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The Biochemical Composition of Green Mass and Silage from *Amaranthus hypochondriacus* and its Potential Application in the Republic of Moldova

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ABSTRACT

Amaranths* have high potential and can be considered as alternative multipurpose crops in most parts of the world. The goal of this study was to evaluate the quality indices of the green mass and silage from the yellowish genotype and the reddish genotype of prince's-feather amaranth, *Amaranthus hypochondriacus*, and the prospects of using them as feed for farm animals and as feedstock for the production of biomethane as renewable energy. The studied *Amaranthus hypochondriacus* genotypes in early flowering stage reached 167-175 cm, the phytomass productivity reached 86.29-93.30 t/ha or green mass or 11.84-12.86 t/ha dry matter with 15.7-16.7% CP, 9.0-10.1% ash, 32.9-34.9% CF, 34.8-36.2% ADF, 52.9-53.4% NDF, 5.4-5.8% ADL, 29.4-30.4% Cel, 17.2-18.1% HC, 608-617 g/kg DDM, RFV=106-109, 9.85-10.20 MJ/kg ME and 5.87-6.03 MJ/kg NEl. The biochemical composition and nutritive value of the silages prepared from the studied yellowish and reddish genotypes of *Amaranthus hypochondriacus* were: pH=3.95-4.03, 29.6-33.3 g/kg lactic acid, 6.6-6.9 g/kg acetic acid, 14.8-16.1% CP, 8.5-9.4% ash, 29.1-32.9% CF, 30.8-34.5% ADF, 48.9-51.5% NDF, 4.0-4.5% ADL, 26.8-30.0% Cel, 17.0-19.0% HC, 567-619 g/kg DDM, RFV=112-121, 12.23-12.75 MJ/kg DE, 10.04-10.47 MJ/kg ME and 6.06-6.49 MJ/kg NEl. The green mass and silage from the studied amaranth genotypes can be used as substrates in biogas plants, possessing a biochemical methane potential of 320-351 l/kg organic matter. The obtained results indicate the possibility of using the studied yellowish and reddish genotypes of *Amaranthus hypochondriacus* as initial material for breeding and implementing new local amaranth cultivars for agricultural production.

Keywords: *Amaranthus hypochondriacus*, biochemical composition, biochemical methane potential, forage quality of green mass and silage, phytomass productivity, reddish genotype, yellowish genotype.

INTRODUCTION

The return of forgotten and neglected crops to the agricultural circuit, as well as the mobilization, acclimatization and breeding of new plant species tolerant to climate change could contribute to the sustainable development of agriculture, the revitalization of the livestock sector, the production of food, feed and raw materials for the circular economy, including feedstock for the production of renewable energy.

The plant species with C_4 photosynthesis pathway differ in the type of leaf anatomy and the mechanism of carbon fixation, therefore they are able to photosynthesize at high temperatures in conjunction with a higher water use efficiency during drought and other environmental stress conditions than many C_3 plants. Most species in Amaranthaceae family use the C_4 photosynthesis pathway (Sage et al., 2007). Most of them are annual or perennial herbs or subshrubs, others are shrubs, very few species are vines or trees. Some of them have economic value as food plants - as pseudo-cereals, greens, source of sugar, some are fodder plants, and others are weeds, which are hard to eradicate. The genus *Amaranthus* belongs to the subfamily of Amaranthoidae, family of Amaranthaceae, order Caryophyllales, contains 60 to 90 species widely spread herbaceous plants, rarely low shrubs. Amaranth plants have been used in the Americas for thousands of years, firstly collected as wild food, and then domesticated multiple times, beginning about 6,000 years ago and they continue to be used essentially worldwide, even to the present day. Sauer (1967)

