THE USE OF AGRI-FOOD BYPRODUCTS IN THE DIET OF LAYING HENS TO PRODUCE EGGS WITH FUNCTIONAL PROPERTIES

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Abstract

Economic, ecological and social sustainability can be improved by using agro-industrial by-products, especially those not intended for human consumption, as alternative to conventional feed in animal nutrition, resulting in the production of animal products without competing for land or causing competition between food and feed. These products are also known to be rich in several bioactive compounds and can improve the health and well-being of laying hens. The potential of agro-industrial by-products such as: winemaking by-products, tomato proces-sing by-products, distillery grain by-products, olive oil industry by-products, pomegranate by-products and their derivatives as functional feed for laying hens, as well as the potential limitations of the use of agro-industrial by-products in the nutrition, are elaborated in this study. The ways in which agro-industrial by-products can improve the productivity and health of laying hens are also analyzed. We suggest eliminating potential hazards, such as mycotoxins, from agro-industrial by-products, by establishing appropriate legislation and also by correctly applying control measures. The use of agro-industrial by-products in the nutrition of laying hens is supported by modern processing means and by appropriate development strategies. This study analyzes agro-industrial by-products as feed, not only for their nutritional value but also for their role as sustainable practices.

Key words: *laying hens, antioxidants, fruit waste, bioactive compounds, poultry, egg quality*

INTRODUCTION

In modern poultry production, significant efforts are focused on reducing the use of synthetic additives and promoting natural approaches to improving the functional value of feed, with particular focus on increasing its antioxidant capacity [1].

From producers and regulators to consumers, the future of livestock feeding is an increasing concern among stakeholders across the agri-food chain, owing to growing pressures to improve environmental sustainability, food system resilience, and resource efficiency [2]

A recent Evidence Assessment conducted by the UK Food Standards Agency [3] highlighted four main categories of innovative feed sources with potential to enhance food system resili-ence and sustainability. These involve genetically modified crops and alternative growing systems designed to increase resource-use efficiency, precision fermentation and cellular agriculture for producing novel proteins and industrial food-processing residues that can be safely redirected from the human food chain to livestock feed, and animal co-products such as insect and rendered proteins that

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contribute to nutrient recovery and circularity. Each category offers regulatory challenges and distinct opportunities within the broader circular feed framework. Among these, food waste, and industrial by-products has attracted growing attention due to nutritional quality, its abundance, compatibility, and cost-effectiveness with existing feed manufacturing systems [4].

Through 2050, the world population is expected to increase from 8 billion in 2022 to 9.7 billion. In addition, it is estimated that greenhouse gas emissions will increase at an average rate of 2-6% annually by 2030 [5].

Owing to their potential to provide a safer and more sustainable solution, natural antioxidants, derived from plant sources, have gained considerable interest from the research industry. Among numerous studied plants in the scientific literature, fruit-derived waste, which includes by-products, seeds, pulp and peels, presents a promising underutilized resource, frequently discarded during food processing, leading to considerable environmental wast [6]. While, these by-products are viewed as waste, they are containing high levels of bioactive compounds with antioxidant potential, like flavonoids, vitamins, and polyphenols, with proven in vivo and in vitro antioxidant properties [7].

Against this background, the poultry industry has started to analyze the potential of incorporating fruit waste into poultry diets, as a natural way of improving overall egg quality. Recent research papers proved that, integrating different types of fruit waste-derived sources of antioxidants into poultry feed has con-tributed to various benefits [8] and improved laying hen health [9].

Furthermore, this approach as well aligns with the growing emphasis on sustainability in food production by reducing the environmental pollution of food waste while concomitantly adding value to by-products that as is well know would otherwise be discarded as waste.

The present study aimed to review the current research on the use of key fruit waste-derived natural antioxidants in laying hens feed and their effects on egg quality. The review concentrated on the waste with the highest potential to be used as source of feed ingredient rich in antioxidant compounds.

MATERIAL AND METHOD

The literature search conducted was limited to recent research articles having the full text available in the English language. The main databases used were Google Scholar and Web of Science, a globally recognized resource for its rigors indexing of high impact scientific literature [10].

