View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Elsevier - Publisher Connector

Saudi Journal of Biological Sciences (2015) 22, 398–403

King Saud University

Saudi Journal of Biological Sciences

www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

Effect of different exposed lights on quercetin and quercetin glucoside content in onion (*Allium cepa* L.)

Eun Young Ko [a,1], Shivraj Hariram Nile [a,1], Kavita Sharma [a], Guan Hao Li [b,*], Se Won Park [a,*]

[a] *Department of Bioresources and Food Science, College of Life and Environmental Sciences, Konkuk University, Seoul 143-701, Republic of Korea*
[b] *Department of Food Science, Agricultural College, Yanbian University, Park Road 977, Yanji City, Jilin Province 133002, China*

Received 13 October 2014; revised 4 November 2014; accepted 9 November 2014
Available online 23 November 2014

KEYWORDS

Onion;
Light effect;
Quercetin;
Quercetin glucosides

Abstract Quercetin and quercetin glucosides are the major flavonols present in onion (*Allium cepa* L.) and are predominantly present as quercetin, quercetin-3,4′-diglucoside and quercetin-4′-glucoside. Effect of different light wavelengths on onion after harvest and storage, with fluorescent, blue, red and ultra violet light influenced the quercetin and quercetin glucosides profile. In a peeled onion, all the light treatments elevated quercetin content in bulb. Among them, particularly fluorescent light effect was more eminent which stimulates the maximum synthesis of quercetin in onion. In case of whole onion bulb, skin and pulp showed different responses to light treatment, respectively. The pulp had the highest quercetin glucosides under blue light, whereas the lowest under fluorescent light. Onion skin showed nearly opposite pattern as compared to the pulp. In particular, light treatment proved to be a better way to increase the level of quercetin content in onions which might be utilized for industrial production of bioactive compounds from onion and onion waste products.
© 2014 The Authors. Production and hosting by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/3.0/).

1. Introduction

Onions and related species have been widely used from ancient times in many parts of the world as flavoring vegetables as well as traditional and folk medicine with a wide range of health benefits, including antioxidant, antiplatelet, antithrombotic, antiasthmatic and antibiotic effects (Nile and Park, 2013). Onion is rich in two groups of phytochemicals (flavonoids and the alk(en)yl cysteine sulphoxides) that are beneficial to human health. The former is divided into two major groups, the flavonols and the anthocyanins which have

* Corresponding authors.
E-mail addresses: ghli@ybu.edu.cn (G.H. Li), sewpark@konkuk.ac.kr (S.W. Park).
[1] E.Y. Ko and S.H. Nile, have equal contribution and considered as first authors.

Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.sjbs.2014.11.012
1319-562X © 2014 The Authors. Production and hosting by Elsevier B.V. on behalf of King Saud University.
This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/3.0/).

