Review Articles

Potato Peels as a Sustainable Animal Feed: Maximizing Environmental Benefits and Nutritional Value

Abdelghani Chihani[1]*, Sophie Geernaert[2]

[1]Doctoral School of Agricultural and Food Sciences, Georgikon Campus, Hungarian University of Agriculture and Life Sciences (MATE), 8360 Keszthely, Hungary; [2]Faculty of Medicine, Dalhousie University, 1459 Oxford Street, Halifax, Nova Scotia, B3H 4R2, Canada.

Abstract | The growing demand for animal protein and rising feed costs have prompted interest in alternative, sustainable livestock feeds. Potato peels (PP), a secondary product of food preparation, are rich in carbohydrates, dietary fiber, micronutrients, and bioactive compounds, suggesting potential nutritional benefits for animals. Research has explored the use of potato peels (PP) as an alternative to conventional livestock feed ingredients, suggesting potential improvements in growth performance and reduced reliance on traditional feed resources. In addition, by keeping organic waste out of landfills and lowering greenhouse gas emissions, the use of PP in livestock diets contributes to waste reduction, methane emission mitigation, and circular economy practices. While these findings highlight the potential of PP, some challenges remain, including variability in nutrient composition, the presence of anti-nutritional factors, and the limited availability of long-term feeding studies. Furthermore, factors such as cultivar, storage conditions, and processing methods can influence the nutritional value of PP, which may affect its consistency as a feed ingredient. Therefore, further research on optimal inclusion levels, species-specific responses, and processing techniques is needed to support its practical use in livestock nutrition. Overall, PP offers a potentially valuable feed resource that aligns with sustainable agricultural practices and circular economy principles, supporting both environmental conservation and cost-effective livestock production.

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***Correspondence** | Abdelghani Chihani, Doctoral School of Agricultural and Food Sciences, Georgikon Campus, Hungarian University of Agriculture and Life Sciences (MATE), 8360 Keszthely, Hungary; **Email:** Chihani.Abdelghani.2@phd.uni-mate.hu
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Introduction

Due to their nutritional value and environmental benefits, fruit and vegetable peels are increasingly being evaluated as animal feed ingredients. Global food demand is expected to rise by approximately 50–60% by 2050, driven by population growth and changing dietary patterns. A substantial share of this increase is associated with rising consumption of animal-source foods, which is expected to contribute to the intensification of livestock production and increased pressure on feed resources and natural ecosystems (Alexandratos and Bruinsma, 2012; Röös *et al.*, 2017). The use of substitute feed sources for livestock has drawn interest as a viable and successful tactic to deal with these problems (Dora *et al.*, 2021; Sufficiency *et al.*, 2022).

Potato (*Solanum tuberosum* L.) is a crucial staple product with significant economic importance, as a crop cultivated and consumed on a global scale. As a result of its extensive processing, large quantities of potato peel waste are generated, which are rich in carbohydrates, fiber, and bioactive compounds, making them a potentially valuable resource for livestock feed. With its major role in human nutrition, it stands immediately after wheat, rice, and maize in global food crop significance (Karamova *et al.*, 2023). At present, the entire potato industry is experiencing considerable changes. In the past, the consumption of fresh potatoes, which formed the foundation of potato use, has been steadily declining, especially in developing countries. This decline is attributed to rising incomes and populations; this has driven increased consumption of value-added potato products, including chips, frozen fries, crisps, canned forms, and purées (Fradinho *et al.*, 2020). A significant amount of solid residue is generated during potato processing, with the peeling stage contributing roughly 6–10% of the total waste, equivalent to about 0.16 tons per ton of processed potatoes (Cardoen *et al.*, 2015; Liang and McDonald, 2014; Wu, 2016).

As a nutrient-rich by-product, potato peels contain greater levels of several nutrients compared with potato flesh. Beyond their nutritional value, they supply several bioactive substances associated with health benefits, including antioxidant compounds, flavonoids, dietary fibers, minerals, and vitamins (Jimenez-Champi *et al.*, 2023). The purpose of this review is to highlight potato peels' nutritional value and environmental significance as a sustainable animal feed option.

