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THE AGROECONOMIC VALUE OF *RUBUS LOGANOBACCUS* L.H. BAILEY CULTIVATED IN THE CONDITIONS OF THE REPUBLIC OF MOLDOVA

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Abstract

The introduced Rubus loganobaccus cultivars 'Lincoln Logan', 'Tayberry Buckingham', 'Tayberry Medana' were studied under the conditions of the Republic of Moldova. The experiments were conducted in the National Botanical Garden (Institute), Republic of Moldova. It has been found that the plant of studied cultivars produces 65 - 75 fruits per floricane, with an average weight of 4.37-6.20 g, their sugar concentration was 9.6 - 11.8 % and the vitamin C 21.1 – 26.2 mg/100 g. The antioxidant value of the leaves constitutes IC_{50} *= 53-56 mg/ml. The leaf dry matter of the researched cultivars contained 15.2 - 18.7% crude protein, 81-13.6 % ash, 7.9-12.5 % cellulose, 12.7-13.9 % hemicellulose and can be used to feed animals or as organic fertilizer in the hybrid berry plantations. When pruning the floricanes after harvest, the wood biomass obtained contained 48.5 % cellulose, 25.4 % hemicellulose with energy value of 18.5 MJ/kg and theoretical ethanol potential* 557 L/t, *it can be used to produce renewable energy. In the Republic of Moldova, the studied Rubus loganobaccus cultivars have agroeconomic value as a food, medicinal plants, also as fodder and energy biomass.*

Key words**:** *agroeconomic value, cultivars, floricanes, fruits, leaves, Rubus loganobaccus*

INTRODUCTION

Agriculture has been a worldwide engine that has allowed overcoming critical states of food shortage, poverty and unemployment, especially in developing countries.

Economic activities in the Republic of Moldova based on agriculture contributed 10.7% to the gross economic production in 2019. Horticulture, traditionally, is one of the priority directions of agriculture in the Republic of Moldova meant to provide products with added value, with a considerable share in exports. Currently, the horticultural sector is growing both in terms of production and exports, provides jobs and wages in rural areas, and is an attractive business area for agricultural producers. Thus, according to the data of the National Bureau of Statistics, over 1,000 companies are directly involved in the primary production and subsequent processing of horticultural production.

The genus *Rubus* L. belongs to the tribe *Rubeae* Dumort., subfamily *Rosoideae*, family Rosaceae Juss. *Rubus* is recognized as one of the largest genera with over 1,350 species, Flora Europaea lists 75 species; in the spontaneous flora of the Republic of Moldova, 8 species have been identified [17]. It includes deciduous or semi-evergreen perennial herbs or shrubs, which are often spiny with a characteristic fruit, formed of a head of one-seeded drupelets. Raspberries, blackberries and dewberries are common, widely distributed members of the *Rubus* genus. The cultivation of berry plants is one of the most important areas of the agricultural industry worldwide. Berries are a rich source of various biologically active compounds, which make them popular both in the food and pharmaceutical industries [4, 5, 2, 3].

Growing berries is an increasingly important driving force for the development of the horticultural sector and agricultural economic growth in the Republic of Moldova due to their high added value. Traditionally, berries were grown on small plots in private gardens for personal use and only a small amount was grown for sale. Due to the increase in the

demand for berries on the domestic market, since 2012, the production areas of berries in Moldova has quadrupled, reaching 4,000 hectares in 2019, as compared with 1,000 hectares in 2010. The berry production in 2020 has reached about 16,000 metric tonnes. Although the berries can be sold as a fresh finished product, they can be processed as freshly squeezed blackberry juice, raspberry and chokeberry juice, blackberry wine, sublimated berry candies, frozen berries and fruit rolls, all of which have great potential for success in both the domestic and export markets.

