Scientific Papers. Series D. Animal Science. Vol. LXIII, No. 1, 2020
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

THE BIOCHEMICAL COMPOSITION AND THE FEED VALUE OF GREEN MASS AND SILAGE FROM *Cynara cardunculus* AND *Helianthus tuberosus* IN THE REPUBLIC OF MOLDOVA

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Abstract

The objective of this research was to evaluate the quality of green mass and silage prepared from cardoon - Cynara cardunculus var. altilis and Jerusalem artichoke - Helianthus tuberosus cv. 'Solar' growing in the experimental field of NBGI, Chişinău, Republic of Moldova. Some assessments of the main biochemical parameters: crude protein (CP), ash, acid detergent fibre (ADF), neutral detergent fibre (NDF) and acid detergent lignin (ADL), total soluble sugars (TSS), digestible dry matter (DDM) have been determined by near infrared spectroscopy (NIRS), the sensorial characteristics of prepared silages – in accordance with the Moldavian standard SM 108, the concentration of hemicellulose (HC), cellulose (Cel), digestible energy (DE), metabolizable energy (ME), net energy for lactation (NEl) and relative feed value (RFV) were calculated according to standard procedures. It was determined that dry matter content in the harvested green mass varied from 19.8% in Cynara cardunculus to 28.9% in Helianthus tuberosus, its biochemical composition and feed value were: 9.4-12.0% CP, 6.0-7.1% ash, 30.2-40.0% ADF, 54.5-60.3% NDF, 3.1-5.1% ADL, 14.6-27.8% TSS, 27.1-34.9% Cel and 20.3-24.3% HC, 57.7-65.3% DDM, RFV = 89-111, 11.87-12.82 MJ/kg DE, 9.41-10.53 MJ/kg ME and 5.43-6.55 MJ/kg NEl. It was found that the prepared silages had pleasant smell, somehow similar to pickled vegetables, the colour of the cardoon silage was homogeneous olive, but Jerusalem artichoke silage contained dark-green leaves with brownish hues and yellow-green stems. The pH of the silage was 3.77-4.17, it contained 9.7-12.5% CP, 8.4-10.3% ash, 30.6-33.4% ADF, 49.6-53.1% NDF, 2.6-5.0% ADL, 19.2-28.0% Cel, 22.5-28.4% HC with feed value 62.9-65.1% DDM, RFV= 114-118, 12.39-12.78 MJ/kg DE, 10.17-10.49 MJ/kg ME and 6.19-6.51 MJ/kg NEl. The studied perennial Asteraceae species were characterized by high green mass productivity with optimal nutrient contents; good silage quality can be used as alternative feed for ruminant animals.

Key words*: biochemical composition, Cynara cardunculus, feed value, green mass, Helianthus tuberosus, silage.*

INTRODUCTION

The identification, mobilization and cultivation of new species, the use of a wider range of forage crops, providing a stable and balanced diet for farm animals, play an important role in the agricultural economy and food security (Marin et al., 2017).

Cardoon, *Cynara cardunculus* L.*, Asteraceae* family, native to the Mediterranean region, is a perennial C_3 plant species, usually growing 75-150 cm tall, but occasionally reaching up to 2 m in height. The root system is very well developed, consists of the main taproot, which can grow to the depth of 2 m, with variable number of secondary fibrous roots. 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, present on the main and other order stems. The flower heads are almost

round in shape and grow to be 4-5 cm across, usually blue-violet coloured. The fruit is a tetragon-shaped or flattened achene, dark-coloured. 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. *Cynara cardunculus*, characterized by large yields, offers a wide spectrum of economic uses: food source, raw material for pharmaceutical industry, for biorefineries and renewable energy production; the aerial parts of the plants

- as green or ensiled forage; fresh flowers are used as a vegetable rennet for milk clotting; achenes - to produce oil that can be used by humans, and cake could be used for animal feed (Ferndndez et al., 1996; Pesce et al., 2017; Gominho et al., 2018).

Jerusalem artichoke, otherwise known as topinambour, *Helianthus tuberosus* L., *Asteraceae* family, native to North America, was brought from France in 1605. It is herbaceous perennial C_4 photosynthetic pathway plant, with strong, vigorous stems, sometimes branched at the base, grows 2.5-3.0 m tall, its large leaves reach the length of 20 cm and are arranged on the opposite sides of the stem, alternately to one another. In the underground part, there are unevenly shaped tubers, round or elongated, with bumps, ranging in size between 2 and 10 cm, their color can vary from brown to white, red and even purple.