Main search keywords used were laying hens, antioxidants; fruit waste; bioactive compounds; poultry and egg quality.

The search focused on the published in peer-reviewed journals and literature published from the most recent years. The Book chapters were also incorporated, if available online. The selection procedure was refined through criteria designed to identify studies directly related to the application of fruit waste in laying hens feed formulations, specifically aimed at evaluating their effects on egg quality, production performances and health status.

Research were considered if they evaluated the functional and chemical aspects of natural antioxidants from fruit waste (pomace, peels, pulps, seeds) and their effects on various egg quality characteristics and nutritional value, evaluating outcomes in egg quality or production as well as their implications on animal health.

Research with insufficient experimental rigor, an unspecified sample size, or those without the potential for use in real-world experimental trials, were not considered. We focused on research that used fruit

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waste with elevated availability after fruit processing and in a sustainable manner.

After the literature review, we found several studies that described the effects on laying hen diets and the chemical composition of the fruit waste or both.

These summarized results aim to emphasize potential mechanisms through which fruit-derived antioxidants contribute to egg quality improvements and the potential trends for future research.

RESULTS

The role of natural antioxidants on laying hen performances and egg quality characteristics

Natural antioxidants, especially those derived from plant-based sources, have been recommended as safer alternatives to synthetic ones and offer additional health advantages including enhanced protection against diseases as well as reduced inflammation [11].

Antioxidants, in laying hen nutrition are important because they protect the tissues and cells from oxidative damage, which, with time, degrades the quality of the eggs. Recent research, by Oke et al., [12], found that oxidative stress in laying hens can be caused by several issues, such as environmental stressors, illness, and the metabolic demands of egg production. Oxidative stress in laying hens can have a detrimental effect on the health status and quality of the eggs they lay a lower quality of the final pro-ducts and leading to lower productivity.

Improved health and productivity in hens was due to the use of natural antioxidant sources de-rived from fruit waste, has gained attention ad well for improving the productive performance of laying hens by using bioactive compounds that contribute significantly to reducing oxidative stress in hens. Hussein et al., [13], reported 1% orange peel as a natural source of antioxidants enhanced lipid quality in eggs, health status, and internal organs, allowing hens to produce consistently more higher quality eggs. also, its usage resulted in optimized feed intake and an improved feed conversion ratio, resulting in a more efficient feed utilization, in cost-effective and a sustainable manner. Similar effects on improved productive performance were as well reported when 6% and 9% grape or 3% rosehip pomaces were tested [14].

Nowadays, consumer demand for “clean labels” products have forced many food producers, to find natural replacements for artificial additives, including the poultry sector [15].

The critical factors that directly affect the profitability and success of the marketing of the poultry industry are egg quality and shelf life [16].

Natural antioxidants derived from fruit waste can produce enriched eggs with more health benefits that may contribute to people’s wellbeing [17].

There is still little known about the natural antioxidants that would perform these roles without compromise the nutritive values and also safety of eggs, which could represent a key area of focus in modern laying hen research.

A recent study shown that addition of pomegranate peel to the diets of laying hens improved shell-breakage strength and yolk color [18].

A similar finding was drawn in a study report conducted by Obianwuna et al., [19], which stated that nutritional interventions with natural antioxidants from plants sources could represent a solution to reducing albumen quality over time during storage, without negative health issues for consumers. The potential effects, of using fruit waste in laying hen diets, are shown in Table 1.

Mechanisms underlying antioxidants activity in laying hens

The enzymatic metabolism plays a crucial role in maintaining cellular health in laying hens, particularly when the birds are exposed to multiple stressors or oxidative

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challenges, where the antioxidant defense system role is reducing the process of these factors [27]. The balance between antioxidant and pro-oxidant substances, at this stage, is shifted toward the formation of pro-oxidant species, in order to reestablish the balance between these species, the antioxidant defense system is activated and the elimination of ROS is conducted through the activation of three phases of the antioxidant defense system [28].

