

## PROSPECTS FOR THE USE OF ARTEMIA AS A NATURAL ASTAXANTHIN SOURCE AND FEED ADDITIVE FOR ANIMALS

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**Abstract:** This article analyzes the prospects of using *Artemia* (brine shrimp) biomass and enriched *Artemia* as a natural source of astaxanthin and a functional feed additive for animals. The presence of astaxanthin among *Artemia* pigments provides a scientific basis for its application in aquaculture for purposes related to pigmentation and product quality. The use of *Artemia* biomass in broodstock diets can improve reproductive performance as well as egg and larval quality. Enrichment and bioencapsulation approaches enhance the effective delivery of astaxanthin and lipid–vitamin complexes by utilizing *Artemia* as an efficient carrier. In poultry production, *Artemia* meal is of interest as a protein source; however, limitations related to salt/electrolyte load and diet balance exist. Issues of biosafety, raw material standardization, and economic efficiency are discussed as key conditions for practical implementation.

**Keywords:** *Artemia*, astaxanthin, natural pigment, aquaculture, broodstock, bioencapsulation, enrichment, feed additive.

**Introduction.** At present, there is a growing demand in livestock production, poultry farming, and especially aquaculture for biologically active feed additives aimed at improving feed efficiency, strengthening animal health, and enhancing product quality (color, texture, and shelf life). One such additive is astaxanthin, a xanthophyll-type carotenoid distinguished by its strong antioxidant properties. Astaxanthin has been extensively studied with respect to its various natural and synthetic sources, extraction methods, stability, and biological activity [1].

In aquaculture practice, the importance of astaxanthin is primarily associated with pigmentation, which directly affects commercial value—for example, the color intensity of salmonids, trout, shrimp, and ornamental fish. In addition, scientific studies indicate that astaxanthin may support antioxidant defense systems, enhance resistance to stress factors, and, in some cases, exert positive effects on immune-related parameters. In particular, a comprehensive review published in *Reviews in Aquaculture* summarized evidence on dietary astaxanthin supplementation in aquaculture species, discussing not only its “classical” role in coloration but also additional physiological effects that depend on species and dosage [2].

From an applied perspective, astaxanthin is obtained from either synthetic or natural sources. However, as the feed and food supply chains increasingly prioritize “natural” ingredients, the search for sustainable, economically viable, and safe delivery mechanisms for natural astaxanthin has become especially relevant. A major review on astaxanthin sources, commercial applications, and biological effects has extensively addressed both market-related and technological aspects of this field [1].

Within this context, *Artemia* (brine shrimp) deserves particular attention. Classical studies have demonstrated that among the pigments present in *Artemia nauplii* (larvae) and cysts, esterified astaxanthin is the principal coloring component: the characteristic “bright orange” coloration of *nauplii* can be attributed specifically to esterified astaxanthin [3]. Therefore, *Artemia* should be regarded not only as a high-protein biological feed organism but also as a functional raw material associated with carotenoids, particularly astaxanthin.

**Scientific Basis for the Use of *Artemia* as a Feed Additive.** *Artemia* is one of the most widely used live feeds in aquaculture and can be applied either in the form of biomass (frozen or dried) or as enriched *Artemia* to address various biological objectives. Compared with bleached or standard formulated feeds, a key advantage of *Artemia* lies in its role as a “living capsule,” facilitating the delivery of specific compounds to the animal organism—an approach known as

bioencapsulation. A critical aspect of the bioencapsulation mechanism is *Artemia*'s filtration behavior and its sensitivity to particle size. For instance, it has been shown that for *Artemia franciscana*, optimal food particle sizes range from approximately 6.8 to 27.5  $\mu\text{m}$ , with an optimal value around  $\sim 16 \mu\text{m}$  [4]. From a practical standpoint, this finding implies that when delivering pigments, vitamins, or lipids via *Artemia* (e.g., through microemulsions or microcapsules), particle and dispersion parameters have a direct impact on success.

Evidence supporting the importance of *Artemia* biomass in broodstock (reproductive breeders) nutrition in aquaculture has been accumulating for several decades. For example, in *Litopenaeus/Penaeus vannamei* production systems, the inclusion of *Artemia* biomass in broodstock diets has been shown to partially replace expensive "fresh" feeds such as polychaetes, while potentially improving overall reproductive outcomes, including mating and hatching tendencies as well as final nauplii production [5].

