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THE QUALITY OF FRESH AND ENSILED BIOMASS FROM WHITE MUSTARD, *Sinapis alba,* AND ITS POTENTIAL USES

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Abstract

We investigated some biological peculiarities and the quality of fresh and ensiled biomass from white mustard, Sinapis alba, which was cultivated on the experimental land in the National Botanical Garden (Institute), Chisinau. The fresh mass was mowed in the flowering stage, some assessments of the main biochemical parameters: crude protein (CP), ash (CA), acid detergent fibre (ADF), neutral detergent fibre (NDF), acid detergent lignin (ADL), total soluble sugars (TSS) 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, the sensorial and chemical characteristics of the prepared silage were determined in accordance with the laboratory standard SM 108. It has been determined that the white mustard fresh mass contained 183-208 g/kg dry matter with 18.3-22.9% CP, 9.2-10.9% CA, 43.9-51.8% NDF, 28.3-34.7% ADF, 4.8-5.6% ADL, 23.5-29.1% Cel, 15.6-17.1% HC, 6.3-8.7% TSS, 63.3-75.9% DMD, 57.3-66.1% DOM, RFV=111-142, 12.22-13.08 MJ/kg DE, 10.03-10.74 MJ/kg ME and 6.04-6.77 MJ/kg NEl. this fact indicates a good quality of the natural feed for ruminants. The white mustard silage was distinguished by homogeneous olive colour, pleasant smell specific of pickled cucumbers with pH = 4.12, it contained 7.4 g/kg acetic acid, 41.8/kg lactic acid, 24.6% CP, 14.1% CA, 41.1% NDF, 28.2% ADF, 2.9% ADL, 25.3 % Cel, 12.9 % HC, 5.3% TSS, 81.7% DMD, 71.3% DOM, RFV=151, 13.11 MJ/kg DE, 10.76 MJ/kg ME and 6.78 MJ/kg NEl. The biochemical methane potential of Sinapis alba substrates reached 295-330 L/kg organic matter.

Key words*: biochemical composition, biochemical methane potential, feed value, fresh mass, silage, Sinapis alba.*

INTRODUCTION

The global population growth has resulted in the intensification of food and energy production, which has been necessary in order to cover the rising demands to maintain the standards of living.

The plants of the family *Brassicaceae* constitute one of the world's most economically important plant groups.

They range from noxious weeds to leaf and root vegetables, to oilseed and condiment crops, fodder, technical and cover crops.

The species of *Brassicaceae* have gained great importance in agricultural systems in the last decades, due to their many environmental and agronomic benefits.

The genus *Sinapis* L. contains 6 species, including white mustard - *Sinapis alba* L. and charlock mustard or wild mustard - *Sinapis arvensis* L., which occur in the local flora of our country.

White mustard, *Sinapis alba* L. (syn. *Brassica hirta* Moench or *Brassica alba* (L.) Rabenh.) is assumed to have its origins in the South-East of the Mediterranean Basin. It was used by ancient civilisations 2000 years BC as an oil, spice and medicinal plant and was introduced into the Western and Northern Europe in the early Middle Ages. *Sinapis alba* is an annual herbaceous plant. Stem branched, bristly, usually clearly coarsely hairy, 50-150 cm tall, vigorous. Leaves are alternate, long, bristly branched, irregularly toothed, petiolate, hairy on both sides. Flowers are small, yellow with four petals, cruciform; stamens tetradynamous; pistil bicarpellate. The fruit is a bristly siliqua, round, ribbed, swollen at the seeds, and with a long ensiform beak, pods spreading in the raceme. The fruit stem is 5 × 14 mm. The fruit is 20-45 × 2-4.5 mm in size and carries a beak of 15-30 mm in size. Beak has 0-1 seed; the lower part of the fruit has 1-4 seeds. Seeds are globular and yellowish. They are about 1.5-

3 mm, minutely pitted, seed coat is thin, endosperm meagre and invisible to the naked eye; embryo large, yellowish, with curved hypocotyls, radicle partially surrounded by two folded cotyledons. *Sinapis alba* plants have extensive root system that penetrates deep into the soil profile, more than 50% of all moisture uptake is from below 1.5 m in the soil profile, and hence can utilize the nitrates that have leached down from other crops. White mustard is highly competitive with weed species (Duke, 1983; Oplinger et al., 1991; Kayaçetin, 2020).

