ПРОБЛЕМНАЯ СТАТЬЯ

PROSPECTS OF ONION (*ALLIUM CEPA* L.) FERTILIZATION BY SELENIUM. MINI-REVIEW

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ABSTRACT. *Allium cepa* is widely used all over the world both in culinary and medicine. High antioxidant activity of biologically active compounds present in onion bulbs and the ability to transfer inorganic forms of selenium to methylated derivatives of selenium-containing aminoacids known to protect the organism against different forms of cancer may be considered as a background for the development of functional product with high antioxidant activity. The review discusses the results of the main investigations devoted to problems of *A.cepa* biofortification with Se, interaction of the element with other antioxidants and trace elements of the plant, intervarietal variability and beneficial effect on human health.

KEYWORDS: *Allium cepa*, onion, selenium, biofortification, health benefits.

Allium cepa is the oldest cultivated crop widely used in traditional and ethno science in treatment of different deseases (Ashwini, Sathishkumar, 2014). Expressing strong antioxidant, anti-carcinogenic, anti-microbial and cardio protective properties onion is also used as anti-helminthic (Hertog et al., 1992), hypoglycemic (Oginmodede et al., 2012; Akash et al., 2014), anti-inflammatory, unti-rheumatic, anti-spazmolitic, diuretic, anti-thrombotic, anti-septic (Goodarzi et al., 2013; Shinkafi, Dauda, 2013; Kirilov et al., 2014), anti-asthmatic and hypo-cholesterolemic remedy (Pineda, de la Calzada, 2013). Onion juice is efficient for cleaning septic wounds and healing of ulcers and burns (Shenoy et al., 2008). Antimicrobial activity of onion against *Bacillus subtilis*, *Salmonella*, and *E. coli* is well known. Regular consumption of raw onion decreases high cholesterol level and blood pressure (Brankovic et al., 2011; Ashwini, Sathishkumar, 2014), that prevents the development of atherosclerosis, decreases the risk of heart attack and stroke. Epidemiological investigations in Western Europe during 15 years on two groups of the population with different levels of onion and garlic consumption revealed statistically significant morbidity decrease of the oral cavity, pharynx, laryngeal, breast, ovarian, prostate and renal cell cancer in a group with high *Allium* consumption level (Galeone., Pelucchi, 2006).

Wide spectrum of onion beneficial effects on human health is determined by the presence of unique chemical compounds, the most important of which are flavonoids, alkenyl cystein sulphoxides, fructo-olygosaccharides, alimentary fibre, steroidal saponins and also some trace elements including selenium (Se) (Fig. 1).

In a group of 28 vegetables and 9 fruits onion ranks the first place by concentration value of quercetin (Hertog et al., 1992) which antioxidant activity (AOA) is known to be the highest among the most common flavonoids of plants (Brown et al., 2001) (Fig. 2).

Frucro-olygosaccharides of *A. cepa* (Hedge, Lister, 2007) decrease the risk of cardiovascular and gastrointestinal diseases, colon cancer, diabet of the 2 type and obesity (Champ et al., 2003). S-Alkenyl cystein sulphoxides – precursors of onion aroma compounds – inhibit thrombocytes aggregation, possess antibiotic properties and decrease blood cholesterol (Randle et al., 1995).

Comparison of macro and trace elements composition of *A. cepa* and garlic grown on experimental fields of All-Russian Institute of vegetable breeding and seeds production (Moscow region) indicates predominant accumulation of Ca, K and Mg, and also Al, B and Mn in onion bulbs (Golubkina et al., 2015) (Fig. 3,*a*,*b*).