Table 1. The potential effects of using fruit waste in laying hen diets

Fruits waste	Bio-Compounds	Effects on			References
		Hen Health	Eqq quality	Shelf life	
Pomegranate waste 	High antioxidants	Anti-inflammatory lower cholesterol and triglycerides	altered yolk color improved egg physical	Reduced MDA (lipid oxidation)	[20]
Citrus waste 	Flavonoids Vitamina C	Improved immunity and gut health	Richer yolk color and shell strength	Extended freshness	[21; 22]
Grape waste 	Tocopherols Resveratrol	Antioxidant support	Omega 3 and vitamin enrichment	Extended stability	[23; 24]
Apple waste 	Prebiotic Fibers	Decreased blood, albumin, lower oxidative stress	Higher egg/albumin weight, thicker shell, better Haugh Unit	Decreased MDA for 28 days	[25; 26]

According to Roy et al. [29], free radicals are neutralized by enzymes, in the first phase (direct enzymatic pathway), such as glutathione peroxidase (GPx), superoxide dismutase (SOD) and catalase (CAT) which are principal components of the antioxidant defense system working to neutralize detrimental reactive oxygen species (ROS) and prevent oxidative damage. Superoxide dismutase is the first line of defense in the enzymatic pathway and where it catalyzes the conversion of superoxide radicals (which are highly reactive oxygen species) into hydrogen peroxide (H2O2) and oxygen [30]. Accumulation of superoxide radicals can lead to significant cellular damage, SOD's role is to re-duce this by transforming these radicals into a substance with reduced harmful effects, hydrogen peroxide [31].

However, to prevent oxidative stress, H2O2 needs to be further neutralized because is still reactive (this is where CAT and GPx come into play). CAT is an enzyme that further breaks down H2O2 into water and oxygen and is particularly important in tissues where high levels of H2O2 may accumulate, such as the liver and kidneys [32].

Proteins and lipids remain protected from oxidative damage due to CAT which converting H2O2 into water, ensures that cellular structures and molecules. Further, GPx also plays a critical role in reducing H2O2, but it does so using GPx as a substrate [33]. GPx also reduces lipid

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hydroperoxides, which are generated during lipid peroxidation [34].

Horváth and Babinszky in 2018, [35] shown that during the second phase reactions that lead to the de-toxification and regeneration of small antioxidant molecules, such as vitamins A, E, and C, and an adequate intake of trace elements such as Zn and Se, they are cofactors for GPx, which can enhance the activity of these enzymes.

According to Hu et al., 2021,[36] the third phase is activated when damaged systems, such as proteins or DNA, are repaired or removed from cells by specific transporters.

Fruit waste bioactive compounds and antioxidant potential

The production of waste from various fruits is vast and food waste is a significant global issue, impacting both environmental sustainability and food security. In 2020, [37] the reports of the Food Agricultural Organization (FAO) and in 2023, European Commission on Agriculture [38] on the amounts of fruits waste produced in different countries after their processing are massive.

The top producers of citrus fruits and cultivated types of fruits are Brazil and United States, citrus fruits are extensively consumed and processed globally, resulting in a large volume of waste, especially in the form of pulp and peels. In 2020, according to the FAO [39] the global production of citrus fruits was above 150 million tons, amounting to approximately 20-30% being wasted during processing. The previously mentioned countries contribute remarkably to producing such food waste. Citrus waste contains 14% fiber, 7% protein, 24.4% total sugars, 2.5% fat and 2.5% moisture [40]. Citrus peels are extremely rich in lutein and zeaxanthin (36.46 to 81.52 mg/kg), polyphenols (8.04 to 12.16 mg/g), vitamin C and antioxidant capacity, compounds that indicate strong antioxidant activities [41].

The residue left after wine production (grape pomace) is composed of grape skins, stems and seeds. Global grape production extends to 77 million tons annually, with pomace waste representing approximately 20-25% of the overall weight of processed grapes. In Europe, especially Italy, France and Spain, according to the FAO,[42] produces important grape waste, since these are the largest wine producers. Grape pomace is rich in polyphenols, including resveratrol, flavonoids, and tannins, which are widely recognized for their antioxidant properties [43]. A recent review study by Caponio et al., [23] showed that grape waste is also rich in proanthocyanidins and minerals as well as substantial amounts of ABTS and DPPH, which have been shown to contain high antioxidant potential. As reported by the FAO in 2021, [44] a cider production and by-product of juice is the apple waste amounting to 20-30% of the fruit weight. The United States, China and Poland, with more than 87 million tons of apples produced globally each year, has the highest amount of apple, producing nations contributing to this waste.

