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THE EVALUATION OF THE BIOMASS QUALITY OF CARDOON, *Cynara carduncululus*, AND PROSPECTS OF ITS USE IN MOLDOVA

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Abstract

Asteraceae is one of the largest families of flowering plants, which are the most promising from economic point of view. We investigated some biological peculiarities and the quality of the biomass of the introduced perennial species Cynara carduncululus var. altilis in the National Botanical Garden (Institute), Chişinău. Research data demonstrated that cardoon, Cynara carduncululus, in the second and next growing seasons, was characterized by intensive growth and development rate that allowed obtaining up to 44-71 t/ha fresh mass and 10-14 t/ha dry matter. It was established that the concentration of nutrients in the prepared silage was 12.5% protein, 28.0% cellulose, 23.0% hemicellulose, 2.6% lignin, 8.4% ash; the dry matter digestibility was 72.3%. The biochemical methane production potential of Cynara carduncululus silage substrate reached 348 l/kg organic matter. The dry biomass, after harvesting the seeds, can be used to produce solid biofuel. The specific density of the briquettes reached 918 kg/m^3, with 19.0 MJ/kg gross calorific value, the ash content in briquettes was 2.8%.
We consider that Cynara carduncululus var. altilis is an excellent source of nectar and pollen for honeybees, and its biomass may be valuable fodder and feedstock for renewable energy production.

Key words: *biological peculiarities, biomethane, Cynara carduncululus, fodder value of silage, physical and mechanical characteristics of dry biomass.*

INTRODUCTION

Asteraceae or *Compositae* is one the largest families of flowering plants, consists of 1911 accepted plant genera and 32913 species. In addition to its large size, the family has a great diversity in growth form, ranging from annual and perennial herbs, dwarf shrubs, shrubs, trees, climbers, succulents, aquatic plants, rosette plants, cushion plants, ericoid, prostrate, grass-like and spine scent. From a human perspective, it is highly relevant because it includes economical, culinary, medical plants as well as numerous ornamentals, but also a great number of weedy representatives.

The Plant List (2013) includes 44 named species from the genus *Cynara*, subfamily *Tubuliflorae*, family *Asteraceae*, 11 of which are accepted species names. Since ancient time, *Cynara* species have been used in traditional medicine for their recognized therapeutic effects: hepatoprotective, anticarcinogenic, antioxidative, antibacterial, diuretic, anticholesterol and antihyperglycemic. *Cynara carduncululus* is an accepted species, native to the Mediterranean region, the Middle East, north-western Africa and the Canary Islands, and has been introduced and has spread in many temperate regions of the world. Recent studies regarding the classification of the genus *Cynara* have sparked debate, on the basis of the study of morphology and phytogeography, it was concluded that wild cardoon is the ancestor of the cultivated globe artichoke and cardoon. The Plant List, 2013, recognized a single species and these plants as varieties: globe artichoke *Cynara carduncululus* var. *scolymus* (L.) Fiori, the wild cardoon *Cynara carduncululus* var. *sylvestris* (Lam.) (L.) Fiori and the leafy cultivated cardoon *Cynara carduncululus* var. *altilis* DC.