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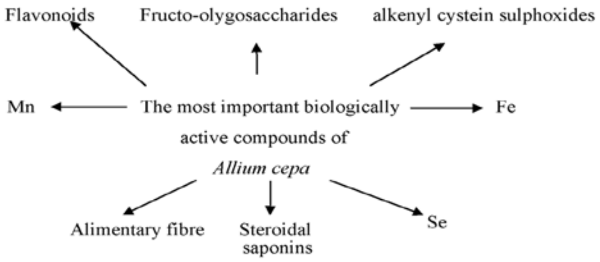

Fig. 1. *The most important biologically active compounds and essential elements of Allium cepa*

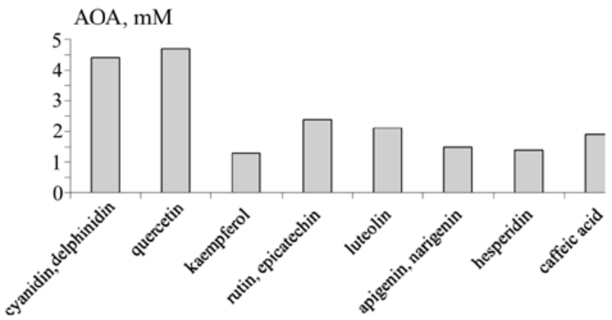

Fig. 2. *Comparison of AOA of several flavonoids of vegetables and fruit (Brown et al., 2001)*

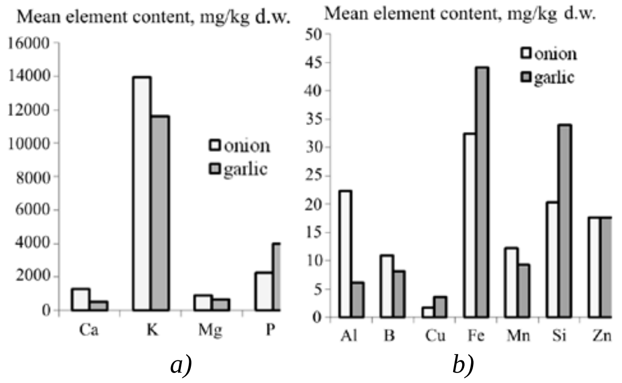

Fig. 3*. Comparative evaluation of element composition of onion and garlic grown in Moscow region, Russia (55º39'23'' NW, 37º12'43'' EL)*

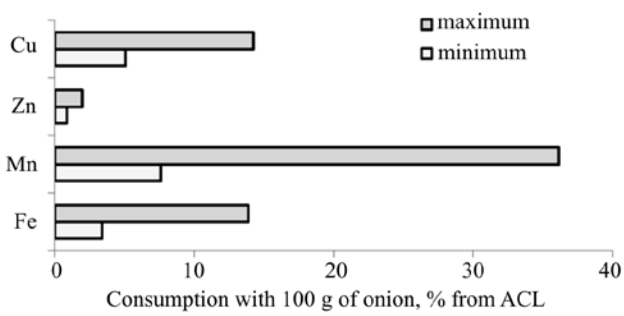

Fig. 4*. Consumption levels of Fe, Mn, Zn, Cu with 100 g of onion bulbs, grown on experimental fields of All-Russian Institute of vegetable breeding and seeds production (55º39'23'' NW, 37º12'43'' EL) (ACL – adequate consumption level) (Golibkina et al., 2015)*

Evaluation of *A. cepa* as a source of essential elements for humans indicates significant consumption levels of Fe, Mn, Cu with 100 g of fresh onion (Fig. 4). The latter is especially important for treatment of iron-deficiency anemia, disturbances in bone tissue development (Mn, Cu), disruption in brain activity (Mn) and processes of blood formation (Cu).

Biofortification of food crops for human consumption is considered to be the most prospect strategy to increase dietary Se intake (Gupta, Gupta, 2002). Many health benefits of Se is connected with its antioxidant properties showing a similarity with properties of onion. For example, anti-inflammatory effect of Se (Kim et al., 2014), cardio protective (Okatan et al., 2013), anti-carcinogenic (Schrauzer, 2000) and anti-asthmatic effects (Gazdik et al., 2002) have been described. Selenium (+4) has beneficial effects on the skin wound healing process by increasing the skin blood flow (Varoglu et al., 2010) Antibacterial properties of Se is also registered (Vasic et al., 2011). Close relationship between biological properties of Se, polyphenols and other antioxidants of *A. cepa* supposes the synergetic effect of different components (including Se) of antioxidant defense system display in fortified product.

