Original article

Nutritional composition of potato (*Solanum tuberosum L.*) Haulms

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Summary. The present study was conducted to investigate the nutritional composition of the haulms of commonly grown 5 potato (*Solanum tuberosum L.*) cultivars (Milva, Laura, Granola, Europrima and Jelly). Plant materials were harvested from potato production fields of Efsane Seed Company just before tuber harvest. Current findings revealed that green herbage yields of potato haulms varied between 416.51 and 670.32 kg/da, dry herbage yields between 381.62 and 527.24 kg/da, crude protein (CP) ratios between 10.85-14.48%, crude ash (CA) ratios between 5.22 and 9.10%, acid detergent fiber (ADF) ratios between 22.46 and 33.94%, neutral detergent fiber (NDF) ratios between 47.99 and 60.91%. Gas production values varied between 33.15 and 47.56 mL, methane productions between 5.27 and 8.35 mL, metabolic energy (ME) values between 7.45 and 9.29 MJ/kg DM and organic matter digestibility (OMD) values between 50.77-63.69%. Considering the mineral content of potato haulms, iron contents varied between 47.35 and 180.07, manganese contents between 28.14 and 85.15, cobalt contents between 0.43 and 1.13, nickel contents between 3.40 and 8.60, copper contents between 10.84 and 15.35, zinc contents between 4.14 and 15.60, cadmium contents between 1.02 and 1.55 and lead contents between 6.74 and 9.80 mg/kg/DM. It was concluded based on current findings from the haulms of five different potato cultivars that haulms had quite high feed quality values. With rich mineral contents, haulms may eliminate supplementary mineral requirements of livestock. Therefore, it can be stated that haulms of all five cultivars can be used as an alternative feed source for animals.

Key words: Potato, alternative feed, chemical composition, gas production, methane

Introduction

Today, present pastures and grasslands are able to meet only 40.5% of roughage needs of livestock. The rest is tried to be met with field crop residues and especially with cereal straws and hay. However, the straw with only 4-5% protein content can provide only a feeling of fullness (Serin and Tan, 2011).

Following the cereals, potato has the greatest share in human nutrition. Just because of cheapness, high yield per unit area, high nutritional value, easy digestion and adaptation to every climate, potato is cultivated almost everywhere in the world (Kolsarıcı, 2009). Potato is cultivated over 18.651.838 ha land area in the world and over 140.665 ha in Turkey (FAO, 2009). With high yield per unit area, it provides significant contributions to country and producer economies (Yıldırım *et al.,* 2005). Potato tubers are quite rich in carbohydrate and leaves are rich in protein. Therefore, different plant parts can reliably be used as livestock feed (Yıldırım *et al.*, 2005). Above-ground parts of potato (haulms) can be ensilaged and used as animal feed

(Nicholson *et al.*, 1978; Pafritt *et al.*, 1982; Muck *et al.*, 1999). Watson and Nash (1960) reported that haulm silage had quite close nutritional value to maize silage and Muck *et al.* (1999) indicated that haulm silage with high protein and low fiber content could be used as animal feed. Based on cultivars and time of harvest, protein content of potato haulms vary between 8-26%. Decreases are observed in protein contents with the prolonged harvest periods (Carruthers and Pirie, 1975; Nicholson *et al.*, 1978; Muck *et al.*, 1999). Solanine content is the most critical issue to be considered in the use of potato haulms as a feed source. Solanine contents of potato haulms can also vary based on cultivars and time of harvest (Karadoğan, 1991). Nicholson *et al.* (1978) carried out a study with Kennebec potato cultivar and indicated that total glucoalkaloid ratio decreased with the progress of ripening and potato haulms could be ensilaged and used in animal feeding. Similarly, Montario (2012) indicated that potato haulms had a great place in animal feeding and pointed out that solanine content of potato haulms did not have a toxic effect since they started to dry out when the tubers were harvested, therefore they could be used in animal feeding.

