THE PROSPECTS OF CULTIVATION AND USE OF THE SPECIES *Amaranthus hypochondriacus* IN MOLDOVA

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Abstract. The goal of this research was to evaluate the quality of seeds and phytomass of the non-native species *Amaranthus hypochondriacus* grown in an experimental field of the National Botanical Garden (Institute), Chişinău, Republic of Moldova. It has been found that the prepared silage was characterized by pleasant smell, its pH was 3.86, it contained 13.4 g/kg DM lactic acid, 5.8 g/kg DM acetic acid, 167 g/kg CP, 348 g/kg ADF, 516 g/kg NDF, 45 g/kg ADL, 158 g/kg HC, 303 g/kg Cel, with feed value RFV=111, 10.05 MJ/kg ME and 6.02 MJ/kg NEl. The biochemical methane potential of the silage substrate made from *Amaranthus hypochondriacus* reached 302 l/kg ODM. The *Amaranthus hypochondriacus* seeds contained 180.8 g/kg protein, 82.3 g/kg fats, 53.2 g/kg crude fibre, 657.4 g/kg nitrogen free extract, 2.5 g/kg calcium and 2.0 g/kg phosphorus, the stalks contained 293 g/kg HC and 404 g/kg Cel. The theoretical ethanol potential from structural carbohydrates of the stalks averaged 421 L/t. The stalk biomass was characterised by moderate calorific values (18.0 MJ/kg) and ash content (2.3 %), the specific density of solid bio fuel, namely briquettes, reached 901 kg/m^3. *Amaranthus hypochondriacus* can be exploited in many ways: as pseudo-grain and fodder and as feedstock in the production of renewable energy.

Keywords: *Amaranthus hypochondriacus*, biochemical composition, feed value, renewable energy.

Rezumat. Perspectiva de cultivare şi valorificare a speciei *Amaranthus hypochondriacus* în Moldova. Scopul cercetării a constatat în evaluarea calităţii seminţelor şi a fitomasei speciei non-native *Amaranthus hypochondriacus*, introdusă și cultivată în câmpul experimental din Grădina Botanică Naţională (Institut), Chişinău, Republic of Moldova. S-a stabilit că silozul obținut se caracterizează printr-un miros plăcut, pH 4.23, conține 13.4 g/kg S.U. acid lactic, 5.8 g/kg S.U. acid acetic, conținut de 167 g/kg proteină brută (CP), 348 g/kg fibre în detergent acid (ADF), 516 g/kg fibre în detergent neutru (NDF), 45 g/kg lignină sulfurică (ADL), 158 g/kg hemiceluloză (HC), 303 g/kg celuloză (Cel) cu valoarea nutritivă RFV=111, încărcătură energetică de 10.05 MJ/kg energie metabolozantă (ME) și 6.02 MJ/kg energie netă pentru lactație (Nel). Potențialul biochimic de obținere a biometanului a substratului de siloz atinge 302 l/kg M.O. Semințele de amarant conțin 180.8 g/kg proteină, 82.3 g/kg lipide, 53.2 g/kg fibre brute, 657.4 g/kg substanțe extractive neazotate, 2.5 g/kg calciu și 2.0 g/kg fosfor, iar tulpinele -293 g/kg HC și 404 g/kg Cel. Potențialul teoretic de etanol a carbohidraților structurali din tulpini constitue 421 L/t. Biomasa de tulpini se caracterizează printr-o valoarea calorifică (18.0 MJ/kg) și conținut de cenușă (2.3 %) moderat, densitatea specifică a biocombustibilului solid – brichete – atinge 901 kg/m^3. *Amaranthus hypochondriacus* poate fi valorificat în mai multe domenii, ca pseudocereale și furaj, de asemenea, ca substrat pentru producerea energiei renovabile.

Cuvinte cheie: *Amaranthus hypochondriacus*, compoziția biochimică, energie regenerabilă, valoare nutritivă.