Se is efficiently taken up by *Alliums* and these species produce organo-Se-compounds that are active in the chemoprevention and anti-oxidant activity. Grown in seleniferous soils onion accumulates high levels of the element (Yadav et al., 2007). For most agricultural crops Se is not an essential element except a small group of hyperaccumulators (Winkel et al., 2015). More stable to high concentrations of Se are *Allium* and *Brassica* representatives capable to accumulate significant concentrations of sulfur. The latfer is easily substituted by Se in natural compounds. Se fortification of non accumulators leads to a formation of Se containing amino acids (SeMet and SeCys) and their incorporation into proteins, which decreases enzymes activity and causes toxicosis. Special defense mechanism against Se toxicity in *Allium* and *Brassica* plants is a formation of methylated derivatives: SeMetSeCys, and γ-Glu-SeMeSeCys, not capable to be incorporated into proteins (Winkel et al., 2015). These compounds are of special interest due to high anti-carcinogenic activity (Golubkina, Papazyan, 2006). Contrary to *Brassica* plants *Allium* representatives are able to increase slightly S accumulation at low Se doses (Kopsell, Randle, 1997), providing reservation of biological activity of thiosulphinates. Inhibition of S accumulation takes place only at high concentrations of Se. On the other hand there is a significant difference in biochemical interactions among antioxidants in fortified and non fortified plants. Thus a negative correlation is demonstrated between Se and quercetin in a collection of 22 onion varieties (Golubkina et al., 2016) (Fig. 5).

On the contrary increase of various value in quercetin and polyphenol content takes place in Se-enriched plants (Poldma et al., 2013; Reilly et al., 2014; Bystricka et al., 2015) (Fig. 6)

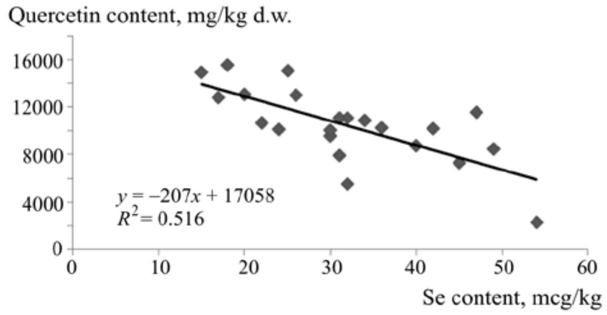

Fig. 5. *Relationship between Se accumulation levels and quercetin concentration in onion bulbs (r = –0.72, p < 0.001) (Golubkina et al., 2016)*

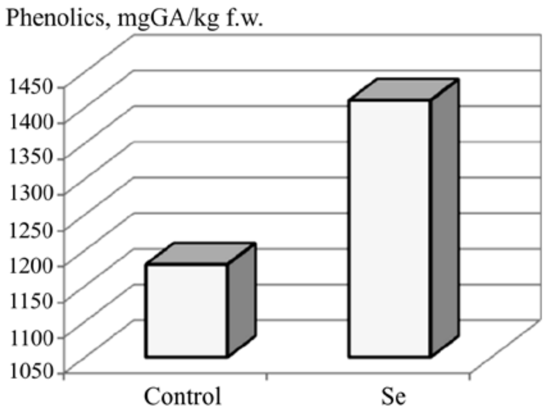

Fig. 6. *Effect of selenate supplementation on phenolics content in onion bulbs (Poldma et al., 2013)*

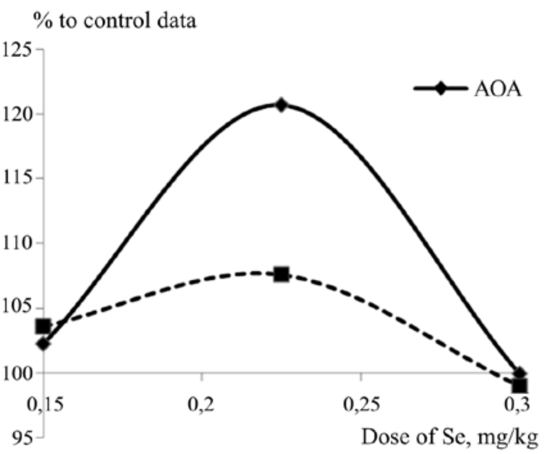

Fig. 7. *Effect of Se supplementation of AOA and phenolics content in A.cepa bulbs (Bystricka et al., 2015)*