Similarly, the use of enriched *Artemia* biomass in *P. vannamei* broodstock diets has been discussed in terms of its effects on reproductive performance and larval quality in a dedicated study [6].

The concept of *Artemia* as a "fresh food substitute" for broodstock has been further reinforced by subsequent research. Experimental evaluations in white shrimp (*L. vannamei*) demonstrated that partial replacement of fresh feeds with *Artemia* biomass offers certain technological advantages, while also highlighting associated risks and practical limitations. Importantly, hatcheries often prefer partial rather than complete use of natural feeds due to sanitary and stability concerns; under such conditions, *Artemia* biomass can serve as a "bridge technology" [7].

The benefits of *Artemia* biomass are not limited to shrimp culture. For instance, supplementation of European sea bass (*Dicentrarchus labrax*) broodstock diets with a combination of palaemon and dried *Artemia* biomass resulted in positive recommendations regarding reproductive performance and egg quality [8]. Such studies provide a basis for viewing *Artemia* not merely as a conventional protein source, but as a functional additive with high biological value.

**Artemia Enrichment and Delivery of Astaxanthin.** The natural composition of *Artemia* may not be optimal for all applications, as levels of highly unsaturated fatty acids (HUFA), vitamins, or pigments may be insufficient or variable. Consequently, *Artemia* enrichment strategies—using feed emulsions, micro-oils, microalgae, vitamins, and pigments—are widely employed in practice. A comprehensive recent review on *Artemia* enrichment systematically discussed the main enrichment approaches, practical protocols, and factors affecting efficiency, including particle size, enrichment duration, stocking density, and carrier medium [9].

In the specific context of astaxanthin, pigmentation should be viewed not merely as "red coloration," but as a complex phenomenon linked to the metabolic status of the animal, its response to oxidative stress, and market-driven quality requirements. A dedicated chapter on carotenoid and pigment sources in aquaculture addressed the concept of color management through diet, the biological roles of carotenoids, and regulatory as well as practical limitations [10].

An evidence-based review assessing astaxanthin use in aquaculture further demonstrated that outcomes vary considerably depending on species, dosage, and intended purpose (coloration, stress resistance, growth), underscoring the importance of optimizing the "source–dose–delivery method" triad [2].

In this respect, the role of *Artemia* as a "natural carrier" is particularly promising. When astaxanthin is added directly to formulated feeds, issues related to stability, oxidative degradation, and bioavailability become critical. Delivery via *Artemia* may technologically mitigate some of these challenges through bioencapsulation and partially protected transport. The mechanical and biological foundations of bioencapsulation—including filtration behavior, particle size, and inconsistencies under enrichment conditions—have been emphasized in a specialized study on *Artemia* bioencapsulation [4].

**Artemia in Poultry Production: Protein and Functional Components.** Beyond aquaculture, Artemia may also be considered as a feed additive in poultry production. A classical study evaluated lyophilized Artemia salina biomass as a partial replacement for fishmeal in broiler starter diets, showing that at certain inclusion levels (e.g., 5%), growth performance did not deteriorate markedly. However, the high Na/Cl (electrolyte) content of Artemia was highlighted as an important consideration in practical diet formulation [11]. Assessments of Artemia meal protein quality have also emphasized the importance of apparent and true amino acid digestibility, with studies determining amino acid digestibility of Artemia meal in broiler chicks [12]. Furthermore, proceedings from a BSAS conference discussed the potential of Artemia meal as a high-energy, high-protein feed ingredient in broiler diets [13].

Nevertheless, the use of Artemia in poultry feeding is not limited to nutritional value alone. Issues of biological safety during raw material collection, transportation, and processing are also critical. A dedicated publication has warned that when brine shrimp are used as food or premix ingredients for birds, appropriate disinfection and risk-reduction measures must be ensured [14].

