Research Article

Nutritional Characteristics of Almond (*Prunus dulcis*) Leaves for Livestock in the Baltistan Region

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Absract | Almond (Prunus dulcis Miller D. A. Webb) is a member of the Rosaceae family and is commonly known as sweet almonds. It is one of the oldest cultivated nut trees in the world. It is also a widely cultivated fruit species in the Baltistan region of Pakistan. Almond leaves are used as a source of fodder. However, the nutritional composition of almond leaves is still not known in the Baltistan region. Therefore, the focus of the presented study was to determine the amount of nutrients present in almond leaves to boost farmer`s awareness about the value of important nutrients for livestock and to help them choose the right forages and feed. The findings demonstrated that the average concentration of nitrogen in almond trees was 1.35%, carbohydrate was 54.16% and protein was 6.75%, respectively. According to our findings, the nitrogen and protein range in Prunus dulcis leaves were extremely close to the adequate range for plant nitrogen and protein levels was typical in such almond leaves. Almond leaves have higher nutritional values and, therefore, can be used as fodder or forages in ruminant diets of animal feed necessities. The prediction results can provide an important reference that the utilization of almond tree leaves has superior nutritional value for ruminant nutrition.

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Introduction

The almond tree (*Prunus dulcis*) is a significant fruit-bearing species known for its historical, agricultural, and nutritional importance. Native to regions stretching from Southwest Asia to Central Asia, it is believed to have been one of the first fruit trees domesticated by humans, with evidence of cultivation dating back approximately 10,000years. This long history has allowed the almond to adapt and thrive in various arid and semi-arid climates around the world (Ladizinsky, 1999; Zohray and Hopf, 1993). Almonds trees are not only valued for their delicious edible nuts but also for their nutritional benefits, making them a key component of human diets. Rich in healthy fats, protein,vitamins and minerals, almonds contribute to heart health and overall well-being (Richardson *et al*., 2009). The yield and chemical composition of almonds trees are closely related to climate factors, including precipitation, temperature extremes, soil water reserves, and bioclimatic conditions such as water deficits (Ighbareyeh *et al*., 2018). Certain tree species, including almonds, can provide valuable nutritional support both during normal conditions and times of scarcity (Reddy, 2006).

The almond tree also has potential as a valuable source of animal fodder. The increasing demand for sustainable and nutritious feed resources in livestock production has prompted researchers to explore alternative forages that can enhance animal health and productivity (Alimi *et al*., 2024). In this context, almond leaves (*Prunus dulcis)* have gained attention as a potential feed resource, particularly in regions where traditional forage options are limited. The Baltistan region, characterized by its unique climatic conditions and diverse agricultural practices (Khan *et al*., 2020), presents an opportunity to evaluate the nutritional value of almond leaves in livestock diets. In many developing countries, including the Baltistan region, animal protein deficiency is a significant concern, largely due to inadequate forage availability. Harsh environmental conditions often limit the grazing options for livestock, making alternative feed sources like tree leaves increasingly important. Almond leaves have the potential to provide essential nutrients that could help improve livestock nutrition (Ulyatt, 1980; Paterson *et al*., 1998; Azim *et al*., 2011).

Almond trees are primarily cultivated for their nuts; however, their leaves, often discarded as agricultural waste, possess a range of nutritional benefits that warrant investigation. Previous studies have highlighted the nutritional composition of almond leaves, revealing a moderate protein content alongside essential vitamins and minerals that are beneficial for livestock health (Nahand *et al*., 2012). Feeding trials conducted with various livestock species; findings suggest that livestock, particularly small ruminants like goats and sheep, may readily consume almond leaves, leading to improved growth rates and feed conversion efficiency (Nahand *et al*., 2010). Additionally, the antioxidant and antimicrobial properties attributed to almond leaves could offer health benefits, potentially reducing the incidence of diseases and promoting overall well-being in animals (Nahand *et al*., 2010). Chou (2008) invented a formulation for animal feed from almond leaves and described that almond leaves fodder can reduce animal feed costs, simultaneously reducing the cost associated with almond forming by eliminating the need to use costly pesticides by removing the principal food source for most insects in almonds orchids. It creates a new economy around what was previously considered as waste products, namely almond leaves. Despite these promising attributes, the integration of almond leaves into livestock diets requires careful consideration of their anti-nutritional factors, which may limit their use if consumed in excessive quantities. As such, a comprehensive evaluation of the nutritional characteristics of almond leaves is essential to understand their viability as a forage option in the Baltistan region.