attracted interest in recent years. Sixteen different flavonols have been identified in onions consisting of the aglycones and glycosylated derivatives of quercetin, isorhamnetin and kaempferol (Hänninen et al., 2000; Soobrattee et al., 2006). It is well known that quercetin has a pronounced effect to allergies, asthma, arthritis, cancer, diabetic complications, goat, neurodegenerative disorder and osteoporosis (Hegarty et al., 2000; Kempuraj et al., 2006). Some authors previously identified 3, 4′-*O*-diglucoside and 4′-*O*-monoglucoside as the major quercetin derivatives of the mature red onion bulb; these components account for about 93% of the total flavonols (Perez-Gregorio et al., 2011). Rodrigues et al. (2009) affirmed that different treatments (curing and cooking) of onion bulbs could influence their flavonol and anthocyanin levels, and demonstrated that intense microwave cooking treatment caused flavonol losses of 16% and 18% for quercetin 3,4′-diglucoside and quercetin 4′-glucoside, respectively. Pérez-Gregorio et al. (2010) determined that flavonol and anthocyanin concentrations in different varieties of red and white onions. They found that flavonols (quercetin 7,4-diglucoside, quercetin 3,4-diglucoside, quercetin 3-glucoside, and quercetin 4-glucoside) were the predominant polyphenolic compounds. The flavonols are often found in high concentrations in the skin of most onions, where they impart the yellow/brown color, unless concealed by the red pigment, such as anthocyanin. In dried red onion, the concentration of quercetin was found to be as high as 2.1% w/w. The total content of quercetin in onion is 300 mg/kg, which is considerably higher than in many other fruits and vegetables (Hollman and Arts, 2000). Flavonols are also found in the flesh scale tissue where it accounts for a yellow color if their concentrations are high or at lower concentrations. This is in contrast to the flesh of white skinned onions, garlic and leek, which contain only trace levels of flavonols (Patil and Pike, 1995). The concentration of these compounds usually increases in the outer scales (Lee et al., 2008). Quercetin diglucoside and monoglucoside account for up to 93% of the total flavonol content in onion (Lombard et al., 2005). The flavonoid content in plants is strongly influenced by extrinsic factors such as variations in variety, cultivation and field curing (Mogren et al., 2006), scales, size (Chu et al., 2000), light (Higashio et al., 2005), storage (Jang et al., 2013) and processing (Kevin et al., 2005). Roasting of onions at 18 °C led to both degradation and alteration of the quercetin to other compounds, while boiling of onions caused release of flavonoids into the cooking water from outer to inner scales by formation of oxidation products (Lee et al., 2008). Domestic processing techniques for example chopping, shredding, peeling, and cooking changes flavonoid content in onions and also the effect of temperature on onions caused an effect in flavonol content but these losses change according to the type of treatment (frying, boiling, roasting, etc.) and the length of exposure to this treatment (Ioku et al., 2001; Gorinstein et al., 2008; Rodrigues et al., 2009). The content of quercetin and quercetin glucoside gets accumulated due to the effect of different lights on onions (Islek et al., 2014). Considering these facts the study is aimed to measure the quercetin and quercetin glucoside content in onion depending on effect of different light conditions during pre and postharvest treatment, variation in quercetin contents has been studied on the basis of different lights provided with different scales, and forced curing of onion.

2. Materials and methods

2.1. Plant material

Fresh onions (*A. cepa* L. cv. Sunpower) were grown at the Mokpo Experiment Station of the National Institute of Crop Science of the Rural Development Administration (Muan, Republic of Korea). The onions harvested in July 2013 were cured in the field for 10 days, trimmed of leaves and roots and transported to the laboratory. The bulbs in a weight range of 160–220 g with no visible defects were taken for the study. The onion bulbs were collected after full maturation and after harvesting.

2.2. Lighting system and culture conditions

Five uniform-sized 'Sunpower' onion bulbs were transferred to a growth chamber maintained at 25 °C and 70% relative humidity. The effect of each light is provided under a designed growth chamber for 3 days of time with 8 h dark and 16 h light effect at a temperature of 25 °C. Four different lights were used in this study; white light, UV-A light and two types of LEDs light with details: (1) dark, (2) white light (white cool fluorescent lamps; phillips, Fluotone 40 W), (3) red LED (peak wavelength: 660 nm; 220 μmol/m^2S), (4) blue LED (peak wavelength; 450 nm; 160 μmol/m^2S) and (5) UV-A light. The LED system was installed by Dyne Bio, Seoul, Korea. The spectral distributions of each LED were set with the help of spectroradiometer (Li-1800, LI-COR, Lincoln, Nebraska, USA). The photoperiod times of LEDs were set as 16 h light and 8 h dark for 3 days and system is operated at a temperature of 25 °C.

2.3. Color measurement

We determined the color values (L: lightness (0 = black, 100 = white), *a* (–a = greenness, +a = redness), *b* (–b = blueness, +b = yellowness) of lighting exposed bulbs. The instrumentation used was a Minolta CR-400 colorimeter as the mean of three measurements taken 4 cm from the center of the axis of onion.

2.4. Extraction of quercetin

The similar sized onion bulbs were selected for analysis of quercetin and quercetin glucosides. The top and bottom of the onion bulbs, outer dry skins, and any inedible outer portions were removed. Then each scale of onion was frozen and lyophilized, and then the lyophilized samples were stored at –70 °C prior to further preparation. For HPLC analysis, approximately 100 mg of lyophilized onion tissue was extracted with 1 mL of 80% methanol by 10 min of sonication. The mixture was vortexed for 5 min, sonicated and vortexed once again, and centrifuged for 10 min (5000 *g* at 4 °C). This step was repeated five times, and the supernatants were collected in a 5 mL bottle (Jang et al., 2013).

