THE QUALITY OF BIOMASS FROM SOME ASTERACEAE SPECIES AND THEIR POTENTIAL APPLICATION IN THE REPUBLIC OF MOLDOVA

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Abstract. The aim of this study was to evaluate the quality of harvested green mass and prepared silage from Asteraceae species: *Helianthus annuus*, *Silybum marianum*, *Cynara cardunculus* and *Silphium perfoliatum* grown in an experimental field of the National Botanical Garden (Institute), Chişinău, Republic of Moldova. It was determined that the nutrient content of the harvested mass varied among the species: 90-159 g/kg CP, 300-358 g/kg CF, 67-88 g/kg ash, 326-379 g/kg ADF, 555-646 g/kg NDF, 49-60 g/kg ADL, 34-145 g/kg TSS, 272-328 g/kg Cel, 209-267 g/kg HC with nutritive and energy values 58.4-63.5 % DDM, RFV=86-104, 11.76-12.50 MJ/kg DE, 9.65-10.26 MJ/kg ME and 5.67-6.28 MJ/kg NEl. The silages prepared from the studied *Asteraceae* species are characterized by specific smell and colour, pH = 3.94-5.39, 4.8-8.4 g/kg acetic acid, 16.4-34.6 g/kg lactic acid, 0-0.8 g/kg butyric acid, 95-166 g/kg CP, 81-135 g/kg ash, 315-380g/kg CF, 355-421 g/kg ADF, 605-653 g/kg NDF, 53-65 g/kg ADL, 302-356 g/kg Cel, 200-276 g/kg HC, 0-36 g/kg TSS, 56.6-61.2 % DMD, 11.18-12.10 MJ/kg DE, 9.18-9.93 MJ/kg ME, 5.19-5.95 MJ/kg NEl. The ensiled mass substrates for anaerobic digestion had optimal C/N=15-30 and biochemical methane potential varied from 300 to 333 l/kg ODM. The studied Asteraceae species have optimal nutrient content, and they can be used as an alternative feed source for livestock, also and as feedstock for biogas production. Among these species, *Cynara cardunculus* has a particularly high economic value.

Keywords: Asteraceae family species, biochemical methane potential, feed value, green mass, silage.

Rezumat. Calitatea biomasei unor specii de Asteraceae şi perspectiva valorificării lor în Republica Moldova. Scopul prezentului studiu a constatat în evaluarea calității masei verzi recoltate și a silozului preparat din specii ale familiei Asteraceae și anume: *Helianthus annuus*, *Silybum marianum*, *Cynara cardunculus* și *Silphium perfoliatum*, cultivate în sectorul experimental din Grădina Botanică Națională (Institut), Chișinău, Republica Moldova. S-a stabilit că conținutul de nutrienți în plantelele recoltate se modifică în dependență de specie: 90-159 g/kg proteină brută (CP), 196-231 g/kg celuloză brută (CF), 67-88 g/kg cenușă, 326-379 g/kg fibre solubile în detergent acid (ADF), 555-646 g/kg fibre solubile în detergent neutru (NDF), 49-60 g/kg lignină sulfurică (ADL), 34-145 g/kg total zaharuri solubile (TSS), 272-328 g/kg celuloză (Cel), 209-267 g/kg hemiceluloză (HC), cu o valoarea nutritivă și energetică de 58.4-63.5 % substanță uscată digestibilă (DDM), valoare relativă furajeră RFV=86-104, 11.76-12.50 MJ/kg energie metabolizantă (ME) și 5.67-6.28 MJ/kg energie netă pentru lactație. Silozurile pregătite se caracterizează printr-o aromă și culoare specifică, pH = 3.94-5.39, 4.8-8.4 g/kg acid acetic, 16.4-34.6 g/kg acid lactic, 0-0.8 g/kg acid butiric, 95-166 g/kg CP, 81-135 g/kg cenușă, 315-380g/kg CF, 355-421 g/kg ADF, 605-653 g/kg NDF, 53-65 g/kg ADL, 302-356 g/kg Cel, 200-276 g/kg HC, 0-36 g/kg TSS, 56.6-61.2 % DMD, 11.18-12.10 MJ/kg DE, 9.18-9.93 MJ/kg ME, 5.19-5.95 MJ/kg NEl. Substraturile de masă însilozată pentru digestia anaerobă se caracterizează printr-un raport optimal de carbon și azot – C/N=15-30, iar potențialul biochimic de obținere a metanului variază de la 300 la 333 l/kg materie organică. Plantele investigate din familia Asteraceae au un conținut optimal de nutrienți, ceea ce permite utilizarea lor ca nutreț pentru animale, de asemenea ca materie primă pentru producere de biogaz. Un deosebit interes economic prezintă plantele de *Cynara cardunculus.*