The analysis of literature sources have revealed that Jerusalem artichoke dry matter yield of aboveground parts ranges from 4 to 30 t/ha and tubers - from 4 to 15 t/ha, depending on the genotype, climatic conditions, soil type and plantation age. It is an economically important plant that can be useful in many ways, such as: functional food and bioactive ingredient source, sustainable feedstock for biorefineries and the production of renewable energy etc. (Duke, 1983; Kays and Nottingham 2008; Ţîţei et al., 2013; Heuzé et al., 2015; Johansson et al. 2016; Herrmann et al., 2016). Jerusalem artichoke has been used as a suitable livestock feed since the mid-1600s, has the potential to replace or be a substitute for other annual and perennial forages for ruminants. The substitution of alfalfa by up to 30% of Jerusalem artichoke foliage, in full bloom stage, did not affect the *in vitro* digestibility of the diet (Cosgrove et al., 2000; Fazaeli et al., 2009; Heuzé et al., 2015).

The melliferous potential of *Cynara scolymus* is 100-150 kg honey/ha, *Helianthus annus* and *Helianthus tuberosus* is 30-60 kg honey/ha (Ion et al., 2018).

The aim of the current study was to evaluate some agrobiological peculiarities and the quality of green mass and silage prepared from *Cynara cardunculus* var. *altilis* and *Helianthus tuberosus* grown under the conditions of the Republic of Moldova.

MATERIALS AND METHODS

The *Asteraceae* species: the cultivar 'Solar' of Jerusalem artichoke*, Helianthus tuberosus,* created in the National Botanical Garden (Institute), registered in 2014, in the Catalogue of Plant Varieties** and patented in 2016, by the State Agency on Intellectual Property (AGEPI) of the Republic of Moldova, patent nr. 205/31.05.2016*, and cardoon, *Cynara cardunculus* var. *altilis*, which were cultivated in the experimental plot of the National Botanical Garden (Institute), Chişinău, served as subjects of the research, and the traditional crop sunflower, *Helianthus annuus*, was used as control.

The green mass of *Cynara cardunculus* was mowed in early flowering stage (early July), *Helianthus tuberosus* - in budding stage (middle August)**,** but the control - *Helianthus annuus* - in the full flowering stage (end of July).

Green mass productivity was determined by weighing the yield obtained from a harvested area of 10 m^2, which was afterwards transformed per hectare.

The leaves/stems ratio was determined by separating the leaves, buds and flowers from the stem, weighing them separately and establishing the ratios for these quantities (leaves/stems). For ensiling, the green mass was shredded and compressed in well-sealed containers.

After 45 days, the containers were opened, and the sensorial and chemical characteristics of prepared silages were determined in accordance with standard laboratory procedures and Moldavian standard SM 108*** for forage quality analysis. Some assessments of the main biochemical parameters: crude protein (CP), ash, acid detergent fibre (ADF), neutral detergent fibre (NDF) and acid detergent lignin (ADL), total soluble sugars (TSS), digestible dry matter (DDM) have been determined by near infrared spectroscopy (NIRS) technique PERTEN DA 7200.

The concentration of hemicellulose (HC), cellulose (Cel), digestible energy (DE), metabolizable energy (ME), net energy for lactation (NEl) and relative feed value (RFV) were calculated according to standard procedures

RESULTS AND DISCUSSIONS

We could mention that, the studied *Asteraceae* species differed in the growth and development rate, ratio of stems to leaves, content of nutrients. Cardoon, *Cynara cardunculus* var. *altilis*, in the first growing season, developed rosettes with 30-35 dark green, pinnate leaves, in the underground part - deep taproot over 100 cm, the yield reached 3.40 kg/m^2 green mass or 0.50 kg/m^2 dry matter, its biochemical composition: 23.6% crude protein, 9.2% ash, 32.6% NDF, 18.3% ADF, 1.6% ADL, 22.0% TSS with 96% DMD. In the second year, after the winter, the development of cardoon plants restarted, an apical bud appeared on the stem apex, the leaf rosette developed and spread in April, the stalk began to elongate in May and flower heads appeared in June.

