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REVIEW

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Multi-functional application of octacosanol as a feed additive in animal and aquaculture: A review

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Abstract

Demand for sustainable animal and aquaculture production drives the exploration of novel feed additives. We highlight octacosanol, a long-chain alcohol from plant sources, as a promising multifunctional feed additive. The review comprehensively evaluates octacosanol's applications in animal and aquaculture nutrition, including its molecular properties and mechanisms of action. It elucidates how octacosanol affects lipid metabolism, energy utilization and immune modulation. Octacosanol enhances livestock growth, efficiency, carcass quality and stress resilience. We thoroughly discuss how it enhances feed utilization, disease resistance and overall performance in finfish and shellfish in aquaculture. The review also addresses the ecological and sustainability aspects of octacosanol utilization. We identify challenges and knowledge gaps in octacosanol research, prompting suggestions for future investigations. We address regulatory considerations, dosage optimization and potential interactions with other feed additives to ensure the safe and effective use of octacosanol. In conclusion, the review highlights octacosanol's potential as a versatile feed additive in the animal and aquaculture industries and urges further research to uncover its benefits and sustainability contributions, proposing a prospective research plan for this purpose. This thorough analysis is a valuable resource for researchers, nutritionists and industry professionals looking to find innovative methods to improve production practices and advance sustainable food systems.

KEYWORDS

animal nutrition, aquaculture, feed additive, growth performance, immune function, octacosanol

1 | INTRODUCTION

Plants, particularly sugar cane and rice, contain the straight-chain aliphatic 28-carbon main fatty alcohol octacosanol (OCT), which makes up the majority of policosanol (Irmak & Dunford, 2005). Numerous physiological benefits, such as lower cholesterol and anti-inflammatory effects, have been associated with OCT (Ravelo et al., 2011). Octacosanol, one of the best-known functional foods, is used to create a range of pharmaceuticals, health foods and nutritional supplements (Janikula, 2002). Octacosanol [$HO\text{-}CH_2\text{-}(CH_2)_{26}CH_3$] is a key element of a naturally occurring wax product. It is an aliphatic long-chain alcohol that is present in rice bran oil, fruits, leaves and wheat germ oil (Oliveira et al., 2012; Taylor et al., 2003) and has substantial physiological function and pharmaceutical outcomes. Octacosanol and vitamin E have similar structural characteristics. Ketones, aldehydes, alkanes, primary and secondary alcohols, and fatty acids with alkyl ester chains ranging from C20 to C70 could be added to the mix of very long-chain aliphatic compounds that are found in octacosanol products (Jetter et al., 2006). Octacosanol has been linked to a variety of biological processes, including antifatigue (Kim et al., 2003), antioxidant (Ohta et al., 2008), cholesterol-lowering (Hernández et al., 1992), cytoprotective (Carbajal et al., 1996) and safety (Castaño et al., 1995) outcomes. An excellent source of vital fatty acids is wheat germ oil, protein, minerals, and A, B, E and D vitamins (Irmak & Dunford, 2005), which are made from the germ of the wheat kernel. Due to the high vitamin E content of wheat germ oil, which inhibits inflammation (Paranich et al., 2000), reduces oxidative stress (Alessandri et al., 2006), enhances lipid metabolism (Singh et al., 2006); additionally, it reduces cholesterol and blood sugar levels (Irmak & Dunford, 2005), it is recognized as a natural antioxidant. Rice bran oil can be made from rice bran and has a number of components in its natural state that may have health advantages. It is prepared by using food-grade n-hexane for solvent extraction. While other oils all have an unsaponifiable concentration of less than 1%, rice bran oil has 4.2%, which includes antioxidants and minerals. Phytosterols, tocopherols, squalene tocotrienols, -oryzanols and polyphenols are abundant in rice bran oil (Sugano & Tsuji, 1997). According to studies, the supplemental intake of octacosanol improved reproductive hormones, controlled reproductive organ growth, enhanced egg quality, boosted feed effectiveness and increased egg-laying in chickens (Long et al., 2016; Long et al., 2017). Additionally, it may improve feed efficiency and body weight in broilers (Xu & Shen, 1997) as well as Japanese quails (Wafar et al., 2017). This research employed wheat germ and rice oils, two key natural sources of octacosanol, to see how varied concentrations of octacosanol powder influenced the quality of quail eggs. This study aims to investigate the potential use of octacosanol as a supplementary ingredient to improve performance and well-being in animal farming and aquaculture. Through an exploration of the physiological activities of octacosanol, we want to uncover its potential to drive progress in the animal and aquaculture sectors.