Contrary to the results of Poldma et al. (2013), Reilly et al. (2014) investigations reveal only a tendency of polyphenol concentration increase in onion bulbs as a result of selenate and selenite supplementation to soils (1.5 g of each salt per 3.8 L of water at the 4th and the 2nd weeks before harvesting). Se concentrations in onion bulbs (Hyskin variety) reach 41-70 mg/kg d.w. after fortification. Later research (Bystricka et al., 2015) on sodium selenate application indicates the existence of maximum in antioxidant activity (AOA) and phenolics content only for medium doses of Se (Fig. 7)

It seems reasonable that in unfortified plants we come across the maintenance of the total antioxidant status via regulation of the level and distribution of various antioxidants: Se and polyphenols. Thus polyphenols concentration decreases from the outer to the inner scales of onion contrary to Se which concentration is the highest in the center part of bulbs, mimicking the distribution of thiosulphinates (Golubkina, Papazyan, 2006). Effect of Se biofortification on polyphenol biosynthesis may be connected with plant protection against prooxidant effect of Se. Indeed studies of *Ulva* sp algae demonstrate that significant Se loading results in hydrogen peroxide formation and an increase of antioxidant enzymes activity (superoxide dismutase and catalase) and elevation of concentrations of metabolites with antioxidant effect (polyphenols, flavonoids and carotenoids) (Moro et al., 2012).

Data from Table 1 indicate that foliar application of sodium selenate in a dose 10 mcg Se/m^2 (Early pink variety) results not only in 3 fold increase of Se level in onion bulbs but also in statistically significant increase of bulb mass, dry matter content, polyphenols, quercetin, anthocianins and a decrease of Cd, Al, Fe, Mn and Co content. These results are in good accordance with the known antagonism between Se and heavy metals and a protection role of Se against heavy metals toxicosis in plants and animals (Golubkina, Papazyan, 2006). A good agreement with the results of long-term utilization of Se-containing fertilizers in Finland is also obvious (Ekholm et al., 2007).

Utilization of stable ^{77}Se isotope (Kapolna et al., 2012) reveals that predominant formation of anti carcinogenic methylated forms of Se-containing amino acids in onion takes place during sodium selenite (Se+4) utilization whereas sodium selenate (Se+6) is less effective (Fig. 8)

At the same time selenate results in 2 fold higher levels of Se accumulation that Se+4 that allows to use 2 time lower doses of the element (50 mcg) than for selenite (100 mcg) (Kapolna et al., 2012).

Table 1. ***Effect of Se biofortification on biochemical characteristics of onion bulbs (Golubkina et al., 2016)***

Parameter	Control	Sodium selenate	% to control
Dry matter %	14.1±0.1[a]	15.4±0.2[b]	109
Ascorbic acid, mg/100 g f.w.	8.5±0.5[a]	9.2±0.5[a]	100
Nitrates, mg/kg f.w.	74±2[a]	69±2[b]	93
Polyphenols, mg GA/ kg f.w.	1610±100[a]	2120±70[b]	132
Quercetin, mg/kg d.w.	5697±1025[a]	11636±2094[b]	204
Anthocianes, %	1.16±0.1[a]	1.75±0.2[b]	151
monosaccarides, %	9.5±0.1[a]	4.4±0.03[b]	46.3
Total sugar, %	57±2.5[a]	60.6±2.6[a]	100
Water soluble compounds, %	9.78±0.6[a]	10.86±0.6[a]	100
Al, mg/kg	22.28±2.23[a]	17.63±1.76[a]	79.1
Cd, mg/kg	0.114±0.014[a]	0.09±0.003[b]	79.0
Co, mg/kg	0.026±0.004[a]	0.017±0.002 [b]	65.4
Fe, mg/kg	32.52±3.25[a]	24.74±2.47[b]	76.1
Mn, mg/kg	12.25±1.23[a]	8.87±0.89[b]	72.4
Se, μg/kg	45±1[a]	140±17[b]	311

Different indexes in one and the same raw indicate statistically significant differences.