Cynara carduncululus is a perennial C_3 plant species, with diploid chromosome number (2n = 2x = 34) and annual growth cycle, usually growing 75-150 cm tall, but occasionally reaching up to 2 m in height. The root system is very developed, consists of the main taproot can grow to the depth of 2 m with variable number of secondary fibrous roots as well as of a rhizome, more or less expanded, containing buds, both single and gathered in groups. The stem is erect and branched in its upper part, rigid, longitudinally strongly ribbed, greyish-green coloured and covered in a cottony down, has a diameter of about 2-4 cm. The leaves form a basal rosette that can be very large - up to 120 cm long and 30 cm wide. Alternate leaves, green-greyish coloured and more or less incised, are present on the main and other order stems. Leaf shape and size depend on the genotype and on the growth stage. The inflorescence occurs singly at the top of a branch on a thick stalk, 1-6 cm long. The flower heads are almost round in shape and grow to be 4-5 cm across. Each head has several hundreds of florets, which are hermaphrodite, tubular and fitted in a well-developed receptacle. At the full anthesis, the florets have very long stigmata (6-7 cm), usually blue-violet coloured. The flowering is centripetal and proterandric. Pollination is entomophilous and reproduction is mainly by cross-fertilization, because of the previously mentioned proterandry mechanism (stigmatic surfaces mature two or three days after pollen shedding). The fruit is a tetragon-shaped or flattened achene, 6-8 mm long, dark-coloured or greyish, uniform or mottled. At physiological ripening of achenes (50-60 days after pollination), heads can reach a weight ranging from 10 to 120 g. Achenes have a prominent pappus with large feathery hairs (25-40 mm long) that contributes to the wind dispersion.

This species reproduces by seed, asexually from pieces of cut root, and also re-grows each year from a long-lived underground crown and taproot. It is well-adapted to the xerothermic conditions of southern Europe, is quite tolerant to salinity and intolerant to prolonged waterlogging, and prefers slightly acidic soils to the alkaline pH 6.5 - 8.2, clay and heavy soils are not recommended. The plant is quite sensitive to frost in the seedling stage but established plants are more frost tolerant.

The cardoon is a very important perennial herbaceous plant and it has been cultivated for many years as a traditional food source, fresh flowers are used as a vegetable rennet for milk clotting, in order to manufacture valuable regional cheeses in some parts of the southern Europe. *Cynara cardunculus*, characterized by large yields, offers a wide spectrum of economic utilizations. The leaves are rich in polyphenols, have strong antioxidant properties and have been used for medicinal and cosmetics purposes. The underground part of the plant has been used as a source of inulin for the pharmaceutical industry, functional and dietary products, biologically active and food supplements; the aerial biomass parts, as green or ensiled forage, have been used as raw material for biorefineries and for the production of renewable energy and building elements. Achenes provide a food source for birds, can be used for oil production, for human consumption, and after oil extraction, the cake could be used for animal feed, for biodiesel production.

According to Cajarville et al. (1999) green forage had high nutritive value, low levels of fibre and lignin, and very high digestibility for organic matter (86%), while ensilage is the most appropriate way for preserving it for long periods.

As regards the yield, Raccuia & Melilli (2004) found average root yield for globe artichoke and cardoon genotypes of 9.8 t/ha with average inulin yield of 3 t/ha.

Cardoon is a non-wood plant, the stalks as well as the hairs and pappi in capitula for paper production, can produce well delignified pulps with high yields, low rejects and very good strength properties (Gominho et al., 2001).

In the Republic of Moldova, only globe artichoke *Cynara cardunculus* var. *scolymus* has been introduced and studied to determine its features as a medicinal plant (Calalb & Bodrug, 2009).

In the last decades, the European policies of energy, agriculture and environment have had a growing interest for biomass crops and for *Cynara cardunculus* in particular, and in recent years, it has been intensively researched as suitable feedstock for solid (pellets, briquettes, chips), liquid (biodiesel) and gaseous (biomethane, syngas) biofuel in many scientific centres and universities (Abelha et al., 2013; Dahl & Obernberger, 2004; Fernandez et al., 2006; Grammelis et al., 2008; Ierna & Mauromicale, 2010; Ottaiano et al., 2017; Pesce et al., 2017; Toscano et al., 2016).

The objective of this research was to evaluate some biological peculiarities and the quality of the biomass of the introduced perennial species cardoon, *Cynara cardunculus* var. *altilis*, and the possibility to use aboveground biomass as fodder for animals and multi-purpose feedstock for renewable energy production in the Republic of Moldova.

