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# Comparison of feed value of *Amaranthus powellii* Willd. forage to some roughage feeds

**Gökhan FİLİK***, **Ayşe Gül FİLİK**
Department of Agricultural Biotechnology, Faculty of Agriculture, Kırşehir Ahi Evran University, Kırşehir, Turkey

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**Abstract:** The aim of this study was to compare the chemical composition, in vitro digestibility, protein and energy value, roughage value of *Amaranthus powellii* Willd. forage to the most commonly used alfalfa hay and wheat straw in ruminant nutrition. *Amaranthus powellii* Willd. forage has the potential to be a third quality roughage according to its relative feed value assessment of 104.55 ± 0.67. In addition, the relative forage quality assessment developed for feeding dairy cattle was 97.73 ± 0.05 for *Amaranthus powellii* Willd. forage, which had a higher the relative forage quality value than alfalfa hay and wheat straw, and it can be used for feeding dairy or fattening cattle. However, it has been generally recommended that Amaranth be given either by grazing at its early flowering time or via silage due to the oxalic acid and nitrate salts. *Amaranthus powellii* Willd. forage should also be determined nitrate, amino acids, and other antinutritional factors before studied in vivo as hay or silage.

**Key words**: Alfalfa hay, amaranth, amaranth hay, in vitro bait value, wheat straw

## 1. Introduction

The world population is predicted to be 9.3 billion people in 2050, and it is perhaps one of the most important problems that the projected population is not only common to humans but to animals as well [1]. As the cereals used in human and animal nutrition are the same, there is a competition for the use of grain. Pseudo-cereals have the same nutritional content as the cereals used in human nutrition, but are not as widely used as corn, rice, and wheat [2]. As alternative feed material, Amaranth can be used in animal nutrition instead of some cereals [3]. Amaranth was known by the Aztecs as a grain equivalent to maize in religious ceremonies, that it can grow in the world any climate or soil condition to produce content-rich in energy and protein, that the seeds and leaves can be eaten by humans and animals, and it is a $C_4$ dicotyledonous plant suitable for carbon fixation [4–10]. In addition, due to the rich nutritional content, it can be compared with other biomass or biogas plants when its potential as a current topic of research is being determined [11–13].

Amaranth contains a higher level of protein, twice the amount of lysine essential amino acid, more fiber, 5 times more calcium and 20 times more iron compared to other cereals [14]. Amaranth seeds contain 5% to 9% ether extract, approximately 77% unsaturated fatty acids, while linoleic acid (5% to 8%) fatty acid [15,16]. In addition, Amaranth contains high concentrations of oxalic acid (12% to 30% by dry weight (DW) including the leaves), nitrates (0.21% to 0.74% by DW including the leaves), antitrypsin proteins and temperature variable factors [17,18]. In terms of health, Amaranth seeds lower cholesterol, increase antioxidant capacity, and are an anticancer, antiallergenic and antihypertensive agent; they act as food to counter celiac disease and immunodeficiency disorders, and in a methanol solution –with the effect of a peptide called lunasin– they have an antitumor, antihyperlipidemic, antidiabetic and anthelmintic effect. Furthermore, in an aqueous solution, they have an antidiarrheal, antifungal and antimalarial effect [19–22].

Amaranth occurs as *Amaranthus hypochondriacus*, *paniculatus* and *edulis* grain; *paniculatus*, *spinosus*, *tenuifolius*, *tricolor* leaves; *caudatus* cereal or ornamental plant; *Polygamus*, *gracilis*, *dubius*, *spinosus*, *tenuifolius*, *blitum*, *lividus* and *cruentus* varieties are grown as vegetables, while *Amaranthus retroflexus*, *albus*, *hybridus*, *powellii* and *quitensis* are 60 species known to be weeds [5,6,14,23–25]. In general, the yield of Amaranth seeds per hectare is about 1 to 6 tonnes and the green material is about 70 tonnes [26]. Amaranth is a suitable forage for ruminant animals in terms of high bypass protein or rumen undegraded intake protein through $C_4$ metabolism [27]. In addition, over 40,000 ha of

* Correspondence: gfilik@ahievran.edu.tr

Amaranth are cultivated for the roughage requirements of pigs in China, and it is recommended that grazing be assessed 84 days after planting due to the nitrate content [27–30]. *Amaranthus caudatus, cruentus, edulis, dubius, hypochondriacus, hybridus, retroflexus, spinosus, tricolor* seed or seed processing (through moist heat: boiling and slurring and through dry heat: popping and roasting), the leaf feed material or grazing or silage are used to feed fish, rodents, monogastric and ruminant animals [25,31–45]. Amaranth can be used as an alternative source of high protein to meet the protein requirements of farm animals yielding high. In general, studies on a wild species like *Amaranthus powellii* [46] are related to biological or chemical control [47–49], but no studies have been found on chemical composition, alternative nutrient availability, in vitro digestibility in animal nutrition or roughage. For this reason, the chemical composition, roughage value, use in dairy cattle nutrition, and in vitro digestibility of *Amaranthus powellii* Willd. forage (APF) were determined by comparing it to wheat straw (WS) and alfalfa hay (AH), which are most commonly used for ruminant animals. The present study aimed to compare WS and AH, which are one of the most commonly used roughage foods used for ruminant animals, with APF that grows wild in all climatic conditions.

## 2. Materials and method

The APF, which is the main material of the study, was harvested from Kırşehir Ahi Evran University research and application area after the maturation of the seeds was completed and dried under a ventilated drying oven at 55 °C for 48 h. In addition, dry WS and AH were taken from industrial animal husbandry farms. Rumen fluid was taken from three different Belgian Blue-Holstein hybrid steers slaughtered at the Kırşehir Meat and Meat Products Food Marketing Industry and Trade Limited Company, Turkey at the age of 28 months. This collected rumen fluids were mixed, before using, to minimize the error caused by a single animal. These three animals' rumen fluids helped to collect sufficient ruminal fluid to carry out in vitro digestibility study. These animals had been fed on 40 concentrates/60 roughages and had a live weight of about 650 kg before coming to slaughterhouse. As stated by Filik [50], chemical analyzes (dry matter: DM, organic matter: OM, crude protein: CP and ash contents) of APF, WH and AH were determined according to AOAC [51], Van Soest et al. (the crude fiber: CF, neutral detergent fiber: NDF, acid detergent fiber: ADF and acid detergent lignin: ADL) [52], AOCS (ether extract: EE) [53] procedures and calculated values according to formulas Sniffen et al. (total carbohydrates: TC, hemicellulose: HCel, cellulose: Cel, and nitrogen-free extracts: NFE contents) [54]. The digestibility analysis of the APF, WH and AH were determined according to Menke and Steingass [55] in vitro gas production technique [50]. The means of the total gas values were corrected according to the average values of blind samples [56,57].

