SOME AGROBIOLOGICAL PECULIARITIES AND THE ECONOMICAL VALUE OF CHIA *SALVIA HISPANICA* L. IN MOLDOVA

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Abstract

The aim of this study was to evaluate some agrobiological peculiarities, the quality of the harvested fresh mass and prepared haylage of the genotypes of chia – *Salvia hispanica*, cultivated under the conditions of the Republic of Moldova. The studied genotypes of chia were characterized by optimal growth and development rates. It was determined that the nutrients of the dry matter of *Salvia hispanica* whole plants cut in the flowering period were: 87-107 g/kg CP, 77-83 g/kg ash, 347-377g/kg CF, 348-362 g/kg ADF, 517-533 g/kg NDF, 62-65g/kg ADL, 283-331 g/kg Cel, 166-174g/kg HC, 107-123 g/kg TSS, with nutritive value: 60.70-61.79% DMD, RFV= 106-111, 12.00-12.19 MJ/kg DE, 9.85-10.1 MJ/kg ME, 5.87-6.03 MJ/kg NEl. The fermentation quality and the nutritive value of the haylage prepared from chia plants were characterized by the following indices: pH= 4.81, 18.5 g/kg lactic acid, 2.3 g/kg acetic acid, 0.3 g/kg butyric acid, 100 g/kg CP, 80g/kg ash, 400 g/kg CF, 419 g/kg ADF, 593 g/kg NDF, 72 g/kg ADL, 347 g/kg Cel, 199 g/kg HC, with nutritive value: 56.3% DMD, RFV= 88, 11.21 MJ/kg DE, 9.20 MJ/kg ME, 5.22MJ/kg NEl. The studied fresh and ensiled substrates from *Salvia hispanica* have C/N=29.2-36.8 and the biochemical methane potential reaches 285-298 l/kg ODM. Chia – *Salvia hispanica* – can serve as multi-purpose crops for forage production and feedstock for renewable energy production.

Key words: agrobiological peculiarities, biochemical composition, biomethane potential, green mass, haylage, nutritive value, *Salvia hispanica*

The incorporation of neglected and underused crops, as well as the domestication of new species would promote agricultural diversity and would provide a solution to many of the problems associated with food security, nutrition, healthcare, medicine and industrial needs.

Salvia L. is the largest genus of the *Lamiaceae* family, *Nepetoideae* subfamily, *Mentheae* tribe, *Salviinae* subtribe, and has about 1000 species that are widely distributed in different areas of the world, including South Africa, Central America, North America, South America and Southeast Asia. *Salvia hispanica* L., known as chia, is native to Central America, the mountainous areas of western and central Mexico, as well as Guatemala, and is a multifunctional plant whose culinary use may be traced back as far as 2500 B.C. Domesticated in Mesoamerica around 2600 B.C., it was a staple food in Mexico between 1500 and 900 B.C. (Pozo S., 2010). It was re-discovered due to its high content of nutraceuticals and therefore the potential for a functional food and a feed capable of increasing the nutritional value of milk and meat products (Ayerza R., Coates W., 2006; Bochicchio R. *et al*, 2015; Porras-Loaiza P. *et al*, 2014; Jamshidi A.M. *et al*, 2019; Noori A., Zebarjadi A., 2022; Rahal E.K. *et al*, 2023). The use of chia for human consumption has been approved by the European Parliament and the European Council (European Commission, 2009; 2020).