Potato growers generally decimate potato haulms before the harvest to harden the peals, to have easy harvest with machines and especially to prevent the spread of diseases in seed potato production (Oral, 1979). The present study was conducted to determine nutritional composition of potato haulms and to investigate possible use of potato haulms as an alternative quality roughage supply for livestock.

Material and Method

Feed Samples

The potato cultivars of Milva, Laura, Granola, Jelly and Europrima (4 of them are registered and one has a production permit) selected among the mostly sold cultivars of Efsane Seed Co. (operating within the research region-Kayseri, Turkey) were used as the plant material. Feed samples were harvested from the production fields of the company to determine haulm yield and quality. Sampling was made from 2.8 x 5 m area from each cultivar in tree replications and samples were subjected to relevant analyses. Before tuber harvest, haulms were reaped and weighed to find green herbage yields. Then, they were dried at 70 °C for 48 hours to determine dry herbage yields.

Chemical Analyses

Dried samples were grinded in a mill with 1 mm sieve and used in analyses. Crude ash was determined by ashing the samples in an ash oven at 550 °C for 8 hours. Kjeldahl method was used to determine nitrogen (N) content of samples. Crude protein was calculated with the formula of Nx6.25 (AOAC, 1990). NDF was determined in accordance with Van Soest and Wine (1967) and ADF with Van Soest (1963) in an ANKOM 200 Fiber Analyzer (ANKOM Technology Corp. Fairport, NY, USA).

In-vitro gas and methane measurements

The rumen fluid used in in-vitro gas measurements was supplied from fistuled Ivesi sheep. The Ivesi sheep was fed with 60% alfalfa and 40% barley ration. Water and licking stone was provided ad libitum. Rumen fluid was taken before morning feeding, filtered through four-folded cheesecloth and mixed with buffer solution at 1:2 ratio. Grinded 0.2 gram sample was placed into 100 ml syringe and 30 ml buffered rumen fluid was added to syringe. Then the syringes with the sample and rumen fluid were placed into a water bath at 39 °C. Another four syringes without samples but including only the rumen fluid were included into the incubation. The gas productions measured from these syringes were deducted from gas production measured from all syringes to get the net gas production. Feeds were incubated for 24 hours and total gas release was determined. Resultant gases were injected to Infrared Methane Analysis device (Sensor Europe GmbH, Erkrath, Germany) with a plastic syringe and methane production was determined (Goel *et al.*, 2008). The device measures the quantity of methane within injected gas as %. The following equation was used to calculate methane production:

Methane production (ml) = Total gas (mL) X Methane (%)

Metabolic energy and organic matter digestibility

Metabolic energy content of feeds was calculated with the following equation by using twenty-four hour gas production and chemical composition parameters (Menke *et al.*, 1979).

ME (MJ /kg DM) = 2.20 + 0.136 ×GP + 0.057 ×CP

OMD (g/kg DM) = 14.88 + 0.889 ×GP + 0.45 ×CP + 0.0651 ×A

GP = 24 h net gas production (ml/200 mg).

CP = Crude protein

A = Ash content

Statistical Analyses

Experimental data were subjected to variance analysis (ANOVA) with SAS (SAS Inst., 1999) software in accordance with randomized blocks experimental design. Means were compared with LSD test.

Results

The differences in chemical composition parameters of the cultivars were found to be significant (P<0.01). Chemical compositions of potato haulms are provided in Table 1. Protein contents of potato haulms varied between 10.85-14.48% with the lowest value from Jelly cultivar and the greatest value from Granola cultivar. The lowest ADF content was observed in Jelly cultivar with 22.46% and the greatest value was observed in Laura cultivar with 33.94% and it was followed by Europrima (32.56%) which was placed in the same statistical group. Considering the NDF contents, the lowest value was seen in Europrima (47.99%) and the greatest value in Jelly (60.91%) cultivar. The lowest ash content was obtained from Laura (5.22%) and the greatest value was obtained from Milva (9.10%) cultivar. Green herbage yields varied between 416.51-670.32 kg/da with the lowest value in Milva cultivar. Dry herbage yields varied between 381.62-527.24 kg/da. As it was in green herbage yields, Milva had the lowest and Jelly cultivar had the greatest value.