The aim of this study is to investigate the nutritional composition of almond leaves as a potential fodder source for livestock, specifically focusing on the essential nutrients they provide. Given that nutrient composition can vary due to climatic conditions and environmental factors, this research seeks to fill the existing knowledge gap regarding the nutrient profile of almond leaves in the region. By assessing their suitability as livestock feed, the study aims to contribute valuable insights for enhancing sustainable livestock production in the area.

Materials and Methods

Plant material and sampling

Random sampling method was used to collect the plant material. Minimum four almond trees of replicate as suggested by ITRC (2012) were selected to collect fresh leave samples from different regions of Skardu, Pakistan. The leave sampling was done in the first week of July 2021.

Determination of nitrogen and protein contents in almond leaves through Kjeldal Method

The experiment was performed at PCSIR laboratory, Skardu. The collected leaves were cleaned through gentle scrubbing in detergent solution and washed two times with distilled water. The washed leaves were allowed to dry overnight air at room temperature and then grind in a grinder to make fine powder.

Digestion process

2g grinded fine powder of leaves was weighed in a 50 mL digestion tube. One digestion tablet as a catalyst and 20 mL concentrated H_2So_4 were added in the same digestion tube and then sample was mixed. The sample mixture was digested by keeping the digestion tube in heating block at 450 °C for 75 minutes. The green color indicated the complete or 98% digestion of the sample. When digestion was completed, the digested samples were allowed to cool at room temperature. At cooling green color changed to blue. After cooling the sample was diluted with deionized water.

Distillation process

50 mL, 20% NaOH solution was added to the tube containing digested sample to neutralize the pH and to convert ammonium (NH_4^{+}) into ammonia (NH_3). The generated ammonia was condensed and transported into a receiving vessel. To remove or capture the dissolved ammonia gas, the distillate receiving vessel was filled with an absorbing solution that contained 4% boric acid [$B(OH_3)$] solution. When ammonia (NH_3) reacts with boric acid, the color of the solution turns green from red violet because of the indicator's transition from an acidic to a basic medium, the ammonia is collected by the boric acid solution and forms solvated ammonia ions. The capturing of ammonia into boric acid solution took 5 minutes and at this point the distillation process was completed.

Titration

To trap the ammonia creating solvated ammonium ions, the distillate was titrated with 0.25 mol/L of HCl until the color of the solution turned into pale shade of pink from green. The change of color showed that titration was completed. The moles of HCl are equal to moles of Nitrogen. The moles of 0.25 mol/L of HCl were noted to calculate the percentage of Nitrogen atoms and then the % of protein content present in the leave samples.

The percentage of nitrogen content was calculated as per formula suggested by Kjeldahl (1883).

$$\% \text{ Nitrogen} = 1.4V^{*}N/W$$

Where, V = acid used in titration (mL)
N = normality of standard acid
W = weight of sample (g)

The percentage of protein was calculated as per formula suggested by Hammarsten and Sebelien (1982).

$$\% \text{ Protein} = \% \text{ Nitrogen} \times 5$$

Determination of moisture content in almond leaves

To determine the moisture content in almond leaves, the empty petri dish was heated in oven at 100 °C for 4 hours to dry and cooled for 30 minutes in desiccator to get constant weight. The empty petri dish was measured. The fresh leaf sample was weighed in petri dish and placed in oven at 100 °C for 2 hours. The heated leaf sample was cooled in desiccator for 30 minutes and then weighed and noted down the reading. The amount of moisture content in percentage was measured using the following formula.

$$\text{Moisture } (\%) = \frac{W - W1}{W} \times 100$$

Where, W= Weight of sample before de-moisturizing; W1= Weight of sample after de-moisturizing

