Eco-Eff™

Preventing Feed Rancidity for Animal Nutrition and Other Benefits

This technical document analyzes the innovative Eco-Eff™ formulation developed by INTABIOTECH, which combines 100% naturally occurring mineral ingredients, biotechnologically processed to prevent oxidative rancidity in feed intended for animal nutrition. It examines the mechanisms of action of both components, their functional synergy, and the additional benefits they bring to quality, stability, and productive efficiency in the animal feed industry.

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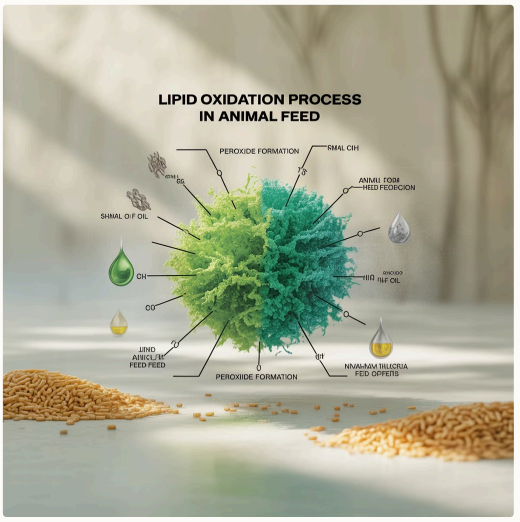
Introduction to the Problem of Rancidity in Feed

The stability of compound feeds intended for animal nutrition is a critical aspect to guarantee safety, quality, and productive efficiency in farms. Among the main challenges is the **oxidative rancidity of fats and oils,** a process that not only reduces the nutritional value of feeds but can also generate toxic and unpleasant compounds for animals, affecting palatability and health.



Oxidative rancidity is a complex biochemical process involving the degradation of unsaturated fatty acids present in fats and oils incorporated into formulations. This phenomenon is characterized by chain reactions initiated by free radicals and catalyzed by factors such as elevated temperature, exposure to light, presence of transition metals (such as iron or copper), and inadequate pH conditions.

The **consequences of rancidity** are multiple and affect various aspects of productive performance:

1

Nutritional Loss

Destruction of fat-soluble vitamins (A, D, E, K) and essential fatty acids, reducing the biological value of the feed.

2

Organoleptic Alteration

Development of unpleasant odors and flavors that decrease palatability and voluntary consumption by animals.

