BIOACTIVE AND BIOENERGY INGREDIENTS OF *RODGERSIA AESCULIFOLIA* GROWN AT HIGH ALTITUDE

by

Zanpei ZHANG[a], Keyu XUE[b], Dongli MA[a], Yuanyuan CHEN[a*], and Dangquan ZHANG[a*]

[a] College of Forestry, Henan Agricultural University, Zhengzhou, China
[b] Agricultural Products Quality and Safety Testing and Inspection Center of Xuchang, Xuchang, China

Original scientific paper
https://doi.org/10.2298/TSCI190609050Z

Rodgersia aesculifolia is a perennial herb wide-distributed in China, and has been used as herbal medicine with long history. Ethanol and diethyl ether extraction were used to explore the bioactive and bioenergy ingredients in leaves and stems of Rodgersia aesculifolia grown at high altitudes in China. The results showed that the Rodgersia aesculifolia grown at high altitude has not only great biomedical value, but also been used as bioenergy materials. In addition, quinic acid and butylated hydroxytoluene were firstly discovered in leaves and stems of fresh Rodgersia aesculifolia grown at high altitudes. As biologically active ingredients, their relative contents are relatively high. All these results have provided a theoretical basis for further utilization of bioactive and bioenergy components from Rodgersia aesculifolia grown at high altitudes.

Key words: *Rodgersia aesculifolia, waste utilization, bioenergy, biogasoline*

Introduction

Rodgersia aesculifolia is a species of perennial herb in *Rodgersia* (Saxifragaceae). As a traditional Chinese folk herb, its rhizome is often used as medicinal material [1, 2]. It has the effect of promoting blood circulation and regulating rheumatism, it also has a good effect on the treatment of bruises, irregular menstruation and rheumatoid arthritis. What's more, it has a significant effect on the treatment of symptoms such as diarrhea, vomiting blood in the stool and sore.

In recent years, there are a number of literatures which focus on the bacteriostatic and pharmacological activities of *Rodgersia aesculifolia*. For example, Wang *et al.* [3] have found that the volatile oil of *Rodgersia aesculifolia* rhizomes have strong antibacterial activity. The research by Li *et al.* [4] revealed the change of chemical composition of different solvent extracts of fresh *Rodgersia aesculifolia* rhizome. However, there is no specific literature of in-depth research on the diversified use of resources in *Rodgersia aesculifolia* growing at high altitude.

Our research focused on the resources in *Rodgersia aesculifolia* at high altitude. Ethanol and diethyl ether (ether) were used to extract bioactive ingredient in fresh *Rodgersia*

* Corresponding author, e-mail: cyuan091@163.com, zhangdangquan@163.com

aesculifolia leaves (RAL) and *Rodgersia aesculifolia* stems (RAS). We hope to find more resources which can be utilized.

Materials and methods

Materials and reagents

Rodgersia aesculifolia is sampled from the Xiao Qinling Mountains at the altitude of 2400 meters. Fresh RAL and RAS were separated from the samples. The RAL and RAS were solidified instantly by liquid nitrogen, and then ground into powder in mortar. Then they were placed in the extraction solution at a certain ratio for mixing and extraction.

Methods

Extraction by two solvents

The 15 g of powdered sample were solved into ethanol and ether respectively. After being placed at 26 °C for 8 hours, they were respectively extracted with ethanol and diethyl ether [5]. After 4 hours of extraction, the extract was filtered and the extract was concentrated to 10 mL by using a rotary evaporator at 25-30 °C. After all of these were done, all the concentrated extracts are placed in a 4 °C medicine cabinet for short-term storage for subsequent sample testing.

The FT-IR spectroscopy analysis

Infrared spectroscopy was performed using potassium bromide tableting. Take an appropriate amount of KBr in an agate mortar and grind it into a powder (about 2.5 μm in diameter). The 140 mg of powdered KBr was placed in a mold for tableting (KBr sheets were colorless and transparent), and then 7 μl of the sample to be tested was dropped into the center of the KBr sheet by a pipette. Then the samples to be tested were dried at 25°C for infrared detection [6]. When the prepared sample was tested using a FT-IR spectroscopy tester (Nicolet IS 10), the instrument parameters were set to the number of acquisitions of 32, the resolution was 4 cm^{-1}, and the data interval was 0.48 cm^{-1}.

