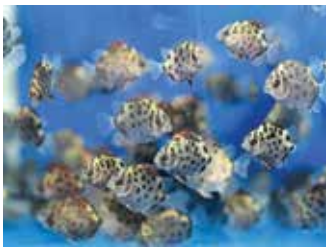
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Editor,
Fish Tech Digest



From the desk of Dean…

Dear esteemed Authors and Readers

It gives us immense pleasure to present this special issue of Fish Tech Digest, dedicated to the fisheries wealth, aquatic ecosystems, and coastal communities of Kanniyakumari District. Located at the southernmost tip of India, Kanniyakumari is blessed with diverse marine and inland aquatic resources that support livelihoods, biodiversity, and economic development.

This issue features insightful articles on the Ramsar wetlands of Vembannur and Suchindram–Theroor, the rich seaweed resources of Cape Comorin, and the vital role of Thengaipattinam Fishing Harbour in the marine fish export chain and coastal economy. Together, these contributions highlight the district's unique ecological and fisheries significance.

We are particularly pleased to showcase articles contributed by the faculty and students of St. Devasahayam Institute of Fisheries Science and Technology (DIFST), reflecting the institution's commitment to fisheries education, research, innovation, and sustainable development.

As the Blue Economy gains momentum, Kanniyakumari stands as a model where natural resources, traditional knowledge, scientific research, and community participation converge to create opportunities for sustainable growth. We hope this issue inspires readers to appreciate, conserve, and responsibly utilize these valuable aquatic resources for future generations.

I extend my heartiest congratulations to all the authors for their invaluable contributions. Your insights significantly enrich our collective academic knowledge and will undoubtedly inspire future research pathways. I trust that this issue of Fish Tech Digest will serve as a highly inspiring and practical resource for you all, as we continue to uphold our institutional benchmark for excellence in fisheries education, research, and community extension.

Best regards,
Prof. S. Felix
Chief Editor
Fish Tech Digest

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The Role of Binders in Aquafeed: Enhancing Nutritional Stability and Promoting Sustainable Aquaculture

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Abstract

Aquaculture is threatened by serious economic and environmental challenges, mainly by feed expense accounting for 50-70% of production costs. Optimizing feed efficiency is thus a priority, which relies heavily on pellet quality. Destabilized pellets quickly break down, resulting in severe leaching of nutrients and high feed conversion ratios (FCRs), degrading water quality and affecting aquatic health. Binders are necessary additives that improve pellet hardness and water stability, retaining nutrients. Natural binders such as starch (via gelatinization) and aquatic polysaccharides, and also synthetic ones, are of great importance. Maximal binder selection and levels are important for profitable and sustainable aquaculture.

Introduction

A large amount of the world's seafood supply comes from aquaculture, a fast-growing industry that is essential to global food security. However, effective resource management feed being the most significant expense is crucial to the financial sustainability and environmental sustainability of aquaculture operations. In shrimp and fish farming, feed costs can make up 50–70% of total production costs, according to the FAO (2019), highlighting the urgent need for feed utilization optimization measures. Because of this, optimizing feed efficiency is crucial for both financial sustainability and profitability. Feed pellet quality is a major influencing factor in determining feed efficiency as well as productivity on the farm. Good-quality pellets have sufficient durability, hardness, and water stability to ensure that they maintain their form during handling, storage, and transportation in water. Poor pellet stability will result in the breakdown of pellets very quickly when submerged, causing extensive nutrient leaching particularly of proteins and lipids prior to ingestion by aquatic animals. This will not only minimize nutritional value offered to stock but also add organic waste to the rearing system, causing water quality to degrade and, even, detrimental effects on fish health. Higher feed conversion ratios (FCRs) are a direct consequence of greater nutrient loss from unstable pellets, which also directly affects water quality and nutrient availability. The farming enterprise's profitability and environmental sustainability are weakened by this inefficiency, which also raises operating costs. To mitigate these challenges and enhance the performance of aquaculture feeds, the inclusion of binders has become a standard practice. Binders are cohesive substances that

bind feed ingredients together and increase the physical strength and water resistance of pellets. The choice and rate of binder inclusion are important, as they have a direct effect on pellet integrity, nutrient stability, and overall feed performance in aquaculture operations. As a result, understanding and maximizing pellet quality through efficient binder application is essential to aquaculture's sustainability and profitability and goes than simple technical considerations.