The digestible crude protein (%, DCP) [58] and total digestible nutrient (%, TDN) values [59], digestible energy (Mcal/kg, DE) [60], metabolizable energy (Mcal/kg, ME) [61], net energy-lactation (Mcal/lb, $NE_L$), net energy-maintenance (Mcal/lb, $NE_M$), net energy-gain (Mcal/lb,$NE_G$) [62], net energy-maintenance (MJ/kg, $NE_m$) and net energy-gain (MJ/kg, $NE_g$) [63], dry matter intake (Live Weight: LW, DMI %), digestible dry matter (DDM), relative feed value (RFV) [64] and relative forage quality (RFQ) [65] values of the APF, WH and AH were calculated by using chemical analysis results.

The experiment samples were divided into 3 groups (APF, WS, and AH) each group contained 8 replicates, 4 of them for chemical and 4 of them in vitro digestibility trial. For the data statistics, descriptive variables were used for the statistical analysis. Mean, standard error (SE) values and Tukey's multiple range test procedures –excluding of in vitro digestibility data– were calculated using the SPSS [66] (v. 17.0) statistical software program package (SPSS Inc., Chicago, IL, USA).

## 3. Results and discussion

The results and discussion were conducted with other Amaranth species since the evaluation of APF as roughage was not found in any publication. Generally, the amount of ADL and ash percentage increase as the plants became dry hay before harvest. Although WS and AH obtained from industrial livestock farms were used to feed dairy cattle and fatten animals, the quality of both sources of roughage were determined to be low in the present study. *Amaranthus hypochondriacus* seed, plant or leaves have been reported to be a low-quality feed when considered as a source of protein, but may be a good quality feed when processed [67]. On the contrary, Sleugh et al. [68] reported that Amaranth can be a good forage according to their studies examining the chemical composition of *Amaranthus cruentus, hybrid, hybridus* and *hypochondriacus* varieties grown in seven different regions and harvested on six dates. A late harvest of *Amaranthus cruentus* and *hypochondriacus*, instead of an early harvest, decreased the percentage of CP but increased the percentage of ADF and NDF [69]. The CP, ash, EE and NFC percentage values for *Amaranthus hypochondriacus* decreased for the early harvest time, while OM, NDF, ADF and ADL percentage values increased, and the result values for the late harvest time were support to our study [70]. NDF may not be used as a source of energy in ruminant feeds, as some of them may bind to lignocellulose complex or fiber, some of which form ADL. In a study into the values for the average moisture, ash, EE, CF and CP percentage values for the branch and leaves of the *Amaranthus albus, blitoides* and *retroflexus* species, they were determined to be: (7.82, 17.65, 1.05, 32.87 and 8.43); (8.66, 10.66, 1.36, 33.38 and 11.09) and (9.26, 12.08, 0.97, 30.82 and 14.40), respectively [71]. Leukebandara et al. [72] reported that *Amaranthus hybridus*, *caudatus*, *hypochondriacus*, *cruentus* and *dubius* species harvested at different periods have a significant potential for being a good dry season forage crop. The amounts of ash percentage for the Amaranth species harvested on the 110th day of the study were support to those for APF result.

Ehsani et al. [73] attributed the changes in the CP, NDF, ADF and ADL percentage values for *Amaranthus hypochondriacus* to late harvesting. The excess of ADL and ash percentage was explained by the high carbon content from a potential $C_4$ plant per unit area. These results are comparable with data mentioned for WS and AH. In addition, the NFE and CF values of Smitha Patel et al. [74] support the use of APF. According to Su et al. [75], the results for ash, CP, EE, ADF and NDF of WS have similar values to our study. Şehu et al. [76] reported that the CP, CF, ADF and NDF percentage values for AH were 3.5, 38.1, 51.2, and 84.0, respectively. On the contrary, Bozkurt Kiraz [77] determined the ADF and NDF percentage values for AH to be 33.76 and 40.15, and the RFV value to be 145.34, respectively. Looked at the results from this perspective, in the present study, the high NDF percentage values for the WS and AH used may indicate that they are a good filler feed.

Fazaeli et al. [70] determined the dry matter digestibility (DMD) and organic matter digestibility values (OMD) for *Amaranthus hypochondriacus* first and second harvest time to be 78.92%, 66.64%, and 75.13%, 64.32%, and the DMD and OMD of APF were 59.99 and 41.67, respectively. Similarly, Rahnama and Safaeie [78] determined the mean DMD value of three different varieties of *Amaranthus hypochondriacus* as 68.3%. According to all these results, APF has a low DMD and OMD value compared to *Amaranthus hypochondriacus*. Sarmadi et al. [79] determined the forage quality of *Amaranthus hypochondriacus* grown at different developmental stages (flowering, milk and death stage) and nitrogen levels (120, 180, and 240 kg N/ha). While the ADL percentage, phenolics and methane production continuously increased with time; the CP percentage, digestibility, in vitro ruminal volatile fatty acids and microbial crude protein values decreased. Compared to other Amaranth species, the low digestibility of APF can be explained by the increase in the amount of ADL in its structure due to its late harvest. While the TC values of fresh grass and silage of Amaranthus Plainsman and D136 cultivars were determined to be 674 and 662, and 641 and 647 $g\,kg^{-1}$ [80], APF, WH and AH were determined to be 79.85, 86.97 and 60.20 $g\,kg^{-1}$, respectively, in our present study (Table 1). According to these results, while the total carbohydrate value of Amaranthus Plainsman and D136 varieties increased in fresh grass and silage, ADL value, structural carbohydrate was higher in dried APF, WS, and AH.

While the $NE_L$ values for Amaranthus Plainsman and D136 cultivars for fresh grass and silage were 4.94 and 5.15, and 4.94 and 5.01 MJ/kg DM according to Seguin et al. [80], in our current study, the APF, WH and AH values were determined to be 3.41, 1.65 and 4.45 MJ/kg DM, respectively.