A general advantage of Moldovan berries is that the harvest starts a few weeks earlier than in competing countries, such as Poland. In addition, Moldovan raspberries taste sweeter and have a higher sugar concentration. The productivity of berry crops in Moldova is lower than in neighbouring countries, with most farmers being small farmers with limited access to machinery, irrigation systems and fertilizers. The vast majority of farmers do not plant approved berry cultivars (certified and approved) that are in higher demand.

Domestic berry products could be more competitive internationally by expanding the range of species and cultivars, implementing progressive technologies in the field of planting material production, founding and maintaining industrial plantations, harvesting, transporting, post-harvest storage and agricultural marketing.

The most cultivated berries in the Republic of Moldova are strawberry, raspberry, black and red currant. Measures are being taken to expand the areas with goji and blackberries.

The purpose of scientific investigations was to assess the agroeconomic value of *Rubus loganobaccus: 'Lincoln Logan', 'Tayberry Buckingham', 'Tayberry Medana'* under the conditions of the Republic of Moldova according to fruit quality indices, amounts of antioxidants and value as animal feed, and also evaluating the potential of using the floricanes pruned after harvest as energy biomass.

MATERIALS AND METHODS

The *Rubus loganobaccus* cultivars 'Lincoln Logan', 'Tayberry Buckingham', 'Tayberry Medana' (Photo 1) served as the subjects of study and were cultivated in experimental plot of the "Alexandru Ciubotaru" National Botanical Garden (Institute) Chişinău, Republic of Moldova, N 46°97′32.0″ latitude and E 28°88′77.4″ longitude. The cultivars represented hybrid berry cultivars bred in the USA 'Lincoln Logan', in Scotland 'Tayberry Buckingham', 'Tayberry Medana', which we received as cuttings by exchange of vegetative material from National Clonal Germplasm Repository Corvallis, Oregon, USA and from *In Vitro* Culture Laboratory, Fruit Research Station Cluj-Napoca, Romania.

The experiment started in the spring of 2016. The trial included blackberries as well as hybrid berries. The planting of plantlets and the maintenance of the plants were carried out according to the agrotechnical procedures described in the previous works [12].

The plant growth, development and productivity were assessed according to methodical indications accepted by NBGI.

Photo 1. *Rubus loganobaccus* experimental plot
Source: Original.

Fresh fruits were collected from each cultivar, weighed and prepared for investigation. The concentration of sugar and vitamin C in fruits was determined in accordance with standard laboratory procedures [19].

The leaves for the determination of phytochemical compounds for medicinal purposes were taken from primocanes. The 1,1-diphenyl-2-picrylhydrazyl radical (DPPH),

which is a stable one, was used for the determination of free radical-scavenging activity of the extracts. The IC_{50} value was calculated graphically and it denoted the sample concentration, which was required to collect 50% of DPPH free radicals [4].

For biochemical analyses and fodder value, leaf samples were collected from both primocanes and floricanes, dried in a forced air oven at 60 °C, milled in a beater mill equipped with a sieve with diameter of holes of 1 mm and some assessments of the main parameters, such as crude protein (CP), crude fibre (CF), ash, acid detergent fibre (ADF), neutral detergent fibre (NDF), acid detergent lignin (ADL) and total soluble sugars (TSS), have been determined by near infrared spectroscopy (NIRS) technique using PERTEN DA 7200 NIR Analyzer. The concentration of hemicellulose (HC) and cellulose (Cel), the digestible energy (DE), the metabolizable energy (ME), the net energy for lactation (NEl) and the relative feed value (RFV) were calculated according to standard procedures. The carbon content of the substrates was obtained using an empirical equation according to [1]. The physical properties of energy dry biomass from pruning *Rubus loganobaccus* floricanes were determined according to the standards: the moisture content of the plant material was determined by SM EN ISO 18134 in an automatic hot air oven MEMMERT100-800; the content of ash was determined at 550 ºC in a muffle furnace HT40AL according to SM EN ISO 18122; the automatic calorimeter LAGET MS-10A with accessories was used for the determination of the calorific value, according to SM EN ISO 18125. To determine the cell wall components in the dry mass of floricanes, the amounts of neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were assessed using the PERTEN DA 7200 NIR Analyzer. The amount of cellulose was calculated as ADF minus ADL and hemicelluloses – NDF minus ADF. The Theoretical Ethanol Potential (TEP) was calculated according to the equations of Goff et al., 2010 based on conversion of hexose (H) and pentose (P):