Binders

Binders are necessary chemicals used in aquafeed processing to improve the feed pellets' overall performance and physical properties. These compounds, which might be manufactured or natural, act as adhesion agents to form films, coatings, or bridges between feed particles. During production, storage, and especially when submerged in water, these polymers form a cohesive network that prevents the contents from dissolving. Since crustaceans, such as shrimp and crabs, are slow feeders and can take up to two hours to ingest pellets, this stability is crucial for aquatic species (Paolucci *et al.*, 2012). Pellets that lack sufficient water stability disintegrate and lose nutrients prior to consumption, resulting in poor development, feed waste, and water pollution. During this feeding stage, effective binders ensure pellets stay intact and retain nutrients, promoting the best possible health and productivity in aquaculture systems. Because they are biodegradable and harmless to the environment, natural binders such sweet potato starch, guar gum, agar, sodium alginate, and carrageenan are used in aquaculture. Because they work reliably, synthetic binders like carboxymethyl cellulose (CMC) are also used. The selection of binders is determined by their physical attributes, cost, accessibility, and the specific requirements of the species being bred. According to Paolucci *et al*. (2012), binders generally play a significant role in defining the sustainability and effectiveness of modern aquafeeds.

Functions of Binders in Aquafeed

Binders increase the quality and stability of pellet feed. They act as binding agents in feed ingredients, minimizing the disintegration of pellet feed in water. This helps to maintain a stable and required diet for aquatic organisms. Binders are chosen based on properties such as palatability, water stability, and dustiness. In the aquatic industry, starches like pea starch have done better than alternatives such as gum and wheat gluten. binders reduce production costs, minimize the use of artificial additives, and maintain the nutritional value of the feed. In addition, some binders can enhance the appearance of the feed, which will be more attractive to aquatic life (Paolucci *et al.*, 2012).

Types of Binders Used in Aquafeed

Various binders have been tested and used in aquaculture to enhance feed durability and effectiveness. Most come from marine sources, cellulose, or natural plant-based materials, as shown in (Table 1).

Sweet Potato Starch & Guar Gum: These natural ingredients help lower waste and nutrient loss, improve faecal quality, and promote nitrogen (N) and phosphorus (P) retention, supporting sustainable aquaculture (Zhou *et al.*, 2025). Guar gum, in particular, increase water stability by helping pellets retain water.

Marine Polysaccharides (Agar, Zein, Alginates, Carrageenan): Marine-based products are valued for creating gels and networks that trap nutrients. For example, agar forms strong gels with high pellet stability but absorbs little water. Sodium alginate and κ-carrageenan are also commonly used because they make the pellets tough and water-resistant. This means the feed stays together in water for a long time, making it suitable for feeding fish over extended periods (Paolucci *et al.*, 2015).

Cellulose Derivatives (Carboxymethyl Cellulose - CMC): CMC is a synthetic but biodegradable binder, helps reduce nutrient loss and improves water stability. It contributes to making durable pellets that species like shrimp and prawns can consume over longer periods without disintegrating in water (Yusoff *et al.*, 2021).

Natural Organic Additives: Seaweed, especially G. gigas, is mostly used as a natural binder in shrimp feed due to its high bioactivity and ability to strengthen pellets.

Other Common Binders: Materials like maize starch, gelatin, bread flour, and palm starch are also popular for making stable, water-resistant pellets because they are low cost and easily available.

Commonly used binders

Commonly used binders in tilapia feed include wheat gluten (up to 4% by weight), wheat flour (up to 15%), polymethylolcarbamide (Aquastab, 0.02-0.08%), calcium lignosulfonate (Lignobond 2X-US), ethylene/vinyl acetate polymer (Aquabind, 1.5-3.0%), and PEGABIND BENTOLI (0.1-0.15%).

