Bulgarian Journal of Agricultural Science, 21 (No 4) 2015, 736-741
Agricultural Academy

COMPARISON OF CHEMICAL COMPOSITION OF SELECTED CULTIVARS OF WHITE, YELLOW AND RED ONIONS

G. JURGIEL-MALECKA, M. GIBCZYNSKA and M. NAWROCKA-PEZIK
West Pomeranian Technological University in Szczecin, Department of General and Ecological Chemistry, 71-434 Szczecin, Poland

Abstract

JURGIEL-MALECKA, G., M. GIBCZYNSKA and M. NAWROCKA-PEZIK, 2015. Comparison of chemical composition of selected cultivars of white, yellow and red onions. *Bulg. J. Agric. Sci.*, 21: 736–741

The analysed six onion cultivars (*Allium cepa* L.) cultivated in Poland were characterised by different colour of onion scale leaf: Albion and Alibaba (white cultivar), Grabowska and Majka (yellow cultivar), Scarlet and Wenta (red cultivar). The onion cultivars were obtained from the Experimental Station of Cultivars Testing in Węgrzce near Kraków. The following was determined for each cultivar: the content of macro- and micronutrients, reducing and total sugar, the vitamin C content. Significant differences in chemical composition between the analysed cultivars were found. The cultivars of the same colour exhibited similar tendencies in terms of accumulating the most of the analysed elements. The greatest differences in the chemical content were found among yellow and red cultivars. Yellow cultivars accumulated significantly greater amounts of nitrogen, phosphorus, potassium, magnesium, iron, manganese, zinc, copper and reducing sugar than red onion cultivars. Red onion cultivars contained significantly greater amounts of total sugar and vitamin C than yellow onion cultivars.

Key words: onion, macroelements, microelements, reducing sugars, total sugars, vitamin C

Abbreviations: DM – dry matter; FW – fresh weight

Introduction

The onion (*Allium cepa* L.) is one of the oldest cultivated vegetable crops. According to data (FAOSTAT, 2014), world production of onion is increasing – in 2012 it reached 82.8 mln against 78.9 mln tons in 2010. Poland is the fifth largest producer of onion in Europe. In 2012 onion was cultivated on an area of 25072 ha and the crop obtained amounted to 642 169 tons. The nutritional and medicinal values as well as the taste of onion (Augusti, 1996; Rabinowitch and Currah, 2002; Lanzotti, 2006), make it a very popular vegetable all over the world, mostly due to various possible applications of the crop. Onion can be consumed raw, processed and stored. Even though onion is mainly used as a pot herb, it constitutes an important element of human food chain because of high content of flavonoids, fructans, macro- and micronutrients. There is a strong correlation between the content of micronutrients found in crops and the health of animals or people consuming it (Ruszkowska and Wojcieska-Wyskupajtys, 1996).

Micronutrients are necessary for normal growth and development of plants as well as people – they are the ingredients or activators of various enzymes and play a catalytic role in many physiological processes. The elements such as iron, manganese, zinc or copper take part in photosynthesis, decarboxylation, and nitrogen fixation processes as well as protein and carbohydrates metabolism. Antioxidants found in onion protect the human organism against free radicals which are responsible for ageing and cardiovascular diseases (Rabinowitch and Currah, 2002). Fructans found in onion are considered prebiotic and stimulate the growth of intestinal microbiota decreasing the risk of diet-related diseases such as colorectal cancer (Grzelak, 2006).

Numerous studies have shown the differences in chemical composition of onion depending on the cultivation conditions (Hamilton et al., 1997; Hamilton et al., 1998; Kaufmann et al., 2000; Randle, 2000; Jurgiel-Małecka and Suchorska-Orłowska, 2008), and cultivar (Kopsell and Randle, 1997; Jadczak and Wójcik-Stopczyńska, 2007; Mysiak and Tendaj, 2008).

E-mail: grazyna.jurgiel-malecka@zut.edu.pl

New onion cultivars of various colours, shapes, odours and flavours are now available on the market. At the same time, the customers are now more health-oriented and aware of healthy eating habits and pay attention not only to the appearance of onion but also to its nutritional prophylactic and medicinal values.

The aim of this paper is the comparison of chemical composition of several onion cultivars and resulting nutritional suitability.

