









Leaves from vine cultivation used for animal feeding purposes

Tomasz Horaczek¹⁾ , Dorota Gryszkiewicz-Zelega¹⁾ , Kamila E. Klimek²⁾ ,
Magdalena Kapłań^{*3)} , Kamil Buczyński³⁾ , Ferah Yilmaz⁴⁾ ,
Selçuk Küçükaydın⁵⁾ , Anna Borkowska⁶⁾ 

¹⁾ Institute of Technology and Life Sciences – National Research Institute, Falenty, Al. Hrabaska 3, 05-090 Raszyn, Poland

²⁾ University of Life Sciences in Lublin, Department of Applied Mathematics and Computer Science, Głęboka St, 28, 20-612 Lublin, Poland

³⁾ University of Life Sciences in Lublin, Institute of Horticulture Production, Głęboka St, 28, 20-612 Lublin, Poland

⁴⁾ Muğla Sıtkı Koçman University, Fethiye Faculty of Agriculture, Department of Plant Protection, Kötekli Mevkii, Köstekli, TR-48300 Fethiye Muğla, Turkey

⁵⁾ Muğla Sıtkı Koçman University, Department of Medical Services and Techniques, Köyceğiz Vocational School of Health Services, Koycegiz, TR-48000 Muğla, Turkey

⁶⁾ Department of Applied Mathematics and Computer Science, University of Life Sciences in Lublin, Głęboka St, 28, 20-612 Lublin, Poland

* Corresponding author

RECEIVED 28.07.2025

ACCEPTED 12.01.2026

AVAILABLE ONLINE 30.04.2026

Abstract: The increasing amount of waste generated by the agricultural industry, especially in the wine sector, poses environmental and economic challenges. This issue is particularly pressing as the global population is projected to reach 8.5 bln by 2030, which will further exacerbate solid waste management problems. Therefore, a study was conducted to investigate the possibility of using grapevine leaves as an alternative animal feed ingredient. The aim of the present study was to analyse the chemical composition of the leaves of four grape varieties, 'Regent', 'Rondo', 'Seyval Blanc' and 'Solaris', in the context of their potential use as animal feed. The results indicated that grapevine leaves are a valuable source of protein, fibre and micro- and macronutrients, with the content of these components differing significantly between varieties. The leaf yield per hectare ranged from 6.08 to 8.78 Mg, with 'Solaris' yielding significantly the highest biomass among the studied cultivars. The analysis also revealed significant differences in the content of amino acids such as cystine, glycine, valine, tryptophan and threonine, as well as in the content of minerals, starch and neutral detergent fibre. The results obtained highlight the variation in nutritional value of grapevine leaves between varieties, suggesting the possibility of selective use depending on the nutritional needs of the animals. Utilizing such by-products supports a circular economy model and reduces the negative environmental impact of wine production.

Keywords: agricultural waste, feed, leaves, nutrition, vitis

INTRODUCTION

The increase in global solid waste production is the result of rapid population growth, intensive urbanisation, increasing demand for agricultural products and the development of the industrial sector. By 2030, the Earth's population is projected to increase to

8.5 bln and the amount of solid waste generated will reach 2.59 bln Mg. This will further exacerbate environmental and climate problems (Peng *et al.*, 2023). The concept of environmental protection is being taken into account in almost all areas of development, including agricultural waste management planning based on the principles of a closed-loop economy, guided

primarily by the words 'waste as a resource'. This waste can be used to produce, among other things, food, promoting innovation and at the same time protecting the environment (Josimović *et al.*, 2021), while improving the current situation and creating new products for animal feed (Ajila *et al.*, 2012). The inadequate management of waste from the agri-food industry is causing global economic concern (Costa *et al.*, 2023). This drastic increase in waste from agricultural activities and the food industry is forcing the development of integrated waste management technology and improved sustainability footprints (Rasool *et al.*, 2023).