In the present study, the 24-h OMD value of wheat straw was determined to be 25.73%. In the study by Şehu et al. [81], which determined the feed value and digestibility of different roughages, the value for 24-h dry matter loss of wheat straw was similar to our study at 30.40% (Table 2).

**Table 1.** Nutritional content of roughages.

| Parameters | N | *Amaranthus powellii* Willd. forage ± **SE** | Wheat straw ± **SE** | Alfalfa hay ± **SE** | p value |
|---|---|---|---|---|---|
| DM[1] | 4 | $941.90^{b} \pm 1.90$ | $961.00^{a} \pm 0.70$ | $922.90^{c} \pm 1.20$ | 0.0001 |
| ash[2] | 4 | $13.22^{a} \pm 0.07$ | $7.16^{b} \pm 0.23$ | $13.68^{a} \pm 0.05$ | 0.0001 |
| CP[2] | 4 | $4.84^{b} \pm 0.46$ | $4.47^{b} \pm 0.27$ | $19.59^{a} \pm 0.99$ | 0.0008 |
| EE[2] | 4 | $2.16^{b} \pm 0.25$ | $1.22^{b} \pm 0.60$ | $6.55^{a} \pm 0.19$ | 0.0044 |
| CF[2] | 4 | $28.14^{b} \pm 0.88$ | $31.86^{b} \pm 0.13$ | $41.52^{a} \pm 1.12$ | 0.0030 |
| ADF[2] | 4 | $37.12^{c} \pm 0.16$ | $49.47^{b} \pm 0.35$ | $58.01^{a} \pm 0.46$ | 0.0001 |
| NDF[2] | 4 | $53.38^{b} \pm 0.45$ | $78.77^{a} \pm 2.70$ | $78.23^{a} \pm 0.76$ | 0.0026 |
| ADL[2] | 4 | $35.06^{b} \pm 0.27$ | $35.44^{b} \pm 0.38$ | $43.01^{a} \pm 0.50$ | 0.0012 |
| HCel[2] | 4 | $16.27^{b} \pm 0.61$ | $29.30^{a} \pm 3.05$ | $20.22^{ab} \pm 1.25$ | 0.0372 |
| Cel* [2] | 4 | $2.06^{b} \pm 0.42$ | $14.04^{a} \pm 0.03$ | $15.01^{a} \pm 0.96$ | 0.0011 |
| TC [2] | 4 | $79.85^{b} \pm 0.30$ | $86.97^{a} \pm 1.11$ | $60.20^{c} \pm 1.11$ | 0.0005 |
| NFE[2] | 4 | $45.81^{a} \pm 0.90$ | $51.17^{a} \pm 1.34$ | $10.86^{b} \pm 0.01$ | 0.0001 |

[1]g/kg of natural material; [2] (%) of dry matter.
DM: dry matter, CP: crude protein, CF: crude fiber, NDF: neutral detergent fiber, ADF: acid detergent fiber, ADL: acid detergent lignin, EE: ether extract, TC: total carbohydrates, HCel: hemicellulose, Cel: cellulose, NFE: nitrogen free extracts.
[a,b,c] Mean values within the same column with no common superscripts differ significantly ($p < 0.01$).

**Table 2.** Total amount of gas measured in 24 h by in vitro gas production technique of roughages.

| Roughages | N | OMD (%) ± **SE** | ME (MJ/kg DM) ± SE | $NE_L$ (MJ/kg DM) ± SE | In vitro gas production (IVGP, mL/200 mg DM) ± SE |
|---|---|---|---|---|---|
| *Amaranthus powellii* Willd. forage | 4 | 41.67 ± 0.84 | 6.27 ± 0.13 | 3.41 ± 0.10 | 29.70 ± 0.99 |
| Wheat straw | 4 | 25.73 ± 1.52 | 3.77 ± 0.24 | 1.65 ± 0.17 | 11.36 ± 1.80 |
| Alfalfa hay | 4 | 50.66 ± 4.34 | 7.75 ± 0.70 | 4.45 ± 0.49 | 39.26 ± 5.14 |

OMD: organic matter digestibility, ME: metabolizable energy, $NE_L$: net energy lactation, IVGP: in vitro gas production.

**Table 3.** Protein and energy values of roughages.

| Parameters | *Amaranthus powellii* Willd. forage ± **SE** | Wheat straw ± SE | Alfalfa hay ± SE | p value |
|---|---|---|---|---|
| DCP (%) | $0.62^b \pm 0.42$ | $0.29^b \pm 0.25$ | $14.02^a \pm 0.90$ | 0.0008 |
| TDN (%) | $53.47^b \pm 0.42$ | $52.83^b \pm 0.28$ | $67.88^a \pm 1.11$ | 0.0010 |
| DE (MJ/kg) | $9.87^b \pm 0.08$ | $9.75^b \pm 0.06$ | $11.53^a \pm 0.21$ | 0.0010 |
| ME (MJ/kg) | $8.09^b \pm 0.07$ | $7.99^b \pm 0.04$ | $10.27^a \pm 0.17$ | 0.0010 |
| $NE_L$ (MJ/kg) | $5.00^b \pm 0.04$ | $4.93^b \pm 0.03$ | $6.48^a \pm 0.11$ | 0.0011 |
| $NE_M$ (MJ/kg) | $5.28^b \pm 0.05$ | $5.21^b \pm 0.04$ | $7.04^a \pm 0.13$ | 0.0010 |
| $NE_G$ (MJ/kg) | $2.27^b \pm 0.05$ | $2.19^b \pm 0.04$ | $4.02^a \pm 0.14$ | 0.0010 |
| $NE_m$ (MJ/kg) | $6.49^b \pm 0.08$ | $6.37^b \pm 0.05$ | $9.77^a \pm 0.31$ | 0.0016 |
| $NE_g$ (MJ/kg) | $4.91^b \pm 0.06$ | $4.81^b \pm 0.04$ | $7.80^a \pm 0.29$ | 0.0018 |

DCP: digestible crude protein: CP * 0.908–3.77, TDN: total digestible nutrient: 50.41 + 1.04 CP – 0.07CF, DE: digestible energy: 0.04409 * TDN % (50% TDN: 6.40 MJ/kg DM of ME), ME: metabolizable energy: 0.82 * DE, $NE_L$: net energy-lactation TDN% * 0.01114 – 0.054 (1 Mcal/lb = 2.2046 Mcal/kg), $NE_M$: net energy-maintenance: TDN% * 0.01318 – 0.132 (1 Mcal/ lb = 2.2046 Mcal/kg), $NE_G$: net energy-gain: TDN% * 0.01318 – 0.459 (1 Mcal/ lb = 2.2046 Mcal/kg),$NE_m$: net energy-maintenance: 1.37 ME – 0.138 $ME^2$ + 0.0105 $ME^3$ – 1.12 and $NE_g$: net energy-gain:1.42 ME – 0.174 $ME^2$ + 0.0122 $ME^3$ – 1.65.