The nutritional composition contains total phenolic content (1.1-289.1 mg/g GAE), carbohydrates (33.77-45.1%), protein (2.91-4.7%), moisture (4.4-10.5%) and ash (1.5-2.95%) [45]. Apple waste is a rich source of bioactive compounds, with antioxidant potential, such as dietary pectin, fiber and vitamins [46]. Fruit waste is an underutilized and abundant resource rich in bioactive compounds that posse antioxidant properties, whose applications in laying hen nutrition might benefit multiple parties. Figure 1 illustrates graphically the most important phytochemicals present in fruits waste.

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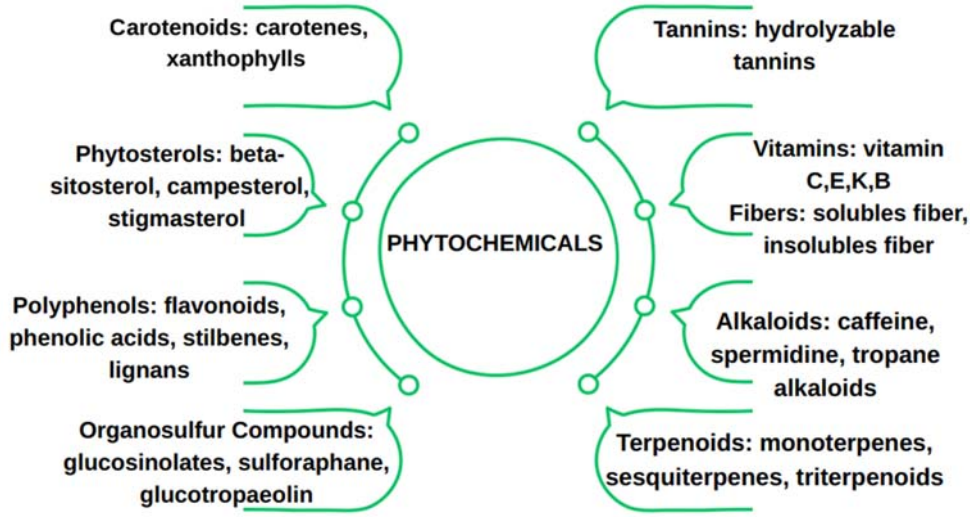


Figure 1. Graphical representation of the phytochemicals in fruits waste

The potential benefits and associated risks of using fruits waste on various aspects in laying hen diets

Seidavi et al., in 2020, [21] found that 1000 mg/L orange peel extract improved the immune system owing to the flavonoid contents of the orange peel, which stimulates the immune system by increasing the anti-inflammatory activity IgG and IgM.

Herranz et al. in 2024, [24] showed that 5% grape pomace had diffe-rent effects when tested on different laying hen hybrids, ISA white and ISA brown. Both hybrids showed an improved laying rate (97.1%) without affecting egg weight. Grape pomace resulted in eggs with higher Haugh Units (96.3 and 99) compared with control eggs (93.8) but decreased the redness parameter in egg yolk. The authors reported that during storage, ISA white hens had better Haugh Units during 21 days of storage compared with the ISA brown hens, even though both received the same level of grape pomace. For laying hens diets, studies have reported that up to 5% grape waste is safe without detrimental effects.

As reported by Kara et al., [47 in laying hen diets, the incorporation of 4-6% grape pomace (which is the solid residue of grape) did not influence growth traits, egg quality indices, egg production, live weight and liver weight, while egg weight was enhanced at a 4% dietary level.

Another study by Reis et al., [48] reported that the inclusion of 1–3% GP in heat-stressed laying hen diets at the end of the productive cycle improved egg quality, growth performance, serum total antioxi-dant capacity, and the activities of glutathione superoxide and peroxidase dismutase activities.