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reported the introduction of amaranth into Spain in 16th century, from where it had spread throughout the Europe, around 1700s, it was known as an ornamental and a minor grain plant in central Europe and Russia. Amaranth plants can grow under drought stress, can tolerate unfavorable abiotic conditions including high salinity, acidity or alkalinity, which makes these plants uniquely suitable for subsistence farming. The amaranth seeds are gluten-free, contain significant amounts of high-quality protein and oils, have several health benefits like lowering cholesterol levels, protection against heart diseases, stimulation of the immune system, anticancer activity, control of blood sugar level, lowering blood pressure, reducing anemia, anti-allergic and antioxidant activity, etc., due to the presence of some bioactive components. In addition, amaranths are utilized as an effective forage crop for poultry, as well as cattle and pigs (grazing, green mass and silage), due to the presence of beneficial compounds in their leaves and seeds. Therefore, they can be easily introduced to regions without previous history of amaranth cultivation, have high potential and can be considered alternative multipurpose crops in most parts of the world. Cultivated amaranth species are conditionally categorized as pseudo-cereals: *Amaranthus caudatus, Amaranthus cruentus, Amaranthus hypochondriacus, Amaranthus paniculatus, Amaranthus mantegazzianus*; as vegetables: *Amaranthus tricolor*, *Amaranthus cruentus, Amaranthus spinosus, Amaranthus graecizans*; as forage crops, medicinal herbs and ornamental plants *Amaranthus caudatus, Amaranthus hybridus, Amaranthus Amaranthus hypochondriacus, Amaranthus molieros, Amaranthus paniculatus*. The *Amaranthus* species have recently been subjects of intensive research around the world (Pisaoikova et al., 2006; Rivelli et al., 2008; Pospisil et al., 2009; Toader and Roman 2009; Marin et al., 2011; Vujacic et al., 2014; Das 2016; Assad et al., 2017; Peiretti, 2018; Ma et al., 2019; Aderibigbe et al., 2020; Nogoy et al., 2021; Oteri et al., 2021; Nazeer and Yaman Fırıncıoğlu, 2022; Tyrus et al., 2023; Yi et al., 2023; Amosova et al., 2024; Zhong et al., 2024; Zubillaga et al., 2024).

Over 75 years of investigations at the National Botanical Garden (Institute), Chişinău, about 60 taxa of 10 *Amaranthus* species have been mobilized. As a result, it has been found that the species *Amaranthus cruentus* and *Amaranthus mantegazzianus* are tolerant to drought and have a high productivity of fresh mass that allows obtaining 5.31-6.68 t/ha nutritive units and 841-926 kg/ha digestible protein (Teleuţă, 1995, Ţîţei and Teleuţă, 1995).

Amaranthus hypochondriacus L. (syn. *A. anardana* Buch; *A. aureus* Besser; *A. flavus* L.; *A. frumentaceus* Buch.-Ham. ex Roxb; *A. leucocarpus* S. Watts), commonly known as the ‘Prince’s feather’ or ‘Prince-of-Wales feather’, is one of the most promising species, being popular due to its ornate and vibrant inflorescence. It is native to southwestern North America, is a vigorous annual plant, with erect stem, growing sometimes even up to 250 cm. The stem is generally branched, mainly at the inflorescence level. The leaves are dark green, less commonly yellowish or greenish, with possible more dark red, purple or deep beet-red color, of ovate-lanceolate shape, carried by long petioles. The inflorescences are predominantly terminal, up to 45 cm long, often with few spikes at distal axils, stiff, erect, dark red, purple, or deep beet-red, less commonly yellowish or greenish, leafless at least in distal part, usually robust. The fruits are obovoid to rhombic capsules, 1.5-2 mm long, circumscissile, with a short beak, 1-seeded. The seeds are obovoid to ellipsoid, compressed, 1 mm long, whitish to yellowish or blackish. The seedlings - with epigeal germination, hypocotyl 10-12 mm long, cotyledons about 18×5 mm, fleshy, petiolate. The chromosome complement is 2n=32 (Ţîţei, 2020).

The goal of this study was to evaluate the quality indices of green mass and silage from the yellowish genotype and the red genotype of *Amaranthus hypochondriacus* and the prospects of using them as feed for farm animals and as feedstock for the production of renewable energy.

MATERIAL AND METHODS

The yellowish genotype and the reddish genotype of the introduced prince's-feather amaranth *Amaranthus hypochondriacus,* which were cultivated in the experimental plot of the National Botanical Garden (Institute) Chişinău N 46°58′25.7″ latitude and E 28°52′57.8″ longitude, served as research subjects and the traditional forage crops - the hybrid 'Porumbeni 374' of corn, *Zea mays,* and the hybrid 'SAȘM-4' of sorghum - Sudan grass, *Sorghum bicolor x Sorghum sudanense*, were used as controls. The green mass of *Amaranthus hypochondriacus* genotypes was mowed in early flowering stage (late July), but corn and sorghum - Sudan grass green mass samples - in wax stage of grains (middle August). 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 silage was produced from chopped green mass and compressed in glass containers, the containers were stored for 45 days, and after that, they were opened and the organoleptic assessment and the determination of the organic acid composition of the persevered forage were done in accordance with the Moldavian standard SM 108. Some assessments of the main biochemical parameters: crude protein (CP), crude fibre (CF), ash, acid detergent fibre (ADF), neutral detergent fibre (NDF) and acid detergent lignin (ADL), digestible dry matter (DDM) 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) and cellulose (Cel), the digestible energy (DE), the metabolizable energy (ME) and the net energy for lactation (NEl) were calculated according to standard procedures. The carbon content of the substrates was determined according to Badger et al. (1979), the biochemical methane potential - according to Dandikas et al. (2015).

