Studii şi Cercetări Ştiinţifice 2017, **18** (4), pp. 427 – 434
Chimie şi Inginerie Chimică, Biotehnologii, Industrie Alimentară

Scientific Study & Research
Chemistry & Chemical Engineering, Biotechnology, Food Industry **ISSN 1582-540X**

ORIGINAL RESEARCH PAPER

MAHONIA AQUIFOLIUM AS A PROMISING RAW MATERIAL FOR THE FOOD INDUSTRY

Vladimir N. Sorokopudov[1], Nina I. Myachikova[2], Cecilia Georgescu[3*]

[1]Federal State Scientific Institution "All-Russia Selection-Technological Institute of Horticulture and Nursery", Department of Genetics and Selection of fruit and berry crops, 4, Zagoryevskaya Street, 115598, Moskow, Russia
[2]Federal State Autonomous Educational Institution of Higher Education "Belgorod National Research University", Institute of Engineering Technology and Natural Sciences, Department of Food Technology, 85, Pobedy Street, 308015, Belgorod, Russia
[3]"Lucian Blaga" University of Sibiu, Agriculture Science, Food Industry and Environmental Protection, 7-9, Ratiu Street, 550012, Sibiu, Romania

*Corresponding author: cecilia.georgescu@ulbsibiu.ro

Received: October, 12, 2017
Accepted: December, 04, 2017

Abstract: The development of the food industry leads to the expansion of the range of processed raw materials. *Mahonia aquifolium* today can be attributed to the non-traditional agricultural plants. However, the analysis of the chemical composition of the fruits showed that they contain significant amount of carbohydrates, vitamin C, various minerals, which recommend it for a wider use in the diet. Also due to the presence in the fruits of *Mahonia aquifolium* anthocyanins can extend of the use as raw material for natural anthocyanin dyes obtaining.

Keywords: *anthocyanins, minerals, natural dyes, vitamin C*

INTRODUCTION

The quality and biological value of food products are determined by its chemical composition and a range of integrated sensory-specific properties of this composition. To give to food an attractive appearance manufacturers decorate them using a wide range of dyes that are classified into three groups: natural, inorganic (mineral) and synthetic [1]. But in order the dye to be used in food industry, it must meet the following requirements:

- absolutely harmless;
- resistance to temperature effects;
- high coloring power;
- no unpleasant foreign flavors and odors;
- stability of color during storage of the product [2].

Natural dyes are inferior in technological characteristics to the synthetic compounds being less stable during storage, and in a number of production workloads [3 – 8]. But the most products from the Russian market of synthetic dyes do not meet the basic requirements of safety for human body. In the media and in the scientific literature often refers to the disruption of the normal functioning of organs and tissues, on the occurrence of allergic reactions, as well as to the development of serious chronic diseases due to the consumption of food product, containing multiple synthetic stained components [7 – 12]. Therefore, to improve the quality of life in modern society, it is necessary to change the policy of use in the food industry more natural substances, in particular natural dyes that are not just coloring additives, but also biologically active components that enrich the food's antioxidant and anticarcinogenic properties [13 – 20].
Natural dyes, in particular, anthocyanins, not only give the color of plant raw materials, but also known to have physiological activity, including antioxidant activity. These antioxidants retain their properties when are used in a plant by another organism. Purifying natural dyes could be find more wide application for the improvement of properties of food products, for the obtaining of biologically active food supplements, pharmaceutical medicines for the treatment and prevention of various diseases.
In some cases, the use of natural dyes is uncontested. This primarily relates to the coloring of fermented milk products. Lactic acid bacteria degrade synthetic azo dyes within a few hours (anaerobic degradation of azo dyes lies even at the basis of the technology related to the decrease in the level of pollutants in ecosystems) [21]. Therefore, for the dying of such products, it is desirable the use of natural pigments, which in this environment is resilient enough. Among the water-soluble natural colorants-antioxidants, able to color the food in various shades of red (alternative to the azo dye – carmoisine) is the anthocyanins [22].
Anthocyanins may be used for the manufacture of all food products without specific quantity limitations, except for those which are not allowed in accordance with the requirements of SanPiN [23].
Food industry is an area where innovation and new discoveries allow us to turn on an ordinary product into a cure for humans.
To non-traditional agricultural plants, this potential of *Mahonia aquifolium* (Pursh) Nutt may extend the range of raw materials available for natural anthocyanin dyes, production. In North America and in Europe, the fruits, the roots and leaves of *Mahonia* are widely used for the production of natural dyes [24 – 25]. In addition, its mature