Materials and Methods

The analysis included six onion cultivars (*Allium cepa* L.) of various scales leaves colour which are cultivated in Poland: Albion and Alibaba (white cultivar), Grabowska and Majka (yellow cultivar), Scarlet and Wenta (red cultivar). In order to ensure the same conditions of vegetation all analysed cultivars were grown in one place (Poland, Research Station for Cultivar Testing in Węgrzce - 50°07′ north latitude, 19º59′ west longitude, 285 m above sea level) and were fertilised in the same manner. Fertilisation with phosphorus and potassium in autumn amounted to 35 kg P/ha and 160 kg K/ha with the use of triple superphosphate ($Ca(H_2PO_4)_2$ + H_3PO_4) and potassium sulphate (K_2SO_4). During vegetation in spring the crops were fertilized with three equal doses of nitrogen in total amount of 150 kg N/ha. The first and the second fertilization was made with the use of ammonium nitrate (NH_4NO_3), and the third with calcium nitrate ($Ca(NO_3)_2$). Onion was harvested at the time when 70% of the onion chive began to fall down. The samples were obtained three weeks after harvesting according to standards (PN-83/R-04012/00; PN-87/R-75357).

The chemical analyses were conducted in two replicates with the use of well-established methods generally accepted in agricultural chemistry. The vitamin C content was determined in fresh mass by means of Tillmans method and other chemical determinations were conducted in dry mass. Dry mass of each cultivar was obtained from 2 kg of randomly selected onions which were peeled, chopped and dried at the temperature of 40°C and grinned.

The content of reducing and total sugar was determined by means of water extract and Luff-Schoorl method.

Total content of macro- and micronutrients was determined after previous wet mineralization of samples in concentrated sulphuric (VI) acid with H_2O_2 or in a mixture (3:1) of nitric (V) acid and chloric (VII) acid.

In the solutions derived from mineralization of samples in sulphuric (VI) acid with H_2O_2, the following was determined:

- nitrogen – Kjeldahl's method,
- potassium, magnesium and calcium – atomic absorption spectrometry.

In the solutions derived from mineralization in the mixture of nitric (V) acid and chloric (VII) acid, the following was determined:

- phosphorus – Barton's method at λ – 470 nm,
- sulphur – turbidimetric method at λ – 490 nm,
- iron, zinc, copper, manganese – atomic absorption spectrometry.

The statistical analysis of the results was conducted using Statistica 10 software. In order to determine the significance of the differences in chemical composition of the analysed onion cultivars, one way analysis of variance (ANOVA) was conducted. For the purpose of determining homogenous subsets of means, the Newman-Keulus test was conducted for $P \leq 0.05$.

Results and Discussion

The analysed onion cultivars differed in the content of the analysed elements (Table 1). The greatest significant differences were recorded as for reducing sugar content while the magnesium accumulation exhibited the least differences between onion cultivars.

Macronutrients (N, P, K, Ca, S)

The highest content of nitrogen (27.58 g/kg DM) and phosphorus (5.64 g/kg DM), respectively 26% and 28% above the average, was recorded in yellow onion cultivar Grabowska. The lowest content of the elements in question (18.20 g N/kg DM and 3.54 g P/kg DM) respectively 17% and 20% below average was recorded in white cultivar Albion. Studies by other researchers concerning the chemical composition of onion cultivars show similar accumulation of nitrogen (Freeman and Mossadeghi, 1971; Kleiber et al., 2010a) and phosphorus (Rodrígues Galdón et al., 2008; Kleiber et al., 2010a).

The highest potassium content (16.44 g/kg DM) as well as calcium content (1.08 g/kg DM) was found in yellow cultivar Majka – respectively 17% and 28% above the average. Similar content of potassium, yet higher content of calcium were determined in cultivars: Renate and Alisa Craig in the study by Chope and Terry (2009). The lowest content of potassium (11.48 g/kg DM, 18% below average) was determined in red cultivar Scarlet, and the lowest content of calcium (0.68 g/kg DM, 19% below average) was determined in white cultivar Albion. Similar contents of macronutrients in question were determined in cultivar Texas in the study by Rodrígues Galdón et al. (2008).