Nutritional and functional attributes of potato peels for use in livestock diets

Potato peels are rich in fiber, carbohydrates, antioxidants, vitamins, and minerals (Figure 1), and can significantly influence animal growth and health (Azizi *et al.*, 2018). Nutritional content of these peels varies depending on the fruit or vegetable maturation stage, processing methods, and variety (Haider *et al.*, 2025).

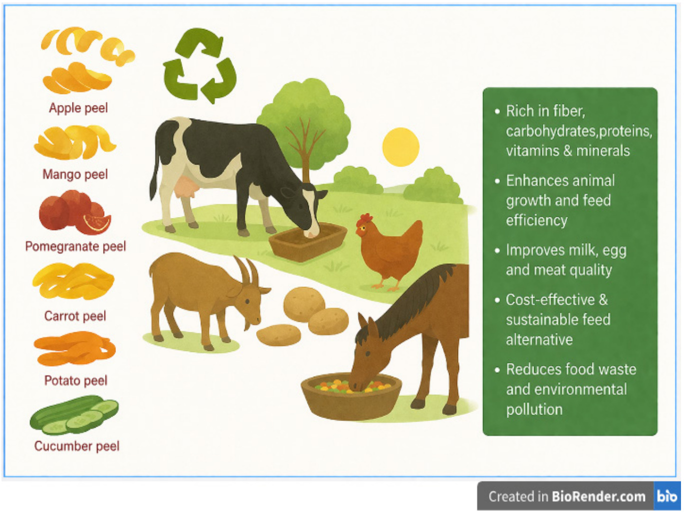

Figure 1: *Fruit and vegetable peels as feed resources in livestock systems and their environmental implications.*

Potato peels refer to the external tissues removed from tubers during industrial processing, according to Kaparaju and Rintala (2005). Potato peels represent a major residue generated during industrial processing, particularly in the production of chips and fries. Their composition is characterized by high levels of polyphenolic compounds and structural dietary fibers, including cellulose, hemicellulose, pectin, and lignin, which collectively contribute to the natural defense of tubers against phytopathogenic organisms (Askari *et al.*, 2017).Within the food industry, potato peels are often treated as low-value residual materials and are often used mechanically, such as in composting or as ruminant fodder. However, in biotechnological procedures, this material has been explored as a feedstock in various value-added processes, notably bioethanol generation (Arapoglou *et al.*, 2010; Liang *et al.*, 2015).

Chemical and nutritional profile of potato peels

An understanding of the chemical and physical characteristics of peel material waste is essential for evaluating its physicochemical behavior. Figure 2 presents the chemical composition of potato peels, including the relative proportions of major components, providing a visual summary of their nutritional profile. Gaining insight into these features would facilitate the development of eco-friendly approaches for utilizing this by-product (Javed *et al.*, 2019).

Cultivation location affects the pigmentation and composition of potatoes and their peels (Pathak *et al.*, 2015). Consequently, potato peels are increasingly recognized for their bioactive potential, providing antioxidants, fiber components, pigments, vitamins, and minerals (Amado *et al*., 2014; Tlay *et al*., 2023). The outer tissues of unprocessed potatoes contain a significant amount of carbohydrates and moisture, while typically having low amounts of lipids and proteins. According to Ijaz *et al*. (2024), potato peels contain approximately 52 g of starch per 100 g of dry weight, highlighting their suitability as a substrate for fermentation.