The Jerusalem artichoke, *Helianthus tuberosus*, in the first year of development, went through all the ontogenetic stages. In the second growing season, the plants started vegetating at the end of April, the fastest growth and development were observed at the end of May and in July.

Plant height, stem thickness and leaves/stems ratio have significant impact on the yield, but also affect the quality of the phytomass. Results regarding some bio-morphological characteristics of the studied *Asteraceae* species and the structure of the harvested phytomass are presented in Table 1. At the time of harvesting, plant height varied from 201 cm (*Cynara cardunculus*) to 326 cm (*Helianthus tuberosus*), stem thickness - from 24-36 mm (*Cynara cardunculus*) to 12-22 mm (*Helianthus tuberosus*), but the control, sunflower (*Helianthus annuus*) - 201 cm and 20-24 mm, respectively. The productivity of *Cynara cardunculus*, in the second year, was 7.12 kg/m^2 green mass or 1.41 kg/m^2 dry matter, with 45% leaves, 42% stalks and 13% heads; *Helianthus tuberosus* - 10.5 kg/m^2 green mass or 3.03 kg/m^2 dry matter, with 34% leaves and 66% stalks, but the control reached 5.03 kg/m^2 green mass or 0.94 kg/m^2 dry matter, with 43% stalks, 26% leaves and 31% heads.

According to Pesce et al. (2017) the green mass productivity of cv. 'Altilis 41' of *Cynara cardunculus* reached 19.1 t/ha dry mater, with 37.7% leaves, 27.7% stalks and 34.6% inflorescence material. Liu et al., 2011 mentioned that Chinese clones of Jerusalem artichoke cultivated in a semiarid region in the northwest China had a biological yield ranging from 25 to 35 t ha dry matter. Seiler (1993) mentioned that the aboveground biomass of Jerusalem artichoke contained 68% stems, 23% leaves and 9% heads.

Table 1. Some agrobiological peculiarities and the structure of the green mass of the investigated *Asteraceae* species

Plant species	Plant height, cm	Stem, g		Leaf, g		Head, g		Yield, kg/m^2	
		green mass	dry matter	green mass	dry matter	green mass	dry matter	green mass	dry matter
Cynara cardunculus	201	410	81	522	25	142	87	7.12	1.41
Helianthus tuberosus	326	243	73	141	38	-	-	10.5	3.03
Helianthus annuus	178	343	60	169	43	254	38	5.03	0.94

Table 2. Biochemical composition and nutritive value of the harvested green mass of the investigated *Asteraceae* species

Indices	*Cynara cardunculus*	*Helianthus tuberosus*	*Helianthus annuus*
Crude protein, g/kg DM	120	94	102
Minerals, g/kg DM	60	71	83
Acid detergent fibre, g/kg DM ,	302	400	267
Neutral detergent fibre, g/kg DM	545	603	401
Acid detergent lignin, g/kg DM	31	51	41
Total soluble sugars, g/kg DM	278	146	243
Cellulose, g/kg DM	271	349	226
Hemicellulose, g/kg DM	243	203	226
Digestible dry matter, %	65.3	57.7	68.1
Dry matter intake, % BW	2.20	1.99	2.99
Relative feed value	111	89	158
Digestible energy, MJ/ kg	12.82	11.47	13.32
Metabolizable energy, MJ/ kg	10.53	9.41	10.94
Net energy for lactation, MJ/ kg	6.55	5.43	6.96

Analyzing the results of the green mass quality of the *Cynara cardunculus* and *Helianthus tuberosus*, Table 2, we found that dry matter content of the harvested green mass contained

94-120 g/kg CP, 71-60 g/kg ash, 302-400 g/kg ADF, 545-603 g/kg NDF, 31-51 g/kg ADL, 146-278 g/kg TSS, 271-349g/kg Cel and 203-243 g/kg HC, 57.7-65.3% dry matter digestibility. The natural fodder of the studied species have RFV = 89-111, 11.47-12.82 MJ/kg DE, 9.41-10.53 MJ/kg ME and 5.43-6.55 MJ/kg NEl, but the control - *Helianthus annuus* - RFV 158, 13.52 MJ/kg DE, 10.94 MJ/kg ME and 5.43-6.96 MJ/kg NEl, respectively. The natural fodder of *Cynara cardunculus* was characterised by higher concentration of total soluble sugars and optimal protein, as compared with *Helianthus tuberosus* and *Helianthus annuus*. *Helianthus tuberosus* had higher concentration of ADF, NDF, ADL and lower concentration of hemicellulose, which had a negative effect on digestibility, relative feed value and net energy for lactation.