Cuvinte cheie: specii din familia Asteraceae, potențialul biochimic de obținere a metanului, valoare nutritivă, masă verde recoltată, siloz.

INTRODUCTION

Under the conditions of regional climate change, characterized by high temperatures and frequent droughts, as well as the expansion of areas with degraded and salinized soils, for the maintenance and development of animal husbandry, fodder production should be supported and diversified, and also balanced in terms of quantity and quality throughout the year, according to the physiological needs of animals and productivity indices. In recent years, there has been a renewed interest in the mobilization of new and non-traditional forage plant species with optimal genetic potential of productivity, which possess important nutritional properties, such as high palatability and high nutritional value, high tolerance to weeds, pests, diseases, drought and frost, are winter hardy and are able to grow with low nutrient and energy input. In the world's flora, there are over 50 000 species of plants that are eaten by animals and about 150 species are cultivated. This huge reserve allows identifying, mobilizing and acclimatizing new species that would expand the range of crops, the productivity and elevate the quality of feed (TELEUŢĂ & ŢÎŢEI, 2016; ***. ECPGR, 2021).

In the latest years, the rapid depletion of fossil fuel resources and the sharp rise in oil and gas prices have motivated an increasing interest in renewable energy production, and phytomass represents a good opportunity. The growing interest in bioenergy crops that do not compete with food production for land use has promoted the implementation of low-input crops on marginal lands. The increased use of biomass as a source of energy will contribute to the reduction of CO_2 emissions, increasing the local energy security and supporting sustainable development and regeneration of rural areas, by opening new jobs and increasing the living standard.

The identification, mobilization and research of new plant species from local and world flora, their breeding and creation of new cultivars, the development of cultivation technologies, including the production of fodder and of energy biomass have been a strategic direction of the research conducted within the "Alexandru Ciubotaru" National Botanical Garden (Institute) of Moldova.

Asteraceae, or Compositae, is one the largest families of flowering plants, *The Plant List (2013)* mentions approximately 27,773 species, belonging to 1,765 plant genera. 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, with grass-like and spine scent. It is highly relevant because it includes economical, culinary, medicinal plants as well as numerous ornamentals, but also a great number of weedy representatives. *The Plant List* (2013) mentions 71 accepted scientific species names in the genus *Helianthus*, 17 accepted species names in the genus *Silphium*, 11 accepted species in the genus *Cynara* and 2 accepted species names in the genus *Silybum*.

Milk thistle *Silybum marianum* (L.) Gaertn (synonym *Carduus marianus* L.) and Globe artichoke *Cynara cardunculus* L. are native to the Mediterranean area, *Helianthus annuus* L. and *Silphium perfoliatum* L. are native to North and South America. These species are studied in different research centres and implemented as multi-purpose crops (HERNÁNDEZ et al., 2005; GONCEARIUC, 2007; BOE et al., 2012; PICHARD, 2012; BOLOHAN et al., 2013; LEDDA et al., 2013; KALAMARAS & KOTSOPOULOS, 2014; MACHEBOEUF et al., 2014; ANDRZEJEWSKA et al., 2015; GANSBERGER et al., 2015; HEUZÉ et al., 2015; KESHAVARZ et al., 2015; FERRERO et al., 2018; JUCSOR & SUMALAN, 2018; GOMINHO et al., 2018; HUNCE et al., 2019; RAKHMETOV et al., 2019; TSIAOUSI et al., 2019; KURT & KAMALAK, 2020; PENI et al., 2020; MARTINELLI, 2020; VON COSSEL et al., 2020; REINHARDT et al., 2021; SAINZ-RAMÍREZ et al., 2021; MARCEDDU et al., 2022; MOLL et al., 2022).