2.5. HPLC analysis

The onion extracts were filtered through a 0.45 micro filter unit (Whatman syringe-filter PVDF) and then transferred to a

1 mL vial for HPLC analysis. HPLC analytical conditions were as follows; Mobile phase consisted of solvent A and B. Solvent A was made of 98.2% water and 0.2% TFA. Solvent B was made of 100% methanol. Each elution step was as follows; <step 1> 0.0–5.0 min, isocratic elution at 5% B; <step 2> 5.0–20.0 min, linear gradient elution from 5 to 50% B; <step 3> 20.0–35.0 min, isocratic elution at 50% B; <step 4> 35.0–38.0 min, isocratic elution at 100% B; <step 5> 38.0–45.0 min, isocratic elution at 5% B. The flow rate was set at 1.0 mL/min. High performance liquid chromatography (HPLC) used was Agilent 1100 (Agilent, Palo Alto, USA). An Agilent Eclipse XDB-C18 analytical column (5 um particle size; 250 × 4.6 mm) was employed for the analysis. UV absorbance was measured at a wavelength of 365 nm (Sharma et al., 2014).

2.6. Quantification

Standard compounds such as quercetin, quercetin-3,4′-diglucoside and quercetin-4′-glucoside were purchased from Sigma–Aldrich, Korea. The flavonoid standards were dissolved in 80% MeOH at several concentrations and a high linearity was obtained from each curve. Quercetin, quercetin-3,4′-diglucoside and quercetin-4′-glucoside were identified based on their retention times and their concentrations were calculated by comparing the peak areas of samples with standards and correlated with obtained results.

2.7. Statistical analysis

Statistical analyses were conducted by the general linear model procedure (GLM) of the 2005 SAS package (Version 9.2, SAS Inst. Inc. Cary, N.C, USA).

3. Results and discussion

The effect of different lights on the quercetin and quercetin glucosides content in onion was studied in dark, using fluorescent, blue, red and UV-A light at 25 °C for three days with 8 h and 16 h exposure. Different lights were treated on onion bulbs with or without outer brown layer and quercetin profiles were measured in the skin and bulb tissues independently. In case of the whole onion, the quercetin profile was analyzed separately with the skin and pulp. The highest quercetin content was observed under blue light conditions whereas the lowest one under fluorescent light. It has been reported that UV light has potential to decontaminate peeled onions and to enhance quercetin content in onions after treatment with lights, a