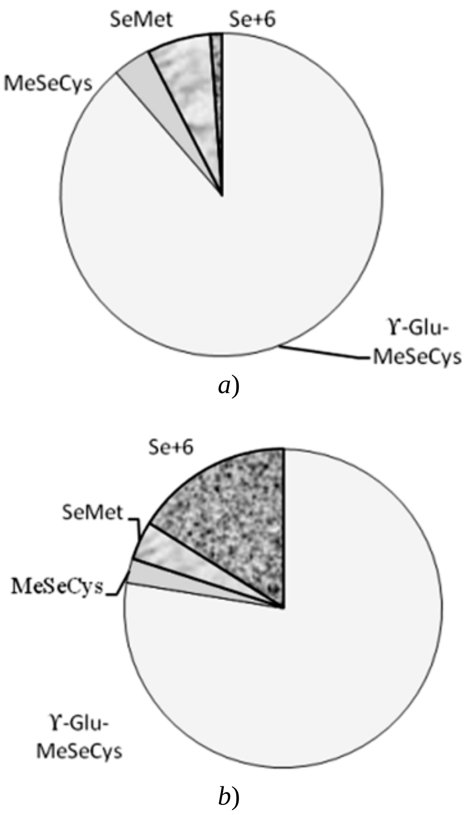

Fig. 8*. Se-speciation in onion fortified with sodium selenite (a) and sodium selenate (b) (Kapolna et al., 2012)*

CONCLUSION

Thanks to anti-carcinogenic properties of Se-enriched garlic the latter is already present in the markets as a functional food product (USA). Indistrial production of *A. cepa* with elevated concentrations of the element should become the next stage in production of functional food with high Se content, though much is to be done for evaluation of specific biological properties of onion fortified with Se.

REFERENCES

Akash M.S.H., Rehman K., Chen S. Spice plant *Allium cepa*: Dietary supplement for treatment of ty pe 2 diabetes mellitus. Nutr. 2014, 30(10):1128–1137.

Ashwini M., Sathishkumar R. Onion (*Allium cepa*) – Ethnomedicinal and therapeutic properties. Handbook of Medicinal plants and their Bioactive compounds. 2014. 27–34. Ed. Nidhi Gupta, Bharathiar University, India.

Brankovic S., Radenkovic M., Kitic D., Veljkovic S., Ivetic V., Pavlovic D., Miladinovic B. Comparison of the hypotensive and bradycardic activity of ginkgo, garlic, and onion extracts. Clin Exp Hypertens. 2011, 33(2):95–99.

Brown P., Blake M., Eagling D., Sterling S. Therapeutic compounds as an onion quality parameter. Final report Prohect No VG99054 Horticultural Australian ltd. 2001.

Bystrická J., Kavalcová P., Musilova J., Tomas J., Toth T., Orsák M. Selenium and its influence on the content of polyphenol compounds in onion (*Allium cepa* L.). J Microbiol, Biotechnol Food Sci. 2015, 4(3):23–26.

Champ M., Langkilde A.M., Brouns F., Kettilitz B., Collet Y.L.B. Advances in dietary fibre characterization. 1. Definition of dietary fiber, physiological relevance, health benefits and analytical aspects. Nutr Res Rev. 2003, 16:71–82.

Ekholm P., Reinivuo H., Mattila P., Pakkala H., Koponen J., Happonen A., Hellstrom J., Ovaskainen M.-L. Changes in themineral and trace element content of cereals, fruits and vegetables in Finland. J Food Comp Anal. 2007, 20:487–495.

Galeone C., Pelucchi C. Onion and garlic use and human cancer. Am J Clin Nutr. 2006, 84(5):1029–1030.