Components analysis by GC-MS

The GC: Column HP-5MS (30 m × 250 μm × 0.25 μm). Elastic quartz capillary column, the carrier gas used for high purity helium, flow rate of 1 mL/min. The split ratio is 5:1. The temperature program of the GC starts at 50 °C, rises to 230 °C at a rate of 10 °C/min, and then rises to 250 °C at a rate of 5 °C/min.

The MS: program scans mass range of 30-600 amu, ionization voltage of 70 eV, ionization current of 150 μA electron ionization (EI). The ion source and the quadrupole temperature were set at 230 °C and 150 °C, respectively.

Results and analysis

Groups change characteristics of extractions

In order to obtain information on the chemical bonds and functional groups contained in RAL and RAS, the substances were detected by infrared spectroscopy [7]. The types of compounds that may be contained are judged based on the different absorption frequencies of different chemical bonds and functional groups contained in RAL and RAS.

From the infrared spectrum results of different solution extracts of RAL and RAS, figs. 1 and 2, we can see that the functional groups or chemical bond types extracted by them are

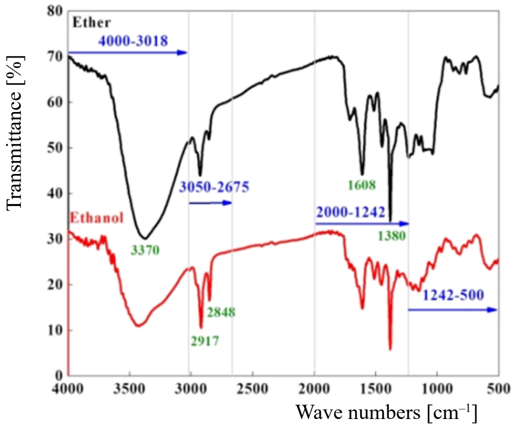

Figure 1. Functional group curve in RAL

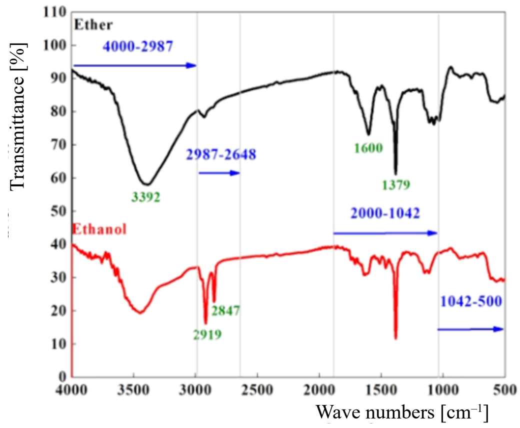

Figure 2. Functional group curve in RAS

similar. However, according to the curve of the infrared spectrum, the absorption peak values of the same type of organic matter in different extracts are different. This also shows that the extraction effect of ether and ethanol are different when extracting the same substance. The infrared spectroscopy results of RAL showed that the double bond may be present in the extracts of ether and ethanol, which indicating that the extract may contain alcohols, aldehydes and ketones. The infrared spectroscopy results of RAS indicate that both ether and ethanol extracts may contain hydroxyl groups and do not contain triple bonds. It is speculated that they may contain alcohols, ketones, alkanes. Comparing the ethanol and ether extracts, it is not difficult to find that the ethanol extract may contain olefins. Comparing the infrared spectra of RAL and RAS, it can be seen that the types of substances contained in RAL may be more abundant than that in RAS, that is, the potential energy substances in RAL may be more.

Volatile compositional diversity in different extracts from RAL and RAS

In order to know the volatile components contained in different extracts of different parts of *Rodgersia aesculifolia*, we analyzed the volatile substances by using GC-MS [8, 9]. The 39 volatiles components were detected in 43 peaks in RAL ethanol extract and 34 volatiles were detected in 39 peaks in the ether extract of RAL. The compounds in ethanol and ether were classified according to functional groups, figs. 3 and 4. It can be seen that the relative content of alcohols in the two extracts is the highest, and the content of phenols is second.

