THE QUALITY AND POTENTIAL APPLICATION OF BIOMASS FROM THE *Avena sativa* AND *Hordeum vulgare* SPECIES

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Abstract. We investigated the quality indices of the biomass from *Avena sativa* and *Hordeum vulgare* species which were grown in the experimental plot of the "Alexandru Ciubotaru" National Botanical Garden (Institute), Chisinau, Republic of Moldova. The results revealed that the dry matter of whole plants of the studied species contained 9.5-11.9% CP, 6.5-7.5% ash, 34.9- 35.6% CF, 36.7-37.4% ADF, 62.7-62.8% NDF, 2.9-4.6 % ADL, 16.3-16.7% TSS, with forage value 598-603 g/kg DDM, RFV= 89, 11.84-11.92 MJ/kg DE, 9.72-9.79 MJ/kg ME and 5.37-5.81 MJ/kg NEl. The nutrient content and energy value of the prepared hays were: 9.0-10.5% CP, 6.9-7.4% ash, 38.1- 43.5% CF, 40.4-45.6% ADF, 66.0-73.6% NDF, 4.5-5.0 % ADL, 5.1-111% TSS, 534-574 g/kg DDM, 10.69-11.40 MJ/kg DE, 8.76-9.36 MJ/kg ME, 4.79-5.39 MJ/kg NEl. The ensiled forage contained 10.2-12.9% CP, 7.8-11.4% ash, 33.8-39.3% CF, 34.7-41.3% ADF, 57.1.0-69.9% NDF, 1.8-4.0 % ADL, 2.6-12.9% TSS, 32.9-37.3% Cel, 22.4-28.6 % HC, 567-619 g/kg DDM, RFV= 76-100, 11.28-12.21MJ/kg DE, 9.26-10.06 MJ/kg ME and 5.29-6.10MJ/kg NEl. The biochemical methane potential of the studied substrates from *Avena sativa* reaches 329-355 l/kg VS, but *Hordeum vulgare* substrates – 361-379 l/kg VS. The collected straw from the studied species contained 6.2-4.5% CP, 5.9-8.2% ash, 5.6-6.8 % ADL, 44.3-48.2% Cel, 23.2-30.1 % HC with biochemical methane potential 282-308 l/kg VS and theoretical ethanol potential 541-574 L/t.

Keywords: *Avena sativa,* biochemical composition, biomethane, ensiled forage, fodder value, green mass, hay, *Hordeum vulgare,* straw, theoretical ethanol potential.

Rezumat. Calitatea biomasei a speciilor *Avena sativa* și *Hordeum vulgare* și potențialul ei de valorificare. S-au investigat indicii de calitate a biomasei speciilor *Avena sativa* și *Hordeum vulgare*, cultivate în sectorul experimental din Grădina Botanică Națională (Institut), Chişinău, Republica Moldova. Rezultatele obținute relevă că substanța uscată a plantelor recoltate conține: 9.5-11.9% proteină brută (CP), 6.5-7.5% cenușă, 34.9- 35.6% celuloză brută (CF), 36.7-37.4% fibre solubile în detergent acid (ADF), 62.7-62.8% fibre solubile în detergent neutru (NDF), 2.9-4.6 % lignină sulfurică (ADL), 16.3-16.7% total zaharuri solubile (TSS), cu o valoarea nutritivă de 598-603 g/kg substanță uscată digestibilă (DDM), valoarea relativă a furajului RFV= 89, 11.84-11.92 MJ/kg energie digestibilă (DE), 9.72-9.79 MJ/kg energie metabolizantă (ME) și 5.37-5.81 MJ/kg energie netă pentru lactație (NEl). Conținutul de nutrienți și valoarea energetică a fînurilor preparate: 9.0-10.5% CP, 6.9-7.4% cenușă, 38.1- 43.5% CF, 40.4-45.6% ADF, 66.0-73.6% NDF, 4.5-5.0 % ADL, 5.1-111% TSS, 534-574 g/kg DDM, 10.69-11.40 MJ/kg DE, 8.76-9.36 MJ/kg ME, 4.79-5.39 MJ/kg NEl. Furajul însilozat conține 10.2-12.9% CP, 7.8-11.4% cenușă, 33.8-39.3% CF, 34.7-41.3% ADF, 57.1.0-69.9% NDF, 1.8-4.0 % ADL, 2.6-12.9% TSS, 32.9-37.3% Cel, 22.4-28.6 % HC, 567-619 g/kg DDM, RFV= 76-100, 11.28-12.21MJ/kg DE, 9.26-10.06 MJ/kg ME și 5.29-6.10MJ/kg NEl. Potențialul biochimic de obținere a metanului în substraturile cercetate de *Avena sativa* atinge valoari de 329-355 la 333 l/kg materie organică, iar în substraturile de *Hordeum vulgare* 361-379 l/kg materie organică. Paiele colectate de la speciile cercetate conțin 4.5-6.2% CP, 5.9-8.2% cenușă, 5.6-6.8 % ADL, 44.3-48.2% Cel, 23.2-30.1 % HC cu un potential biochimic de obținere a metanului de 282-308 l/kg și de bioethanol 541-574 L/t materie organică.

Cuvinte cheie: *Avena sativa,* compoziție biochemică, biometan, fân, furaj însilozat, masă verde, paie, *Hordeum vulgare,* potențial teoretic de obținere a etanolului.

INTRODUCTION

Currently, the *Poaceae* species are the herbaceous plants most commonly used as food, feed and bedding for animals, raw material for biorefinery to produce fuels, power, heat, and value-added chemicals. Corn, *Zea mays* L. is the most popular *Poaceae* species used for livestock feeding and as energy crop for biogas and bioethanol production, but its cultivation, the application of mineral fertilizers and pesticides require high financial and fossil fuel inputs. The adverse climatic conditions, water deficiency in soil, associated with high temperatures and strong evapotranspiration from the last decades, had serious consequences on the corn production. Given the climatic conditions and the limited energy and water resources in the Republic of Moldova, traditionally cultivated cereal forage should be reintroduced in crop rotation and new cultivars species should be bred, characterized by high adaptability and stable productivity, possessing 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. Recently, significant attention, both globally and regionally, has been given to some multi-purpose *Poaceae* crops, such as common oat *Avena sativa* L. and winter barley *Hordeum vulgare* L.