The total area cultivated with mustard species in the world is 616,000 ha, with production of 564,000 tons and yield of 915 kg/ha per year on average. About half of this quantity is produced by Canada and Nepal. The other important mustard growing countries in the world include China, Czech Republic, France, Germany, Myanmar, Pakistan, Russia, Ukraine and USA. Its economic importance is continuously increasing due to many possible uses, such as: seed production, secondary crop, as plant important for nematode control in crop rotation and also as melliferous plant. Yellow mustard seed does not have any odour when crushed in water. The seeds have strong disinfectant properties and can be used as a food preservative. Its essential oil can be used to preserve foods due to its potent antimicrobial activity. Moreover, the seed is used in traditional medicine for its antitumor, antiviral, and analgesic activities, it also has expectorant, stimulant, and antimicrobial activities that are useful for digestive and respiratory diseases (Peng et al., 2014; Kayaçetin, 2020).

White mustard is cultivated in warm regions primarily for seed production, whilst in cool, temperate zones it is grown as a break crop, for forage or as green manure. For animal feed and green manure, the breeding aims concentrate on achieving a high leaf production and resistance to beet nematodes. The cultivars bred to be used as fodder must produce a low mustard oil content. In contrast, the cultivars for spice and mustard production should contain much sinalbin. White mustard, as compared with spring rapeseed, is characterized by a more stable yield and especially by its better resistance to temporary droughts frequent in our regional climatic conditions. White mustard and other cruciferous crops can be successfully used in grass mixtures with spring vetch, peas and other legumes, especially those that need support (Kostenko et al., 2021).

Biofumigation with mustard could be integrated to provide environmentally friendly and affordable control of soil-borne pests and diseases under integrated pest management systems (Santos et al., 2021).

Young seedling leaves, which are rich in vitamin A, C and E, are edible as fresh and tasty salad leaves and are used for medicinal purposes to purify blood (Rahman et al., 2018).

Honey bees, solitary bees, bumblebees, flies etc. frequently visit the flowers of *Sinapis alba* to collect nectar and pollen, and serve as agents of cross pollination. Expert beekeepers could manage to get about 10-50 kg honey per hive during a season or 50-60 kg/ha (Popa & Cîrnu, 1960; Glukhov, 1974; Ion et al., 2018).

White mustard seed oil has garnered interest for its use as a feedstock for biodiesel production and oil meal - a byproduct of the biodiesel industry that can be used for animal feed or further extracted to produce additional oil, thus improving economic benefits (Mitrovic et al., 2020). White mustard straw contained 36.7% cellulose and 21.6% lignin, and may serve as alternative raw material in the production of particle board (Dukarska et al., 2011). Also above-ground biomass has caloric value of 17.09-18.45 MJ/kg and may be used to prepare solid biofuel (Fuksa et al., 2013).

The aim of the current study was to evaluate some biological peculiarities, the quality of fresh and ensiled biomass of white mustard, *Sinapis alba,* as feed for ruminant animals, as well as substrate for the production of biomethane by anaerobic digestion.

MATERIALS AND METHODS

The local ecotype of white mustard, *Sinapis alba*, which was cultivated in the experimental plot of the National Botanical Garden (Institute) of Moldova, Chişinău, N 46°58′25.7″ latitude and E 28°52′57.8″, served as subject of research and the traditional crop alfalfa, *Medicago sativa*, was used as control. The experimental design was a randomised complete block design with four replications, and the experimental plots measured 10 m^2. *Sinapis alba* as primary crop was sown on March 19 and as secondary crop on

June 17, 2020, at a depth of 2.0 cm, in rows at a distance of 15 cm; the sowing density was 100 germinable seeds per m^2.

The plant growth, development and productivity were assessed according to methodical indications. The green mass was harvested in the flowering period, in the primary crop on June 9 and in the secondary crop - on September 8. The green mass yield was measured by weighing. The dry matter content was detected by drying samples up to constant weight at 105°C.

The leaf/stem ratio was determined by separating the leaves 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 the prepared silages were determined in accordance with standard laboratory procedures and the Moldavian standard SM 108 for forage quality analysis.

For chemical analysis, plant samples were dried in a forced air oven at 60°C, milled in a beater mill equipped with a sieve with diameter of openings of 1 mm and some of the main biochemical parameters were assessed: crude protein (CP), ash (CA), 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) were determined by the 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. The carbon content of the substrates was determined using an empirical equation according to Badger et al. (1979). The biochemical methane potential was calculated according to the equations of Dandikas et al. (2014).

RESULTS AND DISCUSSIONS

When we sowed the white mustard, *Sinapis alba,* seeds in spring (the plots with primary crop), the emergence of the seedlings was observed on the 8-10 days, and in the plots with secondary crop, the seedlings emerged on the 3-5 days after sowing, under adequate temperature and moisture conditions.