The 2-Myristynoyl pantetheine and benzoic acid, 4-hydroxy-3, 5-dimethoxy- were detected in the extract of RAS ethanol. Benzoic acid, 4-hydroxy-3, 5-dimethoxy-, which has antibacterial, sedative and local anesthetic effects, is consistent with previous studies. Quinic acid was first discovered in the ethanol extract of RAS and the relative content reached 21.23%. Studies have shown that quinic acid has the effect of enhancing bile, reducing fat, detoxifying the liver, and preventing fatty liver [10, 11]. In addition, after analyzing the volatile substances in the ethanol extract of RAL, it is found that effective biopharmaceuticals such as 2-myristynoyl pantetheine, benzoic acid, 4-hydroxy-3,5-dimethoxy- and 9, 12-octadecadienoic acid (z, z)-,what's more, there is also a substance phenol, 2, 2-methylenebis[6-(1, 1-dimethylethyl)]-4-methyl- that can be used as a phenolic antioxidant and an antioxidant in petroleum products, which is a good bioenergy substance.

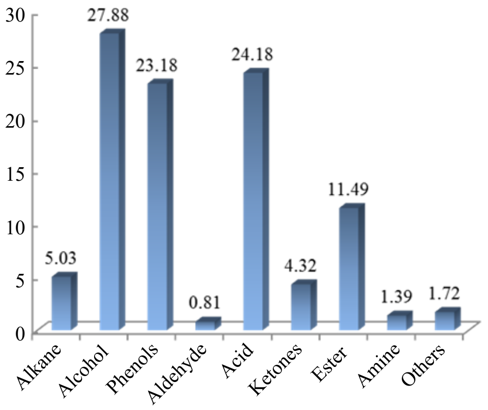

Figure 3. Classification of volatile functional groups in RAL ethanol extracts

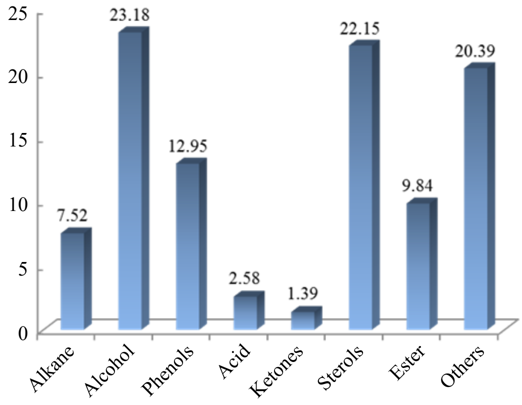

Figure 4. Classification of volatile functional groups in RAL ether extracts

Octadecanoic acid and .gamma.-sitosterol, were detected in the ether extract of RAL. gamma.-sitosterol, which have health functions for the human body [12, 13]. In addition, butylated hydroxytoluene was first discovered in the ether extract of RAL. It is an excellent antioxidant additive for various petroleum products [14-16]. It can effectively prevent the acid value or viscosity of lubricating oil and fuel oil from rising, which is an excellent bio-energy material.

From the comparison of the ionograms of the ethanol extract of RAL and the ether extract, it can be seen that the amount of volatile substances in the ethanol extract is more than that in the ether extract, fig. 5. However, by comparing the two volatile substances, it is found that the relative content of the bio-energy materials contained in the ether extract is relatively high.

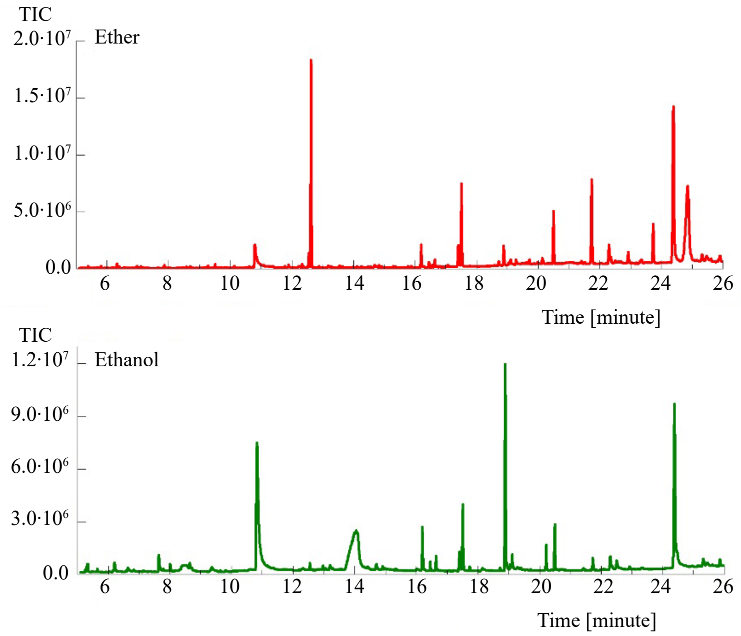

Figure 5. Comparison of total ion chromatograms of volatiles in different extracts of RAL