[a,b,c] Mean values within the same column with no common superscripts differ significantly (p < 0.01).

Amaranth reduces the nitrogen requirements of cultivated soils, while fertilization can provide more plant growth [82]. The late harvest of *Amaranthus cruentus* and *hypochondriacus*, instead of an early harvest, reduced the CP percentage [27]. Abbasi et al. [83] reported that *Amaranthus hypochondriacus* harvested in 60 days as roughage can be increased by nitrogen fertilization. Karimi Rahjerdi et al. [84] showed that the CP percentage value for green grasses of the Kharkovskiy and Sem varieties of *Amaranthus hypochondriacus* decreased to 13.0 and 14.1, respectively. Dumanoğlu and Geren [85] used different doses of nitrogen (5, 10, 15, and 20 kg $ha^{-1}$) and phosphorus (5 and 10 kg $ha^{-1}$) applied to *Amaranthus mantegazzianus* green grass and silage; the N15 and P10 values provided the best plant growth and CP percentage (Table 3).

*Amaranthus caudatus* exhibited a decreased ash percentage in different developmental stages, while gross energy (MJ/kg DM) increased, and early flowering (79d) supported our study [86]. Pond and Lehmann, [34] reported that the lamb alfalfa hay ration can instead be substituted by 50% *Amaranthus cruentus*, as an energy source. Rahnama and Safaeie [78] determined the crude oil average of three varieties of *Amaranthus hypochondriacus* as 2.20, while APF, WS and AH were 2.16, 1.22 and 6.55%, respectively. While the chemical composition and nutritional values of all studies support our current study, the APF results show that it has a feed value.

The TDN values for Amaranthus Plainsman and D136 varieties were determined when fresh and as silage to be 532 and 552, and 532 and 538 g $kg^{-1}$ by Seguin et al. [80]. This present study found the values for APF, WH and AH to be 53.47, 52.83 and 67.88%, respectively.TDN (%), DE (MJ/kg), ME (MJ/kg), $NE_L$ (MJ/kg), $NE_M$ (MJ/kg), $NE_G$ (MJ/kg), $NE_m$ (MJ/kg), $NE_g$ (MJ/kg) and CP percentage values were highest in AH, APF and WS, respectively. The high CP percentage also increases the energy value [87] and the value for the digestible ME (MJ/kg DM) supports the calculated energy values (Table 3).

The RFV value for APF, WS and AH decreased linearly respectively and the decrease was statistically significant (p < 0.0001). According to the RFV assessment, APF has the potential to be a third-tier roughage (Table 4). On the contrary, Rahnama and Safaeie [78] concluded that three varieties of *Amaranthus hypochondriacus* were prime quality roughage on the RFV scale according to changes occurring at different formation times and that they could be used for feeding 18 to 24 month-old dry cows according to the RFQ scale. In our current study, different results to the Rahnama and Safaeie [78] study may be due to regional and species differences. DM, EE, CF, CP and ash contents of APF used in the study were 94.19%, 2.16%, 28.14%, 4.84%, and 13.22%, respectively. This result was supported by Bressani and González [88,89], who concluded that Amaranth would be a good forage or material for silage, and that heat-treated seeds could be used in poultry feed. In addition, the nutritional values of the branches and leaves of Amaranth, in the study by Bressani [90], support our present study. Abbasi et al. [91] reported that there was no quality silage, but there was potential, depending on the amount of ADL in fresh *Amaranthus hypochondriacus*

**Table 4.** Relative feed value and relative feed quality values of roughages.

| Parameters | *Amaranthus powellii* Willd. forage **± SE** | Wheat straw **± SE** | Alfalfa hay **± SE** | p value |
|---|---|---|---|---|
| DDM (LW %) | 59.99[a] ± 0.12 | 50.37[b] ± 0.27 | 43.71[c] ± 0.36 | 0.0001 |
| DMI (%) | 2.25[a] ± 0.02 | 1.53[b] ± 0.06 | 1.54[b] ± 0.02 | 0.0011 |
| RFV | 104.55[a] ± 0.67 | 59.54[b] ± 1.71 | 51.98[c] ± 0.09 | 0.0001 |
| RFQ | 97.73[a] ± 0.05 | 65.50[c] ± 1.89 | 84.68[b] ± 2.23 | 0.0020 |

DMI: dry matter intake (live weight: LW, %): 120/[NDF%], DDM: digestible dry matter: 88.9 – [0.779 * ADF%], RFV: relative feed value: [DMD * DMI]/1.29 and RFQ: relative forage quality: [DMI * TDN]/1.23.

[a,b,c] Mean values within the same column with no common superscripts differ significantly ($p < 0.01$).

(44.6 g/kg). Ehsani et al. [73] reported that there may be better quality forage than AH used for feeding ruminant animals. Alfaro et al. [92] reported that substituting 15% with alfalfa leaf flour would not be a problem, but higher levels would reduce daily weight gain, while 60% of dried amaranth plant meal would contribute to increased live weight in animals. According to Şehu et al. [76], the CP, CF, ADF and NDF values of alfalfa hay were determined to be 3.5%, 38.1%, 51.2%, and 84.0%, respectively. On the contrary, Bozkurt Kiraz [77] determined the ADF and NDF values of alfalfa hay to be 33.76 and 40.15, and the RFV value to be 145.34, respectively. In the present study, CP, CF, ADF and NDF values were determined to be 19.59%, 41.52%, 58.01%, and 78.23%, respectively. Although these values show similarity, the higher ADL value decreased the RFV value of WS and AH, and was calculated to be 59.54% and 51.98%, respectively. The present study was used to compare two forage feed samples: good quality, like AH, and low quality, like WS. The poor RFV value of alfalfa can be attributed to the lack of care during harvesting, handling and storage.