3

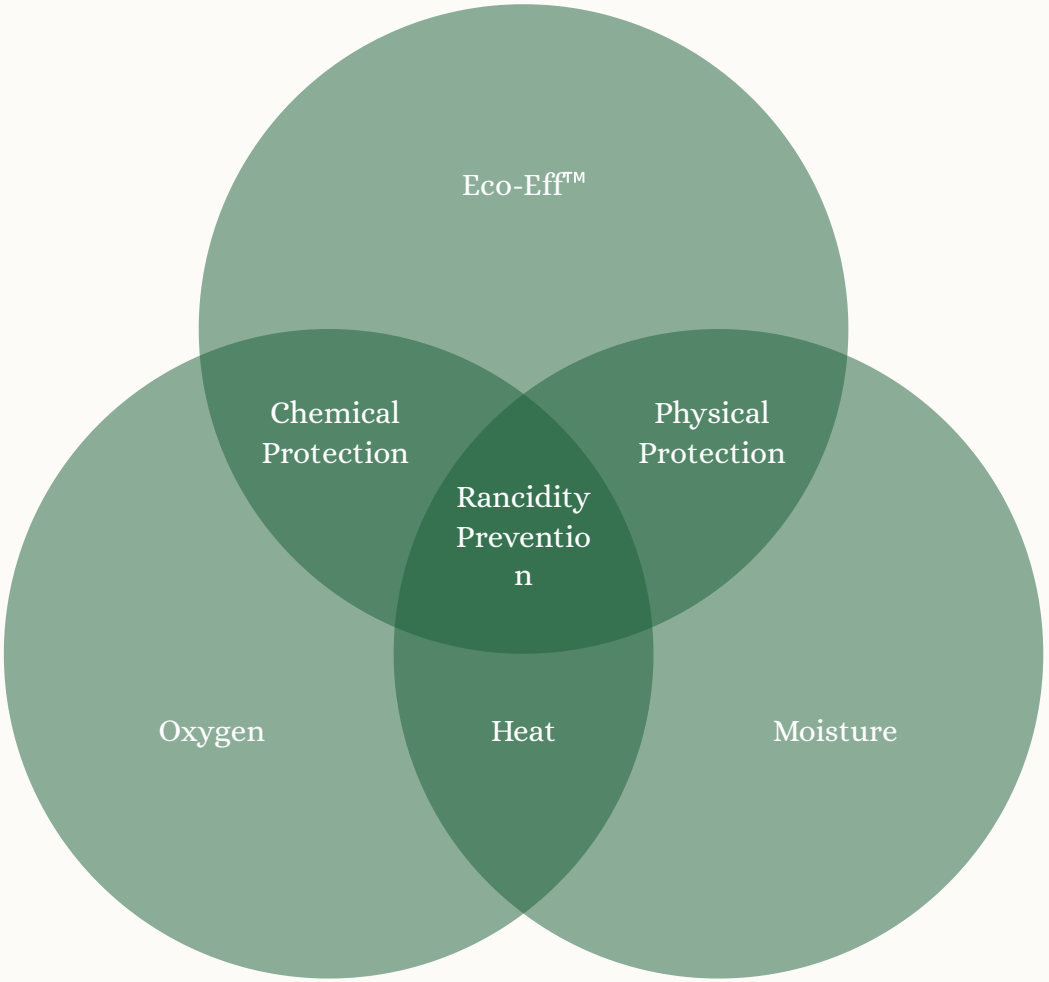
Potential Toxicity

Formation of compounds such as malondialdehyde (MDA) and other aldehydes that can negatively affect animal intestinal health and immune system.

To mitigate these phenomena, multiple **technological strategies** have been proposed. One of these is the application of combined systems of functional additives, such as the one developed by INTABIOTECH under the trade name Eco-Eff™, based on the synergy of its components, natural mineral-origin ingredients and minerals from EC Regulation 1925/2006 and 1170/2009 (Annexes II and III respectively, biotechnologically processed.

Mechanisms of Action in Rancidity Prevention

The Eco-Eff™ formulation bases its effectiveness on the complementary physicochemical properties of its main components. To adequately understand its functioning, it is necessary to analyze the specific mechanisms of action of each component and the synergistic interaction established between them when incorporated into the feed matrix.



The oxidative rancidity process typically develops in three sequential phases:

1. **Initiation:** formation of free radicals from unsaturated fatty acids through hydrogen atom abstraction, generally catalyzed by metals, UV light, or heat.
2. **Propagation:** reaction of lipid radicals with molecular oxygen to form peroxides, which in turn abstract hydrogen from other fatty acids, propagating the chain reaction.
3. **Termination:** interaction between two radicals to form stable non-radical compounds, such as aldehydes, ketones, and alcohols, responsible for rancid odors and flavors.

The **Eco-Eff™** formulation primarily intervenes in the initiation and propagation phases, establishing physicochemical conditions that hinder the development of these degradative reactions. The specific mechanisms of each component are detailed in the following sections.