CONCLUSIONS, CHALLENGES AND FUTURE DIRECTIONS

The incorporation of agri-food by-products into laying hen diets provides multiple nutritional benefits while supporting their sustainable utilization. Using fruit waste as natural source of antioxidants in poultry nutrition can enhance the valorization of agricultural residues, reduce reliance on synthetic additives, minimize environmental impacts

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and support the development of a circular economy. Growing global concerns regarding food waste and environmental sustainability highlight the potential of incorporating fruit waste into laying hen diets as an eco-friendly strategy benefiting both the feed and agricultural sectors.

Dietary antioxidants supplementation modulates metabolic and oxidative processes in laying hens, supporting endogenous antioxidant defenses, maintaining redox balance and enhancing the utilization and bioavailability of dietary nutrients.

Although fruit by-products represent promising feed ingredients for laying hens, their inclusion in dietary formulations requires careful consideration of several nutritional and technological factors.

The nutritional characteristics of fruit by-products can differ substantially depending on the type of fruit and processing methods, which may complicate the formulation of balanced diets for laying hens and compromise nutrient supply when inclusion rates are not carefully determined

New dietary formulations could be developed by adding complementary sources of nutrients, amino acids and minerals to fruit by-products in order to provide a balanced diet for laying hens. This could help develop balanced diets that include fruit by-products while preventing nutrient deficiencies or imbalances.

The strong flavors found in some fruit wastes may reduce feed palatability, which could result in lower feed intake and have negative effects on the productivity and health of laying hens.

Additional studies are needed to evaluate the long-term impact of fruit waste on laying hen health and productivity, as well as on egg quality and shelf life.

REFERENCES

1. Mahfuz, S.; Shang, Q.; Piao, X., Phenolic compounds as natural feed additives in poultry and swine diets: A review. *Journal of Animal Science and Biotechnology*, **2021**, 12(1), 48.https://link.springer.com/article/10.1186/s40104-021-00565-3

2. Gurgel, A. C.; Reilly, J.; Blanc, E., Challenges in simulating economic effects of climate change on global agricultural markets. Climatic Change, **2021**, 166(3), 29. ,https//doi.org/10.1007/s10584%2D021%2D03

3. Pexas, G., I.; Kyriazakis and B. Doherty. Future of Protein Sources in Livestock Feed. *Food*, **2023**

4. Khattak, F.; Mulvenna, C.; Muns, R., Kyriazakis, I.; Short, F. Unlocking sustainable poultry feeding: nutritional, regulatory and sustainability consequences of former food products in poultry diets. *World's Poultry Science Journal,* **2026**, 82(2), 787808.https://doi.org/10.1080/00439339.2026.2628866

5. Georganas, A.; Giamouri, E.; Pappas, A. C.; Zoidis, E.; Goliomytis, M.; Simitzis, P., Utilization of Agro-Industrial By-Products for Sustainable Poultry Production. Sustainability, **2023**, 15(4), 3679. https://doi.org/10.3390/su15043679

6. Majumder, P.; Annegowda, H. V., Fruit and vegetable by-products: novel ingredients for a sustainable society. In Valorization of agri-food wastes and by-products (pp. 133-156). *Academic Press*, **2021**.https://doi.org/10.1016/B978-0-12-824044-1.00006-4

7. Untea, A. E.; Varzaru, I.; Vlaicu, P. A.; Turcu, R. P.; Panaite, T. D., Studies on antioxidant activities of grape pomace using in vitro, ex vivo, and in vivo models. *Journal of Food Measurement and Characterization*, **2023**, 17(1), 121-128.

8. Vlaicu, PA; Untea, AE; Oancea, AG, Sustainable poultry feeding strategies for achieving zero hunger and enhancing food quality. *Agriculture*, **2024**, 14(10), 1811.https://doi.org/10.3390/agriculture14101811

9. Colombino, E.; Ferrocino, I.; Biasato, I.; Cocolin, LS; Prieto-Botella, D.; Zduńczyk, Z.; Juśkiewicz, J., Dried fruit pomace inclusion in poultry diet: growth performance, intestinal morphology and physiology. *Journal of animal science and biotechnology*, **2020**, 11(1), 63.https://link.springer.com/article/10.1186/s40104-020-00464-z