According to the RFQ value developed for the feeding of dairy cattle, an APF, AH and WS ranking is available (Table 4). The RFQ value for APF has the highest value at 97.73 ± 0.05; this is a value that allows it to be used for feeding dairy cattle or fattening cattle [69]. Odwongo and Mugerwa [93] reported that up to 40% of Amaranth leaves can be added to the pre-weaning rations for calves. Olorunnisomo [94] used sun-dried corn and *Amaranthus cruentus*, equal mixtures of sun-dried, separate silages and equal mixture silages as a complementary feed for dry sheep during dry periods. Tan et al. [95] reported that the shape time for *Amaranthus retroflexus* and *Chenopodium album* plants and the addition of additives (salt and barley) were not sufficient to make good quality silage. Alegbejo [42] reported that Amaranth leaves may be a good roughage, but the best grazing period is flowering time. Aliyu [96] reported that *Amaranthus hybridus* can be added to the mixed feed as an alternative forage feed during feeding of nursing rabbits.

## 4. Conclusion

Amaranth is generally considered a human food –or food component– as a source of protein because it contains high levels of crude protein and lysine from essential amino acids. However, *Amaranthus powellii Willd*. is a plant that has not been studied beyond its biological and chemical control, and the current study is perhaps the first resource for its evaluation in terms of animal nutrition. APF compared to WH and AH, has the potential to be a third quality roughage according to its RFV assessment of 104.55 ± 0.67. Our results concluded that APF has the potential to be a forage that can be used in feeding ruminant animals according to nutritional and in vitro digestibility analyses; however, in vivo studies are needed to show the effects on ruminant animals after determining nitrate, amino acids, and other antinutritional factors.

### Conflicts of interest

There are no conflicts of interest to declare.

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### Bioethics and biosecurity committee approval

The study complied with an ethics document taken from the Animal Experiments Local Ethics Committee of Kırşehir Ahi Evran University, dated and numbered 08/08/2018-15-3.

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### Contribution of authors

Gökhan Filik and Ayşe Gül Filik designed and conducted this study. Ayşe Gül Filik worked at laboratory for chemical analyses and in vitro trial with completing statistical analysis while Gökhan Filik supervised and coordinated this study. Both authors wrote this manuscript with making critical revision and approved of the final version.

## References


1. Topwal M. A review on amaranth: nutraceutical and virtual plant for providing food security and nutrients. Acta Scientific Agriculture 2019; 3: 9-15.
2. Peiretti PG. Amaranth in animal nutrition: a review. Livestock Research for Rural Development 2018; 30: 5.
3. Bojórquez-Velázquez E, Velarde-Salcedo AJ, De Léon-Rodríguez A, Jimenez-Islas H, Pérez-Torres JL et al. Morphological, proximal composition, and bioactive compounds characterization of wild and cultivated amaranth (Amaranthus spp.) species. Journal of Cereal Science 2018; 83: 222-228. doi: 10.1016/j.jcs.2018.09.004
4. Brennan MA, Menard C, Roudaut G, Brennan CS. Amaranth, millet and buckwheat flours affect the physical properties of extruded breakfast cereals and modulates their potential glycaemic impact. Starch-Stärke 2012; 64 (5): 392-398. doi: 10.1002/star.201100150
5. Rastogi A, Shukla S. Amaranth: a new millennium crop of nutraceutical values. Critical Reviews in Food Science and Nutrition 2013; 53 (2): 109-125. doi: 10.1080/10408398.2010.517876
6. Assad R, Reshi ZA, Jan S, Rashid I. Biology of amaranthus. The Botanical Review 2017; 83 (4): 382-436. doi: 10.1007/s12229-017-9194-1
7. D'Amico S, Schoenlechner R. Amaranth: its unique nutritional and health-promoting attributes. Gluten-Free Ancient Grains. 2017; 131-159. doi: 10.1016/B978-0-08-100866-9.00006-6
8. Paredes-Lopez O. Amaranth Biology, Chemistry, and Technology. 1st ed. Boca Raton, FL, USA: CRC Press; 2018.
9. Joshi DC, Sood S, Lakshmi Hosahatti R, Kant Pattanayak A, Kumar A et al. From zero to hero: the past, present and future of grain amaranth breeding. Theoretical and Applied Genetics 2018; 131 (9): 1807-1823. doi: 10.1007/s00122-018-3138-y
10. Velarde-Salcedo AJ, Bojórquez-Velázquez E, De la Rosa APB. Amaranth. In: Johnson J, Wallace T (editors). Whole Grains and Their Bioactives: Composition and Health. Hoboken, NJ, USA: John Wiley & Sons Ltd; 2019. pp. 209-250.
11. Pospišil A, Pospišil M, Maćešić D, Svečnjak Z. Yield and quality of forage sorghum and different amaranth species (Amaranthus spp.) biomass. Agriculturae Conspectus Scientificus 2009; 74 (2): 85-89.
12. Sitkey V, Gaduš J, Kliský Ľ, Dudák A. Biogas production from amaranth biomass. Acta Regionalia et Environmentalica 2013; 10 (2): 59-62. doi: 10.2478/aree-2013-0013
13. Pourfarid A, Kamkar B, Akbari GA. The effect of density on yield and some agronomical and physiological traits of Amaranth (Amaranthus spp). International Journal of Farming and Allied Sciences 2014; 3 (12): 1256-1259.
14. Venskutonis PR, Kraujalis Paulius. Nutritional components of amaranth seeds and vegetables: a review on composition, properties, and uses. Comprehensive Reviews in Food Science and Food Safety 2013; 12 (4): 381-412. doi: 10.1111/1541-4337.12021
15. Myers RL, Putnam DH. Growing grain amaranth as a specialty crop. Center for Alternative Crops & Products. Minnesota Extension Service, University of Minnesota. 2500 AGFS-3458. Minneapolis, MN, USA: University of Minnesota 1988.
16. Stallknecht GF, Schulz-Schaeffer JR. Amaranth rediscovered. In: Janick J, Simon JE (editors). New Crops. New York, NY, USA: Wiley; 1993. pp. 211-218.
17. Vityakon P. Effects of environmental factors on nutrients and antinutrient contents of selected leafy vegetables. PhD dissertation, University of Hawaii, Honolulu, HI, USA, 1986.
18. Ulbricht C, Abrams T, Conquer J, Costa D, Grimes Serrano JM et al. An evidence-based systematic review of amaranth (Amaranthus spp.) by the natural standard research collaboration. Journal of Dietary Supplements 2009; 6 (4): 390-417. doi: 10.3109/19390210903280348
19. Ashok Kumar BS, Lakshman K, Jayaveera KN, Shekar DS, Nandeesh R et al. Chemoprotective and antioxidant activities of methanolic extract of Amaranthus spinosus leaves on paracetamol induced-liver damage in rats. Acta Medica Saliniana 2010; 39 (2): 68. doi: 10.5457/ams.v39i2.159
20. Caselato-Sousa VM, Amaya-Farfán J. State of knowledge on amaranth grain: a comprehensive review. Journal of Food Science 2012; 77 (4): 93-104. doi: 10.1111/j.1750-3841.2012.02645.x
21. Vélez-Jiménez E, Tenbergen K, Santiago P, Cardador-Martínez MA. Functional attributes of Amaranth. Austin Journal of Nutrition and Food Sciences 2014; 2 (1): 1-6.
22. Wangui J. Impact of different processing techniques on nutrients and antinutrients content of grain amaranth (Amaranthus albus). MSc thesis, Jomo Kenyatta University of Agriculture and Technology, Juja, Kenya, 2015.
23. O'Brien GK, Price ML. Amaranth grain and vegetable types. Educational Concerns for Hunger Organization (ECHO) Technical Note. North Fort Myers, FL; USA: ECHO; 1983 (revised 2008).
24. Singhal RS, Kulkarni PR. Composition of the seeds of some Amaranthus species. Journal of the Science of Food and Agriculture 1988; 42 (4): 325-331.
25. Písaříková B, Zralý Z, Kráčmar S, Trčková M, Herzig I. Nutritional value of amaranth (genus Amaranthus L.) grain in diets for broiler chickens. Czech Journal of Animal Science 2005; 50 (12): 568-573.
26. Svirskis A. Investigation of amaranth cultivation and utilization in Lithuania. Agronomy Research 2003; 1: 253-264.
27. Grobelnik Mlakar S, Turinek M, Jakop M, Bavec M, Bavec F. Nutrition value and use of grain amaranth: potential future application in bread making. Agricultura 2009; 6 (4).
28. Myers RL. Amaranth: new crop opportunity. In: Janick J (editor). Progress in New Crops. Alexandria, VA, USA: ASHS Press; 1996. pp. 207-220.