It is a commonly known fact that the bio-morphological characteristics: plant height, stem thickness and leaf/stem ratio have significant impact on the productivity, but also affect the biochemical composition and forage value. The structure of the harvested aerial plant biomass and its yield are shown in Table 1. At the harvest time, the height of *Sinapis alba* plants grown as primary crop was 116.1 cm, while those grown as secondary crop reached 60.4 cm, *Medicago sativa* plants at first cut were 84.5 cm tall, but at the third cut - 53.8 cm. The traditional leguminous forage crops reached 84.5-93.1 cm. *Sinapis alba* had the largest weight of a single plant among the studied species. The forage yield of white mustard grown as primary crop reached 35.6 t/ha green mass or 7.3 t/ha dry matter with 71.6 % leaves and flowers, while as secondary crop - 12.8 t/ha green mass or 3.8 t/ha dry matter with 61.8 % leaves, but the leguminous forage crop *Medicago sativa* at the first cut yielded 27.7 t/ha green mass, 7.2 t/ha dry matter with 52.9% leaves and flowers, while at the third cut - 9.6 t/ha green mass, 2.0 t/ha dry matter with 62.5% leaves, respectively.

Several literature sources have described the productivity of *Sinapis alba* plants. As a result of the research conducted in Serbia, Mikić et al. (2009) found that the white mustard lines of Serbian origin reached plant height of 80-112 cm with 4-17 lateral branches and 22-35 internodes, green forage yield 24.64-64.61 g/plant, including 21.10-50.80 g stem mass and 5.00-13.81g leaf mass. Ahlberg & Nilsson (2015) reported that the productivity of the white mustard as intermediate crop was 3235 kg/ha fresh mass.

Table 1. Some agrobiological peculiarities and the structure of the green mass of the studied species

Plant species	Plant height, cm	Stem, g		Leaf+flower, g		Yield, t/ha	
		fresh mass	dry matter	fresh mass	dry matter	fresh mass	dry matter
Sinapis alba, primary crop	116.1	28.5	5.0	62.1	12.6	35.6	7.3
Sinapis alba, secondary crop	60.4	14.5	3.4	29.2	5.5	12.8	3.8
Medicago sativa, first cut	84.5	6.2	1.6	6.9	1.8	27.7	7.2
Medicago sativa, third cut	53.8	5.9	0.9	5.8	1.5	9.6	2.0

Table 2. The biochemical composition and the nutritive value of the harvested green mass of the studied species

Indices	*Sinapis alba*		*Medicago sativa*	
	primary crop	second crop	first cut	third cut
Crude protein, g/kg DM	229	183	170	141
Ash, g/kg DM	109	92	90	90
Acid detergent fibre, g/kg DM ,	283	347	365	393
Neutral detergent fibre, g/kg DM	439	518	558	579
Acid detergent lignin, g/kg DM	48	56	63	66
Total soluble sugars, g/kg DM	63	87	63	69
Cellulose, g/kg DM	235	291	302	327
Hemicellulose, g/kg DM	156	171	193	186
Digestible dry matter, g/kg DM	759	633	611	509
Digestible organic matter, g/kg DM	661	573	541	459
Relative feed value	142	111	101	94
Digestible energy, MJ/ kg	13.08	12.22	11.96	11.57
Metabolizable energy, MJ/ kg	10.74	10.03	9.82	9.50
Net energy for lactation, MJ/ kg	6.77	6.04	5.83	5.51

Analysing the results of the fresh mass quality of the local ecotype of white mustard *Sinapis alba*, Table 2, we would like to mention that the dry matter contained 183-229 g/kg CP, 92-109 g/kg ash, 283-347 g/kg ADF, 439-518 g/kg NDF, 48-56 g/kg ADL, 63-87 g/kg TSS, 235-291 g/kg Cel, 156-171 g/kg HC, with 63.3-75.2% DMD, 57.3-66.19% OMD, RFV=111-142, 12.22-13.08 MJ/kg DE, 10.03-10.74 MJ/kg ME, 6.04-6.77 MJ/kg NEl, but *Medicago sativa* at the first and third cuts: 141-170 g/kg CP, 90 g/kg ash, 365-393 g/kg ADF, 558-579 g/kg NDF, 63-66 g/kg ADL, 63-69 g/kg TSS, 302-327 g/kg Cel, 186-193 g/kg HC, with 50.9-61.1% DMD, 45.9-54.1% OMD, RFV=94-101, 11.57-11.96-MJ/kg DE, 9.50-9.82 MJ/kg ME, 5.83-5.81 MJ/kg Nel, respectively. The white mustard grown as secondary crop contained a low amount of crude protein and high amount of structural carbohydrates, lignin, which contributed to the reduction of digestibility, relative feed value and energy concentration as compared with the forage harvested in the primary crop. The crude protein decreased and the cell wall composition also increased in the third cut forage of *Medicago sativa*.