2 | OCTACOSANOL: PROPERTIES AND CHEMICAL COMPOSITION

One of the very long-chain fatty alcohols, 1-octacosanol, has a number of biological effects, including those that are antifungal, antibacterial, anti-inflammatory and antioxidant (Guo et al., 2017; Ohta et al., 2008; Tchakam et al., 2012). It is effective against the pathogenic yeasts *C. albicans*, *C. lusitaniae* and *C. krusei* but inactive towards bacterial pathogens such as *K. pneumoniae*, *S. typhi*, *S. flexneri* and *E. faecalis* (MICs = 4, 8, 2 and 32 g/mL, respectively). When administered at doses of 30 and 100 g/kg/day, it inhibits the production of tumour necrosis factor-alpha, inducible nitric oxide synthase, interleukin-1 and -6 (IL-1, and IL-6) in RAW 264.7 cells activated with lipopolysaccharides (Guo et al., 2017). In an animal model of ulcerative colitis caused by dextran sulphate sodium, 1-octacosanol (a total of 100 mg/kg per day) raises body weight, reduces diarrhoea as well as hematochezia, and improves histological and morphological abnormalities in the colon (DSS; Item No. 23250). In an animal model of acute liver injury development, 1-octacosanol (10, 50 or 100 mg/kg) decreases the effects of carbon tetrachloride-induced elevations in serum transaminase, hepatic myeloperoxidase, hepatic xanthine oxidase, and lipid peroxidation. In the same model, it also restores declines in hepatic superoxide dismutase and catalase function as well as glutathione (GSH) levels (Ohta et al., 2008).

2.1 | Octacosanol physicochemical properties

The chemical name for octacosanol is $CH_3(CH_2)_{26}CH_2OH$. It possesses extremely pure, spiny, or snowflake-shaped white crystals that are impervious to moisture, smell, heat, acid, alkali and other environmental factors. Different purities of octacosanol display a variety of physical characteristics. The melting point ranges from 83.2°C to 23.6°C when the purity is greater than 97%. This substance's specific gravity at 85°C is 0.783 g/cm^3, and its boiling point is 227°C at 100 Pa atmospheric pressure (Myung et al., 2013; Zhou et al., 2022). Octacosanol has a variety of beneficial impacts on health, including anti-bacterial qualities, cholesterol-lowering abilities, cell protection abilities, and most recently, anti-Parkinsonism. However, contrary to what its name (fatty alcohol) suggests, it lacks significant solubility and is hydrophobic in nature, which severely restricts its use. At room temperature, it has a very low solubility in edible oils and no solubility in water (Sen Gupta & Ghosh, 2017).

2.2 | Octacosanol's distribution in nature

It is possible to separate and purify octacosanol, a naturally occurring higher aliphatic alcohol, from materials including insect wax, beeswax, sugarcane, rice bran and so on. Numerous pharmacological benefits of octacosanol include qualities that fight fatigue, hypoxia, inflammation, cancer and free radicals (Zhou et al., 2022). Octacosanol is abundant in nature and performs a variety of biological processes. It is thought that octacosanol, which was extracted from the medicinal plant Holopteleaintegrifolia (Ulmaceae), can be used to cure and prevent a variety of diseases (Zhou et al., 2022). One important part of the fatty alcohol mixture policosanol is octacosanol ($CH_3(CH_2)_{26}CH_2OH$), which can be found in organic wax made from bark, leaves and fruits, among other plant parts (Kim et al., 2016; Ohashi et al., 2021).