Mean values for gas and methane production, metabolic energy (ME) and organic matter digestibility (OMD) are provided in Table 2. The differences in mean values of cultivars were highly significant (P<0.01). The greatest methane ratio (20.12%) was obtained from Granola and the lowest methane ratio (17.54%) was obtained from Milva cultivar. The greatest gas production (47.56 mL) was observed in Jelly cultivar and it was followed by Granola cultivar (46.41 mL) which was placed in the same statistical group. The lowest gas production was observed in Milva cultivar (33.15 mL). While the greatest methane production (8.81 mL), ME (9.34 MJ/kg DM) and OMD (63.69%) were obtained from Granola cultivar, it was followed by Jelly cultivar (respectively with 8.35 mL, 9.29 Mj/kg DM, 62.95%) which was placed in the same statistical group. The lowest methane production (5.24 mL) was obtained from Milva cultivar and the lowest ME (7.45 MJ/kg DM) and OMD (50.77%) from Laura cultivar.

Mineral contents of potato haulms are provided in Table 3. While the greatest Fe and Mn contents were obtained from Jelly cultivar (respectively with 181.07 mg/kg and 85.15 mg/kg), the lowest values were obtained from Europrima cultivar (respectively with 47.35 mg/kg and 28.14 mg/kg). The highest Co content was observed in Milva (1.13 mg/kg) cultivar and

Table 1. Yield and chemical composition of potato haulms

Cultivars	**GHY**	**DHY**	**CP**	**ADF**	**NDF**	**CA**
Milva	416.51c	381.62d	13.42b	29.76b	51.78c	9.10a
Laura	565.87b	417.54c	11.17cd	33.94a	51.67c	5.22f
Granola	569.05b	428.97bc	14.48a	24.92c	55.36b	8.77b
Europrima	549.84b	459.44b	11.97c	32.56a	47.99d	5.93d
Jelly	670.32 a	527.24a	10.85d	22.46d	60.91a	6.55c
Deg. Sing.	**	**	**	**	**	**
LSD	39.704	35.442	0.9702	1.6429	1.2392	0.1875

*GHY: green herbage yield (kg/da); DHY: herbage yield (kg/da); CP: crude protein (%); ADF: acid detergent fiber (%); NDF: neutral detergent fiber (%); CA: crude ash (%); **: P≤0.01; Deg. Sing.: Degree of significance; LSD: least significant difference* it was followed by Jelly (1.10 mg/kg) cultivar which was placed in the same statistical group. The lowest Co content was obtained from Laura cultivar (0.43 mg/kg). While the greatest Ni content was observed in Milva cultivar (8.60 mg/kg), the lowest value was seen in Granola cultivar (3.40 mg/kg). The greatest Cu and Zn contents were obtained from Granola cultivar (respectively with 15.35 mg/kg and 15.60 mg/kg) and the lowest Cu and Zn contents were observed in Europrima cultivar (respectively with 10.84 mg/kg and 4.14 mg/kg). The greatest Cd content was observed in Jelly cultivar (1.55 mg/kg) and it was followed by Milva cultivar (1.54 mg/kg) which was placed in the same statistical group. The lowest Cd content was obtained from Europrima cultivar (1.02 mg/kg). While the greatest Pb content was obtained from Laura cultivar (9.80 mg/kg), the lowest value was seen in Milva cultivar (6.47 mg/kg).

Discussion

Use of harvest residues in animal feeding is a common practice. Quantity of such residues varies based on cultivar, species, climate and cultural practices. Parfitt *et al.* (1982) carried out a study with different potato genotypes and reported dry herbage yields of potato haulms as between 355-426 kg/da. It was also reported that chemical composition of potato haulms varied based on plant genetics, leaf and shoot ratios, ripening periods, climate and fertilization practices (Rubanza *et al.*, 2005).