Some authors mentioned various findings about the green mass quality of *Brassicaceae* species. According to Medvedev & Smetannikova (1981), the chemical composition of white mustard plants was 19.8% CP, 2.3% EE, 28.1% CF, 36.6% NFE and 13.1% ash. Kamalak et al. (2005) reported that wild mustard, *Sinapsis arvensis,* harvested in early flowering period contained 13.2% CP, 66.5% NDF, 54.4% ADF, 7.4% ash, 72.4% OMD, 10.9 MJ/kg ME, but the fodder harvested in mid-flowering period contained 9.8% CP, 70.7% NDF, 60.8% ADF, 8.6% ash, 69.9% OMD and 10.2 MJ/kg ME. Kshnikatkina et al. (2005) reported that the dry matter from *Sinapis alba* forage contained 148.0-177.6 g/kg dry matter, 21.26-22.18% CP, 1.60-3.31% EE, 19.45-34.00% CF, 14.82-15.80% ash, 0.58-0.90% Ca, 0.06-0.10% P. McLean. (2007) remarked that mustard can be utilised as a grazed forage crop for lambs, and contained 101 g/kg dry matter with 32.2 % CP, 25.4 % DP and 12.6 MJ/kg ME, but clover crops – 191-262 g/kg dry matter, 17.8-19.3 % CP, 12.4-13.8 % DP, 9.5-10.6 MJ/kg ME, respectively. Póti et al. (2014) compared the forage quality of green mass from two brassicaceous species and found that the chemical composition of white mustard was 154 g/kg dry matter, 20.6% CP, 2.9% EE, 19.4% CF, 8.9% ash, 48.2% NFE, 629 g/kg TDN, 11.61 MJ/kg DE, 9.52 MJ/kg ME (ME) and 5.88 MJ/kg net energy for maintenance, but oil radish fodder contained, respectively, 135 g/kg dry matter, 14.8% CP, 3.1% EE, 14.1% CF, 13.0% ash, 55.0% NFE, 616 g/kg total TDN, 11.31 MJ/kg DE, 9.32 MJ/kg ME and 5.70 MJ/kg net energy for maintenance. Lebedev & Vorobeikov (2017) found that in the Leningrad Region, Russia the dry matter productivity of white mustard varied from 12.07 to 17.4 t/ha, the dry matter contained 1.7-2.1% N, 1.0-1.4% P, 1.6-2.6% K. Wilczewski et al. (2018) mentioned that the content of macronutrients in the aboveground biomass of white mustard cultivated as stubble catch crop was 20.2 g/kg N, 3.71 g/kg P, 35 g/kg K, 17.6 g/kg Ca, 2.18 g/kg Mg. Kiliç et al. (2021) studied the feed value and digestibility in some brassica fodder crops and remarked that fodder mustard contained 205 g/kg dry matter, 12.02% CP, 2.26% EE, 33.76% CF, 9.05% ash, 43.29% NFE, 50.42% NDF, 43.84% ADF, 15.61% ADL, 6.58% HC, 28.23%Cel, 64.56% IVTD, RFV 101, but canola fodder – 227.5 g/kg dry matter, 9.60% CP, 2.16% EE, 35.20% CF, 9.05% ash, 44.83% NFE, 50.31% NDF, 41.93% ADF, 10.91% ADL, 9.37% HC, 31.03%Cel, 68.26% IVTD, RFV 104. In our previous research, we found that the rapeseed fresh mass fodder contained 227 g/kg CP, 97 g/kg ash, 285 g/kg ADF, 442 g/kg NDF, 41 g/kg ADL, 170 g/kg TSS, 244 g/kg Cel, 157 g/kg HC 75.2 % DMD, 70.9 % OMD, RFV=140, 13.07 MJ/kg DE, 10.73 MJ/kg ME, 6.75 MJ/kg NEl (Ţoţei, 2021).

Forage preservation is a key element for productive and efficient ruminant livestock farms, which provides a uniform level of high-quality feed for ruminants throughout the year. Silage is as nutritious as green fodders as it preserves the nutrients in the original form and hence it is as good for animal feeding as green fodder itself. The investigated white mustard silage was distinguished by homogeneous olive colour, pleasant smell specific of pickled cucumbers, the consistency was retained, in comparison with the initial green mass, without mould and mucus. As a result of the performed analysis (Table 2), it was determined that the pH index of the *Sinapis alba* silage was 4.74, the concentration of total organic acids is higher, butyric acid has not detected and lactic acid predominates (84.90%).