Salvia hispanica is an annual herb, developing numerous fibrous roots, forming a dense roots mass under favorable conditions. Stems – erect, simple or sparingly branched, quadrangular, deeply sulcate between the prominent, rounded angles, appressed pubescent with whitish hairs, up 200 cm tall. Leaves petiolate, lamina 1.4–11.5 × 0.5–6 cm, ovate to ovate-elliptic, apex acute to shortly acuminate, base cuneate to rounded, margin serrate, adaxially pubescent, abaxially densely pubescent with whitish hairs; petioles 0–3.5 cm, diminishing in length upwards, pubescent. Inflorescence – dense racemes, (1–) 5–17 cm long and 1.3–2 cm wide, terminal on the main stem and on branches from

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the uppermost leaf axils, usually solitary but occasionally with a pair of racemes arising at the base of the main raceme, the flowers grouped in 6–12-flowered verticillasters, imbricate except the lowermost, up to 5 mm apart; peduncles 1.5–11.5 cm long, pubescent; bracts 5–8 × 3–5 mm, narrowly to broadly deltoid, acuminate and mucronate, entire, pubescent, 3-veined, persistent; calyx about 5 mm long in the flowering stage, accrescent to 11 mm in the fruiting stage, rather bulbous (ventricose) at the base, pubescent with sessile glands near base, 2-lipped, the upper lip with 3 prominent veins and sometimes two additional less prominent veins, teeth mucronate, the lower lip 2-lobed; corolla 2-lipped, blue with small white 'honey guide' on lower lip, 7–8 mm long, tube 4–5 mm long, ± enclosed by the calyx, white, ±glabrous, the upper lip about 3 mm long, blue, hooded, densely pubescent, the lower lip 4–5 mm long, shallowly 3-lobed, pubescent on the exterior, papillae absent from the interior; stamens included in the upper lip, anthers about 1.25 mm long, yellowish; style – whitish, glabrous, glandular at base, shortly exserted, bilobed, the arms blue, upper arm reflexed, twice as long as the lower arm. Nutlets ovoid, 1.4–2 mm long, smooth, glabrous, pale grey-brown mottled with white or (rarely) entirely white, becoming mucilaginous when wetted (Wood *et al*, 2022) The seed color varies from black, grey and black spotted to white, and the shape is oval with size ranging from 1 to 2 mm (Wood J.R.I. *et al*, 2022). The weight of 1 000 seeds varies between 0.94 and 1.29 g (Rahal E.K. *et al*, 2023). Chia seed is composed of protein (18.5–22.3%), fibres (20.1–36.1%) and fats (21.5–32.7%) with highest proportion of omega-3 and omega-6 fatty acids, minerals, vitamins, also contains a high amount of antioxidants, phenolic compounds varied from 0.53 to 0.71 mg/g GAE (Porras-Loaiza P. *et al*, 2014).

The chia plants grows well in sandy-loam and loam soils with good drainage. They thrive mainly in acidic soils and grow best at a pH of 6.5–8.5. Temperatures between 11 °C and 36 °C are ideal for seed growth, but they cannot stand frost and freeze in all development stages. Chia is a drought-resistant plant, so it can grow in semiarid and arid environments. It is a short-day plant sensitive to photoperiod. These plants need a lot of sunlight and do not bear fruit in the shade, are sensitive to salt stress, and salinity can considerably diminish the yield of seed oil. Chia is resistant to pests and diseases, has low requirements of water and fertilizer supply, and is a good candidate for organic production (Bochicchio R. *et al*, 2015).

Recently, phytomass production as a potential forage source has gained a lot of attention, opening new possibilities for the introduction of chia, *Salvia hispanica*, in forage production systems (Peiretti P.G., Gai F., 2009; Peiretti P.G., 2010; Amato M. *et al,* 2015; Bilalis D. *et al*, 2016; Jamshidi A.M. *et al*, 2019; Rossi R. *et al*, 2020; Bhardwaj H.L., 2021; Chernov R.V. *et al*, 2022; Filik G. *et al*, 2022).

Under the conditions of the Republic of Moldova, the *Salvia hispanica* genotypes have optimal growth and development rates, the duration of the growing season being 122-126 days, finishing with the ripening of seeds, the weight of 1000 seeds was 1.2-1.4 g and the potential yield reached 2030 kg/ha seeds (Chisnicean L., 2017).

