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Nutritive potential of amaranth weed grains

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***Amaranthus* is a species with immense potential; however, information on its nutritional properties is limited, though widely cultivated in some countries. The objective of this work is to characterise the grains of three species of *Amaranthus* sp. aiming at their food potential, comparing two species considered as weed with a commercially grown species. The selected materials were cultivated and submitted to the same culture method and the experiment was performed as a randomized block design with three replicates. Harvested grains were transformed into flour and centesimal composition was determined, as well as macro and micronutrients, starch content and non-nitrogenous. The results were submitted to analysis of variance and compared in Tukey's test. It can be inferred that in the majority of the analyses for centesimal composition, the species *A. hybridus* and *A. viridis* presented higher levels than the *A. retroflexus* (commercial cultivar). *A. hybridus* has the highest amount of N, Mg, B, Mn and Fe, *A. retroflexus* of P, K, S, Cu and Zn whereas *A. viridis* of Ca and Cu. The content of starch in the grains of the species ranged from 32.86 to 36.21%. Regarding the anti-nutritional constituents, the nitrate content present in these three species does not pose a health risk if consumed moderately. Invasive species *A. hybridus* and *A. viridis* present great potential for grain production, whose nutritional properties of flour in most of the analyses performed in this study were superior to the commercial species.**

Key words: *Amaranthus hybridus*, *Amaranthus retroflexus*, *Amaranthus viridis,* organic agriculture, unconventional vegetables.

INTRODUCTION

Amaranthus sp. are relevant in the agricultural environment as invasive species in a majority of crops, being found mainly on soils with good fertility and high content of organic matter, causing damages in several crops. Although considered a weed, studies prove the nutritional and functional versatility of *Amaranthus* sp.

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(Kinupp and Lorenzi, 2014).

The genus *Amaranthus* is composed of approximately 70 species, among them there is an enormous morphological variety, with annual or short-lived perennial species. The species already cultivated, are used for the production of grains, leaves and for ornamentation of gardens. The most commonly cultivated species for grain production in the Americas and Asia are: *Amaranthus caudatus*, *A. hypochondriacus*, and *A. cruentus*. The grains of these species are rich in nutrients and provide a complete diet of amino acids (Singh, 2017).

Species from this genus are commonly classified as “pseudocereals" and are examples of so-called under-utilised crops that have evolved after centuries of selection and are currently among the 36 most promising crops to feed humans. They contain significant amounts of minerals, nutrients, vitamins and amino acids, besides antidiabetic and antioxidant activities, containing high levels of iron, selenium, phosphorus and low levels of toxic substances (Amaya-Farfán et al., 2005; Ferreira et al., 2007).

Preliminary studies performed in Brazil, e.g. by Samartini (2015), when carrying out the bromatological characterisation and evaluating the antioxidant potential in the leaves of five *Amaranthus* species considered as invasive, with emphasis for *A. spinosus, A. deflexus* and *A. retroflexus* showed higher efficiency in free radical scavenging, thus proving the antioxidant activity of these species. The values obtained by these species can be equated with other crops, such as potato, cauliflower and tomato.

Although studies have already been performed verifying the economic and alimentary potential of the amaranth, few are conducted with such species that are considered as rustic and highly efficient in the production of seeds.

Therefore, scientific studies are important to understand how these species can contribute to the human diet and in the prevention of diseases. Bromatological and phytotechnical studies can encourage the amaranth cultivation on a larger scale and with quality, allowing their commercialisation and hence the consumption of these plants by the population, resulting in economic, social and environmental benefits. In view of the aforementioned, the objective of the present study was to characterize the grains of three *Amaranthus* species, aiming at the food and commercial potential of species considered as invasive non-cultivated.

MATERIALS AND METHODS

The evaluated materials were obtained from the germplasm collection of non-conventional vegetables (2015/2016 harvest). In this collection of germplasm, there are about sixty species of unconventional food plants, with propagation materials available for scientific research, seeking to rescue food species that may contribute to the nutritional enrichment of humanity eating habits.