**Research Problem and Aim of the Study.** The literature reviewed above indicates that Artemia can simultaneously fulfill multiple roles: (i) as a natural source of astaxanthin-related pigments, (ii) as a carrier of biologically active compounds via bioencapsulation and enrichment, and (iii) as a high-protein biomass or meal used as a feed ingredient [3]. At the same time, outcomes strongly depend on species, dosage, processing methods (drying or lyophilization), sanitation, enrichment protocols, and overall diet balance. Consequently, the use of Artemia as a source of “natural astaxanthin” requires scientifically grounded optimization [2].

The aim of the present article is to analyze, based on available literature, the prospects for using Artemia as a natural astaxanthin source and feed additive for animals, and to summarize the main application pathways of Artemia (biomass/meal, enrichment, and bioencapsulation), along with practical examples from aquaculture and poultry production [5].

**Materials and methods. 1) Study design.** This article was prepared using a narrative literature review and a practice-oriented methodological synthesis approach. Application scenarios of Artemia were compared using unified criteria, including: (i) the use of Artemia as biomass/meal serving as a natural astaxanthin and protein source; (ii) the use of enriched “live feed” Artemia (bioencapsulation); and (iii) partial substitution/supplementation in formulated diets. The presence of esterified astaxanthin as the principal Artemia pigment was adopted as the methodological foundation [3].

**2) Data sources and search strategy.** Sources were collected from the following scientific platforms and publisher websites: Royal Society Publishing, ScienceDirect (Elsevier), Wiley Online Library, MDPI (Marine Drugs), Oxford Academic (JCB, Poultry Science archive indexes), Cambridge Core, AJOL/SCIELO, as well as Biotaxa/MJBS [3]. Search keywords (in English) were applied in the following combinations: “Artemia astaxanthin”, “Artemia biomass broodstock”, “enriched Artemia”, “Artemia bioencapsulation particle size”, “Artemia meal broiler”, “astaxanthin feed supplement aquaculture”, “carotenoids pigmentation fish crustaceans”. Priority was given to methodological reviews and key experimental studies [2].

### **3) Selection criteria.**

**Inclusion criteria:** Studies using Artemia as biomass/meal in the diets of animals (aquaculture species or poultry) [5];

Studies on improving the nutritional value of Artemia via enrichment/bioencapsulation (particle size, enrichment strategies) [4];

Reviews summarizing the role of astaxanthin as a feed additive, including stability, extraction, and storage issues [1].

**Exclusion criteria:** Works not directly linked to animal nutrition and focused exclusively on ecology or purely theoretical chemistry; sources without accessible full text or lacking verification/peer review.

**4) Data extraction and analysis.** From each selected source, the following information was

extracted in a standardized format:

animal species and physiological stage (larva/broodstock/broiler chick) [5];

form of Artemia product: nauplii, enriched biomass, dried biomass/meal (including lyophilization, etc.) [5];

inclusion level (dietary proportion or degree of partial replacement of “fresh food”) and duration [5];

outcome measures: reproduction (egg quality, hatching), growth/FCR, pigmentation and quality indicators, and digestibility in poultry [8].

**5) Methodological blocks: approach by practical application scenarios.** In this article, the Artemia-based “natural astaxanthin” concept was divided into three methodological scenarios:

**5.1. Artemia biomass/meal: a “natural pigment + protein” supplement.** Studies using Artemia biomass in broodstock diets in aquaculture—either as a supplement or as a partial replacement of fresh feeds—were treated as the methodological “reference model” [5].

Shrimp broodstock: mixed diets incorporating Artemia biomass and outcomes such as nauplii production/larval quality [5].

Sea bass broodstock: reproductive outcomes and egg quality under supplementation with dried Artemia biomass [8].

In poultry production, experiments administering lyophilized Artemia salina as a partial replacement for fishmeal at inclusion levels of 2.5–10% were used as a methodological analogue [11].

**5.2. Artemia enrichment and bioencapsulation: delivery via a “carrier”.** To convert Artemia into enriched live feed:

Particle size was adopted as the core technological parameter. Conclusions regarding effective particle-size ranges and the optimum point for Artemia filtration were applied as a methodological constraint [4].

Approaches from a major review on enrichment strategies (oils, microalgae, probiotic/mineral, etc.) were synthesized as the “protocol logic” [9].