The aim of this study was to evaluate some agrobiological peculiarities, the quality of the harvested fresh mass and prepared haylage of the 2 genotypes of chia, *Salvia hispanica*, cultivated under the conditions of the Republic of Moldova.

MATERIALS AND METHODS

The *Salvia hispanica* genotype with gray seeds and the genotype with white seeds, grown in monoculture in the experimental sector of the Institute of Genetics, Physiology and Plant Protection of Republic of Moldova, served as research subjects, Common sainfoin – *Onobrychis vicifolia* was used as control variant. The chia seeds were sown in middle May, at a depth of 1.5-2.0 cm and a distance between rows of 70 cm, with soil compaction before and after sowing, the sowing density was 0.6 g germinable seeds per m^2. The surveyed area of the plot constituted 10 m^2.

The green mass samples were collected in the early flowering stage. The haylage was produced from wilted green mass, cut into small pieces, compressed in well-sealed glass containers, stored at ambient temperature (18-20 °C) for 45 days, to allow complete fermentation to occur. Following the 45-day fermentation period, each glass container was opened and the content was visually examined, the colour and the aroma were recorded. The dry matter content was detected by drying samples up to constant weight at 105°C. For biochemical analysis, the 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. The pH of the haylage was measured immediately after removal from the containers. The prepared hay was dried directly in the field. The fresh mass 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 quality of the biomass was evaluated

by analyzing such indices as: crude protein (CP), crude fibre (CF), minerals, total soluble sugars (TSS), acid detergent fibre (ADF), neutral detergent fibre (NDF), acid detergent lignin (ADL), total soluble sugars (TSS), dry matter digestibility (DMD), organic matter digestibility (DMD), which have been determined by near infrared spectroscopy (NIRS) technique PERTEN DA 7200 of the Research and Development Institute for Grassland Braşov, Romania. The concentration of hemicellulose (HC), cellulose (Cel), digestible energy (DE), the metabolizable energy (ME), the net energy for lactation (NEl) and the 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 C.M. *et al* (1979). The biochemical methane potential was calculated according to Dandikas V. *et al* (2015).

RESULTS AND DISCUSSIONS

Some agrobiological peculiarities and the structure of the green mass of the studied *Salvia hispanica* genotypes are presented in Table 1. At the time when the green mass was harvested, the plants of the gray seed genotype reached 200 cm in height, but the white seed genotype – 210 cm. The yield of the white seed genotype reached 6.56 kg/m^2 green mass or 1.48 kg/m^2 dry matter, but the yield of the gray seed genotype was 6.02 kg/m^2 or 1.29 kg/m^2 dry matter, respectively. The harvested green mass of *Salvia hispanica* white seed genotype was characterized by a higher content of dry matter (22.56 %) and leaves (49.55%).

Animals need for growth, development, reproduction and realization of some products, numerous nutrients they receive from feed. Analyzing the results of the determination of the biochemical composition of dry substances of chia whole plants (*table 2*) we would like to mention that the nutrient content was 8.7-10.7 % CP, 34.7-37.7% CF, 34.8-36.2% ADF, 51.7-53.3 % NDF, 6.2-6.5% ADL, 28.3-33.1 % Cel, 16.6-17.4% HC, 10.7-12.3 TSS % and 7.7-8.3 % ash. A higher content of crude protein, total soluble sugars, hemicellulose, ash and lower content of structural carbohydrates was found in the fodder from the chia genotype with white seeds. The content of organic matter and its biochemical composition influence the nutritional and energy value of fodder. Thus, the natural fodder from the white seed genotype of chia is of high quality, reaching 61.8 % DMD, RFV=111 with 12.19 MJ/kg DE, 10.01 MJ/kg ME and 6.03 MJ/kg NEl, but – from the gray seed genotype of chia – 50.7 % DMD and RFV=106 with 12.00 MJ/kg DE, 9.85 MJ/kg ME and 5.87 MJ/kg NEl. We would like to mention that the level of crude protein and energy value of green mass fodder from *Salvia hispanica* was significantly lower as compared with *Onobrychis vicifolia* green mass.