Oat, *Avena sativa,* was domesticated approximately 3000 years ago, under the more favourable climatic conditions of Europe. It is an annual herbaceous plant with a stem (culm) of 5-7 internodes, smooth, glabrous or hairy in the area of the nodes, hollow inside, about 3-6 mm thick and 100-150 cm tall, forming a bush of 3-4 shoots and the main shoot having one node more than the rest of the shoots. The leaves are flat, with 11-13 veins, up to 20 to 45 cm long and 8 to 30 mm wide, glabrous or ciliate on margins, with glabrous sheaths, rarely hairy, there are no leaf lobes; the ligule is white, membranous, medium or short, toothed at the tip. The inflorescence is a pyramidal panicle, with ramifications grouped in alternate clusters on the main axis, in the form of half-whorls, in 5-6 tiers, 15-30 cm long.

Each ramification ends in a spikelet, and the spikelets are attached to the ramification through short pedicels. The spikelets have 2-3 flowers. The glumes – with prominent longitudinal veins, 18-25 mm long, completely cover the flowers. The lower palea is elongated, convex, straight or geniculate on the dorsal side, yellowish-white or brown, with prominent veins, glabrous or rarely short hairy only at the base, with 2 teeth without awn. It blooms in June, pollination is autogamous, not excluding allogamy. The fruit a hairy caryopsis, with adherent paleae, whitish-yellowish, sometimes greyish-brown. The shape of the grain is spindle-shaped, with a groove on the ventral side. The weight of 1000 seeds is 20-35 g. Upon germination, oats develop three embryonic roots, form a fibrous root system, stronger and deeper than other cereals and have a great capacity to utilize nutrients from the heavy soluble compounds of the soil. Oat plants survive high soil acidity, thrive on loamy sands, loamy, clay and peat soils (GASHKOVA, 2008; ŢÎŢEI & ROŞCA, 2021). Barley, *Hordeum vulgare*, was one of the first cultivated crops, and it is the only cultivated species of the *Hordeum* genus, which contains about 32 species and 45 taxa. It is a self-pollinating diploid cereal crop domesticated from its wild relative, *Hordeum spontaneum*. Barley is an annual herbaceous plant. Stalk length varies greatly, from 45 to 160 cm and its thickness – from 1.7 to 6.5 mm, depending on the characteristic traits of varieties and growth conditions. Leaves are alternate, 8 to 25 cm long and 0.4 to 3.2 cm wide. Leaf blades form a sharp angle with the stalk with corniculate auriculae at the both sides of the base, the colour may vary between different shades of green. The tips of the auriculae overlap. The auriculae are whitish. Sometimes they are tinged with anthocyanin and are violet in colour. The shape and colour of barley auriculae allow distinguishing between different cultivars. Barley stalk, its leaf sheath, the leaf and the spike are often covered to a different degree in a waxy film. This is especially strong in arid zones. The upper leaf is smaller, but is similar in shape to the lower ones. The second tier downwards is considered to have the most typical leaves. Inflorescence is a spike without a terminal fruit-bearing spikelet. A barley spike consists of a flat geniculate rhachilla and some alternate sessile spikelets, located in its notches. Each genicula of the barley rhachilla is from 2 mm (with solid-eared varieties) to 4 to 5 mm long (with loose-eared varieties). Each barley spikelet has one floret and forms one caryopsis. Six-rowed barley varieties usually have 3 fertile spikelets at each rhachilla notch. With two-rowed barley varieties, only the middle spikelet is fertile. The two lateral ones remain barren. Each barley spike has 2 spike glumes and 2 floral glumes (outer and inner), 1 gynoecium, 3 stamens and 2 lodicules. Spike glumes may be narrow, linear-lanceolate (up to 1 mm wide) or wide (up to 2 mm wide). They may have hairs or be smooth, often with a very thin awn. The form and other features of hairs on barley spike glumes are constant and are taken into consideration when patenting a cultivar. The inner floral glume adheres to the rhachilla. Is has a two-keeled shape and is always awnless. The outer floral glume in its uppermost part transforms into an awn which may be scabrose or smooth, long or short. Barley flowers are bisexual. Its androecium consists of 3 anther filaments with anthers on their ends. The ovary is unilocular with one egg-shaped ovule. A barley flower is usually fertilized with its own pollen. Thus, barley is cleistogamic. Cross-fertilization occurs with cultivated barley in exceptional cases while self-fertilization is typical for most modern cultivars. Barley fruit is a caryopsis 7 to 10 mm long and 2 to 3 mm in diameter. The caryopsis is diamond-shaped, oblong or elliptical, its colour ranges from yellow and green to brown and violet. 1000 barley kernels weigh from 37 to 48 g. The root system of barley is fibrous. Its primary (embryonic) roots are to be distinguished from its secondary (nodose) roots. Embryonic roots issue from the embryo's rootlet and continue their development preserving their functions till the vegetation of the plant is over. Secondary roots develop underground. They issue from the lower stalk nodes nearer to the surface of the ground (BADR et al., 2000; GASHKOVA, 2008).

The goal of this research was to evaluate the quality indices of the green mass, ensiled mass, hay and straw from common oat *Avena sativa* and winter barley *Hordeum vulgare* as fodder for animals, as well as feedstock for the production of renewable energy.