$$H = [\%Cel+(\%HC \times 0.07)]x\ 172.82$$

$$P = [\%HC \times 0.93] \times 176.87$$

$$TEP = [H + P] \times 4.17$$

Data were expressed as the mean of three replicates and standard error (SE). The statistical significance ($P<0.05$) was evaluated by the Student's test. AII analyses were performed using GraphPad Prism; version 6.01, 2012.

RESULTS AND DISCUSSIONS

Analyzing the results of the assessment of morfo-biological peculiarities under the conditions of the Republic of Moldova, it can be noted that ***Rubus loganobaccus 'Lincoln Logan'*** develop cilindrical canes, without spikes; imparipinnate compound leaves, 5-foliate, linear hair-like stipels; canaliculated rachis, slightly tomentose, leaflets – wide elliptical to subround, subsessile to sessile, irregular double serrated, lower leaflets prone to lobbing, with cordate or rounded base, obtuse tip. The surface of the leaflets is obviously embossed; the adaxial side soft glabrescent, abaxial – slightly tomentose, mostly with ribs; terminal leaflet 10.5x11.5 cm, lateral leaflets 9.5x10.5 cm; the leaflets partially overlap. Cylindrical floricanes with ternate leaves, stipelate; few-flowered inflorescence, corymbated, leafy; erect pedicels, slightly tomentose; sepals (5-7) narrow elliptical, green tomentose, white-edged.

Photo 2. Lincoln Logan with fruits
Source: Original.

When flowering, the flowers are placed horizontally, having 5-7 white petals of an elliptical shape, (0.5-0.8 cm) nail-shaped; flowers 2.5-2.8 cm in diameter, stamens shorter than stigmas, pubescent ovary.

An average floricane produces 65 fruits. The fruits are large (5-6 g), red, elongated, representing a cluster of big drupelets, located close together and attached to the receptacle. The average weight of the fruit is 6.20 g, of which 0.30 g is the weight of the seeds. The wood dry matter of the floricanes is 358.2 g and – of leaves is 629.7 g.

Rubus loganobaccus **'Tayberry Buckingham'** grows curbed canes, glaucescent, without spikes; the leaves are pinnate, 3-5 foliate, linear hair-like stipels; deep canaliculated rachis, soft-glabrescent, without spikes, ovated leaflets, green on both sides, the adaxial side glabrescent, abaxial – pubescent, on the edges imperfect crenate (the terminal macro-leaflet wide ovate – to rhomboidal (6 x 7.5 cm), petiolated, lateral ones subsessile, obtuse tip, rounded base; cylindrical floricanes, soft-pubescent; elongated inflorescence, leafy, with a soft-pubescent axe, without spikes, few-flowered; pedicellate flowers, thin pedicels, with short soft hair, ternate in the leaf axilla; ovate-lanceolated sepals, acuminated, soft hairy, whitish on edges, reflect when flowering; petals (7 x 15 mm), wide ovate to wide elliptical, white, unguicular with rounded tip; subequal stamens with stigma; white anthers; glabrescent ovary; ternate leaves with lanceolate stipels (Photo 3).

Photo 3. Tayberry Buckingham with flowers
Source: Original.

The fruit is larger than that of raspberry, at maturity cherry-red, sweet-sour, very fragrant, sums up the qualities of blackberry and raspberry, containing an increased amount of pectin, soluble fibre, antioxidants and other biologically active substances which provide many health benefits (Photo 4).

The average weight of a fruit is 5.33g, of which 0.22g is the weight of the seeds. An average floricane produces 70 fruits.

