

Review

Utilization of Agro-Industrial Residues from the *Rosa damascena* Mill. Oil Industry: A Literature Review on Biomass Potential for Food and Feed Ingredients

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Abstract: The re-usage of byproducts needs urgent attention as the recycling and reduction in wastes can minimize environmental pollution and ameliorate the present situation by creating new products, such as animal feed and ingredients for the food industry. The industrial production of rose oil from *Rosa damascena* Mill. generates tons of byproducts, due to the low oil yield. Byproducts such as spent petals are systematically used as feed supplements, while the polyphenol-rich extracts are incorporated in numerous animal products. Among their benefits, exogenous (through a dietary strategy) antioxidants such as polyphenols, play a pivotal role in the antioxidant system in intensive farmed animals—influencing the growth performance and increasing the feed conversion. On the other hand, incorporated extracts serve as natural antioxidants retaining the discoloration of meat products, as well as inhibiting the lipid and protein oxidation during storage, extending their shelf-life. *Rosa damascena* Mill. extracts are used as additives in functional and more healthier products with reduced nitrite content and enhanced the biological value of the consumed products. The aim is to systematize the existing knowledge about the potential use of spent *Rosa damascena* Mill. petals and their extracts, as well as highlight the need for further research in dairy and meat products.

Keywords: spent rose petals; nitrite reduction; circular economy; antimicrobial activity; bio-based livestock



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1. Introduction

The European Union's Green Deal promotes a competitive bioeconomy to achieve a sustainable future, focusing on two main pillars: (a) the development of bio-inspired materials from natural feedstocks, and (b) the transition from a linear to a circular economy, supported by renewable energy, sustainable materials, and digital innovation [1]. The circular economy is an alternative to the traditional linear model, aiming to decouple growth from resource consumption. It is based on three key principles: eliminating waste and pollution, keeping products and materials in use, and regenerating natural systems. By closing resource loops, the circular economy enhances environmental sustainability and fosters economic resilience.

The increase in industrial processing of food and agricultural products has been generating large amounts of secondary “waste” products/byproducts. Their quantities are about one third of the total food products produced [2]. Depending on the product and the type of its processing (Figure 1), these byproducts can be in the form of dry mass [3] or washing waters [4]. At the same time, the failure to utilize these byproducts most often leads to environmental pollution, and sometimes to the generation of additional costs for the producers themselves [5]. Agricultural and food-industry residues constitute a major proportion (almost 30%) of worldwide agricultural production. These byproducts mainly include fruit and vegetable wastes, lignocellulosic materials, sugar-industry wastes, as well as animal and fisheries refuse and byproducts. The re-usage of byproducts needs urgent attention as the recycling and reduction in wastes can minimize environmental pollution and ameliorate the present situation by creating new products from byproducts, such as animal feed and ingredients for the food industry [6]. Some of these byproducts have been the subject of research for years and have proven to be a good source of natural antioxidants applied in livestock and in product bio-processing [7]. The resulting extracts can be incorporated into conventional foods, such as meat and fish products, in order to improve their quality and safety.

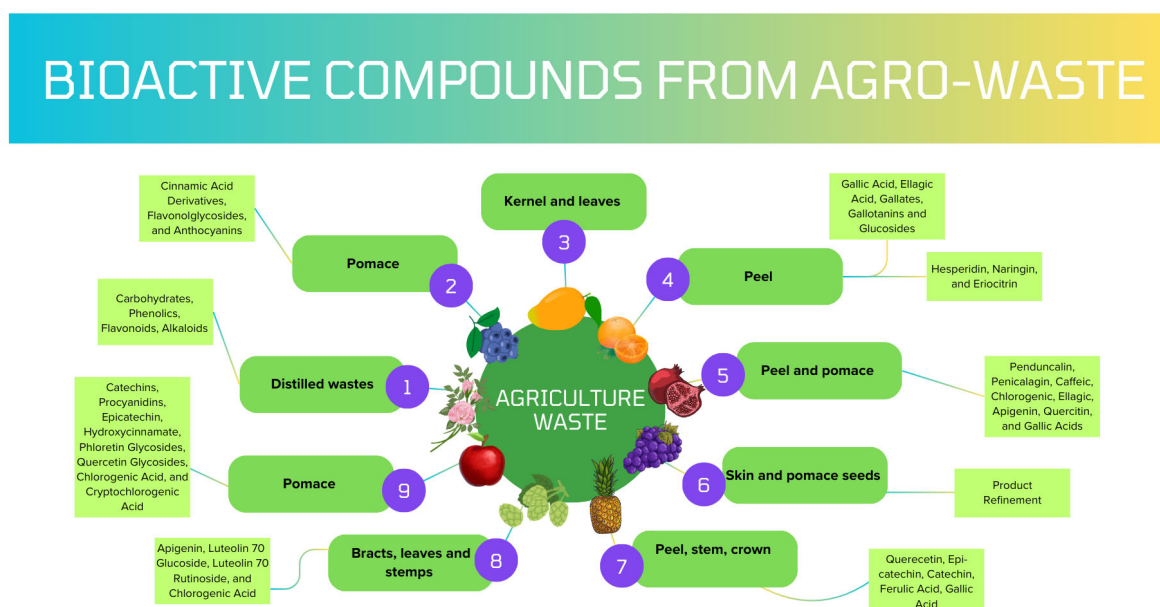


Figure 1. Main bioactive compounds present in agro-wastes (scheme generated using Canva.com free access platform). 1 = rose petal; 2 = blackberry; 3 = mango, papaya; 4 = orange; 5 = pomegranate; 6 = grape; 7 = pineapple; 8 = exotic fruits; 9 = apple.