MATERIALS AND METHODS

The cultivar of winter barley *Hordeum vulgare* 'Excelent', created at the Research Institute for Field Crops “Selectia” Bălți, Republic of Moldova, and common oat *Avena sativa* 'Sorin' created at the Agricultural Research and Development Station Lovrin, România and cultivated in the experimental plot of the National Botanical Garden (Institute) “Alexandru Ciubotaru”, Chişinău, latitude 46°58′25.7″N and longitude N28°52′57.8″E, served as subjects of the research. The plant samples were collected in the pre-flowering stage. The harvested plants were chopped into 1.5-2.0 cm small pieces, with a laboratory forage chopper; the dry matter content was detected by drying the samples to a constant weight, at 105°C. The conserved forage – silage was prepared from fresh mass, and haylage – from pre-wilted in the field plant, chopped and compressed in well-sealed glass containers, stored at ambient temperature (18-20°C). After 45 days, the containers were opened, and the sensorial and fermentation indices of the conserved forage were determined in accordance with standard laboratory procedures – the Moldavian standard SM 108*. The fresh mass and fermented fodder samples were dehydrated in an oven with forced ventilation at a temperature of 60°C; at the end of the fixation, the biological material was finely ground in a laboratory ball mill. The hay was dried directly in the field. Straws were collected after the grains have been removed. The quality of the biomass was evaluated by analysing such indices as: crude protein (CP), crude fibre (CF), ash, acid detergent fibre (ADF), neutral detergent fibre (NDF), acid detergent lignin (ADL) and total soluble sugars (TSS) have been determined by the 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 the 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). The theoretical ethanol potential (TEP) was calculated according to the equations of GOFF et al., (2010) based on conversion of hexose (H) and pentose (P) sugars.

RESULTS AND DISCUSSIONS

As a result of the phenological observations, it has been found that the studied annual *Poaceae* species *Avena sativa* and *Hordeum vulgare* 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 middle October, 9-13 days after sowing. The development of shoots was observed in the second half of April, and their intensive growth – in May. We would like to mention that, at the time of harvesting the whole plants, the studied species differed in height and leaf stem ratio in the forage. Thus, the *Avena sativa* plants reached 87-92 cm with 33-39% leaves and spikelets in the fodder, while *Hordeum vulgare* 98-107 cm with 43-57% leaves and spikelets in the fodder. The biochemical composition, nutritive and energy value of the green mass from the tested species are presented in Table 1. The dry matter of whole plants of studied species contained 9.5-11.9% CP, 6.5-7.5% ash, 34.9- 35.6% CF, 36.7-37.4% ADF, 62.7-62.8% NDF, 2.9-4.6 % ADL, 16.3-16.7% TSS, 25.8-26.1 % HC, 32.8-33.8 % Cel with forage value 598-603 g/kg DDM, RFV= 89, 11.84-11.92 MJ/kg DE, 9.72-9.79 MJ/kg ME and 5.37-5.81 MJ/kg Nel. We found that *Hordeum vulgare* whole plants were characterised by a high content of crude protein and a low content of acid detergent lignin.

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

Indices	*Avena sativa*		*Hordeum vulgare*	
	green mass	hay	green mass	hay
Crude protein, g/kg DM	95	105	119	90
Crude fibre, g/kg DM	356	381	349	435
Ash, g/kg DM	65	74	75	69
Acid detergent fibre, g/kg DM	374	404	367	456
Neutral detergent fibre, g/kg DM	627	660	628	736
Acid detergent lignin, g/kg DM	46	50	29	45
Total soluble sugars, g/kg DM	167	111	163	51
Cellulose, g/kg DM	328	354	338	401
Hemicellulose, g/kg DM	258	256	261	280
Dry matter digestibility, %	59.8	57.4	60.3	53.4
Digestible energy, MJ/kg DM	11.84	11.40	11.92	10.69
Metabolizable energy, MJ/kg DM	9.72	9.36	9.79	8.78
Net energy for lactation, MJ/kg DM	5.73	5.39	5.81	4.79
Relative feed value	89	81	89	67