Some authors mentioned various findings about the yield and nutrient quality of the green mass from *Salvia hispanica*. According to Peiretti P.G., Gai F. (2009), the protein content in *Salvia hispanica* plants varied from 188 g/kg DM at early vegetative stage to 76 g/kg DM during shoot stage. Peiretti P.G. (2010) mentioned that chia herbage contained 84.0-224.0 g/kg DM with 8.60-21.30% WSC. Ouzounidou G. *et al* (2015) reported that chia leaves contained 16.54-22.70% proteins, 7.40-11.20 % carbohydrates and 1.85-3.85% fat. Bilalis D. *et al* (2016) reported that biomass yield ranged between 4.48 and 15.36 t/ha dry mass, depending on the sowing rate and fertilization. Rossi R. *et al* (2020) found that the total plant yield of chia in Italy varied from 5.64 to 9.0 t/ha and crude protein in chia plants varied from 18% in early vegetative to 8% in early flowering stages, respectively. Bhardwaj H.L. (2021) reported that the 60-day old whole *Salvia hispanica* plants, in the vegetative phase, of black-seeded genotype contained 21.40% protein, 2.24% crude fat, 23.8% ADF, 31.4 % NDF, 0.32% phosphorus, 2.03% calcium, and white-seeded genotype 21.1% protein, 2.64% crude fat, 18.6% ADF, 27.2% NDF, 0.36% phosphorus, 2.10% calcium. Chernov R.V. *et al* (2022) revealed that the biochemical composition of the dry matter in the green mass of *Salvia hispanica* was 17.4% CP, 4.8% EE, 21.9% CF, 10.1% ash and the nutritive value 10.21 MJ/kg ME and 0.84 fodder units/kg. Kazydub N.G *et al* (2022) reported that the sucrose content in chia leaves varied over the years between 6.2% and 14.3%.

Table 1

Some agrobiological peculiarities and the structure of the yield of *Salvia hispanica*

Plant species	Plant height, cm	Stem, g		Leaf + flower, g		Productivity, kg/m^2	
		fresh mass	dry matter	fresh mass	dry matter	fresh mass	dry matter
Salvia hispanica genotype gray seeds	200.00	238.00	51.89	151.00	31.55	6.02	1.29
Salvia hispanica genotype white seeds	210.00	273.40	49.21	158.80	48.34	6.56	1.48
Onobrychis viciifolia control	99.20	10.10	2.50	12.50	2.90	4.23	1.01

Table 2

The biochemical composition and the feed value of green mass of *Salvia hispanica*

Indices	*Salvia hispanica*		*Onobrychis viciifolia*
	genotype white seeds	genotype gray seeds	control
Crude protein, g/kg DM	107	87	177
Crude fibre, g/kg DM	347	347	293
Ash, g/kg DM	80	77	96
Acid detergent fibre, g/kg DM	348	362	309
Neutral detergent fibre, g/kg DM	517	533	447
Acid detergent lignin, g/kg DM	65	62	49
Total soluble sugars, g/kg DM	123	107	114
Cellulose, g/kg DM	283	300	260
Hemicellulose, g/kg DM	199	166	138
Digestible dry matter, g/kg DM	618	607	648
Relative feed value	111	106	135
Metabolizable energy, MJ/kg DM	12.19	12.00	12.73
Net energy for lactation, MJ/kg DM	10.01	9.85	10.45
Digestible energy, MJ/kg DM	6.03	5.87	6.48

Table 3

The biochemical composition and the nutritive value of the fermented fodder from *Salvia hispanica*