Gazdik F., Horvathova M., Gazdikova K., Jahnova E. The influence of selenium supplementation on the immunity of corticoid-dependent asthmatics. Bratisl Lek Listy. 2002, 103(1):17–21.

Golubkina N.A, Agafonov A.F., Nadegkin S.M., Antoshkina M.S., Koshevarov A.A Element composition of *Allium cepa*. Vestnik Ulyanovsky Agr. Acad. 2015, 3:11–17 (in Russ).

Golubkina N.A., Papazyan T.T. Selenium in Nutrition: Plants, Animals, Human beingsю M.: Pechatny gorod, 2006 (in Russ).

Golubkina N.A., Kekina H.G., Antoshkina M.S., Nadezhkin S.M. Intervariaty differences in accumulation of biologically active compounds by *Allium cepa* bulbs. Vestnik of Russian agricultural sciences, 2016. In press (in Russ).

Goodarzi1 M., Landy N., Nanekarani S. Effect of onion (*Allium cepa* L.) as an antibiotic growth promoter substitution on performance, immune responses and serum biochemical parameters in broiler chicks. Health. 2013, 5(8):1210–1215.

Gupta U.C., Gupta S.C. Quality of animal and human life as affected by selenium management of soils and crops. Commun Soil Sci Plant Anal. 2002, 33:15–18.

Hedges L.J., Lister C. E. The nutritional attributes of *Allium* species. A report prepared for Horticulture New Zealand New Zealand Institute for Crop & Food Research Limited Private Bag 4704, Christchurch, New Zealand Crop & Food Research Confidential Report No. 1814. Jan. 2007.

Hertog M.G.L., Hollman P.C.H., Kata M.B. Content of potentially anticarcinogenic flavonoids of 28 vegetables and 9 fruit commonly consumed in the Netherlands. J Agric Food Chem. 1992, 40:2379–2383.

Kápolna E., Laursen K.H., Husted S., Larsen E.H. Biofortification and isotopic labeling of Se metabolites in onions and carrots following foliar application of Se and ^{77}Se. Food Chem. 2012, 133(3):650–657.

Kim Y., Kim D.C., Cho E.-S., Ko S.-O., Kwon W.Y., Suh G.J., Shin H.-K. Antioxidant and anti-inflammatory effects of selenium in oral buccal mucosa and small intestinal mucosa during intestinal ischemia-reperfusion injury. J Inflamm (Lond), 2014, 11:36.

Kirilov A., Doycheva A., G. Satchanska Antibacterial activity of mature and green *Allium cepa*. Ecol Eng Environ Prot. 2014, 1:12–17.

Kopsell D.A., Randle W.M. Selenate concentration affects selenium and sulfur uptake and accumulation by ‘Granex 23’ onions. J Amer Soc Hort Sci. 1997, 122(5):721–726.

Moro M.S.I., Pilon-Smits E.A.H., Matozzo V., Malagoli M., Vecchia F.D. Accumulation of selenium in Ulva sp. and effects on morphology, ultrastructure and antioxidant enzymes and metabolites. Aquatic Toxicol. 2012, 122–123:222–231.

Oginmodede O.S., Saalu L.C., Ogunlade B., Akunna G.G., Oyewopo A.O. An evaluation of the hypoglycemic antioxidant and hepato-protective potentials of onion (*Allium cepa* L) on Alloxan-induced dianethic rabbits. Int J Pharmacol. 2012, 8(1):21–29.

Okatan E.N., Tuncay E., Turan B. Cardio protective effect of selenium via modulation of cardiac ryanodine receptor calcium release channels in diabetic rat cardiomyocytes through thioredoxin system. J Nutr Biochem. 2013, 24(12):2110–2118.

Pineda M.R.B., de la Calzada G. Effect of Philippine Red *Allium cepa* L. (Sibuyas na Pula) on Serum LDL. Cholesterol Level Int J Med Biomed Sci. 2013, 1(3):14–20.