Some authors mentioned various findings about the quality of the green mass from studied species. According to HADJIPANAYIOTOU et al., (1983) the dry matter content and chemical composition of *Hordeum vulgare* forage was 180 g/kg DM, 14.1 % CP, 3.7 % fat, 17.5 % CF, 52.0 % NDF, 34.0 %, ADF, 2.6 % lignin, 12.5% ash, 66.0%OMD and 18.0 MJ/kg DE. KHORASANI et al., (1997) the barley plant contained 451 g/kg DM, 91.6% OM, 11.7 % CP, 26.7 % ADF, 49.9% NDF, 3.25 % ADL and oats plant 393 g/kg DM, 92.8% OM, 11.2 % CP, 34.1 % ADF, 54.7% NDF, 4.01 % ADL, respectively. BURLACU et al., (2002) remarked that *Hordeum vulgare* plants contained 175 g/kg DM, 91.2% OM, 13.7 % CP, 2.8% EE, 27.0% CF, 48.0% NFE, 9.0% sugars, 4% starch and 18.1 MJ/kg GE, while *Avena sativa* plants contained 170 g/kg DM, 90.1% OM, 10.3 % CP, 3.1% EE, 26.5% CF, 50.2% NFE, 14.2% sugars, 0.8% starch, 30.0% ADF, 6.6 % lignin, 22.3% Cel, 17.3 % HC and 17.8 MJ/kg GE. HEIERMANN et al., (2009) revealed that the barley whole plants harvested in the anthesis stage had a nutrient content of 188 g/kg DM, 90.2% OM, 15.8 % CP, 30.8 % CF, 2.6% EE, 8.7 % sugar, 0.9 % starch, but in milk stage – 274 g/kg DM, 93.2% OM, 13.1 % CP, 21.4 % CF, 2.2% EE, 9.4 % sugar, 16.3 % starch. KAMBLE et al., (2011) mentioned that barley green forages contained 123 g/kg DM, 15.5% CP, 3.2% EE, 54.9% NDF, 1.8% ADL, 30.3% ADF, 24.5% HC, 22.2% Cel and oat green forages – 121 g/kg DM, 13.5% CP, 3.1% EE, 50.8% NDF, 1.7% ADL, 32.9% ADF, 17.9% HC, 22.5% Cel. KOCER & ALBAYRAK (2012) found that the barley biomass harvested in June contained 10.46% CP, 57.37% NDF, 31.84% ADF, 60.24% TDN, RFV=103.93 and oat biomass – 10.87% CP, 59.12% NDF, 34.40% ADF, 56.67% TDN, RFV=97.45, respectively. HEUZE et al., (2015, 2016) reported that the average feed value of *Hordeum vulgare* plants was: 250 g/kg dry matter, 11.0% CP, 3.8% EE, 28.1% CF, 57.6% NDF, 32.7% ADF, 2.4% lignin, 8.0% starch, 7.8% WSC, 11.5% ash, 4.9 g/kg Ca and 1.7 g/kg P, 69.1% DOM, 17.3 MJ/kg GE, 11.4 MJ/kg DE and 9.2 MJ/kg ME, while *Avena sativa* plants contained 263 g/kg dry matter, 10.5% CP, 4.9% EE, 30.2% CF, 54.2% NDF, 31.0% ADF, 4.5% lignin, 7.1% WSC, 10.1% ash, 3.8 g/kg Ca and 2.2 g/kg P, 67.0% DOM, 18.0 MJ/kg GE, 11.5 MJ/kg DE and 9.3 MJ/kg ME. KUMAR et al., (2015) reported that the chemical composition and nutritive value of oat green fodder was 8.80% CP, 2.74 % EE, 53.25% NDF, 27.41% ADF, 3.73 % ADL, 25.84% HC, 20.22% Cel, 11.97% ash, 8.34 MJ/kg ME, 567.2 g/kg TDDM, 5.85.5 g/kg TDOM. ASKEL et al., (2017) found that the dry matter content and biochemical composition of barley forage was 247.8 g/kg DM, 8.87 % CP, 39.20 % ADF, 70.56% NDF, 4.66% ash. TAMBARA et al., (2017) determined that the biochemical composition of dry matter from *Avena sativa* plants was 24.11% CP, 40.50% NDF and 18.86% ADF, while from *Avena strigosa* 24.38% CP, 43.53% NDF and 19.83% ADF. HORST et al., (2018) reported that the *Avena sativa* forage harvested in the pre-flowering stage contained 185.1-243.4 g/kg DM, 8.85-9.96% CP, 68.85-70.97% NDF, 38.69-44.89% ADF, 26.08-28.16% HC, 5.57-5.62% ash, 564.4-607.6 g/kg TDN, RFV=74.09-84.59 and 0.664-1.029 Mcal/kg NEl, while *Hordeum vulgare* forage contained 251.8-267.9 g/kg DM, 8.65-8.87% CP, 66.85-70.56% NDF, 38.80-39.20% ADF, 28.85-28.64% HC, 4.66-5.05% ash, 604.0-606.8 g/kg TDN, RFV=79.68-82.39 and 0.998-1.022 Mcal/kg NEl. LUIS et al., (2020) found that the harvested barley plants contained 262.5g/kg DM, 8.07% CP, 51.76% NDF, 34.01% ADF, 7.48% ash and oat plants – 166.8 g/kg DM, 13.96% CP, 46.70% NDF, 27.80% ADF, 10.66% ash. BACCHI et al., (2021) evaluating of the quality of annual forages, they mentioned that *Hordeum vulgare* plants harvested in beginning of the earing stage contained 178.6 g/kg DM with 9.58 % CP, *Avena sativa* plants – 201.4 g/kg DM with 10.56 % CP, *Lolium multiflorum* plants contained 217.2 g/kg DM with 8.67 % CP, while *Hordeum vulgare* forage harvested in the hard dough stage contained 348.6 g/kg DM with 8.71 % CP, *Avena sativa* forage 358.4 g/kg DM with 6.63 % CP and *Lolium multiflorum* forage 322.9 g/kg DM with 6.41 % CP. MA et al., (2021) revealed that the nutrient composition of naked oat *Avena nuda* forage was 5.94% CP, 63.83% NDF, 38.28% ADF, 7.99% ash, 3.81% starch, 53.61 % TDN, 59.08 % DDM, RFV=86.11 and RFQ=81.95, while for barley grass *Hordeum violaceum* forage it was 8.90% CP, 67.33% NDF, 37.79% ADF, 8.53% ash, 2.05% starch, 53.87 % TDN, 59.35 % DDM, RFV=82.02 and RFQ=78.09. PATIDAR et al., (2022) remarked that the nutritive value of the oat hay was: 87.68%OM, 10.80% CP, 2.10% EE, 10.84% starch, 53.50% NDF, 47.86% ADF, 10.80% lignin, 55.06% TDN, 16.62MJ/kg GE, 10.23 MJ/kg DE and 8.44 MJ/kg ME. RADY et al., (2022) reported that the nutritive value of oat monoculture plants was 901.9 g/kg OM, 8.30% CP, 2.58 % EE, 11.06% NSC, 69.16 % NDF, 64.67% ADF, 4.48%HC, 55.39% Cel, 11.29% lignin, 533.1 g/kg TDDM, 508.2 g/kg TDOM and barley monoculture plants – 901.8 g/kg OM, 9.94% CP, 1.6 % EE, 19.62% NSC, 59.02 % NDF, 54.15% ADF, 4.87%HC, 41.05%Cel, 13.10% lignin, 637.2 g/kg TDDM, 620.1 g/kg TDOM, respectively.