Rosaceae Family

The *Rosaceae* family includes around 3000 species, such as rhizomatous plants, thorny shrubs, low-stemmed shrubs, or trees [8]. The most important for the food industry are the common dog rose (*Rosa canina* L.), the white oil rose (*Rosa alba* L.), and the Damask rose (*Rosa damascena* Mill.). The oil from *Rosa damascena* Mill. is an extremely expensive product, due to the vast amounts of petals required for its production, as it constitutes only 0.03–0.045% of the total petal mass [9]. According to reports from the Ministry of Agriculture, Food, and Forestry, Bulgaria produces between 10,000 and 15,000 tons of rose blossoms from oil-bearing roses annually [10]. The large quantities of byproducts are a direct result of the low yield, and their processing and utilization could lead to significant economic and environmental benefits. Their industrial processing generates tons of byproducts, whose disposal and storage pose significant environmental challenges.

In general, polyphenols are secondary metabolic products that do not take a direct part in the development of plants and fruits [11,12]. They are part of the substances that form the aroma and taste and play a protective role against bacteria and viruses [13,14]. Depending on the region, season and diet, we consume ≈ 1 g of polyphenols/day through food intake [5]. These polyphenols can protect body cells from the oxidative action of free radicals, which reduces the likelihood of developing cancer [2]. The molecular structure of polyphenols is mainly characterized by an aromatic ring containing one or more hydroxyl groups ($-\text{OH}$). It can vary from the simplest phenolic molecule to that of a complex high-molecular polymer. There is a strong correlation between their structure and their antioxidant activity, specifically the location (whether it is in the para- or ortho-position) and the number of $-\text{OH}$ groups attached to the aromatic nucleus. Their antioxidant activity is also influenced by other functional groups associated with the aromatic nucleus [15]. Flavonoids are part of the group of polyphenols, which includes flavones, flavanones, flavonols, flavanonols, flavan-3-ols, isoflavones, and anthocyanidins. The most famous and common representatives are kaempferol, quercetin, and resveratrol. Their molecule is a three-ring structure of the type C6-C3-C6 (Figure 2), which characterizes more than half (≈ 4000 out of ≈ 8000) of polyphenolic compounds [5].

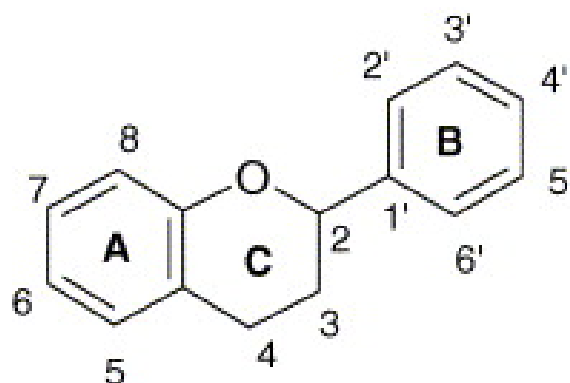


Figure 2. Generalized structure of the flavonoid molecule.

The group of non-flavonoids includes phenolic acids, stilbenes, and lignans. The derivatives of benzoic (gallic, vanillic, etc.) and cinnamic (rosmarinic, ferulic, etc.) acids are of great interest to the food industry. Their structure consists of only one aromatic nucleus and a different number of substituents. Cinnamic acid derivatives are characterized by significantly greater radical-scavenging activity than those of benzoic acid [14]. Conversely, benzoic acid derivatives exhibit a stronger iron-reducing potential than those of cinnamic acid [16]. Both are often used as a standard in the study of plant extracts [17]. Both flavonoids and phenolic acids exhibit their radical scavenging ability through the hydrogen atom (H^+) transfer mechanism known as the “HAT” (hydrogen atom transfer) mechanism (Equation (1)) [15]. They can also directly bind transition metal ions (Fe^{2+} and Cu^{2+}) through the chelation process schematically presented by [15,16].



Due to these properties, they act as inhibitors of lipid peroxidation [12] and oxidative stress [7]. The latter, leading to the alteration of biological macromolecules such as lipids, proteins, and nucleic acids, is considered one of the causes in the pathogenesis of several metabolic disorders. Among the endogenous protective mechanisms that comprise the scavenging of reactive oxygen species (ROS), prevention of ROS formation, and enzymatic and non-enzymatic defences, also the exogenous (through a dietary strategy) antioxidants such as polyphenols, play a pivotal role in the antioxidant system in intensive farmed

animals. While, when incorporated into the meat matrix, they prevent the depletion of endogenous antioxidants (vitamin E and β -carotene) by forming chelate complexes with free metal ions and inhibit iron-catalyzed radical formation [18,19]. In addition to antioxidant properties, polyphenols also exhibit bactericidal and bacteriostatic properties, inhibiting the development of putrefactive microflora, which in turn extends the shelf life of meat products [14].