RESULTS AND DISCUSSION

While researching the biological peculiarities of growth and development, several differences between the agro-morphological traits of the studied *Amaranthus hypochondriacus* genotypes were identified. Both studied of amaranth genotypes are characterized by good early plant vigor and erect growth habit. The stem surface is rigged in both genotypes, but the color differs: the yellowish amaranth genotype has yellowish-green stems and the red genotype amaranth - reddish-green stems, respectively. Yellowish amaranth plants have green leaves with yellowish petioles and veins, and reddish amaranth plants - reddish-green leaves with pinkish-red petioles and veins. Both amaranth genotypes produce mostly upright, terminal, spiny, feathery inflorescences of intermediate density, but they differ in color: yellowish-orange (yellowish genotype) and deep reddish-purple (red variety). Seed color also varies from cream in the yellowish genotype amaranth to a deeper brownish color in the red amaranth. Amaranth seeds fall from their husks quite easily, the plants of both varieties being characterized by good seed popping ability.

Some agrobiological peculiarities and forage productivity of the studied *Amaranthus hypochondriacus* genotypes are presented in Table 1. It was established that in early flowering stage, the plant height of the studied amaranth genotypes varied from 167 cm in reddish amaranth plants to 175 cm in yellowish amaranth plants. Both amaranth genotypes are characterized low dry matter content in the harvested mass. The share of leaves and flowers in the harvested mass was optimal, 43.66-44.38%. The green mass productivity varied from 8.63 kg/m^2 in reddish amaranth to 9.33 kg/m^2 in yellowish amaranth.

Table 1. Some agrobiological peculiarities and productivity of the studied *Amaranthus hypochondriacus* genotypes

Genotype	Plant height (cm)	Stem (g)		Leaf + inflorescence (g)		Productivity (t/ha)		Content of leaves and flowers in fodder (%)
		green mass	dry matter	green mass	dry matter	green mass	dry matter	
Yellowish genotype	175	692.4	79.4	341.0	63.3	93.30	12.86	44.38
Reddish genotype	167	638.8	77.3	332.8	59.9	86.29	11.84	43.66

Some authors have mentioned various findings about the productivity of *Amaranthus hypochondriacus.* According to a study by Rivelli et al. (2008) under the irrigation conditions of southern Italy, the *Amaranthus hypochondriacus* accession PI 615696 was the most productive, 23 t/ha dry matter. Marin et al. (2011) reported that, depending on plant density and growing season, the green mass yield of the studied *Amaranthus hypochondriacus* cultivars ranged from 33.24 to 43.21 t/ha. Rahnama and Safaeie (2017) reported that *Amaranthus hypochondriacus* yield varied from 75.86 to 90.30 t/ha green mass or 11.0-13.05 t/ha dry matter. Ahrar et al. (2020) mentioned that the yield parameters of three genotypes of forage of *Amaranthus hypochondriacus* cultivars was 38.55 t/ha fresh mass or 5.91 t/ha dry matter in the cultivar *'Cim'*, and 31.99 t/ha fresh mass or 5.04 t/ha dry matter in the cultivar '*Kharkovski'*; 37.82 t/ha fresh mass or a 5.86 t/ha dry matter - the cultivar *'Loura'*. Shadi et al. (2020) in a comparative study of corn and four amaranth varieties grown in Iran, found that the yield of corn harvested mass was 35.0 t/ha green mass or 9.10 t/ha dry matter, while the productivity of *Amaranthus hypochondriacus* varieties was 19.0-56.0 t/ha green mass or 4.91-14.1 t/ha dry matter. Hosseini et al. (2022) reported that the yield of *Amaranthus hypochondriacus* varieties was 29.2-35.8 t/ha fresh mass or 4.4-6.4 t/ha dry matter, but the corn yield: 30.0 t/ha fresh mass or 6.5 t/ha dry matter. Zhong et al. (2024) found that the dry matter production in *Amaranthus hypochondriacus* varied from 13.6 to 20.4 t/ha.