1.- Eco-Eff™: Chemical Protection Mechanisms

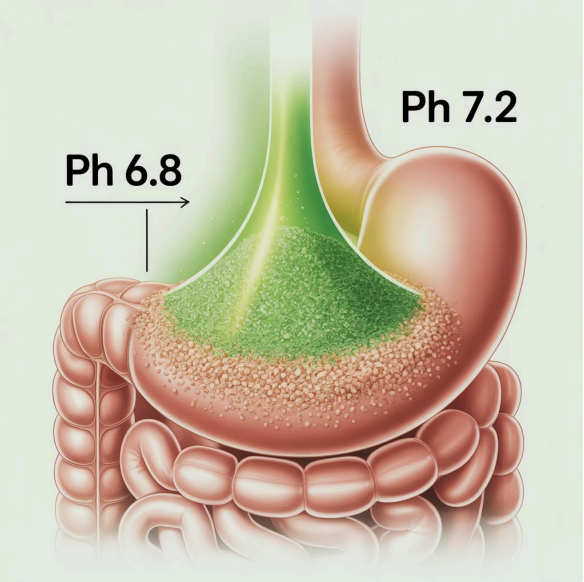
Eco-Eff™ presents a dual function in the context of feed, acting simultaneously as an internal chemical regulator and as a modifier of digestive conditions after ingestion:

pH Regulator and Chemical Stabilizer

Eco-Eff™ contributes to maintaining an environment less conducive to lipid oxidation by reducing the acidity that favors degradative reactions. Recent studies have shown that slightly alkaline pH values (7.2-7.8) can reduce the rate of oxidative reactions by up to 35% compared to slightly acidic environments (pH 6.0-6.5).

The mechanism involved is related to Eco-Eff™'s ability to neutralize protons (H^+) released during the initial stages of lipid oxidation, according to the following reaction:

$$NaHCO_3 + H^+ \rightarrow Na^+ + H_2O + CO_2$$



Buffer Properties and Stabilization

Eco-Eff™ stabilizes the physicochemical conditions of feed, limiting fluctuations that can accelerate oxidation processes. This buffering capacity is especially relevant in feeds with a high content of polyunsaturated fatty acids (PUFA), which are particularly susceptible to oxidation.

Secondary Digestive Effect in Animal Nutrition

In ruminants, the use of **Eco-Eff™** as a ruminal buffer is well documented, improving digestive efficiency and reducing the risk of subclinical acidosis. This effect manifests when the **Eco-Eff™** not consumed in feed stabilization reactions reaches the digestive tract, where:

Ruminal Environment

Neutralizes the excess of volatile fatty acids, stabilizing pH between 6.2-6.8, optimal for the cellulolytic activity of ruminal microbiota.

Intestinal Digestion

Promotes the activity of pancreatic enzymes, optimizing the digestibility of proteins and lipids in monogastrics.