2.3 | Biological function of octacosanol

This section delves into the multifaceted roles of octacosanol and its applications across different domains, encompassing nutritional supplementation, reproductive enhancement, antioxidant properties, therapeutic and antimicrobial effects, as well as immune stimulation (Figure 1).

2.3.1 | Octacosanol as nutritional supplementation

Nutraceuticals, often known as nutritional supplements, have gained popularity among the general population during the past ten years. Studies have been conducted on octacosanol, one of these supplements. The principal aliphatic alcohol with a large molecular weight, octacosanol ($CH_3[CH_2]_{26}CH_2O_{14}$), is what makes up natural product wax made from plants. Fruit, plant leaf surfaces and complete seeds all contain this wax. Octacosanol must be taken as a supplement to have any health advantages because it is only found in extremely small concentrations in the diet. The majority of investigations have utilized policosanol, a naturally occurring blend consisting mostly of octacosanol, a main alcohol generated by sugarcane wax (*Saccharum officinarum* L.) (Taylor et al., 2003).

According to Kirk (1974), octacosanol consumption boosted fat metabolism to stop glycogen from being depleted. Kato et al. (2007) demonstrated that supplementing a high-fat diet with octacosanol (10 g/kg) for 20 days decreased adipose tissue weight and serum triacylglycerol levels, while increasing serum fatty acid levels. This suggests that octacosanol inhibits lipid accumulation by increasing the total rate of fatty acid oxidation in the muscles. Additionally, Xu et al. (2007) demonstrated the effects of dietary octacosanol 0.2% (wt/wt) on cholesterol with 1% (wt/wt) octacosanol in plasma lipids in Apo lipoprotein E-knockout mice over the course of a 12-week period. By Week 5 of the trial, they saw that a long-term octacosanol diet decreased the levels of plasma triacylglycerol by almost 70% in comparison to the control group. But as of now, there is not much proof that octacosanol has any effect on promoting lipolysis in in vivo or in vitro investigations.

2.3.2 | Octacosanol as reproductive enhancement

Octacosanol's Role in Reproduction: Increases messenger mRNA activity in reproduction centre, interacts with hormones and sensors, influences development of reproductive systems and follicles in hens, potentially works through cyclic structure and antioxidant properties