With a harvest of more than 78 mln Mg in 2020, grapes rank among the most widely grown types of fruit in the world (FAO, 2022). A large amount of waste from wine production is dumped on open land, causing environmental and economic problems, posing a challenge for the sector (Kalli *et al.*, 2018). With increasing calls from various institutions to introduce greener cultivation methods, it becomes crucial to add value to production waste from the agricultural sector (Maia *et al.*, 2021). The wine industry generates significant amounts of waste and by-products, which raises environmental challenges. These residues are a source of bioactive secondary compounds, including phenols, which exhibit bacteriostatic and bactericidal properties (Silva *et al.*, 2021). Vines are used, for example, as an ingredient in potato silage for cattle feed (Deng *et al.*, 2023). Vine stems and leaves are partially removed before flowering and during growth to facilitate grape harvesting and improve fruit quality parameters. In addition, vines naturally shed their leaves as they go into winter dormancy, generating additional organic waste in the form of fallen leaves.

Vine leaves, which are by-products of cultivation processes, have antioxidant activity that is ten times greater than that observed in the juice or grape pulp. The use of extracts from these leaves in the treatment of diseases, as well as their consumption in fresh or processed form, offers an important health benefit, without introducing into the body the alcohol inherent in wine or the additional sugars typical of grape juice. This peculiarity of the use of grape leaves highlights their additional value compared to other by-products of the plant (Lacerda *et al.*, 2016). They are a valuable and cheap source of bioactive compounds, especially phenolic compounds (Moldovan *et al.*, 2020).

The growing global demand for alternative sources of protein and energy is fostering research into innovations in animal nutrition. Additionally, a key prerequisite for the use of alternative ingredients in this sector is their safety. Available data show that products meeting the criteria of the main feed and food authorities are characterised by high quality and safety standards (Pinotti *et al.*, 2019). Today, grapevine leaves are common in the diet of several Mediterranean countries and numerous studies indicate the high value of this raw material in the cosmetic, pharmaceutical, food and, most importantly, as a functional food ingredient (Maia *et al.*, 2021). Although vine leaves are considered a delicacy in many regions, in others they are considered waste (Lima *et al.*, 2016). The increase in demand for animal products in the future will result in significant animal feed needs. Meeting these needs will be challenging due to limited natural resources such as land and water. The use of leftovers and wastes as a source of feed can help meet the feed shortages that exist in many developing countries. Additionally, their use in animal nutrition will enable the reintegration of these ingredients

into the human food chain (Wadhwa, Bakshi and Makkar, 2015). Population growth and rising standards of living in both developed and developing countries across the planet are predicted to generate a global demand for meat of 1,250 mln Mg per year by 2050 (Ritala *et al.*, 2017). With numerous studies confirming the high value of grape leaves in human nutrition, it is encouraging to explore the potential of this raw material in animal nutrition. Grape by-products can be used in the feeding of monogastric animals as a way to reduce the costs associated with traditional feedstuffs such as maize or soybean meal (Alfaia *et al.*, 2022). Especially bearing in mind that many vineyards are additionally engaged in oenotourism, which is very popular worldwide, but mainly aimed at adults. It would be worth considering extending their offer to include typical agro-tourism attractions associated with animal husbandry, which could be potentially partly fed on organic waste from the vineyard and also provide attractions for children visiting these farms with their carers. The removal of leaves from the plantations is also very beneficial from a phytosanitary point of view reducing the pressure of pathogens and pests, as well as providing a potential opportunity for the eventual sale of this raw material to livestock farmers, increasing the vineyard's income. All this fits perfectly with the assumptions of integrated plant production, closed-loop farming and the reduction of the negative effects of wine sector production on the environment.

The main objective of this work was to identify differences in the chemical composition of the leaves of four grapevine varieties and to analyse the potential use of this raw material in animal feed.

MATERIALS AND METHODS

The experiment was conducted in 2023 at the Nobilis Winery (50°39'N; 21°34'E) located in the south-eastern part of Poland, in the Sandomierska Upland. Own-rooted vines of the studied varieties were planted in spring 2010 on loess soil at a spacing of 1.0–2.0 m (5000 units per ha). Thirteen-year-old vines of four varieties were included in the study: 'Regent', 'Rondo', 'Seyval Blanc' and 'Solaris'. Plants were managed as a single Guyot twine, with a perennial trunk 40 cm high and one arm about 0.9 m long, which was replaced annually. The following parameters were analysed: the weight of leaves per bush was determined, and this parameter was then presented per area of 1 ha. In autumn, after the fruit was harvested, the leaves were collected separately for 50 plants of each variety, and their weight with petioles was determined by weighing them on an AXIS A250 electronic balance with an accuracy of 0.001 kg.