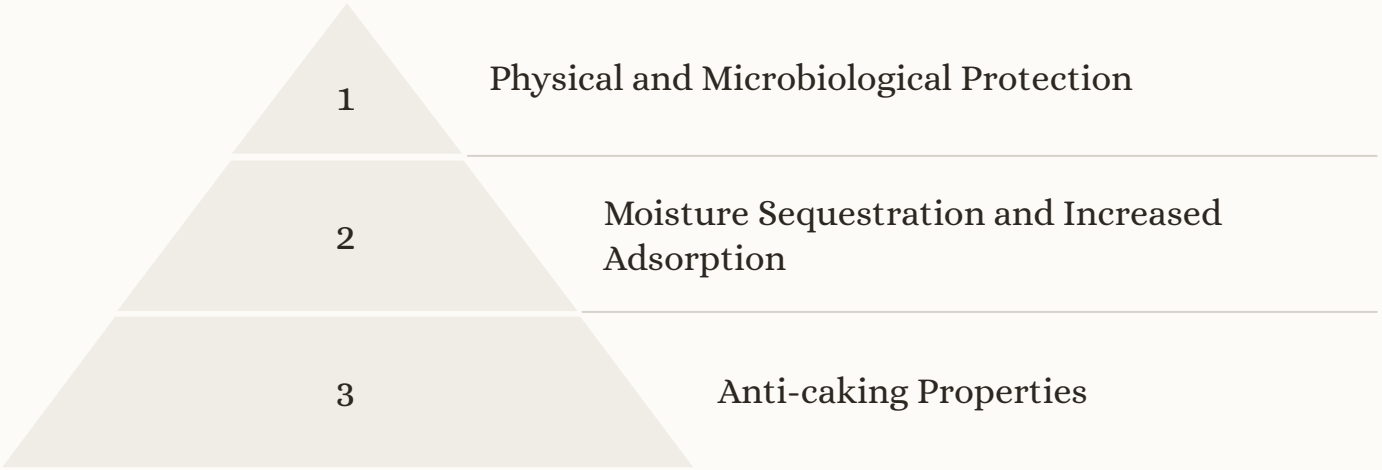
Electrolyte Balance

Contributes to maintaining systemic acid-base balance, especially important under conditions of heat stress or intense production.

The usual dosage of Eco-Eff™ ranges from 0.5-1.5% of the total feed weight, a sufficient concentration to exert stabilizing effects without significantly altering the organoleptic characteristics or nutritional value of the final product.

2.- Eco-Eff™: Physical and Technological Protection

Eco-Eff™ is essential in the formulation and protection of animal feed, providing complementary physical properties that enhance protection against rancidity. This compound, when incorporated as micronized particles (average size 7-15 µm), acts through various synergistic mechanisms:



Anti-caking Agent and Flowability Improvement

Eco-Eff™ improves the flowability of feed, preventing the formation of clumps that can retain moisture and accelerate fat degradation. This property is based on the colloidal nature of the mineral particles that make up **Eco-Eff™**, which act as microspheres that reduce the contact surface between feed particles, decreasing cohesive and adhesive forces.

Studies conducted by INTABIOTECH demonstrate an improvement in the Hausner flowability index (ratio between compacted density and apparent density) of up to 18% when **Eco-Eff™** is incorporated at concentrations of 0.3-0.5% of the total feed weight. This technological improvement facilitates transport, storage, and automated dosing processes.

Moisture Scavenger and Water Activity Control

Eco-Eff™ reduces water activity (aw) in the feed matrix, l**imiting the hydrolytic reactions that promote rancidity.** This effect is due to the high specific surface area of the product$_2$, whose formulation is in micronized form (200-300 m^2/g), which allows the adsorption of water molecules through hydrogen bonds with the silanol groups (Si-OH) present on its surface, as one of its components is this mineral.

The capacity to reduce aw is particularly relevant in the critical range of 0.3-0.6, where numerous degradative reactions reach their maximum speed. Comparative tests show reductions of up to 0.08 aw units after the incorporation of **Eco-Eff™** at 0.5%, sufficient to **extend the shelf life of the feed under high relative humidity conditions.**

3.- Eco-Eff™: Physical Protection Against Oxidation

The dispersion of the individual components of **Eco-Eff™** in the matrix acts as a **barrier that hinders the propagation of free radicals** responsible for **lipid peroxidation**. The silica particles present in **Eco-Eff™** form a microscopic protective layer around fat droplets, reducing contact with oxygen and metallic catalysts. This physical "microencapsulation" constitutes a complementary mechanism to the chemical stabilization provided by the presence of the other mineral components of **Eco-Eff™ when added to feed.**

Studies conducted by the R&D&i department of INTABIOTECH have quantified this synergistic action of the components of **Eco-Eff™** by calculating the synergy index (SI), defined as the ratio between the observed effect of the combination and the sum of individual effects:

$$IS = \frac{E_{NaHCO_3+SiO_2}}{E_{NaHCO_3} + E_{SiO_2}}$$

The results show SI values between 1.4-1.8 for critical parameters such as the peroxide value and malondialdehyde content after 90 days of storage, confirming the mutual potentiation of protective effects.