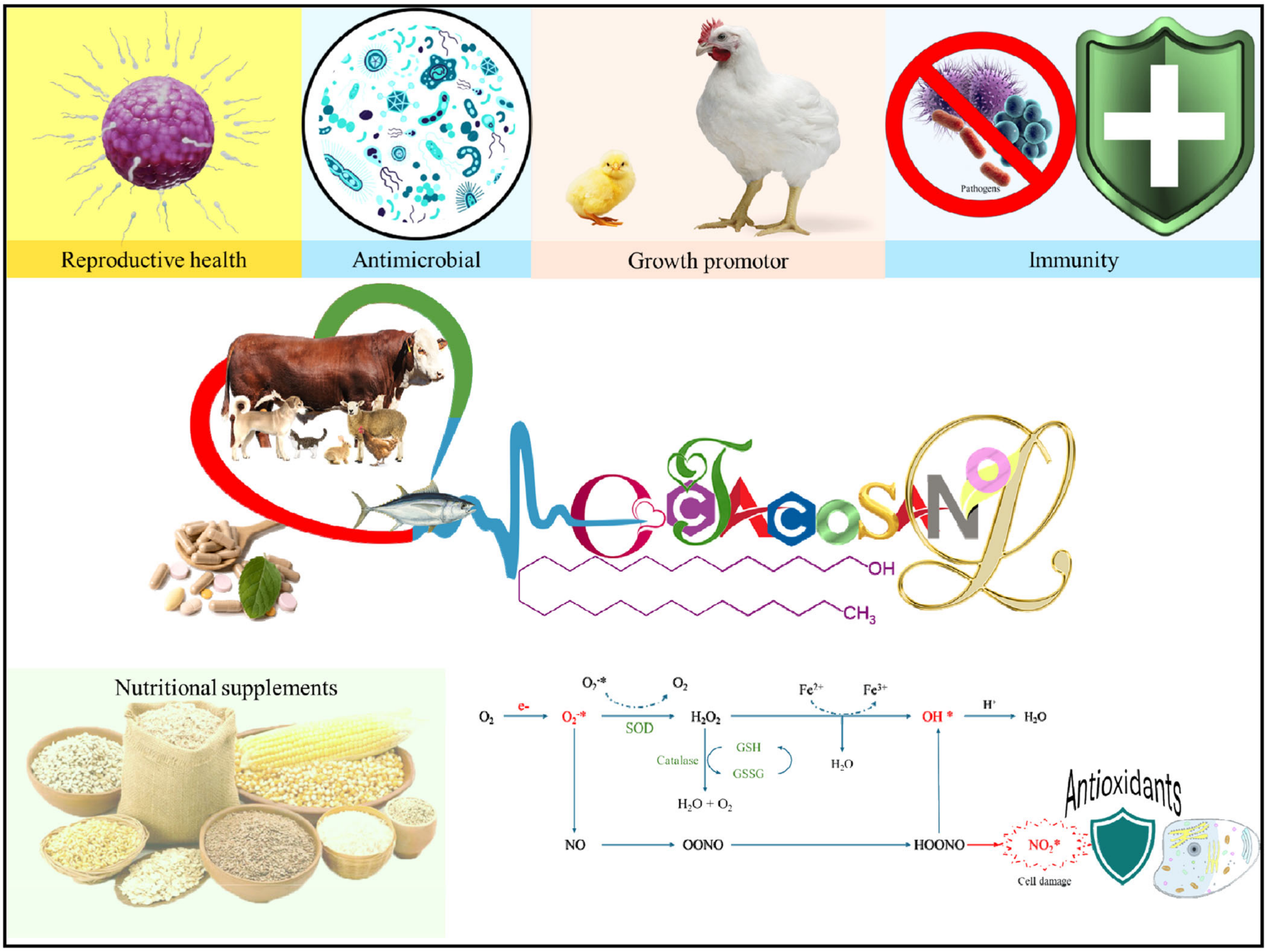

FIGURE 1 Multifunctional roles of octacosanol. [Color figure can be viewed at wileyonlinelibrary.com]

(Long et al., 2017). The rise in antioxidants may help to safeguard the growing fetus outside the body (the egg). Octacosanol has been discovered to have antioxidant properties, which may point to a beneficial effect on sperm protection. The large concentration of polyunsaturated fatty acids in this ability is what distinguishes it. In WGO, there were around 81% and 64% unsaturated fatty acids overall (Wafar et al., 2017). The capacity of the sperm to fertilize the egg and the development and growth of the fetus determine fertility and hatching traits in large part. A number of hormonal and dietary factors affect how many eggs and sperm are produced. The hypothalamic-pituitary-gonad system is accountable for secreting the majority of hormones, also known as gonadotropin-releasing hormone, which is secreted by the hypothalamus. The anterior pituitary gland responds to this stimulation by secreting two chemicals, follicle-stimulating hormone, or FSH, and luteinizing hormone (LH) (Jalil & Allaw, 2021). The gonads of both sexes are affected. When these hormones are present in a male, the testicles are stimulated to produce the hormone testosterone from interstitial cells within the testis. This hormone, in turn, stimulates the LH-producing intermediate cells, which in turn helps the sperm mature. The FSH hormone has a direct impact on sperm production within the seminal tubule. While the ovarian cells are stimulated by the FSH hormone to produce and release progesterone and oestrogen hormones that increase follicle growth and development in females, the LH hormone serves to induce ovulation in females (Sturkie, 2000).