Most of the analysed cultivars did not exhibit significant differences as for sulphur accumulation and formed a

Table 1
Chemical composition of the onion (*Allium cepa* L.) cultivars

Analyzed component	Cultivar						Mean
Macronutrients, g/kg DM	White		Yellow		Red		
	Albion	Alibaba	Grabowska	Majka	Scarlet	Wenta	
N	18.20[a]	23.31[b]	27.58[d]	25.34[c]	18.48[a]	18.76[a]	21.94
P	3.54[b]	4.76[c]	5.64[e]	5.02[d]	3.78[a]	3.80[a]	4.42
K	14.01[c]	14.95[d]	16.13[b]	16.44[b]	11.48[a]	11.54[a]	14.09
Ca	0.68[a]	0.85[bc]	0.73[a]	1.08[d]	0.81[b]	0.92[c]	0.84
S	3.43[a]	3.20[a]	3.79[c]	3.26[a]	3.26[a]	2.18[b]	3.19
Total	39.86	47.07	53.87	51.14	37.81	37.20	44.48
Micronutrients, mg/kg DM							
Mg	545.80[a]	651.63[b]	674.11[b]	658.17[b]	514.13[a]	553.06[a]	599.48
Fe	25.31[a]	25.03[a]	31.71[e]	29.87[d]	18.13[b]	21.35[c]	25.23
Mn	11.46[c]	12.83[b]	14.78[d]	12.80[b]	10.68[a]	10.98[a]	12.25
Zn	19.70[a]	23.65[b]	25.47[c]	26.47[c]	19.67[a]	24.16[b]	23.19
Cu	4.54[b]	5.97[a]	5.70[a]	5.78[a]	3.97[c]	4.83[b]	5.13
Total	606.81	719.11	751.77	733.09	566.58	614.38	665.28
Reducing sugars, g/kg DM	237.6[e]	113.6[b]	204.1[d]	277.7[f]	95.7[a]	129.8[c]	176.4
Total sugars, g/kg DM	512.8[d]	537.2[e]	482.0[c]	417.5[b]	566.5[a]	567.5[a]	513.9
Vitamin C, mg/100g FW	10.87[b]	8.74[a]	8.84[a]	8.13[a]	10.77[b]	9.96[c]	9.55

[abcdef] Mean values with the same letter in each row are not significantly different at $P \leq 0.05$

homogenous subset with mean content of 3.29 g S/kg DM. Significant differences in the content of this element were recorded only in two cultivars: the highest content of sulphur was determined in yellow cultivar Grabowska (3.79 g/kg DM, 19% above average), and the lowest content of sulphur in red cultivar Wenta (2.18 g/kg DM, 32% below average). The literature on the subject indicates slightly higher mean content of sulphur in onion (5-6 g S/kg DM) (Freeman and Mossadeghi, 1971; Jurgiel-Małecka and Suchorska-Orłowska, 2004; Chope and Terry, 2009; Kleiber et al., 2010a). However, from the cultivars analysed by Chope and Terry (2009), the SS1 cultivar showed almost identical sulphur content as cultivar Grabowska (3.82 and 3.79 g/kg DM respectively).

Micronutrients (Mg, Fe, Zn, Cu)

According to data included in Table 1, red cultivar Scarlet accumulated the least of the analysed micronutrients from all the cultivars under study. This cultivar showed the lowest content of magnesium (514.13 mg/kg DM, 14% below average), iron (18.13 mg/kg DM, 28% below average), and manganese (10.68 mg/kg DM, 13% below average), zinc (19.67 mg/kg DM, 15% below average) and copper (3.97 mg/kg DM, 23% below average). The highest content of all the micronutrients was determined in yellow cultivar Grabowska – magnesium (674.11 mg/kg DM, 12% above average), iron (31.71 mg/kg DM, 26% above average) and manganese (14.78 mg/kg DM, 21% above average), as well as higher than average content of zinc (25.47 mg/kg DM) and copper (5.70 mg/kg DM). The highest content of zinc was determined in yellow cultivar Majka (26.47 mg/kg DM, 14% above average), and the highest content of copper in white cultivar Alibaba (5.97 mg/kg DM, 16% above average). The contents of the micronutrients determined in the six onion cultivars are in line with the results obtained by Chope and Terry (2009) and Kleiber et al. (2010b) and slightly higher than the results obtained by Rodrígues Galdón et al. (2008).