It has been found that the concentration of nutrients and energy in *Sinapis alba* silage was: 246 g/kg CP, 24.8 g/kg EE, 141 g/kg ash, 282 g/kg ADF, 411 g/kg NDF, 29 g/kg ADL, 63 g/kg TSS, 253 g/kg Cel, 129 g/kg HC, with 81.7% DMD, 71.3% OMD, RFV=151, 13.11 MJ/kg DE, 10.76MJ/kg ME, 6.78 MJ/kg NEl. As compared with the initial fresh mass, the silage from white mustard had high concentration of crude protein and ash, low content of neutral detergent fibre and acid detergent lignin, which had a positive impact on digestibility, relative feed value and net energy for lactation.

Table 3. The quality of the silage from white mustard, *Sinapis alba*

Indices	primary crop
pH index	4.12
Content of organic acids, g/kg	49.2
Free acetic acid, g/kg	3.2
Free butyric acid, g/kg	0
Free lactic acid, g/kg	13.0
Fixed acetic acid, g/kg	4.2
Fixed butyric acid, g/kg	0
Fixed lactic acid, g/kg	28.8
Total acetic acid, g/kg	7.4
Total butyric acid, g/kg	0
Total lactic acid, g/kg	41.8
Acetic acid, % of organic acids	15.04
Butyric acid, % of organic acids	0
Lactic acid, % of organic acids	84.90
Crude protein, g/kg DM	246
Crude fats, g/kg DM	24.8
Ash, g/kg DM	141
Acid detergent fibre, g/kg DM	282
Neutral detergent fibre, g/kg DM	411
Acid detergent lignin, g/kg DM	29
Total soluble sugars, g/kg DM	53
Cellulose, g/kg DM	253
Hemicellulose, g/kg DM	129
Digestible dry matter, g/kg DM	817
Digestible organic matter, g/kg DM	713
Relative feed value	151
Digestible energy, MJ/ kg	13.11
Metabolizable energy, MJ/ kg	10.76
Net energy for lactation, MJ/ kg	6.78
Calcium, % DM	1.57
Phosphorus, % DM	0.24
Carotene, mg/ kg GM	31.67

Literature sources indicate considerable variation in the chemical composition and nutritional value of Brassicaceae silages. According to Medvedev & Smetannikova (1981), white mustard silage contained 15.3 % DM, including 2.7% CP, 0.7% EE, 4.4% CF, 4.9% NFE, 2.6% ash, 22 g/kg DP and 0.1 feed unit /kg, but rapeseed silage – 12.7% DM, including 2.4% CP, 0.1% EE, 1.3% CF, 5.0% NFE, 2.7% ash, 17 g/kg DP and 0.1 feed unit/kg. Herrmann et al. (2016) studied the biochemical composition of silages made of various crops in Germany and remarked that *Brassica napus* silage contained 265 g/kg dry matter with 91.1% organic matter, pH 4.2, 6.6% lactic acid, 1.7% acetic acid, 0.1% butyric acid, 9.9% CP, 8.1% EE, 39.1% NFE, 48.5% NDF, 39.6% ADF and 7.6% ADL, but *Raphanus sativus* var. *oleiformis* silage - 115 g/kg dry matter with 81.1% organic matter, pH 4.4, 10.3% lactic acid, 3.6% acetic acid, 0.7% butyric acid, 14.9% CP, 2.6% EE, 42.0% NFE, 31.0% NDF, 34.7% ADF, 4.3% ADL. Kiliç et al. (2021) found that mustard silage contained 234.3 g/kg dry matter, 14.6% CP, 3.26% EE, 46.78% CF, 9.05% ash, 24.14% NFE, 48.25% NDF, 41.40% ADF, 6.77% ADL, 7.15% HC, 34.33% Cel, 66.84% IVTD, RFV = 110, but canola silage - 243.2 g/kg dry matter, 10.32 % CP, 3.34 % EE, 35.68% CF, 11.10% ash, 39.58% NFE, 50.61% NDF, 44.58% ADF, 9.14% ADL, 5.84% HC, 35.69% Cel, 67.74% IVTD, RFV= 99.