Some authors mentioned various findings about the green mass quality of the studied *Asteraceae* species. Ferndndez et al. (1996), Romero et al. (1997) reported that the green mass of *Cynara cardunculus*, contained 14.3-18.4% CP, 36.3-38.4% NDF; 25.1-28.9% ADF, and 9.3-13.3% ADL, therefore suitable to be used as green forage. Cajarville et al. (1999) mentioned that green forage had high nutritive value, low levels of fibre and lignin, and very high digestibility for organic matter (86%), while ensiling is the most appropriate way for preserving it for long periods. According to Cosgrove et al. (2000), the crude protein (5%) and digestible protein (3%) concentration are low in Jerusalem artichoke tops as compared with alfalfa (14% and 10%), but it was superior in total digestible nutrients (67%) as compared with alfalfa (50%) and the perennial grass smooth brome (46%). Heuzé et al. (2015), revealed that the aerial part of the *Helianthus tuberosus* contained 32.3% dry matter, 15.3% CP, 15.3% CF, 40.6% NDF, 34.5% ADF, 2.2% ether extract, 11.5% lignin, 14.4 % ash, 63.0% organic matter digestibility, 10.1 MJ/kg DE, 8.2 MJ/kg ME and 5.0-6.0 MJ/kg NEl, for ruminants. Ersahince & Kara (2017) have found that the chemical composition of Jerusalem artichoke herbage harvested in early flowering stage was 7.37% protein, 1.70% fats, 40.15% NFC, 39.03% aNDFom, 31.7% ADFom, 6.78% ADL. Seiler (1993) mentioned that *in vitro* digestibility of dry matter of the Jerusalem artichoke cultivars varied from 542 to 715 g/kg in whole plants in the flowering stage.

Silage is the main conserved green succulent roughage fed to domestic animals. When opening the glass vessels with silages made from green mass of *Cynara cardunculus* and *Helianthus tuberosus*, 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 - it was moderately eliminated. The prepared silages 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, *Helianthus tuberosus* silage - dark-green leaves with brownish hues and yellow-green stems, with pleasant smell, somewhat like the smell of 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 fermentation quality of silage from the studied *Asteraceae* species is illustrated in Table 3. The materials consolidated well and the fermentation was complete with similar acidic pH values 3.77-4.17. 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* species silages (69.5-76.4 g/kg). Most organic acids in tested silages were in fixed form. The butyric acid was detected in fixed form (1.4 g/kg DM) in the *Cynara cardunculus* silage. In the silage from *Helianthus tuberosus*, the content of acetic acid reached 27% of organic acids.

The dry matter content in the prepared silages from *Helianthus annuus* and *Cynara cardunculus* were very low (19.1-19.7%) in comparison with *Helianthus tuberosus* silage (30.5%). The biochemical composition of dry matter and nutritive value of the prepared silages are shown in Table 4. It was determined that the dry matter of the tested silages contained 97-125 g/kg CP, 84-103 g/kg ash, 306-334 g/kg ADF, 496-531 g/kg NDF, 26-50 g/kg ADL, 192-280 g/kg

Cel and 225-284 g/kg HC. The nutritive and energy value of silages from *Helianthus tuberosus* and *Cynara cardunculus*: RFV = 114-118, 12.39-12.78 MJ/kg DE, 10.17-10.49 MJ/kg ME and 6.19-6.51 MJ/kg NEl, but the control - *Helianthus annuus* silage - RFV 161, 14.98 MJ/kg DE, 12.30 MJ/kg ME and 7.12 MJ/kg NEl, respectively.