The aim of this study was to evaluate some agrobiological features, the quality of the harvested green mass and prepared silage from the Asteraceae species: *Helianthus annuus*, *Silybum marianum*, *Cynara cardunculus* and *Silphium perfoliatum* and the possibility to use them as feed for ruminant animals and feedstock for the production of renewable energy.

MATERIALS AND METHODS

The Asteraceae species: *Helianthus annuus*, *Silybum marianum*, *Cynara cardunculus* var. *altilis* and *Silphium perfoliatum* 'Vital' which were cultivated in the experimental plot of the "Alexandru Ciubotaru" National Botanical Garden (Institute) Chişinău, N 46°58′25.7″ latitude and E 28°52′57.8″ longitude, they served as subjects of the research. The green mass samples were collected in the full flowering - seed formation stages. The samples of *Cynara cardunculus* var. *altilis* and *Silphium perfoliatum* 'Vital' were harvested from 4-year-old plants. For chemical analyses, the samples were dried at 65 ± 5°C. The dry matter content was detected by drying samples up to constant weight at 105 °C. For ensiling, the green mass was shredded and compressed in well-sealed containers. After 45 days, the containers were opened, and the sensorial and fermentation characteristics of the prepared silages were determined in accordance with standard laboratory procedures and the Moldavian standard SM 108 for forage quality analysis. Some assessments of the main biochemical parameters: 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 the PERTEN DA 7200 at the Research and Development Institute for Grasslands, Braşov, Romania. The concentration of hemicellulose (HC) and cellulose (Cel), the digestible dry matter (DDM), the relative feed value (RFV), the digestible energy (DE), the metabolizable energy (ME) and the net energy for lactation (NEl) were calculated according to standard procedures. The carbon content of the substrates was obtained using an empirical equation according to BADGER et al., (1979). The biochemical methane potential was calculated according to the equations of DANDIKAS et al., (2015).

RESULTS AND DISCUSSIONS

As a result of the phenological observations, it has been found that the studied annual Asteraceae species *Helianthus annuus* and *Silybum marianum* were characterised by similar growth and development rates. Thus, it has been determined that the seedlings emerged uniformly at the soil surface in the in the first days of May, 14 days after sowing. The development of shoots was observed in the second half of May, and their intensive growth – in June, the flowering stage in *Silybum marianum* began in the middle of July, but in *Helianthus annuus* – 12-16 days later. At the harvest time, *Silybum marianum* plants were 180-197 cm tall and *Helianthus annuus* plants – 277-293 cm tall. The plants of the perennial Asteraceae species *Cynara cardunculus* and *Silphium perfoliatum*, in the 4th year of life, restarted their growth from generative buds in spring, *Silphium perfoliatum* – at the end March, but *Cynara cardunculus* – in middle April. The leaf rosette developed and spread in April and the stalks began to elongate in May. The *Cynara cardunculus* flower heads appeared in the second half of June, but *Silphium perfoliatum* flower heads appeared in the first days of July. At the time of the harvest, in the full flowering - seed formation stages, *Cynara cardunculus* plants (173 cm) were shorter than *Silphium perfoliatum* plants (289 cm), but the stems were thicker. Analysing the results of the green mass quality of the studied Asteraceae species, Table 1, we found that the dry matter content of the green mass harvested from annual Asteraceae species contained 90-159g/kg CP, 331-358 g/kg CF,67-88 g/kg ash, 367-379 g/kg ADF, 576-646 g/kg NDF, 49-51 g/kg ADL, 34-145 g/kg TSS, 318-328 g/kg Cel, 209-267 g/kg HC with nutritive and energy values of 58.4-60.3 % DDM, RFV=86-97, 11.76-11.92 MJ/kg DE, 9.65-9.79 MJ/kg ME and 5.67-5.81 MJ/kg NEl. The natural fodder of *Silybum marianum* was characterised by higher concentration of crude protein, ash, structural carbohydrates, lignin, but very low total soluble sugar content, as compared with *Helianthus annuus*,