Indices	*Salvia hispanica* genotype white seeds	*Onobrychis viciifolia* control
pH index	4.81	4.68
Organic acids, g/kg DM	21.10	23.40
Free acetic acid, g/kg DM	0.90	1.10
Free butyric acid, g/kg DM	0	0
Free lactic acid, g/kg DM	4.50	4.40
Fixed acetic acid, g/kg DM	1.40	2.20
Fixed butyric acid, g/kg DM	0.30	0
Fixed lactic acid, g/kg DM	14.0	15.70
Total acetic acid, g/kg DM	2.30	3.30
Total butyric acid, g/kg DM	0.30	0
Total lactic acid, g/kg DM	18.50	20.10
Acetic acid, % of organic acids	10.90	14.10
Butyric acid, % of organic acids	1.42	0
Lactic acid, % of organic acids	87.68	85.90
Crude protein, g/kg DM	100	142
Crude fibre, g/kg DM	400	312
Ash, g/kg DM	83	118
Acid detergent fibre, g/kg DM	419	317
Neutral detergent fibre, g/kg DM	593	470
Acid detergent lignin, g/kg DM	72	40
Total soluble sugars, g/kg DM	-	135
Cellulose, g/kg DM	347	277
Hemicellulose, g/kg DM	174	153
Digestible dry matter, g/kg DM	563	642
Digestible energy, MJ/kg DM	11.21	12.63
Metabolizable energy, MJ/kg DM	9.20	10.37
Net energy for lactation, MJ/kg DM	5.22	6.38
Relative feed value	88	127

Table 4

The biochemical composition and the biomethane production potential of *Salvia hispanica* substrates

Indices	*Salvia hispanica* genotype white seeds		*Salvia hispanica* genotype gray seeds	*Onobrychis viciifolia*	
	green mass	haylage	green mass	green mass	haylage
Crude protein, g/kg DM	107.00	100.00	87.00	177.00	142.00
Nitrogen, g/kg DM	17.12	16.00	13.92	28.30	22.70
Carbon, g/kg DM	511.11	509.44	512.78	502.20	490.00
Ratio carbon/nitrogen	29.20	31.80	36.80	17.7	21.6
Acid detergent lignin, g/kg DM	65.00	72.00	62.00	49.0	40.0
Hemicellulose, g/kg DM	199.00	174.00	166.00	138.0	153.0
Biomethane potential, L/kg VS	298	285	298	335	343

It is known that the preserved forage has substantial effects on the nutritive value, which has a positive effect on the health of farm animals, particularly in autumn and winter. During the sensorial assessment, it was found that, the haylage from *Salvia hispanica* white seed genotype had light olive leaves and yellow stems with peculiar smell, while the haylage prepared from *Onobrychis viciifolia* consisted of yellowish-green leaves and yellow-green stems and it had a pleasant smell like pickled vegetables. The texture of the plant mass stored as haylages was preserved well, without mold and mucus. The results regarding the quality of the prepared haylages are shown in Table 3. It has been determined that the pH values depended on the species, thus, *Salvia hispanica* haylage had pH=4.81, but *Onobrychis viciifolia* haylage – pH=4.68. The content of organic acids in *Salvia hispanica* haylage was lower in comparison with *Onobrychis viciifolia* haylage. Most organic acids were in fixed form, butyric acid was detected in minor quantities. According to the Moldavian standard SM 108, the ratio of acetic acid and lactic acid of the studied fermented fodder corresponds to the 1-st class quality. It was found that during the process of ensiling, the concentrations of crude protein in *Salvia hispanica* haylage decreased, but the level of minerals, structural carbohydrates and acid detergent lignin increased in comparison with the harvested green mass. In *Salvia hispanica* haylage, the amount of crude protein and energy concentrations were reduced as compared with *Onobrychis viciifolia* haylage.