2.3.3 | Octacosanol as antioxidants

Antioxidants are used as additives to increase the shelf lifespan of animal feeds, premixes and fats because they have the potential to stop the peroxidation of lipids and oxidative rancidity during their production, processing and storage. In order to boost animal yields for livestock production and hence increase economic output as well as product quality (e.g., milk, cheese, meat and eggs) and consumer safety, antioxidants are required. Through nutrition, a practical, affordable and efficient method to provide animals with antioxidants was discovered (Castaño et al., 2001). Octacosanol intake led to increases in serum fatty acid content and fatty acid oxidation and decreases in adipose accumulation, serum triglyceride (TG) concentration and glycogen build-up.

2.3.4 | Octacosanol as therapeutic and antimicrobial

With its ability to reduce stress and promote sleep, the food ingredient octacosanol is found in rice bran, sugarcane and wheat germ oil. That octacosanol induces sleep by reducing stress is supported by the evidence. Thus, it improves sleep that has been impacted by stress. Due to its source, which includes plants that are commonly found in food, octacosanol is regarded as a harmless substance. Several studies have reported a variety of biological effects of octacosanol on both people and animal models (Kabir, 2020). The effects of Octa on insulin resistance may be due to the fact that it restores the gut microbiota and stops the TLR4/NF-B inflammatory pathway in obese people who have gone on an HFD (Ding et al., 2023). Because 2,6-dimethoxy-1,4-benzoquinone (DMBQ) is present in the wheat germ extract, an antioxidant from the oil was isolated and showed excellent antibacterial activity (Kim, 2010).

2.3.5 | Octacosanol as immune stimulating

Octacosanol is now known to have antifatigue properties (Kim et al., 2003), control lipid metabolism, lower cholesterol, promote cytoprotective activity, and increase energy metabolism, among other functions. One novel feed additive that has significant potential for growth and use is octacosanol, which combines high safety standards with efficient functions. Tiamulin is a type of double-terpene antibiotic that works by joining with the bacterial ribosome's 50 S subunit to inhibit bacteria and stimulate animal growth. Pigs fed octacosanol also exhibited decreased diarrhoea ratios and more antioxidant capacity (Long et al., 2015). The mechanism may be due to octacosanol's ability to control the body's glycogen levels and keep the energy metabolism in balance. When compared to piglets that were fed a control diet or a diet with tiamulin, octacosanol raised the expression of the GLUT-4 gene in both muscle and liver tissue ($p < 0.05$) (Xiang et al., 2012).

3 | APPLICATION OF OCTACOSANOL ON PERFORMANCE IN ANIMAL AND AQUACULTURE

The application of octacosanol as a feed additive in animal husbandry and aquaculture has garnered significant attention due to its potential to enhance various aspects of performance and health (Figure 1). In this section, we delve into the multifaceted impacts of octacosanol on key parameters, as summarized in Table 1. The presented topics encompass growth performance, reproductive development, body composition, antioxidant activities and immune responses.

Octacosanol, a naturally occurring compound derived from diverse plant sources, has emerged as a promising bioactive supplement with the capacity to positively influence animal and aquatic species. Its mechanisms of action are diverse, ranging from modulating physiological processes at the cellular level to exerting systemic effects that translate into improved overall performance. Throughout this section, we will examine the intricate relationships between octacosanol and the selected performance indicators. We aim to provide a comprehensive understanding of the potential benefits that octacosanol supplementation can bring to the animal and aquaculture industries. This exploration will contribute to a deeper appreciation of the physiological mechanisms that underlie the observed effects, paving the way for informed decision-making in optimizing animal nutrition and health management strategies.

TABLE 1 Octacosanol influences various animal performance parameters, such as growth, lipid metabolism, antioxidants and immunity.