Roughage is an important component in the ration of ruminants because of the unique physiological characteristics of gastrointestinal tracts. An adequate provision of high quality roughage is essential for maintaining the health and production performance of ruminants. The nutrient content of the dry matter from the green mass is an important indicator in feed quality evaluation.

The biochemical composition and the nutritive value of the green mass from the studied *Amaranthus hypochondriacus* genotypes are presented in Table 2. We found that the dry matter nutrient content of harvested green mass varied between the following values: 157-167 g/kg CP, 90-101 g/kg ash, 329-349 g/kg CF, 348-362 g/kg ADF, 529-534 g/kg NDF, 54-58 g/kg ADL, 294-304 g/kg Cel, 172-181 g/kg HC. We would like to mention that the green forage from yellowish genotype of *Amaranthus hypochondriacus* contained higher amounts of protein and minerals, and lower content of structural carbohydrates and lignin than in the green forage from the reddish genotype, which had a positive impact on the digestibility and energy concentration of forage. The green forage from the studied amaranth genotypes have higher content of crude protein, minerals, lignin and lower content of cellulose and hemicellulose, as compared with sorghum - Sudan grass green forage, also, level of dry matter digestibility and energy supply is much higher. As compared with corn green mass, the forage of the studied amaranth genotypes has much higher concentration of crude protein and minerals, higher content of crude fibre, lignin and cellulose and low level of hemicellulose, dry matter digestibility and energy concentration of feed.

Table 2. The biochemical composition and the nutritive value of the green mass of the studied *Amaranthus hypochondriacus* genotypes

Indices	*Amaranthus hypochondriacus*		*Sorghum bicolor* x *Sorghum sudanense*	*Zea mays*
	Yellowish genotype	Reddish genotype		
Crude protein, g/kg DM	167	157	73	84
Crude fibre, g/kg DM	329	349	415	248
Minerals, g/kg DM	101	90	77	52
Acid detergent fibre, g/kg DM	348	362	424	271
Neutral detergent fibre, g/kg DM	529	534	692	474
Acid detergent lignin, g/kg DM	54	58	45	48
Cellulose, g/kg DM	294	304	379	223
Hemicellulose, g/kg DM	181	172	268	203
Digestible dry matter, g/kg DM	618	607	559	678
Relative feed value	109	106	75	133
Digestible energy, MJ/ kg	12.20	12.00	11.14	13.28
Metabolizable energy, MJ/ kg	10.20	9.85	9.15	10.90
Net energy for lactation, MJ/ kg	6.03	5.87	5.16	6.91