Forage quality is commonly determined by various factors. Storage conditions play a vital role in maintaining forage quality. Ensiling and haying are the two most common forage preservation methods for farmers. Hay is more marketable than silage, but the process of haying is more difficult to mechanize. Farmers select a preservation method according to their requirements and the weather conditions. Analysing the results of the hay quality of the studied species, Table 1, we found that the nutrient content and energy value of prepared hays were: 9.0-10.5% CP, 6.9-7.4% ash, 38.1- 43.5% CF, 40.4-45.6% ADF, 66.0-73.6% NDF, 4.5-5.0 % ADL, 5.1-111% TSS, 25.6-28.0 %HC, 35.4-40.1 %Cel 534-574 g/kg DDM, 10.69-11.40 MJ/kg DE, 8.76-9.36 MJ/kg ME, 4.79-5.39 MJ/kg NEl. As compared with the harvested mass, the prepared hays have high concentration of cell wall fractions and low total soluble sugars. We would like to mention that *Avena sativa* hay is characterized by a higher content of crude protein, optimal content of total soluble sugars and reduced fibre fractions, which had a positive impact on the nutritional value and energy supply of the feed. Literature includes information regarding the chemical composition and nutritional value of prepared hay. HADJIPANAYIOTOU et al., (1983) remarked that, the chemical composition of the dry matter of *Hordeum vulgare* hay was 13.5 % CP, 2.4 % fat, 28.5 % CF, 61.0 % NDF, 37.0 %, ADF, 3.8 % lignin, 9.4 % ash, 59.0%OMD and 10.3 MJ/kg DE. BURLACU et al., (2002) mentioned that the quality of the hay prepared from *Avena sativa* was 8.0 % CP, 3.1% EE, 36.4% CF, 44.6% NFE, 39.7% ADF, 30.8%Cel, 3.9 % lignin, 7.9% ash and 19.3 MJ/kg GE, but *Hordeum vulgare* hay 8.5 % CP, 2.2% EE, 27.0% CF, 54.4% NFE, 37.0% ADF, 3.8 % lignin, 7.4% ash and 18.0 MJ/kg GE. HEUZE et al., (2015, 2016), reported that barley hay contained 8.7% CP, 2.3% EE, 27.1% CF, 53.1% NDF, 32.7% ADF, 2.3% lignin, 8.4% ash, 2.1 g/kg Ca and 2.8 g/kg P, 66.7% DOM, 18.0 MJ/kg GE, 11.4 MJ/kg DE and 9.3 MJ/kg ME, but oat hay – 9.1% CP, 2.2% EE, 34.0% CF, 61.7% NDF, 38.1% ADF, 8.3% ash, 17.7% starch, 4.7 g/kg Ca and 2.0 g/kg P, 60.1% DOM, 18.0 MJ/kg GE, 10.2 MJ/kg DE and 8.3 MJ/kg ME. ABDELRAHEEM et al., (2019) mentioned that the quality of oat hay was characterised by 7.50-7.86 % CP, 1.80-2.12 % fat, 54.13-54.20 % NDF, 28.72-31.17%, ADF, 4.60-5.50 % ash, 61.96-63.82%OMD and 17.71-17.92 MJ/kg GE. PATIDAR et al., (2022) remarked that nutritive value of the oat hay was: 88.91 %OM, 9.48% CP, 1.80% EE, 7.86% starch, 73.24% NDF, 48.24% ADF, 11.48% lignin, 55.40% TDN, 16.64 MJ/kg GE, 8.81 MJ/kg DE and 7.31 MJ/kg ME.

Ensiled forage is a key element for productive and efficient livestock farms, which provides a uniform level of high-quality feed, particularly in the autumn - middle spring period, but also throughout the year. When opening the glass containers with prepared fodder from the studied species, there was no gas or juice leakage from the preserved mass, the consistency was retained, in comparison with the initial plant green mass, without mould and mucus. Common oat haylage had olive colour with dark green hue, with pleasant smell specific to pickled apples. The prepared barley silage was distinguished by homogeneous olive colour with pleasant smell specific to pickled vegetables, but barley haylage was light brown with yellow hues, and had pleasant smell like pickled vegetables and fruits. As a result of the performed analysis (Table 2), it was determined that the fermentation profile of the ensiled forage was pH = 4.04-4.44, 20.8-28.1 g/kg lactic acid, 5.9-8.4 g/kg acetic acid, 21.10-39.00 g/kg fixed lactic acid and butyric acid was not detected. In barley silage, the concentration of total organic acids was lower as compared with oat and barley silage. The ensiled forage contained 10.2-12.9% CP, 7.8-11.4% ash, 33.8-39.3% CF, 34.7-41.3% ADF, 57.1.0-69.9% NDF, 1.8-4.0 % ADL, 2.6-12.9% TSS, 32.9-37.3% Cel, 22.4-28.6 % HC, 567-619 g/kg DDM, RFV= 76-100, 11.28-12.21MJ/kg DE, 9.26-10.06 MJ/kg ME and 5.29-6.10MJ/kg NEl. As compared with the initial green mass, the *Hordeum vulgare* silage had high concentration of crude protein, total soluble sugars and minerals, reduced content of structural carbohydrates and acid detergent lignin, which had a positive impact on dry matter digestibility, relative feed value and net energy for lactation. It has been found that the concentration of crude protein, total soluble sugars, digestible dry matter and energy is higher than in oat haylage.

Table 2. The fermentation profile, the biochemical composition and the nutritive value of the ensiled forage.

Indices	*Avena sativa haylage*	*Hordeum vulgare silage*	*Hordeum vulgare haylage*
pH index	4.10	4.04	4.44
Organic acids, g/kg DM	44.7	38.4	46.4
Free acetic acid, g/kg DM	2.5	3.4	3.7
Free butyric acid, g/kg DM	0	0	0
Free lactic acid, g/kg DM	10.7	10.5	10.5
Fixed acetic acid, g/kg DM	3.4	3.6	4.7
Fixed butyric acid, g/kg DM	0	0	0
Fixed lactic acid, g/kg DM	28.1	20.9	27.5
Total acetic acid, g/kg DM	5.9	7.0	8.4
Total butyric acid, g/kg DM	0	0	0
Total lactic acid, g/kg DM	38.8	31.4	38.0
Acetic acid, % of organic acids	13.2	18.2	18.1
Butyric acid, % of organic acids	0	0	0
Lactic acid, % of organic acids	86.8	81.8	81.9
Crude protein, g/kg DM	102	129	117
Crude fibre, g/kg DM	393	338	381
Ash, g/kg DM	78	114	88
Acid detergent fibre, g/kg DM	413	347	398
Neutral detergent fibre, g/kg DM	699	571	660
Acid detergent lignin, g/kg DM	40	18	26
Total soluble sugars, g/kg DM	26	129	49
Cellulose, g/kg DM	373	329	372
Hemicellulose, g/kg DM	286	224	262
Digestible dry matter, g/kg DM	567	619	579
Digestible energy, MJ/kg DM	11.28	12.21	11.50
Metabolizable energy, MJ/kg DM	9.26	10.02	9.44
Net energy for lactation, MJ/kg DM	5.29	6.10	5.46
Relative feed value	76	100	82

