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Review

Sustainable Poultry Feeding Strategies for Achieving Zero Hunger and Enhancing Food Quality

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Abstract: As global demand increases for poultry products, innovative feeding strategies that reduce resource efficiency and improve food safety are urgently needed. This paper explores the potential of alternative sustainable poultry feeding strategies aimed at achieving SDG2 (Zero Hunger) while increasing production performance and food quality, focusing on the potential recycling of by-products, plants, and food waste derived from fruits, vegetables, and seeds, which account for up to 35% annually. The paper provides a review analysis of the nutritional (protein, fat, fiber, and ash) and minerals (i.e., calcium, phosphorus, zinc, manganese, copper, and iron) content as well as the bioactive compounds (polyphenols, antioxidants, carotenoids, fatty acids, and vitamins) of alternative feed ingredients, which can contribute to resource efficiency, reduce dependency on conventional feeds, and lower production costs by 25%. The nutritional benefits of these alternative feed ingredients, including their effects on poultry production and health, and their potential for improving poultry product quality, are presented. Carrot, paprika, rosehip, and some berry waste represent a great source of carotenoids, polyphenols, and vitamins, while the seed meals (flax, rapeseed, and sea buckthorn) have been reported to enhance the essential fatty acid composition in eggs and meat. Numerous plants (basil, sage, rosemary, and lettuce) are natural reservoirs of bioactive compounds with benefits for both animal and food products. Some challenges in implementing these alternative sustainable feeding strategies, including inconsistencies in quality and availability, the presence of anti-nutrients, and regulatory barriers, are also explored. In conclusion, future research directions in sustainable poultry feeding with alternative feed ingredients should be considered to achieve SDG2.

Keywords: food quality; poultry; eggs; meat; sustainability; zero hunger; SDG; feed ingredients

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1. Introduction

The current global challenge of achieving food security and ensuring access to sufficient, nutritious, and safe food for all while maintaining or improving agricultural sustainability has been presented in the United Nations' Sustainable Development Goals (SDGs), particularly Goal 2, which refers to Zero Hunger. This goal emphasizes the necessity to end hunger while achieving food security through improved nutrition and promote sustainable agricultural practices by 2030.

In the agricultural sector, poultry production plays an important role in the global food system, providing consumers with a major source of high-quality animal protein through meat and eggs [1]. However, since conventional poultry feed raw materials, mainly corn and soybean meal, this poses challenges with respect to its sustainability, such as deforestation, biodiversity loss, and more greenhouse gases associated with their manufacture and transportation [2]. In this context, new strategies are needed to develop and implement alternative feeding strategies for poultry. In recent years, there has been a growing interest in the potential of alternative feed ingredients as viable and practical alternatives to conventional poultry diets. These alternatives not only aim to reduce the ecological footprint of poultry farming but also are great candidates to enhance the nutritional profile of poultry products and performances. The utilization of diverse novel and alternative feed ingredients, such as legume waste [3], oilseed meals [4,5], fruit waste [6,7], leaves or plants [8,9], and other agricultural by-/co-products [10], into poultry diets offers promising ways to mitigate the current challenges in poultry industries. Nevertheless, the transition to alternative feed ingredients for poultry is complex, and the nutritional adequacy, feed palatability, cost-effectiveness, and supply chain logistics should be considered. For example, understanding the nutritional requirements of poultry and the nutrient composition of various feed ingredients is crucial for formulating balanced diets that support optimal growth, health, productivity, and product quality. Moreover, the variability in nutrient content and the presence of anti-nutritional factors in some alternative ingredients require careful laboratory assessments and processing to ensure their effective utilization in poultry diets [11]. However, numerous research studies dealing with feed technology and animal nutrition science have facilitated the development of novel feed formulations that incorporate alternative ingredients without compromising poultry performance while improving poultry product quality, as further presented in the current paper.

In this context, this review paper aims to explore potential alternative and sustainable poultry feeding strategies that align with the Sustainable Development Goal of Zero Hunger (SDG 2). The paper examines the chemical composition, and bioactive compounds present in the alternative feed ingredient options and their potential to enhance poultry production performances, health, and food quality while contributing to a circular economy (Figure 1).

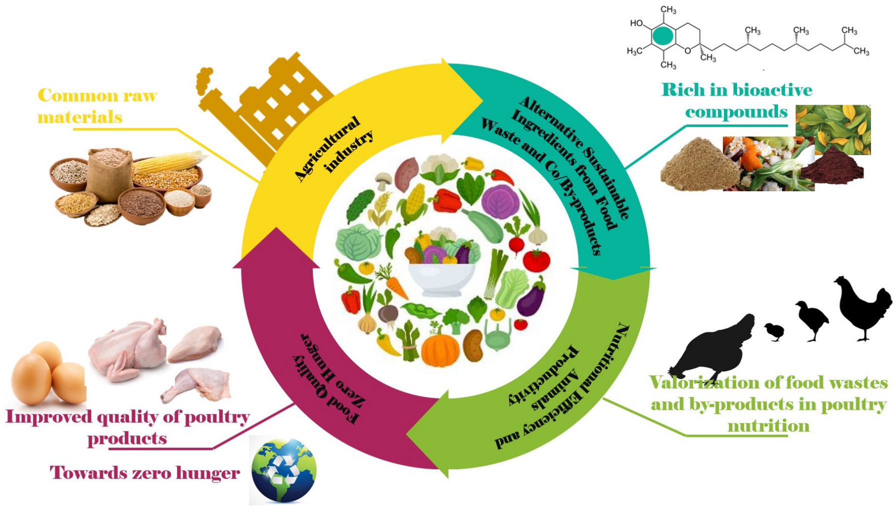

Figure 1. Overview of potential valorisation of co-/by-products and agro-food industry waste in poultry to achieve Zero Hunger.

2. SDG 2: Zero Hunger and the Role of Poultry Production in Global Food Security and the Circular Economy

2.1. SDG 2: Zero Hunger and Why It Is Relevant to Poultry Production

Zero Hunger is one of the 17 SDGs established by the United Nations in 2015 as part of the 2030 Agenda for Sustainable Development, officially known as SDG 2 [12]. This goal, as described in the agenda, addresses a range of interconnected issues related to hunger, food quality, and food security. The main goal is to ensure that all people, especially poor and vulnerable populations, have access to sufficient, nutritious, and safe food products all year round. This involves not only increasing animal-origin food production but also improving food system distribution and reducing food waste [13]. A potential strategy to achieve sustainable nutrition and health for the increasing population can be formulated by following the principles of bioeconomy, which involves the production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products, and bioenergy [14]. Furthermore, to increase the eco-sustainability of the food processing industry, food waste, by-products, co-products, and/or plants should be exploited before they become waste or neglected.

Dealing with food waste is of great importance, especially in terms of combating hunger, raising incomes, and improving food security in the poorest countries. Until a few decades ago, food waste was not considered either a cost nor a benefit. However, to maximize benefits for the environment, society, and economy, the FAO is currently developing a code of conduct (CoC) for the reduction of food loss and waste and has proposed an inverted pyramid, setting priorities on how to best reduce food waste and save natural resources [15]. To achieve this target, SDG 2 emphasizes the importance of sustainable agriculture, which involves promoting agricultural practices that increase productivity and production, among other objectives.

2.2. Poultry Production as a Pillar of Food Security

Poultry production plays a pivotal role in providing affordable, high-quality protein to millions of consumers globally, contributing directly to SDG 2 by enhancing food security and promoting sustainable agricultural practices [16].

From a nutritional point of view, poultry products (chicken meat and eggs) are among the most consumed animal-origin-derived products worldwide, being rich sources of protein, amino acids, fats, vitamins, and minerals, which are crucial for various bodily functions, including immune system support and cognitive development essential for human health, particularly in developing countries [17]. Furthermore, poultry meat generally contains lower levels of saturated fats compared to red meats [18], making it a healthier option for consumers and supporting efforts to reduce diet-related non-communicable diseases.

From an economic point of view, due to efficient feed conversion and short production cycles, poultry production is cost-effective, making poultry products more affordable compared to other animal protein sources [19], which increases their accessibility to a larger population, including low-income families. Eggs and chicken meat products are often included in school feeding programs, pregnant women, and emergency food aid due to their high nutritional value and ease of storage and preparation. Programs targeting such groups often use eggs and poultry meat as key components to improve nutritional outcomes, as recently reported in a study focused on programs from sub-Saharan Africa and South Asia regions [20]. Another important economic aspect is that poultry species are more resilient to climate variations compared to larger livestock, and they can be raised in diverse environmental conditions [21,22], from tropical to temperate climates, making poultry farming a reliable source of food even under changing climatic conditions. Lastly, poultry production generally emits fewer greenhouse gases per unit of meat compared to ruminant livestock [23], supporting sustainable food systems that balance food production with environmental conservation.

From a cultural point of view, poultry is widely accepted across different cultures and religions, making it a versatile and important component of global diets [24]. This cultural acceptance facilitates its inclusion in various food security initiatives without significant dietary restrictions. In this context, the importance of poultry products (eggs and meat) in global food security cannot be overlooked, as it supports the dietary needs of billions humans, particularly in regions where other forms of animal protein are scarce or too expensive for the average consumer [25]. Furthermore, poultry farming is often integrated into larger agricultural practices, providing a steady income stream for smallholder farmers, who represent a significant portion of the world's agricultural producers. These small-scale operations contribute not only to local food security but also to the livelihoods of millions of families, thereby reinforcing the socio-economic stability of rural areas, as shown in a study conducted in South Asia [26].

2.3. Poultry Production and the Circular Economy

The concept of a circular economy is gaining massive attention in discussions about sustainable agriculture, which includes poultry production. A circular economy approach in poultry farming emphasizes the efficient use of resources, waste minimization, and the recycling of discarded by-products [27]. This approach aligns closely with the principles of SDG by reducing environmental impacts, such as carbon footprint, and enhancing resource efficiency, which in the context of SDG 2 are considered critical aspects. Generally, traditional poultry feeding practices rely heavily on common grains such as corn, wheat, and soybeans, which are also staple foods for humans [28]. This competition for these common resources can amplify food insecurity, especially in regions where grain production is not sufficient to meet both human and animal needs. Therefore, the transition to more sustainable feeding practices is essential. Alternative feed ingredients such as insect protein, algae, and agricultural by-products and wastes [29–31] represent promising solutions for reducing the environmental footprint of poultry production. Insects, for example, can be produced using organic waste, which not only diverts waste from landfills but also creates a high-protein feed source for poultry [29]. Algae, another alternative, can be cultivated in environments that are unsuitable for traditional agriculture, making it a viable option in arid regions [30]. Agricultural by-products, such as oil seed meals [31], hulls [32], and other residues (fruits and legumes) from crop production [33–35], can also be repurposed as poultry feed ingredients, thereby closing the loop in agricultural systems and promoting a circular economy. The adoption of these alternative feeding strategies can lead to significant reductions in the environmental impacts of poultry farming. For instance, insect-based feeds have been shown to lower greenhouse gas emissions [36] and reduce the reliance on water-intensive crops like soy. Additionally, it was recently reported in a case study [37] that by utilizing waste materials as feed, the poultry industry can contribute to reducing overall food waste, which is a significant challenge in the global food system.

2.4. Challenges in Implementing Sustainable Feeding Practices

While the benefits of sustainable feeding strategies are clear, several challenges hinder their widespread adoption, particularly when focusing on by-products, food waste, and plant-based alternatives. As recently mentioned in other studies focused on the valorization of food waste, one of the primary economic barriers is the variability in the availability and quality of by-products and food waste [38,39]. Unlike conventional feed ingredients, which are produced in large quantities with a consistent quality, by-products and food waste can vary significantly depending on their source, processing methods, and seasonal availability [40]. This inconsistency poses a challenge for formulating balanced poultry diets that meet nutritional requirements consistently. Another challenge is the presence of anti-nutritional factors and contaminants in plant-based alternatives and by-products. Many of these alternative feeds contain compounds such as tannins, phytic acid, and mycotoxins, which can interfere with the bioavailability of various components, nutrient absorption, and poultry health [41]. Another challenge is given by the influence of soil, climatic conditions, vegetation, and seasons, which will result in wastes with variability in their chemical composition. However, as recently reported, these issues can be addressed by additional processing steps, such as fermentation, enzyme treatment, or heat treatment [42], which later can increase costs and complexity for farmers, particularly those with limited resources.

The logistical challenges associated with collecting, processing, and distributing food waste and by-products also present significant barriers. Farmers often struggle to access alternative feed ingredients reliably and affordably due to the absence of established supply chains. Unlike traditional feeds that are mass-produced and distributed through established networks, by-products and food waste may need new infrastructure for collection, transportation, and storage. The same applies to food waste, which must be treated to make sure it is safe and nutritionally appropriate for poultry to eat. As reported by Salvador et al. [43], solutions to this concerning behavior are crucial for an adequate circular bioeconomy strategy. In addition, regulatory barriers can impede the adoption of sustainable feeding practices. Moreover, consumer perceptions and market acceptance play a crucial role in the success of these alternative feeding strategies [44]. There may be resistance to poultry products raised on diets that include by-products or food waste, especially in markets where traditional feeding practices are well established and preferred by consumers [44,45]. Educating consumers about the sustainability and environmental advantages of these practices as well as ensuring that the final poultry products meet high standards of quality and safety will be essential to building trust and acceptance.

3. The Purpose of Developing Alternative Poultry Feeding Practices

Current poultry feeding includes a variety of traditional and innovative methods designed to meet the nutritional needs of poultry, while improving productivity. Traditional poultry feeding practices are primarily based on well-established ingredients that have been shown to support poultry health and yield. Poultry feeding protocols are largely a matter of tradition, relying on standard ingredients known to help promote poultry health and production. Ingredients that are used frequently among traditional feed ingredients include grains, like corn and wheat, as primary energy sources, while soybean meal is mainly utilized in order to provide protein [46]. Some of these end products are mixed with animal by-products, fats, vitamins, and minerals. This results in a well-balanced diet tailored to the specific needs and growth of different poultry [42]. Balanced macronutrients (proteins, carbohydrates, and fats), as well as perfect combination of essential micronutrients (vitamins and minerals), are key factors to be considered in diet formulation for poultry. Formulating complete feed is important for the best performance and so as to avoid nutrient deficiencies, which can help to produce better chickens', health-wise, regarding their production qualities. However, even the most effective traditional diets are not without their pitfalls. A major challenge is the high costs and price fluctuations of common feed ingredients, such as corn and soybean meal [47,48]. These costs can be limitative for resource-limited smallholder farmers, affecting their profitability and sustainability. Furthermore, the heavy reliance on particular crops raises concerns about the environmental impact of their agriculture on the environment, with issues such as deforestation, water consumption, including its use, and greenhouse gas emissions. To address these challenges, there is growing interest in exploring alternative feed ingredients that can supplement or replace entirely, if possible, the conventional ones [42,49]. These ingredients can provide valuable nutrients while potentially reducing feed costs and environmental impacts. However, their nutritional profiles as shown in Table 1 and effects on poultry health, performance, and product quality need to be thoroughly evaluated to ensure they meet the birds' needs.

Table 1. Chemical composition and bioactive compounds determined in different plants, waste, and their co-/by-products.