10. García, JM; Udenigwe, CC; Duitama, J.; Barrios, AFG, Peptidomic analysis of whey protein hydrolysates and prediction of their antioxidant peptides. *Food Science and Human*

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Wellness, **2022**, 11(2), 349-355https://doi.org/10.1016/j.fshw.2021.11.011
11. Beya, MM; Netzel, ME; Sultanbawa, Y.; Smyth, H.; Hoffman, LC, Plant-based phenolic molecules as natural preservatives in comminuted meats: A review. Antioxidants, **2021**, 10(2), 263.https://doi.org/10.3390/antiox10020263
12. Oke, OE; Akosile, OA; Oni, AI; Opowoye, IO; Ishola, CA; Adebiyi, JO; Abioja, MO, Oxidative stress in poultry production. *Poultry Science***,** **2024**, 103(9), 104003.https://doi.org/10.1016/j.psj.2024.104003
13. Hussein, E.; Alhotan, RA; Ebrahim, A.; Selim, S., Unraveling the potential of orange pulp for improving laying rate, egg quality, oxidative stability, fatty acids composition, and reproductive tract morphology of laying hens. *Animals*, **2023**, 13(13), 2199. https://doi.org/10.3390/ani13132199
14. Li, Z.; Qin, B.; Chen, T.; Kong, X.; Zhu, Q.; Azad, MAK.; He, Q., Fermented Aronia melanocarpa pomace improves the nutritive value of eggs, enhances ovarian function, and reshapes microbiota abundance in aged laying hens. Frontiers in Microbiology, **2024**, 15, 1422172.https://doi.org/10.3389/fmicb.2024.1422172
15. Grant, KR; Gallardo, RK; McCluskey, JJ, Consumer preferences for foods with clean labels and new food technologies. *Agribusiness*, **2021**, 37(4), 764-781.https://doi.org/10.1002/agr.21705
16. El-Sabrout, K.; Aggag, S.; Mishra, B., Advanced practical strategies to enhance table egg production. *Scientifica*, **2022** (1), 1393392.https://doi.org/10.1155/2022/1393392
17. Vlaicu, PA; Untea, AE; Varzaru, I.; Saracila, M.; Oancea, AG, Designing nutrition for health-Incorporating dietary by-products into poultry feeds to create functional foods with insights into health benefits, risks, bioactive compounds, food component functionality and safety regulations. *Foods*, **2023**, 12(21), 4001.https://doi.org/10.3390/foods12214001
18. Bölükbaşı, ŞC; Ürüşan, H., Pomegranate peel supplementation improves performance and lipid metabolism in laying hens*. Archives Animal Breeding*, **2025**, 68(4), 629-639https://doi.org/10.5194/aab-68-629-2025
19. Obianwuna, UE; Oleforuh-Okoleh, VU; Wang, J.; Zhang, HJ; Qi, GH; Qiu, K.; Wu, SG, Potential implications of natural antioxidants of plant origin on oxidative stability of chicken albumen during storage: A review. Antioxidants, **2022**, 11(4), 630.https://doi.org/10.3390/antiox11040630
20. Lioliopoulou, S.; Papadopoulos, GA; Mantzouridou, FT; Giannenas, I.; Kalogeropoulou, A G; Lioupi, A.; Fortomaris, P., Pomegranate peel dietary supplementation in laying hens affects egg yolk color and eggshell quality, decreases yolk lipid oxidation and influences yolk lipidomic profile. *Journal of Applied Poultry Research*, **2024**, 33(4), 100495.https://doi.org/10.1016/j.japr.2024.100495
21. Seidavi, A.; Zaker-Esteghamati, H.; Salem, AZ, A review on practical applications of Citrus sinensis by-products and waste in poultry feeding. *Agroforestry Systems,* **2020**, 94(4), 1581-1589.https://link.springer.com/article/10.1007/s10457-018-0319-2
22. Goliomytis, M.; Kostaki, A.; Avgoulas, G.; Lantzouraki, DZ; Siapi, E.; Zoumpoulakis, P.; Deligeorgis, SG, Dietary supplementation with orange pulp (Citrus sinensis) improves egg yolk oxidative stability in laying hens. *Animal Feed Science and Technology*, **2018**, 244, 28-35.https://doi.org/10.1016/j.anifeedsci.2018.07.015
23. Caponio, GR; Minervini, F.; Tamma, G.; Gambacorta, G., De Angelis, M.. Promising application of grape pomace and its agri-food valorization: Source of bioactive molecules with beneficial effects. *Sustainability*, **2023**, 15(11), 9075https://doi.org/10.3390/su15119075.
24. Herranz, B.; Romero, C.; Sánchez-Román, I.; López-Torres, M.; Viveros, A.; Arija, I., Chamorro, S., Enriching eggs with bioactive compounds through the inclusion of grape pomace in laying hens diet: Effect on internal and external egg quality parameters. *Foods*, **2024**, 13(10), 1553.https://doi.org/10.3390/foods13101553