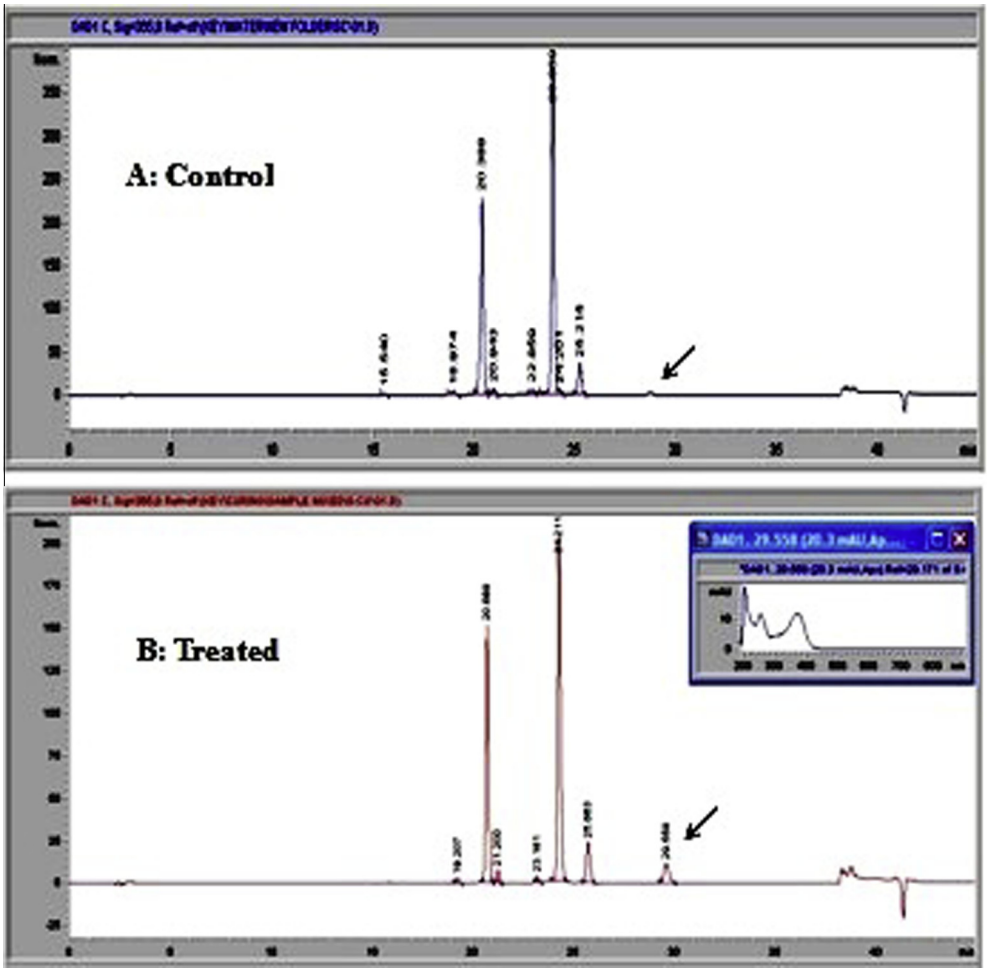

Figure 1 HPLC chromatograms showing the increased amount of quercetin and quercetin glucoside content in onion (*Allium cepa* L.) under exposed lights ((A): control, (B): treated).

sample HPLC analysis was provided for control sample which was not treated with light effect and one treated sample which was treated with blue light as the highest quercetin glucoside content was observed under blue light conditions (Fig. 1). It has been also observed that in the case of skin peeled onion a white light irradiation results in the highest quercetin content whereas dark condition resulted in the lowest one (Fig. 2). Red, blue, and UV-A light treatment also increased the quercetin concentration, although not as profoundly as that of white light (Fig. 3). Quercetin content in onion can be doubled after harvest using UV light lamps. It was reported by Higashio et al. (2005) that UV light helped in the enhancement of quercetin levels in onion slice to some extent, and also its long term exposure increased the quercetin levels up to 50–70%. According to Higashio et al. (2005), the combination of UV light and hydrogen peroxide plays a significant role in the inactivation of human pathogens and spoilage bacteria on the surface and within onion slices. The role of UV-B light for the biosynthesis of quercetin has been studied in many crops. In leaves of barley (*Hordeum vulgare* L.), UV-B has been shown to markedly increase flavonoid accumulation in both of the lower epidermis and underlying tissue. In the same way, in rape (*Brassica napus*), UV-B supplementation resulted in a marked, specific increase in the amount of quercetin glucosides by 70–150% and UV-A has a lesser effect, but is still significantly effective in increasing flavonoid accumulation (Mogren et al., 2006). Onion perceives light as stress signal, which induces the biosynthesis of flavonoids through the polyphenol pathway. In the pheylpropanoids pathway, phenylalanine is the precursor and phenylalanine ammonia-lyase act on it to produce the chalcone (Lattanzio et al., 2006). UV lights play a significant role in the biosynthesis of some secondary metabolites such as potato glycoalkaloids (Friedman, 2006). The correlations between onion skin color and total quercetin glucosides (quercetin-4′-glucoside and quercetin-3,4′-diglucoside) were high; however, the correlation between total quercetin glucosides and pulp color was reasonable, thus suggesting that quercetin concentrations might contribute to onion color and also this was correlated using standards of quercetin and quercetin glucosides (Fig. 4). Gokce et al. (2010) correlated onion scale color with total phenolics and total antioxidant capacity. Although significant, the correlations did not rise above $r = 0.42$. The lack of strong correlations may have been due to the use of total phenolics, which, apart from quercetin did take account of isorhamnetin, kaempferol, and other phenolic acids, such as gallic acid, ferulic acid, and protocatechuic acid, found in red onion skin as well as vitamin C and reducing sugars (including fructose and glucose). These compounds may not contribute to skin color changes (George et al., 2005). The exposure to light can cause differences and be effective on the biological variation in onion bulbs. It was stated in a study that ripeness, time of lifting, and exposing to light are factors effective on phenolic levels in onions (Mogren et al., 2007). Increase in quercetin aglycone was observed under white light and UV-light. This increase might be due to glucosidase activity at this temperature. Several reports have proved that low light effect can increase the susceptibility to induce flavonoid accumulation