Reducing and total sugars

The analysed onion cultivars showed significant differences in terms of the content of reducing sugars which ranged from 95.7 g/kg DM (46% below average, cultivar Scarlet) to 277.7 g/kg DM, (57% above average, cultivar Majka). Vast differences in reducing sugars content in bulb vegetables are also mentioned by various authors (Bajaj et al., 1980; Chagas et al., 2004; Hallmann and Rembiałowska, 2006).

The mean total sugars content (513.9 g/kg DM) was similar to the results obtained in other studies (Ketiku, 1976; Bajaj et al., 1980; Grzelak, 2006; Hallmann and Rembiałowska, 2006; Rodrígues et al., 2009). The highest content of total sugars was determined in red cultivar Wenta (567.5 g/kg DM, 10% above average), and the lowest in yellow cultivar Majka (417.5 g/kg DM, 19% below average).

Vitamin C

The vitamin C content determined in fresh mass ranged from 8.13 mg/100 g FW (cultivar Majka) to 10.87 mg/100 g FW (cultivar Albion) and is similar to the results obtained by Hallmann and Rembiałowska (2006) – from 7.52 to 16.96 mg/100 g FW. However, the results by Bieżanowska-Kopeć et al. (2011) show slightly lower content of vitamin C in the same cultivars.

The colour of the onion and its chemical composition

The analysis of the data presented in table 1 shows a tendency of the onions of the same colour to accumulate comparable amounts of some elements. In order to determine the effect of colour of the onion on its chemical composition, the statistical analysis of the results was repeated and the colour constituted the qualitative factor (Table 2).

The highest mean content of total macro- and micronutrients was found in yellow cultivars (52.51 g/kg DM and 742.43 mg/kg DM respectively). The amount of accumulated nitrogen, phosphorus, potassium, magnesium, iron, manganese and zinc was significantly higher ($P \leq 0.05$) in yellow cultivars than in red and white cultivars. The lowest content of total macro- and micronutrients was found in red cultivars (37.51 g/kg DM and 590.48 mg/kg DM respectively).

Even though no significant differences were found in the content of calcium, sulphur and copper, the mean content of these elements in yellow cultivars was higher than in red and white onion cultivars. The content of reducing sugars was the highest in yellow onion cultivars (240.9 g/kg DM on average), while the content of total sugars was the lowest (449.7 g/kg DM on average). These results are significantly different than those obtained for red onion cultivars which had the lowest reducing sugars content (112.8 g/kg DM on average) and accumulated the most total sugars (567.0 g/kg DM on average). According to Hamilton et al. (1997), the cultivars of higher sulfur content have smaller amounts total sugars. Table 2 confirms this correlation. Moreover, onion with higher sulphur content is characterized by more pungent flavour and intensive odour (Freeman and Mossadeghi, 1970, 1971; Hamilton et al., 1998). The higher content of reducing sugar in yellow onion cultivars indicates the presence of greater amount of active formyl groups taking part in Maillard reactions during food processing such as bak-

Table 2
Effect of the onion (*Allium cepa* L.) color on the chemical composition

Analyzed component	Cultivar			Mean
Macronutrients, g/kg DM	White	Yellow	Red	
N	20.75^{a}	26.46^{b}	18.62^{a}	21.94
P	4.15^{a}	5.33^{b}	3.79^{a}	4.42
K	14.48^{b}	16.29^{c}	11.51^{a}	14.09
Ca	0.77^{a}	0.90^{a}	0.87^{a}	0.84
S	3.32^{a}	3.53^{a}	2.72^{a}	3.19
Total	43.47	52.51	37.51	44.48
Micronutrients, mg/kg DM				
Mg	598.71^{b}	666.14^{c}	533.60^{a}	599.48
Fe	25.17^{b}	30.79^{c}	19.73^{a}	25.23
Mn	12.15^{a}	13.79^{b}	10.83^{a}	12.25
Zn	21.68^{a}	25.97^{b}	21.92^{a}	23.19
Cu	5.26^{ab}	5.74^{b}	4.40^{a}	5.13
Total	662.96	742.43	590.48	665.28
Reducing sugars, g/kg DM	175.6^{ab}	240.9^{b}	112.8^{a}	176.4
Total sugars, g/kg DM	525.0^{b}	449.7^{a}	567.0^{c}	513.9
Vitamin C, mg/100g FW	9.80^{a}	8.48^{b}	10.37^{a}	9.55