Põldma P., Moor U., Tõnutare T., Herodes K., Rebane R. Selenium treatment under field conditions affects mineral nutrition, yield and antioxidant properties of bulb onion (*Allium cepa* L.). Acta Sci Pol, Hortorum Cultus. 2013, 12(6):167–181.

Randle W.M., Lancaster J.E., Shaw M.L., Sutton K.H., Hay R.L., Bussard M.L. Quantifying onion flavor compounds responding to sulfur fertility-sulfur increases levels of aly(en)yl cysteine sulfoxides and biosynthetic intermediates. J Am Soc Hort Sc. 1995, 120:1075–1081.

Reilly K., Valverde J., Finn L., Gaffney M., Rai D.K., Brunton N. A note on the effectiveness of selenium supplementation of Irish-grown Allium crops. Irish J Agric Food Res. 2014, 53:91–99.

Schrauzer G.N. Anticarcinogenic effects of selenium. Cell Mol Life Sci. 2000, 57(13–14):1864–1873.

Shenoy C., Patil M.B., Kumar R., Patil S. Preliminary phyrochemical investigation and wound healing activity of *Allium cepa* Linn (Liliaceae). Int J Pharmacy Pharmaceut Sci. 2008, 2(2):167–175.

Shinkafi S.A, Dauda H. Antibacterial activity of *Allium cepa* (onion) on some pathogenic bacteria associated with ocular infections. Sch J Appl Med Sci. 2013, 1(3):147–151.

Varoglu E., Bedri Seven, Kenan Gumustekin, Omer Aktas, Ali Sahin, Senol Dane. The effects of vitamin E and selenium on blood flow to experimental skin burns in rats using the 133Xe clearance technique. Cent Eur J Med. 2010, 5(2):219–223.

Vasić S., Radojević I., Pešićand N., Čomić L. Influence of sodium selenite on the growth of selected bacteria species and their sensitivity to antibiotics. Kragujevac J Sci. 2011, 33:55–61.

Winkel L.H.E., Vriens B., Jones G.D., Schneider L.S., Pilon-Smits E.A.H., Banuelos G.S. Selenium cycling across soil-plant-atmosphere interfaces: a critical review. Nutrients. 2015, 7(1):4199–4239.

Yadav S., Gupta S., Prakash R. Selenium uptake by *Allium cepa* grown in Se-spiked soils. American-Eurasian J Agric & Environ Sci. 2007, 2(1):80–84.

ПЕРСПЕКТИВЫ ОБОГАЩЕНИЯ ЛУКА РЕПЧАТОГО (*ALLIUM CEPA* L.) СЕЛЕНОМ. ОБЗОР

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РЕЗЮМЕ. Проблема дефицита селена среди населения широко распространена во всем мире. Широкий спектр биологического действия микроэлемента и потенциальная возможность защиты организма человека от возникновения и развития сердечно-сосудистых и онкологических заболеваний путем коррекции селенового статуса определяют интенсивные поиски оптимальных путей ликвидации дефицита. Биофортификация селеном растений, в частности лука репчатого, представляется наиболее перспективной в решении проблемы дефицита. В настоящее время лук репчатый является одной из наиболее важных сельскохозяйственных культур в мире. Широко используясь в кулинарии, *A.cepa* интенсивно применяется также в медицине благодаря присутствию высоких концентраций кверцетина и других природных антиоксидантов, фруктоолигосахаридов, пищевых волокон, а также соединений серы. Способность селена замещать серу в природных соединениях определяет устойчивость растений *Allium* к высоким концентрациям микроэлемента благодаря уникальному механизму образования метилированных производных селеносодержащих аминокислот, обладающих выраженным антиканцерогенным действием, что создает основу для разработки функционального продукта питания с высокой антиоксидантной активностью. В обзоре обсуждаются результаты важнейших исследований, посвященных проблемам биофортификации *A. cepa*, взаимосвязи микроэлемента с другими антиоксидантами и микроэлементами растения, межсортовые различия и положительное действие на здоровье человека.

КЛЮЧЕВЫЕ СЛОВА: *Allium cepa*, лук, селен, биофортификация, положительное действие на здоровье.