Practical Benefits of the Synergistic Components of Eco-Eff™

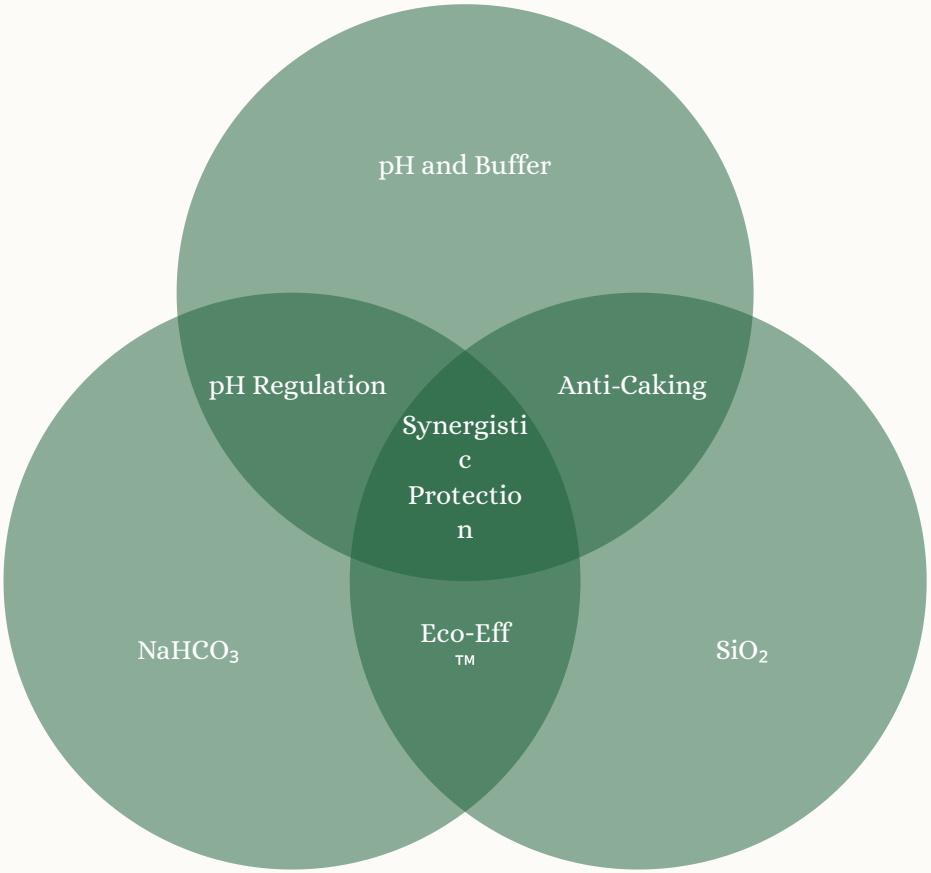
This synergy **prolongs the shelf life of feed, reduces the formation of rancid compounds (peroxides, aldehydes), and preserves the organoleptic and nutritional quality of the food, providing benefits far beyond mere protection against insects, molds, fungi, and certain types of bacteria.** In quantitative terms, comparative tests under accelerated conditions (38°C, 85% RH) demonstrate:

Parameter	Control	Individual Components	Eco-Eff™
Peroxide Value (meq O_2/kg fat)	18.5 ± 2.3	10.2 ± 1.8	5.8 ± 0.9
TBA (mg MDA/kg feed)	4.7 ± 0.6	2.9 ± 0.5	1.3 ± 0.3
Vitamin E Retention (%)	62.3 ± 4.1	78.6 ± 3.5	91.2 ± 2.7
Acidity Index (mg KOH/g)	12.3 ± 1.4	8.1 ± 0.9	4.5 ± 0.7

These results confirm that **the protection offered by Eco-Eff™** significantly surpasses both the absence of protection (control) and the use of individual components, validating the concept of functional synergy that underlies this biotechnological formulation.

Synergy of the Eco-Eff™ Blend: Enhancement of Protective Effects

The strategic combination of $NaHCO_3$ and SiO_2 in the Eco-Eff™ formulation generates a complementary effect that surpasses the sum of the individual actions of each component. This synergy is evident both at the level of protection mechanisms and in the practical results observed in stability tests.