berries are rich in sugar and vitamins and [24, 26 – 27] they are recommended for cooking.
Mahonia aquifolium is an evergreen shrub up to height of 1.5 m. This plant is widely distributed in woodlands of British Columbia in Oregon [28]. *Mahonia* prefers a grey forest soil (pH 6 – 8), but can grow on poor soils, it is resistant to summer drought and can withstand strong, direct light, with hard leathery leaves protect the plant from direct light. The optimum temperature for growth is 22 °C [28 – 30].
Inflorescence *Mahonia aquifolium* is the brush. Shoot growth continues during flowering, the leaves die off in 3-4 years of age [31 – 32].
Mahonia aquifolium was introduced as an ornamental plant in Europe in 1822 and currently grows in many parts of Europe [30, 33 – 34]. *Mahonia* is often cultivated in areas where intense traffic is and there are other chemical pollutants, due to high resistance to contamination [35]. Within the many species of *Mahonia*, in the middle zone of Russia, due to high winter hardiness, the most widely there are two – *Mahonia aquifolium* and *Mahonia repens*. *Mahonia aquifolium* (Pursh) Nutt belongs to the species *Magnoliophyta* (*Angiospermae*); class *Magnoliopsida* (*Dicotyledones*); subclass *Ranunculidae*; order *Ranunculidae Mahonia* Nutt. [36].

MATERIALS AND METHODS

The object of the study was the *Mahonia aquifolium* family *Berberaceae*. The source material for the study of *Mahonia aquifolium* in culture have served as seedlings of plants of different origin and locality, collected in the surroundings of Belgorod (Russia). For analysis of anthocyanins the fruit of *Mahonia aquifolium* samples were collected at the end of September. More samples from different years are analyzed.
The content of sugars and soluble solids were determined with a Refractometer IRF-454 B2M and by the Bertrand method. The content of anthocyanins and ascorbic acid were determined using spectrophotometer SF-102. Spectrophotometric analysis allows also quantifying the amount of anthocyanins extracted from plants [37 – 38].
Experimental data were processed by variance analysis at the B. A. Dospehov [39] G. N. Zaitsev [40] using the software EXCEL (Microsoft Office Professional Plus 2010 license number 60788903).

RESULTS AND DISCUSSION

During the research it was revealed that in 2008 the fruits contained the highest amount of anthocyanins belonged to forms No. 24, 40 and 118. In 2009 and 2010, the maximum content of anthocyanins in fruits was found in forms No. 24, 37 and 118 (Table 1).
Thus, the fruits of *Mahonia* contain a sufficient amount of anthocyanins, so that they can serve as a source for natural food colorants [9, 41].
Carbohydrates are one of the most important groups of organic compounds included in the composition of plant organisms. Sugar is the main energy source and main reference material of plant cells. Sugar combined with the acids and other substances contained in the fruit cause the taste of berries and their technological characteristics [42 – 45].
Studies to determine the content of sugars, dry matter and vitamin C in fruits of *Mahonia* was performed in samples collected in early September from selected forms in

2008, 2009 and 2010 (Table 2, Table 3).

Table 1.*The content of anthocyanins in fruits of the investigated forms [mg %]*

Year / No. Sample	2008	2009	2010
15	202.8	146.6	163.6
19	133.5	113.3	202.2
24	219.3	220.2	-
28	110.2	103.7	105.0
29	201.4	202.5	210.3
31	205.0	185.5	125.5
32	128.9	142.8	215.3
37	210.2	223.1	205.4
40	209.2	-	204.5
46	121.4	-	155.0
50	112.8	123.5	152.1
54	106.8	101.6	103.1
56	108.8	102.6	117.2
102	111.2	106.4	142.7
103	173.4	169.2	154.5
118	226.1	224.3	252.5
120	126.1	-	153.5
126	106.9	105.5	180.8
131	125.7	111.3	121.2