Various methods are reported for obtaining extracts from both fresh and spent petals, using different solvents such as water, n-hexane, methanol, or ethanol [20]. Some authors [17] studied various methanol extracts from spent rose petals (*Rosa damascena* Mill.), determining the total phenolic content using the Folin–Ciocalteu method, along with their radical-scavenging capacity and iron-reducing potential [17]. In addition to being a component of perfumes, the extracts from *Rosa damascena* Mill. petals exhibit an iron-reducing potential (FRAP) similar to that of vitamin E (α -tocopherol) [21]. A year later, other authors [22] confirmed the presence of polyphenols in extracts from dried, distilled rose petals. In a 30% water–ethanol (*v/v*) extract, the presence of flavonol glycosides, mainly quercetin and kaempferol, was identified. Subsequently, the extract from spent distilled rose petals (*Rosa damascena* Mill.) was successfully incorporated into fruit preserves [22,23]. Slavov et al. [8] report substantial amounts of the same phenolic acids, along with rosmarinic acid, as well as significant quantities of quercetin, quercetin-3- β -glucoside, kaempferol, and catechin in extracts from byproducts of the white oil rose (*Rosa alba* L.). In a study of extracts from dried, distilled petals of *Rosa damascena* Mill., the authors of [24] report a similar quantitative ratio of quercetin, its glucosides, and kaempferol, in comparison to Ref. [8]. In [15], the authors studied the properties of methanol extracts of spent rose (*Rosa damascena* Mill.) flowers obtained by different methods, thereby determining the total phenolic content in the extracts using the Folin–Ciocalteu method, the radical scavenging capacity, and the iron-reducing potential. The cold extraction yielded the most significant amounts of polyphenols, while the iron-reducing potential was also higher compared to the extract obtained by hot extraction. The presence of quercetin, kaempferol, gallic acid, etc. polyphenols in the aqueous extract of spent rose (*Rosa damascena* Mill.) petals established by [21] confirms the preliminary studies. The same team investigated the radical scavenging capacity against free radicals: DPPH• and ABTS• of the aqueous extract, and reported promising results even at relatively low concentrations equal to 0.2–0.4 mg/L. In another independent study, it was found that the amount of anthocyanins in the aqueous-ethanolic extract of spent rose (*Rosa damascena* Mill.) flower is negligible, which confirms the hypothesis that its antioxidant activity is entirely due to the identified flavonol glycosides [25].

In the framework of rose production, primary products include rose flowers, rose water, essential oils, vegetative residues, and distillation byproducts [26]. Distilleries often discard these byproducts, which can disrupt the ecological balance and result in the loss of valuable physiologically active compounds such as polyphenols, fragrance molecules, and polysaccharides [27]. However, distillation byproducts can be composted and utilized as animal feed [28]. A rose facility processes approximately 2500 kg of rose flowers to extract oil, generating about 7000 liters of liquid waste per extraction. This extraction process may be repeated two to three times daily over a 45-day flowering season, resulting in an estimated 63,000–94,500 liters of liquid waste from 225,000 to 337,500 kg of rose flowers each season [29]. These byproducts contain a conspicuous nutritional value and can be supplemented to animals directly without any modification or can be used after fermentation of the agro-residues. Generally, byproducts which can be used as feedstuff are supposed to be economical, rich in nutrients, and free of toxins or other substances that may be unhealthy to animals. Recovering byproducts for use as animal feed can help the

agro-industry save money by reducing waste discharges, cut waste-management costs, and prevent environmental pollution. Most of the agro-residues offer an inexpensive source of nutrients as compared to traditional feeds and support animal productive performance, boosting the profitability of farms.

To our knowledge, we found that the use of the same extraction gives a comparable result. The main differences in bioactivity can be due to annual crops yield influenced by weather conditions. This review is aimed at the effect of spent petals on feed and changes in meat quality, as well as the influence of changes in the products due to the incorporation of rose extract.