29. Sauer JD. Grain amaranths Amaranthus spp. (Amaranthaceae). Evolution of Crop Plants1976; 1976: 4-7.

30. Aynehband A. Cultivar and nitrogen splitting effects on amaranth forage yield and weed community. Pakistan Journal of Biological Sciences 2008; 11: 80-85.

31. Connor JK, Gartner RJW, Runge BM, Amos RN. Amaranthus edulis: an ancient food source re-examined. Australian Journal of Experimental Agriculture 1980; 20 (103): 156-161.

32. Laovoravit N, Kratzer FH, Becker R. The nutritional value of amaranth for feeding chickens. Poultry Science Journal 1986; 65 (7): 1365-1370.

33. Acar N, Vohra P, Becker R, Hanners GD, Saunders RM. Nutritional evaluation of grain amaranth for growing chickens Poultry Science Journal 1988; 67 (8): 1166-1173.

34. Pond WG, Lehmann IW. Nutritive Value of a Vegetable Amaranth Cultivar for Growing Lambs. Journal of Animal Science 1989; 67: 3036-3039.

35. Kabuage LW. Nutritive evaluation of grain amaranth (Amaranthus spp.) in broiler chicken diets. PhD dissertation, University of Nairobi, Nairobi, Kenya, 1996.

36. Ravindran V, Hood RL, Gill RJ, Kneale CR, Bryden WL. Nutritional evaluation of grain amaranth (Amaranthus hypochondriacus) in broiler diets. Animal Feed Science and Technology 1996; 63 (1-4): 323-331.

37. He HP, Cai Y, Sun M, Corke H. Extraction and Purification of Squalene from Amaranthus Grain. Journal of Agricultural and Food Chemistry 2002; 50 (2): 368-372.

38. Molina E, González Redondo P, Moreno Rojas R, Montero Quintero K, Bracho B et al. Effects of diets with Amaranthus dubius Mart. ex Thell. on performance and digestibility of growing rabbits. World Rabbit Science 2015; 23: 1-9. doi: 10.4995/wrs.2015.2071

39. Ferreira TAPC, Arêas JAG. Protein biological value of extruded, raw and toasted amaranth grain. Pesquisa Agropecuária Tropical 2004; 34 (1): 53-59.

40. Zralý Z, Písaříková B, Hudcova H, Trčková M, Herzig I. Effect of feeding amaranth on growth efficiency and health of market pigs. Acta Veterinaria Brno 2004; 73 (4): 437-444.

41. Matoušová Z, Nedomová Š, Pisaříková B, Zralý Z. The effects of adding amaranth to fodder mixture on selected qualities of chicken meat. MendelNet´07 Agro, 22.11.2007. Brno, Czech Republic: MZLU; 2007 (in Czech).

42. Alegbejo JO. Nutritional value and utilization of Amaranthus (Amaranthus spp.)–a review. Bayero Journal of Pure and Applied Sciences 2013; 6 (1): 136-143. doi: 10.4314/bajopas.v6i1.27

43. Popiela E, Króliczewska B, Zawadzki W, Opaliński S, Skiba T. Effect of extruded amaranth grains on performance, egg traits, fatty acids composition, and selected blood characteristics of laying hens. Livestock Science 2013; 155 (2-3): 308-315. doi: 10.1016/j.livsci.2013.05.001

44. Rezaei J, Rouzbehan Y, Fazaeli H, Zahedifar M. Carcass characteristics, non-carcass components and blood parameters of fattening lambs fed on diets containing amaranth silage substituted for corn silage. Small Ruminant Research 2013; 114 (2-3): 225-232. doi: 10.1016/j.smallrumres.2013.06.012

45. Bhande SS, Wasu YH. Effect of aqueous extract of Amaranthus spinosus on biochemical parameters of wistar albino rats. Life Sciences Leaflets 2016; 4 (1): 116-120.