25. Akyol, G.; Denli, M., Effects of Dried Tomato, Apple and Grape Pulps on the Performance, and Egg Quality of Laying Hens. Turkish *Journal of Agriculture-Food Science and Technology*, **2023**, 11(2), 307-311.https://orcid.org/0000-0002-6522-5863
26. Fiialovych, L.; Kyryliv, I., Laying performance, egg quality and hatching results in geese fed with dry apple pomaces. *Acta Scientiarum Polonorum Zootechnica,* **2017**,

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15(4), 71-82.https://doi.org/10.21005/asp.2016.15.4.06
27. Emami, NK; Jung, U.; Voy, B.; Dridi, S., Radical response: effects of heat stress-induced oxidative stress on lipid metabolism in the avian liver. *Antioxidants*, **2020**, 10(1), 35.https://doi.org/10.3390/antiox10010035
28. Mnisi, CM; Mhlongo, G.; Manyeula, F., Fruit pomaces as functional ingredients in poultry nutrition: A review. *Frontiers in Animal Science*, **2022**, 3, 883988.https://doi.org/10.3389/fanim.2022.883988
29. Roy, Z.; Bansal, R.; Siddiqui, L.; Chaudhary, N., Understanding the role of free radicals and antioxidant enzymes in human diseases. *Current pharmaceutical biotechnology*, **2023**, 24(10), 1265-1276.https://doi.org/10.2174/1389201024666221121160822
30. Sharma, P.; Jha, AB; Dubey, RS; Pessarakli, M., Reactive oxygen species generation, hazards, and defense mechanisms in plants under environmental (abiotic and biotic) stress conditions. *Handbook of plant and crop physiology*, **2021**, 617-658, Standards Agency. https//doi.org/10.3389/fsufs.2023.1188467
31. Sabuncuoglu, S.; Yalcinkaya, A.; Blumenberg, M., Importance of oxidative stress and antioxidant system in health and disease. *BoD-Books on Demand*, **2023**.https://books.google.ro/books?hl=ro&lr=&id=4_DkEAAAQBAJ&oi=fnd&pg=PP14&ots=fgIwfHZIsO&sig=2NfzLRpfqdZVSrtw2mbxOxxmp0s&redir_esc=y#v=onepage&q&f=false
32. Tehrani, HS; Moosavi-Movahedi, AA, Catalase and its mysteries. *Progress in biophysics and molecular biology*, **2018**, 140, 5-12.https://doi.org/10.1016/j.pbiomolbio.2018.03.001
33. Pei, J.; Pan, X.; Wei, G.; Hua, Y., Research progress of glutathione peroxidase family (GPX) in redoxidation. *Frontiers in pharmacology*, **2023**, 14, 1147414.https://doi.org/10.3389/fphar.2023.1147414
34. Sarıkaya, E.; Doğan, S., Glutathione Peroxidase in Health. *Glutathione system and oxidative stress in health and disease*, **2020** 49.https://books.google.ro/books?hl=ro&lr=&id=Skv9DwAAQBAJ&oi=fnd&pg=PA49&ots=IQ9lcR-_gA&sig=NzHA6FseXnZYlq3rsBamk0lguUY&redir_esc=y#v=onepage&q&f=false
35. Horváth, M.; Babinszky, L., Impact of selected antioxidant vitamins (Vitamin A, E and C) and micro minerals (Zn, Se) on the antioxidant status and performance under high environmental temperature in poultry. A review. *Acta Agriculturae Scandinavica, Section A-Animal Science*, **2018**, 68(3), 152-160.https://doi.org/10.1080/09064702.2019.1611913
36. Hu, L.; Wang, Z.; Carmone, C.; Keijer, J.; Zhang, D., Role of oxidative DNA damage and repair in atrial fibrillation and ischemic heart disease. *International journal of molecular sciences*, **2021**, 22(8), 3838.https://doi.org/10.3390/ijms22083838
37. Food and Agriculture Organization (FAO) on Food Waste. **2020**. Available online:https://www.fao.org/platform-food-loss-waste/flw-data/en/ (accessed on 22 September 2026).
38. European Union Commission (Eurostat) on Food Waste. Available online:https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Food_waste_and_food_waste_prevention_-_estimates accessed on 22 September 2026).
39. Food and Agriculture Organization of the United Nations (FAO) Faostat Database. **2021**. Available online: http://www.fao.org/faostat
40. Saeed, M.; Kamboh, AA ; Huayou, C., Promising future of citrus waste into fermented high-quality bio-feed in the poultry nutrition and safe environment. *Poultry Science*, **2024**, 103(4), 103549.https://www.sciencedirect.com/science/article/pii/S0032579124001287
41. Vlaicu, PA; Untea, AE; Panaite, T D; Turcu, RP, Effect of dietary orange and grapefruit peel on growth performance, health status, meat quality and intestinal microflora of broiler chickens. *Italian Journal of Animal Science*, **2020**, 19(1), 1394-1405.https://doi.org/10.1080/1828051X.2020.1845576
42. Food and Agriculture Organization of the United Nations (FAO). Global Initiative on Food Loss and Waste Reduction. **2015**. Available online:https://openknowledge.fao.org/server/api/core/bitstreams/57f76ed9-6f19-4872-98b4-6e1c3e796213/content (accessed on 22 September 2026)
43. Selim, S.; Abdel-Megeid, NS; Alhotan, RA; Ebrahim, A.; Hussein, E., Grape pomace: Agrifood by-product with potential to enhance performance, yolk quality, antioxidant capacity,