2. Agro-Waste in Bio-Based Livestock

The food and fruit industries experience significant losses, with approximately 20–40% of fruit and vegetable production discarded annually [9]. These agro-industrial residues, often left untreated, pose risks to environmental, human, and animal health. However, they are rich in organic compounds that can be transformed into valuable products. For instance, agro-food-based waste materials exhibit varying compositions of lignin, ash, moisture, carbon, nitrogen, cellulose, and hemicellulose, making them suitable for biogas production, biofuels and other valuable products, and for animal feed [20]. Therefore, modern science must emphasize for research focused on the management of wastes, its processing technology, and subsequent feeding added value for animal husbandry. Recently, animal farming has been facing rapid changes in nutrition evaluation with respect to the target animals and low-cost technology approach. Studies include nutritional evaluation on digestibility, feeding value, bio-hazards, and feasibility for waste management and utilization. Even though the potential of agro-byproducts is very obvious, the utilization of feed from the waste in diet formulation until now is under investigation, due to the constraints imposed by several nutritional and technical considerations. An improvement in animal feeding is one of the important and basic conditions for the better management of farmed animals. It was recognized that the poor quality of the feed is mainly responsible for the poor animal performance [6]. Most of the animal feed is quite expensive for most farming practices; therefore, proper and high-quality feed supplies are the most important factors in farm management. The production of animal feed is one of the most logical ways of re-using a substantial portion of the enormous potential agro-residues. Additionally, more than 70% of the expenditure in farming is mainly for animal feed. Since the demand for animal feed is always stable and large, the production of animal feed from agro-residues represents one of the highest cash returns, especially in the context of circular economy. Regarding the combination of different applications—the key distinction lies in the food industry, where waste materials acquire added value. They are no longer considered mere byproducts, but rather valuable raw materials rich in bioactive compounds. This sets them apart from non-food applications such as biogas production.

Since the inclusion of such diverse applications has been noted as a major critique, the article should emphasize that biogas utilization represents the least efficient approach. This underlines the necessity of exploring alternative strategies, particularly those focused on the extraction of high-value compounds, which are often lost during other processing methods.

2.1. Application of Rose Extracts in Animal Nutrition

The growing resistance of pathogens to antibiotics, along with concerns about antibiotic residues in animal tissues, have driven researchers to explore alternative substances that can enhance animal health, support growth, improve production performance, and reduce their emissions and/or environmental impact [30]. Additionally, increasing consumer demand for healthier food and better animal welfare has encouraged the use of natural

alternatives in both animal nutrition and food preservation [31]. For example, in animal nutrition, natural nutraceutical additives have been shown to enhance overall feed intake, promote growth, and improve digestive enzyme activity while simultaneously reducing intestinal pathogenic load in swine and poultry [31]. It is crucial to identify phytochemical components in order to evaluate the nutritional value and biological properties of plants [32]. The phytochemical analysis of *Rosa damascena* Mill. revealed phenolic acids and flavonoids as the predominant constituents, exhibiting the highest concentrations among the identified bioactive compounds. These were followed by alkaloids and glycosides, which were present in moderate amounts. Carbohydrates were found in the lowest concentrations relative to the other phytochemical groups [29].

Other studies on rosehip used as feed additives have shown antioxidant, anti-inflammatory, antimicrobial, and potential anti-tumour properties in poultry production [33,34], which is particularly relevant given the risk of bacterial infections. Another study demonstrated that including rosehip seed at different levels in layer hen diets significantly increased feed consumption and egg yield, while also reducing the damaged egg ratio and enhancing yolk color, eggshell thickness, and shell weight [35]. Similarly, essential oils as dietary supplements have been identified as a promising approach to enhancing livestock health [36]. It was reported that flower extracts and essential oils obtained from plants such as *Rosa damascena*, *Mentha piperita*, *Origanum onites*, *Juniperus exalsa*, *Thymbra spicata*, and *Satureja cuneifolia* have antioxidant, antimicrobial, and antibacterial activities [37]. Additionally, rosehip was found to have antibacterial properties against several microorganisms, including *Staphylococcus aureus*, *Bacillus cereus*, *Yersinia enterocolitica*, *Klebsiella pneumoniae*, and *Salmonella typhimurium* [36], which is particularly relevant given the risk of bacterial infections in poultry. The results of a study [38], partial or total replacement of wheat bran with 5% or 15% *R. canina* seed in barley–soybean-based concentrates offered to Morkaraman lambs, indicated a positive influence on meat quality traits, without any detrimental effects on the feed conversion efficiency and retail cut percentages.

With the aim to preserve meat stability during prolonged freezing, the authors of [39] supplemented lamb diet with distilled rose petal, thereby obtaining an improvement in the shelf life of stored meat. Research in [40] suggests that polyphenols, particularly flavonoids, may offer superior antioxidative protection compared to traditional vitamins such as E and C. For instance, supplementation with dihydroquercetin derived from distilled roses in lamb diets has been associated with increased carcass fat content and haemoglobin levels, while also leading to a reduction in blood glucose levels [41]. Flavonoids possess significant potential due to their high nutritional value and positive impact on animal health [42]. In poultry meat, fat and ash content decreased, whereas the water holding capacity of meat and higher values of meat color co-ordinates (L^* , a^* , b^*) were improved [43].

In the poultry industry, dried rose dreg (byproduct) decreased the occurrence of pathogen microorganisms including mesophilic aerobic bacteria, *Enterococci*, *Enterobacteriaceae*, and *S. aureus* without any effect on broiler performance and feed conversion ratio during the production period. Indeed, the antimicrobial activity of rose extracts is related to chemical components, such as geraniol, citronellol, and nerol or synergistic effects between these components. The antibacterial and anti-fungal activities of geraniol were confirmed against a large number of microorganisms. Also, the synergistic effect between citronellol, geraniol, and nerol were demonstrated against Gram-positive and Gram-negative bacteria [44].