Plant Family	Plant Common Name	Plant Part	Reported Proximal Composition	Reported Mineral Composition	Reported Lipid Composition	Reported Bioactive Compounds	Reference
Apiaceae	Carrot (*Daucus carota*)	waste	DM (88.29%), CP (6.11%), EE (0.92%), CF (7.03%), ash (6.27%)	NA	SFA (30.09%), MUFA (23.24%), PUFA 46.28%), n-3 (2.99%), n-6 (43.29%).	TPC (2.03 mg GAE/g dw), TFC 1.21 (mg QE/g dm), DPPH (4.28 mg TE/g dm), ABTS (14 mg TE/g dm), lycopene (3.19 µg/g dm), lutein (1.29 µg/g dm), β-carotene (59 µg/g dm), α-carotene (9.99 µg/g dm).	[33,50]
		orange carrot	NA	NA	NA	Lutein (17.2 µg/g dw), α-carotene (255 µg/g dw), β-carotene (1016.35 µg/g dw), TEAC (63.82 µmol TE/100 g fw), ORAC (250.7 µmol TE/100 g fw).	[51]
		black carrot	NA	NA	NA	Lutein (57.58 µg/g dw), α-carotene (21.87 µg/g dw), β-carotene (60.38 µg/g dw), anthocyanins (186.85 mg K Eq/100 g fw), TEAC (1026.43 µmol TE/100 g fw), ORAC (2159 µmol TE/100 g fw).	[51]
		purple carrot	NA	NA	NA	Lutein (37.42 µg/g dw), α-carotene (47.26 µg/g dw), β-carotene (247.45 µg/g dw), anthocyanins (55.13 mg K Eq/100 g fw), TEAC (470.21 µmol TE/100 g fw), ORAC (866.3 µmol TE/100 g fw).	[51]
		leaves	NA	NA	NA	TPC (3.26 mg GAE/g), TFC (1.80 mg RE/g), rutin (3738.50 µg/g dw), quercetin (236.53 µg/g dw).	[52]
		flour	NA	Ca (34 to 80 mg/100 g), P (25 to 53 mg/100 g), Fe (0.4 to 2.2 mg/100 g), Mn (9 mg/100 g),	NA	TPC (13.16 to 18.57 mg GAE/g), thiamine (0.04 mg/100 g), riboflavin (0.02 mg/100 g).	[53]
	Parnship (*Pastinaca sativa*)	root	DM (16.8 to 18.8%), monosaccharides (6.5 to 8%), disaccharides (33.8 to 37.2%),	Ca (1716 to 2436 mg/kg dw), Fe (41.9 to 65.3 mg/kg dw), Zn (12.6 to 19.6 mg/kg dw), P (3518 to 4225 mg/kg dw), Mg (1437 to 1963 mg/kg dw).	NA	TPC (3.6 mg GAE/g dw), TAC (10.6 mg GAE/g dw), DPPH (0.080 µmol TE/g dw).	[54]
	Celery (*Apium graveolens*)	bulb	DM (91.72 to 90.38%), CP (9.4%), CF (2.18%).	Ca (0.34%), K (3.90%), Mg (0.21%), P (0.59%) Zn (31.2 mg/kg), Fe (21 mg/kg),	NA	TPC (265.44 to 368.51 (µM chlorogenic acid/g), EC50 (2.41 to 3.14 mg/mL).	[55,56]
		leaves	NA	NA	NA	choline (1251 to 2224 µg/g), pantothenic acid (26 to 92 µg/g), riboflavin (37 to 79 µg/g), vitamin E (0.54 to 16.8 µg/g), rutin (143 to 267 µg/g), cyanidin (0.94 to 5.65 µg/g), elemicin (9.9 to 177 µg/g), xanthophyll (3 to 55 µg/g), ALA (3.26 to 21 µg/g), DPPH (84 to 90 inhibition ratio), O2 (24 to 97 inhibition ratio).	[57]
		petioles	NA	NA	NA	choline (405 to 626 µg/g), pantothenic acid (16 to 245 µg/g), riboflavin (4.4 to 12.2 µg/g), vitamin E (0.25 to 0.46 µg/g), rutin (6.75 to 35 µg/g), cyanidin (0.16 to 0.23 µg/g), elemicin (0.55 to 5.8 µg/g), xanthophyll (1.3 to 12 µg/g), ALA (0.17 to 0.36 µg/g), DPPH (23 to 39 inhibition ratio), O2 (14 to 25 inhibition ratio).	[57]
		entire plant	NA	NA	NA	Flavonoids (85.31 to 174.72 mg/100 g dw),apigenin (55.56 to 142.85 mg/100 g dw) luteolin (24.83 to 65.91 mg/100 g dw); phenolic acids (114.81 to 223.49 mg/100 g dw) caffeic (7.15 to 30.26 mg/100 g dw) ferulic (10.94 to 94.33 mg/100 g dw), p-coumaric (80.18 to 102.75 mg/100 g dw); TPC (3.48 to 5.02 mg GAE/100 g dw), DPPH (86.67 to 105.79 µmol TE/100 g dw), ABTS (81.90 to 114.38 µmol TE/100 g dw).	[58]
	Fennel (*Foeniculum vulgare*)	seed	CP (9.5 g/100 g), EE (10 g/100 g), carbohydrates (42.3 g/100 g), CF (18.5 g/100 g),	Ca (1.3 g/100 g) P (1.7 g/100 g)	NA	vitamin B1 and B2 (0.41 and 0.36 mg/100 g), niacin (6 mg/100 g), vitamin C (12 mg/100 g).	[59]
		shoots	CP (1.33 g/100 g), EE (0.49 g/100 g), carbohydrates (21.49 g/100 g), sugars (6.57 g/100 g),	NA	SFA (19.95%), MUFA (2.72%), PUFA (77.33%), n-3 (36.96%), n-6 (39.99%).	NA	[60]
		leaves	CP (1.16 g/100 g), EE (0.61 g/100 g), carbohydrates (18.44 g/100 g), sugars (1.29 g/100 g),	NA	SFA (27.99%), MUFA (4.96%), PUFA (67.05%), n-3 (43.72%), n-6 (23.25%).	NA	[60]
		stems	CP (1.08 g/100 g), EE (0.45 g/100 g), carbohydrates (19.39 g/100 g), sugars (4.92 g/100 g),	NA	SFA (33.81%), MUFA (4.78%), PUFA (61.04%), n-3 (23.04%), n-6 (38.22%).	NA	[60]
		inflorescences	CP (1.37 g/100 g), EE (1.28 g/100 g), carbohydrates (22.82 g/100 g), sugars (4.07 g/100 g),	NA	SFA (37.47%), MUFA (5.59%), PUFA (56.95%), n-3 (17.69%), n-6 (38.94%).	NA	[60]

Table 1. *Cont.*

Plant Family	Plant Common Name	Plant Part	Reported Proximal Composition	Reported Mineral Composition	Reported Lipid Composition	Reported Bioactive Compounds	Reference
Apiaceae	Anise (*Pimpinella anisum*)	seeds	CP (19.93 to 20.49 g/100 g DW), fiber (12.64 to 13.14 g/100 g), carbohydrates (49 g/100 g dw),	Fe (122.4 mg/kg), Ca (10.56 g/kg), K (33.16 g/kg).	NA	TPC (64.63 mg GAE/g), carotenoids (23.33 mg/100 g), tannins (83.31 mg), ALA (1.07%), catechin (3.31 ppm), chlorogenic (2.875 ppm), salicylic (1.704 ppm), coumarin (0.132 ppm), hypersoid (47.103 ppm), quercetin (17.239 ppm), luteolin (159.3 ppm), kaempferol (7.177 ppm), apigenin (6.88 ppm).	[61,62]
	Coriander (*Coriandrum sativum*)	leaves	CP 21.93 (g/100 g), EE 4.78 g/100 g), carbohydrate (52.10 g/100 g), CF (10.40 g/100 g),	Ca (1246 mg/100 g), Fe (42.46 mg/100 g), Mg (694 mg/100 g), P (481 mg/100 g), K (4466.mg/100 g), Na (211 mg/100 g), Zn (4.72 mg/100 g),	SFA (0.115 g/100 g), MUFA (2.232 g/100 g), PUFA (0.328 g/100 g)	vitamin C (566.7 mg/100 g), thiamine (1.252 mg/100 g), riboflavin (1.500 mg/100 g), niacin (10.707 mg/100 g), vitamin A, (293 µg/100 g).	[63]
		seeds	CP (12.37 g/100 g), EE (17.77 g/100 g), carbohydrate (54.99 g/100 g), CF (41.9 g/100 g),	Ca (709 mg/100 g), Fe (16.32 mg/100 g), Mg (330 mg/100 g), P (409 mg/100 g), K (1267 mg/100 g), Na (35 mg/100 g), Zn (4.70 mg/100 g).	SFA (0.990 g/100 g), MUFA (13.58 g/100 g), PUFA (1.75 g/100 g), SFA (12.13 g/100 g), UFA (87.87 g/100 g), n-6/n-3 (0.009),	vitamin C (21.0 mg/100 g), thiamine (0.239 mg/100 g), riboflavin (0.290 mg/100 g), niacin (2.130 mg/100 g), TPC (14.81 to 89.81 mg GAE/g extract), TFC (4.89 to 19.11 mg QE/g extract).	[63,64]
	Parsley (*Petroselinum crispum*)	leaves	CP (23.49%), EE 1.40%), CF (8.73%), ash (20.17%).	Zn (56.16 mg/kg), Fe (3817.7 mg/kg), Cu (12.64 mg/kg), Mn (121.59 mg/kg),	NA	vitamin E (25.33 mg/kg), TPC (304.57 to 425.76 mg GAE/100 g fw), TPC (7.71 mg GAE/g dw), DPPH (13.05 mM Trolox), TFC (141.39 to 185.47 mg GAE/100 g fw), vitamin C (73.39 to 162.09 mg/100 g fw), TAC (2.19 to 2.29 mM TE/L), carotenoids (0.08 to 0.16 mg/g).	[65,66]
		stem	NA	NA	NA	TPC (65.02 to 165.12 mg GAE/100 g fw), TFC (30.73 to 73.72 mg GAE/100 g fw), vitamin C (13.6 to 40.77 mg/100 g fw), TAC (1.25 to 2.24 mM TE/L), carotenoids (0.02 to 0.03 mg/g).	[66]
		root	NA	NA	NA	TPC (55.21 to 75.01 mg GAE/100 g fw), TFC (25.83 to 35.67 mg GAE/100 g fw), vitamin C (9.37 to 26.93 mg/100 g fw), TAC (0.69 to 0.98 mM TE/L).	[66]
	Dill (*Anethum graveolens*)	leaf blade	NA	NA	NA	vitamin C (159 to 186 mg/100 g fw), carotenoids (27.8 to 34.9 mg/100 g fw), β-carotene (4.07 to 5.62 mg/100 g fw), TPC (173 to 331 mg/100 g fw).	[67]
		petiole	NA	NA	NA	vitamin C (33 to 38 mg/100 g fw), carotenoids (6 to 6.8 mg/100 g fw), β-carotene (0.64 to 0.73 mg/100 g fw), TPC (54 to 92 mg/100 g fw).	[67]
		whole leaf	NA	NA	NA	vitamin C (116 to 138 mg/100 g fw), carotenoids (20.5 to 25.3 mg/100 g fw), β-carotene (2.79 to 3.95 mg/100 g fw), TPC (129 to 248 mg/100 g fw).	[67]
		stem	NA	NA	NA	vitamin C (29 to 39 mg/100 g fw), carotenoids (2 to 3.2 mg/100 g fw), β-carotene (0.2 to 0.25 mg/100 g fw), TPC (49 to 66 mg/100 g fw).	[67]
		whole plant	NA	NA	NA	vitamin C (55 to 116 mg/100 g fw), carotenoids (8.8 to 16.9 mg/100 g fw), β-carotene (1.32 to 3.57 mg/100 g fw), TPC (100 to 129 mg/100 g fw).	[67]
	Lovage (*Levisticum officinale*)	leaves + stems	CP (3.01 g/100 g fw), EE (0.37 g/100 g fw), carbohydrates (5.7 g/100 g fw), organic acids (1.26 g/100 g fw),	NA	SFA (18%), MUFA (2.93%), PUFA (79%), n-3 (49.2%), n-6 (29.9%)	vitamin E (0.80 mg/100 g fw).	[68]
		leaves	NA	NA	NA	protocatechuic (6.63 µg/g fw), hydroxybenzoic (3.56 µg/g fw), syringic (4.23 µg/g fw), vanillic (5.54 µg/g fw), synaptic (18.78 µg/g fw), salicylic (9.59 µg/g fw), caffeic (5.80 µg/g fw), ABTS (3.20 µM Trolox/g fw), RP (10.02 mg Trolox/g fw), iron chelation (711.71 mg EDTA/g fw).	[69]

Table 1. *Cont.*

Plant Family	Plant Common Name	Plant Part	Reported Proximal Composition	Reported Mineral Composition	Reported Lipid Composition	Reported Bioactive Compounds	Reference
Adoxaceae	American elderberry (*Sambucus canadensis* L.)	fruits	NA	NA	NA	TP (2898 to 4585 μg GAE/g fw), FRAP (13.4 to 31.7 μmol TE/g fw), DPPH (7 to 16.9 μmol TE/g fw), anthocyanins (1308 to 4004 (μg Cy−3GE/g fw).	[70]
	European elderberry (*Sambucus nigra* L.)	fruits	CP (2.7 to 2.9%), glucose (33.33 to 50.23 g/kg fw), fructose (33.99 to 52.25 g/kg fw)	K (2953 to 5494 mg/kg fw), P (735 to 1337 mg/kg fw), Ca (574 to 1528 mg/kg fw), Na (13 to 146 mg/kg fw), Mg (396 to 739 mg/kg fw), Fe (12.4 to 84.7 mg/kg fw), Zn (1.9 to 11.3 mg/kg fw), Mn (3.6 to 9.5 mg/kg fw), Cu (1.7 to 2.9 mg/kg fw)	NA	TPC (364 to 582 mg GAE/100 g fw), TPC (4917 to 8974 mg GAE/100 g dw), sambunigrin (0.08 to 0.77 μg/g fw).	[71]
		flowers	NA	Ca (2674 to 3334 μg/g), Mg (494 to 1556 μg/g), Fe (53 to 103 μg/g), Cu (6.5 to 13.8 μg/g), Zn (31.8 to 41.1 μg/g), Mn (19.7 to 49.7 μg/g), to 94.15%),	NA	TPC (1021.7 mg GAE/100 g fw), TPC (194 mg GAE/g dw), proteins (2.5%), sambunigrin (1.23 to 18.88 μg/g fw), DPPH (91.95 TFC (527 to 1319 mg RE/100 g dw).	[71,72]
Asteraceae	Jerusalem artichoke (*Helianthus tuberosus*)	tubers	CP (10.88 g/100 g dw), carbohydrate (81.67 g/100 g dw), inulin (78.22 g/100 g dw)	Ca (1.93 mg/g), K (10.56 mg/g), Zn (0.03 mg/g), P (4.17 mg/g), Na (0.15 mg/g), Fe (0.07 mg/g),	NA	TPC (4259.89 mg/kg).	[73]
		leaves	CP (5.65 to 21.40%), CF (21 to 27.4%), EE (1.52 to 6.14%)	Ca (102 to 760 mg/100 g), K (3.600 to 4.500 mg/100 g), Mg (60 to 690 mg/100 g), P (7 to 105 mg/100 g), Na (4 to 7 mg/100 g), Zn (4.40 to 7.20 mg/10 g), Fe (0.10 to 8 mg/100 g),		carotenoids (167.80 to 415.22 mg/100 g dw).	[74,75]
	Chicory (*Cichorium intybus*)	roots	DM (24.37%), CP (4.65%), ash (4.25%), EE (1.69%), carbohydrates (89.41%), inulin (44.69%)	Ca (181.26 mg/100 g), K (103.7 mg/100 g), Mg (20.14 mg/100 g), Na (67.42 mg/100 g), Fe (1.77 mg/100 g), Cu (0.36 mg/100 g), Mn (0.31 mg/100 g), Zn (0.39 mg/100 g), Pb (0.04 mg/100 g),	NA	TPC (20 mg GAE/g dw), protocatechuic acid (1.77%), chlorogenic acid (10.85%), caffeic acid (24.36%), m-coumaric acid (27.90%), p-coumaric acid (25.03%).	[76]
		leaves	CP (86.03%), EE (3.68%), ash (10,91%), carbohydrates (70.71%), inulin (10.95%),	Ca (292.61 mg/100 g), K (166.57 mg/100 g), Mg (6.94 mg/100 g), Na (88.84 mg/100 g), Fe (9.18 mg/100 g), Cu (0.60 mg/100 g), Mn (0.90 mg/100 g), Zn (0.91 mg/100 g), Pb (0.03 mg/100 g),	NA	TPC (26.4 mg GAE/g dw), protocatechuic acid (2.50%), chlorogenic acid (17.84%), p-hydroxybenzoic acid (11.04%), caffeic acid (35.22%), isovanillic acid (1.97%), p-coumaric acid (9.65%).	[76]
		seeds	CP (18.61%), EE (21.18%), ash (11.39%), CF (23.70%), carbohydrates (18.40%)	Cu (18.93 ppm), Zn (92.61 ppm), Mn (43.20 ppm), Fe (641 ppm)	NA	tannins (1.72 mg/g), vitamin C (23.85 mg/100 g).	[77]
	Calendula (*Calendula officinalis*)	flowers	CP (2.4 g/100 g), EE (5.6 g/100 g), ash (14 g/100 g), carbohydrates (78 g/100 g), sugars (11.7 g/100 g), organic acids (2830 mg/100 g),	NA	NA	tocopherols (23.33 mg/100 g), SFA (76.70%), MUFA (2.78%), PUFA (20.51%), TPC (4351 mg/100 g), TFC (4161 mg/100 g), TPA (190 mg/100 g), DPPH (4.6 EC50 mg/mL).	[78]
		leaves	NA	NA	NA	Total phenylpropanoids (3.23 to 20.17 mg/g dw), total quercetin derivatives (4.58 to 12.16 mg/g dw), TFC (6.11 to 15.74 mg/g).	[79]
	Dandelion (*Taraxacum mongolicum*)	flower	NA	Ca (328.33 mg/kg), Mg (5.19 mg/kg).	NA	DPPH (118.24 to 130.49 mg Trolox/g dw), FRAP (88.16 to 103.14 mg Trolox/g dw), TPC (26.06 mg GAE/g dw), TFC (4.98 mg QE/g dw), vitamin C (58.54 mg/kg), total carotenoids (43.56 mg/kg).	[80]
		leaves	NA	Ca (448.26 mg/kg), Mg (6.31 mg/kg).	NA	DPPH (121.18 to 135.14 mg Trolox/g dw), FRAP (98.23 to 119.27 mg Trolox/g dw), TPC (30.05 mg GAE/g dw), TFC (2.26 mg QE/g dw), vitamin C (106.49 mg/kg), total carotenoids (198.29 mg/kg), chlorophylls (427.18 mg/kg).	[80]
		stem	NA	Ca (366.28 mg/kg), Mg (4.23 mg/kg).	NA	DPPH (98.27 to 109.28 mg Trolox/g dw), FRAP (90.28 to 108.14 mg Trolox/g dw), TPC (23.89 mg GAE/g dw), vitamin C (96.89 mg/kg), chlorophylls (47.21 mg/kg), total carotenoids (24.87 mg/kg).	[80]
		roots	NA	Ca (408.21 mg/kg), Mg (2.17 mg/kg).	NA	DPPH (50.89 to 61.36 mg Trolox/g dw), FRAP (45.34 to 53.54 mg Trolox/g dw), TPC (4.23 mg GAE/g dw), vitamin C (18.02 mg/kg).	[80]
	Lettuce (*Lactuca sativa*)	red	NA	NA	NA	TPC (64.90 mg/100 g dw), TFC (291.6 mg/100 g dw), anthocyanins (23.7 mg/100 g dw), carotenoids (108.3 mg/g), lutein (51.5 mg/g), β-carotene (48.3 mg/g), DPPH (77.5 μL/mL).	[81]
		green	NA		NA	TPC (49.4 mg/100 g DW), TFC (223 mg/100 g dw), anthocyanins (7.4 mg/100 g dw), carotenoids (92.4 mg/g), lutein (39.4 mg/g), β-carotene (44.4 mg/g), DPPH (77.2 μL/mL).	[81]
		red oak	NA	Fe (1.21 to 1.79 mg/kg), Zn (103.6 to 146.3 mg/kg).	NA	Chlorophyll (10.70 to 27.40 mg 100/g fw), β-carotene (11.98 to 16.45 mg 100/g fw), vitamin C (25 to 30.61 mg 100/g fw), TPC (1.61 to 2.81 mg GAE/100 g fw), DPPH (46.26 to 48.46 mg GAE/100 g fw), ABTS (2.64 to 6.05 mg TEAC/100 g fw), FRAP (126.75 to 127.46 mg TEAC/100 g fw).	[82]