MATERIALS AND METHODS

The introduced perennial species cardoon, *Cynara cardunculus* var. *altilis* which was cultivated in 2016-2018, in the experimental plot of the National Botanical Garden (Institute) served as subject of the research, and the traditional crop sunflower, *Helianthus annuus*, was used as control.

The green mass of *Cynara cardunculus* was mowed in the first year in the middle of September, and in the second and in the third years of growth - in early flowering stage (late June - early July), but the control *Helianthus annuus* - in the full flowering stage (end of July). The green mass was shredded and compressed in well-sealed containers. After 45 days, the containers were opened, and the organoleptic assessment and biochemical composition of the silage was determined in accordance with the Moldavian standard SM 108. Some assessments of the main biochemical parameters: protein, ash, acid detergent fibre (ADF), neutral detergent fibre (NDF) and acid detergent lignin (ADL), total soluble sugars (TSS), digestible dry matter (DDM), digestible organic matter (DOM) have been determined by near infrared spectroscopy (NIRS) technique PERTEN DA 7200. The concentration of hemicelluloses (HC) was approximated from subtraction of the ADF from the NDF, while the concentration of cellulose (Cel) of each sample was estimated by subtracting the ADL from the ADF.

The carbon content of the substrates was obtained from data on volatile solids, using an empirical equation reported by (Badger et al., 1979).

The biochemical biogas potential (Yb) and methane potential (Ym) were calculated according to the equations of Dandikas et al. (2014) based on the chemical compounds - acid detergent lignin (ADL) and hemicellulose (HC) values:

- biogas Yb = 727 + 0.25 HC - 3.93 ADL;
- methane Ym = 371 + 0.13 HC - 2.00 ADL.

The stems of cardoon and sunflower were mowed manually in the first days of September, after harvesting the seeds. The dry biomass was chopped and milled in a beater mill equipped with a sieve with diameter of openings of 10 mm. The following scientific research on biomass for the production of solid biofuel was carried out: the moisture content of the plant material was determined by CEN/TS 15414 in an automatic hot air oven MEMMERT100-800; the content of ash was determined at 550ºC in a muffle furnace HT40AL according to CEN/TS 15403; automatic calorimeter LAGET MS-10A, with accessories, was used for the determination of the calorific value, according to CEN/TS 15400; the particle size distribution was determined using standard sieves; the cylindrical containers were used for the determination of the bulk density; the briquetting was carried out by using the equipment developed in the Institute of Agricultural Technique "Mecagro"; the mean compressed (specific) density of briquettes was determined immediately after removal from the mould, as a ratio of measured mass over calculated volume.

RESULTS AND DISCUSSIONS

We could mention that, under the conditions of the Republic of Moldova, in the year when the seeds were sown in mid-April, the mass emergence of the seedlings of cardoon occurred in 12-19 days after sowing. Thus, this plant requires, for germination, more moisture and higher soil temperature, with 2-4°C, as compared with sunflower. During 20-25 days, the underground part developed more intensively, in the epigeic part, 3-5 leaves emerged, then the growth and development rate intensified. In the middle of September, the cardoon showed a "rosette", since its stalk was very short (4-5 cm) and it had 30-35 leaves, alternate and pinnate. The leaves reached a length of more than 65 cm and the width was over 25 cm, they were characterized by a well-developed petiole and a large midrib. It was dark green coloured or ashen on the top of the leaf and greyish on the bottom of the leaf, because of its thick hairiness. *Cynara cardunculus* var. *altilis* did not flower in their first year, rather their energy was focused on the development of its deep taproot. The plant's aboveground parts in autumn, when the temperatures were below -5ºC, died off, but the underground part overwintered. Long periods without snow or thaws are typical in winter, frequent in our region, which negatively influence the overwintering of *Cynara cardunculus* annual plants.

The green mass yield in the first year, harvested in mid-September, reached 3.40 kg/ m^2. The dry matter content of harvested biomass was 14.8%, its chemical composition 23.6% protein, 9.2% ash and structural carbohydrates 32.6% NDF, 18.3% ADF, 1.6% ADL, 22.0% total soluble sugars.