INTRODUCTION

Climate change, which is characterized by the rise of local and global temperatures, frequency of droughts, water deficits and salinity stress is an important yield-limiting factor that poses a significant threat to agriculture worldwide. The problem of food security is often related to the availability and accessibility of land, water and energy resources to meet the growing needs of human societies. Global agriculture is dependent on a relatively small number of crop species, which have been bred to optimize productivity within a relatively narrow range of environmental variations. The incorporation of neglected and underused crops, the domestication of new species would promote agricultural diversity and could provide a solution to many of the problems associated with food security, nutrition, healthcare, medicine and industrial needs. It has been well established that the species with C_4 photosynthesis are more efficient during drought and other environmental stress conditions. Amaranth is such a crop, it has 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 it continues to be used essentially worldwide, even to the present day. Amaranth grows under drought stress, can tolerate unfavourable abiotic conditions including high salinity, acidity or alkalinity, which makes this plant uniquely suitable for subsistence farming. Amaranth grains 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 immune system, anticancer activity, control of blood sugar level, improved condition of hypertension and anaemia, anti-allergic and antioxidant activity, etc., due to the presence of some bioactive components. Amaranth has high potential and can be considered an alternative multipurpose crop in most parts of the world (DAS, 2016; SORIANO-GARCÍA et al., 2018).

The genus *Amaranthus L.* belongs to the *Amaranthoidae* subfamily of the *Amaranthaceae* family, *Caryophyllales* order. It includes annual, biennial and rarely perennial herbaceous species. The Plant List includes 455 scientific plant names of species rank for the genus *Amaranthus*, of which 105 are accepted species names. Most of these species are native to the Americas, and only a few species are native to Africa, Europe and Asia. All the species fall roughly under one of the four categories – grain, vegetable, ornamental and weed. *Amaranthus hypochondriacus*, *Amaranthus cruentus*, *Amaranthus caudatus* are the major grain producing species, *Amaranthus tricolor*, *Amaranthus dubius*, *Amaranthus lividus* and *Amaranthus hybridus* are used as vegetables and ornamentals.

Amaranthus hypochondriacus L. (syn. *A. anardana* Buch; *A. aureus* Besser; *A. flavus* L.; *A. frumentaceus* Buch.-Ham. ex Roxb; *A. leucocarpus* S. Watts) is known as the 'Prince's feather' or 'Prince-of-Wales feather' due to its ornate and vibrant inflorescence, native to southwestern North America, is a vigorous plant, with erect, annual growth that grows between 40 and 200 cm in height, sometimes even up to 250 cm. The stem is generally branched, mainly at the inflorescence level. The leaves are green in colour, with possible more or less intense shades of purplish colour, ovate lanceolate shape, carried by long petioles. 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 fruit is an obovoid to rhombic capsule 1.5–2 mm long, circumscissile, with a short beak, 1-seeded. The seed is obovoid to ellipsoid, compressed, 1 mm long, whitish to yellowish or blackish. Seedlings have epigeal germination, hypocotyl 10–12 mm long, cotyledons about 18 mm × 5 mm, fleshy, petiolate. The chromosome complement is 2n = 32.

Amaranthus hypochondriacus is studied and cultivated as ornamental, pseudo-cereal, fodder and energy crop in many regions of the world (RAVINDRAN et al., 1996; RIVELLI et al., 2008; MARIN et al., 2011; RAHNAMA & SAFAEIE, 2017; MA et al., 2019; VON COSSEL, 2019).

The goal of this research was to evaluate the quality of the seeds and phytomass of the non-native species *Amaranthus hypochondriacus* and its usage potential as feed, fodder and feedstock for the production of renewable energy in the Republic of Moldova.

MATERIALS AND METHODS

The non-native species *Amaranthus hypochondriacus* which was cultivated in the non-irrigated experimental plot of the National Botanical Garden (Institute) Chişinău N 46°58′25.7″ latitude and E 28°52′57.8″ longitude, served as subject of the research, and the traditional fodder crop – corn, *Zea mays*, was used as control variant.