Twenty-four volatile components were detected in 26 peaks in the ethanol extract of RAS, and 29 volatiles were detected in 29 peaks in the ether extract of RAS. The volatile compounds in the ethanol and ether extracts were classified according to functional groups, figs. 6 and 7. It can be seen that the relative content of sterols in the two extracts are the highest, indicating that the sterols in RAS are the most.

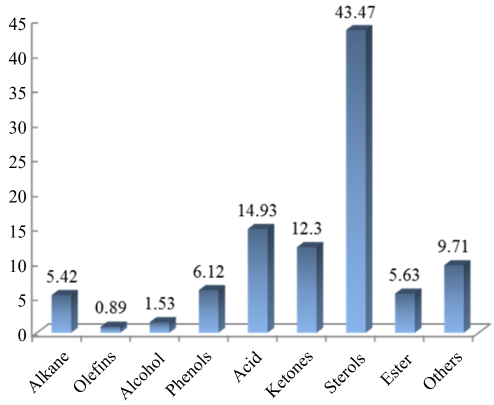

Figure 6. Classification of volatile functional groups in RAS ethanol extracts

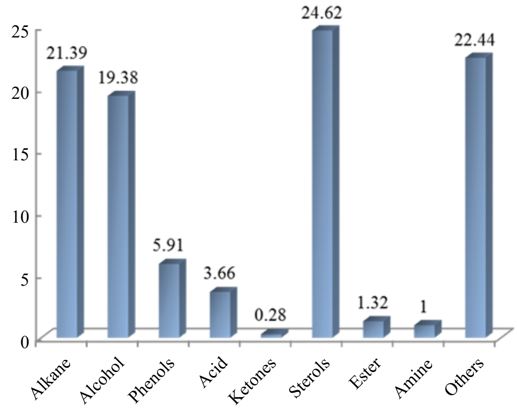

Figure 7. Classification of volatile functional groups in RAS ether extracts

The sterols substance in the ethanol extract of RAS is mainly .gamma.-sitosterol, which has health care functions. Raw materials that can be used as biomedicine have been detected in ethanol extracts of RAS, such as .gamma.-sitosterol, vitamin E, clindamycin and n-hexadecanoic acid [17-19]. Vitamin E can be used to regulate menopausal disorders, progressive malnutrition, and it also can prevent coronary heart disease, arteriosclerosis, thrombosis and prevent aging [20]. Of course, the quinic acid was first discovered in the ethanol extract of RAS, with a relative content of about 7.3%. In addition, there are also substances whichcan be used as bioenergy in the ethanol extract of RAS, such as phenol, 2, 2'-methylenebis [6-(1, 1-dimethylethyl)]-4-methyl-.

The sterols detected in the ether extract of RAS are mainly composed of .gamma.-sitostero and stigmasterol, both of which are good health supplements. Stigmasterol is mainly used as a raw material for the synthesis of steroid hormones and vitamin D3, and it is also a raw material for the manufacture of progesterone in medicine [21, 22]. In addition to those substances whichcouldbe used as biomedicine, there are substances that can be used as bioenergy, such as dodecane and butylated hydroxytoluene. Butylated hydroxytoluene is the first to be found in the ether extract of RAS. It is not only an excellent antioxidant additive for various petroleum products, but also a food antioxidant and stabilizer in food-grade plastics and packaged foods to delay the rancidity of food.

From the comparison of the total ion chromatograms of the volatiles of the ethanol and ether extracts of RAS, fig. 8, it can be seen that the ether extract of RAS contains more volatile substances than the ethanol extract. Furthermore, the ether extract can be used as bioenergy substances are relatively high, the substances which can be used as biomedicine has a relatively large amount in the ethanol extract.