After weighing, the leaves were dried in a laboratory dryer at 105°C to a moisture content of no more than 10%. This was followed by grinding of the dried material. After grinding, the leaf material was analysed by NIRS (Near Infrared Spectroscopy) using the NIR Flex N-500 ready calibration for roughage evaluation from INGOT. The NIRS method is based on the evaluation of the absorption intensity of a laser light beam by specific chemical compounds. Each is characterised by the absorption of said radiation in a specific spectral range (Gaşior, 2013). On the basis of the degree of absorption of the beam in a specific range, the percentage content in the tested sample is determined.

RESULTS AND DISCUSSION

The weight of vine leaves on an area of 1 ha, oscillated between approximately 6.08 Mg and 8.78 Mg. The lowest leaf yield was obtained from the ‘Seyval Blanc’ cultivar, while significantly the highest from the ‘Solaris’ cultivar. Statistical analysis showed that leaf weight per hectare in the grapevine cultivars ‘Seyval Blanc’, ‘Regent’ and ‘Rondo’ did not differ significantly between them. In a study by Kaplan, Maj and Klimek (2023), grapevine leaf mass on an area of 1 ha for the ‘Regent’ cultivar, depending on the rootstock used, oscillated between 7.1 and 9.0 Mg·ha⁻¹ (Fig. 1).

Moisture levels in all varieties were very similar, ranging from 10.26% in ‘Rondo’ to 11.24% in ‘Regent’, indicating that

there were no significant differences in water content between varieties (Tab. 1).

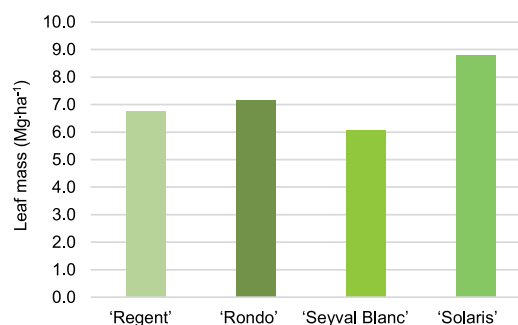


Fig. 1. Leaf mass of the tested grapevine cultivars on an area of 1 ha (Mg); source: own study

Table 1. Chemical composition and nutrient content in leaves of selected grape varieties