**5.3. Working with astaxanthin: principles of stability and extraction/storage**

Key aspects of astaxanthin relevant to feed technology—sources, extraction approaches, and storage stability—were summarized as methodological rules [1]. Methodological concepts on diet-based pigmentation control, the applied–regulatory context, and carotenoid biology were adopted from a book chapter discussing pigment sources and application logic [10]. A review evaluating the evidence base for astaxanthin as a dietary supplement in aquaculture species was used as a methodological background for interpreting results, particularly differences across species, doses, and objectives [2].

**6) Poultry-specific methodological criterion: biosafety.** The need for disinfection of raw materials and equipment when using Artemia as a premix/feed component for birds (risk of infections/parasites via wild birds) was incorporated as a methodological risk factor [14].

**7) Comparative approach for results.** Findings from selected sources were compared across four dimensions:

production objectives (pigmentation, growth/FCR, reproduction, digestibility) [2];

form of Artemia (nauplii, enriched biomass, dried biomass/meal) [6];

technological parameters (enrichment strategy and particle-size requirements) [4];

safety and application constraints (sanitation in poultry, dietary minerals/electrolyte load) [11].

**Results and discussion.** In the following section, key findings reported in the literature on incorporating Artemia (brine shrimp) into animal diets—as a natural source of astaxanthin and/or a carrier of bioactive compounds—are discussed in a structured manner. The predominance of esterified astaxanthin among Artemia pigments, documented in classical studies, provides the biochemical basis for this analysis [3].

**1) Artemia biomass in aquaculture: effectiveness in broodstock diets.** Evidence supporting the use of Artemia biomass in shrimp broodstock nutrition emerged relatively early. Naessens et

al. (1997) concluded that mixed maturation diets supplemented with *Artemia* biomass in *Penaeus vannamei* could produce positive trends in mating success and hatching performance, potentially resulting in significant differences in overall nauplii production. The authors assessed *Artemia* biomass as a feasible supplement or partial substitute for polychaetes, which are expensive fresh feeds [5].

Subsequent research emphasized advantages of providing *Artemia* not merely as biomass but as enriched biomass. Wouters et al. (1999) discussed improvements in reproductive outcomes and larval quality when enriched *Artemia* biomass was included in *P. vannamei* broodstock diets, including enrichment strategies involving lipid/vitamin combinations [6].

In addition, Wouters, Nieto, and Sorgeloos (2002) tested scenarios in which 50% (on a dry-matter basis) of fresh food was replaced with formulated diets. In that context, a freeze-dried *Artemia* biomass-based diet (ART) was evaluated as a practical alternative, supporting the view that *Artemia* can serve as a technological “bridge” in broodstock feeding [7].

Collectively, these studies suggest that *Artemia* biomass fulfills two strategic functions in broodstock systems: (i) providing nutritional/biological value (protein plus lipid fractions) and (ii) delivering components in a “natural” form—including carotenoids—that may be important for reproductive processes [5].

**2) *Artemia* in fish broodstock: the European sea bass case.** The broodstock benefits of *Artemia* are not limited to shrimp. El-Gamal et al. (2020) reported that supplementation of European sea bass (*Dicentrarchus labrax*) broodstock diets with *palaemon* plus dried *Artemia* biomass was associated with significant improvements in fertilization and hatching rates, as well as certain reproductive hormone indicators, and recommended dried *Artemia* biomass supplementation for practical use. These outcomes support viewing *Artemia* not simply as a conventional feed ingredient, but as a functional component capable of supporting broodstock reproductive performance and egg/larval quality [8].

**3) The *Artemia*–astaxanthin link: pigmentation and beyond.** The “natural astaxanthin” concept of *Artemia* is rooted primarily in its pigment profile. Gilchrist & Green (1960) showed that astaxanthin—particularly esterified forms—plays a major role among *Artemia* pigments [3]. Lim et al.’s review summarized that the most consistent and robustly demonstrated practical role of astaxanthin as a feed additive in aquaculture is pigmentation (color enhancement), while additional physiological benefits may be discussed depending on species and conditions [2].

The biological, applied, and regulatory aspects of diet-driven coloration, as well as the role of carotenoids as pigment sources, are also systematically addressed in the chapter by Amaya & Nickell (2015) [10]. However, the simplified notion that “astaxanthin solves everything” is not scientifically justified. Reviews—particularly in aquaculture—emphasize that effects beyond pigmentation (stress tolerance, immune responses, growth) are sensitive to species, dose, duration, and delivery form [2].