The work began with seven species of amaranth, with different characteristics, remembering that amaranthus is not cultivated in Brazil. The materials went through a screening process and were previously selected in the field in function of their potential for grain production. Among the seven species, three were selected. Both species present interesting phenotypic characteristics, such as panicle size and high grain yield. Two species considered invasive and of common occurrence in Brazil and another one selected as standard of comparison, being acquired in the local food market as grain (imported from another country), representing a commercial cultivar. The others did not have these characteristics, presenting no commercial interest, such as the presence of spines, small panicles, difficulty in separating the straw from the grain, low rusticity and low productivity.

The materials were identified through exsiccates by EPAMIG (Agricultural research agency of the state of Minas Gerais), being recorded and included in the Epamig Herbarium of Minas Gerais (PAMG) herbarium collection. The records of the *Amaranthus* species are 57999, 58002 and 58003, which refer to the species *A. retroflexus* L., *A. viridis* L. and *A. hybridus* L., respectively. The *A. retroflexus* L. species is the commercial cultivar and the other two are considered as invasive species.

After identification, seeds were sown for on-field evaluation of each species (*A. viridis, A. hybridus* and *A. retroflexus*) when subjected to the same cultivation method. The experiment was performed as a randomized block design (RDB) with three replicates, being each replicate as one block. Each plot had 78 plants with the purpose of selecting for breeding, besides quantifying the yield of each species through a sample within the plot, composing three useful plants per plot. The edge effect was considered in order to prevent the influence of neighbouring plots. Moreover, a physical barrier was also used with maize culture in order to avoid crossing between species, since polyploidy with interspecific hybridizations is common in these species, masking its characteristics (Olusanya, 2017).

The experiment was carried out in two agricultural years, sown in October 2016/2017 and harvested in April 2017/2018 in the experimental area in Lavras, south of the State of Minas Gerais, Brazil, located at 21° 14’ S, 45° 00' W and 918.8 m altitude. The climate of the region is Cwa (mesothermal) with dry winter and rainy summer, according to Köppen classification (Brasil, 1992). The seeds were sown directly in the field in shallow pits, and then thinned in a spacing of 0.5 m x 0.5 m, with a density of 40,000 plants per hectare, without using irrigation.

By means of the soil analysis, the soil corrections were chosen, opting for the organic management of plants, avoiding influence in their bromatological characteristics. A total of 1 t of dolomitic limestone ha^{-1}, 15 t of poultry manure ha^{-1} (before sowing) and 15 t of compound ha^{-1} (after 40 days of sowing). The phytosanitary management was performed from biofertilisers and plant extracts of *Ricinus communis* L. with insecticidal and fungicidal principles.

The grains were harvested at 74, 78 and 137 days after planting in *A. viridis*, *A. hybridus* and *A. retroflexus*, respectively, being harvested manually every 15 days, and the final harvest at 149, 108 and 167 days after planting, accounting for the total yield of each *Amaranthus* species.

The samples were sent to the laboratory and consisted of a grain mixture of each species, making a composite sample. The grains were milled up to the flour point. In the laboratory analyses, the experimental design was completely randomized (CRD), with three replicates for each treatment. The percent composition of the flour was performed: Moisture by the gravimetric method, based on the weight loss of the material subjected to the oven heating at 65ºC until constant weight. The ether extract was determined using the continuous extraction method in Soxhlet apparatus using diethyl ether as solvent. The fixed mineral residue (ash) was determined by

Table 1. Grain yield analysis of three *Amaranthus* species.

Species	First year yield (t ha^{-1})	Second year yield (t ha^{-1})	Standard deviation
A. viridis	1.96[b]	1.96[b]	±0.00
A. hybridus	2.56[a]	2.61[a]	±1.85
A. retroflexus	0.13[c]	0.26[c]	±0.18
CV (%)	30.22	17.55	

Averages followed by the same letter on the column do not differ significantly among themselves by Tukey test (P<0.05).

Table 2. Percent composition of grain flours of different *Amaranthus* species.