which had a negative effect on dry matter digestibility, relative feed value and net energy for lactation. It has been found that the concentration of nutrients in the harvested mass from perennial Asteraceae species was: 117-154 g/kg CP, 300-335 g/kg CF, 76-85 g/kg ash, 326-376 g/kg ADF, 555-599 g/kg NDF, 54-60 g/kg ADL, 38-80 g/kg TSS, 213-229 g/kg HC, 272-316 g/kg Cel. Thus, the fresh mass of *Cynara cardunculus* contained a higher amount of crude protein, total soluble sugars and hemicellulose, but low amount of crude fibre, structural carbohydrates, lignin than *Silphium perfoliatum*, which had a positive impact on the dry matter digestibility, relative feed value and the energy concentration of the feed. The natural fodder from *Cynara cardunculus* is of high quality, reaching 63.5 % DMD, RFV=106 with 12.50 MJ/kg DE, 10.26 MJ/kg ME and 6.28 MJ/kg NEl, but – from *Silphium perfoliatum* – 59.6 % DMD and RFV=94 with 11.80 MJ/kg DE, 9.69 MJ/kg ME and 5.71 MJ/kg NEl.

Table 1. The biochemical composition and the feed value of the green mass from the studied Asteraceae species.

Indices	*Helianthus annuus*	*Silybum marianum*	*Cynara cardunculus*	*Silphium perfoliatum*
Crude protein, g/kg DM	90	159	154	117
Crude fibre, g/kg DM	358	331	300	335
Ash, g/kg DM	67	88	76	85
Acid detergent fibre, g/kg DM	367	379	326	376
Neutral detergent fibre, g/kg DM	576	646	555	599
Acid detergent lignin, g/kg DM	49	51	54	60
Total soluble sugars, g/kg DM	145	34	80	38
Cellulose, g/kg DM	318	328	272	316
Hemicellulose, g/kg DM	209	267	229	213
Dry matter digestibility, %	603	584	635	596
Digestible energy, MJ/kg DM	11.92	11.76	12.50	11.80
Metabolizable energy, MJ/kg DM	9.79	9.65	10.26	9.69
Net energy for lactation, MJ/kg DM	5.81	5.67	6.28	5.71
Relative feed value	97	86	106	94