Documented Synergistic Mechanisms

Chemical Stabilization

Eco-Eff™ acts as a chemical stabilizer, neutralizing free fatty acids and reducing the risk of pH-catalyzed oxidation.

Physical Protection

Eco-Eff™ provides a physical barrier that reduces contact between fats, oxygen, and metallic catalysts.

Technological Optimization

Eco-Eff™ improves the rheological properties of the feed, facilitating its handling and homogeneous distribution of active components.

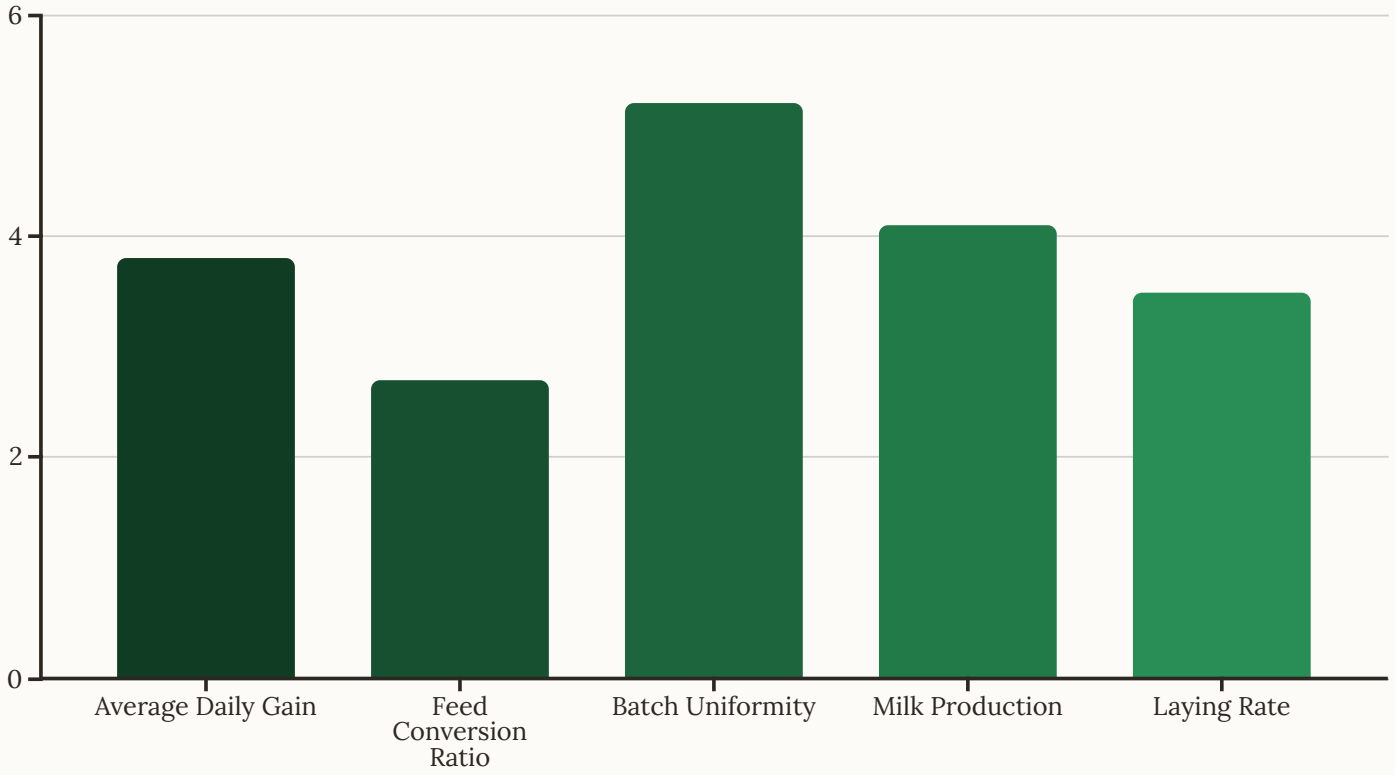
Additional Benefits in Animal Nutrition

The Eco-Eff™ formulation has been primarily designed as an integral protection system against common problems affecting food products and raw materials intended for animal feed and nutrition, also resulting in a potentiated effect against oxidative rancidity in feed.