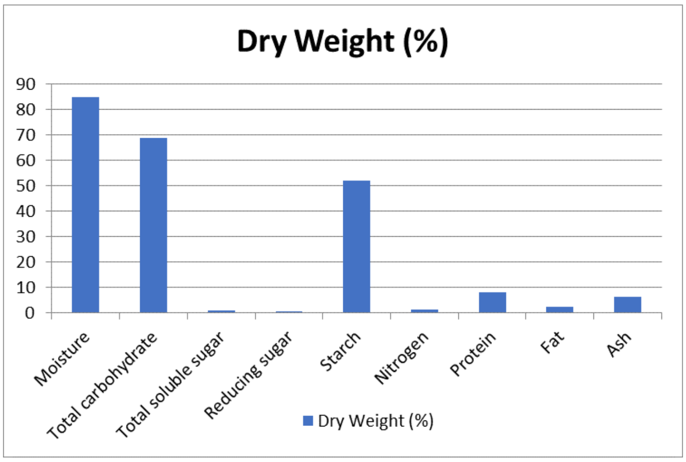

Figure 2: *Chemical composition of potato peel (Arapoglou et al., 2010).*

Exploitation of potato peels for beneficial uses

Potato peels (PP) serves as a rich source of various nutrients. Relative to the edible flesh, potato peel material exhibits higher levels of several nutrients. Moreover, it contains a diverse range of health-promoting constituents, such as antioxidant and flavonoid compounds, dietary fiber fractions, essential minerals, and vitamins (Jimenez-Champi *et al*., 2023). A large quantity of waste is generated from potatoes because of their widespread use across industries. Peels, pulp, and starch obtained from potatoes are commonly incorporated into livestock feed formulations (Khanal *et al*., 2024).

Figure 3 highlights the multiple applications of PP, made possible by its distinctive properties.

Feed applications for livestock

The cost of livestock feed is rising due to increased compost prices and adverse climatic conditions, making the utilization of food waste a necessary and innovative alternative feed source. This strategy reduces feed expenses and waste-management costs while contributing to a lower environmental burden (Rivin *et al*., 2012). Food waste streams can offer significant nutritional value for livestock, as shown in feeding trials and digestibility studies. For instance, feeds made from food waste and crop leftovers have nutritional qualities similar to regular forages while keeping diet digestibility in cattle (Dou *et al*., 2022). In dairy production systems, adding potato-based by-products up to 30% of concentrate mixtures maintained milk yield at 27.5–28.0 kg/day. Additionally, using silage increased milk production from 26.3 to 28.6 kg/day (Schneider *et al*., 1985). Similarly, incorporating potato steam peel at levels up to 30% of the diet's dry matter in growing-finishing pigs showed high digestibility (88.4% dry matter and 80.1% crude protein) without harming growth performance (Van Lunen *et al*., 1989). These findings show that feed ingredients from food waste can effectively replace regular feed components without reducing animal productivity. In an evolving nation, consumption of livestock-derived products continues to grow. However, feed shortages pose a significant challenge, making unconventional feed resources crucial. Significant volumes of processing residues arise from fruit and vegetable industries, offering potential value as feed resources for livestock (Wadhwa and Bakshi, 2013). Despite having a low amount of protein, potato peel is a noteworthy food waste choice for substitute animal feed because it is an organic source of energy and fiber (Ncobela *et al*., 2017).

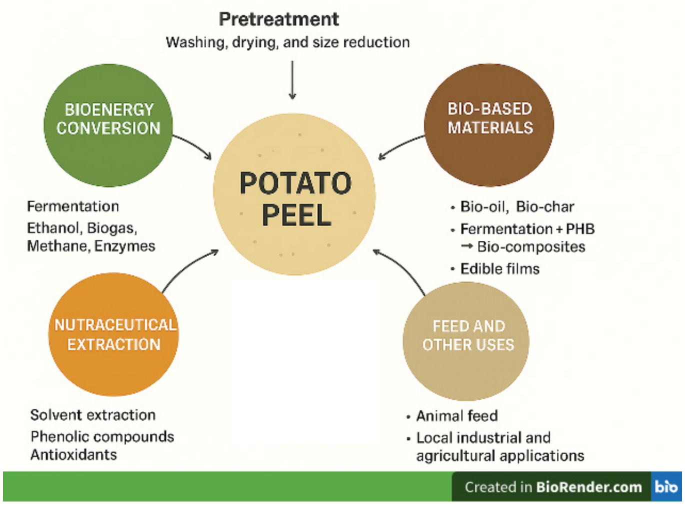

Figure 3: *Valorization of potato peel extracts (Ijaz et al., 2024). Created with BioRender.com (Fig. 1 and Fig. 3).*