Natural binders

Natural binders, derived from renewable sources, act as eco-friendly adhesives with both industrial and nutritional importance. They include cellulose and hemicellulose, which provide structural support in plant materials. Starch and dextrins, sourced from potatoes, corn, and rice, offer strong adhesive properties due to their ability to form hydrogen bonds. Pectin, found in potato pulp, aids in swelling and bonding, while glucans and exopolysaccharides produced by fungi and bacteria enhance adhesion and durability. Other effective natural binders such as glucomannans and chitosan, obtained from tubers and crustacean shells, provide strong bonding strength. Proteins like albumins, caseins, soybean, and wheat proteins improve flexibility and durability in adhesives. Lignin and tannins, polyphenolic compounds found in wood and plants, further increase resistance and longevity. From a nutritional perspective, starch and proteins serve as rich sources of energy, while pectin and cellulose contribute dietary fiber to support digestion. Additionally, chitosan and glucans have antimicrobial properties, offering potential health benefits. Although mainly used in industrial applications, some natural binders also contribute to the nutritional value of food products, blending functional adhesion with health benefits (Müller *et al.*,2007).

Role of binders in Starch gelatinization

Different binders have their specific properties that make them suitable for different farming conditions and target pests. One important process is starch gelatinization, which occurs when heat and water cause starch granules to absorb moisture, swell, and break down their crystalline structure. Gelatinization transforms

starch into a natural binder that holds the feed ingredients together, increasing strength and reducing disintegration in water. The extent of starch gelatinization depends on factors such as processing temperature and moisture levels. Proper gelatinization ensures the pellet's integrity over time, prevents nutrient loss, and makes the feed suitable for slow-feeding aquatic organisms. Overall, the right level of gelatinization is crucial to producing high-quality, water-stable pellet feed and reducing waste.

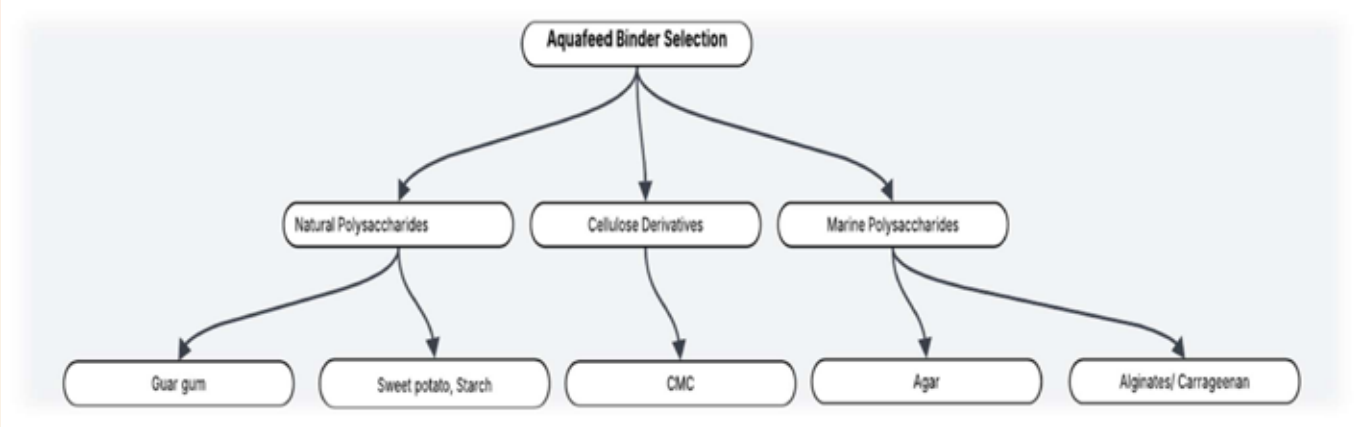


Table 1. Types of Binders Used in Aquafeed

Benefits of using Binders in Aquafeed

- Adding appropriate binders to aquafeed has many benefits that go beyond simple pellet stability. These benefits extend directly to both the production process and the ecological footprint of aquaculture facilities:
- The binders contribute to greatly enhancing the physical durability of feed pellets, making them strong in water, as required for species with more complex or longer feeding patterns. Stable pellets allow fish or crustaceans eat their full amount without waste. (Solis, 1992).
- Agar or CMC binders reduce the leaching of essential nutrients such as proteins, lipids, N, and P upon water immersion. This maintains the nutritional content of the feed and prevents water pollution through soluble nutrients (Yusoff *et al.*, 2021).
- Pellet stability through binders equates to reduced organic waste and runoff of nutrients, resulting in improved water quality and reduced chemical oxygen demand (COD). Good water conditions increase the growth of healthy, fast-growing aquatic life and minimize farming expenses related to water management (Won *et al.*, 2018).
- Research shows that adding binders like guar gum and xanthan gum helps sea cucumbers and prawns grow better and gain more weight. These binders also improve the feed's physical qualities, making it easier for animals to eat and use nutrients (Ayuhafizah *et al.*, 2024).
- By reducing waste and nutrients leaking into the water, binders help make aquaculture more sustainable. They support eco-friendly practices that balance good production