Percent composition	*A. retroflexus*	*A. hybridus*	*A. viridis*	CV (%)
Moisture (%)	12.30[c]	13.34[b]	14.23[a]	1.31
Ether extract (%)	5.58[b]	6.46[a]	5.58[b]	4.45
Ash (%)	2.51[b]	2.79[b]	3.21[a]	4.42
Protein (%)	12.79[a]	13.75[a]	12.60[a]	7.47
Crude fibre (%)	2.05[b]	3.32[a]	2.45[b]	9.91
Non-nitrogenous extract (%)	65.85[a]	61.22[b]	61.65[b]	2.21

Averages followed by the same letter on the row do not differ significantly among themselves by Tukey test (P<0.05).

calcination of the sample in muffle at 550°C until clear ash was obtained. The crude protein value was obtained by the Kjeldahl method by determining the nitrogen of food and multiplied by 6.25. The fiber fraction was determined according to the gravimetric method, after digestion in acidic medium (HOROWITZ, 2016), and the carbohydrate fraction was obtained by 100% difference of the sum of the other components, according to the equation: CHF = 100 - (M + EE + P + CF + A), where: CHF is carbohydrate fraction; M is moisture; EE is ether extract; P is protein; CFis crude fiber and A is ash. For analysis of macro and micronutrients, the samples were subjected to the method of analysis of vegetal tissues for fertility evaluation, through wet digestion (Malavolta et al., 1997), determining the percentage of macro and micronutrients.

The starch content of amaranth grain flour was identified by washing through sugar removal, autoclaving, neutralization, deproteinisation and determination by spectrophotometer reading at 510 nm, following the standards of the Instituto Adolfo Lutz (2008).

The anti-nutritional analysis of nitrate was done according to the methodology of Cataldo et al. (1975). The nitrate calculation was made by comparing the results from the standard curve, being expressed in mg NO_3^- kg^{-1} dry sample. The standard curve used in this study was represented by the equation y = 0.0054x + 0.0212 and R^2 = 0.9945.

The results were submitted to analysis of variance and the averages were compared by Tukey test (P<0.05). The experimental accuracy was analysed using the coefficient of variation (CV), and the statistical analysis was performed using the SISVAR® software (Ferreira, 2011).

RESULTS

According to the analysis of variance (Table 1), there was a significant difference for yield among the *Amaranthus* species in the two years of cultivation.

On average, *A. hybridus* showed higher yield in the field, being 92.45% higher than the commercial cultivar. *A. viridis* obtained a yield of 90.05% greater than this same species. *A. retroflexus* (commercial) had the lowest average yield, with 0.195 t ha^{-1}.

The species had a very uneven behaviour in the field when dealing with invasive species (*A. viridis* and *A. hybridus*), which is well understood, since these plants did not undergo a genetic improvement process and were not subjected to crops for grain yield. However, the commercial species had a good uniformity in relation to the emergence of plants and a rapid growth in the field.

Data on the grain composition of *Amaranthus* are presented in Table 2.

A. viridis showed the highest moisture percentage in the grain flour (14.23%), followed by *A. hybridus* (13.34%) and *A. retroflexus* with the lowest percentage (12.30%).

For the ether extract contents, *A. hybridus* obtained the highest value (6.46%), and the other species did not differ statistically among themselves, with a value of 5.58% for both species.

In relation to ash percentage, *A. viridis* showed the highest value (3.21%) and the other two species did not differ statistically among themselves, with 2.79% for *A. hybridus* and 2.51% for *A. retroflexus*.

When evaluating the nutritional quality of macro and micronutrients of the amaranth grain flours, the following results were obtained (Tables 3 and 4).

The *A. retroflexus* had the highest macronutrient

Table 3. Macronutrient content in grain flour of three *Amaranthus* species.

Species	%N	%P	%K	%Ca	%Mg	%S
A. viridis	2.42[b]	0.42[c]	0.52[b]	0.49[a]	0.32[b]	0.14[b]
A. hybridus	2.48[a]	0.46[b]	0.45[c]	0.37[b]	0.35[a]	0.19[a]
A. retroflexus	2.42[b]	0.54[a]	0.76[a]	0.20[c]	0.31[b]	0.18[a]
CV (%)	0.41	2.11	1.73	2.83	3.06	5.88

Averages followed by the same letter on the column do not differ significantly among themselves by Tukey test ($P<0.05$).

Table 4. Micronutrient content in grain flour of three *Amaranthus* species.