The green mass of *Amaranthus hypochondriacus* was mowed in the early flowering stage (late July), while the control *Zea mays* – in the kernel milk-wax stage (middle August). The green mass productivity was determined by weighing the yield obtained from a harvested area of 10 m^2, which was afterwards transformed per hectare. The leaves/stems ratio was determined by separating leaves and panicles from the stem, weighing them separately and establishing the ratios for these quantities, using samples of 1.0 kg of harvested plants. After seed formation, panicles from five plants on each plot were protected with paper bag to prevent grain loss, before and upon harvesting, to assess the potential yield. Hand-harvesting was carried out at maturity, the panicles were threshed and the grains were cleaned by sieves and a wind separation system, the stems were cut at the soil level and dried in a ventilated oven. For chemical analyses, the samples were dried at 65 ± 5 °C. The dry matter or total solid (TS) content was detected by drying samples up to a constant weight at 105 °C. For ensiling, the green mass was shredded and compressed in well-sealed containers. After 45 days, the containers were opened, the organoleptic assessment was carried out and the biochemical composition of the silage was determined in accordance with the Moldavian standard SM 108*. The silage was prepared and evaluated in accordance with the Moldavian standard SM 108. The ash content was detected by heating in a muffle furnace at 550 °C; crude protein (CP) – by the Kjeldahl method; crude fat (EE) – by the Soxhlet method; crude cellulose (CF) – by the Van Soest method; calcium concentration – using the atomic absorption spectrometry method and phosphorus – using the spectrophotometric method in the Laboratory of Nutrition and Forage Technology of the Scientific-Practical Institute of Biotechnology in Animal Husbandry and Veterinary Medicine. 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), total soluble sugars (TSS), digestible dry matter (DDM), digestible organic matter (DOM) 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 nitrogen free extract (NFE), 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 biochemical biogas potential (Yb) and the methane potential (Ym) were calculated according to the equations of DANDIKAS et al., (2014) based on the chemical compounds – acid detergent lignin (ADL) and hemicellulose (HC) values: $Yb = 727+ 0.25\ HC- 3.93\ ADL$; $Ym = 371+ 0.13HC - 2.00ADL$.

The dry stalks were chopped and disintegrated by a knife mill with a sieve with the mesh size of 1 mm. **the** Theoretical Ethanol Potential (TEP) was calculated according to the equations of GOFF et al., 2010 based on the conversion of hexose (H) and pentose (P) sugars: $H = [\%Cel+(\%HC \times 0.07)] \times 172.82$; $P = [\%HC \times 0.93] \times 176.87$; $TEP = [H + P] \times 4.17$.

For the production of solid biofuel, the harvested stalks were chopped into chaff with the use of a stationary forage chopping unit. The chopped phytomass was milled in a beater mill equipped with a sieve with diameter of openings of 10 mm using the equipment SM 100. The physical and mechanical properties of dry biomass were determined according to the European Standards, at the State Agrarian University of Moldova: the moisture content of the plant material was determined by SM EN ISO 18134 in a MEMMERT100-800 automatic hot air oven; the content of ash was determined at 550 ºC in a HT40AL muffle furnace according to SM EN ISO 18122; a LAGET MS-10A automatic calorimeter with accessories was used for the determination of the calorific value, according to SM EN ISO 18125; the particle size distribution was determined according to SM EN ISO 17827 using standard sieves, the collected particles in each sieve were weighed; the cylindrical containers were used for the determination of the bulk density, calculated by dividing the mass over the container volume according to SM EN ISO 17828, SM EN ISO 18847. The briquetting was carried out by the BrikStar 50-12 hydraulic piston briquetting press (Briklis). The mean compressed (specific) density of the briquettes was determined immediately after removal from the mould as a ratio of measured mass over calculated volume.

RESULTS AND DISCUSSIONS

Analysing the results of the assessment of agro-biological peculiarities, it can be noted that *Amaranthus hypochondriacus* seedlings emerged uniformly on the soil surface 3-5 days after sowing, or 2-3 days earlier than the control *Zea mays.* In early stages, amaranth plantlets were characterized by slow growth of the stem and leaves due to the small supply of nutrients in small seeds. Over the next 25-50 days, the growth and development of the aerial part of the plant was intense. The root system developed actively from the seedling stage to the inflorescence stage. The *Amaranthus hypochondriacus* root system was dominated by a strong taproot, which in some plants exceeded 1.7-2.0 m in depth, with lateral roots on the upper 35-40 cm that spread laterally about 55 cm. In the early flowering stage, the branched stalks of *Amaranthus hypochondriacus* reached up to 155-160 cm tall and 16-22 mm thick. The biomass productivity of *Amaranthus hypochondriacus* harvested in early flowering stage, late July, achieved 6.85 kg/m^2 green mass or 1.04 kg/m^2 dry matter, but the yield of *Zea mays* harvested in kernel milk-wax stage, middle August, was 4.09 kg/m^2 green mass or 1.22 kg/m^2 dry matter. The harvested amaranth biomass was richer in leaves (54 %), but poorer in dry matter (18 %), in comparison to the control variant.