The wood dry matter of the floricanes is 605.4 g and the dry matter of leaves is 291.1 g per plant.

Photo 4. Tayberry Buckingham with fruits
Source: Original.

Rubus loganobaccus **'Tayberry Medana'** under the conditions of the Republic of Moldova is characterized by cylindrical canes, straight spikes; linear-narrow stipels; imparipinnate compound leaves, 5-foliate; canaliculated rachis, short and scattered, pubescent with straight, cylindrical spines; short-petiolate ovate leaflets, on the adaxial side glabrescent, on the abaxial side slightly tomentose, on the edges imperfectly biserrate; the terminal leaflet 5.5-6 cm long, petiolate cordate. The leaves of the floricanes are ternate; the inflorescence – few-flowered corymb; the pedicels long, slightly tomentose, with fine spines, slightly falcate; sepals 5, triangular, long acuminate, with white-tomentose indument, after flowering deflect; petals 5-7, white, wide-elliptical to subround; stamens do not overcome stigmas; pubescent ovary (Photo 5).

Photo 5. Tayberry Medana with flower
Source: Original.

The average weight of a fruit is 4.37 g, of which 0.15g is the weight of the seeds. An average floricane produces 75 fruits.

The wood dry matter of the floricanes of a plant is 826.63 g per plant. The dry matter of the leaves is 424.8 g per plant.

Photo 6. Tayberry Medana with fruits
Source: Original.

Table 1. Comparative fruit and dry matter production by variety of ***Rubus loganobaccus***

Variety	Average weight of a fruit, g/fruit	of which, average weight of seeds, g/fruit	Average number of fruits per floricane, No./ Floricane	Average weight of fruits per floricane, g/Floricane	Average dry matter,	
					Canes after harvest, g/plant	Leaves, g/plant
Lincoln Logan	6.20	0.30	65	403	358.2	629.7
Tayberry Buckingham	5.33	0.22	70	373.1	605.4	291.1
Tayberry Medana	4.53	0.15	75	339.75	826.63	424.8

Source: Own determination.

Table 1 shows that Lincoln Logan produces 403 g fruits per floricane, being the most productive variety. On the 2nd position is Tayberry Buckingham which produces 373.1 g fruits in average per floricane, and finally on the 3rd position comes Tayberry Medana with only 339.75 g fruits per floricane.

Regarding dry matter of the canes after harvest, the highest amount is produced by Tayberry Medana, followed by Tayberry Buckingham and on the last position is Lincoln Logan.

The highest average dry matter in leaves per plant is carried out by Lincoln Logan, then comes Tayberry Medana and finally Lincoln Logan is ranked the 3rd (Table 1).

The composition of fruits largely determines their sensory properties, their nutritional value, and hence, consumer preference and the final profit for fruit growers. Among other compounds, vitamins and carbohydrates are one of the major determinants of the fleshy fruit quality. Vitamin C, also known as L-ascorbic acid, is a water-soluble vitamin that is naturally present in some foods, added to others, and available as a dietary supplement, it plays an important role in the normal functioning of the immune system, in controlling infections and healing wounds, and is a powerful antioxidant that can neutralize harmful free radicals. Humans, unlike most animals, are unable to synthesize vitamin C endogenously, so it is an essential dietary component [5, 11].

The results regarding the concentration of vitamin C and soluble sugar in *Rubus loganobaccus* fruits are presented in Figure 1 and 2. It was found that the content of vitamin C in *Rubus loganobaccus* fruits ranged from 21.1 mg/100g in *'Tayberry Medana'* to 26.2

mg/100 g in *'Tayberry Buckingham'* (Figure 1).

