for two cultivars of the researched constituent. In the last week of vegetation all the cultivars, except for the 'Boro $F_1$', were characterized by a fall in the content of sugars.

Factors such as cultivar, sowing and harvesting term, weather and crop conditions have influence on the content of the analysed ingredients. According to Wolyn and Gabelman (1986), the roots of red beets of the same cultivar sown later, contain higher amounts of betalain pigments than those sown at an earlier date. Pigment content in the roots of red beet is significantly affected by the temperature and it is probably the most important factor influencing the color of red beet. Since the half of XIX century it was well known, that a dry and hot summer with temperatures above 25°C adversely affects the betalain pigment content (Bradley and Dyck 1967). Similar conclusions can be reached on the basis of performed research. Average temperatures above 25°C occurred during the initial growing period in 2010, which in turn contributed to the decrease in the content of betalain pigments, both betacyanins and betaxanthins (Fig. 3).

In the first year of the conducted research, within the last two weeks before harvesting, there was a growth of the red pigments among all the cultivars. 'Nochowski' contained the most betanin, whereas 'Czerwona Kula' had the least. In 2010, 'Regulski Cylinder' presented the highest volume of betanin until the 13$^{th}$ week of vegetation. Nevertheless, a significant drop was noticed within the last two weeks of vegetation (13$^{th}$ – 15$^{th}$ week). During the harvesting, 'Nochowski' cultivar had the most betanin while 'Czerwona Kula' and 'Boro' $F_1$ contained the least.

In 2009 an increase of vulgaxanthin was observed among all the examined cultivars between the 9$^{th}$ and 11$^{th}$ week. 'Nochowski' proved the highest escalation. Nonetheless, in 2010 the rise of this pigments was considerably larger between the 11$^{th}$ and 15$^{th}$ week of vegetation. Vulgaxanthin increased by 300% for 'Boro $F_1$', 'Czerwona Kula' and 'Nochowski'. The least vulgaxanthin was found in the roots of 'Regulski Cylinder' cultivar. The largely diverse weather conditions prevailing in 2009 and 2010 may have caused the differences in the content of betanin and vulgaxanthin between the first and second year of study.

Nilsson (1973) showed that the level of red pigments increases up to about 110 days (about 16 weeks), while the level of yellow pigments increases even after 134 days of cultivation (about 19 weeks). According to Watson and Gabelman (1982) and Wolyn and Gabelman (1986) there is a continuous increase in both red and yellow pigments between 50-100 days of the growing season (about 7-14 weeks). Shannon (1972) noted in his work that the highest levels of betacyanin pigments occur between the 67$^{th}$ and 109$^{th}$ day of the crop (about 10-16 weeks). Thus, according to Michalik et al. (1995), red beet intended for the production of pigments should not be grown for more than 100 days (about 14 weeks). Red pigments rapidly reach their maximum level, while the amount of betaxanthin increases throughout the growing season, which ultimately affects the color change. In this study, the ratio between betanin to vulgaxanthin content, at the time of harvest was within the range of 2.46-3.25 in both years.

Research conducted in 2009 shows a fall in the ratio of betanin to vulgaxanthin in the following weeks of cultivation. The largest value was observed in the 6$^{th}$ week of vegetation. At the harvesting the ratio was on a similar level for 'Boro $F_1$', 'Nochowski' and 'Regulski Cylinder' cultivars, however, 'Czerwona Kula' presented the lowest value. In 2010, as in the previous year, there was a gradual decline in the ratio of betanin to vulgaxanthin during the vegetation period. After 15 weeks the largest value of the coefficient was observed for 'Nochowski' and the lowest for 'Czerwona Kula'.

Extending the time of harvesting means that the ratio of betacyanin to betaxanthin pigments may fall even below 2.0, which adversely affects the