According to RAHNAMA & SAFAEIE (2017), *Amaranthus hypochondriacus* can produce 75.86-90.30 t/ha fresh mass and 11.0-13.05 t/ha dry forage yield containing 11.5-12 % CP, 2.1-2.4 % EE, 67.4-69.1 % DMD, RFV 157.1-171.5, RFQ 158-174.6. RIVELLI et al., (2008) reported that, in an irrigated field in southern Italy, the total aboveground dry matter of tested *Amaranthus* species, ranged from 15 t/ha (*Amaranthus cruentus*) to 23 t/ha (*Amaranthus hypochondriacus*). MARIN et al., (2011) mentioned that, under the pedoclimatic conditions of the central part of the Romanian Plain, the recorded green mass productivity of the studied *Amaranthus hypochondriacus* cultivars was 431 q/ha for a density of 100,000 plants/ha.

Silage is the main conserved green succulent roughage fodder for domestic animals, but in recent decades, it has also been used as substrate in biogas production. During the sensorial assessment, it was found that the prepared silage from harvested *Amaranthus hypochondriacus* green biomass had a pleasant smell, specific to pickled vegetable, the consistency of the silage was retained, in comparison with the initial green mass, without mould and mucus. As a result of the performed analysis, it was determined that the pH index varied from 3.61 in corn silage to 3.86 in amaranth silage. The pH index of the prepared silages from the studied species met the standard SM 108 for 1st class quality. It has been determined that the content of organic acids varied from 24.5 g/kg in *Amaranthus hypochondriacus* silage to 32.8 g/kg, while in *Zea mays* silage most organic acids were in fixed form. The butyric acid was not detected in the studied silages. The *Amaranthus hypochondriacus* silage was characterised by high acetic acid concentration (5.8 g/kg) and lower lactic acid concentration (13.4 g/kg) in comparison with the *Zea mays* silage. The dry matter content in the prepared silage from *Amaranthus hypochondriacus* was low (184 g/kg) in comparison with the *Zea mays* silage (314.5 g/kg). The results of the study on dry matter indicate that the *Amaranthus hypochondriacus* silage contained 167 g/kg CP, 30 g/kg EE, 295 g/kg CF, 123 g/kg ash, 516 g/kg NDF, 348 g/kg ADF, 45 g/kg ADL, 12 g/kg TSS, 158 g/kg HC and 303 g/kg Cel, but *Zea mays* silage – 53 g/kg CP, 28 g/kg EE, 225 g/kg CF, 50 g/kg ash, 514 g/kg NDF, 303 g/kg ADF, 50 g/kg ADL, 276 g/kg TSS, 211g/kg HC and 257 g/kg Cel. The nutritive and energy value of *Amaranthus hypochondriacus* was RFV= 111, 12.02 MJ/kg DE, 10.05 MJ/kg ME and 6.02 MJ/kg NEl, but the control *Zea mays* silage – RFV= 118, 12.8 MJ/kg DE, 10.52 MJ/kg ME and 6.54 MJ/kg NEl, respectively. The calculated annual fed productivity of ensiled *Amaranthus hypochondriacus* achieved 1650 kg/ha protein, 100 GJ/ha metabolizable energy and 60 GJ/ha net energy for lactation, but the control *Zea mays* silage contained 620 kg/ha protein, 148 GJ/ha metabolizable energy and 76 GJ/ha net energy for lactation.

Some authors mentioned various findings about the quality of the silage prepared from the studied species. According to COŞMAN (2014), the amaranth silage was characterized by 23.29 % DM, pH 4.02, 25.7 g/kg DM lactic acid, 23.0 g/kg DM acetic acid and 0.04 g/kg DM butyric acid, 99.1 g/kg CP, 261.9 g/kg CF, 35.8 g/kg EE, 119.3 g/kg ash, 11.5 mg/kg carotene, while corn silage 31.07%DM, pH 3.51, 32 g/kg DM lactic acid, 5.3 g/kg DM acetic acid, 44.4g/kg CP, 216.1 g/kg CF, 28.4 g/kg EE, 49.4 g/kg ash and 15.2 mg/kg carotene. REZAEI et al. (2014) compared the ensilability of amaranth and corn and remarked that the amaranth silage had a pH of 3.9 and 23.5 % DM, contained 81.8 g/kg lactate, 17.6 g/kg acetate, 1.1 g/kg propionate, 14.6 g/kg butyrate, 122 g/kg CP, 440 g/kg NDFom, 278 g/kg ADFom, 35 g/kg lignin, 24.1g/kg EE, 304 g/kg NFC, 101 g/kg starch, 17.8 g/kg calcium, 2.6 g/kg phosphorus with 9.2 MJ/kg metabolizable energy, while the corn silage had a pH of 4.0 and 22.0 % DM, contained 76.7 g/kg lactate, 19.2 g/kg acetate, 3.1 g/kg propionate, 0.9 g/kg butyrate, 77g/kg CP, 480 g/kg NDFom, 281 g/kg ADFom, 45 g/kg lignin, 34.2g/kg EE, 332 g/kg NFC, 213 g/kg starch, 2.3 g/kg calcium, 2.2 g/kg phosphorus with 10.1 MJ/kg metabolizable energy. MA et al., (2019) reported that the dry matter and the chemical composition of amaranth silage varied depending on the time when the plants were harvested and ensiled: 15.31-22.00 % DM, 13.21-11.51 % CP, 47.88-54.14 % NDF, 29.79-39.03 % ADF, 2.53-4.67 % ADL.