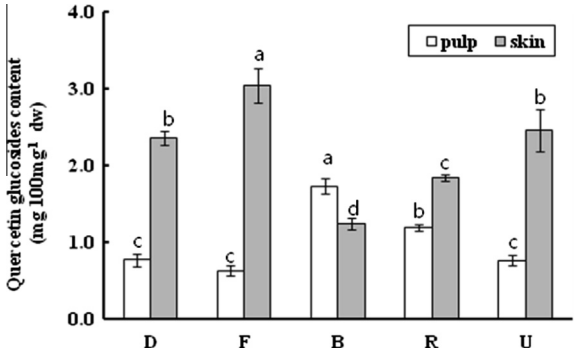

Figure 2 Effect of different lights on total quercetin glucoside contents in pulp (□) and skin (■) of onion (D = dark; F = white light; B = blue LED; R = red LED; U = UV-A).

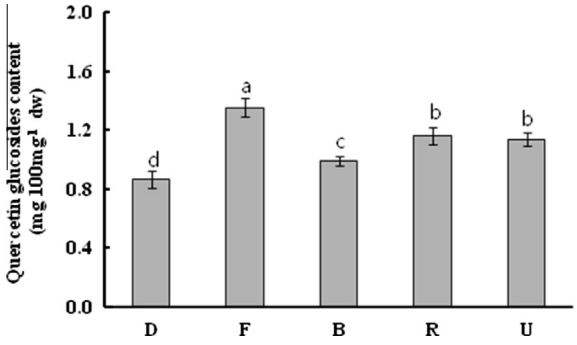

Figure 3 Effect of different lights on total quercetin glucoside content in onion after removal of skin (D = dark; F = white light; B = blue LED; R = red LED; U = UV-A).

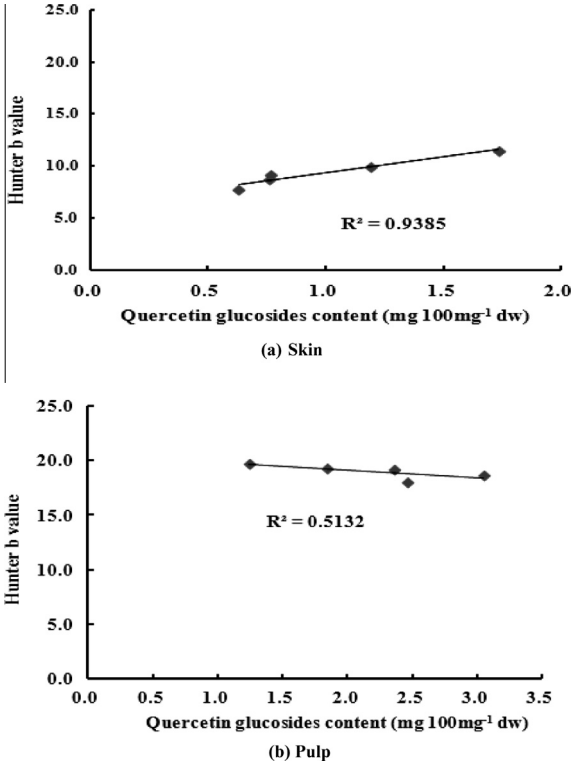

Figure 4 Correlation between Hunter (b) value and quercetin glucosides in onion skin (a) and pulp (b).

on apple or strawberries (Rodrigues et al., 2010). However, limited number of studies on phenolic contents of vegetables during storage at freezer temperatures is available (Awad and Jager, 2003). From overall results, it is obvious that at different light conditions it gives the best results for flavonoids. However, it was stated in a study that UV response is related to the irradiation dose and tissue sensitivity and overexposure could cause flavonoid depletion (Rodov et al., 2010). In another study, UV-C (200–280 nm) radiation was applied to fresh-cut tomatoes as a sanitizing agent that caused an increase (26%) in total phenolic contents of the samples (Slimestad and Verheul, 2009). During storage at air atmosphere under light, it is clear that quercetin 3,4′-diglucoside is converted into quercetin 4′-glucoside and further quercetin 4′-glucoside is broken down into quercetin aglycon, which is the result of enzymatic hydrolysis of glucosides (Rodrigues, et al. 2009). The same trend was observed in a study of Rodrigues, et al. (2009) in which onion bulbs were chopped and kept at room temperature under continuous light exposition. The levels of both quercetin 3,4′-diglucoside and quercetin 4′-glucoside might be reduced with all studied light effects with increase in quercetin content. No information about effect of different atmospheric conditions on onion flavonoids, which are kept under light, could be found in the literature.