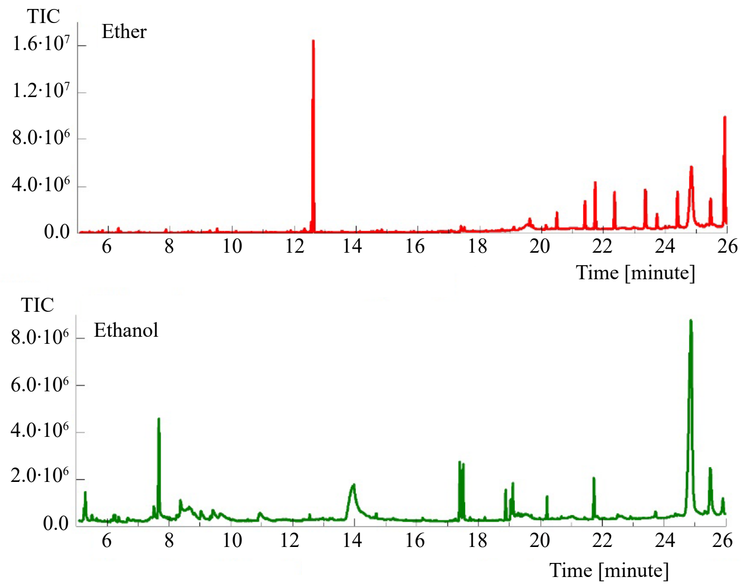

Figure 8. Comparison of total ion chromatograms of volatiles in different extracts of RAS

Conclusions

The volatiles in the different extracts of the leaves and stems of *Rodgersia aesculifolia* at high altitudes contain n-hexadecanoic acid and phenol, 2, 2'-methylenebis [6-(1, 1-dimethylethyl)]-4- Methyl-. But there is a significant difference in their relative content. The relative content of n-hexadecanoic acid in RAS ethanol extract reached 3.7%, which is the highest relative among the four. The relative content of Phenol, 2, 2'-methylenebis [6-(1, 1-dimethylethyl)]-4-methyl- in the RAL ether extract is the highest (7.09%) one. This indicates that there are a large number of n-hexadecanoic acid in RAS, while RAL have a large amount of phenol, 2, 2'-methylenebis [6-(1, 1-dimethylethyl)]-4-methyl-, it further illustrates that RAL do have potential bioenergy materials, which confirms the results of infrared spectroscopy.

Quinic acid and butylated hydroxytoluene were first discovered in *Rodgersia aesculifolia* at high altitudes. In RAL ethanol extracts and RAS ethanol extracts, quinic acid was first discovered as a biopharmaceutical ingredient, indicating that RAL and RAS at high altitudes contain quinic acid, and ethanol can effectively extract this component. The butylated hydroxytoluene was first found in RAL ether extract and RAS ether extract, with relative contents of 15.09% and 18.50%. This shows that RAL and RAS contain butylated hydroxytoluene, and ether can effectively extract it.

All these results have been provided a theoretical reference for further research on the multi-resource utilization of *Rodgersia aesculifolia,* especially in the areas of biomedical and bioenergy applications. And in production practice, different methods can be adopted according to different needs in order to make rational use of *Rodgersia aesculifolia* at high altitude.

Acknowledgment

This project was supported by the Project of Henan Provincial Science Research, China (192102110174), and the Talent Project (Dangquan Zhang) of Henan Agriculture University, China.