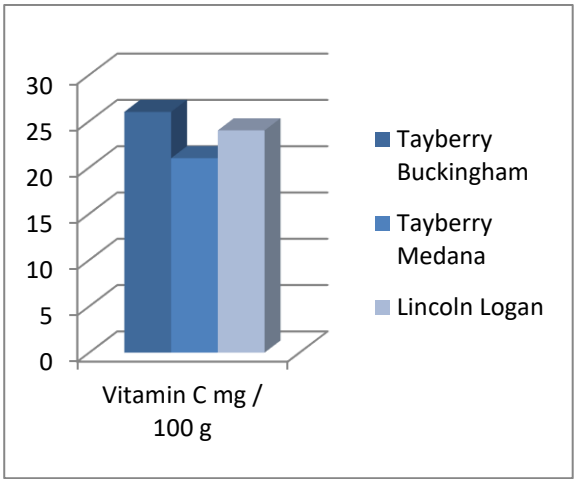

Fig. 1. The vitamin C content of *Rubus loganobaccus* fruits, mg/ 100g
Source: Original graphic based on the data from Pantelidis et al.(2007).

The soluble sugar concentration in fruit dry matter varied from 9.6% in *'Tayberry Buckingham'* to 11.8 % *'Tayberry Medana'* [14]. (Figure 2).

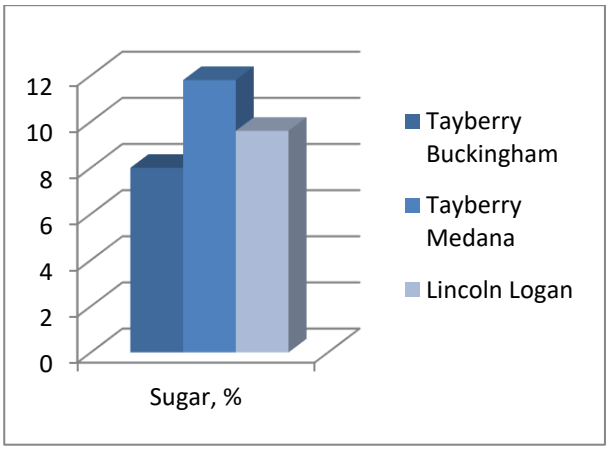

Fig. 2. The sugar content of *Rubus loganobaccus* fruits, %
Source: Original graphic based on the data from Pantelidis et al. (2007).

Flavonoids, phenolic acids, tannins and stilbenes are the main categories of phenolic compounds found in the berries. Antioxidants can exert large spectra of biological and physiological functions, including anti-allergic, anti-atherogenic, anti-inflammatory, antimicrobial, antioxidant, anti-thrombotic, cardioprotective effects. In the specialized literature, it has been mentioned that DPPH is a stable free radical and accepts an electron or hydrogen radical to become a stable diamagnetic molecule. A commonly used parameter to measure the antioxidant activity is the IC_{50}, which stands for concentration of antioxidant needed to decrease the initial DPPH concentration by 50%. The higher antioxidant power has the extract, the lower value IC_{50} have. The results on DPPH radical scavenging of *Rubus loganobaccus* leaf extracts are shown in Figure 3.

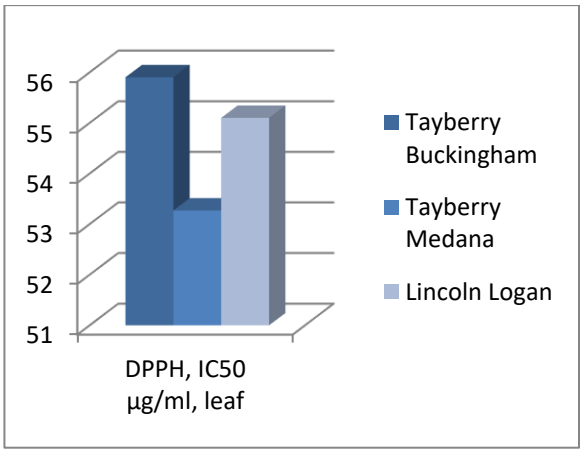

Fig. 3. The antioxidant activity of *Rubus loganobaccus* leaf extracts, DPPH, IC_{50} µg/ml
Source: Original graphic.