$^{a\,b\,c}$ Mean values with the same letter in each row are not significantly different at $P \leq 0.05$

ing, frying and cooking. The products of Maillard reaction are partly responsible for the flavour and colour of a dish. Since yellow onion cultivars contain more macro- and micronutrients than white and red cultivars, they would constitute a better source of nutrients as far as the use of onion as pot herb and in food processing is concerned.

Red onion cultivars exhibit significantly higher content of the vitamin C than yellow cultivars (on average 10.37 mg/100 g FW and 8.48 mg/100 g FW). The literature on the subject confirms the higher content of the vitamin C in red onion cultivars (Hallmann and Rembiałowska, 2006; Gorinstein et al., 2008; Elhassaneen and Sanad, 2009). Red onion cultivars have milder taste and odour than yellow onion due to high content of total sugar and lower content of sulphur. Consequently, red onions are more likely to be consumed raw in salads.

Conclusions

- The analysed onion cultivars showed significant differences in chemical composition.
- The onions of the same colour exhibited similar tendencies to accumulate most of the analysed elements. The greatest differences were found between yellow and red onion cultivars.
- Generally, yellow onion cultivars accumulated more nitrogen, phosphorus, potassium, magnesium, iron, manganese, zinc, copper and reducing sugar than red onion cultivars.
- Red onion cultivars contained significantly more total sugar and the vitamin C than yellow onion cultivars.

References

Augusti, K. T., 1996. Therapeutic values of onion (*Allium cepa* L.) and garlic (*Allium sativum* L.). *Indian Journal of Experimental Biology,* **34:** 634-640.

Bajaj, K. L., G. Kaur, J. Singh and S. P. Gill, 1980. Chemical evaluation of some important of onion (*Allium cepa* L.). *Plant Foods for Human Nutrition* **30:** 117-122.

Bieżanowska-Kopeć, R., K. Galas and T. Leszczyńska, 2011. Effect of heat treatment on the basic chemical composition of onion (*Allium cepa* L.). *Designed Food,* III: 7-15.

Chagas, S. J., Resende, G. M. and L. V. Pereira, 2004. Qualitative characteristics of onion cultivars in southern Minas Gerais State. *Ciencia e Agrotechologia,* **28**: 102-106.

Chope, G. A. and L. A. Terry, 2009. Use of canonical variate analysis to differentiate onion cultivars by mineral content as measured by ICP-AES. *Food Chemistry,* **115:** 1108-1113.

Elhassaneen, Y. A. and M. I. Sanad, 2009. Phenolics, selenium, vitamin C, amino acids and pungency levels and antioxidant activities of two Egyptian onion varieties. *American Journal of Food Technology,* **4:** 241-254.

FAOSTAT, 2014. The Food and Agriculture Organization of the United Nations Statistical Database. http://data.fao.org/database?entryId=262b79ca-279c-4517-93de-ee3b7c7cb553 (Accessed 11 June 2014)

Freeman, G. G. and N. Mossadeghi, 1970. Effect of sulfate nutrition on flavour components of onion (*Allium cepa*). *Journal of the Science of Food and Agriculture,* **21:** 610-615.

Freeman, G. G. and N. Mossadeghi, 1971. Influence of sulphate nutrition on the flavour components of garlic (*Allium sativum*) and wild onion (*Allium vineale*). *Journal of the Science of Food and Agriculture,* **22:** 230-234.

Gorinstein, S., H. Leontowicz, M. Leontowicz, J. Namiesnik, K. Najman, J. Drzewiecki, M. Cvikrova, O. Martincova, E. Katrich and S. Trakhtenberg, 2008. Comparison of the main bioactive compounds and antioxidant activities in garlic and white and red onions after treatment protocols. *Journal of Agricultural and Food Chemistry,* **56:** 4418-4426.

Grzelak, K., 2006. Onion as a source of prebiotics in autumn-winter period. *Żywność. Nauka. Technologia. Jakość,* **47** (Supl): 67-75.