Sample	'Regent'	'Rondo'	'Seyval Blanc'	'Solaris'	<i>p</i> -value
Moisture (%)	11.24 ±0.77 ^A	10.26 ±0.88 ^A	10.34 ±0.65 ^A	11.16 ±2.42 ^A	0.0882
Fat (%)	5.79 ±0.98 ^A	5.23 ±1.19 ^A	4.83 ±1.26 ^A	5.52 ±1.00 ^A	0.2785
Protein (%)	18.03 ±0.86 ^A	17.68 ±0.57 ^A	16.19 ±0.76 ^{AB}	12.51 ±0.66 ^B	0.0186
Ash (%)	20.48 ±0.71 ^B	16.54 ±0.72 ^C	22.81 ±0.28 ^A	18.39 ±1.01 ^B	<0.0001
Fibre (%)	13.54 ±2.22 ^A	11.08 ±1.87 ^B	13.32 ±1.38 ^A	13.55 ±2.14 ^A	0.0027
Acid insoluble ash (%)	5.46 ±1.15 ^A	4.28 ±1.22 ^A	5.58 ±1.32 ^A	9.68 ±0.86 ^A	0.6092
Alanine (%)	0.40 ±0.08 ^A	0.80 ±0.41 ^A	0.78 ±0.08 ^A	0.41 ±0.17 ^A	0.2007
Arginine (%)	2.34 ±29.83 ^A	1.74 ±27.5 ^A	2.23 ±28.92 ^A	3.02 ±31.84 ^A	0.2226
Aspartic acid (%)	3.58 ±2.67 ^A	2.93 ±1.4 ^A	3.21 ±1.46 ^A	4.57 ±2.95 ^A	0.2971
Cystine (%)	0.53 ±0.45 ^A	0.46 ±0.9 ^B	0.44 ±0.99 ^B	0.26 ±0.90 ^C	<0.0001
Glutamic acid (%)	0.77 ±0.14 ^A	0.88 ±0.41 ^A	0.65 ±0.05 ^A	0.82 ±0.47 ^A	0.3014
Glycine (%)	0.98 ±1.69 ^B	1.19 ±1.45 ^{AB}	1.26 ±1.41 ^A	1.00 ±1.89 ^B	0.0030
Hystidine (%)	0.86 ±14.51 ^A	0.57 ±17.84 ^A	0.76 ±16.11 ^A	0.66 ±13.39 ^A	0.5511
Isoleucine (%)	0.71 ±0.36 ^A	0.72 ±1.00 ^A	0.28 ±0.26 ^A	1.01 ±0.55 ^A	0.1123
Leucine (%)	2.22 ±0.29 ^A	1.87 ±0.11 ^A	1.38 ±0.15 ^A	2.14 ±0.17 ^A	0.2211
Lysine (%)	1.15 ±1.49 ^A	1.22 ±1.18 ^A	1.32 ±0.90 ^A	0.86 ±1.24 ^A	0.1106
Methionine (%)	0.08 ±1.45 ^B	0.41 ±1.19 ^A	0.08 ±1.02 ^B	0.17 ±1.11 ^{AB}	0.0031
NDF (%)	29.83 ±0.32 ^B	27.50 ±0.19 ^C	28.92 ±0.22 ^B	31.84 ±1.57 ^A	<0.0001
Phenylalanine (%)	2.67 ±0.33 ^A	1.40 ±0.22 ^A	1.46 ±0.39 ^A	2.95 ±1.61 ^A	0.0721
Phosphorus (%)	0.45 ±0.6 ^A	0.90 ±0.58 ^A	0.99 ±0.64 ^A	0.90 ±5.94 ^A	0.1701
Proline (%)	0.14 ±1.51 ^B	0.41 ±1.01 ^A	0.05 ±1.09 ^B	0.47 ±1.31 ^A	<0.0001
Serine (%)	1.69 ±0.44 ^A	1.45 ±0.24 ^A	1.41 ±0.17 ^A	1.89 ±2.22 ^A	0.3941
Starch (%)	14.51 ±0.58 ^{BC}	17.84 ±0.48 ^A	16.11 ±0.60 ^{AB}	13.39 ±14.64 ^C	<0.0001
Threonine (%)	0.36 ±0.06 ^{BC}	1.00 ±0.10 ^A	0.26 ±0.03 ^C	0.55 ±0.83 ^B	<0.0001
Tryptophan (%)	0.29 ±0.04 ^A	0.11 ±0.03 ^B	0.15 ±0.03 ^{AB}	0.17 ±2.05 ^{AB}	0.0163
Tyrosine (%)	1.49 ±0.06 ^A	1.18 ±0.09 ^A	0.9 ±0.05 ^A	1.24 ±3.07 ^A	0.1166
Valine (%)	1.45 ±0.02 ^A	1.19 ±0.02 ^{AB}	1.02 ±0.02 ^B	1.11 ±0.07 ^B	0.0022

Explanations: A–C = differences between averages shown with different letters in the same column are significant ($p < 0.05$). Source: own study.

Similarly, fat content showed no significant variation between varieties, with values ranging from 4.83% in 'Seyval Blanc' to 5.79% in 'Regent' (Tab. 1). Tayer, Nobakht and Pishjang (2012) showed a vine leaf fat content of 7.47%, while Abbas and Khayoon (2021) showed 6.79%.

A significant difference was found in the protein content for leaves, the leaves of 'Solaris' (12.51%) had a significantly lower content of this component than 'Regent' (18.03%), in which the level of this parameter was not significantly different from the other varieties tested. Kocadayıoğulları, Boğa and Ermetin (2024), showed a protein content for grapevine leaves of 12.83%, and for leaves of other species mulberry, apple, apricot and cherry, respectively 13.09, 11.25, 10.99 and 10.33%. In the case of a study by Abbas and Khayoon (2021), the protein content for grapevine leaves was 20.30% and for seeds 12.30%.