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and eggshell ultrastructure in laying hens. *Veterinary Sciences*, **2023**, 10(7), 461.https://www.mdpi.com/2306-7381/10/7/461
44. Food and Agriculture Organization of the United Nations (FAO). Global Initiative on Food Loss and Waste Reduction. **2015**. Available online:https://openknowledge.fao.org/server/api/core/bitstreams/57f76ed9-6f19-4872-98b4-6e1c3e796213/content (accessed on 22 September 2026)
45. Zhang, F.; Wang, T.; Wang, X.; Lü, X., Apple pomace as a potential valuable resource for full-components utilization: A review. *Journal of Cleaner Production,* **2021**, 329, 129676.https://doi.org/10.1016/j.jclepro.2021.129676
46. Gumul, D.; Ziobro, R.; Korus, J.; Kruczek, M., Apple pomace as a source of bioactive polyphenol compounds in gluten-free breads. *Antioxidants*, **2021**, 10(5), 807.https://doi.org/10.3390/antiox10050807
47. Kara, K.; Kocaoğlu Güçlü, B.; Baytok, E.; Şentürk, M., Effects of grape pomace supplementation to laying hen diet on performance, egg quality, egg lipid peroxidation and some biochemical parameters. *Journal of Applied Animal Research*, **2016**, 44(1), 303-310.https://doi.org/10.1080/09712119.2015.1031785
48. Reis, JH; Gebert, RR; Barreta, M.; Boiago, MM; Souza, CF; Baldissera, MD; Da Silva, AS, Addition of grape pomace flour in the diet on laying hens in heat stress: Impacts on health and performance as well as the fatty acid profile and total antioxidant capacity in the egg. *Journal of Thermal Biology*, **2019**, 80, 141-149.https://doi.org/10.1016/j.jtherbio.2019.01.003

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