Determination of ash content in almond leaves

To determine the ash content in almond leaves, crucible with lid was washed, and placed in oven overnight to remove impurities. The crucible with lid cooled in desiccator for 30 minutes. After cooling the empty crucible with lid was weighed three times. The 2g sample was weighed in crucible and then the leaf sample with crucible was heated on heater placed in fume hood. When the sample was totally burned put it in a furnace for 1 hour. After one hour put the sample in the desiccator till it cool down and weighed it again. Ash content in leaf sample was determined using the following formula.

$$\text{Ash } (\%) = \text{weight of ash obtained from leaf} \div \text{weight of original leaf sample} \times 100$$

Determination of crude fat in almond leaves

10g leaf sample was weighed on a paper thimble and placed in Soxhlet extractor. Fat extraction was done with 75 to 100 mL diethyl ether for 4 hours in a previously tarred 150 mL round bottom flask. The solvent diethyl ether was completely evaporated, and fat residues were weighed on electronic balance using the following formula.

$$\text{Crude fat } (\%) = \text{Wt. of flask with fat- Wt. of empty flask} \div \text{Wt. of sample} \times 100$$

Determination of crude fiber in almond leaves

2g fat free sample or sample obtained from oil extraction was taken in a beaker containing 200 mL 0.225 N sulfuric acid (H_2SO_4). The mixture was boiled for 30 minutes, the mixture volume was maintained using deionized water. The mixture was filtered, and the remaining residues were washed with deionized water to get an acid free sample. The collected residues again dissolve in 200 mL 0.313 N NaOH solution, boiled mixture for 30 minutes, filtered, washed with water to remove alkali traces. The obtained residues were transferred to a crucible and heated in oven at 130 °C for 1 hour then put it in furnace at 100 °C for 2 hours. The crucible weight with fiber was noted after cooling. Fiber percentage was calculated using the following formula (ISO, 1981).

Crude fiber (%) = (loss in weight on ignition – loss in weight of fiber blank) ×100/weight of test portion.

Determination of carbohydrate content in almond leaves
The following formula was used to calculate the carbohydrate content in almond leaves sample.

Carbohydrate= (percentage of moisture+ percentage of Fat+ percentage of Protein+ percentage of Fiber+ percentage of ash)-100

Determination of nutritional value
The determination of the nutritive value is ultimately achieved by the following formula.

Nutritive value = 4 x percentage of protein + 9 x percentage of fat + 4 x percentage carbohydrate.

Results

The results of various nutrients of leaves of T1, T2, T3, and T4 are summarized in Table 1 and are presented in (Figure 1). The average percentages of various nutrients are depicted in Table 2 and (Figure 2). In the current study, an average of 1.35% Nitrogen, 6.75% protein, 54.16% carbohydrate, 7.32% fat, 16.12% ash, 9.58% moisture content were found in almond leaves. The nutritive value of almond leaves was notably high, measuring average at 309.625 Cal/g as presented in table and (Figure 3).

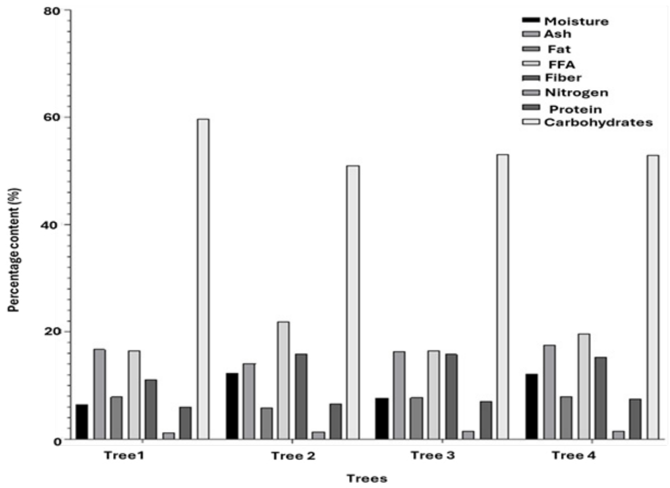

Figure 1: *Percentage of moisture, ash, fat, free fatty acid (FFA), fiber, nitrogen, protein and carbohydrate in almond leaves.*