The digestibility of dry matter was very high - 96%. Thus, *Cynara cardunculus* green mass can be fed to animals together with coarse fodder, such as grass hay and cereal straw.

Table 1. Some agro-biological peculiarities of *Cynara cardunculus* plants in second growing season

Indices	*Helianthus annuus*	*Cynara cardunculus*
Sowing	15.04	-
Emergence of plantlets	05.05	10.04
Inflorescence initiation period	10.07-20.07	16.06-28.07
Flowering period	22.07-27.07	30.06-31.07
Seed ripening	14.09	31.08
Plant height, cm	178	201
The total yield :		
- fresh mass, kg/m^2	5.03	7.12
- dry matter, kg/ m^2	0.94	1.41
Leaves + heads in biomass, %	56.8	57.8

In our study, in the second growing year, has been established that after the winter plant development restarted, an apical bud appeared on the caule apex, there was an induction period, which depended on temperature and photoperiod, the leaf rosette, developed and spread in April, the stalk began to elongate in May. The main flower heads (capitula) appeared in June, and the period of flowering of other heads began in July, the seed ripening ended in August, accompanied by the progressive desiccation of the aboveground biomass, the stems became dry in September (Table 1). The green mass yield of *Cynara cardunculus* in the second year, harvested in early July, reached 7.10 kg/m^2, in the harvested areal biomass, there were 45% leaves, 42% stalks and 13% heads, but the productivity of *Helianthus annuus* was 5.03 kg/m^2 with 26% leaves, 43% stalks and 31% heads.

In the third growing season (2017-2018 y.) new regrowth occurred after the autumn rains, *Cynara cardunculus* plants sprouted in the end of September, the leaf rosette developed in October. The plants overwintered normally, but the harsh weather conditions from the spring of 2018, characterised by high temperatures and lack of precipitation, affected all the stages of ontogenetic development, as well as the growth and development rate of plants. We found out that plant development started much earlier that year, stem elongation in April-May, full blossom - in June, achenes reached ripeness in late July - early August, fully dry aerial biomass - in August. In the middle of June the plants were 125-135 cm tall, the green mass productivity was 4.4 kg/m^2 with 23% dry matter content.

Bolohan et al. (2013), investigating the crop yield of *Cynara cardunculus* plants under the climatic conditions of south-eastern Romania, have found that leaf fresh matter production of *Cynara cardunculus* plants, in the first growing season, ranged from 31483 to 41044 kg/ha or 5358-6195 kg/ha dry matter in the dependence of cultivars. Under the conditions Catania, Italy, the green mass productivity of *Cynara cardunculus* cv. 'Altilis 41', harvested in the growth stage of 8 capitula and seed ripening, late June, reached 19.1 t/ha dry mater, with 37.7% leaf, 27.7% stalk and 34.6% inflorescence material (Pesce et al., 2017).

Silage is one of the key components of the feed for herbivorous domestic animals, but in recent decades, it has also been used as feedstock for anaerobic digestion in biogas reactors. The main principles of silage preservation are a rapid achievement of a low pH by lactic acid fermentation and the maintenance of anoxic conditions. Lactic acid bacteria play a key role in ensuring the success of the ensiling process. They are capable of converting fermentable carbohydrates that are present in forage crops at a high rate to lactic acid and, to a lesser extent, acetic acid.

When opening the glass vessels with silage made from green mass of *Cynara cardunculus*, there was no gas or juice leakage from the preserved mass, but from the vessels with *Helianthus annuus* silage, carbon dioxide - a by-product of fermentation - was moderately eliminated. The silages obtained from

Asteraceae species were of agreeable colour and had specific aroma, the consistency was retained, in comparison with the initial green mass, without mould and mucus. During the organoleptic assessment, it was found that the colour of the *Cynara cardunculus* silage was homogeneous olive, with pleasant smell, similar to pickled vegetables but, in the *Helianthus annuus* silage, the stems were yellow and the leaves - dark green, its scent was similar to the smell of fresh coniferous wood.