Species	B (ppm)	Cu (ppm)	Mn (ppm)	Zn (ppm)	Fe (ppm)
A. viridis	7.88[b]	2.77[a]	20.90[b]	26.75[c]	137.65[c]
A. hybridus	8.54[a]	1.91[b]	27.26[a]	29.71[b]	457.52[a]
A. retroflexus	6.56[c]	2.86[a]	15.92[c]	49.95[a]	339.97[b]
CV (%)	0.13	4.93	0.27	0.03	0.02

Averages followed by the same letter on the column do not differ significantly among themselves by Tukey test ($P<0.05$).

contents, such as phosphorus (0.54%), potassium (0.76%) and sulfur (0.18%). The *A. hybridus* showed the highest contents of nitrogen (2.48%), magnesium (0.35%) and sulfur (0.19%), not statistically differing from the sulfur content of *A. retroflexus*. The *A. viridis* was the species with the lowest overall macronutrient contents, obtaining only the highest calcium content (0.49%) among the three species. Although it is the species with the highest ash content in the percent composition (Table 2), there are other minerals not quantified in this study that influence the total ash content.

The species *A. hybridus* showed the highest micronutrient contents boron (8.54 ppm), manganese (27.26 ppm) and iron (457.52 ppm). The *A. retroflexus* species had the highest contents of copper (2.86 ppm) and zinc (49.95 ppm). For *A. viridis* species, the highest micronutrient content in relation to the other species was copper (2.77 ppm), which did not differ statistically from *A. retroflexus*. Protein contents in amaranth grains did not differ statistically (Table 2).

The *A. hybridrus* had the highest crude fiber content (3.32%), and the other two species did not differ statistically from each other, with 2.45% for *A. viridis* and 2.05% for *A. retroflexus* (Table 2).

The *A. retroflexus* (commercial cultivar) grains have white color as major characteristic, but the other used species are black colored and are recognized as invasive plants in Brazil. It can be suggested that in the majority of the analyses, the species *A. hybridus* and *A. viridis* showed higher contents and dark colored seeds. Therefore, the seed color does not affect the bromatological characteristics of the species.

In relation to the starch content obtained from the spices under study, the following results were obtained (Table 5).

Table 5. Analysis of the starch content in grain flour of three *Amaranthus* species.

Species	% starch
A. viridis	35.72[a]
A. hybridus	32.86[b]
A. retroflexus	36.21[a]
CV (%)	1.77

Averages followed by the same letter on the column do not differ significantly among themselves by Tukey test.

The flour of the species *A. retroflexus* and *A. viridis* showed a higher starch percentage, 36.21% and 35.72%, respectively. The *A. hybridus* contains the lowest starch percentage, 32.86%. However, the *A. hybridus* obtained a grain yield higher than the other two species, being this practical factor very important for large-scale cultivation with the intention to obtain starch.

In relation to the antinutritional nitrate constituent, this study presented the following results for the three amaranth species (Table 6).

The *A. hybridus* was the species with the highest nitrate value among the species (1597.51 mg NO_3^- kg^{-1}), followed by *A. retroflexus* (1452.29 mg NO_3^- kg^{-1}) and *A viridis* (1093.32 mg NO_3^- kg^{-1}).

DISCUSSION

Although the crop management was similar, there was a

Table 6. Analysis of nitrate in the grain flour of three *Amaranthus* species.

Species	mg NO_3^-/kg
A. viridis	1093.32[b]
A. hybridus	1597.51[a]
A. retroflexus	1452.29[ab]
CV (%)	14.54

Averages followed by the same letter on the column do not differ significantly among themselves by Tukey test (P<0.05).

great difference between the species. The *A. retroflexus* underwent great injuries due to the environment, suffering several pest attacks, which certainly hindered its development, showing less adaptability and rusticity for cultivation in the southern Minas Gerais, in Brazil. A larva with a curculioniform shape from the Coleoptera family was observed in all blocks. This pest was difficult to identify because the symptoms resembled to a nutritional deficiency, precluding the control action. In contrast, the other species did not show a single specimen of this larva. The *Diabrotica speciosa* and the *Epicauta atomaria* were common to all species, mainly affecting the leaves, but were not difficult to control.