The increasing energy demand that has been noticed worldwide, the risk of depletion of fossil energy sources and their injurious impact on environment led to our coal-based society recognizing the potential of renewable energy sources. Versatile energy sources such as biomass, including biogas production, can play an important role next to solar, wind and hydropower utilization. Renewable energy sources coming from agricultural crops could play an important role in terms of energy supply and positive environmental effects. Biogas has become important as a renewable source of energy, because of its decentralized approach. The use of plant biomass as substrate for biogas production has recently become of major interest in Europe. Plant biomass may be used for anaerobic digestion directly after harvest and as ensiled substrates. Anaerobic decomposition will produce methane, carbon dioxide, some hydrogen and a final product that can be used as a fertilizer. The results regarding the quality of the *Sinapis alba* substrates and the potential for obtaining biomethane are shown in Table 4. The carbon to nitrogen ratio constitutes a basic factor governing the correct course of methane fermentation. Methanogenic bacteria need a suitable ratio of carbon to nitrogen for their metabolic processes, ratios higher than 30:1 were found to be unsuitable for optimal digestion, and ratios lower than 10:1 were found to be inhibitory, due to low pH, poor buffering capacity and high concentrations of ammonia in the substrate. The nitrogen concentration in the tested *Sinapis alba* substrates ranged from 29.3 g/kg to 36.6 g/kg, the estimated content of carbon - from 477.2 g/kg to 504.4%, the C/N ratio varied from 12.2 to 17.2, but the *Medicago sativa* substrates contained 26.6-27.2 g/kg nitrogen, 500.0 g/kg carbon and C/N = 18.4-18.9. Essential differences were observed between the lignin contents. The white mustard substrates contained acceptable amounts of hemicellulose and low amounts of lignin. The biochemical methane potential of tested white mustard substrates varied from 281 l/kg VS to 330 l/kg VS, but in alfalfa substrates - from 263 l/kg VS to 270 l/kg VS The best methane potential was achieved in *Sinapis alba* silage substrate - 330/kg VS, the lowest – in the third cut fresh mass substrate of *Medicago sativa*.

Table 4. The biochemical biomethane production potential of the investigated substrates

Indices	*Sinapis alba*			*Medicago sativa*	
	fresh mass, primary crop	fresh mass, secondary crop	silage, primary crop	fresh mass, first cut	fresh mass, third cut
Minerals, g/kg DM	109.0	92.0	141.0	90	90
Nitrogen, g/kg DM	36.6	29.3	39.4	27.2	26.6
Carbon, g/kg DM	495.0	504.4	477.2	500.0	500.0
Ratio carbon/nitrogen	13.5	17.2	12.2	18.4	18.8
Cellulose, g/kg DM	235	291	253	302	327
Hemicellulose, g/kg DM	156	171	129	193	186
Acid detergent lignin, g/kg DM	48	56	29	63	69
Biomethane potential, L/kg VS	295	281	330	270	263

According to Zubr (1986), the methane potential of mustard substrate was 300 l/kg VS. but – of rapeseed silage substrate - 330 l/kg. Molinuevo-Salces et al. (2013) reported that, in four different locations of Denmark, the methane yields of *Sinapis alba* substrates ranged between 251 and 379 l/kg VS or 72-1077 m^3 /ha net energy yield per hectare, but - from *Brassica napus* 362-448 l/kg VS or 48-470 m^3 /ha and from *Raphanus sativus* 356-474 l/kg VS or 66-948 m^3/ha. Ahlberg & Nilsson (2015) found that the accumulated specific methane yield for the intermediate crops after 30 days BMP tests ranged from 278 to 290 l/kg VS in the white mustard substrates, 297-304 l/kg VS in oilseed radish substrates and 305-343 l/kg VS in hairy vetch substrates. Murphy et al. (2011) reported that oilseed rape produced 2.5-7.8 t/ha dry matter and the measured methane yield was 240-340 m^3/t VS.

Herrmann et al. (2016) mentioned that rapeseed silage substrates had C/N=29, biochemical methane potential 259.2 l/kg VS; the fodder radish silage substrates had C/N=17 and biochemical methane potential 29l.0 l/kg VS, but alfalfa grass mixtures silage: C/N=18 and biochemical methane potential 280.0 l/kg VS. In our previous research (Ţîţei, 2016; 2021), we found that the *Isatis tinctoria* substrates achieved a biochemical methane productivity of 242-251 l/kg VS and *Brassica napus* substrates 309-324 L/kg. Słomka, & Wójcik Oliveira (2021) reported that the concentration of macronutrients in the white mustard substrate depending on the location were 40.66-41.58% organic carbon and 2.6-2.08% nitrogen, C/N=15.5-19.9, whereas its biogas potential amounted to 350–440 m^3/t DM.