Some authors mentioned various findings about the quality of ensiled forage from the studied species. According to BURLACU et al., (2002) the *Avena sativa* silage contained 185g/kg DM, 91.2% OM, 11.1 % CP, 3.7% EE, 31.5% CF, 44.9% NFE, 5.7% sugars, 4.1% starch, 33.1% ADF, 4.7 % lignin, and 18.3 MJ/kg GE; *Hordeum vulgare* silage contained 180g/kg DM, 90.5% OM, 13.0 % CP, 3.0% EE, 31.3% CF, 48.0% NFE and 18.1 MJ/kg GE. GEREN et al., (2014) reported that *Hordeum vulgare* silage prepared in different harvest stages was characterized by pH 4.14-4.58, 8.8-11.7% CP, 53.7-59.3% NDF, 33.9-38.5% ADF and *Avena sativa* silage – by pH 3.91-4.64, 9.2-12.2% CP, 51.3-54.9% NDF, 34.2-39.7% ADF, respectively. HEIERMANN et al., (2009) found that the quality of the ensiled barley mass harvested in anthesis stage was: pH=4.7, 382 g/kg DM, 90.2% OM, 15.3 % CP, 31.5 % CF, 0.9 % sugar, 0.5 % starch; barley silage prepared in milk stage – pH=4.3, 253 g/kg DM, 93.4% OM, 13.0 % CP, 24.6 % CF, 3.5% EE, 7.6 % sugar and 24.7 % starch. HERRMANN et al., (2016) studied the nutrient and fibre composition of crop silages in Germany and remarked that the *Avena sativa* silage contained 379 g/kg DM, 92.4% OM, pH 4.3, 5.6% lactic acid, 1.1% acetic acid, 9.2% CP, 3.1% EE, 51.5% NDF, 34.3% ADF and 5.5% ADL; in *Hordeum vulgare* silage, there was 379 g/kg DM, 93.9% OM, pH 4.1, 3.9% lactic acid, 1.0% acetic acid, 0.2% butyric acid, 9.9% protein, 3.4% fat, 53.1% NDF, 28.4% ADF, 4.7% ADL. HEUZE et al., (2015, 2016) reported the feed value of the silage from *Hordeum vulgare* plants was: 363 g/kg dry matter, 10.2% CP, 2.3% EE, 33.5% CF, 47.6% NDF, 29.6% ADF, 4.4% lignin, 15.6% starch, 9.3% ash, 2.7 g/kg Ca and 2.2 g/kg P, 63.9% DOM, 17.3 MJ/kg GE, 10.9 MJ/kg DE and 8.7 MJ/kg ME, while

Avena sativa plant 305 g/kg dry matter, 9.5% CP, 5.8% EE, 37.4% CF, 53.4% NDF, 35.9% ADF, 4.1% lignin, 9.7 % starch, 10.1% ash, 4.6 g/kg Ca and 3.1 g/kg P, 65.0% DOM, 17.6 MJ/kg GE, 10.7 MJ/kg DE and 8.7 MJ/kg ME. ASKEL et al., (2017) mentioned that the chemical composition of barley haylage was 8.26 % CP, 71.50 % NDF, 39.56 % ADF and 4.21 % ash. LEÃO et al., (2017) compared the feed quality of winter cereal ensiled at the soft dough stage and subjected to different storage periods, remarked than *Avena sativa* silage contained 54-78 g/kg CP, 50-54 g/kg ash, 660-711 g/kg NDF, 417-459 g/kg ADF, 243- 253 g/kg HC, 485-509 g/kg TDN; *Avena strigosa* silage contained 43-60 g/kg CP, 55-58 g/kg ash, 709-799 g/kg NDF, 443-520 g/kg ADF, 265- 279 g/kg HC, 451-494 g/kg TDN, but *Hordeum vulgare* silage 86-99 g/kg CP, 48-53 g/kg ash, 617-642 g/kg NDF, 331- 378 g/kg ADF, 264-283 g/kg HC, 531-558 g/kg TDN. TEIXEIRA & FONTANELI (2017), mentioned that the chemical composition of barley silage was: 6.55-9.10% CP, 33.02-36.45% ADF, 61.44-62.24 % NDF, 60.42-64.89 DMD, but oat silage 6.57-10.72% CP, 37.23-39.02 % ADF, 59.45-62.46 % NDF, 58.53-60.66 DMD, respectively. SEYDOSOGLU (2019) found that barley silage contained 320 g/kg DM, pH=4.11, 1.83% lactic acid, 14.43% CP, 30.05 % ADF, 44.39 % NDF and 8.66% ash.

