

## The sustainability conundrum of fishmeal substitution by plant ingredients in shrimp feeds

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Aquaculture is central in meeting expanding global demands for shrimp consumption. Consequently, increasing feed production is the main responsible for overall environmental impact. Significant amounts of fishmeal are included in shrimp diets, causing dependency on finite marine resources. Driven by economic incentives, terrestrial plant ingredients are widely viewed as sustainable alternatives.

We modelled the incremental fishmeal substitution by plant ingredients in shrimp feed and assessed effects on marine and terrestrial resources, such as fish, land, freshwater, nitrogen and phosphorus. We find that complete substitution of 20-30% fishmeal totals led to increasing demand for freshwater (+63%), land (+81%) and phosphorus (+83%), while other substitution rates lead to proportionally lower impacts. These findings suggest added pressures on essential agricultural resources, socio-economic and the environment, as a trade-off to pressures on finite marine resources. The importance of utilizing by-products and novel ingredients such as microbial biomass, algae and insect meals in mitigating the use of marine and terrestrial resources is discussed.

Keywords: Aquaculture; Shrimp feed; Aquafeed; Fishmeal; Plant ingredients; Marine resources; Terrestrial resources; Feed transition; Food system; Food security