Table 1. *Cont.*

Plant Family	Plant Common Name	Plant Part	Reported Proximal Composition	Reported Mineral Composition	Reported Lipid Composition	Reported Bioactive Compounds	Reference
Asteraceae	Lettuce (*Lactuca sativa*)	green oak	NA	Fe (1.17 to 1.82 mg/kg), Zn (99.1 top 122.7 mg/kg).	NA	Chlorophyll (17.64 to 34.55 mg 100/g fw), β-carotene (9.22 to 13.12 mg 100/g fw), vitamin C (9.52 to 21.55 mg 100/g fw), TPC (0.71 to 0.86 mg GAE/100 g fw), DPPH (37.69 to 44.99 mg GAE/100 g fw), ABTS (0.88 to 3.02 mg TEAC/100 g fw), FRAP (15.59 to 87.74 mg TEAC/100 g fw).	[82]
		green curly	NA	Zn (87.4 to 118.4 mg/kg), Fe (1.09 to 1.73 mg/kg).	NA	Chlorophyll (11.55 to 34.61 mg 100/g fw), β-carotene (6.59 to 13.90 mg 100/g fw), vitamin C (13.49 to 26.50 mg 100/g fw), TPC (0.39 to 1.14 mg GAE/100 g fw), DPPH (42.85 to 54.76 mg GAE/100 g fw), ABTS (1.31 to 2.53 mg TEAC/100 g fw), FRAP (16.85 to 110.24 mg TEAC/100 g fw).	[82]
		lollo rossa	NA	Fe (1.39 to 1.69 mg/kg), Zn (85.3 to 99.7 mg/kg).	NA	Chlorophyll (16.40 to 25.73 mg 100/g fw), β-carotene (8.63 to 13.07 mg 100/g fw), vitamin C (27.67 to 29.97 mg 100/g fw), TPC (1.78 mg GAE/100 g fw), DPPH (45.43 to 50.89 mg GAE/100 g fw), ABTS (2.33 to 4.80 mg TEAC/100 g fw), FRAP (99.58 to 127.57 mg TEAC/100 g fw).	[82]
		bativa	NA	Fe (1.87 mg/kg), Zn (109 mg/kg).	NA	Chlorophyll (23.84 mg 100/g fw), β-carotene (9.57 mg 100/g fw), vitamin C (25.11 mg 100/g fw), TPC (0.96 mg GAE/100 g fw), DPPH (44.76 mg GAE/100 g fw), ABTS (2.46 mg TEAC/100 g fw), FRAP (122.88 mg TEAC/100 g fw).	[82]
	Artichoke (*Cynara cardunculus*)	receptacle	DM (9.9 to 16 g/100 g), CP (189 to 269 g/100 g)	Ca (3.4 to 7.3 g/kg), Mg (0.8 to 1.4 g/kg), Na (0.6 to 0.9 g/kg), K (16.4 to 18.6 g/kg), Fe (25.8 to 31.4 g/kg), Zn (19 to 28.8 g/kg), Mn (5.8 to 10.2 g/kg), Cu (4.5 to 7.5 g/kg)	NA	TPC (2.5 to 6 g/kg fw), inulin (185 to 265 g/kg DM).	[83]
		heads	DM (16 to 25 g/100 g fw), EE (0.26 to 0.57 g/100 g fw), ash (1.01 to 1.67 g/100 g fw), CP (1.69 to 4.25 g/100 g fw), carbohydrates (13.49 to 19.09 g/100 g fw)	K (276 to 579 mg/100 g fw), Na (17 to 104 mg/100 g fw), Ca (158 to 861 mg/100 g fw), Mg (31 to 91 mg/100 g fw), Mn (0.68 to 1.17 mg/100 g fw), Fe (1.7 to 2.90 mg/100 g fw), Zn (0.48 to 1.17 mg/100 g fw)	SFA (39.28 to 69.7%), MUFA (2.26 to 10.3%), PUFA (23.08 to 57.36%), n-6/n-3 (4.64 to 7.95)		[84]
	Yarrow (*Achillea millefolium*)	wild inflorescences and upper leaves	CP (12.53 g/100 g dw), EE (5.20 g/100 g dw), Ash (6.43 g/100 g dw), Carbohydrates (75.84 g/100 g dw), sugars (3.14 g/100 g dw), organic acids (4.55 g/100 g dw)	NA	SFA (22.09 g/100 g fat), MUFA (28.75 g/100 g fat), PUFA (49.16 g/100 g fat)	Total tocopherols (16.62 mg/100 g dw).	[85]
		commercial inflorescences and upper leaves	CP (19.53 g/100 g dw), EE (8.03 g/100 g dw), Ash (8.54 g/100 g dw), Carbohydrates (63.90 g/100 g dw), sugars (4.86 g/100 g dw), organic acids (4.46 g/100 g dw),	NA	SFA (44.06 g/100 g fat), MUFA (12.64 g/100 g fat), PUFA (43.30 g/100 g fat),	Vitamin E (15.16 mg/100 g dw).	[85]
Arecaceae	Coconut (*Cocos nucifera*)	shell	DM (89.9%), CP 0.46%), ash (2.28%), CF 32.39%), EE (2.14%), carbohydrate 52.63%),	P (11.64 mg/100 g), Ca (16.02 mg/100 g), Mg (1.22 mg/100 g), Na (0.76 mg/100 g), K (3.30 mg/100 g), Fe (618 mg/100 g), Zn (1.20 mg/100 g), Mn (6 mg/100 g).	NA	NA	[86]
Brassicaceae	Rapeseed (*Brassica napus*)	meal	DM (89.25%), CP (33.56%), EE (15.07%), CF (10.10%),	NA	SFA (16.83 mg/100 g), MUFA (42.90 mg/100 g), PUFA (40.26 mg/100 g), n-3 (4.42 mg/100 g), n-6 (35.85 mg/100 g),	TPC (7.95 mg GAE/g), TAC (24.57 mM Trolox/g), TFC (4.51 µg rutin/g).	[5]
		seeds	DM (92.99 to 93.98%), CP (17.42 to 21.01%), EE (40.58 to 54.20%), CF (7.16 to 23.20%), ash (3.60 to 9.02%),	NA	n-3 (9.64 mg/100 g), n-6 (24.70 to 33.90 mg/100 g).	NA	[87]
		cake	DM (89.50 to 95.30%), CP (28 to 36.10%), EE (12.20 to 17.80%), CF (11.20 to 13.10%), ash (5.60 to 7.10%),	NA	n-3 (13.05 mg/100 g), n-6 (21.96 mg/100 g).	NA	[87]
	Kale (*Brassica oleracea*)	leaves	DM (17.08%), CP (4.06 g/100 g), EE (0.67 g/100 g), ash (2.11 g/100 g), carbohydrates (10.14 g/100 g), CF (8.39 g/100 g)	Na, (38.5 mg/100 g), K, (440.2 mg/100 g), Ca, (384.8 mg/100 g), Mg, (34.9 mg/100 g), Zn, (0.83 mg/100 g)	NA	Vitamin C (62.27 mg/100 g), β-carotene, (6.40 mg/100 g), TPC (574.95 mg/100 g), ABTS (33.22 µm Trolox/g).	[88]
	Mustard (*Brassica juncea*)	seeds	DM (92.85%), CP (33.93), EE (14.71%), CF (20.76%), ash (5.23%),	Cu (30.55 mg/kg), Fe (201.25 mg/kg), Mn (59.18 mg/kg), Zn (111.35 mg/kg),	NA	Vitamin E (243.8 mg/kg), lutein 7.163 mg/kg), canthaxanthin (1.02 mg/kg), β-carotene (52.28 mg/kg), TPC (28.47 mg GAE/g), TAC (33.78 mM eq. Trolox).	[89]
	Cabbage (*Brassica oleracea*)	waste	DM (89.65 g/100 g), CP (12.28 g/100 g), EE (0.80 g/100 g), ash (18.05 g/100 g), Carbohydrate (59.59 g/100 g),	Ca (1671.11 mg/100 g), Mg (292.68 mg/100 g), Fe (3.79 mg/100 g), Zn (3.64 mg/100 g), K (8582 mg/100 g), Cu (0.24 mg/100 g), Mn (6.04 mg/100 g), Na (75.41 mg/100 g).	NA	NA	[90]

Table 1. *Cont.*

Plant Family	Plant Common Name	Plant Part	Reported Proximal Composition	Reported Mineral Composition	Reported Lipid Composition	Reported Bioactive Compounds	Reference
Cannabaceae	Hemp (*Cannabis sativa*)	seeds	DM (94.47%), CP (23.93%), EE (31.86), NDF (54.08%), ADF (31.25%)	NA	SFA (10.70%), MUFA (10.92%), PUFA (77.72%), n-6 (57.35%), n-3 (20.37%).	α-tocopherol (20.05 µg/g), β-carotene (4.13 µg/g), TPC (6.41 mg GAE/g).	[91]
Cucurbitaceae	Pumpkin (*Cucurbita pepo*)	flesh	DM (3.23 g/kg fw), CP (2.08 g/kg fw), EE (0.55 g/kg fw), CF (3.72 g/kg fw), ash (3.44 g/kg fw),	NA	NA	α-tocopherol (1.40 mg/kg fw), β-carotene (1.48 mg/kg fw).	[92]
		peel	DM (6.40 g/kg fw), CP (9.25 g/kg fw), EE (4.71 g/kg fw), CF (12.28 g/kg fw), ash (6.30 g/kg fw),	NA	NA	α-tocopherol (4.49 mg/kg fw), β-carotene (39.48 mg/kg fw)	[92]
		seeds	DM (25.94 g/kg fw), CP (308.83 g/kg fw), EE (439.88 g/kg fw), CF (148.42 g/kg fw), ash (55.02 g/kg fw),	NA	SFA (18.62%), MUFA (32.40%), PUFA (36.40%),	α-tocopherol (21.33 mg/kg fw), β-carotene (17.46 mg/kg fw).	[92]
	Cucumber (*Cucumis sativus*)	fruits	DM (15.8%), CP (3.01%), CF (1.02%), ash (0.94%), EE (0.55%), carbohydrates (0.28%),	NA	NA	Tannins (1.26 mg/g), polyphenols (8.51 mg/g), phenols (7.72 mg/g), glycosides (32.23 mg/g), reducing sugars (574.36 mg/g), saponins (2.01 mg/g), alkaloids (2.22 mg/g), flavonoids (2.14 mg/g), terpenoids (26.27 mg/g), steroids (11.69 mg/g), resins (50.70 mg/g).	[93]
	Watermelon (*Citrullus lanatus*)	rind	DM (16.35%), ash (0.23%), CF (0.23%), CP (0.53%)	Ca (0.095 ppm), Fe (0.144 ppm), Mg (0.107 ppm), Zn (0.058 ppm), Na (0.085 ppm), K (0.114 ppm).	NA	NA	[94]
		pulp	DM (5.53%), ash (0.31%), CF (0.45%), CP (0.34%),	Ca (0.136 ppm), Fe (0.242 ppm), Mg (0.167 ppm), Zn (0.086 ppm), Na (0.140 ppm), K (0.158 ppm).	NA	NA	[94]
	Pumpkin (*Cucurbita moschata*)	seed meal	DM (91.90%), CP (26.16%), EE (26.44%), CF (21.11%)	NA	PUFA (51.22 g/100 g), n-6 (48.75 g/100 g), n-3 (2.47 g/100 g), n-6/n-3 ratio (19.73)	TPC (25. 01 mg GAE/g), TAC (14. 80 mM Trolox), TFC (80 µg rutin/g).	[95]
Elaeagnaceae	Sea buckthorn (*Hippophae rhamnoides*)	leaves	DM (91.63%), CP (14.48%), EE (5.12%), CF (13.68%), ash (6.37%)	NA	SFA (30.76%), MUFA (32.66%), PUFA (35.65%), UFA (68.31%),	TPC (58.61 mg/g GAE), TFC, 9.03 mg/g QE, lutein and zeaxanthin (583.4 µg/g), Vitamin E, 321.29 µg/g, TAC, 1147.91 µM Trolox, Co (3.05 mg/kg), Fe (334.79 mg/kg), Mg (159.59 mg/kg), Zn (126.78 mg/kg).	[96]
		seed meal	DM (89.36%), CP (11.44%), EE (8.92%), CF (23.26%)	NA	SFA (23.69 g/100 g), MUFA (45.39 g/100 g), PUFA (30.44 g/100 g), n-3 (5.04 g/100 g), n-6 (25.40 g/100 g),	TPC (90.72 mg GAE/g), TAC (118.50 mM Trolox), TFC (120.01 µg rutin/g).	[31]
	Elaeagnus Angustifolia	leaves	NA	NA	NA	TPC (7.78 to 10.91 mg GAE/100 g fw), TFC (4.81 to 5.20 mgQE/100 g fw).	[97]
		flowers	NA	NA	NA	TPC (4.63 to 6. 24 mg GAE/100 g fw), TFC (1.43 to 2.35 mgQE/100 g fw).	[97]
		fruits	DM (80 to 89.8%), EE (24.45 to 30.13%),	NA	SFA (8.82 to 12.16%), MUFA (28.71 to 34.18%), PUFA (54.58 to 59.08%)	TPC (46.1 to 138.7 mg GAE/100 g dw), TAC (1.4 to 50.3 µmol TE/g dw), TFC (8.01 to 135.2 mg CE/100 g dw).	[98]
Ericaceae	Cranberry (*Vaccinium macrocarpon*)	leaves	DM (93.11%), CP (6.63%), EE (2.52%), CF (20.15%), ash (3%),	Cu (2.18 mg/kg), Fe (114.6 mg/kg), Mn (448.9 mg/kg), Zn (33.88 mg/kg)	NA	NA	[99]
Fabaceae	Alfalfa (*Medicago sativa*)	plant pellets	CP (17.06%), EE (1.31%), CF (26.21%), ash (11.89%),	Cu (7.26 mg/kg), Fe (2318 mg/kg), Mn (57.12 mg/kg), Zn (31.24 mg/kg),	SFA (29.73 g/100 g), MUFA (9.87 g/100 g), PUFA (59.72 g/100 g), n-3 (41.97 g/100 g), n-6 (17.75 g/100 g).	TPC (31.24 mg GAE/g), TAC (17.78 mM Trolox), luetin and zeaxantin (28.53 mg/kg), vitamin E (53.17 mg/kg).	[100]
	Pea (*Pisum sativum*)	seeds	DM (93.1 to 90.82%), CP (20.51 to 23.80%), EE (2.19 to 2.63%), CF (9.14 to 11.24%), ash (3.16 to 3.72%), carbohydrates (50.86 to 56.54%),	NA	NA	α-tocopherol (10.9 to 13.3 mg/100 g).	[101]
	Lentil (*Lens culinaris*)	seeds	DM (94.4 to 92.12%), CP (20.5 to 25.5%), EE (0.78 to 1.25%), ash (2.59 to 3.40%), CF (20.90 to 29.11%), carbohydrates (64.3 to 69.8%), sugars (2.47 to 3.08 g/100 g FW),	NA	SFA (15.4 to 20.8%), MUFA (22.8 to 33.9%), PUFA (45.3 to 63.7%).	Tocopherols (6.46 to 10.1 mg/100 g fw).	[102]