Significant differences in ash content were detected, with 'Seyval Blanc' showing significantly the highest content (22.81%) and 'Rondo' significantly the lowest (16.54%). In a study by Kazemi and Bezdi (2021), the ash content for grapevine leaves was 88.6 g·kg⁻¹ dry matter (DM), while in a study by Kocadayıoğulları, Boğa and Ermetin (2024) it was 9.47%. In the case of the study by Abbas and Khayoon (2021), the ash content of grapevine leaves was 15.76% and for seeds 3.15%. On the other hand, Tayer, Nobakht and Pishjang (2012) showed an even lower level of ash in grapevine leaves at 9.53%.

Cystine, from the endogenous amino acid group, showed significant variability, with the lowest concentration in leaves of the 'Solaris' cultivar (0.26%) and significantly highest in 'Regent' (0.53%). Leaves of the 'Regent' variety also had the highest valine content (1.45%), also included in the endogenous amino acid group. The lowest levels of this amino acid were found in leaves of the 'Seyval Blanc' (1.02%) and 'Solaris' (1.11%) cultivars. In the case of glycine, which is a protein amino acid, its content was significantly highest in the Seyval 'Blanc cultivar' (1.26%) and lowest in the 'Regent' (0.98%) and 'Solaris' (1.00%) cultivars. However, for another protein amino acid (threonine), the leaves of the 'Seyval Blanc' variety were characterised by the lowest value of this amino acid at 0.26%. In contrast, the 'Solaris' variety showed the highest value for this parameter (1.00%). Also for tryptophan, belonging to the same group of amino acids, a significant effect of cultivar on its content in leaves was shown, oscillating between values of 0.11% ('Rondo') and 0.29% ('Regent'). A significant effect of cultivar was shown for proline (α-amino acid) content, with the lowest values for 'Seyval Blanc' (0.05%) and 'Regent' (0.14%) and the highest values for 'Rondo' (0.41%) and 'Solaris' (0.47%). The leaves of the varieties also differed significantly in the content of the protein amino acid methionine, with the highest content found in the 'Rondo' variety (0.41%) and the lowest for the 'Regent' and 'Seyval Blanc' varieties at 0.08%. The glycine content also, depended on the variety and ranged from 0.98% ('Regent') to 1.26% ('Seyval Blanc'). Analysis of the other amino acids showed no statistically significant differences between varieties. The maximum values for these amino acids were, alanine (0.80%), arginine (3.02%), histidine (0.86%), isoleucine (1.01%), leucine (2.22%), lysine (1.32%), phenylalanine (2.95%), serine (1.89%), tyrosine (1.49%), aspartic acid (4.57%) and glutamic acid (0.82%). For soybean meal, which is considered one of the most valuable sources of amino acids in animal nutrition, Chen *et al.* (2010), showed contents for individual amino acids at, aspartic acid (5.43%), threonine

(1.83%), serine (2.09%), glutamine (8.26%), proline (2.38%), glycine (1.71%), alanine (2.01%), valine (2.17%), methionine (0.66%), isoleucine (2.09%), leucine (3.58%), tyrosine (1.75%), phenylalanine (2.38%), histidine (1.26%), lysine (2.87%), arginine (3.41%). Significant differences in fibre content were found between the varieties, with 'Solaris', 'Regent' and 'Seyval Blanc' not significantly different (13.55%), while 'Rondo' showed the lowest fibre value (11.08%). Tayer, Nobakht and Pishjang (2012) found a fibre content of 2.51% in grape leaves in their study, while Abbas and Khayoon (2021) found a fibre content of 20.15%. Among the dietary strategies that can directly influence animal resistance, diets with reduced protein content, supplementation with amino acids, including functional amino acids, and adjustment of dietary fibre levels and sources are of particular importance (Rodrigues *et al.*, 2022).

The leaves of the 'Rondo' variety contained significantly the most starch (17.84%), while the least was shown in the 'Solaris' variety (13.39%), highlighting how variable the nutritional profiles of different grape varieties can be. For maize, which is one of the most common sources of starch, its value according to a study by Shi *et al.* (2024) is 72.63% on a dry matter basis. For the neutral detergent fibre (NDF) parameter, values oscillated between 27.50% ('Rondo') and 31.84% ('Solaris'), indicating significant differences between varieties. In the case of alfalfa hay, characterised by a high NDF value, Jiao *et al.* (2022) showed it at 56.45%. Statistical analysis showed no effect of cultivar on phosphorus content, whose value ranged from 0.45 to 0.99% (Tab. 1).