Another critical aspect in feed technology is astaxanthin stability (oxidation), extraction, and storage. Ambati et al. (2014) reviewed sources, extraction, stability determinants, and applications of astaxanthin in feed/food/nutraceutical contexts, indicating that storage and oxidative risks must also be considered within *Artemia*-based “natural astaxanthin” strategies [1].

**4) Enrichment and bioencapsulation: the delivery mechanism via *Artemia*.** The scientific foundation for using *Artemia* as a natural carrier rests on enrichment and bioencapsulation technologies. Gelabert Fernández (2001) demonstrated that particle size is a decisive factor in *Artemia franciscana* filtration: to achieve efficient capture/filtration, feed particle parameters must be optimized, directly influencing the design of enrichment emulsions or microcapsules [4]. A comprehensive review by Ramena et al. (2025) synthesized *Artemia* enrichment strategies (oil emulsions, microalgae, probiotics, etc.) and discussed evidence that enriched *Artemia* under larviculture conditions may improve outcomes related to growth, survival, and stress resistance [9].

These findings support a two-level approach to viewing *Artemia* as an astaxanthin delivery

platform:

1. the effect of Artemia's intrinsic carotenoids, including astaxanthin [3];
2. the additional enrichment of Artemia to deliver astaxanthin or other lipid/vitamin complexes in a protected and biologically compatible form [9].

**5) Artemia meal/biomass in poultry: nutritional value and constraints.** In poultry production, the relevance of Artemia is primarily linked to its value as a protein source and its potential to introduce functional components (including carotenoids) into the diet. Corazza & Saylor (1983) tested lyophilized Artemia salina biomass as a partial replacement for fishmeal in broiler starter diets at 2.5–10% inclusion levels and reported that replacement at 5% did not markedly impair chick performance; nevertheless, they emphasized that the high Na/Cl (salt) content of Artemia requires caution in practical diet formulation [11]. Regarding digestibility, Aghakhanian et al. (2009) used Artemia meal as the sole protein source in broiler chicks and determined apparent/true amino acid digestibility values. Such data highlight the need for proper formulation (amino acid balance) and an appropriate energy-to-protein ratio when incorporating Artemia into poultry diets [12].

Zarei et al. (2008) (BSAS proceedings) discussed the use of Artemia meal as a protein supplement in broiler diets and noted its potential as an energy- and protein-rich feed ingredient [13].

Overall, the key conclusion for poultry is that while Artemia meal is promising for niche (targeted) applications, broader implementation requires careful evaluation of (i) raw material cost, (ii) salt/electrolyte load, and (iii) supply-chain stability [11].

**6) Biosafety: raw material and disinfection considerations.** Because Artemia is commonly associated with saline lake ecosystems and is ecologically linked to wild birds, infectious or parasitic risk factors may, in some cases, accompany raw material collection. Volf (2009) explicitly emphasized that when brine shrimp are used as food/premix ingredients in poultry, wild birds may act as disease vectors, and therefore disinfection measures for raw materials and equipment are necessary. This implies that within Artemia-based feed additive concepts, a biosafety protocol should be treated as a mandatory component alongside biological efficacy [14].

**7) General synthesis: prospects and an applied model.** Integrating the above evidence, the most realistic prospects of the Artemia-based “natural astaxanthin” approach can be summarized as follows:

**Hatchery/larviculture:** delivering astaxanthin and lipid/vitamin complexes via bioencapsulation using enrichment strategies and emulsions designed to meet particle-size requirements [9].

**Broodstock systems:** using Artemia biomass (standard or enriched) as a functional component potentially improving reproductive performance and offspring quality [5].

**Pigmentation and product quality:** the most reliable applied role of astaxanthin is coloration control; Artemia can serve in this role both as a natural pigment source and as an enrichment platform [2].

**Niche poultry applications:** partial replacement of fishmeal with Artemia meal appears feasible; however, salt/electrolyte and economic constraints make targeted rather than large-scale use more reasonable [11].

**Biosafety:** standardization of raw material sourcing, processing, and disinfection requirements should be considered a prerequisite for implementation [14].