Biogas production is one of the sustainable technologies with the considerable benefit of being able to generate useful energy carriers from various raw materials of biomass origin including plants and plant residues. The digestate from biogas plants can play an important role in agriculture by providing nutrients, improving soil structure and reducing the use of mineral fertilizers, increasing hydraulic conductivity and enhancing the moisture retention capacity. One promising option to improve the biomethane yield from plant biomass is to apply a pre-treatment. Energy crops can be a suitable feedstock for anaerobic digestion and if ensiled they can be supplied to biogas plants continuously throughout the year. The ensiling process could also be considered a biomass pre-treatment method. During ensiling, mono sugars are converted by lactic acid bacteria into lactic acid, the partial hydrolysis of structural polysaccharides makes cellulose and hemicellulose more accessible to anaerobic digestion. The carbon nitrogen ratio (C/N ratio) is one of the factors that influence the methane fermentation process. The optimal C/N ratio in biomass should range from 10 to 30, which does not affect the development of microflora involved in anaerobic digestion. Based on the biochemical composition data (Table 4), it was found that the *Amaranthus hypochondriacus* substrate contained 48.7 % carbon and 2.67 % nitrogen, the C/N ratio constituted 18, the amount of lignin 45 g/kg and hemicellulose 158 g/kg, the biogas potential was 590 l/kg and the biochemical methane potential – 302 l/kg. The *Zea mays* silage substrate didn't differ essentially in the potential for biogas production – 599 l/kg and biochemical methane potential – 306 l/kg, due to the high amount of hemicellulose (211 g/kg) and substrate digestibility (72.3 %).

Several literature sources describe the methane potential of amaranth substrate. MURSEC et al., (2009) reported that the methane production from amaranth silage was 125 L/kg VS and maize silage 187 L/kg VS. EBERL et al. (2014) reported that the amaranth silage was characterized by a poor dry mater content (23.6%) accompanied by high contents of ash (13.7 % of VS), ADL (5.8 % of VS) and cellulose (26 % of VS), which caused a much lower specific methane yield (270 L/kg) compared to maize (350 L/kg). Based on the batch experiments, DUBROVSKIS & ADAMOVICS (2015) found that the average methane yield per unit of dry organic matter added from digestion of amaranth silage was 403 L/kg, with catalyst Metaferm 434-484 L/kg. According to VON COSSEL (2019), the specific methane yield of *Amaranthus hypochondriacus* substrate was on average 266 L/kg VS, which was negatively affected by the high contents of ash (13.6 % of VS), lignin (6.5 % of VS) and cellulose (32.9 % of VS).

Table 1. The biochemical composition of the grains of the studied species.

Indices	*Amaranthus hypochondriacus*	*Zea mays*
Dry matter, g/kg	898.1	873.2
Crude protein, g/kg DM	180.8	83.5
Crude fats, g/kg	82.3	43.7
Crude fibre, g/kg DM	53.2	27.5
Nitrogen free extract, g/kg DM	657.4	829.6
Ash, g/kg DM	26.3	15.7
Calcium, g/kg DM	2.5	2.5
Phosphorus, g/kg DM	2.0	0.3