Some authors mentioned various findings about the quality of the green mass from 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 is suitable to be used as green forage. CAJARVILLE et al., (1999) mentioned that the green forage from *Cynara cardunculus* contained 12.3-13.8% DM, 812-850 g/kg OM, 13.2 % CP, 1.4-2.8% EE, 12.4-13.4 % CF, 16.2-16.5 % ADF, 23.9-26.4 % NDF, 2.6-3.5 % ADL, 1.55-1.93 % cutin, 53.7-78.3 % DMD, 14.60-15.90 MJ/kg GE, 9.62-13.19 MJ/kg DE, 7.90-11.0 MJ/kg ME. and 5.71 MJ/kg NEl. MELLO et al., (2006) found that the dry matter and the chemical composition of *Helianthus annuus* hybrids harvested in the flowering stage were: 28.5-35.9% DM, 91.5-92.1% OM, 12.0-12.9 % CP, 35.9-40.8 % ADF, 41.4-47.0 % NDF, 8.2-10.8 % ADL. MACHEBOEUF et al., (2014) mentioned that *Silybum marianum* plants, in the fruiting stage, contained 869 g/kg OM, 412 g/kg NDF, 292 g/kg ADFg/kg, 160 g/kg ash. MOJADDAM et al., (2015) indicated that, in regions of Iran, 90-day-old plants of *Silybum marianum* contained 14.84% CP, 45.32% NDF, 26.45% ADF, 17.35% ash. OZINAN et al., (2017) reported that *Silybum marianum* harvested in the flowering stage contained 8.30% CP, 58.29% NDF, 43.63% ADF, 15.06% ash. RAKHMETOV et al., (2019) found that the investigated species of *Silphium* genus contained 211.4-290.2 g/kg DM, 3.54-12.17 %TSS, 29.46-48.24 %CF, 77.12-296.35 mg% ascorbic acid, 0.23-1.54mg% carotene, 14.18-26.08 % CP, 2.34-4.26 %EE. 3.25-7.82 % ash, 0.78-2.18 % K, 1.66-3.07 % Ca, 0.13-0.35 %P. COŞMAN et al., (2020) mentioned that *Silphium perfoliatum* contained 10.33-16.53% DM, 9.56-12.25% ash, 8.25-13.35 % CP, 1.86-2.73% EE, 20.32-34.13 % CF, 42.15-52.32 % NFE. KURT & KAMALAK (2020) determined the effect of the harvesting stage on the nutritive value of *Silybum marianum* plants and remarked the *Silybum marianum* plant have 11.9 -43.26% DM, 12.68-16.56 % ash, 11.11-15.77 % CP, 2.47-5.86 %EE, 39.88-60.85% NDF, 24.96-44.52% ADF, 7.67-8.70 MJ/ kg ME, 48.87-64.40% OMD. MARTINELLI (2020) found *Silybum marianum* biomass compositional analysis highlighted an average content of 140.0 g /kg extractives, 66.2 g /kg CP, 20.6 g /kg ash, 175.1g/kg insoluble lignin, 37.8 g/kg soluble lignin, 334.8 g/kg glucose, 120.4 g/kg xylose, 3.3 g /kg N, 462.8 g /kg C, 54.8 g /kg H, 18.01 MJ/kg.

Ensiling is one of the most effective methods of conservation of succulent fodder. It retains most of the nutrients and other valuable qualities of green fodder (succulence, dietetic qualities and high digestibility). Silage plays an essential role in livestock feeding, especially in providing a balanced diet throughout the year, but in recent decades, it has also been used as substrate in biogas production. Corn silage is one of the most common, but frequent droughts, rising prices of seeds, agricultural equipment, fuel and fertilizers have a negative impact on the productivity and the cost of corn, therefore it is necessary to study the capacity of ensiling other species. We would like to mention that when opening the glass vessels with silages made from green mass of *Helianthus annuus*, *Cynara cardunculus* and *Silphium perfoliatum*, there was no gas or juice leakage from the preserved mass, but from the vessels with *Silybum marianum* silage, carbon dioxide – a by-product of fermentation – was intensively emitted. 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 annuus* silage was homogeneous, yellow-green with specific smell; the silage mass from *Silphium perfoliatum* contained dark green leaves and yellow-

green stems, had a pleasant smell like pickled tomatoes, *Silybum marianum* silage – yellow-green stems, olive leaves, not very pleasant, specifically, its scent was similar to the smell of fresh coniferous wood, characteristically, about 10 minutes after opening, under the presence of atmospheric air, the colour of the silage obviously darkened.