The analysis showed significant differences between the leaves of the grape varieties in the content of all macro- and micronutrients. The nitrogen content of the 'Regent' (2.42%) and 'Rondo' (2.01%) cultivars was significantly higher than that of the 'Solaris' cultivar (1.60%). For potassium and iron, the 'Seyval Blanc' variety had the lowest amount of these elements in the leaves (0.83% and 149.10 ppm, respectively) and the 'Solaris' variety the highest (1.46% and 211.00 ppm). Phosphorus content was lowest in the leaves of the 'Regent' cultivar (0.21%) and highest for the 'Solaris' cultivar (0.21%), while in the case of copper, significantly the lowest level of this element in the leaves was found in the 'Seyval Blanc' cultivar (204.79 ppm) and the highest in the 'Solaris' cultivar (562.10 ppm).

The varieties 'Regent', 'Rondo' and 'Seyval Blanc' had the same sodium content (0.01%), while the variety 'Solaris' had the highest content of this micronutrient (0.02%). The value of magnesium for 'Rondo', 'Seyval Blanc' and 'Regent' varieties was 0.72, 0.67 and 0.64% respectively, while the significantly lowest value, compared to these three varieties, was shown for the 'Solaris' variety (0.50%). The significantly highest leaf manganese content was shown in the 'Solaris' and 'Regent' cultivars (561.22 ppm, 524.36 ppm), while the significantly lowest in the 'Seyval Blanc' cultivar (352.68 ppm). The difference in zinc content was significantly lower in the 'Regent' (67.62 ppm) and 'Seyval Blanc' (64.74 ppm) varieties, while it was significantly highest in the 'Rondo' (82.39 ppm) and 'Solaris' (79.00 ppm) varieties. These findings highlight the complex interactions between grapevine genetics and their nutritional profiles, offering insights into their suitability for use in animal nutrition (Tab. 2.) Kazemi and Bezdi (2021), showed the content of individual minerals for grapevine leaves to be 26.5 Ca, 3.27 K, 3.66 Mg, Na 0.79 (g·kg⁻¹ DM), Fe 107, Mn 104, Zn 21.9 (mg·kg⁻¹ DM).

Table 2. Analysis of the concentration of mineral components in the leaves of selected grape varieties

Sample	'Regent'	'Rondo'	'Seyval Blanc'	'Solaris'	p-value
N (%)	2.42 ±0.07 ^A	2.01 ±0.17 ^B	2.18 ±0.06 ^{AB}	1.60 ±0.10 ^C	0.0001
P (%)	0.21 ±0.01 ^C	0.24 ±0.01 ^B	0.23 ±0 ^{BC}	0.28 ±0.01 ^A	0.0001
K (%)	1.19 ±0.13 ^B	1.28 ±0.09 ^{AB}	0.83 ±0.04 ^C	1.46 ±0.03 ^A	0.0001
Na (%)	0.01 ±0.00 ^B	0.01 ±0.00 ^B	0.01 ±0.00 ^B	0.02 ± 0.00 ^A	0.0001
Ca (%)	1.68 ±0.23 ^{AB}	1.46 ±0.17 ^B	1.91 ±0.09 ^A	1.68 ± 0.13 ^{AB}	0.0574
Mg (%)	0.64 ±0.05 ^A	0.72 ±0.04 ^A	0.67 ±0.03 ^A	0.50 ± 0.06 ^B	0.0001
Fe (ppm)	189.40 ±8.30 ^A	165.8 ±9.3 ^B	149.1 ±4.3 ^B	211.00 ± 10.70 ^A	0.0001
Mn (ppm)	524.36 ±14.75 ^{AB}	464.67 ±8.79 ^B	352.68 ±32.25 ^C	561.22 ± 36.66 ^A	0.0001
Zn (ppm)	67.62 ±2.40 ^B	82.39 ±2.59 ^A	64.74 ±1.59 ^B	79.00 ± 2.94 ^A	0.0001
Cu (ppm)	389.02 ± 33.83 ^B	285.73 ±22.89 ^{BC}	204.79 ±13.62 ^C	562.1 ± 77.32 ^A	0.0001

Explanations: A–C = differences between averages shown with different letters in the same column are significant ($p < 0.05$).