The amaranth species show very interesting plant characteristics such as rustic plants and resistant to water stress, developing in environments unfavourable to other cereals and legumes. Moreover, it contains great capacity of using water, light and nutrients, mainly due to its deep root system that assures its survival in dry periods. They have the capacity to develop and fruit in environments at high temperatures (35 to 45°C). Species from this genus are also characterized by their wide climatic adaptation. It has fast and vigorous growth, showing high biomass production capacity (Spehar and Trecenti, 2011).

Despite the few studies performed in Brazil, agronomic tests carried out in the northeastern Brazil indicate that it is possible to obtain, in sites without water restriction, average yields of 3 and 1 t ha^{-1} under low humidity conditions (Amaya-Farfan et al., 2005).

Another study performed in Slovenia using the cultivar "G6" (*A. cruentus*) discusses that the amaranth grain yield depends on the environment, weather conditions, species, genotypes and production techniques, thus widely varying from 500 to 2,000 kg of grains ha-1. With suitable varieties and production techniques, yields from 1,500 to 3,000 kg of grains ha^{-1} can be expected. In Europe, there are reports of grain yields between 2,000 and 3,800 kg ha^{-1} (MLAKAR et al., 2010).

Despite the scarcity of scientific knowledge regarding the yield of the species used in this study (Table 1), the yields were similar to those found in the literature for other widely cultivated species. It is noteworthy that, in the present study, the plants were cultivated in the organic system and in the dry farming, without genetic improvement of the species, indicating a good grain yield in relation to the other studies.

In percent composition of grain flours, the lower moisture percentage in the flour represents a trend towards better food conservation. According to the Brazilian legislation that determines that flours, cereal starch and bran should have a maximum moisture content of 15.0 g 100 g^{-1} (Brasil, 2005), thus, the three studied species meet the requirements of this legislation (Table 2).

A study performed by Marcílio et al. (2003) obtained moisture of 9.2% of *A. cruentus*, which is lower than that found in this study, which can be caused by being from different species. The increase in moisture allows a greater interaction between grain sub-structures (germ, bark, fiber and starchy endosperm).

Fujita and Figueroa (2003) evaluated the ether extract content present in cereals and derivatives, such as oat, wheat, triticale and barley showed average values of 5.27, 1.89, 2.07 and 2.26%, respectively. The amounts of oils and fats found in the amaranth composition were higher than the cereals of wheat, triticale and barley. Therefore, the intake period for this food will be lower when in relation to the other cereals, due to the rancidification process. However, these values indicate a higher amaranth potential for oil production.

The oil content in this grain ranges from 6 to 10%, from which 76% are unsaturated, containing interesting linoleic acid contents. They show 7% esquilant, which is superior to that from other vegetables. Another important factor is the presence of tocotrienols, antioxidant substances that resemble vitamin E, which reduce the LDL cholesterol content, have anticancer activities, protect against skin aging and prevent the onset of cardiac and obstructive diseases (Costa and Borges, 2005). When comparing the amaranth oil content with the maize, it is possible to observe lower values in the maize kernels. Studies show values that range according to the cultivar genetics, and Cazares-Sanchez (2015) evaluated oil content in a collection of Mexican maize populations and found values between 3.37 and 4.52%.

Generally, the mineral fraction in ash is composed of macro and micronutrients in large part of their constitution (HOROWITZ, 2016), and these are fundamental for the maintenance of the proper functioning of organism. The qualification and quantification of the minerals present in these amaranth species is suggested by the research because the availability of each mineral can be evaluated (Tables 3 and 4). Recommendations for mineral intake vary according to the demand of each organism, and each element is required at different quantities.

In the literature, different results regarding ash content among some amaranth species, such as 2.28% (± 0.5) in the *A. cruentus* L. flour (Capriles et al., 2006), 2.2 and

1.7% (± 0.1) in the whole and refined flour of the *A. cruentus* L. grain, respectively (Marcílio, 2003). The ash contents found in the flours were consistent with this study, being superior to the studied species (Table 2).

Buratto (2012) studied contents of minerals and proteins in common bean grains and presented values from 8.9 to 161.50 ppm iron and from 11.5 to 69.9 ppm zinc in the grains. These values are closely related to the cultivar genotype. The deficiency of these nutrients in the human diet is considered as challenging, affecting the health of thousands of people worldwide. The values found in the literature for iron are much lower than that found in the three amaranth species under study (Table 4), whereas for zinc, the contents were similar to that of beans.