Table 2.*The content of sugars and soluble dry matter in fruits of Mahonia [%]*

Year	2008		2009		2010		The average	
No. sample	Sugar	Soluble dry matter	Sugar	Soluble dry matter	Sugar	Soluble dry matter	Sugar	Soluble dry matter
15	5.2	18.6	5.0	17.5	5.4	17.1	5.20 ± 0.30	17.73 ± 0.48
19	4.9	17.1	5.1	19.2	4.6	18.8	4.87 ± 0.37	18.37 ± 0.83
24	6.0	18.8	5.6	17.8	-	-	5.80 ± 0.42	18.30 ± 1.65
28	5.9	18.7	6.0	18.7	6.4	18.4	6.10 ± 0.39	18.60 ± 0.26
29	5.2	18.6	5.6	18.4	5.6	18,5	5.47 ± 0.34	18.50 ± 0.15
31	5.4	18.6	6.0	17.6	5.8	18.5	5.73 ± 0.45	18.23 ± 0.82
32	6.2	19.7	6.0	18.0	5.8	17.8	6.00 ± 0.30	18.50± 2.06
37	5.2	18.8	5.7	18.8	5.4	18.4	5.13 ± 0.37	18.67 ± 0.75
40	5.6	18.9	-	-	5.7	18.2	5.65 ± 0.11	18.55 ± 0.74
46	4.8	17.9	-	-	4.2	17.4	4.50 ± 0.63	17.65 ± 0,53
50	5.9	18.7	5.8	18.4	6.1	18.7	5.93 ± 0.23	18.60 ± 0,26
54	7.2	19.8	7.1	19.5	7.4	19.6	7.23 ± 0.23	19.63 ± 0,23
56	6.7	19.0	6.6	19.3	6.8	19.0	6.67 ± 0.09	19.10 ± 0,26
102	6.3	18.3	6.2	18.4	6.7	19.2	6.40 ± 0.39	18.63 ± 1.59
103	5.7	18.2	5.5	18.3	5.4	17.6	5.53 ± 0.23	18.03 ± 0.56
118	6.5	18.5	6.4	18.9	6.7	18.6	6.53 ± 0.23	18.67 ± 0.31
120	5.0	18.7	-	-	5.7	17.5	5.35 ± 0.74	18.10 ± 1.26
126	5.9	18.6	6.5	18.7	5.2	17.6	5.87 ± 0.97	18.30 ± 0.90
131	5.0	17.6	5.1	17.9	5.8	17.4	5.30 ± 0.65	17.63 ± 0.46

Depending on weather conditions during vegetation period the content of sugars in the berries can vary considerably. Plants respond to conditions differently, which is connected with the individuality of the development cycle each of them [42]. Studies have shown that fruits of *Mahonia aquifolium* characterized by low variability of sugar content, depending on weather conditions 2008-2010. The highest content of sugars in the fruit was characterized by breeding samples *Mahonia* No. 54, 56, 102, and 118 (Table 2).

Table 3. *Vitamin C content in Mahonia fruits [mg %]*

No. samples	2008	2009	2010
8	84.8 ±2.04	86.2 ± 1.17	72.3 ± 1.57
15	85.6 ± 1.98	88.2± 1.60	80.6 ± 1.76
19	102.3 ± 2.09	98.2 ± 0.60	87.2 ± 1.96
24	110.2 ± 2.03	102.5 ± 0.30	95.3 ± 1.71
28	95.3 ± 2.06	96.3 ± 0.38	84.8 ± 2.07
29	104.9 ± 0.25	101.3 ± 0.40	98.3 ± 1.78
31	80.2 ± 0.94	89.3 ± 1.44	78.3 ± 1.52
32	86.3 ± 1.79	90.3 ± 1.70	76.3 ± 1.24
37	79.3 ± 1.15	84.3 ± 0.46	74.3 ± 1.14
40	92.3 ± 1.25	94.3 ± 0.56	81.7 ± 2.03
46	95.3 ± 0.82	94.7 ± 1.47	87.2 ± 1.91
50	85.3 ± 0.77	88.7 ± 1.87	80.9 ± 1.75
54	99.8 ± 0.63	90.4 ± 1.71	89.1 ± 1.85
56	87.2 ± 0.55	82.4 ± 1.35	81.3 ± 1.92
102	110.1 ± 0.29	99.7 ± 1.16	95.6 ± 1.81
103	86.4 ± 1.34	83.2 ± 1.91	81.2 ± 1.98
118	102.5 ± 1.23	94.3 ± 1.20	91.3 ± 1.83
120	81.2 ± 1.08	84.3 ± 2.10	74.3 ± 1.92
126	78.9 ± 1.12	80.2 ± 1.11	76.8 ± 1.92
131	75.3 ± 1.14	85.3 ± 0.98	72.3 ± 1.84

The Vitamin C content in fruit breeding *Mahonia aquifolium* in 2008 and 2009, was more than in 2010. This is due to the extreme heat and drought in 2010.