with protecting the environment (Zhou *et al.*, 2025).

Inclusion level of specific binders

The inclusion levels of binders in aquafeed vary according to scientific research. Carboxymethyl Cellulose (CMC) is typically added at 1–3% of the diet (Lim & Cuzon, 1994). Gum Acacia is used at lower concentrations, usually 1–2%, to improve pellet water stability and integrity (Shiau & Liang, 1995). Sodium/Potassium Bentonite, which helps retain moisture, also falls within the 1–3% range. Polysaccharide-based binders like Agar Agar and Guar Gum are generally included at 1–2%, while protein-based binders such as casein and gelatin are used at 2–5%, enhancing the physical quality and nutritional value of the pellets (Lim & Cuzon, 1994). Starch Powder is added at higher levels, between 5% and 20%, because it serves as both an energy source and a binder. Wheat Gluten Meal and Maize Gluten Meal are used at 2–5% to balance binding and protein content (Shiau & Liang, 1995; Kaushik & Seiliez, 2010). These ranges serve as general guidelines and can be optimized based on the target species, processing conditions, and specific formulation needs.

Considerations and Challenges

Despite all their advantages, binders play an important role in aquafeed, but they can also bring about some issues that need to be managed. Balancing binder inclusion to an optimum is needed: Excessive inclusion could threaten pellet stability, whereas excessive addition makes pellets too hard to ingest by aquatic organisms. Optimal binder concentration depends on the type of binder, fish or shrimp species, and farm condition (Yusoff *et al.*, 2021). Cost is an important factor, particularly when employing costly natural binders such as agar. Others, for example, seaweed or starches, are less costly but may vary in quality or availability seasonally or geographically. Moreover, certain binders could have unforeseen effects on digestion or nutrient absorption if employed excessively. A further challenge is in the processing methods. For instance, steam processing can have an effect on pellet stability, and the methods need to be optimized for every binder for achieving preferred physical properties. Additional research on mixing more than one binder is needed to optimize a synergistic effect so as to enhance the performance of pellets at lower cost (Solis, 1992).

Current Advances and Future Perspectives

Current research is extending the boundaries of conventional binder uses, emphasizing naturally sourced, environmentally friendly, and inexpensive materials. Sea-derived polysaccharides like agar and sodium alginate are gaining popularity because they possess high-quality gel-forming properties and biocompatibility, making them promising candidates for creating stable, water-resistant bio composites (Paolucci *et al.*, 2015). Innovative strategies involve synergizing bio-based binders with other functional ingredients to enhance not just pellet stability but also gut health and immune function in cultured animals. There is an increasing focus on creating biodegradable, renewable binders from algae, seaweed, and other environmentally sustainable sources, as part of world efforts towards environmentally sound aquaculture. Development in processing technologies, including extrusion and steam conditioning, further increases the efficiency

of binders so that producers can make specific pellet properties to suit various aquatic species and environmental conditions. Future studies will continue to seek the genetic and biochemical properties of natural binders that can further enhance their functionality and cost-effectiveness.

Conclusion

Binders play a pivotal position in creating aquafeeds of high quality with water stability. They are not mere inert ingredients but active components that play roles in pellet strength, nutrient stability, water quality, and finally, the sustainability of aquaculture operations. As the demand for sustainable seafood increases, the aquaculture industry is moving towards using natural and biodegradable binders. These binders promote healthy growth in aquatic animals while minimizing environmental impact. Thanks to ongoing technological progress and a focus on renewable resources, future binders in aquafeed are expected to be more efficient, eco-friendly, and cost-effective, supporting the continued growth of global aquaculture.

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