Hallmann, E. and E. Rembiałowska, 2006. Antioxidant compounds content in selected onion bulbs from organic and conventional cultivation. *Journal of Research and Applications in Agricultural Engineering,* **51:** 42-46.

Hamilton, B. K., L. M. Pike and K. S. Yoo, 1997. Clonal variations of pungency, sugar content and bulb weight of onions due to sulphur nutrition. *Scientia Horticulturae,* **71:** 131-136.

Hamilton, B. K., K. S. Yoo and L. M. Pike, 1998. Changes in pungency of onion by soil type, sulphur nutrition and bulb maturity. *Scientia Horticulturae,* **74:** 249-256.

Jadczak, D. and B. Wójcik-Stopczyńska, 2007. Influence of plant covering on some organic compound content and pungency of shallot grown for bunching harvest. *Vegetable Crops Research Bulletin,* **66:** 25-30.

Jurgiel-Małecka, G. and J. Suchorska-Orłowska, 2004. The effect of nitrogen fertilization doses on total sulphur content in crop of some onion species. *Folia. Universitatis Agriculturae Stetinensis,* **234:** 139-143.

Jurgiel-Małecka, G. and J. Suchorska-Orłowska, 2008. The effect of nitrogen fertilization on content of microelements in selected onions. *Journal of Elementology,* **13:** 227-234.

Kaufmann, F., E. Holke and E. Grinberg, 2000. Effect of central European and west siberian cultivares on the growth and yield of shallots (*Allium cepa* L. *var. ascalonicum* Backer). *Roczniki Akademii Rolniczej w Poznaniu. Seria Ogrodnictwo,* **31:** 307-312.

Ketiku, A. O., 1976. The chemical composition of nigerian onions (*Allium cepa*, linn). *Food Chemistry,* **1:** 41-47.

Kleiber, T., M. Bosiacki and B. Markiewicz, 2010a. Effect of the controlled fertilization on the mineral components of cho-

sen varieties of onion (*Allium cepa* L.). Part I. Macroelements. *Ecological Chemistry and Engineering A,* **17:** 269-278.

Kleiber, T., M. Bosiacki and B. Markiewicz, 2010b. Effect of the controlled fertilization on the mineral components of chosen varieties of onion (*Allium cepa* L.). Part II. Microelements and sodium. *Ecological Chemistry and Engineering A,* **17:** 935-941.

Kopsell, D. E. and W. M. Randle, 1997. Onion cultivars differ in pungency and bulb quality changes during storage. *Horticultural Science,* **32:** 1260-1263.

Lanzotti, V., 2006. The analysis of onion and garlic. *Journal of Chromatography A*, **1112:** 3-22.

Mysiak, B. and M. Tendaj, 2008. Content of phenolic acids in edible parts of some species grown for the green bunching. *Acta Scientiarum Polonorum, sec. Hortorum***,** *7***:** 57-62.

PN-83/R-04012/00. Chemical and Agricultural Analysis. Sampling. The Range of the Standard and General Provisions.

PN-87/R-75357. Fresh Vegetable. Onion.

Rabinowitch, H. D. and L. Currah, 2002. Allium Crop Science: Resent Advances. *CABI Publishing*, New York, USA, pp. 357-378.

Randle, W. M., 2000. Increasing nitrogen concentration in hydroponic solutions affects onion flavor and bulb quality. *Journal of American Society for Horticultural Science,* **125:** 254-259.

Rodrígues, G. B., R. O. González, E. R. Rodrígues and C. Diaz Romero, 2008. Comparison of mineral and trace element contents in onion cultivars (*Allium cepa* L.). *Journal of the Science of Food and Agriculture,* **88:** 1554-1561.

Rodrígues, G. B., C. T. Rodrígues, E. M. Rodrígues and C. Díaz Romero, 2009. Fructans and major compounds in onion cultivars (*Allium cepa*). *Journal of Food Composition and Analysis,* **22:** 25-32.

Ruszkowska, M. and U. Wojcieska-Wyskupajtys, 1996. Micronutrients - physiological and ecological aspects of their deficiencies and excesses. *Zeszyty Problemowe Postępów Nauk Rolniczych,* **434:** 1-11.