A study quantified the nutrients present in 100 g of *Amaranthus* grain, comparing with the wheat grain, demonstrating the nutritional superiority of amaranths. Regarding the nutrients found, the potassium content was 101% higher than wheat, with 0.366 g per 100 g of the grain; the calcium content was 528%, with 0.153 g per 100 g of the grain; the phosphorus content was 158%, with 0.455 g per 100 g of the grain; the magnesium content was 211%, with 0.266 g per 100 g of the grain; the iron content was 238%, with 7.59 mg 100 g^{-1} of the grain; the zinc content was 120%, with 3.18 mg 100 g^{-1} of the grain; and copper was 179%, with 0.777 mg 100 g^{-1} of the grain (Costa and Borges, 2005).

Although amaranth grain flour is an important source of nutrients, it is worth mentioning that the concentration of a certain nutrient in food is not necessarily a reliable indicator of the value to be absorbed by the organism. Studies are needed to understand the bioavailability of these nutrients, thus quantifying the nutrient portion that will be available for use by the body in metabolic processes (Chitarra and Chitarra, 2005).

One of the most interesting nutritional properties of *Amaranthus* is the content of biological quality proteins in its grains (approximately 15%), having lysine (representing 5% protein) and other essential amino acids (being 4.4% sulfur-containing amino acids). Another study shows that amaranth has between 12 and 17% proteins, containing well-balanced amino acids, a characteristic not found in other cereals, including a large amount of lysine, ranging between 0.73 and 0.84% of the total protein content. This species also has carbohydrates, fats and minerals. These characteristics are the most limiting factors from the other cultivated grains. Studies show that amaranth has values of proteins, fats and fibers higher than cereals such as wheat, maize, rice and oats (Amaya-Farfan et al., 2005).

Research on cereals show different crude fiber contents for white oats (8.88%), common black oats (8.76%), rye (3.34%), barley (3.89%), triticale (2.50%) and wheat (2.19%) (Guarienti et al., 2001). Based on these data, it can be said that the amaranth has similar contents to other cereals, such as rye, barley, triticale and wheat in relation to the crude fiber percentage present in its food composition (Table 2).

For the non-nitrogenous extract (NNE), the largest value was found in *A. retroflexus* (65.85%), but *A. hybridus* (61.22%) and *A. viridis* (61.65%) did not differ statically (Table 2). The Brazilian food composition table (TACO) (Lima, 2012) does not contemplate this analysis; however, it can be calculated through the difference between carbohydrates and dietary fiber. It is known that NNE constitutes the carbohydrate portion of the food, that is, it provides energy readily available to humans.

Zhu (2017) performed a review on the starch characteristics from different amaranth species and reached the following result; the starch yield, the contents of amylose, total lipid and protein of amaranth starches from different studies in the last five decades were reported to be between 2.0 and 65.2%, 0.0 and 34.3%, 0 and 1.8% and 0.02 and 0.98%, respectively. The species with the highest starch yields are *A. hypochondriacus*, *A. cruentus* and *A. hypochondriacus* x *A. hybridus*.

When a study quantified the starch content of quinoa, amaranth (*A. caudatus*) and wheat, found values between 66.3 and 68.1%, and did not differ statistically among themselves (Srichuwong et al., 2017). Pilat et al. (2016) evaluated the starch content in *A. cruentus* and found the value of 55.53%. The values of starch content found in the literature were higher than in this study (Table 5), this may be an effect of the different species studied and the environmental conditions in which the plants were submitted.

Costa and Borges (2005) concluded that due to the nutritional characteristics of the amaranth, it is possible to substitute other cereals without causing any food deficiency, whether this grain be adopted as basic morning food, through flours, cakes, pancakes etc. Moreover, amaranth can be consumed by people who have allergy to gluten and with high cholesterol rates. The grains of this plant represent a more balanced and energetic diet than other grains, such as maize, wheat or rice, being nutritionally comparable to milk, meat and egg. Due to its agronomical, nutritional and medicinal characteristics, amaranth can minimize food deficiencies in poor or developing regions of the world.