According to Peiretti P.G. (2010) the chia silage from fresh mass contained 228.0 g/kg DM with pH=5.1, 0.14 g/kg methanol, 1.4 g/kg ethanol, 0.66 g/kg acetic acid, 0.67 g/kg propionic acid, 0.35 g/kg butyric acid, 1.30 g/kg isobutyric acid, lactic acid was not detected, 12.9 g/kg total nitrogen, 18.10MJ/kg GE, but – from wilted plants: 285.0 – 531.0 g/kg DM with pH= 5.3-5.4, 0.05-0.12 g/kg methanol, 0.5-2.1 g/kg ethanol, 0.26-0.39 g/kg acetic acid, 0.01-0.82 g/kg propionic acid, butyric acid, 0.1-0.5 g/kg isobutyric acid, butyric and lactic acids – not detected, 12.9-13.1 g/kg total nitrogen, 17.50-18.80 MJ/kg GE. Filik G. *et al* (2022) reported that quality of chia plant silage was: pH=4.17, 4.32+0.01 CP %, 5.40±2.36% EE, 51.74±0.92% NFE, 42.69±2.89 g/kg NFC, 65.95±3.99 ADF%, 36.73±0.69 NDF%, 26.72±0.05 ADL%, 27.68±1.28 % HC, 10.88±0.18% ash, RFV=95.23±9.68, RFQ=140.71±2.40, 2.34±0.01 Mcal/kg DE, 1.92±0.01 Mcal/kg ME, 1.18±0.00 Mcal/kg NEl.

Biogas is a product of anaerobic digestion of organic products. The methane produced from plant mass has a great importance and can successfully replace natural gas to obtain electric power and heat, and the material remaining after anaerobic digestion of substrates is called digestate and consists of liquid phase (fugate) and solid phase (called digestate). Digestate and fugate are believed to be good fertilizers in organic farming. The results regarding the quality of the phytomass substrates and the potential for obtaining biomethane are shown in Table 4. We found that in the investigated *Salvia hispanica* substrates, according to the C/N ratio, which constituted 29.2-36.8, the amount of acid detergent lignin (62-72 g/kg) and hemicellulose (166-199 g/kg) met the established standards; the biochemical methane potential of studied substrates varied from 285 to 343 l/kg ODM. The lowest results were achieved in chia haylage substrate, with rather high concentration of acid detergent lignin. A high biochemical methane potential was also characteristic of *Onobrychis viciifolia* substrates.

CONCLUSIONS

The dry matter of *Salvia hispanica* whole plants cut contained: 87-107 g/kg CP, 77-83 g/kg ash, 347-377g/kg CF, 348-362g/kg ADF, 517-533 g/kg NDF, 62-65g/kg ADL, 283-331 g/kg Cel, 166-174 g/kg HC, 107-123 g/kg TSS, with nutritive value 60.70-61.79% DMD, RFV= 106-111, 12.00-12.19 MJ/kg DE, 9.85-10.1 MJ/kg ME, 5.87-6.03 MJ/kg NEl.

The white seed genotype of *Salvia hispanica* was characterized by higher yield, nutritional and energy value of fodder.

The quality indices of *Salvia hispanica* haylage: pH= 4.81, 18.5g/kg lactic acid, 2.3 g/kg acetic acid, 0.3 g/kg butyric acid, 100 g/kg CP, 80g/kg ash, 400 g/kg CF, 419 g/kg ADF, 593 g/kg NDF, 72 g/kg ADL, 347 g/kg Cel, 199 g/kg HC, with nutritive value 56.3% DMD, RFV=88, 11.21 MJ/kg DE, 9.20 MJ/kg ME, 5.22 MJ/kg NEl.

The fresh and ensiled substrates chia from have C/N=29.2-36.8 and the biochemical methane potential reaches 285-298 l/kg ODM.

The *Salvia hispanica* is characterized by optimal productivity and the harvested green mass may be used as forage for farm animals as natural fodder and haylage, and also may be used as substrates for renewable energy production.

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development of agriculture and guarantees high quality raw material predestined to the perfumery, cosmetic, pharmaceutical and food industry" and 20.80009.5107.12 "Strengthening the "food-animal-production" chain by using new feed resources, innovative sanitation methods and schemes"

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