On the basis of our observations, *Amaranthus hypochondriacus*, under the pedoclimatic conditions of the Republic of Moldova, reached seed maturity in middle August - early September, 23-32 days earlier than corn. The average grain yield of *Amaranthus hypochondriacus* was about 3.75 t/ha in comparison with 6.21 t/ha corn grain, control variant. It has been found that *Amaranthus hypochondriacus* grain contained 180.8 g/kg CP, 82.3 g/kg EE, 53.22 g/kg CF, 657.4 g/kg NFE, 26.3 g/kg ash, 2.5 g/kg calcium, 2.0 g/kg phosphorus, but *Zea mays* grain – 83.5 g/kg CP, 43.7 g/kg EE, 27.5 g/kg CF, 829.6 g/kg NFE, 15.7 g/kg ash, 2.5 g/kg calcium, 0.3 g/kg phosphorus (Table 1). Thus, amaranth contained a higher amount of protein, fats, fibre and minerals than corn grain. The calculated potential productivity of *Amaranthus hypochondriacus* grain achieved 610 kg/ha protein and 277 kg/ha fats, while the control *Zea mays* grain – 450 kg/ha protein and 236 kg/ha fats.

RAVINDRAN et al., (1996) revealed that the *Amaranthus hypochondriacus* grain contained 168 g/kg crude protein, 58 g/kg crude fat, 60 g/kg crude fiber, 26 g/kg ash, 2.2 g/kg calcium, 5.6 g/kg total phosphorus, 10.1 g/kg lysine, 3.5 g/kg methionine, 17.66 MJ/kg gross energy, but corn grain – 80.6 g/kg crude protein, 35 g/kg crude fat, 26 g/kg crude fibre, 0.2 g/kg calcium, 2.5 g/kg total phosphorus, 2.6 g/kg lysine, 1.4 g/kg methionine, 17.64 MJ/kg gross energy. The processed *Amaranthus hypochondriacus* grain can be included in the diet of broiler chicken up to an amount of 400 g/kg without adverse effects on performance. TOADER & ROMAN (2009) found that the grain productivity of the studied *Amaranthus hypochondriacus* cultivars, which had been grown in the central part of the Romanian Plain, characterized by frequent droughts and high temperatures, was 11.1-25.3 q/ha, while the chemical composition of grains was the following: 15.73-17.83 % proteins, 60.75-62.83 % starch, 5.17-6.49 % lipids, 4.34-4.93 % fibre and 3.31-3.93 % ash. MARIN et al., (2011) mentioned that, under the optimal climatic conditions, *Amaranthus hypochondriacus* achieved a grain productivity of 45767 kg/ha.

The residual *Amaranthus* biomass after seed harvesting may be a feedstock for biorefineries, an option that is worth considering for energy production. The major components of phytomass are cellulose, hemicellulose and lignin. The amounts of these components vary significantly depending on the plant species, type of biomass, harvesting period. The possibility of converting lignocellulosic biomass in bioethanol fuel is currently an area of great research interest around the world. The bioethanol yields are influenced by tissue composition, ratios of cellulose, hemicellulose and lignin. Analysing the cell wall composition of dehydrated stalks (Table 2), we could mention that the concentration of structural carbohydrates in *Amaranthus hypochondriacus* stalks substrate was 680 g/kg, including 404 g/kg cellulose, 203 g/kg hemicellulose and 73 g/kg lignin, but *Zea mays* substrates – 749 g/kg, 417 g/kg, 250 g/kg and 82 g/kg, respectively. The estimated content of fermentable sugars in amaranth stalks reached 72.3 g/kg pentose carbohydrates and 33.4 g/kg hexose carbohydrates, but in corn stalks – 75 g/kg and 41 g/kg, respectively. The theoretical ethanol yield from fermentable sugars averaged 441 L/t in amaranth substrates, compared to 485 L/t in corn substrates. According to BARBASH et al. (2011), the stalks of amaranth consisted of 17.9 % hot-soluble substances, 3.7 % ash, 19.8 % pentosans, 31.9 % cellulose, 26.5 % lignin. PREMJET et al., (2013) reported that the chemical composition of the biomass of another amaranth species, *Amaranthus viridis*, was: 34.7 % cellulose, 34.2 % hemicellulose and 5.1 % lignin, but the biomass of *Amaranthus spinosus* – 32.1 % cellulose, 14.1 % hemicellulose and 10.0 % lignin, the calculated bioethanol production potential reached 521 L/t and 334.4 L/t, respectively. MARX et al., (2014) stated that amaranth lignocellulose substrates contained 363.5 g/kg cellulose and 124.9 g/kg hemicellulose, the microwave pre-treatment with KOH followed by enzymatic hydrolysis gave the highest total sugar yield, i.e. 488.23 g/kg. For comparison, according to GOFF et al., (2010), the theoretical ethanol potential of sorghum lignocellulosic biomass ranged from 560 to 610 L/t.