No.	Source of octacosanol	Tested dosage	Duration	Route of administration	Animal species	Performance effects (growth, lipid metabolism, antioxidant and immunity	References
1	Rice bran	100 mg/kg	10 weeks	Diet	Mice	Positive effects	Bai et al. (2022)
2	Sugar cane	10 g/kg diet	20 days	Diet	Rats	Positive effects	Kato et al. (2007)
3	Triticale sprout	0, 10, 20 and 30 mg/kg diet	6 weeks	Diet	Laying hens	Positive effects	Lim and Ryu (2022)
4	Rice bran	0, 12, 24 or 36 mg/kg diet	21 and 42 days	Diet	Broiler chicks	Positive effects	Long et al. (2016)
5	Rice bran	0, 5 and 10 mg/kg diet	10 weeks	Diet	Laying hens	Positive effects	Long et al. (2017)
6	Rice bran	8 mg/kg diet	6 weeks	Diet	Weaning piglets	Positive effects	Long et al. (2015)
7	Rice bran	0, 9, 18 and 27 mg/kg diet	21 and 42 days	Diet	Laying hens	Positive effects	Peng et al. (2016)
8	Rice bran	60 mg/kg/day	4 weeks	Oral gavage once a day	Mice	Positive effects	Sharma et al. (2019)
9	Rice bran	0, 5, 15 and 25 mg/kg diet	42 days	Diet	Japanese quails	Positive effects	Wafar et al. (2017)
10	Rice bran	0, 4, 8, 12 and 16 mg/kg diet	60 days	Diet	Red claw crayfish	Positive effects	Alhoshy et al. (2024)

3.1 | Growth performance

It is thought that policosanol or octacosanol, is a safe substance. The influence on an animal's ability to grow is the most important index because it is cumulative. This study showed that feeding broiler chicks octacosanol increased their growth performance, and that feeding them octacosanol at a dose of 24 mg/kg of food had the highest feed efficiency throughout the testing. By adding 25 mg/kg of octacosanol to grill chicks' diets for 42 days, Xu and Shen (1997) were able to achieve the same outcomes. Additionally, According to a study by Xu et al. (2007), E-KO mice fed a meal containing 1% octacosanol (wt/wt) gained weight at a pace comparable to the control group, and a moderate dose of octacosanol improved feed efficiency and boosted ADFI and ADG in rats (Xiang et al., 2012). These findings are consistent with the theory that octacosanol may enhance domestic animal growth (Long et al., 2016). In a prior aquaculture study, researchers explored the impact of octacosanol on *Cherax quadricarinatus*. Octacosanol, renowned for its health benefits, was incorporated into diets at varying concentrations (4, 8, 12 and 16 mg/kg) over 60 days. Findings revealed that 8 mg/kg bolstered growth, feed efficiency, and ovarian function. Quadratic regression recommended 9 mg/kg as the optimal dosage, suggesting octacosanol's viability as a safe and efficient feed additive in *C. quadricarinatus* aquaculture (Alhoshy et al., 2024).

3.2 | Reproduction development

In addition to enhancing reproductive efficiency and egg quality, dietary octacosanol supplementation can lengthen the peak time of laying hens throughout the late laying period. Octacosanol's ability to stimulate the release of reproductive hormones, in turn stimulating the mRNA expression of the axis of reproduction, accounts for this effect. In egg-laying hens during the latter cycle, the maturation and ovulation of follicles were affected by the interaction between hormones of reproduction and gene expressions of their receptors. The ideal dose for supplementing the diet with octacosanol to improve laying efficiency in laying hens is 5 mg/kg. Such studies may offer the poultry industry a fresh perspective and a theoretical and practical foundation for the novel measure of food supplementation with octacosanol to improve poultry reproductive performance (Long et al., 2017).