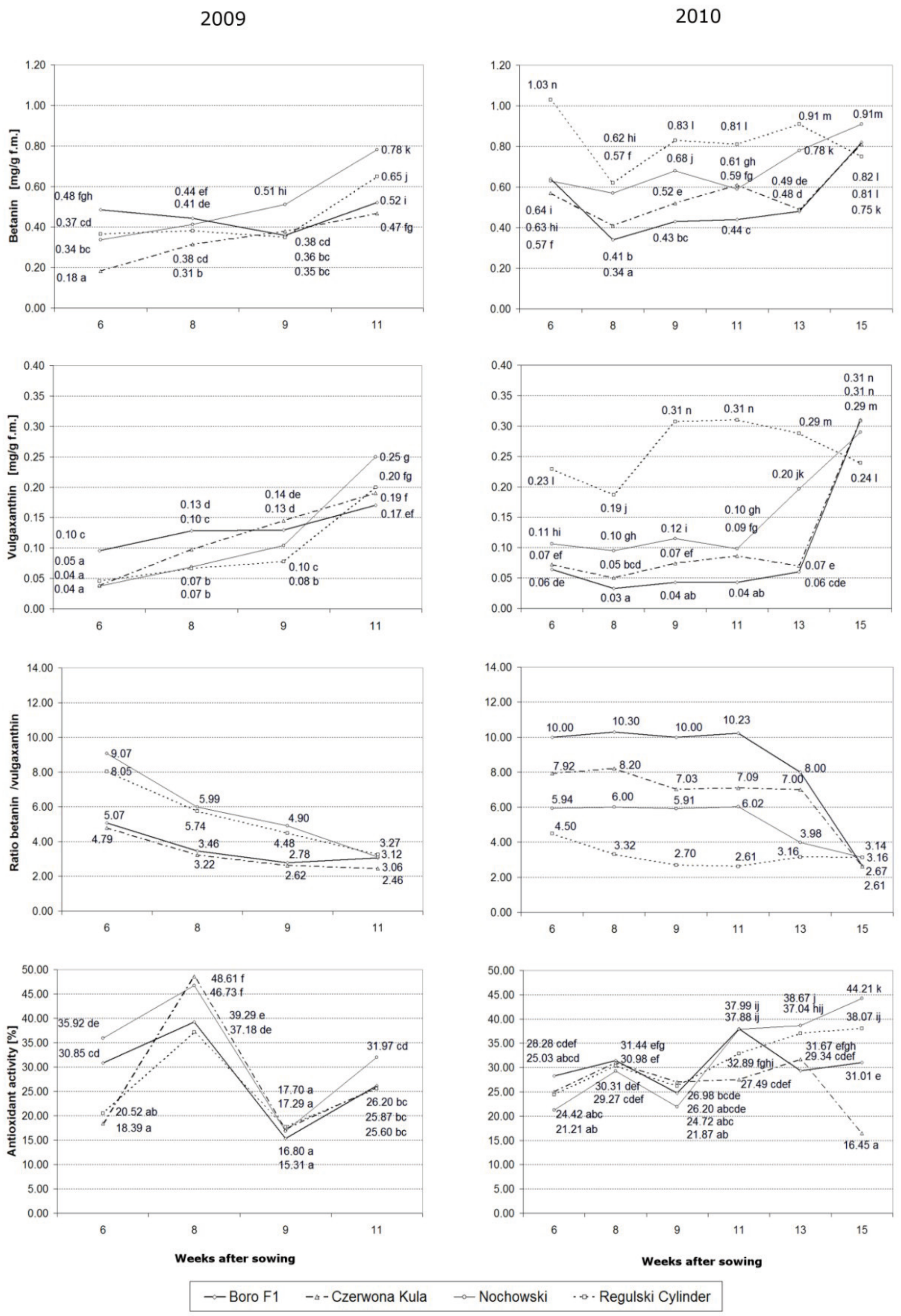


**Figure 3.** Betanin, vulgaxanthin, betanin to vulgaxanthin ratio and antioxidant activity of the roots of 4 cultivars of red beet in particular weeks after sowing

color and the commercial value of the roots of red beet (Michalik et al. 1995).

During the first year of the study, antioxidant activity showed a significant increase between 6 and 8 week of vegetation. The largest rise was observed for 'Czerwona Kula' (about 160%), the lowest for 'Regulski Cylinder' (about 100%). There was a drop of free radical scavenging by about 50-80% between the 8th and 9th week of growth. Within the next two weeks of vegetation there was once more an increase of anti-radical activity; at the time of harvesting the highest values were recognized for 'Nochowski' (there were no substantial dissimilarities between the particular cultivars).

One year later at the same time, these changes were not so drastic. Between the 9th and 11th week, once again, there was a growth of anti-radical activity. The best in this manner, as in the previous year, proved to be 'Nochowski' cultivar. The trend persisted in the following weeks. In the 13th and 15th week there was a slight increase in anti-radical activity, apart from 'Boro $F_1$' which presented a fall in the activity in the 13th week and 'Czerwona Kula' where the drop occurred within the 15th week of vegetation.

On the basis of the research conducted over two-years it can be noticed that in 2009 compared to 2010 there was higher anti-radical activity despite the lower content of betalain pigments. It should be noticed that the anti-radical activity is influenced principally by betalain compounds but also by other compounds such as vitamin C, the content of which was not analysed within the conducted research.

Research conducted by Michalik and Grzebelus (1995) showed a gradual decline of betalain pigments, sugars and the dry mass after 100, 120 and 140 days (about weeks 14, 17 and 20) of cultivation. In performed studies, no declines in these components in the final weeks of cultivation were noted, probably because the growing season was much shorter.