In various publications, researchers have presented different results regarding the biochemical composition and the nutritive value of the harvested green mass from *Amaranthus hypochondriacus*. According to a study by Pospisil et al. (2009), the *Amaranthus hypochondriacus* dry matter forage contained 8.5-11.3% CP, 60-91 g/kg DP, 1.3-2.0% EE, 23.9-29.0% CF, 42.3-47.8% NDF, 30.1-36.6% ADF, but sorghum forage contained 6.4-9.2% CP, 43-65 g/kg DP, 1.9-2.1% EE, 29.5-32.9% CF, 63.7-65.9% NDF, 35.2-38.9% ADF. Rezaei et al. (2014) mentioned that the dry matter nutrient composition of *Amaranthus hypochondriacus* herbage was 221 g/kg dry matter with 12.3% CP, 46.1% NDFom, 31.5% ADFom, 3.59% ADL, 7.69% WSC and 9.7% ash, but *Zea mays* - 209 g/kg, 8.9% CP, 51.7% NDFom, 37.9% ADFom, 4.56% ADL, 10.8% WSC, 5.1% ash. Rahnama and Safaeie (2017) reported that *Amaranthus hypochondriacus* dry forage matter contained 11.5-12.0% CP, 2.1-2.4% EE, 67.4-69.1% DMD, RFV= 157.1-171.5, RFQ=158-174.6. Leukebandara et al. (2015) found that the *Amaranthus hypochondriacus* plants contained 132 g/kg dry matter with 18.43% CP, 3.17% EE, 24.50% CF, 16.83% ash, but *Zea mays* plants - 182.7 g/kg dry matter with 8.13% CP, 2.43% EE, 25.70% CF, 5.07% ash. Biel et al. (2017) reported that dry matter nutrient composition and feed value of *Amaranthus hypochondriacus* was: 10.1% CP, 1.76% EE, 24.0% CF, 44.0% NDF, 33.2% ADF, 6.31% lignin, 26.9% Cel, 10.9% HC, 14.4% ash, 638 g/kg DMD, 10.8 MJ/kg DE and 8.7 MJ/kg ME. Abbasi et al. (2018) mentioned that fresh amaranth forage contained 233 g/kg dry matter with 18.7% CP, 42.0% NDFom, 27.5% ADFom, 4.46% ADL, 14.5% ash and 8.4 MJ/kg ME. Shadi et al. (2020) found that the dry matter content and the chemical composition of harvested mass from *Amaranthus hypochondriacus* varieties was 246-258 g/kg dry matter with 8.3-17.6% CP, 37.3-41.3% NDFom, 24.6-28.9% ADFom, 4.73-6.46% ADL, 5.38-7.55% WSC, 20.0-32.1% NFC, 4.0-4.4% EE, 15.0-19.0% ash, 1.16-1.24% Ca, 0.36-0.40% P. As a result of our previous studies (Țîței, 2020) we found that the *Amaranthus hypochondriacus* dry matter of whole plants contained 17.2% CP, 33.0% ADF, 46.2% NDF, 5.5% ADL, 6.8% TSS 8.8% ash, 10.22 MJ/kg ME and 6.23 MJ/kg NEl. Haque et al. (2022) reported that leaf fresh mass of *Amaranthus hypochondriacus* red morphological type contained 40.10 g/kg CP, 69.12 g/kg carbohydrates, 7.17 g/kg dietary fibres, 38.69 g/kg ash and 44.43 kcal/kg, but the green morphological type - 39.15 g/kg CP, 69.89 g/kg carbohydrates, 7.31 g/kg dietary fibres, 45.90 g/kg ash and 42.71 kcal/kg, respectively. Anokhina et al. (2023) found that the nutrient content of *Amaranthus hypochondriacus* raw green mass was 15.5% CP, 4.3% EE, 21.3% CF. Hosseini et al. (2022) mentioned that *Amaranthus hypochondriacus* varieties contained 133-174 g/kg dry matter with 14.8-17.0% CP, 33.9-37.8% NDFom, 24.4-29.0% ADFom, 5.89-6.50% ADL, 5.0-5.7% WSC, 23.6-24.9% NFC, 3.61-4.39% EE, 17.7-22.2% ash, 1.33-1.51% Ca, 0.49-0.55% P, but corn green forage contained 202 g/kg dry matter with 7.7% CP, 49.3% NDFom, 30.8% ADFom, 4.83% ADL, 12.0% WSC, 33.2% NFC, 2.64% EE, 7.2% ash, 0.32% Ca, 0.24% P. Wang et al. (2024) revealed that *Amaranthus hypochondriacus* contained 25% CP, 4% lignin and lower levels of nitrate and oxalic acids.

Storage conditions play a vital role in maintaining forage quality for farm animals. 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, especially in the dairy cow industry. When opening the glass containers with silage prepared from the studied amaranth genotypes, 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. The silage prepared from the yellowish genotype of amaranth was characterized by homogeneous olive-yellowish colour, but the silage from the reddish genotype - dark yellow leaves with pink hues and light pink stems. Amaranth silages had pleasant smell like pickled vegetables. As a result of the performed analysis (Table 3), it was determined that the fermentation profile of the prepared amaranth silages was pH = 3.95-4.03, 29.6-33.3 g/kg lactic acid, 6.6-6.9 g/kg acetic acid, but butyric acid was not detected, and the obtained amaranth silages met the standard SM 108 for the 1-st class quality. In the silage from the yellowish amaranth genotype, the concentration of lactic acid was higher as compared with the silage from the reddish genotype. The dry matter from amaranth silages contained 14.8-16.1% CP, 8.5-9.4% ash, 29.1-32.9% CF, 30.8-34.5% ADF, 48.9-51.5% NDF, 4.0-4.5% ADL, 26.8-30.0% Cel, 17.0-19.0 % HC, 567-619 g/kg DDM, RFV=112-121, 12.23-12.75 MJ/kg DE, 10.04-10.47 MJ/kg ME and 6.06-6.49 MJ/kg NEl. During the process of ensiling of *Amaranthus hypochondriacus* chopped green mass, we observed a significant reduction in the content of structural carbohydrates, lignin and minerals. As compared with the harvested green mass, the digestibility indices and the feed energy value of the prepared amaranth silages was higher. The silage prepared from the yellowish amaranth genotype had higher concentration of protein and lower concentration of structural carbohydrates and lignin, higher level of digestibility and energy supply. The prepared amaranth silages differ from corn silage in a higher concentration of crude protein, cellulose, lignin, and from sorghum x Sudan grass silage - in low content of structural carbohydrates, high level of crude protein, digestibility, metabolizable energy and net energy for lactation.