References

[1] Ma, X. G., *et al.*, Historical Introgression Among the Species of Rodgersia (Saxifragaceae) in Mountainous Forests of Southwest China, *Molecular Phylogenetics and Evolution, 125* (2018), Aug., pp. 93-99
[2] Zhang, Y., Wang, Z., Comparative Analysis of Essential Oil Components of Three Phlomis Species in Qinling Mountains of China, *Journal of Pharmaceutical and Biomedical Analysis, 47* (2007), 1, pp. 213-217
[3] Wang, J., *et al.*, Study on Antimicrobial Activities of the Essential Oil and Various Extracts of Rodgersia Aesculifolia Batalin, *Science and Technology of Food Industry,* (2013), 1, pp. 74-76,84
[4] Li, T., *et al.*, The Study on Volatile Components from Different Solvent Extracts of Fresh Rodgersia Aesculifolia Batalin, *Acta Chinese Medicine and Pharmacology,* (2011), 1, pp. 87-90
[5] He, H., *et al.*, Effects of Exogenous 6-BA and NAA on Growth and Contents of Medicinal Ingredient of Phellodendron Chinense Seedlings (Article), *Saudi Journal of Biological Sciences*, *25* (2018), 6, pp. 1189-1195
[6] Xu, K., *et al.*, High-Efficient Extraction of Principal Medicinal Components from Fresh Phellodendron Bark (Cortex Phellodendri), *Saudi Journal of Biological Sciences, 25* (2018), 4, pp. 811-815
[7] Jordan, M. M., *et al.*, Mineralogical Analysis of Historical Mortars by FTIR, *Materials*, *12* (2019), 1, 55
[8] Abiedalla, Y., *et al.*, Differentiation of the Six Dimethoxypyrovalerone Regioisomers: GC-MS, GC-MS/MS and GC-IR, *Talanta, 171* (2017), Aug., pp. 220-228
[9] Bozlee, M., Novel Sample Preparation and GC-MS/MS Analysis of Triclosan and Methyl Triclosan in Biosolids, *LC-GC North America, 35* (2017), 10, pp. 6-13
[10] Feistel, F., *et al.*, Acylated Quinic Acids Are the Main Salicortin Metabolites in the Lepidopteran Specialist Herbivore Cerura vinula (Article), *Journal of Chemical Ecology, 44* (2018), Mar., pp. 497-509
[11] Assoah, B., *et al.*, Biomass-Based and Oxidant-Free Preparation of Hydroquinone from Quinic Acid, *European Journal of Organic Chemistry, 22* (2016), Aug., pp. 3856-3861
[12] Calligaris, S., *et al.*, Effect of Oil Type on Formation, Structure and Thermal Properties of Gamma-Oryzanol and Beta-Sitosterol-Based Organogels, *Food Biophysics*, *9* (2014), Aug., pp. 69-75
[13] Okuro, P. K., *et al.*, Lecithin and Phytosterols-Based Mixtures as Hybrid Structuring Agents in Different Organic Phases*, Food Research International*, *111* (2018), Sept., pp. 168-177
[14] Mahalleh, A. A., *et al.*, Evaluation of the Oxidation Kinetics and Stability of Soybean Oil Supplemented with Ethanolic Extract of Nepeta (Nepeta Binaludensis Jamzad) as Compared to Butylated Hydroxytoluene, *Chemical Papers*, *73* (2019), Apr., pp. 2231-2239
[15] Garca Ibarra, V., *et al.*, Migration Studies of Butylated Hydroxytoluene, Tributyl Acetylcitrate and Dibutyl Phthalate into Food Simulants, *Journal of the Science of Food & Agriculture*, *99* (2019), 4, pp. 1586-1595
[16] Kang, K., *et al.*, Migration Study of Butylated Hydroxytoluene and Irganox 1010 from Polypropylene Treated with Severe Processing Conditions (Article), *Journal of Food Science*, *83* (2018), 4, pp. 1005-1010
[17] Niu, Z. Y., *et al.*, Dietary Vitamin E Improves Meat Quality and Antioxidant Capacity in Broilers by Upregulating the Expression of Antioxidant Enzyme Genes, *Journal of Applied Animal Research*, *46* (2018), 1, pp. 397-401
[18] Cantero, A., *et al.*, The Triaxiality Role in the Spin-Orbit Dynamics of a Rigid Body, *Applied Mathematics & Nonlinear Sciences, 3* (2018), 1, pp. 187-208
[19] Lopez, J. C. C., *et al.*, Computing the Two First Probability Density Functions of the Random Cauchy-Euler Differential Equation: Study about Regular-Singular Points, *Applied Mathematics & Nonlinear Sciences, 2* (2017), 1, pp. 213-224
[20] Bennett, A. E., Kearney, J. M., Predictors of Vitamin D Supplementation Amongst Infants in Ireland Throughout the First Year Of Life, *Journal of Public Health*, *26* (2018), Jan., pp. 577-583
[21] Chhikara, N., *et al.*, Bioactive Compounds, Food Applications and Health Benefits of Parkia Speciosa (Stinky Beans): A Review, *Agriculture and Food Security*, *7* (2018), Jula, 46
[22] Haque, N., *et al.*, Stigmasterol Activates Cdc42-Arp2 and Erk1/2-Creb Pathways to Enrich Glutamatergic Synapses in Cultures of Brain Neurons, *Nutrition Research*, *56* (2018), Aug., pp. 71-78

Paper submitted: June 9, 2019
Paper revised: September 13, 2019
Paper accepted: November 13, 2019