CONCLUSIONS

The local ecotype of white mustard, *Sinapis alba,* cultivated under the climatic conditions of the Republic of Moldova, is characterized by optimal growth and development rates. If grown as primary crop, sown in spring, it has a forage productivity of 35.6 t/ha fresh mass or 7.3 t/ha dry matter, and if grown as secondary crop, it yields 12.8 t/ha fresh mass or 3.8 t/ha dry matter.

The forage dry matter contains 18.3-22.9% CP, 9.2-10.9% CA, 43.9-51.8% NDF, 28.3-34.7% ADF, 4.8-5.6% ADL, 23.5-29.1 % Cel, 15.6-17.1 % HC, 6.3-8.7% TSS, 63.3-75.9% DMD, 57.3-66.1% DOM, RFV=111-142, 12.22-13.08 MJ/kg DE, 10.03-10.74 MJ/kg ME and 6.04-6.77 MJ/kg NEl.

White mustard is characterized by pH = 4.12, it contains 7.4 g/kg acetic acid, 41.8/kg lactic acid, 24.6% CP, 14.1% CA, 41.1% NDF, 28.2% ADF, 2.9% ADL, 25.3% Cel, 12.9% HC, 5.3% TSS, 81.7% DMD, 71.3% DOM, RFV=151, 13.11 MJ/kg DE, 10.76 MJ/kg ME and 6.78 MJ/kg NEl.

The biochemical methane potential of fresh mass and silage substrates from white mustard reaches 281-330 L/kg organic matter.

The local ecotype of white mustard may be used as multi-purpose crop to prepare green fodder and silage for ruminants and also as substrate for biomethane production.

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REFERENCES

Ahlberg, I., Nilsson, T.L.S. (2015). *Investigation on the use of intermediate crops for anaerobic digestion as a renewable source of energy.* Lund University. *https://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=5472252&fileOId=5472409*

Badger, C.M., Bogue, M.J., Stewart, J. (1979). Biogas production from crops and organic wastes. *New Zeland Journal of Science*, *22*. 11–20.

Dandikas, V., Heuwinkel, F., Drewes, J.E., Koch, K., (2014). Correlation between biogas yield and chemical composition of energy crops. *Bioresource Technology*, *174*. 316–320.

Dukarska, D., Łęcka, J., Szafoni, K. (2011). Straw of white mustard (*Sinapis alba*) as an alternative raw material in the production of particle boards resinated with uf resin. *Acta Scientiarum Polonorum Silvarum Colendarum Ratio et Industria Lignaria*, *10*(1), 19–28

Duke, J.A. (1983). *Sinapis alba* L. Handbook of Energy Crops.unpublished.*https://hort.purdue.edu/newcrop/duke_energy/Sinapis_alba.html*

Fuksa, P., Hakl, J., Brant, V. (2013). Energy balance of catch crops production. *Zemdirbyste-Agriculture*, *100*(4), 355–362

Glukhov, M.M. (1974). Honey-bearing plants. M.,Kolos, 304 p. [in Russian].

Herrmann, C., Idler, C., Heiermann, M. (2016). Biogas crops grown in energy crop rotations: Linking chemical composition and methane production characteristics. *Bioresource Technology*, *206*. 23–35.

Ion, N., Odoux, J.F., Vaissiere, B.E. (2018). Melliferous potential of weedy herbaceous plants in the crop fields of Romania from 1949 to 2012. *Journal of Apicultural Science, 62*(2), 1–17.

Kamalak, A., Canbolat, O., Gurbuz, Y., Ozkan, C. O., Kizilsimsek, M. (2005). Determination of nutritive value of wild mustard, *Sinapsis arvensis* harvested at different maturity stages using in situ and in vitro measurements. *Asian-Australasian Journal of Animal Science*, *18*(9), 1249–1254.

Kayaçetin, F. (2020). Botanical characteristics, potential uses, and cultivation possibilities of mustards in Turkey: a review. *Turkish Journal of Botany, 44.* 101–127.

Kılıç, Ü., Erişek, A., Garipoğlu, A., Ayan, İ., Önder, H. (2021). The effects of different forage types on feed values and digestibilities in some brassica fodder crops. *Türk Tarım ve Doğa Bilimleri Dergisi Turkish Journal of Agricultural and Natural Sciences, 8* (1), 94–102.

Kostenko, S.I., Kostenko, N.Yu., Sedova, E.G., Kharkov K.S. (2021). The problems of breeding new varieties of forage and other plants for improving the soil in organic farming in Russia. *IOP Conference Series: Earth and Environmental Science, e 901 012053.*

Kshnikatkina, A.N., Gushchina, V.A., Galiullin, A.A., Varlamov, V.A., Kshnikatkin, S.A. (2005). *Nontraditional fodder crops.* RIO PGSKHA Penza. 240 pp. [in Russian].