Table 3. The biochemical composition and the fodder value of the *Amaranthus hypochondriacus* silage

Indices	*Amaranthus hypochondriacus*		*Sorghum bicolor* x *Sorghum sudanense*	*Zea mays*
	Yellowish genotype	Reddish genotype		
pH index	3.95	4.03	4.06	3.77
Organic acids, g/kg	39.9	36.5	26.7	48.6
Free acetic acid, g/kg DM	2.9	3.1	3.3	5.1
Free butyric acid, g/kg DM	0.0	0	0	0
Free lactic acid, g/kg DM	10.4	9.1	7.9	17.0
Fixed acetic acid, g/kg DM	3.7	3.8	3.6	5.2
Fixed butyric acid, g/kg DM	0.0	0	0	0.2
Fixed lactic acid, g/kg DM	22.9	20.5	11.9	21.1
Total acetic acid, g/kg DM	6.6	6.9	6.9	10.3
Total butyric acid, g/kg DM	0.0	0.0	0	0.2
Total lactic acid, g/kg DM	33.3	29.6	19.8	38.1
Acetic acid, % of organic acids	16.54	18.90	26	21
Butyric acid, % of organic acids	0	0	0	0.41
Lactic acid, % of organic acids	83.45	81.10	74	78
Crude protein, g/kg DM	161	148	61	80
Crude fibre, g/kg DM	291	329	397	245
Minerals, g/kg DM	94	85	84	59
Acid detergent fibre, g/kg DM	308	345	403	258
Neutral detergent fibre, g/kg DM	498	515	670	469
Acid detergent lignin, g/kg DM	40	45	39	37
Cellulose, g/kg DM	268	300	364	221
Hemicellulose, g/kg DM	190	170	267	211
Digestible dry matter, g/kg DM	649	620	575	688
Relative feed value	121	112	80	136
Digestible energy, MJ/ kg	12.75	12.23	11.42	13.45
Metabolizable energy, MJ/ kg	10.47	10.04	9.26	11.04
Net energy for lactation, MJ/ kg	6.49	6.06	5.40	7.06

Different results regarding the biochemical composition and the nutritive value of the ensiled mass from *Amaranthus* species have been presented in the specialized literature. Rezaei et al. (2015) found that the dry matter of *Amaranthus hypochondriacus* silage contained 235 g/kg dry matter with pH=3.99, 6.91% lactic acid, 1.93% acetic acid, 1.03% butyric acid, 11.4% CP, 45.1% NDFom, 31.0% ADFom, 3.56% ADL, 0.73% WSC, 11.1% ash, 676 g/kg OMD and 9.34 MJ/kg ME, but *Zea mays* silage 224 g/kg dry matter with pH=3.92, 7.18% lactic acid, 2.04% acetic acid, 0.09% butyric acid, 8.3% CP, 51.0% NDFom, 33.5% ADFom, 4.57% ADL, 0.97% WSC, 5.48% ash, 661 g/kg OMD and 9.71 MJ/kg ME. Ma et al. (2019) reported that the dry matter and the nutrient composition of silage form amaranth cut in the early flowering stage was 171.9 g/kg dry matter with 12.52% CP, 50.85% NDF, 31.03% ADF, 2.60% ADL, while the silage prepared from plants cut in the full flowering stage contained 188.2 g/kg dry matter with 12.41% CP, 53.39% NDF, 33.84% ADF, 3.39% ADL. During our previous investigations