Table 1. *Cont.*

Plant Family	Plant Common Name	Plant Part	Reported Proximal Composition	Reported Mineral Composition	Reported Lipid Composition	Reported Bioactive Compounds	Reference
Fabaceae	Mung Bean (*Vigna radiata*)	seeds	CP (17.36 to 24.89 g/100 g), EE (4.24 to 12.18 g/100 g), ash (2.78 to 3.53 g/100 g),	NA	NA	TPC (2.87 to 3.81 mg GAE/g), TFC (1.44 to 3.52 mg RE/g).	[103]
Juglandaceae	Walnuts (*Juglans regia*)	meal	DM (92.88%), CP (29.47%), EE (16.24%), CF (18.41%), ash (3.88%),	Cu (19.66 mg/kg), Fe (225.35 mg/kg), Mg (72.57 mg/kg), Zn (185.21 mg/kg),	NA	TAC (32.77 mM Trolox), vitamin E (69.32 mg/kg), lutein and zeaxanthin (2.90 mg/kg), phenolic acids (971.27 mg/100 g), Flavonoids (169.02 mg/100 g).	[99]
Lamiaceae	Spearmint (*Mentha spicata*)	leaves	DM (914 g/100 g dw), CP (2.3 g/100 g dw), EE (0.4 g/100 g dw), ash (1.7 g/100 g dw),	NA	NA	Carbohydrates (9.6 g/100 g DW), TPC (76.32 mg/g).	[104]
	Basil (*Ocimum basilicum*)	leaves	DM (91.35%), CP, 22.53%), EE, (1.51%), CF (12.22%), ash (14.12%),	Cu (27.69 mg/kg), Fe (624.51 mg/kg), Mn (78.46 mg/kg), Zn (54.63 mg/kg),	SFA (40.52%), MUFA (21.99%), PUFA (36.57%)	TPC (21.53 mg GAE/g), TAC (42.66 mM Trolox), vitamin E (291.71 mg/kg), lutein and zeaxanthin (267.91 mg/kg).	[24]
	Thyme (*Thymus vulgaris*)	leaves	DM (91.65%), CP (15.38%), EE (2.09%), CF (17.08%), ash (9.43%),	Cu (7.41 mg/kg), Fe (690.05 mg/kg), Mn (96.11 mg/kg), Zn (31.74 mg/kg),	SFA (43.86%), MUFA (11.98), PUFA (43.19%),	TPC (31.73 mg GAE/g), TAC (54.09 mM Trolox), vitamin E (379.37 mg/kg), lutein and zeaxanthin (535.79 mg/kg).	[24]
	Sage (*Savia officinalis*)	leaves	DM (90.64%), CP (9.56%), EE (3.15%), CF (27.92%), ash (10.36%),	Cu (7.89 mg/kg), Fe (732.72 mg/kg), Mn (68.92 mg/kg), Zn (38.87 mg/kg),	SFA (38.79%), MUFA (19.70%), PUFA (40.96%).	TPC (38.87 mg GAE/g), TAC (19.91 mM Trolox), vitamin E (148.07 mg/kg), lutein and zeaxanthin (99.89 mg/kg)	[24]
	Rosemary (*Rosmarinus officinalis*)	leaves	CP (5.35%), EE (3.62%), CF (22.25%), ash (6.61%),	Ca (0.14 mg/g), Fe (37.14 mg/g), Mn (2.20 mg/g), Zn (3.12 mg/g),	NA	TPC (53.42 mg GAE/g), vitamin E (15.61 mg/g), lutein and zeaxanthin (7.63 mg/g).	[105]
Liliaceae	Garlic (*Allium sativum*)	bulb	DM (41.9%), monosaccharides (2.6%), disaccharides (39.4%).	Ca (468 mg/kg dw), Fe (30 mg/kg dw), Zn (17.1 mg/kg dw), P (2825 mg/kg dw), Mg (540 mg/kg dw).	NA	TPC (3.7 mg GAE/g dw), TAC (8.3 mg GAE/g dw), DPPH (0.090 µMol TE/g dw).	[54]
		leaves	DM (13.31%), CP (29.25 g/100 g), ash (10.36 g/100 g), CF (38.86 g/100 g), EE (3.18 g/100 g), carbohydrates (57.22 g/100 g),	NA	NA	Ascorbic acid (9.65 mg/100 g fw), TPC (241.73 mg CGA/g fw), TAC (29.51 µmol TEAC/g fw).	[106]
	Onion (*Allium cepa*)	waste	DM (6.3 to 51.9%), CP (2.3 to 15.6%), ash (4.4 to 10.6%),	Ca (1.8 to 30.7 mg/g), Mg (0.6 to 1.5 mg/g), Fe (19.6 to 888.9 µg/g), Zn (14.9 to 53.8 µg/g), Mn (6.5 to 28.8 µg/g), Se (0.03 to 0.93 µg/g), K (4.2 to 15.9 mg/g)	NA	TPC (9.4 to 52.7 mg GAE/g), TFC (7 to 43.1 mg QE/g).	[107]
	Asparagus (*Asparagus officinalis*)	whole plant	CP (2.2 g/100 g), EE (0.12 g/100 g), CF (2.1 g/100 g), sugars (1.9 g/100 g),	Ca (24 mg/100 g), Cu (0.19 mg/100 g), Fe (2.14 mg/100 g), Mg (14 mg/100 g), Mn (0.158 mg/100 g), K (202 mg/100 g), Se (2.3 µg/100 g), Na (2 mg/100 g), Zn (0.54 mg/100 g).	NA	Vitamin B1 (0.143 mg/100 g), vitamin B2 (0.141 mg/100 g), vitamin B3,(0.978 mg/100 g), vitamin B9, (52 µg/100 g), vitamin C (5.6 mg/100 g), vitamin E (1.13 mg/100 g), vitamin K (41.6 µg/100 g).	[108]
Musaceae	Plantain (*Musa paradisiaca*)	peel	DM (95.62%), ash (6.17%), CP (3.97%), CF (8.36%), EE (3.01%), carbohydrate (74.12%),	Cu (1.35 mg/100 g), Fe (5.06 mg/100 g), Mn (10.38 mg/100 g), Zn (11.60 mg/100 g), Ca (17.85 mg/100 g), Mg (49.32 mg/100 g), Na (58.16 mg/100 g), K (38.22 mg/100 g), P (22.64 mg/100 g).	NA	NA	[109]
	Banana (*Musa* spp.)	peel	DM (90.17%), ash (9.56%), CP (3.23%), CF (12.67%), EE (0.89%), carbohydrate (63.82%),	Cu (0.59 mg/100 g), Fe (7.89 mg/100 g), Mn (1.25 mg/100 g), Zn (13.30 mg/100 g), Ca (14.70 mg/100 g), Mg (45.21 mg/100 g), Na (76.88 mg/100 g), K (26.14 mg/100 g), P (28.95 mg/100 g).	NA	NA	[109]
Oleaceae	Olive (*Olea europaea*)	seeds	EE (30.4%), CP (17.2%), CF (47.6%), insoluble fibre (32.7%), ash (2.67%), carbohydrates (2.13%),	K (5579.0 mg/kg), Na (2758.2 mg/kg), Ca (2615.4 mg/kg), Mg (1878.5 mg/kg), P (745.5 mg/kg), Fe (12.8 mg/kg), Zn (45.6 mg/kg), Mn (31.5 mg/kg).	SFA (12.34%), MUFA (62.78%), PUFA (24.63%),	α-tocopherol (401 mg/kg), campesterol (72.7 mg/kg), stigmasterol (53.9 mg/kg), β-Sitosterol (1674.9 mg/kg), lanosterol (10.5 mg/kg), cycloartenol (109.7 mg/kg), citrostadienol (17.2 mg/kg), 24-methylenecycloartanol (365.3 mg/kg).	[110]

Table 1. *Cont.*

Plant Family	Plant Common Name	Plant Part	Reported Proximal Composition	Reported Mineral Composition	Reported Lipid Composition	Reported Bioactive Compounds	Reference
Rosaceae	Apple (*Malus domestica*)	peel	NA	K (695.3 to 980.9 mg/100 g dw), Ca (35.6 to 61.2 mg/100 g dw), Mg (18.5 to 65.9 mg/100 g dw), Na (2.9 to 7.3 mg/100 g dw), Zn (0.4 to 1.2 mg/100 g dw), Fe (1.1 to 2.4 mg/100 g dw).	NA	TPC (1907.5 to 2587.9 mg GA/100 g dw), TFC (1214.3 to 1816.4 mg catechin eq./100 g dw).	[111]
		pulp	NA	K (490.1 to 790.1 mg/100 g dw), Ca (19.8 to 36.7 mg/100 g dw), Mg (15.6 to 34.8 mg/100 g dw), Na (5.9 to 10.8 mg/100 g dw), Zn (0.2 to 0.9 mg/100 g dw), Fe (0.8 to 2.1 mg/100 g dw).	NA	TPC (1185.2 to 1475.5 mg GA/100 g dw), TFC (711.8 to 999.3 mg catechin eq/100 g dw).	[111]
	Rosehip (*Rosa canina*)	meal	DM (92.37%), CP (10.53%), EE (4.48%), CF (49.53%)	NA	PUFA (67.65 g/100 g), MUFA (22.80 g/100 g), SFA (9.55 g/100 g), n-3 (14.28 g/100 g), n-6 (53.07 g/100 g).	TPC (60.23 mg GAE/g), TAC (23.87 mM Trolox), TFC (12.18 mg eq rutin/g).	[6]
		seeds	DM (989.7 g/100 g fw), CP (2.99 g/100 g dw), EE (6.29 g/100 g dw), ash (1.64 g/100 g dw), carbohydrate (89.07 g/100 g dw)	NA	NA	TPC (2554 µg/g), carotenoids (2.92 µg/g), vitamin C (1798 µg/g).	[112]
	Raspberry (*Rubus* spp.)	leaves	DM (92.3 g/100 g dw), CP (19.54 g/100 g dw), EE (2.06 g/100 g dw), CF (18.18 g/100 g dw), ash (5.14 g/100 g dw),	Cu (4.09 mg/kg dw), Fe (172.5 mg/kg dry dw), Mn (75.23 mg/kg dry dw), Zn (46.14 mg/kg dry dw), Ca (0.66 g/100 g dw), P (0.28 g/100 g dw),	SFA (33.35%), MUFA (19.88%), PUFA (46.64%), n-3 (66.53%), n-6 (34.48%),	Lutein (261 mg/kg), zeaxanthin (1040 mg/kg), astaxanthin (38.52 mg/kg), canthaxanthin (1.12 mg/kg), vitamin E (149.7 mg/kg), TPC (26.19 mg GAE/g), TFC (10.6 mg/g).	[113]
	Blackberry (*Rubus* spp.)	leaves	DM (91.66 g/100 g dw), CP (18.37 g/100 g dw), EE (1.89 g/100 g dw), CF (20.48 g/100 g dw), ash (6.2 g/100 g dw),	Cu (6.51 mg/kg dw), Fe (115.6 mg/kg dry dw), Mn (80.63 mg/kg dry dw), Zn (23.81 mg/kg dry dw), Ca (1.01 g/100 g dw), P (0.29 g/100 g dw),	SFA (24.56%), MUFA (10.31%), PUFA (64.20%), n-3 (74.51%), n-6 (50.80%)	Lutein (547.1 mg/kg), zeaxanthin (3041 mg/kg), astaxanthin (38.52 mg/kg), canthaxanthin (3.04 mg/kg), vitamin E (179.9 mg/kg), TPC (14.57 mg GAE/g), TFC (5.961 mg/g).	[113]
	Strawberry	leaves	CP (80.63 mg/g)	NA	NA	TPC (108.83 mg GAE/g), TFC (10.25 mg QE/g), carotenoids (0.0074 mg/g dw).	[114]
	Aronia (*Aronia melanocarpa*)	fruits	DM (91.76%), CP (1.53%), EE (4.17%), CF (8.29%), ash (2.01%), carbohydrates (75.78%),	Fe (72.93 mg/kg), Mn (4.54 mg/kg), Zn (6.67 mg/kg),	SFA (10.78%), MUFA (23.08%), PUFA (66.13%), n-3 (2.04%), n-6 (64.09%)	NA	[115]
		leaves	DM (90.92%), CP (10.11%), EE (6.75%), CF (13.33%), ash (7.82%), carbohydrates, (52.93%),	Fe (94.29 mg/kg), Mn (205.48%), Zn (20.13 mg/kg),	SFA (30.20%), MUFA (9.16%), PUFA (67.14%), n-3 (29.99%), n-6 (30.50%).	NA	[115]
		pomace	DM (94.9%), CP (5.25%), EE (2.51%), CF (14.3%), ash (2.41%), carbohydrates (70.44%),	Fe (94.27 mg/kg), Mn (15.3 mg/kg), Zn (10.54 mg/kg),	SFA (12.09%), MUFA (20.21%), PUFA (67.14%), n-3 (3.45%), n-6 (63.69%).	NA	[115]
Rutaceae	Orange (*Citrus* × *aurantium*)	peel	CP (4.85%), EE (1.10%), CF (9.70%), ash (2.95%),	Zn (4.74 mg/kg),	NA	Vitamin E (100.5 mg/kg), lutein and zeaxanthin (81.52 mg/kg), TPC (8.035 mg GAE/g), TAC (238.51 mmoli/kg eq. vitamin C), TAC (231.33 mmoli/kg eq. vitamin E).	[116]
	Grapefruit (*Citrus* × *paradisi*)	peel	CP (5.39%), EE (0.95%), CF (11.82%), ash (3.51%),	NA	NA	Vitamin E (89.93 mg/kg), lutein and zeaxanthin (36.46 mg/kg), TPC (12.162 mg GAE/g), Zn (5.41 mg/kg), TAC (238.25 mmoli/kg eq. vitamin C), TAC (227.75 mmoli/kg eq. vitamin E).	[116]
	Lemons (*Citrus* × *limon*)	peel	CP (9.42%), CF (15.18%), EE (4.98%), ash (6.26%).	Na (755.5 mg/100 g), K (8600 mg/100 g), Ca (8452.5 mg/100 g), Cu (4.94 mg/100 g), Fe (147.65 mg/100 g), Mg (1429.5 mg/100 g), Zn (13.94 mg/100 g), P (6656.25 mg/100 g).	NA	NA	[117]
Solanaceae	Tomato (*Solanum lycopersicum*)	waste	DM (95.19%), CP (13.58%), EE (3.53), CF (43.6%), ash (3.59%),	NA	PUFA (57.31 g/100 g), n-6 (53.08 g/100 g), n-3 (4.23 g/100 g),	Astaxanthin (0.076 mg/kg), lutein (3.57 mg/kg), zeaxanthin (0.78 mg/kg), cantaxanthin (0.27 mg/kg), lycopene (105.38 mg/kg), β-carotene (9.50 mg/kg).	[50]
	Bell Pepper (*Capsicum annuum*)	fruit	DM (7.8 g), CP (0.99 g), EE (0.30 g), ash (0.47 g), CF (2.1 g), g), carbohydrates (6.03 g).	Na (4 mg), K (211 mg), Ca (7 mg), Mg (12 mg), P (26 mg),	NA	Niacin (0.979 mg), pyridoxine (0.291 mg), vitamin C (127.7 mg), vitamin E (1.58 mg), TPC (4.51 to 52.65 mg GAE/g), TFC (2.1 to 41 QE mg/g), carotenoids (1219 to 8800 µg/g).	[118]
	Eggplant (*Solanum melongena*)	fruit	CP (0.86 g/100 g fw), EE (0.05 g/100 g fw), Ash (0.56 g/100 g fw), carbohydrates (3 g/100 g fw), total sugars (3 g/100 g fw),	NA	SFA (83.8%), MUFA (4.5%), PUFA (11.8%).	NA	[119]
		pulp	CP (0.78 g/100 g fw), EE (0.04 g/100 g fw), Ash (0.56 g/100 g fw), carbohydrates (2.89 g/100 g fw), total sugars (2.89 g/100 g fw).	NA	SFA (89.6%), MUFA (5.5%), PUFA (4.89%).	NA	[119]

Table 1. *Cont.*

Plant Family	Plant Common Name	Plant Part	Reported Proximal Composition	Reported Mineral Composition	Reported Lipid Composition	Reported Bioactive Compounds	Reference
Vitaceae	Grape (*Vitis vinifera*)	pomace	DM (89.92%), CP (12.33%), EE (5.95%), CF (35.17%), ash (2.83%),	NA	SFA (30.06 g/100 g), MUFA (42.63 g/100 g), PUFA (66.60 g/100 g), n-3 (1.12 g/100 g), n-6 (65.48 g/100 g),	TPC (26.65 mg GAE/g), TAC (148.35 mM TE/g 148.35).	[120]
		seed meal	DM (91.85%), CP (12.9%), CF (7.22%),	NA	SFA (12.30 g/100 g), MUFA (20.39 g/100 g), PUFA (67.14 g/100 g), n-3 (0.68 g/100 g), n-6 (66.45 g/100 g).	TPC (90.42 mg GAE/g), TAC (496 mM Trolox), TFC (100.08 µg rutin/g).	[6,121]
Zingiberaceae	Ginger (*Zingiber officinale*)	rhizome	DM (10.86 to 15.84 g/100 g), CP (0.93 to 1.05 g/100 g), carbohydrate (97.19 to 97.26 g/100 g), EE (0.52 to 0.55 g/100 g), CF (1.01 to 1.05 g/100 g), ash (0.16 to 0.28 g/100 g)	NA	NA	Gingerol (5.54 to 6.11 mg/100 g).	[122]

NA—not determined.