An increase in content of beneficial nutrients in the first weeks of vegetation and the subsequent decline was probably due to the intense growth of the root, which in turn contributed to the effect of dilution and drop in content of desired substances. A smaller jump in soluble sugars content and antioxidant activity in 2010 was probably caused by a large amount of rain, which caused a dilution effect.

## CONCLUSIONS

1. The optimal time for harvest of red beet roots to maximize the yield and the content of favorable nutrients and pro-health components falls between weeks 8th and 11th of the growing season, depending on the weather conditions in a given year. A cultivar recommended for consumption during this period is 'Nochowski'
2. The growth of anti-radical activity, soluble sugars, betanin and vulgaxanthin (2009) was observed between 6 and 8 and in the 11th week of cultivation.
3. During the period of vegetation a gradual drop of betanin to vulgaxanthin ratio was noted. At the time of harvest the highest betanin to vulgaxanthin ratio was shown for 'Nochowski' and 'Regulski Cylinder'.

## REFERENCES


Azeredo H.M.C., 2009. Betalains: properties, sources, applications and stability - a review. Int. J. Food Sci. Tech. 44: 2365-2376

Biegańska–Marecik R., Czapski J., Błaszczyk P., 2007. Determination of cultivar and technological process effect on the occurence of bitter taste in red beet. Food Sci. Techn. 3(52): 62-70.

Bradley G.A., Dyck R.L., 1967. Yield and quality of table beets. Ark. Farm. Res. 16: 9.

Czapski J., Mikołajczyk K., Kaczmarek M., 2009. Relationship between antioxidant capacity of red beet juice and contents of its betalain pigments. Pol. J. Food Nutr. Sci. 59(2): 119-122.

Delgado-Vargas F., Jimenez A.R., Paredes Lopez O., 2000. Natural pigments: carotenoids, anthocyanins and betalains. Characteristics, biosynthesis, processing and stability. Crit. Rev. Food Sci. Nutr. 40: 173-289.

Krełowska-Kułas M., 1993. Research on quality of food products. PWE, Warsaw.

Michalik B., Grzebelus D., 1995. Betanine and nitrate contents in table beet cultivars as a function of growth period and manner of nitrogen fertilization. Acta Hort. 379: 205-212.

Michalik B., Żukowska E., Ślęczek S., 1995. Changes in quality of red beet cultivars with growing time. Folia Hort. 7(1): 127-136.

Mikołajczyk K., Czapski J., 2006. The antioxidant activity and content of betalain pigments in different variety of red beet. Bromat. Chem. Toksykol., 2006, Supl., 437–441.

Miliauskas G., Venskutonis P.R., Van Beek T.A., 2004. Screeming of radical scavenging activity of some medicinal and aromatic plant extracts. Food Chem. 85: 231-237

Nillson T., 1970. Studies into the pigments in beetroot (*Beta vulgaris* ssp. *vulgaris* var. *rubra* L.). Lantbrukhog. An. 36: 179-219.

Re R., Pellegrini N., Prottegente A., Pannala A., Yang M., Rice-Evans C., 1999. Antioxidant activity applying an improved ABTS radical cation decolorization assay. Free Rad. Biol. Med. 9/10: 1231-1237.

Shannon S., 1972. Changes in soluble solids, red pigment content and firmness of table beet cultivars with growing time and season. J. Amer. Soc. Hort. Sci. 97(2): 233-228.

Stintzing F.C., Carle R., 2004. Functional properties of anthocyanins and betalains in plants, food and in human nutrition. Trends Food Sci. Techn. 15: 19-38.

Stintzing F.C., Trichterborn J., Carle R. 2006. Characterisation of anthocyanin-betalain mixtures for food colouring by chromatic and HPLC-DAD-MS analyses. Food Chem. 94: 296-309

Stintzing F.C., Carle R., 2007. Betalains – emerging prospects for food scientists. Trends Food Sci. Techn. 18: 514-525.

Vinson J.A., Hao Y., Su. X., Zubik L., 1998. Phenol antioxidant quantity and quality in foods: vegetables. J. Agric. Food Chem. 46: 3630-3634.

Watson J.F., Gabelman W.H., 1982. Seasonal changes and cultivar differences in pigment concentrations and percent dissolved solids in roots of table beets. J. Amer. Soc. Hort. Sci. 107(5): 713-716.

Wettasinghe M., Bolling B., Plhak L., Parkin K., 2002. Screening for phase II enzyme-inducing and antioxidant activities of common vegetable. J. Food Sci. 67: 2583-2588

Wolyn D.J., Gabelman W.H., 1986. Effects of planting and harvest date on betalain pigment concentrations in three table beet genotypes. Hort. Sci. 21(6): 1339-1340.

Yemm E.W., Wills A.J., 1954. The estimation of carbohydrates in plant extracts by anthrone. Biochem. J. 54: 508-514.

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