The materials consolidated well and the fermentation was complete with similar acidic pH values 3.77-3.82. It has been determined that the amounts of organic acids, in the silages prepared from *Asteraceae* species, differed essentially. *Cynara cardunculus* silage was characterised by a very low content of organic acids (43.1 g/kg), in comparison with *Helianthus annuus* silage (76.4 g/kg). Most organic acids were in fixed form. In the silage from *Cynara cardunculus*, the content of fixed lactic acid reached 21.6 g/kg and free lactic acid - 12.6 g/kg DM. The butyric acid content was below the detected level in fixed form (1.4 g/kg DM) in the *Cynara cardunculus* silage (Table 2).

Table 2. The fermentation quality of the silages from *Cynara cardunculus* plants, second growing season

Indices	*Helianthus annuus*	*Cynara cardunculus*
pH index	3.82	3.77
Content of organic acids, g/kg	76.4	43.1
Free acetic acid, g/kg	9.3	4.0
Free butyric acid, g/kg	0.0	0.0
Free lactic acid, g/kg	20.3	12.6
Fixed acetic acid, g/kg	10.2	3.5
Fixed butyric acid, g/kg	0.1	1.4
Fixed lactic acid, g/kg	36.5	21.6
Total acetic acid, g/kg	19.5	7.5
Total butyric acid, g/kg	0.1	1.4
Total lactic acid, g/kg	56.8	34.2
Acetic acid, % of organic acids	24	18
Butyric acid, % of organic acids	1	3
Lactic acid, % of organic acids	75	79

The dry matter content in the studied silages was low - about 19.1-19.7%. It was determined that the biochemical composition of the silage dry matter varied depending on the species: raw protein 102-125 g/kg, raw cellulose 230-291 g/kg, ash 84-99 g/kg, structural carbohydrates: NDF 401-503 g/kg, ADF 252-306 g/kg, ADL 26-35 g/kg. In *Cynara cardunculus* silage, the amount of protein was high and acid detergent lignin (ADL) - low, the digestibility of nutrients was significantly higher, the concentrations of calcium and carotene were acceptable, but phosphorus - very low (Table 3).

Table 3. Biochemical composition and feed value of the silages from the studied *Asteraceae* species

Indices	*Helianthus annuus*	*Cynara cardunculus*
Raw protein, g/kg DM	102	125
Raw cellulose, g/kg DM	230	291
Ash, g/kg DM	99	84
Acid detergent fibre, g/kg DM	252	306
Neutral detergent fibre, g/kg DM	401	531
Acid detergent lignin, g/kg DM	35	26
Dry matter digestibility,%	68.2	72.3
Organic matter digestibility,%	61.4	68.3
Calcium, %	-	1.11
Phosphorus, %	-	0.18
Carotene, mg/kg	4.0	13.5

Some authors mentioned various findings about the quality of silage. According to Cajarville et al. (1999) the quality of the *Cynara cardunculus* silage varied depending on the wilting time: 15.0-21.8% dry matter, 832-836 g/kg organic matter, pH 4.03-4.28, lactic acid 91.2-167 g/kg, acetic acid 31.2-34.6 g/kg, butyric acid not detected, crude protein 133-136 g/kg, crude fibre 129-147 g/kg, neutral detergent fibre 240-281 g/kg, water soluble carbohydrates 140-159 g/kg.

Pesce et al. (2017) determined that *Cynara cardunculus* produced silage with 32.8-37.1% dry matter, had a pH level 3.3-4.1, contained 0.8-1.4% lactic acid, 1.0-1.9% acetic acid, 0.1-0.3% butyric acid, 12.8-14.6% protein, 2.0-2.8% fats, 5.3-8.5% ash, 72.6-44.7-48% NDF and 28.1-37.4% ADF, in dependence of the growing seasons.