Another innovative approach in poultry feeding practices is the use of feed additives and supplements designed to enhance feed efficiency and animal health. Pliego et al. [123] reviewed the beneficial effects of medicinal and herbal plants, while other authors explored the uses of legumes [124,125], fruit pomaces and co-products [126,127], and other unexplored plants by/co-products [128,129] are nowadays used to improve digestion, nutrient absorption, and gut health. These additives can be particularly beneficial when incorporating alternative feed ingredients, as they help mitigate potential nutritional imbalances and enhance the bioavailability of nutrients, resulting in products with improved nutritional quality, which can further provide nutritious and healthier affordable food products. Sustainable feeding practices are also gaining attention as producers seek to reduce the environmental footprint of poultry production [130]. This involves optimizing feed formulations to minimize waste and enhance nutrient utilization, as well as adopting practices that promote resource efficiency. It was shown recently by Lefter et al. [131] that locally sourced ingredients that match the dietary supply of the birds' nutritional requirements can be a sustainable approach. Such a strategy will also contribute to reducing transportation emissions and environmental pollution.

These evolving practices are directly aligned with the SDG2 of Zero Hunger by adopting innovative feeding strategies, ensuring the availability of nutritious and affordable poultry products. These strategies not only enhance the animal's production performances and the quality of food but also support the sustainability of food systems, making a substantial impact on global food security.

4. Innovative Feeding Strategies for Sustainable Poultry Production

Sustainable feeding strategies in poultry production focus more on the use of alternative feedstocks to overcome the challenges of traditional feed practices, such as high cost, input restrictions, and environmental impact. These alternatives can replace conventional ingredients such as corn and soybean meals [132] and include plant substitutes such as wastes from legumes, oilseeds, plants, and various agricultural co-/by-products. Furthermore, some recent review reports showed that other unconventional sources like insects [133], algae [134], and food waste [135] are being investigated for their potential as sustainable alternative poultry feed ingredients. The benefits of using plant-based and by-product feeds are manifold. First, these innovations can significantly reduce feed costs, making chicken production economically viable, especially for smallholder farmers with limited resources. Secondly, many of these substitutes are by-products of other agricultural practices, which means they can be obtained cheaply and even contribute to reducing waste in the feed system. Moreover, additional feed supplementation to poultry feed can reduce competition between feed and food crops, resulting in more balanced agricultural sustainability [136].

Nutritionally, many alternative feed ingredients offer a diverse array of essential nutrients that can meet the dietary needs of poultry. For example, legumes and oilseeds are rich in proteins and amino acids, while by-products provide valuable energy, fibers, and numerous beneficial bioactive compounds [42]. Babatunde et al. [136] recently stated that the use of alternative feeds can enhance the resilience of poultry production systems. By diversifying their feed base, producers can reduce their vulnerability to market fluctuations and supply chain disruptions that commonly affect the availability and price of conventional feed ingredients. Other authors [137,138] showed that this resilience is particularly important in the context of global food security, as it helps ensure a steady supply of poultry products even in times of economic or environmental stress. All in all, such feeding strategies that incorporate alternative feed ingredients hold significant promise for advancing the goals of Zero Hunger and sustainable agriculture.

Furthermore, by reducing costs, minimizing environmental impacts, and improving the nutritional profile of poultry diets and final products, these feeding strategies can enhance the sustainability and productivity of poultry farming, aligning also to the principles of the 3 R's, which can now be considered as 5 R's (Figure 2).

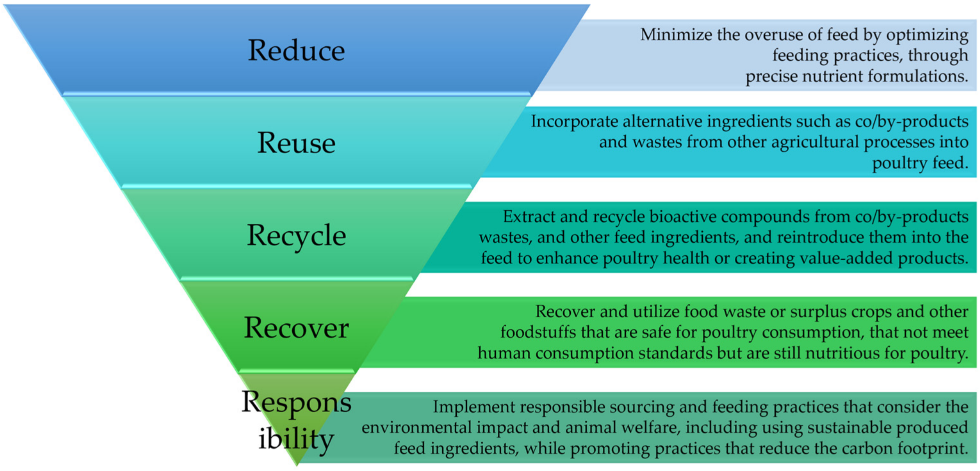

Figure 2. The principle of the 5 R's for alternative sustainable poultry production system.

4.1. Plant-Based as Alternative Feed Ingredients

Plant-based feeds have long been a cornerstone of poultry feed, primarily due to their availability, low cost, and high nutritional value. Traditional plant-based feeds, such as corn, barley, wheat, and soybean meals, are used as main sources of energy and protein, making them ideal for supporting fast growth and productivity in poultry [135]. But as demand for these crops increases worldwide for human consumption and animal feed, competition for agricultural products has intensified, as noted by Frona et al. [139]. This has raised concerns about sustainability as they rely heavily on these foods. In response to these challenges, researchers and industry stakeholders are looking for plant-based alternatives that are not only nutritious but also sustainable. These alternatives take less resources to manufacture, which are usually obtained as commodities resulting from other agricultural methods. For example, lupins, faba beans, chickpeas, and peas [140] are gaining attention as potential protein sources due to their high protein content and low environmental impact compared to soybeans. Similarly, oilseed meals like canola, flax, and rapeseed meal [87], which are by-products of oil extraction processes, offer substantial protein and fat content and can partially replace soybean meals in poultry diets.

Another promising approach is the use of agricultural residues and by-products as feed ingredients. These include rice bran, wheat bran, and other cereal by-products that are commonly discarded or used in low-value products [141]. These products can be recycled as poultry feed, contributing to a circular economy, which will result in reducing waste and improving food production. The challenge of using such by-products is in their variable nutrient content and potential presence of anti-nutritional compounds [142], which requires careful formulations and processing when it comes to poultry nutritional needs to ensure that they do not compromise health or performance.

In addition to diversifying the sources of plant-based feed ingredients, there is ongoing research into enhancing the nutritional quality of these alternatives. Some techniques, such as fermentation, enzyme supplementation, and genetic modification, are being explored to improve the digestibility and nutrient availability of plant-based feeds, as revived by Samtiya et al. [143]. The shift towards more sustainable plant-based feed alternatives also aligns with broader environmental goals, as they have a lower carbon footprint compared to animal-based feeds [144], and their production often requires less water and land. This makes them an attractive option for reducing the environmental impact of poultry farming, particularly in regions facing resource constraints. Nevertheless, the transition to these alternative plant-based feeds is not without challenges. Economic factors and challenges, like the cost and availability, the variability in nutrient content, and the presence of anti-nutritional factors of these ingredients, can be significant barriers to their worldwide implementation. Despite these challenges, the continuous research and development efforts in this area are paving the way towards more sustainable and resilient poultry production systems.

4.2. Insect-Based as Alternative Feed Ingredients

Over the past 10 years, insect-based feed has emerged as one of the most promising poultry alternative protein sources due to its high nutritional value, low environmental footprint, and potential to contribute to a circular economy. As the demand for sustainable livestock feed increases, insects such as black soldier fly larvae, mealworms, and crickets are increasingly recognized for their ability to efficiently convert organic wastes into high-quality protein sources [145,146]. Insects are highly nutritious, with protein content ranging from 30% to 80% depending on species and growth stage. These are rich in essential amino acids, fats, and minerals, making them a viable alternative to traditional protein sources such as fish meal and soybean meal [145]. For example, black soldier larvae have a balanced amino acids profile as reported by Khalifa et al. [133], while insect feed can provide essential fatty acids such as n-3 and n-6, which are essential for poultry health and productivity. Insects also have the advantage of being able to efficiently convert organic waste into biomass. They can be raised on a variety of natural materials, such as agricultural residues, food waste, and even garbage, making them an integral part of the waste management process. Not only does this diminish the environmental impact of waste disposal but also provides a valuable by-product of the process in the form of insect proteins [147]. By recycling waste into feed ingredients, insect farming supports the principles of a circular economy, reduces reliance on traditional feed crops, and reduces the overall carbon footprint of poultry production, as mentioned by Chavez et al. [148]. Despite the clear benefits, there are challenges associated with the use of insect-based feeds in poultry diets. One of the main barriers is the regulatory framework governing the use of insects in animal feed. In many regions, the approval process for insect-based feed ingredients is still in its early stages, and there are strict regulations regarding the substrates that can be used for insect rearing [149]. However, in a recent study conducted by Żuk-Gołaszewska et al. [150], it was reported that *H. illucens*, *M. domestica*, *T. molitor*, *A. diaperinus*, *G. sigillatus*, *A. domesticus*, and *G. assimilis* insect species fulfil safety conditions as insect production for feeding purposes, according to European Commission Regulation no. 893/2017, European Parliament Regulation no. 999/2001, and of the European Council and Commission Regulation no. 142/2011. This approval is important and ensures the safety and quality of insect meals in terms of contaminants that can potentially be transferred to the poultry. Another challenge is the scalability and economic viability of insect farming. While insect farming is less resource-intensive compared to conventional agriculture, Madau et al. [151] reported that it requires significant investment in infrastructure and technology to be scaled up to a level where it can meet the demands of the poultry industry. Other authors [152] mentioned that the cost of insect protein is currently higher than that of traditional feed ingredients, although this is expected to decrease as the industry matures and production processes become more efficient. All in all, ongoing research is exploring ways to optimize insect farming practices, improve the nutritional quality of insect meals, and assess the long-term effects of insect-based feeds on poultry health and productivity. Studies have shown that insect protein can successfully replace a significant portion of conventional protein sources in poultry diets without negatively affecting growth performance or feed efficiency [133,145]. In some cases, the inclusion of insect protein has been associated with improved gut health and immune function in poultry [153,154], suggesting potential additional benefits beyond basic nutrition.

4.3. Co-/By-Products and Wastes as Alternative Feed Ingredients—Nutritional Composition and Bioactive Compounds

The nutritional content of alternative poultry feed ingredients is an important factor in determining their suitability for poultry feed. Poultry species require a balanced diet of proteins (16 to 18% for laying hens; 20 to 23% for broilers), essential amino acids such as lysine (0.9 to 1.1% for laying hens; 1.1 to 1.3% for broilers), methionine (0.4 to 0.5% for laying hens; 0.5 to 0.6% for broilers), threonine (0.6 to 0.8% for laying hens, 0.8 to 1.0% for broilers), and tryptophan (0.2% for both hens and broilers), carbohydrates (50 to 60% of the total diets), fats (3 to 6% of the total diet), vitamins such as A (7500 to 12,000 IU/kg), D3 (2000 to 3000 IU/kg), and E (10 to 20 mg/kg)and minerals like Ca (3.5 to 4.5% for laying hens; 1% for broilers) and P (0.45 to 0.5% for both hens and broilers) to maintain optimal health, growth and productivity. These nutritional requirements are mentioned in each hybrid management breeding guide. The chemical composition of alternative feeds varies greatly depending on the source, but in general, these products provide essential nutrients that support poultry health and yield. A comprehensive understanding of the nutritional value of these new ingredients is essential for composing a balanced diet. These components include protein, fiber, fat, a mixture of vitamins and minerals, and several bioactive compounds, as shown in Table 1. After an extensive literature review, we classified several sources, compounds, and plant and vegetable food wastes based on their genus and identified them as potential sources of new alternative feed ingredients for poultry nutrition.

The literature revealed that the *Apiaceae* family includes plants, such as carrots, parsnips, celery, fennel, coriander, parsley, dill, anise, and lovage, which are known for their rich medicinal properties and potential bioactive compounds. Carrot (*Daucus carota*) waste exhibits a wide range of nutrients in different areas, including high levels of carotenoids such as β-carotene and α-carotene, especially in orange, black, and purple varieties, which also exhibit strong antioxidant activity [33,51]. Carrot flour and leaves contain significant amounts of TPC and TFC, contributing to their nutritional value [52,53]. Parsnip roots (*Pastinaca sativa*) are notable for their high dry matter content, monosaccharides, disaccharides, and minerals. They also contain substantial TPC and antioxidant capacities, enhancing their health benefits [54]. Celery (*Apium graveolens*) in its bulbs, leaves, and roots offers high levels of protein, fiber, and the essential minerals, with significant amounts of choline, pantothenic acid, and rutin in the leaves contributing to its resistance against infection [55–58]. Fennel (*Foeniculum vulgare*) seeds and shoots contain proteins, fats, carbohydrates, and essential fatty acids like PUFA and other essential fatty acids; the seeds also contain vitamins B1, B2, and niacin [59,60]. Anise (*Pimpinella anisum*) seeds contain protein and fiber content and are rich in TPC, carotenoids, tannins, and various phenolic compounds, making them more nutritious, as reported by Sun et al. [61] and Ghosh et al. [62]. In addition, the leaves and seeds of coriander (*Coriandrum sativum*) contain high levels of protein, fiber, essential minerals, and vitamins, with the leaves containing high levels of vitamin C and the seeds containing high levels of MUFA and PUFA [63,64]. Parsley (*Petroselinum crispum*) leaves are particularly rich in protein, fiber, vitamins, and phenolic compounds, which confer significant antioxidant properties, according to Cornescu et al. [65] and Dobricevich et al. [66]. In addition, the leaves and stems of dill (*Anethum graveolens*) contain large amounts of vitamin C, carotenoids, β-carotene, and TPC [67], while the leaves and stems of lovage (*Levisticum officinale*) provide essential proteins, carbohydrates, and fatty acids, with significant amounts of n-3 and n-6 fatty acids [68,69].

Another important alternative feed ingredient is represented by the fruits of American and European elderberries. These unexplored sources are rich in total phenolics, exhibit significant antioxidant capacity, and contain various essential nutrients such as glucose, fructose, proteins, and a variety of minerals, including K, P, Ca, and Mn [70]. They also contain notable amounts of anthocyanins, which contribute to their health benefits. However, they also have trace amounts of toxic compounds like sambunigrin [70,71]. The flowers of European elderberry are also rich in phenolics and proteins and exhibit strong antioxidant activity and minerals like Ca, Mn, Fe, Cu, and Zn [71,72].

Jerusalem artichoke (*Helianthus tuberosus*) are tubers from the *Asteraceae* family that are rich in carbohydrates and inulin, making them a significant source of dietary fiber. They are also a good source of Ca and K with high TPC content [73]. The Jerusalem artichoke leaves vary widely in protein content and are high in fiber. They are also rich in minerals (Ca, Mg, and K) and contain notable amounts of carotenoids [74,75]. Chicory (*Cichorium intybus*) roots have high inulin content (44.69%) and provide significant amounts of carbohydrates (89.41%). The roots are also rich in phenolic acids, such as chlorogenic and caffeic acids, which contribute to their antioxidant properties [76]. The leaves of chicory contain a notable amount of TPC and a variety of phenolic compounds, including protocatechuic and caffeic acids [76]. The chicory seeds are rich in protein (18.61%) and fat (21.18%) and contain high levels of Fe, Cu, and Zn, along with a modest amount of vitamin C [77]. Some authors [78,79] revealed that calendula (*Calendula officinalis*) flowers are high in TPC and TFC, with notable levels of tocopherols, containing significant amounts of carbohydrates and organic acids. Similarly, dandelion (*Taraxacum mongolicum*) has high antioxidant activity in its flower, leaves, and stem, with TPC values ranging from 23.89 to 30.05 mg GAE/g dry weight. The flowers and leaves are also rich in vitamin C and carotenoids, with notable levels of Ca and Mg [80]. Another important agricultural crop that produces waste is lettuce (*Lactuca sativa*). Although the results presented by Mampholo et al. [81] show variation in antioxidant content across different varieties, they present important bioactive compounds suitable as alternative feed ingredients in poultry [81,82]. Moreover, artichoke (*Cynara cardunculus*), particularly the receptacle and heads, were reported as rich sources of inulin and various minerals. The receptacle has high dry matter and protein content, while the heads contain a balance of fats, carbohydrates, and antioxidants [83,84]. Lastly, another important crop with high protein and fat content and a notable amount of PUFA in both wild and commercial varieties is the yarrow (*Achillea millefolium*). The commercial inflorescences have higher fat and protein levels, contributing to their nutritional profile [85].

In the *Arecaceae* family, coconut (*Cocos nucifera*) shell waste was identified as a source of high crude fiber (32.39%) and carbohydrate content (52.63%). Ewansiha et al. [86] showed that despite its low protein and fat levels, the shell is rich in Fe (618 mg/100 g), making it a significant source of this mineral.