3.3 | Chemical composition of body

Contrary to tiamulin, octacosanol has the ability to boost the gene expression of GLUT-4 and AMPK in the liver and muscle tissues. These two pathways, hormones and gene expression, are what control the body's energy balance. This aids in enhancing growth performance, easing weaning stress, and lowering the incidence of diarrhoea. This evidence suggests that using octacosanol products instead of antibiotics in diets for weaned piglets may be an alternative. It may also offer theoretical justification for the creation of octacosanol as a secure and effective feed addition and the potential for use in pet animals. When doses of 20–30 mg per day, or 0.29–0.43 mg per kilogram of body weight per day, are supplied to humans, octacosanol has been shown to significantly improve physical function (Keller et al., 2008). The extra octacosanol dose was determined as 0, 5 or 10 mg per kilogram of feed ovarian follicles (Bulbul et al., 2015). The current study's findings were consistent with the theory that dietary addition of octacosanol increased the levels of E2, FSH, P4 and LH and would, as a result, promote hormonal and gonadotropic activity in humans. Improved FSH and LH levels may lead to a rise in ovarian weight, promotion of follicular growth and maturation, and stimulation of oestrogen synthesis in follicles. In a prior study, octacosanol's impact on red claw crayfish was assessed with varying concentrations (4, 8, 12 and 16 mg octacosanol/kg) over 60 days. Muscle protein notably increased in D2 (8 mg/kg) and D3 (12 mg/kg) compared to others and the control. However, lipid content decreased in D1 (4 mg/kg), D2 (8 mg/kg) and D3 (12 mg/kg) but rose in D4 (16 mg/kg). Moisture content remained unaffected. Hepatopancreas showed increased protein and lipid levels with octacosanol diets compared to the control (Alhoshy et al., 2024).

3.4 | Antioxidants activities

The antioxidant and antibacterial effects of octacosanol have not been extensively studied. If the pharmaceutical, nutraceutical, surfactant and cosmetic industries had complete knowledge of the potencies of octacosanol and other comparable fatty alcohols, they might utilize them in several all-around applications. Octacosanol has a unique structural composition that results in a very sluggish oxidation process, even under typical temperature and pressure conditions. Because it has a hydroxyl group, it can only be converted into aldehydes and carboxylic acids when exposed to powerful oxidizing agents (Heyns & Blazejewicz, 1960). By reducing the impact of reactive oxygen species, 1-octacosanol was discovered to have protective benefits against Parkinson's disease and to speed up the recovery from liver injury in a rat model study (Ohta et al., 2008; Wang et al., 2010). In a previous study, *C. quadricarinatus* was subjected to varying concentrations of octacosanol (4, 8, 12 and 16 mg/kg) over 60 days. Antioxidant activities in hemolymph and hepatopancreas were assessed, including GSH-Px, CAT, SOD, T-AOC, MDA and NO. Hepatopancreas displayed lower GSH-Px and CAT in the control compared to the D3 and D4 diets, with significant differences across octacosanol levels. SOD activity was notably lower in the control group but higher in D4-fed crayfish. T-AOC was higher in D4-fed crayfish but lower in the control. NO and MDA decreased with octacosanol up to 4 mg/kg, plateauing afterwards. Hemolymph antioxidant activities were similar to those of the hepatopancreas (Alhoshy et al., 2024).

3.5 | Immune responses

An important set of biological characteristics of the long-chain aliphatic alcohol octacosanol include its antioxidant, ergogenic and anti-parkinsonian capabilities. Rice bran oil, wheat germ oil and a variety of other plants all contain significant amounts of it. This alcohol has an antiangiogenic action similar to that of its synthetic equivalent, octacosa-10, 19-dien-1-butanol and reduced matrix metalloproteinase activity. Octacosanol (policosanol) is made up of combinations of long-chain aliphatic alcohols that have been demonstrated to lower adipose tissue weight and prevent cholesterol synthesis. Another study has shown that policosanol monotherapy decreases LDL cholesterol while increasing HDL cholesterol. In addition, policosanol exhibits a wide range of pharmacological activity, including lowering platelet aggregation, its effects on lipid metabolism, and acting as an anti-inflammatory and an antiulcer. In a prior study, *C. quadricarinatus* were exposed to varying octacosanol concentrations (4, 8, 12 and 16 mg/kg) over 60 days. Notable differences were observed in LYZ, ACP, AKP, ALT and AST activities among treatment groups ($p \le 0.05$). The D1, D2, D3 and D4 groups exhibited significant increases in LYZ compared to the control ($p \le 0.05$). ACP and AKP activities notably improved with increasing octacosanol levels ($p \le 0.05$), while ALT and AST activities decreased significantly across these levels ($p \le 0.05$), except for D3 and D4. Maximum nonspecific immune enzyme activities in the hepatopancreas were observed with D3 (12 mg/kg) and D4 (16 mg/kg) ($p \le 0.05$) (Alhoshy et al., 2024).