Increasing NDF and ADF ratios slows down the digestion of feeds, let the animals physically feel full and thus limit feed consumption of them. Just because of negative effects of ADF and NDF on feed digestibility, they are desired to be at low quantities in rations (Bozkurt, 2011; Canbolat and Karaman, 2009). Cur-

Table 2. Methane, gas production, metabolic energy and organic matter digestibility of potato haulms

Cultivars	**CH_4 %**	**GP**	**CH_4mL**	**ME**	**OMD**
Milva	17.54c	33.15b	5.24b	7.47b	51.32b
Laura	17.98c	33.96b	5.47b	7.45b	50.77b
Granola	20.12a	46.41a	8.81a	9.34a	63.69a
Europrima	17.88c	34.19b	5.48b	7.53b	51.39b
Jelly	19.28b	47.56a	8.35a	9.29a	62.95a
Deg. Sing.	**	**	**	**	**
LSD	0.4686	3.1080	0.7831	0.4188	2.7655

*CH_4 %: percent methane; GP: gas production (mL); CH_4 mL: milliliter methane: ME: metabolic energy (MJ/kg DM): OMD: organic matter digestibility (%); **: P≤0.01; Deg. Sing.: Degree of Significance; LSD: least significant difference*

Table3. Mineral content of potato haulms

Cultivars	**Fe**	**Mn**	**Co**	**Ni**	**Cu**	**Zn**	**Cd**	**Pb**
Milva	98.33b	70.05b	1.13a	8.60a	12.20c	9.80c	1.54a	6.74e
Laura	63.12d	44.86d	0.43c	4.80c	14.30b	14.01b	1.10bc	9.80a
Granola	66.90c	61.01c	0.90b	3.40d	15.35a	15.60a	1.20b	8.50b
Europrima	47.35e	28.14e	0.45c	5.02c	10.84d	4.14e	1.02c	7.35c
Jelly	181.07a	85.15a	1.10a	7.02b	14.10b	7.33d	1.55a	7.10d
Deg. Sing.	**	**	**	**	**	**	**	**
LSD	1.3451	1.0809	0.0734	0.2272	0.4680	0.2793	0.1101	0.1614

: P≤0.01; Deg. Sing.: degree of significant; LSD: least significant difference

rent findings on NDF ratios were quite similar with the results of Olorunnisomo (2007) investigating nutritional composition of sweet potato residues, but current values were higher than the findings of An *et al.* (2006). Current ADF values on the other hand were similar with the findings of both researchers. Ball *et al.* (2001) indicated that feed quality might vary based on plant cultivars and species, leaf ratio, climate and soil conditions and other cultural practices.

Crude protein content is a critical parameter in assessing the quality of feeds (Assefa and Ledin, 2001). Current protein ratios were lower than the values reported by these researchers for sweet potato haulms. Muck *et al.* (1999) reported crude protein ratios of potato haulms as between 19-26%, Nicholson *et al.* (1978) reported protein ratios of two cultivars and 6 different harvest periods as between 8-21% and indicated decreasing protein ratios with prolonged harvest periods. Low protein ratios of the present study were because of close haulm harvest dates to tuber harvest dates, low leaf ratio and different cultivars.

Lopez *et al.* (2010) classified anti-methanogenic potential of the feeds based on the amount of methane within the gas released during fermentation as low (>11% and ≤14%), medium (>6% and <11%) and high (>0% and <6%). Since methane contents of potato haulms of the present study varied between 17.54-20.12%, it can be stated that current potato haulms did not have anti-methanogenic potential.