The *Brassicaceae* family includes several nutritionally significant plants. Rapeseed (*Brassica napus*) is notable for its various components, such as meals, seeds, and cake. The meal is a rich source of protein and healthy fats, including significant amounts of MUFA and PUFA, and it contains valuable antioxidants and phenolic compounds [5]. Rapeseed seeds offer a substantial amount of crude protein and fat, with a noteworthy balance of n-3 and n-6 fatty acids. These seeds also provide essential minerals and fiber, making them a nutritious food source [87]. The cakes, which are by-products of oil extraction, are rich in protein and healthy fats, as well as essential fiber and minerals [87]. The kale (*Brassica oleracea*) leaves are another member of the Brassicaceae family, known well for having numerous essential nutrients (dietary fiber, vitamins, and minerals, including vitamin C and beta-carotene), and exhibit strong antioxidant properties due to their high phenolic content [88]. Similarly, mustard seeds (*Brassica juncea*) were reported by Oancea et al. [89] to contain high protein and fat content and are particularly rich in essential minerals such as Fe, Mg, and Zn. These seeds contain a variety of beneficial antioxidants and vitamins, contributing to their health-promoting properties. Commonly discarded cabbage (Brassica oleracea) waste is high in protein, fiber, and various minerals [90], making it a valuable source of nutrients.

Another important by-product belongs to the *Cannabaceae* family, which includes hemp (*Cannabis sativa*), whose seeds are highly nutritious, containing a balanced profile of proteins and fats, including a high proportion of PUFA. Mierlita et al. [91] reported recently that they offer significant amounts of dietary fiber and antioxidants, such as tocopherols and carotenoids, suitable for poultry nutrition.

In the *Cucurbitaceae* family, cucumbers (*Cucurbita pepo*) yield edible parts, such as flesh, peel and seeds, which are suitable for poultry feed, each with their own unique nutritional value. The flesh is low in calories but rich in vitamins and minerals. However, the peel contains high levels of protein, fiber, and antioxidants [92]. Cucumber (*Cucumis sativus*) and watermelon (*Citrullus lanatus*) also belong to this genus, where cucumber stands out for its high-water content and various mineral and vitamin properties in organic matter, extract, and juice, which are important [93,94]. Pumpkin seed meal (*Cucurbita moschata*) is also a rich source of protein, fat, and beneficial n-3 fatty acids [95].

Sea buckthorn (*Hippophae rhamnoides*) from the *Elaeagnaceae* family, whose leaves and fruits are rich in protein, fat, and antioxidants, contains important minerals and vitamins, making them highly nutritious and suitable for poultry nutrition [31,96]. Additionally, other important co-products are the leaves and flowers of *Elaeagnus angustifolia*, which were reported by Saboonchian et al. [97] as sources rich in phenolic and flavonoid compounds. The fruits of this plant provide a good source of fats, including a balanced ratio of SFA and UFA, along with significant amounts of antioxidants [98].

In a recent study, conducted by Untea et al. [99], it was revealed that the *Ericaceae* family cranberry (*Vaccinium macrocarpon*) offers significant nutritional benefits, particularly in its leaves. These coproducts contribute to a robust nutrient profile that includes protein, fat, fibers, and essential minerals such as Fe, Mn, and Zn.

The alfalfa plant, scientifically known as *Medicago sativa* and belonging to the *Fabaceae* family, is well known for its remarkable nutritional value. The alfalfa plant is abundant in protein and fiber, and it also has significant levels of healthy fats, such as a high proportion of PUFA. Alfalfa is additionally a beneficial supplier of antioxidants, such as tocopherols and carotenoids [100]. Pea (*Pisum sativum*) seeds are a beneficial legume, offering a good amount of protein and important nutrients such as tocopherols. Peas provide a beneficial combination of carbs, fiber, and fats [101]. Lentil seeds, containing high levels of protein and fiber, as well as a notable quantity of PUFA, are a healthy option for nutrition. Lentils have sugars and tocopherols that enhance their nutritional worth [102].

Mung bean (*Vigna radiata*) seeds are rich in protein and fat, and they offer antioxidant benefits through their TPC and TFC [103].

One important by-product from the *Juglandaceae* family includes walnuts (*Juglans regia*), whose meal is highly nutritious, contains protein and essential lipids, with a significant amount of antioxidants, including phenolic acids and flavonoids, as well as essential minerals, such as Mg and Zn, and has a high TAC [99].

The *Lamiaceae* family encompasses several aromatic herbs with notable nutritional profiles. Spearmint (*Mentha spicata*) leaves are characterized by their high dry matter content and significant levels of fiber and phenolic compounds [104]. Basil (*Ocimum basilicum*) leaves are rich sources of nutrients such as protein, fiber, and essential minerals and contain a balanced profile of fatty acids along with substantial antioxidant activity [24]. Thyme (*Thymus vulgaris*) leaves also have a high TPC and TAC, with a substantial amount of essential minerals and beneficial fatty acids [24]. Sage (*Salvia officinalis*) leaves are another member of this family with a high protein and fiber content and contain significant levels of antioxidants, including vitamin E and lutein [24]. Rosemary (*Rosmarinus officinalis*) leaves are noted for their high antioxidant content, including phenolic compounds and vitamin E, although they contain relatively lower levels of protein and fat compared to other herbs [105].

The *Liliaceae* family includes garlic (*Allium sativum*), which is valued for both its bulb and leaves. The bulb is noted for its high content of dry matter and minerals, alongside significant amounts of monosaccharides and disaccharides. The antioxidant properties of garlic are also noteworthy, with appreciable TPC and TAC [54]. In contrast, garlic leaves exhibit high protein content and crude fiber, along with notable antioxidant levels including TPC and TAC [106]. Onion (*Allium cepa*) waste provides a broad range of nutrients, with variability in dry matter, protein, and mineral content such as K, Ca, and Mg. The antioxidant properties are also significant, with variations in TPC and TFC as reported by Benítez et al. [107]. Further, another important crop, asparagus (*Asparagus officinalis*), offers a diverse nutritional profile, including fibers, sugars, proteins, and a variety of vitamins such as B and C vitamins and essential minerals like Ca and Mg [108].

In the *Musaceae* family, important food wastes are produced by plantain and banana peels. Plantain peel is rich in carbohydrates and contains essential minerals, including K and

Mg, with moderate levels of protein and fat [109]. Similarly, banana peel is characterized by its high carbohydrate content and significant levels of fiber and minerals, though with slightly lower protein and fat content compared to plantains [109].

The *Oleaceae* family includes olive (*Olea europaea*) seeds, which are rich in lipids, especially MUFA and PUFA. The seeds also provide various sterols and essential minerals, contributing to their nutritional richness as alternative feed ingredients [110].

Within the *Rosaceae* family, the nutritional profiles of apple (*Malus domestica*) and rosehip (*Rosa canina*) are distinct. Apple waste (peels, seeds, and pulp) is rich in TPC and TFC, with varying levels of K, Ca, and Mg [111]. Rosehip meal and seeds offer a high dry matter content and are rich in antioxidants, including high levels of PUFA, with substantial amounts of vitamin C and carotenoids [6,112]. The co-products of raspberry and blackberry (*Rubus* spp.) leaves have been recently shown to have a high dry matter content and are rich in proteins, fibers, and essential minerals. They also have significant levels of antioxidants and carotenoids [113]. Strawberry leaves are noted for their protein content and high TAC [114]. Another important crop that recently gained attention are the aronia (*Aronia melanocarpa*) fruits, leaves, and pomace, which were described by Saracila et al. [115] to be rich in dry matter and provide a balanced profile of nutrients including carbohydrates, proteins, and fats, along with high levels of Fe, Mn, and Zn.

Further, in the *Rutaceae* family, citrus fruits are prominent for their diverse nutritional benefits. *Citrus aurantium*, or orange, peels are known for having high levels of total polyphenol content (TPC) and large total antioxidant content (TAC), as expressed in terms of both vitamin C and E equivalents. The peel is also high in lutein and zeaxanthin, which are critical for eye health, and has a little amount of crude protein, fat, and fiber [116]. Similarly, the peel of grapefruits (*Citrus paradisi*) displays a strong TPC and TAC pattern, but it also has somewhat greater crude protein and fiber content than orange peel. Important antioxidants found in grapefruit peel include vitamin E and carotenoids like lutein and zeaxanthin [116]. Conversely, lemons (*Citrus* × *limon*) offer a more significant nutritional profile, including high levels of fiber, protein, and important minerals like Mn, Ca, and K. The high nutritional density of lemon peel, particularly with regard to minerals, underscores its potential to augment dietary consumption of these components [117].

As further highlighted by Panaite et al. [50], tomato (*Solanum lycopersicum*) waste is a member of the *Solanaceae* family and is rich in crude protein and fiber. It is also notable for its high amount of PUFA and carotenoids, such as lycopene and beta-carotene, which are known for their antioxidant effects. Waste from bell peppers (*Capsicum annuum*) is a good source of carotenoids and vitamins C and E. The varying TPC and TFC across different bell pepper samples underline its antioxidant potential [118]. Eggplant (*Solanum melongena*), both in its fruit and pulp forms, has relatively low levels of protein and fat but provides a balanced ratio of lipids [119].

Within the *Vitaceae* family, grape (*Vitis vinifera*) pomace and seed meal are the most important and studied sources rich in both PUFA and antioxidants. The pomace is high in crude protein and fiber, with a significant amount of fatty acids and a balanced profile of SFA, MUFA, and PUFA [120]. The seed meal, which contains high dry matter content, shows substantial antioxidant activity and a similar fatty acid profile, though with a higher proportion of unsaturated fats [121].

Lastly, in the *Zingiberaceae* family, ginger (*Zingiber officinale*) rhizome, known for its aromatic and medicinal properties, is primarily composed of carbohydrates and moisture, while its nutritional content is complemented by trace amounts of protein, fat, and fiber, and it contains gingerol, a compound with known health benefits [122].

All these reviewed plants, by-products, co-products, and plants, containing various amounts of nutrients and bioactive compounds, have been reported as safe and with multiple benefits when used in poultry diets, as presented further in Table 2.

5. Effects of Reviewed Alternative Feed Ingredients on Poultry Performance, Health Status, and Product Quality

In recent studies, various plants from different botanical families have been explored for their effects on poultry performance, health, and product quality. Each plant species tested by researchers showed unique impacts and effects depending on the poultry hybrid, dosage, and part or type of the plant used, as summarized in Table 2.

The reviewed alternative feed ingredients from the *Apiaceae* family demonstrate significant potential in improving the health and productivity of poultry through enhanced nutrient intake, better egg and meat quality, and improved immune responses. Carrot waste has shown positive effects on both laying hens and broilers. In laying hens, carrot waste was effective in improving internal and external egg quality [50]. Similarly, carrot leaf increased production performances and nutrient digestibility, as reported by Siti et al. [122], as well as egg quality. Anise seed, according to the results of Barakat et al. [155], was effective in improving the immune system of broilers and meat quality. For broiler chickens, coriander seed at a 1.5% dose was most effective in improving dressing percentage and the overall health status of the broilers [156]. Parsley leaves tested in laying hens raised under heat stress conditions improved production performances and antioxidant compounds in eggs [65], as well as the quality characteristics of eggs during 28 days of storage. In broiler chickens, parsley leaves in higher doses significantly increased feed intake and carcass quality and health parameters, according to Ali et al. [157]. The dill leaves in lower doses used in broiler chickens significantly improved production performance and improved lipid metabolism [158,159].

The reviewed alternative feed ingredients from the *Asteraceae* family exhibit various beneficial effects on poultry health and performance. The incorporation of these plants and their by-products into poultry diets can lead to improved growth rates, better immune responses, enhanced egg quality, and improved health status of poultry, aligning with sustainable feeding strategies and contributing to improved food quality and security. Jerusalem artichoke was evaluated for its effect on broiler chickens' diets, which significantly improved production performance, as reported by Al-Abboodi et al. [160]. Chicory has demonstrated several beneficial effects in broiler chickens, showing a significant reduction in abdominal fat pad and improved health status [161]. In laying hens, free access to chicory vegetation resulted in better production performance and improved lipid composition in the eggs [162]. Calendula flower supplement in broilers improved carcass yield; however, more than 1% could affect production performances [163]. In layers, petal and leaf supplements significantly increased carotenoid deposition in egg yolks, with no effect on egg production or quality characteristics [164]. Dandelion leaves and meal in different broiler hybrids and laying hens was demonstrated to be effective in improving product quality (meat and eggs) as well as production performance and health status [165–167]. However, in laying hens, a 4% dandelion meal had detrimental effects on feed consumption and egg weight, as shown by Saenz et al. [168]. Similar effects were reported for echinacea supplementation in broiler chickens, demonstrating its potential in improving health and performance [169].

Ginseng was not very effective when tested in laying except for a notable increase in egg production, according to Kang et al. [170], however, had a notable effect on the health status of laying hens.

Rapeseed has been extensively studied as an alternative feed ingredient for poultry. In broilers, rapeseed can be used up to 30% without detrimental effects on production performances, while in laying hens' lower levels < 20% are preferred [171]. The same effect was noted by others in laying hens [172]. In terms of egg quality, rapeseed meal had a significant impact on n-6 PUFA and health-related indices [5].

According to Mustafa et al. [8], broccoli waste up to 9% was suitable for broiler chickens' diets, with significant effects on production performance and nutrient digestibility. In a different study with broiler chickens, broccoli stem and leaf meal had no effect on growth performance but significantly increased antioxidant compounds in meat samples and enzyme activity [173]. For laying hens, broccoli stem and leaf meal did not affect production performance but significantly increased the xanthophyll content in egg yolk and decreased cholesterol content [174]. Further, cabbage waste in broiler chickens had no effect on production performance but improved nutrient digestibility [175]. In laying hens, cabbage waste up to 12% significantly improved egg quality, however, might negatively impact eggshell percentage [176]. These findings suggest that incorporating by-products from the *Araliaceae* and *Brassicaceae* families into poultry diets can enhance production performance, immune responses, and nutrient digestibility and health, contributing to sustainable feeding strategies and improved food quality.

Hemp seed by-products also have shown promising results when included in poultry diets. In broiler chickens, hemp seed cake significantly improved the fatty acid profile in the thigh and breast meat and health status but had no significant effects on performance, as shown by Tufarelli et al. [177]. In laying hens, significant effects were reported on both egg quality and performance [91].

Pumpkin (*Cucurbita pepo*) seed meal up to 20% inclusion levels in broiler chickens significantly increased production performance, with no effect on commercial parts [178]. The watermelon (*Citrullus lanatus*) rind in laying might have some detrimental effects on egg weight, but the overall health status was significantly improved [126]. However, further research is required. Pumpkin (*Cucurbita moschata*) seed meal significantly improved shelf-life and egg quality parameters in laying hens [95].

In broiler chickens, dietary supplements with cranberry leaves stimulated the deposition of bioactive compounds in meat samples and exhibited a strong effect in counteracting oxidative processes in broiler meat [99,128]. A 30% cranberry pomace in broilers diet significantly affected nutrient absorption but improved the plasma lipid profile [179]. These findings support the potential of these plant by-products from the *Cannabaceae*, *Cucurbitaceae*, and *Ericaceae* families as sustainable alternative feed ingredients in poultry nutrition, contributing to improved food quality and Zero Hunger initiatives.

Alfalfa (*Medicago sativa*) from the *Fabaceae* family has been extensively studied for its beneficial effects in poultry diets as a dietary fiber source. In broiler chickens, up to 5% was demonstrated to be effective in improving antioxidant compounds in meat except carotenoids content while maintaining the production performances [100,180]. In laying hens, 5 to 10% dietary alfalfa meal significantly decreased FCR, mortality, abdominal fat yield, and egg yolk cholesterol content while demonstrating potential health benefits [181,182]. Pea (*Pisum sativum*) has also been explored for its potential as an alternative protein and energy source. In broiler chickens, 4 to 48% raw pea was used as a replacement for soybean meal and corn, which had no detrimental or additional effects on meat quality, as mentioned by Dotas et al. [183]. Another group of authors reported significant effects on meat quality and significant improvements in health-related indices [184].

In a study by Untea et al. [128], walnut meal, when included in the diets of broiler chickens, improved meat lipid and nutritional composition; however, some minerals' ability to deposit in the tissue was affected [99]. These plant-based feed ingredients from the *Fabaceae*, *Cucurbitaceae*, and *Juglandaceae* families offer promising alternatives to traditional feed ingredients, improving meat and egg quality, enhancing health parameters, and contributing to sustainable poultry production practices.

Further, several plants from the *Lamiaceae* family, including peppermint, spearmint, basil, thyme, rosemary, and sage, have been investigated for their effects on broiler chicken diets. Each of these plants showed varying impacts on production performance, meat quality, and health parameters. Peppermint significantly improves oxidative stability and immune responses [185], while others showed its potential effects on production performance [186]. Spearmint also influenced the performance of broiler chickens while reducing cholesterol levels and increasing hemoglobin and superoxide dismutase activity, as showed by Abu Isha et al. [187]. Basil and thyme, when included in the diet of broilers, had similar effects. Both herbs decreased production performance; however, they significantly improved the deposition of bioactive compounds in breast and thigh meat samples [24,180]. Moreover, rosemary in broilers improves intestinal health, with potential negative effects above 1.5% inclusion on production performance [188,189]. Sage leaves had similar effects as basil and thyme [24,180]. Overall, these findings highlight the potential of *Lamiaceae* plants to modulate various aspects of broiler chicken health and production. While some herbs like peppermint and spearmint can improve production performance at optimal inclusion levels, others like basil, thyme, and sage offer more substantial benefits in enhancing meat quality, particularly in terms of antioxidant and lipid profiles. However, the inclusion rates are critical, as higher levels can sometimes lead to decreased performance metrics.