However, field studies and zootechnical trials have r**evealed a series of additional benefits** that expand its value in the context of intensive animal production.

Impact on Productive Parameters

Trials conducted in various production species (swine, poultry, ruminants) have documented **beneficial effects that transcend mere feed preservation,** positively impacting zootechnical indicators of economic relevance:



These positive effects are attributed to various complementary mechanisms:

- **Preservation of the nutritional value of the feed throughout its period of use.**
- **Improvement of digestive conditions, especially in ruminants,** due to the buffering effect of the **Eco-Eff™** formula.
- **Reduction of the load of toxic compounds** derived from lipid oxidation (4-hydroxynonenal, malondialdehyde), which can **affect intestinal integrity.**
- **Increased palatability and acceptance of the feed**, promoting more regular and sustained consumption.

Practical Applications and Technical-Economic Benefits

In addition to its antioxidant and preservative action, the application of **Eco-Eff™** in feed offers complementary advantages that help optimize various aspects of the compound feed production and utilization chain:

Optimization of the Production Process

The incorporation of **Eco-Eff™** into feed formulations leads to significant improvements in various technological aspects of the manufacturing process:

- **Improved fluidity and reduced bridge formation:** The anti-caking effect reduces adherence between particles, facilitating product flow in hoppers, conveyors, and automatic dosing systems.
- **Increased granulation efficiency:** The presence of **Eco-Eff™** improves starch gelatinization during the granulation process, increasing pellet durability and reducing fines formation.
- **Reduced energy consumption:** Comparative studies indicate an **average reduction of 3.8%** in the electrical consumption of the granulator when **Eco-Eff™** is incorporated into the formula, due to improved rheological properties of the mixture.

Impact on Stability during Storage

Eco-Eff™ demonstrates its maximum effectiveness under challenging storage conditions, especially in:

Hot and humid climates where the rate of oxidative reactions accelerates exponentially.

Extended storage exceeding 90 days, common in farms far from production centers.

Feeds with high polyunsaturated fat content (>4%), particularly susceptible to rancidity.

Food Safety and Final Quality

By reducing lipid degradation, **Eco-Eff™** significantly contributes to the improvement of food safety in the animal production chain:

Reduction of Toxic Compounds

Documented decrease of 65-78% in the concentration of malondialdehyde (MDA) and other toxic aldehydes derived from lipid oxidation, reducing the risk of negative effects on intestinal health and productive performance.

Preservation of Micronutrients

Maintenance of optimal levels of fat-soluble vitamins and carotenoids, which in the absence of protection can degrade by up to 40% during prolonged storage.

Product Homogeneity

Greater uniformity in the distribution of micro-ingredients (vitamins, trace elements, additives) thanks to the improved mixing properties provided by **Eco-Eff™**, ensuring that each ration contains the designed nutritional profile.

Sustainability and Environmental Impact Reduction

By extending the shelf life of feed, **Eco-Eff™** contributes to the **sustainability of the production chain** through:

- **Reduction of losses and waste** in the supply chain, estimated at 4.2% compared to formulations without antioxidant protection.
- **Decrease in the carbon footprint** associated with the replacement of degraded feed during storage.
- **Optimization of raw material usage,** especially high-value nutritional and economic oils and fats.

The cost-benefit analysis performed by INTABIOTECH demonstrates a return on investment (ROI) of 4.8:1 for the incorporation of Eco-Eff™ in standard formulations, considering both the direct cost of the formula and the benefits derived from improved preservation and animal performance.