The *Cynara cardunculus* silage, after 160 days of ensiling, from whole plants mowed in full bloom stage, was characterized by 20.6% dry matter, 8.79% ash, pH 4.13, 72.3 g/kg lactic acid, 21.5 g/kg acetic acid and 49.5 g/kg ethanol. However, the silage prepared from whole plants mowed in the seed ripening stage, contained 44.7% dry matter, 9.53% ash, pH 4.90, 8.6 g/kg lactic acid, 31.6 g/kg acetic acid and 0.7 g/kg ethanol (Ferrero et al., 2018).

The nutritive value and the fermentation characteristics of artichoke, *Cynara scolymus*, by-products were 150.1 g/kg crude protein, 524.1 g/kg NDF, 411.7 g/kg ADF, the highest matter digestibility at 96 h incubation *in vitro*:

786 g/kg DMD and 804 g/kg OMD (Sallam et al., 2018).

Fresh artichoke by-products are suitable for ensiling, with a pleasant smell, good silage characteristics, crude protein content 88 g/kg dry matter and fibre content 509 g/kg dry matter (Meneses et al., 2007)

According to the results obtained by Martinez-Teruel et al. (2007), the silage of the artichoke by-product had a fermentation of the acetic type, 44.9% organic matter digestibility, 53.0% *in vitro* disappearance of neutral detergent fibre.

Biorefining offers a way for combining feed and bioenergy production. Biomass based raw materials can be converted into the more valued energy forms using biochemical methods such as ethanol fermentation, methane fermentation and thermochemical methods such as pyrolysis and gasification.

The stability and productivity of anaerobic digestion is mostly influenced by the content of organic matter, its biochemical composition, biodegradability and ratio of carbon and nitrogen (C/N). The silages investigated in the present study revealed C/N ratios in a wide range, on average 26-30, which is regarded as optimal for methanogenesis.

Table 4. Biochemical methane potential of silage substrate from the studied *Asteraceae* species

Indices	*Helianthus annuus*	*Cynara cardunculus*
Organic matter, g/kg	901.00	916.00
Carbon,%	50.00	51.00
Nitrogen,%	1.63	2.00
Carbon/nitrogen	30	26
Lignin, g/kg	35	26
Cellulose, g/kg DM	217	280
Hemicellulose , g/kg DM	149	230
Biogas, l/kg ODM	626	681
Biomethane, l/kg ODM	320	348

It was determined that the substrate of *Cynara cardunculus* silage was characterised by a high content of organic matter, cellulose, hemicellulose and low content of lignin, as compared with *Helianthus annuus* silage. The estimation of biogas and methane yields, based on the concentration of acid detergent lignin and hemicellulose of *Cynara cardunculus* substrate, reached values of 681 l/kg and 348 l/kg, but in *Helianthus annuus* substrate - 626 l/kg and 320 l/kg, respectively (Table 4).

Pesce et al. (2017) found that in the substrate from *Cynara cardunculus* cv. 'Altilis 41', carbon and nitrogen ratio was 22-27 and the methane yield varied from 243 to 248 l/kg, the annual biomethane production ranging from 3647 to 4501 m^3/ha, depending on the growing seasons. Ferrero et al. (2018) determined that the biogas and methane production potential of *Cynara cardunculus* varied from 422 to 577 l/kg and from 209 to 293 l/kg, the production potential was affected by the stage of maturity and the conservation period.

The knowledge of the engineering properties of biomass, such as moisture content, ash content, particle size distribution, bulk and specific density, heating value, is important for the design and operation of processing facilities for handling, storage, transportation and conversion to solid fuels, heat and power. Our study showed that *Cynara cardunculus* milled chaffs, have the highest percentages of particles larger than 5 mm (41.2%), and the lowest values for the particles of 1-2 mm (16.1%), in comparison with *Helianthus annuus* chaffs (Table 3). This is probably an effect of the anatomical nature of *Cynara cardunculus*, the level of pith microstructures and sclerenchyma fibres in the bark, which influences the passage of particles through the sieve meshes and leads to a decrease in the bulk density of milled chaffs.