Avocado seed meal reduced BW without affecting FCR, as showed in the study by George et al. [190], while another group of authors [191] reported that using up to 8% seed meal found no significant effect on broilers health, indicating that avocado seed meal does not negatively affect broilers' health.

Garlic (*Allium sativum*) was found to have varying effects based on its preparation and dosage. In laying hens, garlic had no effect on productivity and egg characteristics but significantly improved the bird's health status [192]. Raw garlic powder slightly improved broiler performances but influenced meat aroma; however, boiled garlic powder did not show these beneficial effects, indicating that the method of preparation plays a critical role in the efficacy of garlic as a supplement [193]. Onion (*Allium cepa*) demonstrated similar effects to garlic in laying hens.

Plantain peel waste is a suitable maize substitute in broiler finisher diets, with a recommended inclusion rate of up to 10% for optimal blood characteristics [194].

Olive leaf powder in laying hens had no significant effect on production performances but improved egg yolk quality, making olive leaf powder a potential agent for reducing egg yolk cholesterol [195]. In broilers, olive pulp waste improved footpad dermatitis and feather cleanliness without affecting growth performance or health [196].

Rosehip (*Rosa canina*) showed promising effects in laying hens by improving TAC and TPC in PUFA-enriched eggs while extending the shelf life of stored eggs [6]. In broiler chickens, low levels of rosehip fruits improved BW, FI, protein intake, and dressing percentages, as reported by Monesa et al. [197]. Another recent study showed that the leaves of rosehip, which are co-products, can be used as feed additives in the first stage of laying hens and could potentially improve the production performance and some egg quality parameters [70].

Citrus waste, such as orange (*Citrus sinensis*) and grapefruit (*Citrus paradisi*) peels, was tested in broiler chickens, and showed promising effects on performances, meat quality, and health status [116]; however, grapefruit peel decreased final BW.

Tomato wastes up to 7.5% enriched egg yolk quality; however, more than 7.5% level depressed the absorption and deposition of n-3 fatty acids in the yolk, indicating that optimal dosing is critical [34]. The 5% inclusion rate showed the best effect in this study.

The grape seed meal from the *Vitaceae* family was beneficial for broilers, significantly improving performance, meat quality, and health [121]. In laying hens, improved production performance and antioxidant compounds in eggs, although n-6 fatty acids were more prevalent than n-3 [5]. Recently, Costa et al. [198] concluded that in poultry, the effect of grape by-products is more variable, and these sources should not be incorporated in broiler diets at more than 6–10% to prevent an impairment of animal growth.

Ginger (*Zingiber officinale*) powder, when tested in broilers, had no effect on production performance; however, it reduced gizzard weight, indicating potential benefits for gut health [199].

These findings highlight the diverse impacts of alternative feed ingredients on poultry, emphasizing the importance of selecting the appropriate dosage and plant part to achieve desired outcomes in production performance, health status, and product quality, as detailed in Table 2.

Table 2. Main effects of plants when administered in poultry diets.

Plants Family	Plants Common Name	Poultry Species	Dose and Type	Main Effect on Laying Hens and/or Broilers	Reference
Apiaceae	Carrot (*Daucus carota*)	Lohmann Brown, laying hens	2% carrot waste	Increased ADFI and had no significant effect on FCR. Increased the carotenoids content in egg yolk positively affected the physical properties (e.g., yolk pH, egg thickness). Decreased the cholesterol content in eggs and significantly improved oxidative stability.	[50]
		Lohmann Brown laying hens	2% carrot leaf	Increased ADFI, egg production, and feed efficiency. Better nutrients digestibility of DM, OM, and CP. The supplement improved egg yolk color, eggshell thickness, β-carotene and cholesterol contents of the eggs.	[122]
	Anise (*Pimpinella anisum*)	Cobb 500 broiler chickens	0.5%, 1%, and 1.5% seed	Improved BW and FI of broilers, but higher FCR. The serum IgA, IgG, IL-2 and IL-10, IgM, and INF-γ of broilers were significantly increased. MDA levels decrease in breast and thigh samples with all three doses.	[200]
	Coriander (*Coriandrum sativum*)	Ross 308 broiler chickens	1.5%, 2.5%, and 3.5 seed	No effect on growth performances. The 1.5% dose was the most effective in improving dressing percentage and health status of broilers.	[155]
	Parsley (*Petroselinum crispum*)	Tetra SL-LL laying hens	2% leaves	Increased production performances. Egg yolk color and the antioxidant compounds in eggs were significantly improved (antioxidant capacity, vitamin E, lutein, and zeaxanthin) and quality characteristics of the eggs during storage. Affected Fe and Zn content in egg yolks.	[65]
		Ross 308 broiler chickens	3, 6, 9, and 12 g/kg leaves	Significant increase in BW at 9 and 12 g/kg of parsley supplement, improved FI, carcass weight and dressing percentage. However, the FCR was higher at 3 and 6 g/kg of supplements.	[201]
		Ross 308 broilers	0.5%, 1%, and 1.5% leaves	Significant improvement in broiler health parameters at 1% and 1.5% leaves were tested. The 0.5% was not very effective on any of the parameters.	[157]
	Dill (*Anethum graveolens*)	Ross 308 broiler chickens	1%, 2%, and 3% leaves	The diet with 1% significantly improved the production performance. The diets with 2% and 3% were not very effective in any aspects. Using 1% significantly reduced cholesterol, triglyceride, and LDL levels in serum.	[158,159]
Asteraceae	Jerusalem artichoke (*Helianthus tuberosus*)	Ross 308 broiler chickens	0.5%, 1%, 1.5% and 2%	Except for the 1% diet, all other three significantly improved production performances; however, the 2% was reported as the best option for Ross 308 broilers.	[160]
	Chicory (*Cichorium intybus*)	Ross 308 broiler chickens	0.10%, 0.15%, and 0.20%	The BW of broilers fed the 0.10% chicory was significantly higher than those fed on the other treatments. The abdominal fat pad was significantly lower in all chicory groups. Blood triglycerides and LDL levels were reduced significantly while HDL increased significantly. Decreased the counts of *Escherichia coli* and increased the counts of *Lactobacillus*.	[161]
		Lohmann Brown laying hens	Free-access chicory	Better production performances than control group. The fatty acids composition of the hens fed freely with chicory vegetation contributed to the production of eggs with higher PUFA and favorable n-6 to n-3 ratio.	[162]
	Calendula (*Calendula officinalis*)	Ross 308 broilers	0.5% and 1.0% flower	The 0.5% flower improved BW and carcass yield, while 1% led to significantly lower BW. None of the tested doses exerted effect on immune parameters.	[163]
		Hy-Line Brown layers	0.5%, 1%, 2%, and 4% petal	Significant increase in egg yolk color; 4% supplement had the best egg yolk carotenoid deposition. No improvements in egg production or egg weight. The egg quality characteristics were not influenced.	[164]
			1% leaves	Significant increase in egg yolk color, without any alterations on egg freshness or egg quality characteristics.	[164]

Table 2. *Cont.*

Plants Family	Plants Common Name	Poultry Species	Dose and Type	Main Effect on Laying Hens and/or Broilers	Reference
Asteraceae	Dandelion (*Taraxacum mongolicum*)	Arbor Acres broilers	1% raw or enzymatically treated plant	Enzymatically treated significantly decreased FCR, increased apparent nutrient digestibility of nutrients. Same diet led to higher breast muscle rate, lower drip loss and water-holding capacity while lowered drip loss and water holding capacity. Improved serum IgA and IgG. Raw dandelion had no notable effect except for increased organic matter digestibility.	[165]
		Arbor Acres broilers	0.5% and 1% dandelion	The 0.5% and 1% increased eviscerated percentage, cooking loss and shear force. The 0.5% significantly increased the n-3 PUFA, while significantly lowered the TBARS values.	[166]
		Cobb 273 broilers	0.5% leaves	Significantly improved cecal health by reducing harmful bacteria. No effect on pH and moisture content of chicken litter.	[167]
		Hisex laying hens	1%, 2%, 3%, and 4% meal	The diet with 3% was the most effective in improving egg production and intestinal histomorphology parameters. The 4% showed detrimental effects on FI and egg weight.	[168]
	Echinacea (*Echinacea purpurea*)	Hubbard broiler chickens	0.5% powder	Dietary supplementation with 0.5% echinacea improves the final BW and immune response of broiler chickens and had a significant effect on *Escherichia coli*, and hematological, serum biochemical adverse effects, and histopathological alterations that occur by E. coli infection.	[169]
Araliaceae	Ginseng (*Panax ginseng*)	Hy-Line Brown laying hens	0.5% and 1% by-product	No effect on production performances, except for egg production which was significantly increased. No effect on triglyceride, aspartate aminotransferase, and alanine aminotransferase however, increased the serum IgG and IgM content. Improved the proliferation of intestinal *Lactobacillus* population but no effect on *Salmonella* and *Escherichia coli*.	[170]
Brassicaceae	Rapeseed (*Brassica napus*)	Cobb 500 broilers	10% and 30% seed	A total of 30% rapeseed reduced BW and FI, cecal colonization and fecal shedding. Histomorphology showed that 30% had the highest duodenum and jejunum villus height and to crypt depth ratio. A total of 10% was more effective on production performance and laying hens' health.	[171]
		Brown Nick laying hens	20% and 30% cakes	Rapeseed cakes up to 20% have no adverse effects on productivity or egg quality. Both diets reduced digestibility of dry matter, gross energy, crude protein and the digestibility of indispensable amino acids except tryptophan, was reduced also reduced.	[172]
		Tetra SL LL laying hens	9% meal	The effect on production performance was not significant, only tendencies were noted. Also, no effect on egg weight and its components. The diet with 9% rapeseed meal had a significant effect on n-6 PUFA, as well as health related indices.	[5]
	Broccoli (*Brassica oleracea*)	Ross 508 broiler chickens	3, 6, and 9% waste	All diets increased BW and FCR with no effect on FI. Apparent ileal crude protein and dry matter digestibility increased as the level of broccoli waste in the diet increased in the grower phase, however, in the finisher phase (>35 days) decreased. The 3 to 6% broccoli waste may improve the growth of broiler chickens with no detrimental effects on nutrient digestibility and retention while the 9% may affect ileal and total tract nutrient digestibility.	[8]
		Ross 308 broiler chickens	4, 8, and 12% stem and leaf meal	No effect on broilers growth performances. Significantly increased the yellowness in shank and breast skin, and the concentrations of xanthophylls in abdominal fat and breast skin. The TAC was improved significantly while lowering the MDA concentration. The activities of superoxide dismutase and catalase of breast muscle increased with 8% and 12% broccoli leaf and stem supplementation.	[173]

Table 2. *Cont.*

Plants Family	Plants Common Name	Poultry Species	Dose and Type	Main Effect on Laying Hens and/or Broilers	Reference
Brassicaceae	Broccoli (*Brassica oleracea*)	Roman brown shell laying hens	3%, 6%, and 9% stem and leaf meal	No effect on production performance of laying hens. Significantly increased the xanthophyll content of egg yolk, while decreased the content of cholesterol in egg yolk. No effect on egg quality characteristics (albumen height, Haugh unit, shell thickness and shell strength of eggs). Hepatic hydroxymethylglutaryl-coenzyme A (HMG-CoA) reductase activity was decreased, and concentrations of cecal short chain fatty acids were increased with increasing broccoli stem and leaf meal supplementation.	[174]
	Cabbage (*Brassica oleracea var. capitata*)	Ross 508 broiler chickens	3, 6, and 9% waste	Cabbage waste had no effects on BW, FI, or FCR. Inclusion of cabbage waste reduced apparent ileal dry matter, organic matter and crude protein in the grower phase, but no effect on finisher phase. Up to 9% had no negative impact on bird performance and apparent ileal digestibility and improved apparent total tract nutrient digestibility.	[175]
		White Leghorn laying hens	4, 8, and 12% waste	No effect on FI, egg production, FCA, egg yolk, and albumen percentage; however, the eggshell percentage decreased with increasing waste supplement. The α-tocopherol, PUFA and linolenic acid increased in egg yolks with increasing dietary waste, with no effect on egg yolk cholesterol concentration. It can be used up to 12% without adverse effects on production parameters and may improve total tract nutrient utilization and egg quality.	[176]
Cannabaceae	Hemp (*Cannabis sativa*)	Hubbard broiler chickens	5% and 10% cake	Regardless of the level of hemp seed cake inclusion, no differences among groups were found for performance and meat quality traits. The thigh and breast fatty acid profile were significantly improved in both groups, with an increase of the long chain fatty acids of n-3 series and decrease in n-6/n-3 ratio. The MDA concentration and lipid hydroperoxides in breast meat decreased significantly. The tested diets improved intestinal health status in broilers.	[177]
		Tetra SL laying hens	8% hemp seed	The production performances in laying hens were improved using hemp seeds. The egg yolk had significantly lower cholesterol and SFA content, while the concentration of total and individual (ALA, EPA, and DHA) PUFA (n-6 and n-3 FAs) was significantly higher.	[91]
Cucurbitaceae	Pumpkin (*Cucurbita pepo*)	Anak 2000 broiler chickens	5, 10, 15, and 20% seed meal	All four-level used led to significantly increased production performances in broilers, however significant differences among dietary treatments for live BW and dressed weight, were noted. Dressing percent, breast, thigh, abdominal fat, kidney, gizzard, liver and lungs weights did not differ significantly as the levels of pumpkin seed meal increased in the diets.	[178]
	Watermelon (*Citrullus lanatus*)	Tetra SL laying hens	1% rind	Regarding the production performance, egg weight significantly decreased and improved FCR. The health status of animals was significantly improved by decreasing the concentration of cholesterol and triglycerides from blood samples. The intestinal histomorphology was improved, while alpha-amylase decreased in both duodenum and jejunum. The 1% supplement increased the *Firmicutes* and *Lactobacillus* spp. while reducing the counts of Bacteroidetes and Enterobacteriaceae.	[126]
	Pumpkin (*Cucurbita moschata*)	Tetra SL laying hens	9% seed meal	Significantly improved ADFI but had no effect on egg quality characteristics. The egg yolk cholesterol decreased significantly while the total PUFA, especially the n-3 ALA and DHA, increased significantly. The shelf-life on eggs stored at room and refrigerator temperatures, was better than those from the control group.	[95]
Ericaceae	Cranberry (*Vaccinium oxycoccus*)	Cobb 500 broiler chickens	1% and 2% leaves	The supplements led to higher concentrations of Cu and Fe deposition in breast meat samples compared with the control group. The lutein and zeaxanthin concentrations were also higher in the meat samples, while vitamin E concentrations decreased. The leaves stimulated the synthesis of n-3 PUFA and exhibited a powerful effect in counteracting the oxidative processes of broilers meat.	[99,128]

Table 2. *Cont.*

Plants Family	Plants Common Name	Poultry Species	Dose and Type	Main Effect on Laying Hens and/or Broilers	Reference
Ericaceae	Cranberry (*Vaccinium oxycoccus*)	Ross 708 broiler chickens	30% pomace	The pomace had a significant effect for apparent retention of dry matter, nitrogen, neutral detergent fiber, gross energy, and apparent metabolizable energy. The plasma concentration of bile acid and cholesterol significantly decreased.	[179]
Fabaceae	Alfalfa (*Medicago sativa*)	Cobb 500 broiler chickens	5% meal	Significantly increased FCR, thigh muscles and gizzard weights. Improves meat quality by enhancing antioxidant potential and n-3 PUFA, while significantly decreasing cholesterol content in breast and thigh meat samples. Significantly increased the TPC and vitamin E content in meat samples, however no effect on TAC and carotenoids content in meat.	[100,180]
		Beijing-you laying hens	5%, 8%, and 10% meal	Significantly decreased FCR, mortality, abdominal fat yield, and yolk cholesterol content. All diets improved meat and eggs protein quality. The diets with alfalfa stimulate the proliferation of beneficial bacteria in both duodenum and ileum, showing their potential in boosting health status. Up to 10% was recommended as the optimal inclusion level.	[181]
		Zhuanghe Dagu chickens	3%, 6%, and 9% meal	Dietary inclusion of alfalfa meal was beneficial to improve the laying performance, egg quality, small intestinal morphology, cecal microbiota diversity and cecal metabolic function, with the optimum dose being 6%.	[182]
	Pea (*Pisum sativum*)	Ross 308 broiler chickens	4%, 8%, 12%, 16%, 18%, 24%, 36%, and 48% raw pea	The doses were used as a soybean meal and corn replacement. The production performances (BW, FI, and FCR) were not significantly altered. Also, carcass yield traits, skin color, and chemical composition of meat samples were not affected. Some significant differences were observed in fatty acid composition of breast and leg muscles. Up to 48% can be used as an alternative protein and energy source to replace soybean meals and corn in broiler chicken diets.	[183]
		Hubbard broiler chickens	19% and 40% dehulled peas	No significant effect on growth performance, dressing percentage, the percentage of breast or drumstick muscles, and abdominal fat. Significantly lower L* (lightness) and b* (yellowness, drumstick muscle) values and fat content. The PUFA concentration in breast and drumstick muscles was significantly increased, while lowering the n-6/n-3 ratio. Significant improvement in health-related indices.	[184]
Juglandaceae	Walnuts (*Juglans regia*)	Cobb 500 broiler chickens	6% meal	Increased content of crude fat, Cu, vitamin E, and deoxymyoglobin in breast meat samples, while significantly decreased the Fe, Zn, and concentrations metmyoglobin. The content n-3 PUFA was double in samples of chickens fed walnut meal compared with the control samples.	[99,128]
Lamiaceae	Peppermint (*Mentha x piperita*)	Ross 308 broiler chickens	1% and 2% plant	From the production performances, a significant effect was noted for final BW in broilers. Also, both experimental diets showed an antioxidative potential to improve oxidative stability and immune responses in broilers.	[185]
		Ross 308 broiler chickens	0.5%, 1%, and 1.5% leaves	The BW and FI increased corelated to the level of the leaves added, while FCR decreased in the same way. No effect on meat characteristics or organs development. A dose of 1.5% was recommended to improve production performances.	[186]
	Spearmint (*Mentha spicata*)	Arbor Acres broiler chickens	0.25%, 0.5%, 1%, and 2% plant	The level of 2% spearmint significantly decreased BW, BWG, FCR and cholesterol levels while significantly increased the concentrations of hemoglobin and superoxide dismutase activity compared with the other groups. The 1% group had significantly higher concentration of total plasma lipid and TAC.	[187]
	Basil (*Ocimum basilicum*)	Cobb 500 broiler chickens	1% plant	The production performances decreased, especially final BW and FI, while increasing the FCR. However, 1% basil led to deposition of significantly higher concentration of Zn, TPC, TAC, and vitamin E in thigh meat samples compared with the control group, while significantly improving the n-3 fatty acids deposition. The cholesterol concentration in breast samples was significantly lowered and the TPC and TAC were increased.	[24,180]