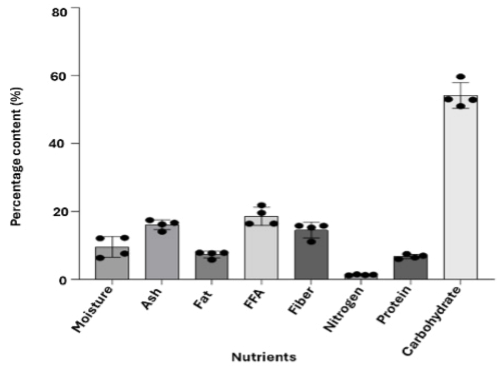

Figure 2: *Average nutrient composition of almond leaves.*

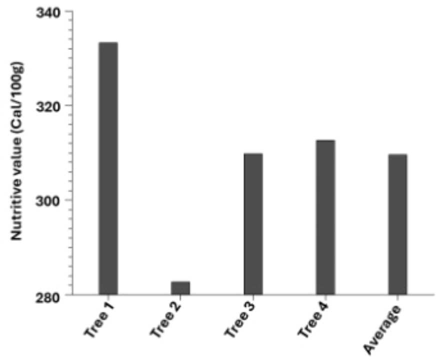

Figure 3: *Nutritive value (Cal/100g).*

Table 1: *Percentage of moisture, ash, fat, free fatty acid (FFA), fiber, nitrogen, protein and carbohydrate content in Almond leaves*

Trees	Moisture content (%)	Ash content (%)	Fat content (%)	FFA content (%)	Fiber content (%)	Nitrogen content (%)	Protein content (%)	Carbohydrate content (%)
T1	6.36	16.68	07.83	16.45	11.08	1.2	6	59.70
T2	12.24	14.07	05.82	21.87	15.81	1.3	6.5	51.01
T3	07.62	16.25	07.73	16.42	15.79	1.4	7	53.06
T4	12.11	17.47	07.88	19.59	15.30	1.5	7.5	52.90

Table 2: *Average nutrient composition of almond leaves.*

Nutrients	Average percentage (%)
Moisture	9.58
Ash	16.12
Fat	7.32
Free faty acid (FFA)	18.58
Fiber	14.50
Nitrogen	1.35
Protein	6.75
Carbohydrate	54.18

Table 3: *Nutritive value.*

Trees	Nutritive value (Cal/100g)
Tree 1	333.27
Tree 2	282.74
Tree 3	309.81
Tree 4	312.68
Average	309.625

Discussion

This exploratory research illustrates nutrients dynamics in summer, where the data from samples collected in 2021. Leaf samples were characteristically collected in July from almond tree. The result will be helpful by providing important information on nutrient status in the almond leaves.

In current study tree number 2 (T2) showed significant differences in moisture content (12.24%), free fatty acid (FFA) content (21.87%), and fiber content (15.81%) compared to the other trees (Table 1). This variation could be due to several factors, such as differences in soil composition, microclimatic conditions, or genetic variability among the trees (White, and Brow, 2010).

An average of 1.35% nitrogen content was found in almond leaves. However, the previous report (Micke and Warren, 1996) suggested the adequate level of nitrogen content should be around 2.2-2.4%. The result showed that nitrogen content is deficient in almond leaves during summer season in Skardu region. According to (Muhammad *et al*., 2015) almond flowering often occurs before leaf out, and during that time, reduced transpiration, an availability of remobilized nitrogen, and forced root activity may hinder soil nutrient uptake. Early in the season, there is a better requirement for nitrogen in almond annual tissues such as fruits and leaves. A spike in nitrogen content was seen between early November and mid-December as a result of nitrogen remobilization from senescing leaves and root nitrogen uptake from the soil. Senescing leaves give 9 to 87 percent of their weight to the nitrogen storage pool, depending on the species (Millard and Grelet, 2010). Plants down regulate photosynthesis or stop growing under nitrogen deficit, most likely because of these roots. On the other hand, to make up for the mineral shortage, it is stretched to extract residual minerals at 0.5% nitrogen (Hermans *et al*., 2006). Nitrogen has direct effects on leaf development and biomass accumulation, as well as indirect effects on floral bud development. Almond trees' floral bud production starts in July, and there is a correlation between leaf area and floral bud production that is favorable (Polito *et al*., 1996; Lampinen *et al*., 2011).