(Țîței, 2020) we found that the prepared silage from *Amaranthus hypochondriacus* had pH 3.86, 13.4 g/kg lactic acid, 5.8 g/kg acetic acid, 167 g/kg CP, 348 g/kg ADF, 516 g/kg NDF, 45 g/kg ADL, 303 g/kg Cel and 156 g/kg HC with 10.05 MJ/kg ME and 6.02 MJ/kg NEl. Shadi et al. (2020) remarked that *Amaranthus hypochondriacus* silages had pH=4.0-4.6, 5.85-6.30% lactic acid, 1.6-1.78% acetic acid, 0.02-0.05% butyric acid, 251-267 g/kg dry matter with 8.14-18.2% CP, 36.1-40.5% NDFom, 23.5-28.1% ADFom, 5.3-6.2% ADL, 1.10-1.51% WSC, 15.9-26.5% NFC, 7.7-9.03% EE, 18.2-21.5% ash, 1.16-1.27% Ca, 0.36-0.40% P. Anokhina et al. (2023) mentioned that *Amaranthus hypochondriacus* silage contained 2.91% lactic acid, 7.03% acetic acid, 0.01% butyric acid, 6.3% CP, 2.9% EE, 20.7% CF, but silages with starter cultures contained 5.76-7.51% lactic acid, 2.49% acetic acid, 0-0.02% butyric acid, 8.1-13.9% CP, 3.3-4.3% EE, 20.8-21.3% CF, while corn silage 6.3% CP, 0.9% EE, 23.6% CF, respectively. Hosseini et al. (2022) found that *Amaranthus hypochondriacus* silages were characterized by pH=4.28-4.96, 5.10-6.01% lactic acid, 1.59-1.89% acetic acid, 0.06-0.11% butyric acid, 152-187 g/kg dry matter with 14.4-16.3% CP, 31.7-35.5% NDFom, 23.4-27.1% ADFom, 5.65-6.52% ADL, 1.12-1.40% WSC, 23.8-25.1% NFC, 4.32-5.62% EE, 19.7-23.9% ash, 1.39-1.59% Ca, 0.44-0.54% P, but corn silage - pH=3.90, 7.03% lactic acid, 2.33% acetic acid, 0.07% butyric acid, 217 g/kg dry matter with 7.7% CP, 49.2% NDFom, 30.8% ADFom, 4.76% ADL, 11.0% WSC, 34.4% NFC, 2.60% EE, 7.1% ash, 0.33% Ca, 0.25% P. Yi et al. (2023) remarked that *Amaranthus hypochondriacus* silages had 189 g/kg dry matter with 13.42% ash. 10.16% CP, 67.32% NDF, 39.87% ADF, 10.83% ADL, 12.80% WSC, 18.06 MJ/kg GE, 9.79 MJ/kg DE, 7.72 MJ/kg ME and 4.37 MJ/kg NEl. Zhong et al. (2024) found that *Amaranthus hypochondriacus* silages had pH=4.52-6.39, 0.66-2.37% lactic acid, 0.13-0.99% acetic acid, 0-0.02% butyric acid, 192.9-243.0/kg dry matter. Zubillaga et al. (2024) mentioned that the nutritional parameters of the silage from amaranth green mass were as follows: 202.4 g/kg dry matter with 11.14% CP, 14.19% ash, 48.58% NDF, 26.36% ADL, 68.37% DMD and 2.47 Mcal/kg, but silage from wilted amaranth mass 344.7 g/kg dry matter with 13.43% CP, 14.31% ash, 44.07% NDF, 24.30% ADL, 69.97% DMD and 2.53 Mcal/kg.

Bioenergy is a versatile resource to overcome fossil fuel scarcity and energy crises. It can be feasibly derived from organic materials that are known as biomass. Although the sole utilization of biomass to obtain bioenergy is unreasonable; organic waste can be effectively up-scaled to generate biofuels that have potential applications. Biogas is a promising renewable energy source, that is why the search for suitable substrates is at the centre of attention. The quality indices of the substrates from the studied *Amaranthus hypochondriacus* genotypes and their biomethane production potential are presented in Table 4. The nitrogen content in the *Amaranthus hypochondriacus* genotypes substrates ranged from 23.68 g/kg to 26.72 g/kg, the estimated content of carbon - from 499 g/kg to 508 g/kg, the C/N ratio varied from 18.7 to 21.5 and met the established standards, but in Sudangrass substrates C/N = 43.9-52.1 and in corn substrates C/N = 39.2-40.8. The biomethane production potential in studied amaranth substrates varied from 320 to 351 l/kg ODM, but in Sudangrass substrates - from 325 to 333 l/kg ODM and corn substrates from 319 to 336 l/kg ODM The best biomethane production potential was achieved in the silage substrate from the yellowish amaranth genotype.