Source: own study.

CONCLUSIONS

1. Shrubs of the 'Solaris' cultivar had the highest leaf yield per unit area among the grapevine cultivars evaluated. This relationship is particularly favourable from the point of view of the efficiency of obtaining raw material for fodder production.
2. The differences in protein, fibre, ash, amino acids, minerals and the value of the neutral detergent fibre parameter between the cultivars, suggest the possibility of adapting rations based on grapevine leaves to the specific nutritional needs of different animal species.
3. The use of vine leaves as feed can contribute to sustainable resource management and supports a circular economy model, while reducing the negative environmental impact of agricultural waste.
4. Further research into the bioavailability of nutrients and their impact on animal health and production efficiency is necessary to fully exploit the potential of vine leaves in animal nutrition, which can increase the competitiveness of the agri-food sector and contribute to reducing the cost of feed production.

CONFLICT OF INTERESTS

All authors declare that they have no conflict of interests.

REFERENCES

- Abbas, R. and Khayoon, T.H. (2021) "Effect of adding different levels of grapes (*Vitis vinifera* L.) seeds and leaf powder or their extracts on some bone characteristics and total ash content in broiler chickens," *Asian Journal of Dairy and Food Research*, 40(3), pp. 341–344. Available at: <https://doi.org/10.18805/ajdrf.DR-220>.
- Ajila, C.M. *et al.* (2012) "Bio-processing of agro-byproducts to animal feed," *Critical Reviews in Biotechnology*, 32(4), pp. 382–400. Available at: <https://doi.org/10.3109/07388551.2012.659172>.
- Alfaia, C.M. *et al.* (2022) "Use of grape by-products to enhance meat quality and nutritional value in monogastrics," *Foods*, 11(18), 2754. Available at: <https://doi.org/10.3390/foods11182754>.
- Chen, C.C. *et al.* (2010) "Evaluating nutritional quality of single stage- and two stage-fermented soybean meal," *Asian-Australasian Journal of Animal Sciences*, 23(5), pp. 598–606. Available at: <https://doi.org/10.5713/ajas.2010.90341>.
- Costa, J.M. *et al.* (2023) "Recent advances in the processing of agri-food by-products by subcritical water," *Food Bioprocess Technology*, 16, pp. 2705–2724. Available at: <https://doi.org/10.1007/s11947-023-03071-8>.
- Deng, J. *et al.* (2023) "Effect of potato vine and leaf mixed silage compared to whole corn crops on growth performance, apparent digestibility, and serum biochemical characteristics of fattening angus bull," *Animals*, 13(14), 2284. Available at: <https://doi.org/10.3390/ani13142284>.
- FAO (2022) *FAOSTAT. Crops and livestock products*. Food and Agriculture Organization of the United Nations. Available at: <https://www.fao.org/faostat/en/#data/QCL> (Accessed: October 25, 2024).
- Gašior, R. (2013) "The magnitude of errors in feed analysis by NIRS and chemical methods," *Industrial Feeds*, 1, pp. 44.
- Jiao, Y. *et al.* (2022) "The effect of supplemental concentrate feeding on the morphological and functional development of the pancreas in early weaned yak calves," *Animals*, 12(19), 2563. Available at: <https://doi.org/10.3390/ani12192563>.
- Josimović, B. *et al.* (2021) "Multi-criteria evaluation in strategic environmental assessment in the creation of a sustainable agricultural waste management plan for wineries: Case study: Oplenac Vineyard," *Journal of Agricultural and Environmental Ethics*, 34, 4. Available at: <https://doi.org/10.1007/s10806-021-09846-3>.
- Kalli, E. *et al.* (2018) "Novel application and industrial exploitation of winery by-products," *Bioresource Technology and Bioprocesses*, 5, 46. Available at: <https://doi.org/10.1186/s40643-018-0232-6>.
- Kaplan, M., Maj, G. and Klimek, K.E. (2023) "The analysis of energy potential in vine leaves of the 'Regent' cultivar as bio-weed depending on the year of cultivation and the type of rootstock used," *Journal of Water and Land Development*, 58, pp. 171–177. Available at: <https://doi.org/10.24425/jwld.2023.146609>.
- Kazemi, M. and Bezdi, K.G. (2021) "The nutritional value of some fruit tree leaves for finishing lambs," *Animal Biotechnology*, 33(6), pp. 1296–1307. Available at: <https://doi.org/10.1080/10495398.2021.1891929>.