In the course of the experiment revealed that the fruits of all the studied forms of *Mahonia aquifolium* contain a sufficiently large amount of vitamin C (72.3-110.2 mg %), which is also confirmed by the works of Kulevoy [46].

Of great importance in the introduction and acclimatization of plants have trace minerals, which play an important role in metabolism of plants in the conditions of existence [47 – 51]. It is noted there is a relationship between the accumulation in plants of certain groups of biologically active substances and the content of microelements [52]. It is believed that plants which contain alkaloids in large quantities can accumulate cobalt, manganese, zinc [47]. However, in higher concentrations than necessary content of ions of heavy metals are showing strong toxic properties. Getting food in the human body, heavy metal ions can cause disruption of the balance between the elements and cause pathological changes in the body.

Elements content in fruits of *Mahonia aquifolium* presented in Table 4.

Table 4. *The elemental composition of the fruits of Mahonia (2009-2011)*

No. Sample	Pb [mg·kg^{-1}]	Zn [mg·kg^{-1}]	Cu [mg·kg^{-1}]	Ca [%]	P [%]	K [%]	Fe [mg·kg^{-1}]	Mn [mg·kg^{-1}]
The maximum admissible quantity	0.40	10.00	5.00	–	–	–	–	–
15	0.49	3.01	0.98	0.062	0.040	0.28	12.3	6.36
19	0.40	3.25	0.78	0.065	0.052	0.24	12.8	8.36
24	0.63	3.41	0.66	0.062	0.053	0.32	11.5	8.00
28	0.52	2.55	1.00	0.064	0.050	0.41	10.9	7.23
29	0.41	2.91	1.26	0.034	0.052	0.36	9.5	5.23
31	0.51	2.42	1.45	0.041	0.048	0.32	5.3	5.36
32	0.48	3.13	0.12	0.052	0.049	0.30	11.2	8.52
37	0.47	3.44	0.36	0.061	0.052	0.29	10.6	4.98
40	0.45	2.15	0.98	0.060	0.051	0.28	11.4	7.36
46	0.43	2.00	1.36	0.052	0.047	0.25	12.0	6.89
50	0.54	3.24	0.12	0.064	0.056	0.29	10.4	6.45
54	0.62	2.92	1.36	0.041	0.054	0.30	10.8	8.25
56	0.41	2.50	1.08	0.051	0.055	0.36	10.0	7.63
102	0.60	2.96	0.99	0.050	0.050	0.24	10.3	7.36
103	0.43	2.78	1.00	0.041	0.055	0.26	11.1	8.12
118	0.41	2.99	1.02	0.065	0.051	0.34	10.4	8.12
120	0.40	3.00	1.36	0.068	0.045	0.30	8.6	7.36
126	0.41	2.41	0.65	0.064	0.040	0.32	8.4	5.36
131	0.52	2.48	0.85	0.065	0.042	0.27	9.3	4.36
The average	0.48	2.82	0.91	0.060	0.050	0.30	10.4	6.91

The study revealed that the content of zinc and copper in the fruits of *Mahonia aquifolium* does not exceed the maximum permissible concentration (MPC), the lead content is slightly higher than this limit (Table 4). This is due to the growth of *Mahonia* in the vicinity of the highway. Lead compounds can accumulate in the soil and come from the soil to plants, in addition, volatile compounds of lead with the flow of air masses can move far away from emission sources. This leads to the common lead pollution of the environment. But, for example, when washing fruit surfaces with running water, according to the source Donchenko [53], the total content of lead ions can be reduced by more than 50 %. The content of micro - and macroelements (calcium, phosphorus, potassium, iron, manganese) in the berries slightly varies.

CONCLUSION

Thus, the fruits of *Mahonia aquifolium* can be recommended for wider use in the diet, because contain a significant amount of carbohydrate 4.5-7.4 %, vitamin C 72.3-110.2 mg %, have a variety of mineral composition (Pb - 0.48 mg·kg^{-1}; Zn - 2.82 mg·kg^{-1}; Cu - 0.91 mg·kg^{-1}, Ca - 0.91 %, P - 0.05 %, K - 0.3 %, Fe - 10.4 mg·kg^{-1}, Mn - 6.91 mg·kg^{-1}). In addition, the presence in the fruits of *Mahonia aquifolium* anthocyanins allows its use as raw material for natural food coloring. The quantity of anthocyanins was between 101.6 and 252.5 mg %, the highest quantity was found in sample for 2005.

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