Table 4. The biochemical biomethane production potential of *Amaranthus hypochondriacus* substrates

Indices	*Amaranthus hypochondriacus*				*Sorghum bicolor* x *Sorghum sudanense*		*Zea mays*	
	Yellowish genotype		Reddish genotype					
	fresh mass	silage	fresh mass	silage	fresh mass	silage	fresh mass	silage
Organic dry matter, g/kg	899	906	910	915	923	916	948	941
Minerals, g/kg DM	101	94	90	85	77	84	52	59
Crude protein, g/kg DM	167	161	157	148	73	61	84	80
Nitrogen, g/kg DM	26.72	25.76	25.20	23.68	11.68	9.76	13.44	12.80
Carbon, g/kg DM	499	503	506	508	513	509	527	523
Ratio carbon/nitrogen	18.7	19.5	20.1	21.5	43.9	52.1	39.2	40.8
Cellulose, g/kg DM	294	269	304	300	379	364	223	221
Hemicellulose, g/kg DM	181	190	172	170	268	267	203	211
Acid detergent lignin, g/kg DM	54	40	58	45	45	39	48	37
Biomethane potential, L/kg DM	295	318	288	302	300	305	302	317
Biomethane potential, L/kg ODM	328	351	320	330	325	333	319	336

Several literature sources describe the methane potential of amaranth substrates. According to Seppälä (2013), the methane yield from amaranth biomass reached 290 l/kg, but from Sudan grass biomass - 330 l/kg VS. Mursec et al. (2009) reported that the methane production from amaranth silage was 125 l/kg VS, while from maize and sorghum silages 187-188 l/kg VS. Eberl et al. (2014) remarked that the amaranth silage substrate contained 236 g/kg dry mater, 13.7% ash, 5.8% ADL, 26% cellulose and specific methane yield was 270 l/kg lowest compared to maize substrate 350 l/kg methane yield. Dubrovskis and Adamovics (2015) reported that the methane yield of pure amaranth silage substrate reached 403 l/kg dry organic matter, while in amaranth silage with catalyst Metaferm substrates 434-484 L/kg. Herrmann et al. (2016) mentioned that *Amaranthus cruentus* silage substrate had 211 g/kg dry matter with 9.5% CP, 33.9% ADF, 40% NDF, 5.2% ADL, C/N=27 and the biochemical methane potential was 278.4 l/kg, *Zea mays* silage substrate - 302 g/kg dry matter with 7.8% CP, 24.0% ADF, 41.2% NDF, 2.9% ADL, C/N=37 and biochemical methane potential 328.2 l/kg, *Sorghum bicolor x Sorghum sudanense* silage substrate - 251 g/kg dry matter with 8.9% CP, 36.6% ADF, 58.0% NDF, 5.5% ADL, C/N=33 and biochemical methane potential 288.9 l/kg. Eberl and Fritz (2018) revealed that the potential methane yield of amaranth substrates ranged from 240 to 310 l/kg, largely depending on the amaranth genotype. Von Cossel et al. (2017) found that the specific methane yield of *Amaranthus hypochondriacus* substrate (266 l/kg VS) was much lower than that of maize substrate (330 l/kg VS), due to higher contents of ash, lignin and cellulose in the amaranth substrate. Yan et al. (2017) reported that the *Amaranthus tricolor* leafy vegetable residues contained 306 g/kg DM, 5.1% CP, 1.2% EE, 37.98% HC, 10.50% Cel, 11.13% lignin, 33.06% carbon, 4.62% nitrogen and methane production potential was 430 l/kg. Förster et al. (2019) showed that the methane yield of yellow amaranth substrates was 238.5-285.9 l/kg, substrates for grain amaranth type as a whole plant had 206.2-277.3 l/kg and the lowest methane yields substrates for grain amaranth type straw 170.86-229.08 l/kg.

CONCLUSIONS

The biomass productivity of *Amaranthus hypochondriacus* harvested in the early flowering stage reached 12.86 t/ha dry matter in the yellowish genotype, and 11.84 t/ha dry matter in the reddish genotype.

The forages from *Amaranthus hypochondriacus* genotypes contained a much higher amount of crude protein than the forage from sorghum-Sudangrass hybrid and corn.

The yellowish genotype of *Amaranthus hypochondriacus* had higher content of crude protein and lower content of structural carbohydrates than the reddish genotype.

The studied genotypes of *Amaranthus hypochondriacus* are characterized by higher quality indices of the fodders for farm animals and substrates for biomethane production as compared with hybrid *Sorghum bicolor x Sorghum sudanense.*

The green mass and silage obtained from the studied yellowish and reddish genotypes of *Amaranthus hypochondriacus* contain many nutrients, which make them suitable to be used as alternative fodder for farm animals and have high potential as feedstock for biomethane production.

The obtained results indicate the possibility of using the studied yellowish and reddish genotypes of *Amaranthus hypochondriacus* as initial material for selecting, breeding and implementing new local cultivars for agricultural production.

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