In the current study an average of 6.75% protein content was found in almond leaves. The previous study (Nahand *et al*., 2012) reported that for almond trees proportion of crude protein concentration varied from 6.79%. The result of the presented study was corroborated with the result suggested by Nahand *et al*. (2012) and showed that the protein content in almond leaves collected from Skardu region during spring season is normal. Almonds have a protein concentration that ranges from 10% to 35% (Gradziel, 2017). Using a nitrogen to protein conversion factor, protein concentration is usually calculated from nitrogen levels. In this regard, it's worth noting that different values for this component have been reported, resulting in discrepancies in the declared protein content of almonds. Protein content in almond kernels progressively increases up to harvest, as stated, since the seed has a higher protein synthesis activity.

The chemical makeup of the nuts and potential uses of the wild almond genetic resources have gained attention at present (Sorkheh *et al*., 2016; Wang *et al*., 2018, 2019). For early spring development in almond trees carbohydrates stores are a limiting factor, as is the fact that carbohydrate stores drop when photosynthesis decreases in drought conditions (Esparza *et al*., 2001). In terms of growing this vegetation, continuity, and product production, estimation of almond species' carbohydrate levels based on changing climatic circumstances can be crucial.

In the present study, the term "nutritive value" refers to the energy content of almond leaves, specifically measured in calories per 100 grams. This value indicates the amount of energy that livestock can derive from consuming the leaves, which is an important factor in assessing their potential as a feed resource. In Table 3, we present the caloric values of almond leaves from different tree samples, highlighting variability among them. The average nutritive value of 309.625 Cal/100g suggests that almond leaves can provide a significant energy source for livestock. Understanding these values is essential for evaluating the overall contribution of almond leaves to livestock diets, especially in regions where traditional forage options may be limited. Similar result was reported in previous study (Nahand *et al*., 2012). The substantial nutritive value further confirms their suitability as fodder, food, and a significant source of various nutrients for livestock. The presence of ample carbohydrates, sufficient protein, elevated nutritive value, and low-fat content collectively establish almond leaves as an excellent feed source for livestock.

Conclusions and Recommendations

The nutrient content in almond leaves varied significantly among cultivars, likely due to genetic factors, soil composition, microclimatic conditions, or nutrient uptake efficiency. Almond leaves (*Prunus dulcis*) were found to be rich in protein (6–7.5%) and carbohydrates (51–59.7%), highlighting their potential as high-quality fodder for livestock.

It is recommended to explore their use as a sustainable and cost-effective feed option. Further research should assess palatability, digestibility, and their impact on livestock health and productivity. Future studies should include feeding trials to evaluate the comparative sources of protein and energy in almond leaves and their impact on performance. Additionally, the effects of processing methods (e.g., drying, pelleting) on nutrient retention and bioavailability should be investigated to optimize their application in animal feed systems.

In conclusion, almond leaves show promising potential as a livestock feed resource, and further research is essential to fully integrate them into sustainable agricultural practices.

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Novelty Statement

This study is the first to systematically analyze the nutritional composition of almond (Prunus dulcis) leaves specifically in the Baltistan region of Pakistan. While almond trees are well-known for their nuts, the nutritional potential of their leaves as livestock fodder has not been previously documented in this region. By providing detailed insights into the concentrations of key nutrients such as nitrogen, carbohydrates, and protein—this research highlights the significant nutritional value of almond leaves. The findings offer valuable information for farmers, enhancing their ability to select effective forages and potentially improving livestock nutrition. This novel contribution underscores the potential of almond leaves as a viable and nutritious feed resource in ruminant diets, which may lead to more sustainable and diversified feeding practices

Author's Contribution

Asiya Batool and Ammarah Kanwal: Executed the research and data curation.
Shazia Kausar: Helped in data analysis.
Ishrat Jamil: Finalized the manuscript.
Ghulam Raza: Supervised the work.

Generative AI and AI-assisted technology statement
We affirm that this research process has been conducted without the use of Generative AI or AI-assisted technologies. All research methods, data analysis, and conclusions have been derived through traditional academic processes and manual efforts.

Conflict of interest
The authors declare that there is no conflict of interest.

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