- Kocadayıoğulları, F., Boğa, M. and Ermetin, O. (2024) "Nutrient composition and metabolic energy of different fruit tree leaves as feeding sources for ruminants," *JOTAF*, 21(3), pp. 816–829. Available at: <https://doi.org/10.33462/jotaf.1405298>.
- Lacerda, D. *et al.* (2016) "Benefits of vine leaf on different biological systems," in A. Morata and I. Loira (eds.) *Grape and Wine Biotechnology*. IntechOpen. Available at: <http://dx.doi.org/10.5772/64930>.
- Lima, A. *et al.* (2016) "Selection of grape vine leaf varieties for culinary process based on phytochemical composition and antioxidant properties," *Food Chemistry*, 212, pp. 291–295. Available at: <https://doi.org/10.1016/j.foodchem.2016.05.177>.
- Maia, M. *et al.* (2021) "More than just wine: The nutritional benefits of grapevine leaves," *Foods*, 10(10), 2251. Available at: <https://doi.org/10.3390/foods10102251>.
- Moldovan, M. *et al.* (2020) "Phytochemical profile and biological activities of tendrils and leaves extracts from a variety of *Vitis vinifera* L.," *Antioxidants*, 9(5), 373. Available at: <https://doi.org/10.3390/antiox9050373>.
- Peng, X. *et al.* (2023) "Recycling municipal, agricultural and industrial waste into energy, fertilizers, food and construction materials, and economic feasibility: A review," *Environmental Chemistry Letters*, 21, pp. 765–801. Available at: <https://doi.org/10.1007/s10311-022-01551-5>.
- Pinotti, L. *et al.* (2019) "Review: Insects and former foodstuffs for upgrading food waste biomasses/streams to feed ingredients for farm animals," *Animal*, 13(7), pp. 1365–1375. Available at: <https://doi.org/10.1017/S1751731118003622>.
- Rasool, K. *et al.* (2023) "Comprehensive insights into sustainable conversion of agricultural and food waste into microbial protein for animal feed production," *Reviews in Environmental Science and Biotechnology*, 22, pp. 527–562. Available at: <https://doi.org/10.1007/s11157-023-09651-6>.
- Ritala, A. *et al.* (2017) "Single cell protein-state-of-the-art industrial landscape and patents 2001–2016," *Frontiers in Microbiology*, 8. Available at: <https://doi.org/10.3389/fmicb.2017.02009>.
- Rodrigues, L.A. *et al.* (2022) "Formulating diets for improved health status of pigs: Current knowledge and perspectives," *Animals*, 12(20), 2877. Available at: <https://doi.org/10.3390/ani12202877>.
- Shi, C. *et al.* (2024) "From food waste to sustainable agriculture: Nutritive value of potato by-product in total mixed ration for Angus bulls," *Foods*, 13(17), 2771. Available at: <https://doi.org/10.3390/foods13172771>.
- Silva, A. *et al.* (2021) "Valorization of winemaking by-products as a novel source of antibacterial properties: New strategies to fight antibiotic resistance," *Molecules*, 26(8), 2331. Available at: <https://doi.org/10.3390/molecules26082331>.
- Tayer, M., Nobakht, A. and Pishjang, J. (2012) "Effects of different levels of green grape (*Vitis vinifera*) leaves on performance, carcass traits, blood biochemical and immunity parameters of broilers," *International Research Journal of Applied and Basic Sciences*, 3(1), pp. 103–111. Available at: https://www.researchgate.net/publication/351513874_Effects_of_different_levels_of_green_grape_Vitis_vinifera_leaves_on_performance_carcass_traits_blood_biochemical_and_immunity_parameters_of_broilers (Accessed: October 26, 2024).
- Wadhwa, M., Bakshi, M. and Makkar, H. (2015) "Waste to worth: Fruit wastes and by-products as animal feed," *CAB Reviews*, 15, pp. 1–26. Available at: <https://doi.org/10.1079/PAVSNNR201510031>.