At the same time, the literature analysis indicates that several open tasks remain in the Artemia–astaxanthin–feed additive domain: (i) quantitative assessment of astaxanthin in Artemia biomass/meal using standardized analytical protocols; (ii) identification of optimal dose and duration tailored to species and life stage; (iii) control of enrichment parameters (emulsion/microcapsule), particularly particle size, under production conditions; and (iv) joint optimization of economic efficiency and biosafety [4].

**Conclusion and recommendations.** The integration of natural astaxanthin sources into animal

diets remains a highly relevant issue in aquaculture and poultry production, particularly from the perspectives of improving product quality, biological robustness, and feed efficiency. Reviews addressing astaxanthin sources, extraction and stability, biological activity, and commercial applications consistently indicate that the most effective pathway is the combination of a “natural source + an appropriate delivery technology” approach.

Within this framework, *Artemia* (brine shrimp) has a dual significance. First, the presence of esterified astaxanthin as a major component of *Artemia* pigments is scientifically well established. Second, *Artemia* is already widely used as live feed in aquaculture and may also function as a carrier for delivering bioactive compounds to the animal organism.

The literature indicates that inclusion of *Artemia* biomass in broodstock diets (in either standard or enriched form) can improve reproductive outcomes and indicators associated with egg and larval quality in shrimp and fish. In particular, the positive influence of enriched *Artemia* biomass on broodstock performance has been emphasized.

In aquaculture, the most consistently demonstrated applied role of astaxanthin is pigmentation. At the same time, reviews suggest that, depending on species, dose, and rearing conditions, additional physiological benefits may also be discussed. Therefore, the *Artemia*-based “natural astaxanthin” strategy appears especially promising for species where coloration and market quality are critical (e.g., fish and shrimp).

A technological basis has also been established for using *Artemia* as a “carrier platform” through enrichment and bioencapsulation. Parameters such as particle size during filtration have been shown to determine enrichment efficiency, while enrichment strategies have been systematically described in modern reviews.

In poultry production, available sources suggest that *Artemia* meal/biomass may partially replace fishmeal; however, due to salt/electrolyte load, formulation constraints, and economic considerations, this direction currently appears more suitable for niche (targeted) applications. Nevertheless, available amino acid digestibility data provide an important foundation for rational diet design.

Finally, because *Artemia* raw material may originate from ecosystems associated with wild birds, special emphasis should be placed on disinfection of raw materials and equipment and on standardizing biosafety measures.

The following recommendations were formulated based on results and methodological approaches reported in the literature:

**For aquaculture (larviculture/hatchery): expand the carrier-based approach via *Artemia*.**

*Artemia* enrichment strategies (emulsions/microcapsules, microalgae, lipid–vitamin complexes) should be implemented using established practical protocols, while controlling key parameters such as particle size, which determines enrichment efficiency.

**For broodstock systems: apply *Artemia* biomass as a functional “fresh food” component.** In shrimp and fish broodstock, inclusion of *Artemia* biomass (standard or enriched) may positively affect egg/larval quality and reproductive outcomes. In practice, it may be used to partially replace expensive fresh feeds such as polychaetes.

**For pigmentation objectives: optimize “natural astaxanthin” in relation to product-quality criteria.** Astaxanthin provides the most reliable outcomes in terms of coloration, whereas additional physiological effects are species-sensitive. Therefore, an *Artemia*-based strategy should be optimized by the “species–dose–duration–delivery form” framework.

**For poultry production: use *Artemia* meal in limited proportions with strict attention to diet balance.** In scenarios of partial replacement of fishmeal, *Artemia* meal/biomass can be considered; however, attention must be paid to its salt (Na/Cl) content and amino acid balance. Formulation should be guided by available digestibility data.

**For biosafety: standardize raw material sourcing and processing protocols.** Without strict protocols for raw material origin, drying/storage, disinfection, and microbiological risk control, large-scale application of *Artemia*-based feed additives may be associated with unacceptable

risks.

**For future research: prioritize quantitative standardization and economic evaluation.**

Future work should focus on standardized quantitative assessment of astaxanthin content in Artemia biomass/meal using unified analytical protocols, determination of species-specific optimal inclusion levels, and integrated cost–benefit analysis to evaluate economic feasibility.

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