It is commonly known that, during the process of ensiling, epiphytic bacteria (microflora from the plant) develop in the fodder and produce organic acids, lactic acid bacteria – lactic acid, a natural preservative of the silage. But, on the plant, lactic acid bacteria, which pickle the fodder, are not always the most numerous, but there can be other types of microorganisms that can taint the fodder. The fermentation and nutritive quality of silages prepared from the studied Asteraceae species is illustrated in Table 2. As a result of the performed analysis, it was determined that the pH index of the prepared silages varied from 3.94 to 5.39. Except the *Silybum marianum* silage, the pH index of the other studied silage meets the standard SM 108 for the 1st class quality. 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 high content of organic acids (43.3 g/kg), in comparison with *Silybum marianum* silage (28.3 g/kg). Most organic acids in the tested silages were in fixed form. The butyric acid was detected in fixed form, in very small quantities (0.02-0.2 g/kg DM). In the silage produced from *Silybum marianum*, the concentration of acetic acid was very high and reached 42.05% of total organic acids. It was determined that the dry matter of the tested silages from annual Asteraceae species contained 95-166 g/kg CP, 81-135 g/kg ash, 315-380 g/kg ADF, 619-653 g/kg NDF, 59-62 g/kg ADL, 318-337 g/kCel and 200-276 g/kg HC with 56.2-58.5 % DDM, 11.38-11.79 MJ/kg DE, 9.34-9.68 MJ/kg ME and 5.22-5.70 MJ/kg NEl, but the silage from perennial species: 117-162 g/kg CP, 322-381 g/kg CF, 85-93 g/kg ash, 355-421 g/kg ADF, 605-637 g/kg NDF, 53-65 g/kg ADL, 250-252g/kg HC, 302-356 g/kg Cel, 11.18-12.10 MJ/kg DE, 9.18-9.93 MJ/kg ME and 5.19-5.95 MJ/kg NEl. During the process of ensiling of Asteraceae plants, we observed an insignificant change in the crude protein content and an increase in the neutral detergent fibre content. *Cynara cardunculus* silage was characterized by a high content of protein and total soluble sugars and a low content of structural carbohydrates and lignin, these factors had a positive impact on digestibility, nutritive and energy value. The prepared silages from *Helianthus annuus*, *Silybum marianum* and *Silphium perfoliatum* did not differ substantially in the indices of digestibility, nutritive and energy value.

Table 2. The fermentation profile, the biochemical composition and the nutritive value of the silage from Asteraceae species.

Indices	*Helianthus annuus*	*Silybum marianum*	*Cynara cardunculus*	*Silphium perfoliatum*
pH index	4.01	5.39	3.94	4.18
Organic acids, g/kg DM	30.1	28.3	43.3	36.6
Free acetic acid, g/kg DM	2.4	1.0	4.4	3.2
Free butyric acid, g/kg DM	0	0	0	0
Free lactic acid, g/kg DM	7.8	3.4	13.5	10.0
Fixed acetic acid, g/kg DM	2.4	10.9	3.9	5.2
Fixed butyric acid, g/kg DM	0.2	0	0.08	0.02
Fixed lactic acid, g/kg DM	173	13.0	21.1	18.2
Total acetic acid, g/kg DM	4.8	8.4	8.3	8.4
Total butyric acid, g/kg DM	0.02	0	0.8	0.02
Total lactic acid, g/kg DM	25.1	16.4	34.6	28.2
Acetic acid, % of organic acids	15.95	42.05	19.17	22.90
Butyric acid, % of organic acids	0.06	0	0.18	0.06
Lactic acid, % of organic acids	83.35	57.95	79.91	77.04
Crude protein, g/kg DM	95	166	162	117
Crude fibre, g/kg DM	380	315	322	381
Ash, g/kg DM	81	135	93	85
Acid detergent fibre, g/kg DM	419	337	355	421
Neutral detergent fibre, g/kg DM	619	653	605	637
Acid detergent lignin, g/kg DM	62	59	53	65
Total soluble sugars, g/kg DM	-	-	36	-
Cellulose, g/kg DM	337	318	302	356
Hemicellulose, g/kg DM	200	276	250	252
Digestible dry matter, g/kg DM	562	585	612	561
Digestible energy, MJ/kg DM	85	85	94	77
Metabolizable energy, MJ/kg DM	11.38	11.79	12.10	11.18
Net energy for lactation, MJ/kg DM	9.34	9.68	9.93	9.18
Relative feed value	5.22	5.70	5.95	5.19

Some authors mentioned various findings about the quality of Asteraceae silages. According to VALDEZ et al., (1988) that *Helianthus annuus* silage had pH 4.1, 234 g/kg DM, including 11.5% CP, 14.5% ash, 43.4% NDF, 35.2% ADF, 1.21% EE, 7.6% lignin, 69.1% TDN, 1.47 Mcal/kg ME. HAN et al., (2000) found that the quality of the silage prepared from *Silphium perfoliatum* plants harvested in the mid-bloom period was 265g/kg DM with pH = 5.3, 16.8 g/kg N, 373 g/kg ADF, 503 g/kg NDF, but in the silage prepared for the regrowth material harvested in mid-October was 305 g/kg DM with pH = 4.5, 17.9 g/kg N, 217 g/kg ADF, 290 g/kg NDF. MAFAKHER et al., (2010) reported that *Helianthus annuus* silage prepared in milk-dough seed stage was characterized by 24.19 % DM, pH 4.30, 16.50% ash, 12.87% CP, 32.75% CF, 65.87% IVDMD, 62.72 % IVOMD. HERRMANN et al., (2016) studied the