Table 2. The cell wall composition and theoretical ethanol potential of the studied species.

Indices	*Amaranthus hypochondriacus* stalks	*Zea mays* stalks
Acid detergent fibre, g/kg	477	499
Neutral detergent fibre, g/kg	680	749
Acid detergent lignin, g/kg	73	87
Cellulose, g/kg	404	417
Hemicellulose, g/kg	203	250
Hexose sugars, g/kg	72.3	75.1
Pentose sugars, g/kg	33.4	41.1
Theoretical ethanol potential	441	485

Baling, briquetting and pelleting are the most common biomass densification methods used for solid fuel applications. Densification can produce more compact products with uniform shape and size, which can be more easily handled using the available handling and storage equipment and thereby reduce the costs associated with transportation, handling and storage. The quality and structural integrity of a briquette is affected by the size of particles, moisture, contents of lignin and cellulose, but also by the cellular structure of plant stems and leaves. It is commonly known that low ash and moisture contents increase combustibility, and high bulk density fuel is convenient to be transported. The results of physical and mechanical investigations (Table 3) indicate that the ash content in amaranth stalks was lower (2.3 %) than in corn stalks (4.4 %), amaranth biomass had moderate gross calorific value (18.0 MJ/kg). The bulk density of the amaranth chopped chaffs reached 165 kg/m^3 and milled chaffs 188 kg/m^3, but corn stalk chaffs – 87 kg/m^3 and 100 kg/m^3, respectively. The amaranth briquettes had optimal specific density (901 kg/m^3), but still lower than corn briquettes (923 kg/m^3). The net calorific value of amaranth briquettes reached 14.4 MJ/kg, and corn briquettes 14.0 MJ/kg. According to VIGLASKY et al., 2009, in the Slovak Republic, the higher heating value of studied *Amaranth* biomass varied from 15.5 to 17.0 MJ/kg DM, the lower heating value varied from 13 to 14 MJ/kg at 10 % moisture content and the ash content varied from 10.17 to 22 %. PREMJET et al., (2013) stated that the heating value of *Amaranthus spinosus* biomass was 16.6 MJ/kg and the ash content – 10.0 %, but *Amaranthus viridis* biomass – 16.2 MJ/kg and 16.9 %, respectively.

Table 3. Some physical and mechanical properties of biomass and solid biofuel.

Indices	*Amaranthus hypochondriacus* stalks	*Zea mays* stalks
Ash content of biomass, %	2.3	4.4
Gross calorific value of biomass, MJ/kg	18.0	17.8
Bulk density of chopped chaffs, kg/m^3	165	87
Bulk density of milled chaffs, kg/m^3	188	100
Specific density of briquettes, kg/m^3	901	923
Bulk density of briquettes, kg/m^3	516	501
Net calorific value of briquettes, MJ/kg	14.4	14.0

CONCLUSIONS

The biomass productivity of *Amaranthus hypochondriacus* harvested in the early flowering period is about 6.85 kg/m^2 green mass or 1.04 kg/m^2 dry matter.

The *Amaranthus hypochondriacus* silage contains 167 g/kg CP, 30 g/kg EE, 295 g/kg CF, 123 g/kg ash, 516 g/kg NDF, 348 g/kg ADF, 45 g/kg ADL, 12 g/kg TSS, 158 g/kg HC and 303 g/kg Cel. It can achieve a productivity of 1650 kg/ha protein, 100 GJ/ha metabolizable energy and 60 GJ/ha net energy for lactation.

The biochemical methane potential of *Amaranthus hypochondriacus* substrates is 302 l/kg ODM.

Amaranthus hypochondriacus grains contain a higher amount of protein, fats, fibre and minerals than corn grains. The potential productivity of *Amaranthus hypochondriacus* grains is 610 kg/ha protein and 277 kg/ha fats, while that of *Zea mays* grains is 450 kg/ha protein and 236 kg/ha fats.

The amount of ethanol that can be produced from *Amaranthus hypochondriacus* stalks averages 421 L/t; the briquettes have optimal specific density (901 kg/m^3), ash content (2.3 %) and net calorific value (14.4 MJ/kg).

Amaranthus hypochondriacus can be exploited in many ways: as pseudo-grain and fodder and as feedstock in the production of renewable energy.

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