Historically, livestock diets have included potato peel residues. Due to their high starch content, they offer a good source of energy, especially for ruminants. Including them in diets has been linked to changes in how animals use nutrients and their performance. For instance, when sheep diets replaced some concentrate feed with potato peel waste at levels of 25% and 50% (w/w), moderate inclusion at 25% maintained digestibility and rumen function. However, higher inclusion at 50% reduced crude protein digestibility and overall nutritional value (Tawila *et al*., 2008). Potato peels, comparable to apple and citrus peels, are rich in dietary fiber and contribute to the regulation of glucose metabolism and overall energy balance in animals (Yitbarek, 2019).Vitamin E can be found in the peels of carrots and sweet potatoes (Khattak and Rahman, 2017). It promotes skin health, reproductive efficiency, and serves as a natural antioxidant (Nayyar and Jindal, 2010). The peels of potatoes contain B-complex vitamins, which contribute to metabolic energy pathways and maintain normal nervous system activity, and growth in animals (Alamgir, 2018). PP are carbohydrates and fiber dense, which is used for immediate energy production, and essential for extended periods of physical work and the vitamins and minerals aid in muscle function and stamina (Akonor *et al*., 2023; Laufenberg *et al*., 2003). Additionally, PP serves as a nutritious feed for fish. Research by Maske and Satyanarayan (2012) indicates that when fish are fed PP for a duration of 30 days, increased protein and lipid deposition in muscle and liver tissues is observed. However, the study did not report quantitative growth performance indicators such as weight gain or feed conversion ratio, which limits the strength of these findings. Therefore, incorporating PP into the diet of ruminants and fish may have potential health benefits without apparent adverse effects.

Limitation of using potato peels as animal feed

Potato peels are high in carbohydrates, fiber, vitamins, and bioactive compounds. However, they also have significant drawbacks as a feed ingredient. They contain steroidal glycoalkaloids, mainly α-solanine and α-chaconine, which can be harmful to animals at high levels (EFSA CONTAM Panel, 2020). These compounds are mostly found in the peel, and their levels can vary greatly based on the cultivar, environmental conditions, and storage. Typically, their concentration ranges from tens to several hundred mg/kg of fresh weight. In some stressed or wild types, it may exceed 1000 mg/kg (Friedman *et al*., 2017; Jimenez-Champi *et al*., 2023). However, no safe limit for livestock diets has been set because of a lack of toxicological and exposure data (EFSA CONTAM Panel, 2020). It is more difficult to formulate homogenous rations since the concentration of these chemicals greatly relies on the cultivar, production techniques, and the circumstances of storage (Vescovo *et al*., 2025). Plant remnants (PP) and their safe application in animal feed therefore requires careful monitoring and, in many cases, pretreatment such as drying or detoxification, which incurs additional costs and logistical challenges (Vescovo *et al*., 2025). Moreover, the nutritional composition of PP is highly variable and may not me*et al*l the essential nutritional needs of livestock if used as a main component of the diet (Vescovo *et al*., 2025). Factors contributing to this variability include potato cultivar, stage of maturity at harvest, and processing methods, as different cultivars vary in starch and fiber content, less mature tubers contain more moisture, and peeling methods remove different depths of outer tissue. Additionally, a high moisture content lowers food safety and durability by increasing the danger of microbial contamination and spoiling (Asuquo *et al*., 2022). Although short-term feeding trials indicate that PP can promote growth and overall health, for example, Asuquo *et al*. (2022) observed improved growth and survival in *Labeo rohita* receiving diets formulated with potato peel material over an extended feeding period; however, long-term studies on potato peel–based diets in animals remain limited, if not nonexistent. This limits knowledge on chronic effects, reproductive performance, product quality, and safety for large-scale applications. Ultimately, despite the potential of PP as an alternative food ingredient, these toxicity risks, the variability of nutritional values, the processing requirements, and the lack of long-term data are significant limitations. Rigorous evaluation, quality control, and further research are needed before PP can be recommended for widespread or sustainable use in livestock and aquaculture feed.