In general, in all assays, the leaf extracts of studied cultivars *of Rubus loganobaccus* showed higher values of antioxidant activity. It was determined that, the leaf extracts of *Rubus loganobaccus* 'Tayberry Medana' showed a higher level of free-radical sequestering.
The industrial plantations and the anti-erosion protection belts of species of the genus Rubus can serve as habitat and food source for various species of animals and birds, both in the growing season and in the winter-spring dormancy period; the leaves have a higher feed value for animals.
The results of the research on the biochemical composition and economic value of the leaves of the investigated *Rubus loganobaccus* cultivars are shown in Table 2.
We have found that *Rubus loganobaccus* leaves are characterized by higher crude protein content and a lower structural carbohydrate and lignin concentration as compared with the traditional forage crop

Trifolium pratense. This has had a positive effect on the nutritional value and the supply of metabolizable energy and net energy for lactation of the feed for livestock. The leaves of 'Tayberry Buckingham' and ′Tayberry Medana′ cultivars as fodder have a very low content of ADF, cellulose, hemicellulose and lignin and a high supply of crude protein, metabolizable energy and net energy for lactation, which would allow their use as feed for livestock [15]. The esteemed biochemical indices of *Rubus loganobaccus* leaves have a favorable ratio of C/N = 17-19, thus it can be used as organic fertilizer in the hybrid berry plantations.

Table 2. The biochemical composition and fodder value of the leaves of studied *Rubus loganobaccus cultivars*

Indices	*Rubus loganobaccus*			*Trifolium pratense*
	Lincoln Logan	Tayberry Buckingham	Tayberry Medana	
Crude protein, g/kg DM	152	181	187	169
Ash, g/kg DM	88	97	93	89
Acid detergent fibre, g/kg DM ,	136	96	81	252
Neutral detergent fibre, g/kg DM	263	231	22	422
Acid detergent lignin, g/kg DM	11	8	2	31
Total soluble sugars, g/kg DM	201	228	229	222
Cellulose, g/kg DM	125	88	79	221
Hemicellulose, g/kg DM	127	135	139	170
Digestible dry matter, g/kg DM	814	888	879	811
Digestible organic matter, g/kg DM	655	732	732	763
Relative feed value	277	328	349	153
Digestible energy, MJ/ kg	15.15	15.71	15.91	13.52
Metabolizable energy, MJ/ kg	12.44	12.90	13.07	11.10
Net energy for lactation, MJ/ kg	8.45	8.91	9.08	7.12

Source: Own determination.

Several studies have evaluated the fodder potential of *Rubus* species. According to Drożdż, *In vitro organic matter digestibility* of the leaves of *Rubus* sp. during the growing season decrease from 69.2% in May to 48.3% in November [6]. White, mentioned that senescent leaves of the woody biennial blackberry contained 2.14 % nitrogen, 75.5 % acid detergent soluble material, 5.3 % lignin, 19.2 % cellulose [18]. Grace, reported 12.46% crude protein concentration in fodder from *Rubus* spp. [8]. Filley's laboratory tests for nutritive value mentioned that Himalaya blackberry *Rubus armeniacus* had a content of 15-16% crude protein, 62-64% TDN, 0.5-0.67 %Ca, 0.18-0.26% P, but grass hay and alfalfa hay 8-22% CP, 51-57%TDN [7], respectively. Ryu, in 2013, established that forage qualities of leave from the mutant lines of *Rubus fructicosus* were: 5.86 % crude fat, 13.88 % crude fiber, 5.77% crude ash, 16.61% crude protein, 26.04% NDF, 15.51 % ADF, 76.65 %TDN and RFV=298, but forage qualities of stems 1.68 % crude fat, 42.57 % crude fiber, 3.48% crude ash, 7.39% crude protein, 58.80% NDF, 49.18 % ADF, 50.05%TDN and RFV=82.31, respectively [15].

Horrell, remarked that the foliage of *Rubus argutus* and *Rubus trivialis* contained 7.9- 9 % CP and of *Rubus armeniacus* 8.09-8.31% crude protein [10].

