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Towards a Circular Aquaculture: Assessing Sustainability and Consumer Acceptance of Insect-Based Feed for Trout Farming

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Abstract: Addressing the urgent need for sustainable aquaculture amidst escalating protein demand and environmental burdens from conventional practices, the newRIFF project investigates a novel circular economy solution: the valorization of agricultural organic waste into alternative protein sources for trout feed. This research critically evaluates the technical, economic, environmental (via LCA), and social (via S-LCA) sustainability of replacing traditional fishmeal and oil with insect meal derived from Hermetia illucens and Tenebrio Molitor reared on locally available by-products. Beyond the comprehensive multi-disciplinary assessment of production performance and product safety, a distinctive focus of newRIFF lies in analyzing consumer perception and acceptance. Through willingness-to-pay (WTP) studies, we explore the influence of innovative packaging, clear labelling, nutritional claims, and environmental impact information on consumer purchasing decisions. This holistic approach generates crucial insights into the market potential and policy implications for insect-based feeds, offering a scalable pathway to enhance resource efficiency, mitigate environmental degradation, and foster a more resilient and circular global food system, directly aligning with themes on innovative environmental solutions.

Keywords: *Sustainable Aquaculture; Insect-Based Feed; Consumer Acceptance; Life Cycle Assessment.*

1. Introduction

Global protein demand and the environmental footprint of conventional aquaculture necessitate innovative feeding strategies. Current fish farming, reliant on fishmeal and fish oil, contributes to overfishing and deforestation, while agriculture generates significant organic waste. The newRIFF project addresses these issues by proposing a circular economy solution: valorizing agricultural organic waste into alternative protein sources for trout feed. This multidisciplinary research aims to comprehensively evaluate the technical, economic, environmental, and social sustainability of replacing conventional protein sources with insect meal derived from Hermetia illucens and Tenebrio Molitor. A pivotal component of this assessment is understanding consumer perception and acceptance, crucial for market integration of such innovative products.

2. Methodology

The newRIFF project adopts a comprehensive, integrated approach across several interlinked work packages to achieve its objectives:

2.1 Project Scope and Experimental Design

The project encompasses the entire value chain from waste valorization to final product acceptance. This includes:

- Insect Rearing Optimization: Identifying optimal growth conditions and substrate mixes for Hermetia illucens and Tenebrio Molitor using various organic waste matrices (e.g., rice by-products, agricultural residues) to produce high-quality insect meal.
- Aquaculture Feeding Trials: Conducting controlled trials where trout are fed diets with varying inclusion levels of insect meal, assessing growth performance, feed conversion ratios, and fish health.
- Product Safety and Quality Analysis: Rigorous laboratory testing of insect meal and trout products for food safety parameters (e.g., contaminants, heavy metals, allergens) and evaluation of nutritional and sensorial characteristics.

2.2 Sustainability Assessment

A robust sustainability assessment is integral to newRIFF:

1. Environmental Impact (LCA): Life Cycle Assessment (LCA) is employed to quantify the environmental footprint of the insect-based feed production and trout farming systems, comparing them against conventional practices. Key indicators include greenhouse gas emissions, eutrophication potential, and land use.
2. Economic Performance (LCC): Life Cycle Costing (LCC) evaluates the economic viability and cost-effectiveness of the proposed circular value chain.
3. Social Impact (S-LCA): Social LCA assesses the social implications across the lifecycle, considering aspects like

employment, working conditions, and local community impacts.

2.3 Consumer Acceptance Survey

Central to understanding market potential, a dedicated Consumer Acceptance Survey is currently being designed and implemented, targeting Italian fish consumers aged 18+. This comprehensive Questionnaire Design explores various dimensions, commencing with Socio-demographics (gender, age, education, residence, and household income). It then delves into Food Consumption Habits, assessing general food preferences (e.g., meat, pasta, fish, dairy) alongside specific fish consumption frequency and preferred purchasing channels (supermarkets, local markets, fishmongers, direct producers, online platforms). A Food Neophobia Scale (FNS), a validated psychometric instrument (Likert 1-7), is integrated to gauge respondents' openness to new foods and novel culinary experiences. The survey further evaluates Influencing Factors for Fish Purchase, examining the importance of aspects such as sensory qualities, production origin, species, quality-price ratio, fish health and welfare, sustainability certifications, nutritional value, and specific farming methods (Likert 1-7). Preference for Fish Types (wild, conventionally farmed, organic farmed) is also assessed. A key focus is on Initial Acceptance of Insect-Fed Fish, with options exploring acceptance contingent on factors like guaranteed salubrity, price convenience, or lower environmental impact, contrasting with outright rejection or naturalistic acceptance. This leads into Willingness-to-Pay (WTP) for insect-fed fish products, measured both before and potentially after providing specific informative stimuli on sustainability benefits, with open-ended sections to capture qualitative motivations. Further sections investigate Packaging and Information Preferences, including the impact of specific logos, desired information (e.g., improved nutritional values like higher protein/lower fat; environmental benefits like reduced CO2/eutrophication/GHG emissions), and preferred in-store placement strategies (e.g., with other fish, ready-to-cook section, dedicated area). Finally, Communication Channels preferred for product introduction by supermarkets (e.g., flyers, social media campaigns, in-store information stands with tastings) are explored. Data Collection & Analysis will be conducted online, employing a range of statistical methods, including descriptive statistics, inferential tests, and regression analysis, to identify distinct consumer segments, key drivers of acceptance, and determinants of WTP.

3. Anticipated Results

While data collection for the consumer survey is ongoing, the newRIFF project anticipates generating several key insights:

a. Feasibility and Sustainability Metrics: Quantifiable data on the technical viability and environmental benefits (e.g., reduced carbon footprint, less reliance on marine resources) of insect-based trout feed compared to conventional feed.
b. Consumer Acceptance Drivers: Identification of specific factors (e.g., perceived health benefits, environmental awareness, price sensitivity, information transparency, neophobia) that significantly influence consumer willingness to purchase and pay for insect-fed fish.
c. Market Segmentation: Understanding different consumer segments based on their attitudes and preferences towards novel aquaculture products, enabling targeted marketing strategies.
d. Optimal Communication Strategies: Insights into the most effective ways to communicate the benefits of insect-fed fish to consumers, including preferred labelling, packaging information, and retail placement.

4. Discussion & Conclusion

The newRIFF project's integrated approach allows for a comprehensive understanding of insect-based feed's potential in sustainable aquaculture. By linking technical performance and environmental benefits with consumer acceptance, the project addresses critical barriers to the adoption of novel food technologies. The anticipated findings will illuminate how positive environmental and nutritional attributes translate into consumer willingness-to-pay, a key factor for market viability. Furthermore, understanding the nuances of consumer perception will inform policy development, helping to create an enabling regulatory environment that supports sustainable innovation. The project contributes to the broader discourse on circular economy principles in food systems, demonstrating a tangible pathway to transform waste into valuable resources while meeting protein demands responsibly. NewRIFF represents a significant step towards a more circular and sustainable aquaculture. By scientifically validating the use of insect-based feed for trout and deeply analyzing consumer acceptance, the project offers actionable insights for industry, policymakers, and researchers. The outcomes will underscore the environmental merits of waste valorization through insect bioconversion and provide crucial guidance on fostering consumer trust and market demand for innovative, eco-friendly food products, ultimately contributing to a more resilient and environmentally conscious global food system.

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