46. Mosyakin SL, Robertson KR. Amaranthus Linnaeus. In: Flora of North America Editorial Committee (editors). Flora of North America North of Mexico, 4 (Magnoliophyta: Caryophyllidae, part 1). New York, NY, USA: Oxford University Press; 2003. pp. 410-435.

47. McNaughton KE, Letarte J, Lee EA, Tardif FJ. Mutations in ALS confer herbicide resistance in redroot pigweed (Amaranthus retroflexus) and Powell amaranth (Amaranthus powellii). Weed Science 2005; 53 (1): 17-22. doi: 10.1614/WS-04-109

48. Tardif FJ, Rajcan I, Costea M. A mutation in the herbicide target site acetohydroxyacid synthase produces morphological and structural alterations and reduces fitness in Amaranthus powellii. New Phytologist 2006; 169 (2): 251-264. doi: 10.1111/j.1469-8137.2005.01596.x

49. Milani A, Scarabel L, Sattin M. A family affair: resistance mechanism and alternative control of three Amaranthus species resistant to acetolactate synthase inhibitors in Italy. Pest Management Science 2019. doi: 10.1002/ps.5667

50. Filik G. Biodegradability of quinoa stalks: the potential of quinoa stalks as a forage source or as biomass for energy production. Fuel 2020; 266: 117064. doi: 10.1016/j.fuel.2020.117064

51. AOAC. Official Procedure. Official methods of analysis of AOAC. International 17th ed. Gaithersburg, MD, USA: Association of Analytical Communities; 2000.

52. Van Soest PV, Robertson JB, Lewis BA. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. Journal of Dairy Science 1991; 74 (10): 3583-3597.

53. AOCS. Official Procedure. Approved procedure Am 5-04, rapid determination of oil/fat utilizing high temperature solvent extraction. Urbana, IL, USA: American Oil Chemists' Society; 2005.

54. Sniffen CJ, O'connor JD, Van Soest PJ, Fox DG, Russell JB. A net carbohydrate and protein system for evaluating cattle diets: II. carbohydrate and protein availability. Journal of Animal Science 1992; 70 (11): 3562-3577.

55. Menke KH, Steingass H. Estimation of the energetic feed value obtained from chemical analysis and in vitro gas production using rumen fluid. Animal Research and Development 1988; 28: 7-55.

56. Cornou C, Storm IMD, Hindrichsen IK, Worgan H, Bakewell E et al. A ring test of a wireless in vitro gas production system. Animal Production Science 2013; 53 (6): 585-592. doi: 10.1071/AN12091

57. Erdem F. Determination the digestibility of Juncus acutus by in-vitro gas production and its effect on ruminal cellulolytic bacteria by real-time PCR methods. PhD dissertation, Ondokuz Mayıs University, Samsun, Turkey, 2014.

58. Schroeder JW. Interpreting forage analysis (AS1080). Fargo, ND, USA: North Dakota State University; 1994.

59. Heeney MW. Estimating digestibility of livestock feedstuffs. Service in action; no. 1.605. Fort Collins, CO, USA: Colorado State University; 1978.

60. NRC (National Research Council). Nutrient requirements of dairy cattle. Washington, DC, USA: National Academy of Science; 2001. p. 381.

61. Moe PW, Flatt WP, Tyrell HF. Net energy value of feeds for lactation. Journal of Dairy Science 1972; 55 (7): 945-958.

62. Schroeder JW. Quality Forage: Interpreting Composition and Determining Market Value (AS1251). Fargo, ND, USA: North Dakota State University; 2004. pp. 1-11.

63. Garrett WN. Energy utilization by growing cattle as determined in 72 comparative slaughter experiments. Energy Metabolism (Studies in the Agricultural and Food Sciences) 1980: 3-7.

64. Rohweder DA, Barnes RF, Jorgensen N. Proposed hay grading standards based on laboratory analyses for evaluating quality. Journal of Animal Science 1978; 47 (3): 747-759.

65. Undersander D, Moore JE. Relative forage quality. Focus on Forage 2002; 4 (5): 1-2.

66. SPSSWIN. 2007. SPSS Statistics 17.0 release 17.0.0 (Aug 23, 2008) for Windows. WinWrap Basic, Copyright 1993-2007. Nikiski, AK, USA: Polar Engineering and Consulting; 2008.

67. Cheeke PR, Carlsson R, Kohler GO. Nutritive value of leaf protein concentrates prepared from Amaranthus species. Canadian Journal of Animal Science 1981; 61 (1): 199-204.

68. Sleugh BB, Moore KJ, Brummer EC, Knapp AD, Russell J et al. Forage nutritive value of various amaranth species at different harvest dates. Crop Science 2001; 41: 466-472.

69. Stordahl JL, Sheaffer CC, DiCostanzo A. Variety and maturity affect amaranth forage yield and quality. Journal of Production Agriculture 1999; 12: 249-253.

70. Fazaeli H, Ehsani P, Safayee AR, Mehrani A. Amaranth (Amaranthus hypochondriacus) as a new forage source. In: Vth International Conference: Balkan Conference on Animal Science, University of Agronomical Sciences and Veterinary Medicine; Bucharest, Romania; 2011.

71. Çolak G. Şanlıurfa'da doğal olarak bulunan Amaranthus türlerinin yem değerliklerinin belirlenmesi/Determination of valences feed of Amaranthus species naturally existing in Şanlıurfa. PhD dissertation, Harran University, Şanlıurfa, Turkey, 2013.

72. Leukebandara IK, Premaratne S, Peiris BL. Nutritive quality of Thampala (Amaranthus spp.) as a forage crop in Sri Lanka. Tropical Agricultural Research 2015; 26 (4): 624-631.

73. Ehsani P, Fazaeli H, Karkoudi K, Mehrani A. Digestibility, chemical compound and protein quality of amaranthus forage at two harvested cut. Iranian Journal of Applied Animal Science 2016; 7 (4): 428-436.

74. Smitha Patel PA, Alagundagi SC, Mansur CP, Kubsad VS, Hosamani SV et al. Effect of row spacing and seed rate on growth, fodder productivity and economics of amaranth genotypes. Karnataka Journal of Agricultural Sciences. 2011; 24 (5): 651-653.