nutrient and fibre composition of crop silages in Germany and remarked that the *Silphium perfoliatum* silage contained 27.1% DM and 88.4% OM, pH 5.1, 4.2% lactic acid, 1.9% acetic acid, 11.5% CP, 4.0% EE, 52.3% NDF, 36.5% ADF and 7.9% ADL; in *Helianthus annuus* silage there was 23.0% DM and 87.5% OM, 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. PESCE et al., (2017) revealed that *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 *Cynara cardunculus* silage produced from whole 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). 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., 2008). According to AMORIM et al., (2019), *Helianthus annuus* silage quality was 19.6% DM, 7.0% ash, 16.7 % CP, 1.46% EE, 12.3%NFC, 34.7 % ADF, 44.1 % NDF, 4.2% ADL, 30.5% Cel, 9.4%HC and 65.6%TDN, but – of corn: 40.45% DM, 5.75% ash, 6.67 % CP, 1.65% EE, 15.92%NFC, 34.17 % ADF, 66.99 % NDF, 2.2% ADL, 30.5% Cel, and 9.4%HC. COŞMAN et al., (2020) mentioned that *Silphium perfoliatum* silage had pH= 4.22-4.44, 20.03-2.3 g/kg lactic acid, 5.4-6.4 g/kg acetic acid, 0 g/kg butyric acid, 17.73-23.75% DM, 10.15-12.04% ash, 4.42-9.11 % CP, 2.79-4.03% EE, 35.35-39.02 % CF. BASMACIOĞLU MALAYOĞLU et al., (2016) remarked that the quality of pure silage from *Silybum marianum* was 351.8 g/kg DM, pH= 5.51, 25.7 g/kg lactic acid, 22.7 g/kg acetic acid, 10.5 g/kg butyric acid, 79.5% OM, 8.71% CP, 5.07%EE, 15.97 % ash, 43.81% ADF, 50.8% NDF, 38.3% DDM, 30.31% OMD, 1.27 Mcal/kg DE, 1.04 Mcal/kg ME, 0.59 Mcal/kg NEl, but the characteristics of silage with additives – 343.2 g/kg DM, pH= 5.68-5.70, 21.9-22.6 g/kg lactic acid, 23.8-27.7 g/kg acetic acid, 11.1-16.1 g/kg butyric acid, 77.77-79.99 % OM, 8.76-9.29 % CP, 4.71-5.98 % EE, 15.85-6.41 % ash, 41.84-43.43 % ADF, 50.07-50.65 % NDF, 39.53-40.82 % DDM, 30.19-33.89 % OMD, 1.27-1.42 Mcal/kg DE, 1.04-1.17 Mcal/kg ME, 0.58-0.67Mcal/kg Nel.

Table 3. The biochemical composition and the biomethane production potential of the studied Asteraceae species.

Indices	***Helianthus annuus***	***Silybum marianum***	***Cynara cardunculus***	***Silphium perfoliatum***
Crude protein, g/kg DM	95	166	162	117
Ash, g/kg DM	81	135	93	85
Nitrogen, g/kg DM	15.2	26.6	29.92	18.78
Carbon, g/kg DM	510.6	480.6	503.9	508.3
Ratio carbon/nitrogen	33.6	18.1	16.8	27.1
Acid detergent lignin, g/kg DM	62	59	53	65
Hemicellulose, g/kg DM	200	276	250	252
Biomethane potential, L/kg VS	300	323	333	302