4. Conclusion

In this study the post-harvest light treatment on onion played a significant role in elevating quercetin content. The highest quercetin content was observed under blue light conditions whereas the lowest one under fluorescent light. It was reported that UV light has potential to decontaminate peeled onions and to enhance quercetin and quercetin glucoside content in onion after treatment with lights. It has been also observed that in the case of skin peeled onion a white light irradiation results in the highest quercetin content whereas dark condition resulted in the lowest one. Red, blue, and UV-A light treatment also increased the quercetin concentration, although not as profoundly as that a white light. Quercetin content in onion can be doubled after harvest using UV light lamps. The contents of quercetin get accumulated due to the effect of different lights on onions. The levels of both quercetin 3,4′-diglucoside and quercetin 4′-glucoside might be reduced with all studied light effects with increase in quercetin content.

Conflict of interest

We (authors) have declared that there is no conflict of interests in the study.

Acknowledgments

This research was supported by Republic of Korea and Cooperative Research Program for Agriculture Science & Technology Development (Project No. PJ008973), Rural Development Administration, Republic of Korea.

References

Awad, M.A., Jager, A., 2003. Influences of air and controlled atmosphere storage on the concentration of potentially healthful phenolics in apples and other fruits. Postharvest Biol. Technol. 27, 53–58.

Chu, Y.H., Chang, C.L., Hsu, H.F., 2000. Flavonoid content of several vegetables and their antioxidant activity. J. Sci. Food Agric. 80, 561–566.

Friedman, M., 2006. Potato glycoalkaloids and metabolites: roles in the plant and in the diet. J. Agric. Food Chem. 54, 8655–8681.

George, S., Brat, P., Alter, P., Amiot, M.J., 2005. Rapid determination of polyphenols and vitamin C in plant-derived products. J. Agric. Food Chem. 53, 1370–1373.

Gokçe, A.F., Kaya, C., Serçe, S., Ozgen, M., 2010. Effect of scale color on the antioxidant capacity of onions. Sci. Hort. 123, 431–435.

Gorinstein, S., Leontowicz, H., Leontowicz, M., Namiesnik, J., Najman, K., Drzewiecki, J., Cvikrova, M., Martincová, O., Katrich, E., Trakhtenberg, S., 2008. Comparison of the main bioactive compounds and antioxidant activities in garlic and white and red onions after treatment protocols. J. Agric. Food Chem. 56, 4418–4426.

Hänninen, K.K., Rauma, A.L., Nenonen, M., Törrönen, R., Häkkinen, A.S., Adlercreutz, H., Laakso, J., 2000. Antioxidants in vegan diet and rheumatic disorders. Toxicology 155, 45–53.

Hegarty, V.M., May, H.M., Khaw, K.T., 2000. Tea drinking and bone mineral density in older women. Am. J. Clin. Nutr. 71, 1003–1007.

Higashio, H., Hirokane, H., Sato, F., Tokuda, S., Uragami, A., 2005. Effect of UV irradiation after the harvest on the content of flavonoid in vegetables. Acta Hort. 682, 1007–1012.

Hollman, P.C.H., Arts, I.C.W., 2000. Flavonols, flavones and flavanols – nature, occurrence and dietary burden. J. Sci. Food Agric. 80, 1081–1093.

Ioku, K., Aoyama, Y., Tokuno, A., Terao, J., Nakatani, N., Takei, Y., 2001. Various cooking methods and the flavonoid content in onion. J. Nutr. Sci. Vitaminol. 47, 78–83.

Islek, M., Nilufer-Erdil, D., Knuthsen, P., 2014. Changes in flavonoids of sliced and fried yellow onions (*Allium cepa* L. var. *zittauer*) during storage at different atmospheric, temperature and light conditions. J. Food Proc. Pres.. http://dx.doi.org/10.1111/jfpp.12240.

Jang, M., Leonid, A., Nile, S.H., Keum, Y.S., Kim, H.Y., Park, S.W., 2013. Ultrasound-assisted extraction of quercetin from onion solid wastes. Int. J. Food Sci. Technol. 48, 246–252.