The accumulation of nitrates in raw vegetables, herbs and fruits has a wide range of accumulation. There are a number of factors that influence nitrate accumulation as: Plant species and their genotypes, agronomic factors, environmental conditions prevailing during plant growth (such as light intensity, spectral quality, photoperiod, air temperature and concentration of carbon dioxide), harvesting phase, as well as harvesting time during the day. In addition, post-harvest factors in particular, storage conditions may also cause or inhibit the conversion of nitrates into nitrites (Colla et al., 2018).

Human exposure to nitrate is mainly exogenous, due to the consumption of raw vegetables (80%). Nitrate is relatively harmless since the fatal dose for adults is considered to be greater than 7.35 g, which is about 100 times higher than the acceptable daily dose of NO_3 as defined by the European Union (3.7 mg/kg body weight per day), equivalent to 222 mg NO_3 per day for individual 60 kg. The EU regulatory commission has set maximum nitrate values for fresh vegetables such as spinach, lettuce and rucula to be between 2,000 and 7,000 mg of NO_3 kg^{-1} fresh matter (Colla et al., 2018). These values are much higher than those found in the grains of the three amaranthus species in this study; these grains were consumed moderately and did not represent an anti-nutritional risk for humans. It should be emphasized that nitrogenous chemical fertilizers can alter the nitrate content of grains from these plants (Colla et al., 2018), and further studies are necessary to establish the food safety of these foods in the conventional system of cultivation.

A diet with nitrate is mainly obtained by the intake of vegetables. Older literature shows nitrate in the diet as a contaminant associated with increased risks of stomach cancer and methemoglobinemia. Consequently, nitrate levels for human intake have always sought to be restricted, being the exposure levels of an acceptable daily intake is 3 to 7 mg kg^{-1}. The average intake of nitrates in the UK is approximately 70 mg/day, although some population groups such as vegetarians can consume three times this value. When assessed clinically, they did not present health-related problems with nitrate (Ashworth and Bescos, 2017).

More recent studies suggest that dietary nitrate can significantly reduce blood pressure and may reduce the incidence of hypertension and mortality from stroke. There is a lack of data demonstrating the actual chronic effect from high nitrate intake in humans. However, due to potential health benefits, some authors recommend that nitrate be considered as a necessary nutrient for health rather than as a contaminant that needs to be restricted. Although nitrate toxicity is low, the oral lethal dose of nitrate to humans has been reported at about 330 mg/kg per day (equivalent to about 23,100 mg for an adult of 70 kg day^{-1}). However, further studies are necessary for the actual understanding of nitrate in the human body (Ashworth and Bescos, 2017).

As final considerations, amaranth plants considered as invasive have a high nutritional and productive potential in relation to other cereals commonly consumed by Brazilians. The present study aimed to demonstrate the possibility of using amaranth as an alternative source for human or even animal feeding.

Borneo and Aguirre (2008) reported that the potential of *Amaranthus* species has been rediscovered along the years, and since then, several studies have been performed emphasizing high protein quality, the presence of unsaturated oil and other valuable components, besides several uses, including high quality roasts, edible films, functional ingredients, among others.

Based on the obtained results, it can be suggested that in the majority of the analyses related to the percent composition, the species *A. hybridus* and *A. viridis* showed contents higher than the commercial cultivar (Table 2).

It was possible to observe that the species showed different amounts of nutrients. The *A. hybridus* has the highest amount of N, Mg, B, Mn and Fe, the *A. retroflexus* of P, K, S, Cu and Zn, and *A. viridis* of Ca and Cu (Tables 3 and 4). This result indicates a food potential of the species considered as weeds, obtaining results as interesting as the commercial cultivar *A. retroflexus*.

Regarding the starch content found in the three species (Table 5), these values were lower than that found in the literature, and this difference could be correlated with the species under study and the environmental conditions to which they were subjected.

In relation to the anti-nutritional constituents, the nitrate content present in these species did not represent a health risk when consumed moderately for the three studied species (Table 6).

Conclusion

The invasive species *A. hybridus* and *A. viridis* showed great potential for grain yield; nutritional properties of flour in most of the analyses performed in this study were superior to the commercial species (*A. retroflexus*).

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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