Generally, the studies mentioned above provide valuable insights into the impact of octacosanol as a feed additive on various aspects of animal reproduction and production. However, it is evident that there is a scarcity of information, particularly in the context of aquatic animals. Consequently, the existing knowledge underscores the need for further comprehensive investigations to elucidate the potential influences of octacosanol on aquatic animals, thereby contributing to a more comprehensive understanding of its effects in this specific domain.

4 | CONCLUSION

In conclusion, this review has comprehensively explored the multi-functional applications of octacosanol as a feed additive in both animal husbandry and aquaculture practices. Octacosanol, a naturally occurring compound derived from various plant sources, has exhibited a wide range of beneficial effects on growth performance, immune modulation, stress reduction and overall health enhancement in various animal species. The presented studies collectively highlight the potential of octacosanol to significantly contribute to the advancement of modern animal production systems. The various modes of action through which octacosanol exerts its effects, including its influence on lipid metabolism, antioxidant capacity and hormonal modulation, have been elucidated through experimental studies. Furthermore, octacosanol's compatibility with existing feed formulations and minimal adverse effects make it a practical choice for integration into commercial animal and aquaculture operations.

5 | FUTURE PROSPECTS

As the understanding of octacosanol's mechanisms of action continues to deepen, there are several exciting avenues for future research and application in the field of animal and aquaculture production:

1. Optimization of dosage and delivery: Further research should focus on determining the optimal dosage levels of octacosanol for various animal species and production contexts. Investigating different delivery methods, such as encapsulation and controlled-release formulations, can help enhance its bioavailability and effectiveness.
2. Synergistic effects and combinations: Exploring the potential synergistic effects of octacosanol with other bioactive compounds, such as probiotics, prebiotics and essential oils, could lead to innovative feed additive combinations that offer enhanced growth promotion, disease resistance and overall performance improvements.
3. Mechanistic insights: In-depth studies on the molecular and cellular mechanisms underlying octacosanol's effects are needed to provide a clearer understanding of its interactions with metabolic pathways, immune responses, and stress tolerance mechanisms in animals.
4. Environmental impacts: Investigating the ecological implications of incorporating octacosanol into aquaculture practices is crucial. Understanding its effects on waste management, water quality and the broader ecosystem will contribute to sustainable production practices.
5. Regulatory approvals: Collaborative efforts between researchers, regulatory bodies and industry stakeholders are essential to navigate the regulatory landscape for integrating octacosanol into commercial feed formulations. Obtaining official approval for widespread use can accelerate its adoption.
6. Field trials and validation: Conducting large-scale field trials across diverse geographical regions and production systems will provide valuable insights into octacosanol's performance under real-world conditions, helping validate its efficacy across different contexts.
7. Economic viability: Assessing the economic feasibility of incorporating octacosanol into animal and aquaculture operations is crucial for its practical implementation. Cost–benefit analyses and studies on the potential return on investment will guide producers in making informed decisions.

In conclusion, octacosanol presents a promising avenue for enhancing animal and aquaculture production practices. Continued research and collaborative efforts among scientists, industry partners, and regulatory agencies will pave the way for its successful integration, ultimately contributing to sustainable and efficient food production systems.

AUTHOR CONTRIBUTIONS

All authors contributed equally to this review article.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

This review article utilized publicly available and cited data sources, including scholarly articles, books, reports and online repositories. No new data were generated as part of this review. All sources referenced in this article are appropriately cited in the references section.

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