Technical Conclusions

The **Eco-Eff™** formulation represents an effective, safe, and sustainable strategy to combat the rancidity of fats and oils in feed intended for animal nutrition. Its synergistic effects not only improve the stability and quality of the feed but also provide additional benefits in the management and productive efficiency of livestock farms.

Scientific Evidence Supporting its Efficacy

The extensive research program developed to validate the Eco-Eff™ formulation has generated a robust body of scientific evidence supporting its efficacy:

In vitro Studies

Evaluations in model systems have demonstrated a **68-74% reduction in peroxide formation and a 57-65% reduction in secondary oxidation compounds** after 30 days under accelerated conditions (45°C, intermittent UV light).

Stability Trials

Studies under real commercial storage conditions document an **average shelf life extension of 85% in high-fat feeds (>6%) and 115% in standard feeds (3-4% fat).**

Zootechnical Tests

Trials in various productive species confirm positive effects on parameters such as **average daily gain (+3.8%), feed conversion ratio (-2.7%), and batch homogeneity (+5.2%).**

Differentiating Aspects Compared to Conventional Alternatives

The Eco-Eff™ formulation offers significant advantages over conventional antioxidant strategies:

Parameter	Conventional Antioxidants	Eco-Eff™ System
Mechanism of action	Mainly chemical (radical scavenging)	Combined (chemical + physical)
Efficacy in extreme conditions	Limited (accelerated degradation)	High (self-stabilizing system)
Positive secondary effects	Not documented	Multiple (fluidity, palatability, digestibility)
Toxicological safety	Variable (synthetic components)	High (GRAS ingredients)
Organoleptic impact	Potential (residual aromas)	Neutral or positive
Cost-effectiveness	Variable depending on dose	Favorable (ROI 3.8:1)

The results obtained in the different trials demonstrate that Eco-Eff™ constitutes a comprehensive solution to the problem of rancidity in feed, simultaneously addressing the chemical, physical, and technological aspects involved in this degradative phenomenon.

In a global context characterized by the pursuit of productive efficiency, food safety, and sustainability, Eco-Eff™ represents a technological contribution aligned with the current and future demands of the animal nutrition sector, demonstrating that innovation can arise from the strategic combination of well-known ingredients when applied with a solid scientific foundation and oriented towards specific market needs.

Note for industry professionals

INTABIOTECH offers personalized technical advice for the integration of Eco-Eff™ into specific formulations, considering the particularities of each type of feed, animal species, and storage conditions. For more information, contact our technical department at **soporte.tecnico@intabiotech.es** or visit our website **www.intabiotech.es/eco-eff**.

Future Perspectives and Continuous Innovation

Research Lines in Development

INTABIOTECH's R&D+i department continues to work on the refinement and expansion of **Eco-Eff™** technology, far beyond the comprehensive protection the product already offers against insects, mites, molds, fungi, mycotoxins, etc., focusing on:

- Optimization of specific formulation ratios for different feed matrices and environmental conditions.
- Development of variants enriched with chelated trace elements to enhance endogenous antioxidant effects.
- Specific formulations for aquaculture feeds, a sector with particular stability challenges.

Eco-Eff™ thus positions itself as an innovative tool that responds to the growing demand from the sector for effective, natural, and respectful solutions for animal health and food safety. This formulation represents a significant advance in feed preservation technology, combining well-established scientific principles in a novel and synergistic application.

Integration into Global Animal Production Strategies

The future of Eco-Eff™ transcends its application as a mere technological additive, to integrate into global sustainable animal production strategies:

1 — 2023-2024

Consolidation as a standard in high-stability formulations for export markets and tropical zones.

2 — 2024-2025

Development of specific applications for precision nutrition and high-stability medicated feeds.

3 — 2025-2026

Integration into circular production systems and formulations based on valorized by-products with high oxidative risk.

Eco-Eff™

Far Beyond Insects, Mites, Moulds and Certain Bacteria

Intabiotech SL

Inspired by Nature-Driven by Science

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