75. Su H, Akins MS, Esser NM, Ogden R, Coblentz WK et al. Effects of feeding alfalfa stemlage or wheat straw for dietary energy dilution on nutrient intake and digestibility, growth performance, and feeding behavior of Holstein dairy heifers. Journal of Dairy Science 2017; 100 (9): 7106-7115. doi: 10.3168/jds.2016-12448

76. Şehu A, Yalçın S, Önol AG. Bazı buğdaygil samanlarının in vivo sindirilme dereceleri ve rumende parçalanma özellikleri/ The in vivo digestibility coefficients and rumen degradability characteristics of some cereal straws. Ankara Üniversitesi Veteriner Fakültesi Dergisi 1996; 43: 469-477 (in Turkish with an abstract in English).

77. Bozkurt Kiraz, A. Determination of relative feed value of some legume hays harvested at flowering stage. Asian Journal of Animal and Veterinary Advances 2011; 6 (5): 525-530. doi: 10.3923/ajava.2011.525.530

78. Rahnama A, Safaeie AR. Performance comparison of three varieties of amaranth (Amaranthus hypochondriacus L.) at different harvest time. Asian Journal of Scientific Research 2017; (7-6): 224-230. doi: 10.18488/journal.2.2017.76.224.230

79. Sarmadi B, Rouzbehan Y, Rezaei J. Influences of growth stage and nitrogen fertilizer on chemical compositon, phenolics, in situ degradability and in vitro ruminal variables in amaranth forage. Animal Feed Science and Technology 2016; 215: 273-284. doi: 10.1016/j.anifeedsci.2016.03.007

80. Seguin P, Mustafa AF, Donnelly DJ, Gélinas B. Chemical composition and ruminal nutrient degradability of fresh and ensiled amaranth forage. Journal of the Science of Food and Agriculture 2013; 93 (15): 3730-3736. doi: 10.1002/jsfa.6218

81. Şehu A, Yalçın S, Önol AG, Koçak D. Kaba yemlerin bazı özelliklerinden yararlanarak kuzularda kuru madde tüketimi ve canlı ağırlık artışının belirlenmesi/ Prediction of dry matter intake and live weight gain in lambs by some characteristics of roughages. Turkish Journal of Veterinary and Animal Sciences 1998; 22: 475-483.

82. Elbehri A, Putnam DH, Schmitt M. Nitrogen fertilizer and cultivar effects on yield and nitrogen-use efficiency of grain amaranth. Agronomy 1993; 85 (1): 120-128.

83. Abbasi D, Rouzbehan Y, Rezaei J. Effect of harvest date and nitrogen fertilization rate on the nutritive value of amaranth forage (Amaranthus hypochondriacus). Animal Feed Science and Technology 2012; 171 (1): 6-13. doi: 10.1016/j.anifeedsci.2011.09.014

84. Karimi Rahjerdi N, Rouzbehan Y, Fazaeli H, Rezaei J. Chemical composition, fermentation characteristics, digestibility, and degradability of silages from two amaranth varieties (Kharkovskiy and Sem), corn, and an amaranth–corn combination. Journal of Animal Science 2015; 93 (12): 5781-5790. doi: 10.2527/jas2015-9494

85. Dumanoğlu Z, Geren H. Effect of different nitrogen and phosphorus levels on the herbage yield and some silage characteristics of Amaranth (Amaranthus mantegazzianus), Ege Üniversitesi Ziraat Fakültesi Dergisi 2019; 56 (1): 45-52. doi: 10.20289/zfdergi.439940

86. Peiretti PG, Meineri G, Longato E, Tassone S. Chemical composition, in vitro digestibility and fatty aci profile of Amaranthus caudatus herbage during its growth cycle. Animal Feed Science and Technology 2018; 18: 107-116. doi: 10.5958/0974-181X.2018.00010.0

87. Pedersen B, Kalinowski LS, Eggum BO. The nutritive value of amaranth grain (Amaranthus caudatus). Plant Foods for Human Nutrition 1987; 36 4: 309-324.

88. Bressani R, González JM. Uso potencial del residuo de la materia seca vegetative del amaranto en la alimentación, de rumiantes: estudios preliminares. In: El amaranto y su potencial. Archivos Latinoamericanos de Nutrición 1984; 4 (in Spanish).

89. Bressani R, González JM. The nutritive value of the amaranth seed calyx as tested in growing chickens. Amaranth Newsletter, no 1. Guatemala: Archivos Latinoamericanos de Nutrición; 1986.

90. Bressani R. Amaranth: the nutritive value and potential uses of the grain and byproducts. Food and Nutrition Bulletin 1988; 10 (2): 1-11.

91. Abbasi M, Rouzbehan Y, Rezaei J, Jacobsen SE. The effect of lactic acid bacteria inoculation, molasses, or wilting on the fermentation quality and nutritive value of amaranth (Amaranthus hypochondriaus) silage. Journal of Animal Science 2018; 96 (9): 3983-3992. doi: 10.1093/jas/sky257

92. Alfaro MA, Ramírez R, Martínez A, Bressani R. Evaluación de diferentes niveles de harina de amaranto (parses vegetativas) en sustitución de harina de alfalfa pare conejos en crecimiento. Archivos Latinoamericanos de Nutrición 1987; 37: 174-185.

93. Odwongo WO, Mugerwa JS. Performance of calves on diets containing Amaranthus leaf meal. Animal Feed Science and Technology 1980; 5: 193-204.

94. Olorunnisomo AO. Nutritive value of conserved maize, amaranth or maize-amaranth mixture as dry season fodder for growing West African Dwarf sheep. Livestock Research for Rural Development 2010; 22: 10.

95. Tan M, Gül DZ, Çoruh İ. Horozibiği (Amaranthus retroflexus L.) ve sirken (Chenepodium album L.) yabancı otlarının silaj değerlerinin belirlenmesi/ Determination of silage value of redroot Amaranth (Amaranthus retroflexus L.) and lamb's quarters (Chenepodium album L.) weeds. Atatürk University Faculty of Agriculture 2012; 43 (1): 43-47.

96. Aliyu Y. Evaluation of the feeding potentials of Amaranthus stem and F. thoningii foliage as supplements to concentrate diet for weaner rabbits. American Journal of Biomedical Science and Research 2019; 1 (6). doi: 10.34297/ajbsr.2019.01.000551