It was found that *Cynara cardunculus* biomass contained a higher amount of ash, which caused a decrease in the gross calorific value.

We could mention that the briquettes produced from *Asteraceae* species in our study were very solid and not cracking, their specific density reaching values of 907-918 kg/m^3. The bulk density of briquettes from *Cynara cardunculus* was 479 kg/m^3, but *Helianthus annuus* - 454 kg/m^3 (Table 5).

According to literature *Cynara* biomass showed good performance as feedstock for the production of heat and power. Fernández et al. (2006) mentioned that the highest and the lowest heating value of *Cynara cardunculus* whole biomass were 4083 and 3795 kcal/kg, respectively.

The results obtained by Grammelis et al. (2008) for cardoon dry biomass, harvested in Central Greece, were as follows: 7.9-8.2% moisture, 6.9-7.2% ash and higher calorific value 13.7-16.3 MJ/kg dry basis.

Table 5. Some physical and mechanical properties of biomass and briquettes from *Cynara carduncululus*

Indices	*Helianthus annuus*	*Cynara carduncululus*
Particle size distribution:		
<5mm	9.1	41.2
4-5mm	14.2	12.5
3-4 mm	20.9	14.4
2-3 mm	25.7	15.7
1-2 mm	17.7	8.5
1 mm	12.4	7.6
Biomass properties:		
moisture content, %	11.5	9.9
ash content,%	1.6	2.8
gross calorific value, MJ/kg	19.3	19.0
bulk density, kg/m3	118	107
Solid biofuel properties:		
specific density, kg/m^3	907	918
bulk density, kg/m^3	454	479

In Portugal, Abelha et al. (2013) reported, for 5-30 mm chips of the whole aboveground *Cynara* biomass, a bulk density of 125 kg/m^3 and a densification of biomass into durable compact pellets with bulk density that increased to about 500-600 kg/m^3. The aboveground cardoon biomass presented calorific values of 18-22 MJ/kg dry matter, depending on the plant fraction (Gominhoa et al., 2018). The results obtained by Toscano et al., 2016, for cardoon pellets were: 11.2% moisture, 6.3% ash, 20399 J/kg high heating value and 19247 J/kg lower heating value, 0.55% nitrogen, 0.12% chlorine and 0.65% sulphur content. Hăbăşescu, 2011, stated that the pellets from sunflower stems had net calorific value of 14.8 MJ/kg and the ash content was 3.78%, the pellets from corn stems were characterized by 14.2 MJ/kg and 5.14%, respectively, and wheat straw - by 14.3 MJ/kg and 6.25%, respectively. Dahl & Obernberger (2004), reported that the pellets from cardoon contained 17.4% ash and 1.1% nitrogen, with bulk density 561 kg/m^3 and gross calorific value 20.3 MJ/kg.

CONCLUSIONS

The preliminary studies carried out showed that:

1. *Cynara cardunculus*, in the second and next growing seasons, was characterized by intensive growth and development rate that allowed obtaining up to 44-71 t/ha fresh mass or 10-14 t/ha dry matter.
2. The *Cynara cardunculus* silage contained 12.5% protein, 28.0% cellulose, 23.0% hemicellulose, 2.6% lignin, 8.4% ash; the dry matter digestibility was 72.3%.
3. The biochemical methane production potential of *Cynara cardunculus* silage substrate reached 348 l/kg OM, but *Helianthus annuus* - 320 l/kg OM.
4. The specific density of the briquettes reached 918 kg/m^3, with 19.0 MJ/kg gross calorific value and the ash content 2.8%.

We consider that *Cynara cardunculus* is an excellent source of nectar and pollen for honeybees, and its biomass may be valuable feed for livestock and multi-purpose feedstock for the production of renewable energy.

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