Methane production is a significant issue in ruminant livestock farming. Rosehip seed oil and seed residue, both byproducts with potential as livestock feed ingredients, have been investigated for their ability to lower production costs and reduce methane emissions [29]. Researchers studied the effects of liquid wild dog rose (*Rosa canina*) seed oil and solid

seed residue, obtained through CO₂ extraction under supercritical conditions, on rumen methane production in vitro. The results indicated that only the treatment with wild dog rose seed oil demonstrated potential for mitigating methane production [45]. Additionally, several authors [46,47] report the lack of negative impact on growth performance, blood metabolites, or in vivo rumen fermentation in cattle and sheep, respectively, supplemented with *Rosa roxburghii* Tratt residue, suggesting its usage as an alternative novel feed.

2.2. Application of Rose Oil By-Products as Feed

Several studies have been conducted to examine the in vivo effects of dried spent rose petals and rose water (Table 1), added to the feed mixtures of broilers [48–50], pigs [51–53], and lambs [54]. In a study conducted by [48] on broiler chickens, the inclusion of dried residue from distilled rose petals in the feed did not lead to increased feed intake. However, the experimental group exhibited the highest feed conversion ratio, despite the absence of a significant positive effect on body weight gain compared to the control group. On the other hand, the TBARS and fatty acid composition in breast fillets (*m. pectoralis major*) and thighs (*m. biceps femoris*) of the broilers stored for 365 days at -18°C have shown that the inclusion of 40 mg biological active components from RPE to 1 kg body weight inhibits the lipid oxidation [51]. At the same time, the authors of [50] reported a positive effect of added rose water on the hot carcass weight and intestinal health of broilers. Based on these results, it is clear that both spent rose petals and rose water can be used successfully as feed supplement broilers due to their antioxidant activity.

The effect of supplementation with 0.255 g of dry distilled rose petals (DDRP)/kg/d or 0.545 g/kg/d was studied by different merits. First, the authors of [53] reported that supplementing pig diets with 0.255 g and 0.545 g of dried distilled rose petal residue resulted in a 127% and 115% increase in average daily gain, respectively, compared to the control group. The corresponding growth rates were 0.911 kg/pig/day and 0.828 kg/pig/day. On the other hand, the quality characteristics of porcine meat were influenced by the dietary supplementation of pigs with dry distilled *Rosa damascena* petals (DDRP) at 0.255 or 0.545 g/kg/day for 45 days prior to slaughter. Marked changes were observed in the saturation level of fatty acids, as well as in the content of sterols, tocopherols, and carotenoids in the *Longissimus lumborum et thoracis* (LL) and *Semimembranosus* (SM) muscles, as well as in backfat and leaf fat tissues stored for 24 h at $0-4^{\circ}\text{C}$ [53]. The effects varied depending on the specific muscle and fat depot, indicating tissue-specific responses to DDRP supplementation.

The addition of DDRP improved the unsaturated fatty acid composition in both muscle and adipose tissues. It also contributed to reduced lipid oxidation during storage. In short-term chilled storage (7 days at $2 \pm 1^{\circ}\text{C}$), DDRP supplementation led to a notable decrease in lipid oxidation in adipose tissues. In long-term frozen storage (315 days at $-18 \pm 1^{\circ}\text{C}$), both DDRP concentrations positively influenced oxidative stability in muscle and fat samples [54].

The supplementation had minimal influence on pork pH, with the most observable effects occurring at 24 h post mortem. No major changes were detected in meat color of either lean or fatty tissues under any storage condition.

Findings also indicate that supplementation with 0.545 g DDRP/kg/day contributed to enhanced proteolytic activity in the *Longissimus thoracis* muscle, while 0.242 g DDRP/kg/day was associated with a strong inhibitory effect on free amino nitrogen (FAN) accumulation in the *Semimembranosus* muscle. These results point to a dose- and tissue-specific impact of DDRP on muscle proteolysis [52].

The study of [55] also showed that the sex of the pigs significantly influenced most meat quality traits, often more so than dietary supplementation. Entire males had lower

backfat and intramuscular fat contents, but higher lean meat percentages in the *Longissimus lumborum* muscle compared to the control group. The fatty acid profile of the LL muscle in entire males was positively influenced by DDRP, with increases observed in n-6 and n-3 polyunsaturated fatty acids, especially alpha-linolenic acid, when compared to castrated males. Additionally, DDRP supplementation contributed to an increase in meat color intensity and showed a trend toward reducing boar taint in the meat of entire males.

Table 1. Reported application of rose byproducts as feed for domestic animals.