Table 2. *Cont.*

Plants Family	Plants Common Name	Poultry Species	Dose and Type	Main Effect on Laying Hens and/or Broilers	Reference
Lamiaceae	Thyme (*Thymus vulgaris*)	Cobb 500 broiler chickens	1% plant	The production performance decreased, but not significantly. The 1% thyme significantly increased the concentration of Zn, TPC, TAC, and vitamin E in thigh meat samples compared with the control group, while significantly improving the n-3 fatty acids deposition. The cholesterol concentration in breast samples was significantly lowered and the antioxidant compounds were increased.	[24,180]
	Rosemary (*Rosmarinus officinalis*)	Ross 308 broiler chickens	0.5% and 1% powder	No effect on antibody titters against viruses nor lymphoid tissues weight but has the potential to modulate the humoral immunity of broilers.	[188]
		Ross 308 broiler chickens	0.5%, 1%, and 1.5% plant	No significant effect on production performances. The gastrointestinal tract weight, relative to body weight, increases in all rosemary groups when compared with control. The intestinal health was significantly improved by increasing the Lactobacilli counts and decreased the *Escherichia coli*. A dose of more than 1.5% could have significant detrimental effects on production performance.	[189]
	Sage (*Savia officinalis*)	Cobb 500 broiler chickens	1% plant	The final BW and FI were significantly decreased. The concentration of Zn, TPC, TAC, and vitamin E, and n-3 fatty acids deposition in thigh meat samples were significantly increased. The cholesterol concentration in breast samples was significantly lowered and the antioxidant compounds were increased. Significant alteration in breast meat color and texture quality were obtained.	[24,180]
Lauraceae	Avocado (*Persea americana*)	Cobb 500 broiler chickens	0.5%, 1%, and 1.5% seed meal	The BW was decreased by 1.5% seed meal inclusion, with no effect on FCR. The Mg level in the serum of same group was significantly increased, while urea was significantly higher with 0.5% seed meal. The recommended level was 0.5%.	[190]
		Cobb 500 broiler chickens	2%, 4%, 6%, and 8% seed meal	The results showed no significant difference in the hematological parameters except lymphocytes and mean cell hemoglobin except at the normal range, which implied that the inclusion level of seed meal in broiler diets had no negative effect on the birds up to 8% inclusion level that was studied. It also has positive effect on the total protein, albumin, and globulin.	[191]
Liliaceae	Garlic (*Allium sativum*)	Bovan Brown layers	0.5% and 1%	No significant effect on egg weight and FI but had a significant improvement in the number of eggs, egg production, egg mass, and FCR. The egg quality characteristics were not influenced, but the cholesterol content was significantly decreased in eggs. The general health status also improved significantly.	[192]
		Shaver Starbo chicks	0.5% and 5% raw powder	Raw garlic powder marginally improved BW, with the highest weight gain observed at the 5% level. While the carcass and organ characteristics were not significantly affected by the garlic supplementation, the abdominal fat content was significantly reduced. Additionally, the garlic aroma and palatability scores of the meat improved with higher levels of dietary garlic, with thigh muscle exhibiting the highest garlic aroma score.	[193]
		Shaver Starbo chicks	0.5% and 5% boiled powder	Boiled garlic powder did not produce any significant beneficial effects on broiler performance or meat quality. Specifically, there were no notable differences in weight gain, feed intake, or feed conversion ratio, and the carcass and organ characteristics, as well as the moisture content of the meat, were unaffected.	[193]
	Onion (*Allium cepa*)	Bovan Brown layers	1% leaves	No significant effect on egg weight and FI but had a significant improvement in the number of eggs, egg production, egg mass, and FCR. The egg quality characteristics were not influenced, but the cholesterol content was significantly decreased in eggs. General health status was also improved significantly.	[192]

Table 2. *Cont.*

Plants Family	Plants Common Name	Poultry Species	Dose and Type	Main Effect on Laying Hens and/or Broilers	Reference
Musaceae	Plantain/Banana (*Musa* × *paradisiaca*)	Marshall broilers	10% and 20% peel waste	No significant differences in the blood parameters except for erythrocyte sedimentation rate, white blood cell count and heterophil values of birds from control versus plantain supplements. Serum biochemical parameters analyzed except for serum globulin, albumin, urea, potassium, phosphorus, and aspartate aminotransferase were similar. It was concluded that plantain peel is a suitable substitute for maize in broiler finisher diet at inclusion rate not beyond 10% for optimal blood characteristics.	[194]
Oleaceae	Olive (*Olea europaea*)	Lohmann Brown laying hens	1%, 2%, or 3% leaf powder	No effect on FI, egg weight, egg yield and FCR but increased BW. Yellowness in yolk color was increased without affecting other quality parameters. Yolk cholesterol content tended to decrease by about 10%. Suggested to be used for reducing egg yolk cholesterol content and egg yolk coloring agent in layer diets.	[195]
		Ross 308 broiler chickens	3% and 6% pulp waste	Improved foot pad dermatitis and feather cleanliness. No effects growth performance or fecal microbiota population. Changes of β-diversity in an age-dependent way were only observed. Both diets beneficially affected chickens' health and welfare.	[196]
Rosaceae	Rosehip (*Rosa canina*)	Tetra SL laying hens	1.5% and 3% meal	Rosehip meal in eggs enriched with PUFA exhibited a positive effect on eggs protein and lipids quality. The TAC and TPC in eggs were significantly improved. The 3% dose was more effective on shelf life of eggs stored for 28 days at refrigerator and room temperature.	[6]
		Cobb 500 broiler chickens	0.10%, 0.20%, and 0.30% fruits	The 0.10% treatment improved BW, FI and protein intake. All treatments reduced percent GIT length of large intestine and ceca at higher supplement value. It was concluded that it can be safely used up to 0.30%, producing higher dressing percentage.	[197]
		Lohmann Brown laying hens	0.5% and 1% leaves	Significantly improved laying rate, FCR, egg mass, with no effect on egg weight and its components. The chromomeric parameters (L*, a* and b*) were significantly altered, as well as the n-3 and n-6 fatty acids.	[9]
Rutaceae	Orange (*Citrus sinensis*)	Cobb 500 broiler chickens	2% peel	Significant increase in BW, health status and the total PUFA. Significantly reduced the oxidation process occurring during storage in thigh meat, and the growth of pathogenic *Escherichia coli* and *Staphylococcus* spp., proving their antimicrobial effect, while the beneficial bacteria, *Lactobacillus* spp. were increased.	[116]
	Grapefruit (*Citrus paradisi*)	Cobb 500 broiler chickens	2% peel	Decreased BW, glucose, cholesterol, and triglyceride from blood serum and the total PUFA. Significantly reduced the oxidation process occurring during storage in thigh meat. Reduced the growth of pathogenic *Escherichia coli* and *Staphylococcus* spp., proving their antimicrobial effect, while the beneficial bacteria, *Lactobacillus* spp. were increased.	[116]
Solanaceae	Tomato (*Solanum lycopersicum*)	Tetra SL Laying hens	2.5%, 5%, and 7.5% waste	Improved egg yolk color and carotenoids deposition. The 5% diet increased the oxidative stability of n-3 PUFA enriched eggs. The 7.5% tomato waste has depressed the absorption and deposition of n-3 fatty acids in egg yolk.	[34]
Vitaceae	Grape (*Vitis vinifera.*)	Hubbard broilers	2% seed meal	BW, FI, and FCR improved significantly, as well as meat quality. The PUFA were significantly higher in breast samples, while cholesterol content was significantly lower in thigh samples. The plasma glucose, cholesterol and triglyceride levels were significantly lower.	[121]
		Tetra SL laying hens	3% seed meal	Improved production performances, TAC and TPC in eggs. The fatty acids profile was improved, however, the percentage on n-6 was higher than the n-3.	[5]
Zingiberaceae	Ginger (*Zingiber officinale*)	Ross 308 broiler chickens	0.15%, 0.20%, and 0.25% powder	No effect on production performance, however, ginger at all levels resulted in a significant decrease in gizzard weight and abdominal fat. No effect on blood biochemistry and antibody production against sheep red blood cells. The *Lactobacillus* counts in the ileal content of birds fed 0.20 and 0.25% ginger were higher.	[199]

6. Environmental and Economic Impacts and Limitations of the Presented Sustainable Poultry Feeding

6.1. Environmental and Economic Impacts of Sustainable Feeding Strategies

The shift towards alternative and sustainable feeding strategies in poultry production is driven not only by the need to improve nutrition and animal welfare but also by the imperative to reduce the environmental and economic impacts associated with conventional poultry farming. As the global demand for poultry products continues to rise, it is essential to adopt practices that minimize the carbon footprint, resource use, and economic costs of production [202]. The studies conducted by Campos et al. [203] and Osorio et al. [204] revealed that the use of agricultural by-products as feed ingredients contributes to a circular economy by recycling waste materials and reducing the environmental burden of waste disposal. This approach helps to lower the overall carbon footprint of poultry production. However sustainable feeding practices have obvious environmental benefits, chicken producers will only embrace them if they can be made economically viable [205]. However, the price of these substitute feeds should drop as the market for sustainable feed ingredients expands and manufacturing techniques advance. Economies of scale, advances in processing technologies, and increased competition in the market will likely drive down prices, making these feeds more accessible to a broader range of producers. Another economic consideration is the potential for alternative feeds to create new markets and revenue streams [206,207].

It is important to achieve a balance between environmental sustainability and economic viability for adopting alternative feeding strategies on a large scale. Moreover, there are surveys [208–210] suggesting that the rising awareness of environmental issues and preference for ethical food leads to increased customer demand for ecologically sustainable poultry products. As a result, such changes in consumer preferences can give rise to market opportunities for farmers who decide to go green in terms of their feed provisions, with possible high prices being charged on their goods.

However, moving away from conventional feeds poses challenges but also presents significant opportunities aimed at reducing the ecological burden from poultry farming as well as strengthening its economic resilience. Consequently, continued investments in research, technology, and policy support will be necessary towards unlocking the full potential of such approaches and making poultry production environmentally friendly in the long run.

6.2. Limitations of the Presented Alternative Sustainable Poultry Feeding

Feed control is a very important aspect in poultry diets, especially when incorporating fruit waste or other raw materials, due to their variability in nutritional composition. These materials offer potential nutritional benefits but also carry risks and limitations due to varying levels of anti-nutritive substances. In this regard, multiple levels of control are essential to ensure that the feed is both safe and nutritionally adequate for poultry. Poultry diets, as mentioned before, are composed of a balance of energy sources, proteins, vitamins, minerals, and additives, which all contribute to overall bird health and productivity. For these nutritional reasons, when including unconventional waste materials in poultry diets, several aspects must be carefully evaluated, as explained below.

The nutritional value of any ingredient, especially novel ones like fruit waste, needs to be thoroughly analyzed for proximate composition for basic nutrients (proteins, fats, and fibers), amino acids, fatty acids, and vitamins (like A, C, and E) content, knowing that they can vary in composition based on growing conditions and processing methods [211].

Anti-nutritional compounds present a significant challenge in alternative feed ingredients, especially tannins, saponins, phytic acid, and oxalates found in by-products, which can interfere with nutrient absorption and reduce feed efficiency, inhibit enzyme activity, reduce mineral bioavailability, and impair protein digestion [212].

Digestibility is a key factor when formulating poultry diets, particularly when using waste products. Ingredients with high fiber content, like many fruit peels, may lower feed digestibility if not processed correctly. Fiber-rich ingredients need to be included in controlled amounts to avoid increasing intestinal bulk, which can interfere with the digestion of essential nutrients like proteins and fats [212]. Palatability is another critical factor, as poultry may reject feed if it has an unpleasant taste, smell, or texture. Some by-products may contain bitter compounds or unfamiliar flavors, which could reduce feed intake as reported by others [211,213].

Considering the variability in the chemical composition of novel ingredients, they should be included in the compound feeds at levels that do not negatively affect the balance of the formulation. Although majority plant-derived waste can provide useful antioxidants or fiber, the excessive amounts may dilute energy-dense components or overwhelm the birds with non-digestible matter [213]. For this reason, formulation software and nutritional modeling are recommended to be used to adjust and balance the inclusion rates of novel ingredients tested based on their nutritional content.

7. Future Research Directions in Sustainable Poultry Feeding with Alternative Feed Ingredients

In order to fully exploit alternative feeding options, it is important that policy makers create an enabling environment that promotes research, innovation, and uptake of sustainable systems. Some aspects to consider for future research include the following:

Further investigations to improve upon alternative feed nutritional contents so that they can meet poultry nutrition requirements while still being cost-effective for farmers. This will require further studies on the digestibility, palatability, and nutritional advantages of new feed ingredients.

Comprehensive analyses should be performed to assess the environmental impacts of different poultry feeding strategies, including lifecycle analysis, potential carbon footprint savings, water usage, and other environmental indicators linked with alternative feeds.

The economic viability of alternative feeding strategies needs to be evaluated at various scales of production, ranging from small-holder farms to large commercial enterprises. It is important to understand such dynamics in terms of cost–benefit relationships when considering widespread adoption. Furthermore, consumer perception studies could identify barriers to market acceptance of poultry products raised on alternate feeds and suggest ways in which these could be overcome.

To maintain industry standards of production, there is a need for long-term health and productivity studies on the effect of alternate feeds on the health status, growth rate, reproduction indices, and the quality of products (meat and eggs) from poultry farms.

One example is that governments as well as international organizations must introduce economic incentives like grants or reduced taxes for chicken farmers who apply ecological principles when it comes to feeding their birds. For example, this could involve support for the establishment of infrastructure necessary for production or sourcing of alternative feeds, such as insect- and plant-based proteins.

Increased investment in research geared towards optimizing alternative feed formulations, their long-term effects on avian health status, and the existence of scalable production methods. Academia–industry–government collaborations can enable the development of affordable, sustainable feeding solutions.

Sustainable poultry feeding strategies should be explained to farmers, industry players, and consumers. Through awareness campaigns, resistance against new practices shall be overcome while building consumer demand for poultry products from birds fed using sustainable feeds.

It is vital to develop clear guidelines that ensure the safety, quality, and environmental benefits of alternative feed ingredients, in addition to setting standards for the use of insect-based feeds, which are still relatively new to the market.

8. Conclusions

In conclusion, it is important to embrace alternative sustainable feeding strategies in poultry production to achieve SDG 2, Zero Hunger. Through exploration of innovative alternatives and alignment of feeding practices with circular economic principles, the poultry industry can greatly contribute towards global food security as well as environmental sustainability. Further research supported by enabling policies will be critical in addressing challenges and ensuring successful implementation of these strategies.

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Abbreviations

DM	dry matter
dw	dry weight
fw	fresh weight
CP	crude protein
EE	ether extract (crude fat)
CF	crude fiber
TPA	total phenolic acids
TPC	total phenolic compounds
TAC	total antioxidant capacity
TFC	total flavonoids content
SFA	saturated fatty acids
MUFA	monounsaturated fatty acids
PUFA	polyunsaturated fatty acids
n-3	total omega 3 fatty acids
n-6	total omega 6 fatty acids
GAE	gallic acids equivalent
QE	quercetin acids equivalent
DPPH	2,2-diphenyl-1-picrylhydrazyl
ABTS	2,2′-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid)
FRAP	ferric reducing antioxidant power
TEAC	trolox equivalent antioxidant capacity
TBARS	thiobarbituric acid reactive substance
FCR	feed conversion ratio
BW	body weight
FI	feed intake
SDG	Sustainable Development Goal

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