Bioenergy production is considered an important component in the transformation of the current energy system in order to mitigate greenhouse gas emissions and decrease the dependency on fossil energy sources. Biogas has become important as a renewable source of energy because of its decentralized approach, and it can be used to obtain heat and electrical power in special installations, but also as fuel in internal combustion engines. The anaerobic digestion process of biomass consists in the conversion of organic matter, by anaerobic bacteria, into biogas, mixture of methane, carbon dioxide and other substance, and also fermentation residue, digestate rich in macronutrients and micronutrients, which may be used as fertilizer in organic farming systems. Gas production by anaerobic digestion depends on the chemical composition and the anaerobic organic matter digestibility of biomass. The biochemical methane potential (BMP) is the most relevant method used to determine the biogas production potential of biomass. The results regarding the biochemical biomethane production potential of the investigated substrates are shown in Table 3. The nitrogen concentration in the tested substrates ranged from 15.2 g/kg to 20.6 g/kg, the estimated content of carbon – from 492.2 g/kg to 519.0 g/kg, the C/N = 24-34, but the substrates from the studied leguminous species contained 22.72-28.64 g/kg nitrogen, 490.00-502.22 g/kg carbon and C/N = 18-22. Essential differences were observed between concentrations of acid detergent lignin. As we have mentioned above, the process of ensiling decreased the lignin content, which had a positive effect on the activity of methanogenic bacteria. The *Avena sativa* substrates contained high concentration of acid detergent lignin. The biochemical methane potential varied from 329-361 l/kg VS in green mass substrates to 355-379 l/kg VS in ensiled mass substrates. The best biomethane potential was achieved in *Hordeum vulgare* silage substrate.

Table 3. The biochemical composition and the biomethane production potential of the investigated substrates.

Indices	*Avena sativa*		*Hordeum vulgare*		
	green mass	haylage	green mass	silage	haylage
Crude protein, g/kg DM	95.0	102.0	119.0	129.0	117.0
Nitrogen, g/kg DM	15.2	16.3	19.0	20.6	18.7
Ash, g/kg DM	65.0	78.0	75.0	114.0	88.0
Carbon, g/kg DM	519.0	512.2	513.9	492.2	506.7
Ratio carbon/nitrogen	34	31	27	24	27
Acid detergent lignin, g/kg DM	46.0	40.0	29.0	18.0	26.0
Hemicellulose, g/kg DM	258.0	286.0	261.0	224.0	262.0
Biomethane potential, L/kg VS	329	355	361	379	366

According to LEHTOMAKI (2006), the barley substrate contained 92% OM, 3.2% N, 47.5 % C, C/N=15 21.6% lignin, with methane potential 300 l/kg. DUBROVSKIS et al., (2009) reported that methane yields of oat-barley silage were 288.3-299.2 l/kg and maize silage 293.4-296.8 l/kg. HEIERMANN et al. (2009) found that barley fresh mass substrates have C/N = 18.1- 34.7, 618-730 l/kg biogas yields and 55-57% methane content of biogas, while ensiled barley mass substrates have C/N = 18.6- 23.3, 618-730 l/kg VS biogas with 56-59% methane content. HERRMANN et al., (2016) remarked that the carbon / nitrogen ratio and specific methane yields of silage substrates ranged from C/N = 33 and 277 l/kg ODM in *Avena sativa* silage to C/N = 31 and 321 l/kg ODM in *Hordeum vulgare* silage. ALLEN et al., (2016) reported that the quality indices of barley substrates were 44.17-44.38% C, 5.87-6.32% H, 0.60-0.64% N, C/N= 69.37-73.97, with theoretical biomethane potential 438-439 l/kg, methane yield 361.81-366.53 l/kg and oat substrate – 43.39% C, 6.38% H, 0.55% N, C/N= 80.70 with biomethane potential 450 l/kg and methane yield 281.26 l/kg, respectively. ZHANG et al., (2021) reported that the methane potential of barley substrates ranged from 280 to 356 l/kg VS, while in the oats substrate – from 203 to 402 l/kg VS.

Straw as an agricultural by-product has multiple different uses: as feed and bedding for animals, frost prevention for overwintering crops, as a mulch, natural fertilizer and soil remediator. Today, cereal straw represents a large but mostly unexploited resource, however, studies on the straw conversion into energy and valuable chemicals show very promising future applications. The biochemical composition and the economic value of the straw from the studied species are presented in Table 4. It can be noted that the straw dry matter contained of 4.5-6.2 % CP, 5.9-8.2 % ash, 46.7-49.6 % CF, 49.9-55.0 % ADF, 79.2-80.0 % NDF, 5.6-6.8 % ADL, 7.9-16.6 % TSS, with nutritive and energy forage values 461-500 g/kg DDM, RFV= 54-58, 7.71-8.28 MJ/kg ME and 3.72-4.30 MJ/kg NEl. The concentration of crude protein, total soluble sugars, digestible dry matter and energy is higher than in oat straw.