Animal Model	Treatment	Duration	Evaluated Parameters
Broilers Ross 308	40 mg biological active components (RPE) to 1 kg body weight	49-day feeding at 7-day intervals	Growth performance, feed conversion, carcass analysis [49]
		365-day storage at -18°C	TBARS, fatty acid composition in breast fillets (<i>m. pectoralis major</i>) and thighs (<i>m. biceps femoris</i>) [43]
	Extruded feed with rose petal meal at dose rate of 25 g.kg^{-1} and 50 g.kg^{-1}	60-day feeding	Proximate composition, pH, WHC, instrumental color, cooking loss, sensory profile [44]
	2 and 4% rose water	Feeding for 35 d	Growth performance, feed intake, feed conversion carcass parameters, hot carcass yield, histomorphology parameters [50]
Pigs <i>Danube White</i> –155-day old	0.255 g dry distilled rose petals (DDRP)/kg/d or 0.545 g/kg/d	45-day feeding	FAN content and WHC of <i>m. longissimus thoracis</i> and <i>m. Semimembranosus</i> [51]
			pH, instrumental color, AV, POV, TBARS [52]
			Growth performance, blood parameters, liver weight and histology of ovaries and liver, lean meat content, proximate composition of muscles [53]
Pigs <i>Danube White</i> –uncastrated males–146-day old	5 g of dried distilled rose petals (DDRP) in 1 kg of feed	40-day feeding	Live weight, hot carcass weight, dressing, backfat thickness, lean meat, pH, instrumental color, WHC, fatty acids profile [53]
Lambs	545 mg dry distilled rose petals (DDRP)/kg live weigh/d	50-day feeding	Growth performance, feed intake, pH of <i>m. Longissimus lumborum et thoracis</i> , and blood count [41]
			Proximate composition, sterols, tocopherols and carotenoids content, amino acid profiles, WHC, and microbiological status [56]
		7-day storage at ($0\text{--}4^{\circ}\text{C}$)	α -aminoacidic nitrogen, AV, POV, TBARS, fatty acid composition, instrumental color, microbiological status [54]
		365-days storage at (-18°C)	<i>Longissimus dorsi</i> and <i>Semimembranosus</i> muscles and <i>perirenal adipose tissue</i> –pH, instrumental color, TBARS, proteolysis and oxidative status of total proteins, fatty acid profiles, biogenic amines [54]

Abbreviations: Rose petals extract (RPE); Dried distilled rose petals (DDRPs); 2-thiobarbituric acid reactive substances (TBARSs); Water holding capacity (WHC); Free amino nitrogen (FAN); Acid value (AV); Peroxide value (PV).

We can conclude that the dietary inclusion of dry distilled *Rosa damascena* petals in the feed of pigs can beneficially modulate fatty acid composition, oxidative stability, proteolysis, and certain sensory traits in pork. These effects are also influenced by the sex of the animals,

with entire males showing distinct metabolic and compositional responses. DDRP presents a promising natural feed additive for improving pork quality and potentially mitigating boar taint without negatively affecting pH, color, or water-holding capacity.

Dietary supplementation of lambs with 545 mg/kg/day of dry distilled *Rosa damascena* petals (DDRP) during the fattening period resulted in several effects on meat and fat quality without negatively impacting animal health or performance (Table 2).

Table 2. Reported incorporation of functional ingredients from roses in the processing of meat products.

Product	Treatment	Storage	Evaluated Parameters
Cultured sea bass (<i>Dicentrarchus labrax</i>) fillets	Immersion into rose waste water/osmotic solution	20 days (5 °C)	Phenolic impregnation, water loss, ca_w , NaCl concentration, instrumental color, microbial growth, TBA value [4]
Cooked beef/pork—50/50 sausages	RPE—0.05 and 0.1% + partial nitrite reduction	6 days (0–4 °C)	AV, TBARS, FAN, and protein carbonyls [55]
	FDRPE—0.05 and 0.1 g/kg; dihydroquercetin—0.05 and 0.1 g/kg; sodium L-ascorbate—0.05 and 0.1 g/kg	7 days (0–4 °C)	pH, PV, microbiological status, and sensory profile [57]
	Three-component antioxidant blend—FDRPE—0.1 g/kg; dihydroquercetin—0.09 g/kg and sodium L-ascorbate—0.1 g/kg + partial nitrite reduction	7 days (0–4 °C)	DPPH, FRAP, instrumental color, TBARS, protein carbonyls [58]
			Residual nitrites, DPPH, FRAP, AV, PV, TBARS, FAN, and protein carbonyls [58]
Dry fermented beef/pork—60/40 sausages	DDRPE—1.140 and 2.280 g/kg + partial nitrite reduction	18 days of processing (10–12 °C)	pH, instrumental color, microbiological status, and sensory profile [59]
Bacon pork	90 mg phenolic compounds/kg raw meat	49 days (5,10,15 °C)	Instrumental color, pH, AV, PV, TBARS, and sensory profile [60]
			Microbiological analysis, TBARS, color change, sensory attributes of raw meat samples, microbial growth modeling [61]

Abbreviations: Dry distilled rose petals extract (DDRPE); Rose petals extract (RPE); Freeze-dried distilled rose petals extract (FDRPE); Acid value (AV); Peroxide value (PV); 2-thiobarbituric acid reactive substances (TBARSs); Thiobarbituric value (TBA value); Free amino nitrogen (FAN); 1,1-diphenyl-2-picrylhydrazyl (DPPH·) radical scavenging; ferric reducing antioxidant power (FRAP).