Lebedev, V.N., Vorobeikov, G.A. (2017). Productivity of *Brassicaceae* plants inoculated with bacterial preparations. *Transactions of Karelian Research Centre of the Russian Academy of Sciences*, *12*. 80–86.

McLean, B. (2007) Alternative forage crops for finishing lambs. ADAS Pwllpeiran *https://orgprints.org/id/eprint/10813/1/altcrops07.pdf*

Murphy, J., Braun, R., Weiland, P., Wellinger, A. (2011). Biogas from Crop Digestion. Task 37 Energy from Biogas. 24p. https://www.ieabioenergy.com/wpcontent/uploads/2011/10/Update_Energy_crop_2011.pdf

Medvedev, P.F., Smetannikova, A.I. (1981). The forage crops of European part of the USSR. Leningrad, Kolos. [in Russian].

Mikić, A., Mihailović, V., Petrović, S., Dimitrijević, M., Vasiljević, S., Karagić, O., Pataki, I. (2009). Green forage yield components in white mustard (*Sinapis alba* L. subsp. *alba*). *Cruciferae Newsletter*, *28*. 20–21.

Mitrovic, P.M., Stamenkovic, O.S., ´Bankovic-Ilic, I., Djalovic, I.G., Nježic, Z.B., Farooq, M., Siddique, K.H.M., Veljkovic, V.B. (2020) White mustard ´ (*Sinapis alba* L.) oil in biodiesel production: a review. *Frontiers in Plant Science, 11*. 299.

Molinuevo-Salces, B., Ahring, B. K., & Uellendahl, H. (2013). Catch crops as an alternative biomass feedstock for biogas plants. In "Dry Fermentation, Substrate Treatment and Digestate Treatment" Berlín, http://ibbk.fachgruppe-biogas.de/index.php?id=32&L=1&eventId=91

Oplinger, E.S., Oelke, E.A., Putnam, D.H., Kelling, K.A., Kaminsid, A.R., Teynor, T.M., Doll, J.D., Durgan, B.R. (1991). Mustard. In. *Alternative Field Crops Manual. https://hort.purdue.edu/newcrop/afcm/mustard.htmll*

Peng, C., Zhang, T., Zhao, G., and Wang, S. (2013). Analysis on fat–soluble components of *Sinapis semina* from different habitats by GC–MS. *Journal of Pharmaceutical Analysis, 3*. 402–407.

Popa, E., Cîrnu, I. (1960). Plante melifere din R.P. Romînă. *Apicultura*, *33*. 6–11.

Póti, P., Pajor, F., Bodnár, Á., Penksza, K., Tőzsér, J., Gyuricza, C. (2014). Potential of second crops of oil radish and white mustard as fall grazing pasture for german mutton merino sheep. *Notulae Botanicae Horti Agrobotanici, 42*(1), 286–288.

Rahman, M., Amina Khatun, A., Liu, L., Barkla, B. J. (2018). Brassicaceae mustards: traditional and agronomic uses in Australia and New Zealand. *Molecules, 23.* 231.

Santos, C.D., Abboud, A.C., & Carmo, M.G. (2021). Biofumigation with species of the *Brassicaceae* family: a review. *Ciencia Rural, 51*. *https://doi.org/10.1590/0103-8478cr2020040*

Słomka, A., Wójcik Oliveira, K. (2021). Assessment of the biogas yield of white mustard (*Sinapis alba*) cultivated as intercrops. *Journal of Ecological Engineering, 22*(7), 67–72.

Ţîţei, V. (2016). Agrobiological peculiarities and prospects for valorification of woad, *Isatis tinctoria* L., in Moldova. *Lucrări Ştiinţifice, seria Agronomie, 59*(2), 267–272.

Ţîţei, V. (2021). The quality of fresh and ensiled biomass of *Brassica napus oleifera* and prospects of its use. *Scientific Papers. Series A. Agronomy*, *64*(2). 330–335.

Wilczewski, E., Harasimowicz-Hermann, G., Sokół, B. (2018). The effect of weather conditions on the yield and macronutrient content in the aboveground biomass of white mustard (*Sinapis alba* L.) cultivated as stubble catch crop. *Acta Scientiarum Polonorum. Agricultura, 17*(3), 143–151.

Zubr, J. 1986. Methanogenic fermentation of fresh and ensiled plant materials. *Biomass, 11*. 156–171.