Kempuraj, D., Castellani, M., Petrarca, C., Frydas, S., Conti, P., Theoharides, T., Vecchiet, J., 2006. Inhibitory effect of quercetin on tryptase and interleukin-6 release, and histidine decarboxylase mRNA transcription by human mast cell-1 cell line. Clin. Exp. Med. 6, 150–156.

Kevin, L., Ellen, P., Emanuel, G., Leslie, T., Andy, H., 2005. Quercetin in onion after heat-treatment simulating home preparation. J. Food Comp. Anal. 18, 571–581.

Lattanzio, V., Lattanzio, V.M.T., Cardinali, A., 2006. Role of phenolics in the resistance mechanism of plants against fungal pathogens and insects. In: Imperato, F. (Ed.), Phytochemistry: Advances in Research. Research Signpost, Trivandrum, Kerala, India, pp. 23–67.

Lee, S.U., Lee, J.H., Choi, S.H., Lee, J.S., Kameyama, M.O., Kozukue, N., Levin, C.E., Friedman, M., 2008. Flavonoid content in fresh, home-processed, and light-exposed onions and in dehydrated commercial onion products. J. Agric. Food Chem. 56, 8541–8548.

Lombard, K., Peffley, E., Geoffriau, E., Thompson, L., Herring, A., 2005. Quercetin in onion (*Allium cepa* L.) after heat-treatment simulating home preparation. J. Food Comp. Anal. 18, 571–581.

Mogren, L.M., Olsson, M.E., Gertsson, U.E., 2006. Quercetin content in field-cured onions (*Allium cepa* L.), Effects of cultivar, lifting time, and nitrogen fertilizer level. J. Agric. Food Chem. 54, 6185–6191.

Mogren, L.M., Olsson, M.E., Gertsson, U.E., 2007. Effects of cultivar, lifting time and nitrogen fertiliser level on quercetin content in onion (*Allium cepa* L.) at lifting. J. Sci. Food Agric. 87, 470–476.

Nile, S.H., Park, S.W., 2013. Total phenolics, antioxidant and xanthine oxidase inhibitory activity of three colored onions (*Allium cepa* L.). Front. Life Sci. 7, 224–228.

Patil, B.S., Pike, L.M., 1995. Distribution of quercetin content in different rings of various coloured onion (*Allium cepa* L.) cultivars. J. Hort. Sci. 70, 643–650.

Perez-Gregorio, M.R., Regueìro, J., González-Barreíro, C., Ríal-Otero, R., Símal-Gándara, J., 2011. Changes in antioxidant flavonoids during freeze-drying of red onions and subsequent storage. Food Control 22, 1108–1113.

Perez-Gregorio, R.M., García-Falcón, M.S., Símal-Gándara, J., Rodrigues, A.S., Almeida-Domingos, P.F., 2010. Identification and quantification of flavonoids in traditional cultivars of red and white onions at harvest. J. Food Comp. Anal. 23, 592–598.

Rodov, V., Tietel, Z., Vinokur, Y., Horev, B., Eshel, D., 2010. Ultraviolet light stimulates flavonol accumulation in peeled onions and controls microorganisms on their surface. J. Agric. Food Chem. 58, 9071–9076.

Rodrigues, A.S., Pérez-Gregorio, M.S., Garcia-Falcón, M.S., Simal-Gándara, J., 2009. Effect of curing and cooking on flavonols and anthocyanins in traditional varieties of onion bulbs. Food Res. Int. 42, 1331–1336.

Rodrigues, A.S., Pérez-Gregorio, M.S., Garcia-Falcón, M.S., Simal-Gándara, J., Almeida, D.P., 2010. Effect of post-harvest practices on flavonoid content of red and white onion cultivars. Food Control 21, 878–884.

Sharma, K., Assefa, A.D., Kim, S., Ko, E.Y., Lee, E.T., Park, S.W., 2014. Evaluation of total phenolics, flavonoids and antioxidant activity of 18 Korean onion cultivars: a comparative study. J. Sci. Food Agric. 94, 1521–1529.

Slimestad, R., Verheul, M., 2009. Review of flavonoids and other phenolics from fruits of different tomato (*Lycopersicon esculentum Mill.*) cultivars. J. Sci. Food Agric. 89, 1255–1270.

Soobrattee, M.A., Bahorun, T., Aruoma, O.I., 2006. Chemopreventive actions of polyphenolic compounds in cancer. BioFactors 27, 19–35.