Supplementation with DDRP did not significantly affect slaughter weight or carcass yield. Blood glucose levels were reduced in lambs receiving DDRP, while all other blood parameters remained within physiological norms, suggesting a safe metabolic response [41].

The proximate composition and tocopherol content of the *Longissimus dorsi* and *Semimembranosus* muscles were not significantly altered by DDRP supplementation. However, DDRP increased the levels of essential amino acids in muscle tissue and slightly reduced water-holding capacity in both muscles. Carotenoid content in muscle tissue increased, and a favorable shift in fatty acid composition was observed, with a reduction in saturated fatty acids (SFAs) and an increase in monounsaturated fatty acids (MUFAs), especially in the *Longissimus dorsi* [56].

After 365 days of frozen storage at −18 °C, DDRP did not significantly affect peroxide value (POV), biogenic amines, protein-bound carbonyls (PBCs), or TYMC. These changes were primarily due to long-term freezing rather than the feed supplement. Color stability was modestly improved, with a smaller total color difference (ΔE) evaluated in the DDRP group compared to controls. These effects were more pronounced in *Longissimus dorsi* muscle than in *Semimembranosus* [54].

In conclusion, DDRP supplementation at 545 mg/kg/day in lamb diets supports modest improvements in amino acid content, lipid stability, microbial quality, and fatty acid profile of lamb meat. While it does not impact basic carcass or proximate composition, its contribution to sensory and storage traits makes it a promising natural additive. Further studies are necessary to explore the impact of higher doses and to better understand interactions with breed, age, and storage conditions. Care should be taken in future studies to account for the metabolic transformation of polyphenols, as excessive doses may act as prooxidants and interfere with nutrient absorption.

2.3. Application of Rose Extracts in Meat Production

The resulting meat products were characterized by improved fatty acid composition and increased oxidative stability. Meat from pigs fed with dried spent rose petals and dihydroquercetin was successfully used in the production of cooked sausages with a 50% reduction in sodium nitrite content [57]. These sausages exhibited significantly better sensory characteristics and relatively higher oxidative stability.

Additionally, several studies have been conducted using various model systems of meat products with added extract from spent distilled rose petals (*Rosa damascena* Mill.). Delayed lipolytic processes and reduced formation and accumulation of secondary lipid oxidation products (TBARS) in samples of cooked sausages containing 0.1% and 0.05% extract of spent distilled rose petals and 50% reduced sodium nitrite content were reported [58]. The same study found that the added rose petal extract did not affect protein hydrolysis, but it did inhibit protein oxidation and the formation of protein carbonyls at a concentration of 0.05%.

Similarly, the authors of [59] studied the effects of various concentrations of dried distilled rose petal extract (0.01%, 0.03%, and 0.05%) in combination with different levels of sodium nitrite reduction (50%, 70%, and 90%) in a model system of cooked sausages. Using up to 0.05% rose petal extract, no changes were detected in sensory characteristics (color, taste, aroma, and texture), and the color stability of the cut surface of sausages with 50% reduced sodium nitrite content was also confirmed [59]. Oxidative stability in the sausage model system was also studied. The authors reported that a combination of 0.05% spent rose petal extract and 50% sodium nitrite reduction significantly inhibited oxidative processes in both the lipid and protein fractions.

The incorporation of the three examined biologically active substances—sodium L-ascorbate, dihydroquercetin, and freeze-dried extract from distilled rose petals (*Rosa damascena* Mill.) (FDRPE) helped the stabilization of the color and enhanced the sensory properties, improving the overall quality of the cooked sausages. Based on the results, an optimal three-component blend was formulated, containing 0.100 g FDRPE, 0.091 g dihydroquercetin, and 0.100 g sodium L-ascorbate [58,59]. Hydrolytic and oxidative changes in the lipid and protein fractions of the sausage model system, with a 50% reduction in sodium nitrite, were minimized through the incorporation of the optimal three-component blend of biologically active substances [60]. In the production of functional meat products, it is important not only to incorporate biologically active components but also to reduce substances with potential negative health effects for consumers. In cooked meat products, one such potentially harmful substance is nitrite. The addition of biologically active compounds in the production of meat products has been reported by several authors (see Table 2). The pig processed-meat product in [61] enriched with *Rosa damascena* distillation byproduct extract (RSE) presented the lowest microbial growth rate for all microorganisms examined, followed by the samples representing the conventional manufacture procedure (CNT, containing the maximum nitrite content permitted). On the contrary, the RSE samples exhibited a color similar to the CNT samples, despite containing only half the amount of

nitrites. This suggests that the rose extract used did not deteriorate color stability, offering a viable option for the reduction in the content of nitrites. Similar observations can be made for the overall sensory characteristics of the samples, with the RSE samples showing similar acceptability to the CNT samples. Overall, the results of this study provide preliminary proof on the potential use of rose extract (derived of rose steam distillation) as an effective natural antimicrobial agent, that could potentially reduce or partially substitute nitrites in cured meat products (see Table 2).