Environmental and economic value of using potato peels for animal feed

Incorporating fruit and vegetable peels in animal feed is better for enhancing environmental safety through minimizing waste, conserving resources, and supporting sustainable farming methods (Wadhwa and Bakshi, 2013). Current environmental deterioration and resource scarcity are significant issues, making the idea of leveraging agricultural by-products an ever-important eco-friendly approach that benefits the environment and livestock systems (Grădinaru *et al*., 2019). Discarded edible materials have emerged as a pressing environmental issue, largely due to the high volume of residues generated from fruit and vegetable processing (Esparza et al., 2020; Sagar et al., 2018). Waste disposal methods such as landfilling of peels result in increased greenhouse gas emissions, particularly methane (Blümmel et al., 2009). Quantitative evidence indicates that methane emission factors during food waste composting range from 6.6 to 8.8 kg CH_4–C Mg^{-1} of wet food waste, and overall composting emissions are 38–84% lower than those from equivalent landfilling emissions (Pérez et al., 2023). Redirecting waste into animal feed decreases the amount of organic material sent to landfills, thereby directly lowering methane emissions and improving overall environmental sustainability (Pal et al., 2024). The approach of PP turns an environmental threat into a useful resource.

Furthermore, it takes a lot of energy, water, and land to cultivate animal feeds, especially those made from grains (Gomiero, 2016). Producing crops such as maize and soybeans contributes to deforestation, which in turn leads habitat destruction and soil degradation (Sahoo et al., 2021). Transitioning from traditional feeds to using fruit and vegetable peels reduces the ecological footprint of animal production systems (Jalal et al., 2023; Schlink et al., 2010). Life cycle assessment (LCA) studies back this claim. Teigiserova et al. (2022) found that using orange peel waste as animal feed avoided net greenhouse gas emissions of –150 kg CO_2 equivalent per tonne of wet peel. This was mainly because it replaced conventional feed crops like maize and soybean meal. Likewise, Dilek et al. (2025) reported that using orange peel for animal feed lowers environmental impacts compared to landfilling and composting. Peel-based feed demands fewer resources including, water and land, which reduces the strain of natural ecosystems. Besides altering resources, there is improvement to soil health through the peel-based livestock feed approaches. For animals that consume nutrient-dense peels, their manure has increased organic matter, which boosts soil fertility when used like a natural compost (Dahunsi et al., 2021). This reduces the need for synthetic substances, which contaminate soil and water through chemical runoff. By enhancing soil quality and making sure that agricultural regions continue to be productive and sustainable for future generations, the entire ecosystem is balanced (Haider et al., 2025).

Biodiversity is also improved through the peel-based livestock approach (Isbell et al., 2017; Wadhwa et al., 2015). The decreased reliance on monoculture crops, which are cultivated over large areas with limited biodiversity, as animal feed promotes varied agriculture systems and a reduced pressure on ecosystem (Mori et al., 2013). Biodiversity is important for withstanding climate and weather extremes (Ferri et al., 2017). Additionally, when reducing the necessity for synthetic inputs and livestock-targeted crop production, the environmental dangers linked to pesticide and herbicide application are reduced, leading to cleaner air and water.

Water conservation is a crucial priority for environmental efforts, but feed production typically has high water demands. Standard feed production requires substantial irrigation, which can cause water depletion in surrounding areas (Sánchez et al., 2021). The peel-based livestock feed contains a lot of water which provides hydration for livestock and decreases the amount of additional water needed during feed processing (Majumder and Annegowda, 2021). Hence, peel-based livestock feed efforts also contribute to preserving water resources, which improves the sustainability agricultural practices, particularly in regions dealing with water shortages (Haider et al., 2025). Fruits and vegetable peels are often thrown away after people eat them, but repurposing them as feed ingredients for farm animals represents a sustainable approach to reducing total waste generation (Pereira et al., 2022). Instead of contributing to methane emissions and occupying space (Vardar et al., 2022). Incorporating peels into animal feed, redirects peels from the waste stream and utilized in a productive manner that is further beneficial for livestock and emissions reduction efforts (Diarra, 2018; Zema et al., 2018).