Biogas is a product of anaerobic digestion of organic products. Among the biofuels from phytomass, biogas has a great importance and can successfully replace fossil fuels to obtain electric power and heat, and the accumulated digestate is used as fertilizer in organic farming. In order to supply biogas plants over the entire year, it is necessary to preserve the material. Silages are the main feedstock for anaerobic digestion in European countries with a dynamic development of agricultural biogas plants (MAST et al., 2014; HERRMANN et al., 2016). The results regarding the quality of the silage substrates and the potential for obtaining biomethane are shown in Table 3. We found that in the investigated substrates, according to the C/N ratio, which constituted 15-30, the amount of acid detergent lignin (53-65 g/kg) and hemicellulose (200-276 g/kg) met the established standards; the biochemical methane potential of studied substrates varied from 300 to 333 l/kg ODM. A high biochemical methane potential was also characteristic of *Cynara cardunculus* silage substrate, followed by *Silybum marianum* silage substrate.

GONZÁLEZ et al., (2021) reported that *Silybum marianum* substrate digestion resulted in a methane yield of 308.5 L/kg VS. KALAMARAS & KOTSOPOULOS (2014) found that methane yields of 267-308 L /kg were obtained by co-digestion of cattle manure with cardoon silage and milk thistle stalks. The Hohenheim Biogas Yield Test showed that the specific methane yield of *Silphium perfoliatum* was 232- 274 l/kg ODM, depending on the harvest time, the methane yield per hectare was up to 4301 m^3/ha (MAST et al., 2014). HAAG et al., (2016) found the specific methane yield (SMY) potential of cup plant in the batch test was 0.251 ± 0.0141 m^3/kg oDM, but in the continuous test was measured at 0.227 ± 0.0158 m^3/kg oDM. HERRMANN et al., (2016) remarked that the specific methane yields of silages substrates ranged from 203 l/kg ODM in *Silphium perfoliatum* silage to 248 l/kg ODM in *Helianthus annuus* silage. PESCE et al., (2017) found a methane production ranging from 196 to 249 l/kg ODM in three different *Cynara cardunculus* silages. FERRERO et al., (2018) remarked that the production of methane in thistle silages varied from 208 to 293 l/kg ODM. SCHMIDT et al., (2018), reported that the biochemical methane potential of the silage substrate of *Silphium perfoliatum* was 288.31-345.21 l/kg ODM. HUNCE et al., (2019) remarked that the biogas production potential of the aerial vegetative biomass of *Silybum marianum* was 194-223 L/kg and of *Helianthus annuus* biomass – 134-154 L/kg.

CONCLUSIONS

The harvested green mass Asteraceae species under the scope of our study contained 90-159 g/kg CP, 300-358 g/kg CF, 67-88 g/kg ash, 326-379 g/kg ADF, 555-646 g/kg NDF, 49-60 g/kg ADL, 34-145 g/kg TSS, 272-328 g/kg Cel, 209-267 g/kg HC with nutritive and energy values 58.4-63.5 % DDM, RFV=86-104, 11.76-12.50 MJ/kg DE, 9.65-10.26 MJ/kg ME and 5.67-6.28 MJ/kg NEl.

The silages prepared from the studied Asteraceae species are characterized by specific smell and colour, pH = 3.94-5.39, 4.8-8.4 g/kg acetic acid, 16.4-34.6 g/kg lactic acid, 0-0.8 g/kg butyric acid, 95-166 g/kg CP, 81-135 g/kg ash, 315-380g/kg CF, 355-421 g/kg ADF, 605-653 g/kg NDF, 53-65 g/kg ADL, 302-356 g/kg Cel, 200-276 g/kg HC, 0-36 g/kg TSS, 56.6-61.2 % DMD, 11.18-12.10 MJ/kg DE, 9.18-9.93 MJ/kg ME, 5.19-5.95 MJ/kg NEl. The ensiled mass substrates for anaerobic digestion had optimal C/N=15-30 and biochemical methane potential varied from 300 to 333 l/kg ODM.

The studied Asteraceae species have optimal nutrient content, and they can be used as an alternative feed source for livestock, also and as feedstock for biogas production. Among these species, *Cynara cardunculus* has particularly high economic value.

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