The utilization of straws for energy production includes the production of liquid, gaseous and solid fuels. We would like to mention that straw substrates for anaerobic digestion have a carbon to nitrogen ratio C/N=51-73 and an approximate biochemical methane potential 282-308 l/kg ODM. Due to its optimal cellulose and hemicellulose content that can be readily hydrolysed into fermentable sugars and other characteristics, straw makes an attractive material for the production of bioethanol fuel. The concentration of structural carbohydrates in *Avena sativa* straw substrate was 443 g/kg cellulose and 301 g/kg hemicellulose, but *Hordeum vulgare* straw substrate 482 g/kg cellulose and 242 g/kg hemicellulose, respectively. The estimated theoretical ethanol yield averaged 574 L/t in *Hordeum vulgare* straw substrate, compared to 541 L/t in *Avena sativa* straw substrate. Several literature sources describe the straw nutritive value and energy biomass potential. BURLACU et al., (2002) mentioned that the forage quality of oats straws was 3.3-3.9 % CP, 1.8-2.2% EE, 41.1-41.9% CF, 45.8-46.8% NFE, 47.4% ADF, 41.9% Cel, 31.9% HC, 10.2 % lignin, 6.0-7.2% ash and 18.3 MJ/kg GE, but barley straw 3.8 % CP, 1.6-1.8% EE, 40.0-42.0% CF, 43.5-48.5% NFE, 53.4% ADF, 7.4 % lignin, 5.9-6.9% ash and 18.0 MJ/kg GE. KIM & DALE (2004) remarked that the quality indices of barley straw were 810 g/kg DM, 9.0% lignin, 70% carbohydrates and 0.310l/kg ethanol yield, while for oat straw – 901 g/kg DM, 13.75% lignin, 59.1% carbohydrates and 0.26 l/kg ethanol yield, respectively. HEUZE et al., (2015, 2016), mentioned that barley straw contained 3.8% CP, 1.4% EE, 40.5% CF, 80.5% NDF, 48.3% ADF, 6.5% lignin, 7.5% ash, 4.6 g/kg Ca and 1.0 g/kg P, 47.5% DOM, 18.2 MJ/kg GE, 8.0 MJ/kg DE and 6.5 MJ/kg ME, but oats straw – 3.6% CP, 1.5% EE, 39.8% CF, 76.0% NDF, 44.6% ADF, 6.5% ash, 2.5 g/kg Ca and 1.2 g/kg P, 48.2% DOM, 18.0 MJ/kg GE, 8.1 MJ/kg DE and 6.6 MJ/kg ME. DOROFTEI et al., (2021) reported that the biochemical composition of straw from grass species was: 36-83 g/kg CP, 400-555 g/kg CF, 46-98 g/kg ash, 647-918 g/kg NDF, 424-604 g/kg ADF, 53-86 g/kg ADL, 371-518 g/kg Cel, 223-314g/kg HC, with nutritive and energy value 103-393 g/kg DMD, 7.08-9.14 MJ/kg ME and 3.10-5.45 MJ/kg NEl, biochemical methane potential 254-313 l/kg VS and the theoretical ethanol yield from structural carbohydrates averaged 432-605 L/t. FJORTOFT et al., (2019) found that the untreated barley straw contained 4.7% ash, 46.4 % cellulose, 22.2% hemicellulose, 8.6% lignin with 215 l/kg VS methane yield, while the oat straw substrate 7.7% ash, 43.1 % cellulose, 23.6% hemicellulose, 6.4% lignin with 240 l/kg VS methane yield. LALLEMENT et al., (2023) remarked that barley straw contained 92.8% total solids, 3.3% ash, 46.84 % C, 5.31% H, 0.14% N, 62.2% total structural carbohydrates, 37.9 % cellulose (glucan), 24.3% hemicellulose, 16.8 % lignin, 3.4 % lipids with theoretical methane yield 428 l/kg TS and ultimate methane yield 340 l/kg TS.

Table 4. The biochemical composition and the economic value of the straw from the studied species.

Indices	***Avena sativa***	***Hordeum vulgare***
Crude protein, g/kg DM	62	45
Crude fibre, g/kg DM	467	496
Ash, g/kg DM	82	59
Acid detergent fibre, g/kg DM	499	550
Neutral detergent fibre, g/kg DM	800	792
Acid detergent lignin, g/kg DM	56	68
Total soluble sugars, g/kg DM	166	79
Cellulose, g/kg DM	443	482
Hemicellulose, g/kg DM	301	242
Dry matter digestibility, %	50.0	46.1
Digestible energy, MJ/kg DM	10.09	9.38
Metabolizable energy, MJ/kg DM	8.28	7.71
Net energy for lactation, MJ/kg DM	4.30	3.72
Relative feed value	58	54
Ratio carbon/nitrogen	51	73
Biomethane potential, L/kg VS	308	282
Hexose sugars, g/kg DM	80.20	97.87
Pentose sugars, g/kg DM	49.51	39.81
Theoretical ethanol potential, L/t	541	574

CONCLUSIONS

The dry matter of whole plants of *Hordeum vulgare* 'Excelent' and *Avena sativa* 'Sorin' contains 9.5-11.9% CP, 6.5-7.5% ash, 34.9- 35.6% CF, 36.7-37.4% ADF, 62.7-62.8% NDF, 2.9-4.6 % ADL, 16.3-16.7% TSS, with forage value 598-603 g/kg DDM, RFV= 89, 11.84-11.92 MJ/kg DE, 9.72-9.79 MJ/kg ME and 5.37-5.81 MJ/kg NEl.

The nutrient content and energy value of hays prepared from *Hordeum vulgare* 'Excelent' and *Avena sativa* 'Sorin' is on average 9.0-10.5% CP, 6.9-7.4% ash, 38.1- 43.5% CF, 40.4-45.6% ADF, 66.0-73.6% NDF, 4.5-5.0 % ADL, 5.1-111% TSS, 534-574 g/kg DDM, 10.69-11.40 MJ/kg DE, 8.76-9.36 MJ/kg ME, 4.79-5.39 MJ/kg NEl.

The ensiled forage contains 10.2-12.9% CP, 7.8-11.4% ash, 33.8-39.3% CF, 34.7-41.3% ADF, 57.1.0-69.9% NDF, 1.8-4.0 % ADL, 2.6-12.9% TSS, 32.9-37.3% Cel, 22.4-28.6 % HC, 567-619 g/kg DDM, RFV= 76-100, 11.28-12.21 MJ/kg DE, 9.26-10.06 MJ/kg ME and 5.29-6.10MJ/kg NEl.

The biochemical methane potential of the studied substrates from *Avena sativa* reaches 329-355 l/kg VS, but *Hordeum vulgare* substrates reach 361-379 l/kg VS. The nutrient content of prepared hay is characterised by: 9.0-10.5% CP, 6.9-7.4% ash, 38.1- 43.5% CF, 40.4-45.6% ADF, 66.0-73.6% NDF, 4.5-5.0 % ADL, 5.1-111% TSS, 534-574 g/kg DDM, 10.69-11.40 MJ/kg DE, 8.76-9.36 MJ/kg ME, 4.79-5.39 MJ/kg NEl.

The collected straw from the studied species contains 4.5% CP, 4.5-6.2 % CP, 5.9-8.2 % ash, 46.7-49.6 % CF, 49.9-55.0 % ADF, 79.2-80.0 % NDF, 5.6-6.8 % ADL, 7.9-16.6 % TSS, 44.3-48.2% Cel, 23.2-30.1 % HC with nutritive and energy forage values 461-500 g/kg DDM, RFV= 54-58, 7.71-8.28 MJ/kg ME and 3.72-4.30 MJ/kg NEl. The biochemical methane potential of straw substrates averages 282-308 l/kg VS and the theoretical ethanol potential – 541-574 L/t.

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