Economic value of using potato peels for animal feed

Sourcing peels locally or from food processing sectors decreases transportation expenses, further improving the economic feasibility of utilizing them as feed (Wadhwa et al., 2015). Economic analyses show cost savings when using peel-based feed ingredients. For instance, Stephens et al. (2025) found that substituting conventional feed grains with potato waste in beef feedlot diets cut feed costs by about 10 to 21%. In a similar way, Daniel et al. (2024) found that adding sweet potato peel meal to quail diets reduced the feed cost per gram from No.484 to No. 37. It also lowered the daily feed cost per bird from ₦6.24 to ₦5.56. This highlights the economic advantages of peel based feed ingredients. This cost-effective strategy promotes circular economies in agriculture by converting debris into useful nutritional substances, promoting sustainability in terms of the environment and the economy (Haque *et al*., 2023). However, transportation expenses depends on proximity of processing plants, storage, seasonality (growing patterns), and scale of growth. In some regions, logistics costs could outweigh direct cost saving. Additionally, fruit and vegetable peels may contain naturally occurring compounds such as tannins, phytates, and oxalates, which can interfere with nutrient uptake (Yusuf *et al*., 2017). The high levels of anti-nutrients present can bind to nutrients, thus limiting their digestibility and availability index (Samtiya *et al*., 2020). Nevertheless, it is clear that balancing the amounts of anti-nutrients and nutrients can mitigate the adverse effects on digestibility while also providing health benefits (Nath *et al*., 2022). However, adequate processing and assessment of peel digestibility and safety are essential to maximize benefits and avoid any potential antinutritional issues.

Future research directions

To maximize benefits and minimize risks, several actions are recommended. Species-specific inclusion and processing studies are needed to determine optimal inclusion rates for ruminants, pigs, poultry, and fish, accounting for digestibility, nutrient availability, and anti-nutritional factors. Processing optimization should investigate methods such as drying, fermentation, or enzymatic treatments to improve nutrient bioavailability and reduce potential contaminants or toxins. Long-term animal health and productivity monitoring is required to track growth, reproductive outcomes, milk and meat quality, and overall animal health under PP-inclusive diets. Environmental and economic assessment is also necessary, including life cycle analysis of water use, land requirements, energy inputs, and greenhouse gas emissions, as well as cost–benefit evaluation considering logistics, storage, and opportunity costs. Comparative analysis with alternative feed sources should be conducted to identify the most effective and sustainable feed options. Finally, policy and practical guidance development is needed to support the safe and sustainable incorporation of PP into livestock feed, taking into account regulatory frameworks and regional food processing practices.

Conclusion

Potato peels (PP) represent a promising nutrient-rich byproduct with potential to enhance the sustainability of livestock feeding systems. Their considerable fiber, micronutrient, carbohydrate, and bioactive compound content can promote animal growth and productivity when incorporated appropriately into diets. Redirecting PP from waste streams to livestock feed also offers environmental benefits, including reduced methane emissions, decreased reliance on conventional feed crops, and alignment with circular economy principles. Economically, PP may lower feed costs and increase the value of processing by-products.

However, the practical integration of PP into livestock diets requires careful consideration. Variability in nutrient composition, the presence of anti-nutritional factors, and limited long-term feeding data constrain current understanding. Robust empirical evidence is still needed to support safe and effective large-scale application.

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Novelty Statement

This review highlights the nutritional, environmental, and economic benefits of potato peels as a sustainable feed option in livestock production. It also emphasizes their role in supporting circular agriculture and reducing waste.

Author's Contribution

AC came up with the idea and structure for the review. AC and SG gathered research and wrote the first draft of the manuscript. AC carefully reviewed the manuscript and gave it the green light. All authors read and approved the final manuscript.

Generative AI and AI assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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