2.4. Application of Rose Extracts in Dairy Production

Some authors [62] recently described rose as one of the Ayurveda herbs used in milk products (flavored milk, ice cream) by the dairy industry. Over the years, most of the research regarding the application of *Rosaceae* family in dairy products was primarily focused on rose oil and rose water. Research was focused primarily on extending the shelf life of fresh dairy products. The influence of extract and oil on the quality characteristics of the product has been shown—chemical structure, and the sensory profile was determined (Table 3). Ref. [63] fortified dairy mixtures with different amounts of rose water. The authors established that the addition of Damask rose flower extract to dairy products enhanced their flavor and aroma, and by preventing oxidation and spoilage, the shelf life of the final product was extended. There are relatively few studies on the applicability of rose extract obtained as a byproduct of rose oil production. As an excellent source of anthocyanins, rose petals water extract was used in order to replace artificial colors in yoghurt production [64]. Rose cold water extracts as well as rose oils were used in order to determine their effect on yoghurt preservation [65]. Still, in yoghurt production, the authors of [66] established a strong correlation between the addition of *Rosa rugosa* cv. *Plena* extract and the yoghurt's physicochemical, sensory, and functional properties.

Table 3. Reported incorporation of functional ingredients from roses in the processing of dairy products.

Product	Treatment	Storage	Evaluated Parameters
Fresh dairy mixtures	Mix of full-fat powdered milk, caw butter, powdered white sugar, soy-lecithin, rose water (16%, 25%, and 40%)	14 days (0–4 °C)	Chemical composition, microbiological tests, and organoleptic parameters [63]
Lactic acid beverage	Rose (<i>Rosa damascena</i> Mill.) extract (30 µL/L)	14 days (4 ± 2 °C)	Organoleptic and physicochemical parameters, dynamic of coagulation [67]
Whey-based drink	Whey (50 mL), apple juice (20 mL), rose root concentrate (0.1 mL), sugar (3 g), apple pectin (0.5 g), 0.4 g of citric acid (0.4 g), ionized water (30 mL)	4 ± 2 °C	Sensory, physicochemical, and microbiological characteristics and composition of biologically-active compounds [68]
Yoghurt	Milk, rose petals water extract	7 days (0–4 °C)	Proximate composition, free sugars, fatty acids, and anthocyanins [64]
	Milk, rose water extract (2%, 4%, and 6%) or oil extract (2%, 4%, and 6%)	14 days (0–4 °C)	Chemical composition, bacteriological tests, and sensory evaluation [65]
	Reconstituted skim milk, freeze dried <i>Rosa rugosa</i> cv. <i>Plena</i> extract (0.1%, 0.3%, and 0.5%)	21 days (0–4 °C)	Physicochemical properties, functional attributes, sensory properties, and storage stability [66]
	Rose (<i>Rosa damascena</i> Mill.) petals polyphenol extract (0.39 mg/100 g)	15 days (4 ± 2 °C)	Microbiological and physicochemical characteristics [69]
	Rose petals (<i>Rosa damascena</i> and <i>Rosa gallica</i>) (%)	21 days (4 ± 2 °C)	Organoleptic, microbiological, physicochemical analysis, antimicrobial activity, and minimum inhibitory concentration [70]

The impact on microorganisms traditionally used as starter cultures in various productions is little studied. No data are found on the influence of the extract when bifidobacteria were added to the traditional starter culture. The effect on ripened dairy products is not established.

3. Conclusions

The studies reviewed focus on the possibilities of rose petal extract application in bio-based livestock and product bio-processing (milk, meat, and animal food products). The limited data reported in the literature, regarding the application of rose petal waste in animal nutrition, allows the results to be described as promising and offers ample room for investigation to validate the results obtained and transfer them into the breeding practice. Incidentally, since the demand for animal feed is always stable and huge, and since the rose petal waste has been successfully considered a safe feed additive in animal husbandry, the production of animal feed from agro-residues represents one of the highest cash returns, especially in the context of circular economy. Few data are available regarding the application of rose (certain plant parts or extract) in fresh dairy products. No data can be found regarding the effect of rose extract and its application in mature dairy products. Of interest is the influence of this extract on starter cultures traditionally used by the dairy industry, as well as on *Bifidobacterium* spp. The antimicrobial effect of rose extract was little studied. There is a real scientific niche for studying the influence of *Rosa damascena* extract on the ripening and storage processes of various dairy products. Additionally, a technological approach was not developed to modify the composition and to improve the functional properties of model cooked sausage systems with a reduced nitrite content. Taken together, these findings can contribute to better manage the safe usage of agro-waste in animal husbandry, and meat and dairy products quality and traceability.

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Abbreviations

The following abbreviations are used in this manuscript:

HAT	hydrogen atom transfer
SET	single electron transfer
RMS	response surface methodology
SLA	sodium L-ascorbate
FDRPE	freeze-dried spent rose petals extract

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