The minerals which may affect the quality of forage crops are identified as Ca, P, Mg, Na and S and trace elements as Co, Cu, I, Mn, Se and Zn (Judson and McFarlane, 1998). Mineral content of plants may vary based on several factors like plant cultivar and species, harvest time, climate and soil conditions, biotic and abiotic stress conditions (Gralak *et al.,* 2006). Iron requirement of farm animals was indicated as 30 pmm and zinc requirement as 50 ppm (Agricultural Research Council, 1965). While iron requirement was able to be met with potato haulms, they were found to be poor in zinc. Mn requirement of ruminant animals is indicated as 40 mg/kg (Anonymous, 1996). Current values were low in some cultivars and were below maximum tolerable levels in some others (Anonymous, 1996). Copper intake may decrease with the progress of ripening and high iron contents may also hinder copper uptake (Phillippo *et al.,* 1987). Current Cu values comply with the values indicated by NRC (1985) for the ruminant animals. Ni contents of the present study were quite below the toxic levels (National Research Council, 1980).

Conclusions

Potato cultivation is quite common both in the world and in Turkey. With regard to nutrient composition, potato haulms of the present study yielded close values to the forage crops. It was concluded based on present findings that potato haulms could be used as an alternative roughage source and partially met the roughage deficits in periods with deficit feed sources for livestock. Although potato is produced for tubers, it was asserted that haulms could provide a quality roughage supply and may provide significant contributions to agricultural economy.

References

1. Agricultural Research Council, 1965. The nutrient requirements of farm livestock. No. 2. Ruminants. London. 264.
2. An, L.V., Hong, T.T.T., Lindberg, J.E., 2006. Ideal and total tract digestibility in growing pigs fed cassava root meal diets with inclusion of fresh, dry and ensiled sweet potato (Ipomoea batatas L. (Lam.)) leaves. Anim Feed Sci Technol. 114, 127–139.
3. Anonymous, 1996. Nutrient requirements of beef cattle (Seventh Ed.). National Academy Press, Washington, D.C.
4. AOAC, 1990. Official Method of Analysis. 15th. edn. Association of Official Analytical Chemist, Washington, DC. USA, 1990
5. Assefa, G., Ledin, I., 2001. Effect of variety, soil type and fertilizer on the establishment, growth, forage yield, quality and voluntary intake by cattle of oats and vetches cultivated in pure stand and mixtures. Animal Feed Sci. Technol., 92: 95-111.
6. Ball, D.M., Collins, M., Lacefield, G.D., Martin, N.P., Mertens, D.A., Olson, K.E., Putnam, D.H., Undersander, D.J., Wolf, M.W., 2001. Understanding forage quality. American Farm Bureau Federation Publication 1-01, Park Ridge.
7. Bozkurt, K.A., 2011. Determination of relative feed value of some legume hays harvested at flowering stage. Asian Journal of Animal and Veterinary Advances, 6, 525-530.
8. Canbolat, O., Karaman, ., 2009. Comparison of in Vitro Gas Production, Organic Matter Digestibility, Relative Feed Value and Metabolizable Energy Contents of Some Legume Forages. Journal of Agricultural Sciences, 15, 188-195.