Table 3. The fermentation quality of the silage prepared from the investigated *Asteraceae* species

Indices	*Cynara cardunculus*	*Helianthus tuberosus*	*Helianthus annuus*
pH index	3.77	4.17	3.82
Content of organic acids, g/kg	43.1	69.5	76.4
Free acetic acid, g/kg	4.0	8.9	9.3
Free butyric acid, g/kg	0.0	0.0	0.0
Free lactic acid, g/kg	12.6	10.4	20.3
Fixed acetic acid, g/kg	3.5	9.7	10.2
Fixed butyric acid, g/kg	1.4	0.0	0.1
Fixed lactic acid, g/kg	21.6	40.5	36.5
Total acetic acid, g/kg	7.5	18.6	19.5
Total butyric acid, g/kg	1.4	0.0	0.1
Total lactic acid, g/kg	34.2	50.9	56.8
Acetic acid, % of organic acids	18	27	24
Butyric acid, % of organic acids	3	-	1
Lactic acid, % of organic acids	79	73	75

Table 4. Biochemical composition and nutritive value of the silage prepared from the investigated *Asteraceae* species

Indices	*Cynara cardunculus*	*Helianthus tuberosus*	*Helianthus annuus*
Raw protein, g/kg DM	125	97	102
Minerals, g/kg DM	84	103	99
Acid detergent fibre, g/kg DM Neutral	306	334	252
Detergent fibre, g/kg DM	531	496	401
Acid detergent lignin, g/kg DM	26	50	35
Cellulose, g/kg DM	280	192	217
Hemicellulose , g/kg DM	225	284	149
Digestible dry matter, %	65.1	62.9	69.29
Dry matter intake, % BW	2.26	2.42	2.99
Relative feed value	114	118	161
Digestible energy, MJ/ kg	12.78	12.39	14.98
Metabolizable energy, MJ/ kg	10.49	10.17	12.30
Net energy for lactation, MJ/ kg	6.51	6.19	7.12

During the process of ensiling of *Helianthus tuberosus* plants, we observed a significant reduction in the neutral detergent fibre content and an obvious increase in the hemicellulose content, and these factors had a positive impact on digestibility, nutritive and energy value of the preserved feed and also on the methane yield.

Some authors mentioned various findings about the quality of *Asteraceae* silages.

According to Pesce et al. (2017), *Cynara cardunculus* produced silage with 32.8% DM, pH 3.3, 1.3% lactic acid, 1.4% acetic acid, 0.2% butyric acid, 14.6% CP, 11.9% ash, 48% NDF, 28.1% ADF. 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). The *Cynara cardunculus* silage produced from whole cordon plants mowed in full bloom stage was characterized by 20.6% DM, 8.79% ash, pH 4.13, 72.3 g/kg lactic acid, 21.5 g/kg acetic acid and 49.5 g/kg ethanol (Ferrero et al., 2018).

Herrmann et al. (2016) studied the nutrient and fibre composition of crop silages in Germany and remarked that the Jerusalem artichoke silage contained 28.2% dry matter and 89.7% organic matter, pH 3.9, 7.2% lactic acid, 1.6% acetic acid, 9.8% protein, 1.9% fat, 44.1% NDF, 39.6% ADF and 11.7% ADL; in sunflower silage there was 23.0% dry matter and 87.5% organic matter, pH 4.2, 7.4% lactic acid, 2.0% acetic acid, 9.4% protein, 11.1% fat, 39.9% NDF, 37.6% ADF, 9.5% ADL.

CONCLUSIONS

The nutritive and energy value of green mass from *Cynara cardunculus:* 120 g/kg CP, RFV = 111, 12.82 MJ/kg DE, 10.53 MJ/kg ME and 6.55

MJ/kg NEl, but the prepared silage - 34.2 g/kg lactic acid, 125 g/kg CP, RFV = 114, 12.78 MJ/kg DE, 10.49 MJ/kg ME and 6.51 MJ/kg NEl.

The nutritive and energy value of *Helianthus tuberosus* aerial part: 94 g/kg CP, RFV = 89, 11.47 MJ/kg DE, 9.41 MJ/kg ME and 5.43 MJ/kg NEl, but the prepared silage - 50.9 g/kg lactic acid, 97 g/kg CP, RFV = 118, 12.39 MJ/kg DE, 10.17 MJ/kg ME and 6.19 MJ/kg NEl.

The studied species *Cynara cardunculus* and *Helianthus tuberosus* can be used as alternative feed for ruminant animals.

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