Ever year, growers burn raspberry stalks after pruning bushes in order to limit diseases that could contribute to the reduction of crops or plantation diseases. Therefore, the best solution may be to promote the use of waste biomass for energy production in order to prevent competitiveness of both sectors, therefore the use of raspberry stems for energy purposes could be a profitable solution for the renewable energy market [16].

The production of energy from vegetable biomass constitutes an important component, initially making use of the already existing forest, agricultural and agro-industrial residues and subsequently giving more importance to the production of biomass for energy purposes. Agricultural residues such as lignocellulosic biomass present extensive possibilities for research and use in the production of renewable energy and as a raw material for biorefineries that can be used in various applications and in obtaining other chemicals important to the national economy. Analyzing the quality of pruned wood biomass

of *Rubus loganobaccus*, Table 3, we could mention that the ash content and calorific value are optimal; the concentrations of structural carbohydrates and acid detergent lignin in *Rubus loganobaccus* stem substrate are much higher in comparison with *Malus domestica* pruning residue substrates.

The estimated content of fermentable sugars in *Rubus loganobaccus* stems: 86.89 g/kg pentoses and 41.68 g/kg hexoses, but in *Malus domestica* pruning residues – 78.17 g/kg and 36.02 g/kg, respectively.

The esteemed theoretical ethanol yield from structural carbohydrates averaged 557 L/t in *Rubus loganobaccus* substrate, as compared to 476 L/t in *Malus domestica* pruning residue substrates.

Table 3. Some energy properties, the cell wall composition and theoretical ethanol potential of pruned wood biomass from *Rubus loganobaccus*

Indices	*Rubus loganobaccus*	*Malus domestica*
Ash content of biomass, %	3.5	4.7
Calorific value, MJ/kg	18.5	18.3
Acid detergent fibre, g/kg	592	547
Neutral detergent fibre, g/kg	847	760
Acid detergent lignin, g/kg	111	92
Cellulose, g/kg	485	437
Hemicellulose, g/kg	254	219
Hexose sugars, g/kg	86.89	78.17
Pentose sugars, g/kg	41.68	36.02
Theoretical ethanol potential, L/t	557	476

Source: Own determination.

Some authors mentioned various findings about the pruning residues. White, stated that the blackberry canes contained 0.44 % nitrogen, 28.5 % acid detergent soluble material, 19.4 % lignin, 52.1 % cellulose [18].

According to Mustelier, in Latvia, *Rubus ulmifolius* pruned canes contained 50.71 % moisture, 3.4 % ash, 74.99 % volatile matter, 21.57 % fixed carbon, 17.82 MJ/kg gross calorific value, the quality indices of produced pellets were 4.14 % moisture, 2.71 % ash, 16.40 MJ/kg gross calorific value, 1252.7 kg/m^3 density and 98.50% durability [13].

Gudîma, reported that the calorific value of the biomass resulted from pruning apples trees was 18.98 MJ/kg and from technical varieties of vine canes – 18.34 MJ/kg [9]. Słupska, noted that briquettes obtained from raspberry stalks achieved satisfactory parameters to be used as an alternative source for the production of energy, the average heat of combustion of the produced briquettes was 17.3 MJ/·kg [16].

CONCLUSIONS

As a result of scientific investigations, it has been established that *Rubus loganobaccus* cultivars 'Lincoln Logan', 'Tayberry Buckingham', 'Tayberry Medana' the can be used to create industrial plantations for the production of berries, but also for the foundation of agroforestry protection strips.

The leaves have antioxidant potential and can be used in the production of herbs and in the pharmaceutical industry. For medicinal purposes, it is recommended to collect the leaves from the primocanes.

If planted in protection belts, these cultivars can be recommended for the nutrition of wild animals and the increase of the hunting fund.

Floricanes are recommended for use as energy biomass for the production of various types of biofuels as renewable energy sources.

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