9. Carruthers, I.B., Pirie, N.W., 1975. The yield of extracted protein and of residual fiber from potato haulm taken as by-product. Biotechnology and bioengineering, 17(12):1775-1782.
10. FAO, 2009. http// www.fao.org. 2009.
11. Goel, G., Makkar, H.P.S., Becker, K., 2008. Effect of Sesbania sesban and Carduus pycnocephalus leaves and Fenugreek (Trigonella foenum-graecum L.) seeds and their extract on partitioning of nutrients from roughage-and concentrate-based feeds to methane. Anim. Feed Sci. Tech. 147: 72–89.
12. Gralak, M.A., Bates, D.L., Von Keyserlingk, M.A.G., Fisher, L.J., 2006. Influence of species, cultivar and cut on the micro element content of grass forage. Slovak J. Anim. Sci. (1-2):84-88.
13. Judson, G.J. and McFarlane, J.D., 1998. Mineral disorders in grazing livestock and the usefulness of soil and plant analysis in the assessment of these disorders. Aust. J. Experi. Agric. 38: 707-723.
14. Karadoğan, T., 1991. Evaluation of potato haulms as animal feed. Ataturk Univ. Agr. Fac. J., 22 (2), 101-106.
15. Kolsarıcı, Ö., 2009. Industrial Crops. In: Agronomy Textbooks. 434-435, Ankara Uni. Agr. Fac. publications, Publication No:1569, Textbook:521, Ankara.
16. Lopez, S., Makkar, H.P.S., Soliva, C.R., 2010. Screening plants and plant products form ethane inhibitors. In: Vercoe PE, Makkar HPS, Schlink A, (Eds): In vitro screening of plant restuffs for extra nutritional attributes in ruminants: Nuclear and related methodologies. London, New York, pp. 191-231.
17. Menke, K.H., Raab, L., Salewski, A., Steingass, H., Fritz, D., Schneider, W., 1979. The estimation of the digestibility and metabolizable energy content of ruminant feeding stuffs from the gas production when they are incubated with rumen liquor in vitro. J. Agr. Sci. 93: 217–222.
18. Montario, A., 2012. Potato glycol alkaloid: solanine. http://www.safespectrum.com/articles/potato-toxicity-solanine.php,
19. Muck, R.E., Weinberg, Z.G., Rouse, D.I., Igl, B.R., 1999. Ensiling of potato vines. Transaction of the ASAE, 42(3): 565-572.
20. National Research Council (US), 1980. Committee on Dietary Allowances, National Research Council (US). Food, and Nutrition Board. Recommended dietary allowances. Vol. 2941. National Academies.
21. Nicholson, J.W.G., Young, D.A., Mcqeen, R.E., Dejong, H., Wood, F.A., 1978. The feeding value of potential of potato vines. Can J Anim Sci, 58: 559-569.
22. NRC, 1985. Nutrient requirements of Sheep. Sixth Revised Edition. National Academy Press, Washington D.C.
23. Olorunnisomo, O.A., 2007. A cost-benefit analysis of sweet potato production for sheep feeding in the southwest of Nigeria. 19 (6): Livestock Research for Rural Development http://www.lrrd.org/lrrd19/6/olor19080.htm, 2007, Accesses:11.12.2011
24. Oral, E., 1979. Growing Techniques of starch and sugar plants. Textbook. Erzurum.
25. Pafritt, D.E., Peloquin, S.J., Jorgensen, N.A., 1982. The nutrional value of pressed potato vine silage. Am Potato J, 59: 415-423.
26. Phillippo, M., Humphries, W.R., Atkinson, I., Henderson, G.D. and Garthwaite, P.H., 1987. The effect of dietary molybdenum and iron on copper status, puberty and oestrous cycle in cattle. Journal of Agriculture Science, Cambridge, 109: 321-331.
27. Rubanza, C.D.K., Shem, M.N., Otsyina, R., Bakengesa, S.S., Ichinohe, T. and Fujihara, T., 2005. Polyphenolics and tannins effect on in vitro digestibility of selected Acacia species leaves. Anim. Feed Sci. Technol. 119:129-142.
28. SAS, 1999. SAS User's Guide. Statistic. Statistical Analysis Systems Institute Inc., Cary, NC.
29. Serin Y, Tan M 2011. Introduction to forage crops culture. Ataturk Univ. Agr. Fac. Course Publications No: 206, Erzurum.
30. Van Soest, P.J., 1963. The use of detergents in the analysis of fibre feeds. II. A rapid method for the determination of fibre and lignin. Journal of the Association of Official Analytical Chemists, 46,829-835.
31. Van Soest, P.J. and Wine, R.H., 1967. The use of detergents in the analysis of fibrous feeds. IV. Determination of plant cell wall constituents. Journal of the Association of Official Analytical Chemists, 50, 50-55.
32. Watson, S.J., Nash, M.J., 1960. The conservation of grass and forage crops. Oliver and Boyd, Edinburg.
33. Yıldırım, B., Tunçtürk, M., Çiftçi, C., 2005. Effects of Various Planting Times on the Yield and Yield Traits of Different Potato Cultivars (Solanum tuberosum L.). Yuzuncu Yil Univ. Journal Agric. Sci., 15(1): 1-9.

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