How feed-derived nutrients reach plants

Grant Kinkead
Independent Researcher, Melbourne, VIC, Australia
grant@kinkead.au

***Abstract*—Aquaponics connects fish feeding with plant nutrition, but the presence of nutrients in a fish system does not, by itself, explain how those nutrients reach plants. This paper synthesises evidence for the principal causal pathway. Fish metabolism releases ammonia into the water, principally through the gills. Fish-system effluent then carries nutrients towards the plant unit, while biological filtration converts ammonia to nitrate. Together, these processes explain an important route by which a feed-derived nutrient can become part of the water supplied to plants. Studies of lettuce grown with aquaculture water add evidence that nutrient composition matters to plant performance: measured nutrient concentrations and responses to supplementation show that fish-derived water need not meet every plant requirement. These studies do not, however, trace individual nutrients continuously from feed through transformation to plant uptake. The strongest supported account is therefore a linked explanation of fish nitrogen release, waterborne transport and biological conversion, rather than a complete accounting of every feed nutrient. Distinguishing those established steps from unmeasured transfers makes the explanation useful without treating plant response as proof of a particular nutrient pathway.**

I. Introduction

In aquaponics, the route from fish feed to plant nutrition passes through the water shared by the fish and plant components. A review of aquaponic systems identifies fish-system effluent as a nutrient input to the plant unit and biological filtration as the process that converts ammonia to nitrate [1]. These are distinct steps: water conveys material between components, whereas filtration changes the chemical form of part of that material. Explaining both steps matters because the fact that feed enters a fish system does not mean its nutrients reach plants unchanged. The central question is which parts of this pathway the available evidence establishes and where a fuller account of nutrient fate remains necessary.

The fish-side origin of dissolved nitrogen can be understood from nutritional and metabolic evidence. Dietary arginine participates in fish metabolism, and a fish-nutrition review describes ammonia excretion through the gills [2]. This connects a dietary constituent with a release route into the surrounding water, but it is not a measurement of that constituent arriving in plant tissue. The distinction prevents an overly direct account in which nutrients are assumed simply to pass from feed to roots. Once nitrogen has left the fish, its subsequent movement and transformation must be considered separately from the metabolic processes that produced the ammonia.

A broader review of fish nitrogen metabolism likewise describes the production of ammonia through amino-acid deamination and its excretion principally through the gills [3]. Taken with the aquaponic account of effluent and filtration [1], this supports a causal explanation extending from feed-associated nitrogen metabolism towards the plant unit. It does not establish the fate of every nutrient in feed or prove plant uptake from any single metabolic observation. This paper first distinguishes the evidence for fish release from the evidence for system transport, then examines what studies of plant responses add to that explanation and where the resulting account must remain qualified.

II. Background and Scope

Plant-response studies offer a different perspective from studies of fish metabolism. In a fish and lettuce system, researchers measured water nutrients and examined plant responses when iron alone, or iron together with potassium, was added [4]. Those comparisons show why delivery of fish-system water should not be equated with adequate provision of every plant nutrient: the measured nutrient environment and the plant response both matter. Supplementation also complicates causal attribution. A response in a supplemented system demonstrates that nutrient availability can constrain plants under the studied conditions, but it does not identify the complete route by which the unsupplemented, feed-derived fraction reached them.

Trials using solutions containing recirculating aquaculture water similarly relate measured nutrient concentrations to lettuce responses [5]. They are valuable evidence about the plant-facing solution because they examine the medium in which plants grow rather than inferring its adequacy solely from feed input. Yet comparison of solutions and plant growth cannot reconstruct every prior transformation within the fish system. In particular, a plant response to aquaculture water does not distinguish nutrient release by fish from subsequent conversion and transport. The trials therefore complement, rather than replace, evidence describing the intervening pathway between fish metabolism and the water supplied to plants.

The scope of this synthesis is the supported causal chain, not a complete inventory of feed constituents. Fish-metabolism reviews establish a route by which dietary nitrogen can become ammonia in the water [2], [3]; an aquaponics review links fish-system effluent and biological filtration to the plant unit [1]. Studies of water composition and lettuce response then test aspects of the plant-facing environment [4], [5]. Each approach observes a different portion of the process. Their combined value lies in connecting these portions carefully, while recognising that none of the plant-response comparisons

alone tracks a particular nutrient continuously from feed into a plant.

III. Core Concepts and Mechanisms

The clearest supported nitrogen pathway begins with fish metabolism, not with direct contact between feed and roots. Amino-acid deamination can generate ammonia, which fish release principally through their gills [3]. Evidence concerning dietary arginine provides a further example of a feed-related metabolic route associated with ammonia excretion [2]. Once released, ammonia is in the fish-system water rather than retained as the original dietary compound. This is the first important change in the explanation: the feed-derived contribution to plant nutrition may appear downstream in a different chemical form. These fish studies establish release, but do not measure what proportion of released nitrogen subsequently reaches plants.

Waterborne movement and biological conversion provide the next supported links. The aquaponics review describes effluent from the fish component as an input to the plant component and identifies biological filtration that converts ammonia to nitrate [1]. Transport and conversion should not be collapsed into a single event. Effluent provides a route for nutrients to enter water supplied to plants, while filtration alters the form of nitrogen along that route. This account explains how a nutrient originating in feed can become present in the plant-facing water without assuming that all feed nutrients behave identically. It also stops short of demonstrating uptake of a measured feed-derived quantity by a particular plant.

Plant-facing water composition is a further condition on whether delivery meets plant needs. Measurements in an aquaponic fish and lettuce system, together with responses to iron and iron-plus-potassium additions, show that nutrient limitations can be visible even where fish and plants share a production system [4]. Trials with recirculating aquaculture water likewise measure nutrient concentrations alongside lettuce responses [5]. These observations concern the availability and effects of the resulting solution, not the metabolic origin of each measured nutrient. They qualify the pathway described by the aquaponics review [1]: movement of fish-system water establishes a route of supply, but cannot by itself establish that its composition satisfies every plant requirement.

IV. Evidence Synthesis

The sources form a sequence of complementary, rather than interchangeable, observations. Fish-nutrition evidence relates dietary metabolism to ammonia release through the gills [2], [3]. The aquaponics review then supplies the system-level connection, describing nutrient-bearing effluent entering the plant unit and ammonia conversion by biological filtration [1]. Finally, measurements of aquaculture-water solutions and lettuce responses characterise conditions at the plant-facing end of the pathway [5]. Together they support a coherent explanation of how feed-associated nitrogen can travel through a fish system towards plants. No single observation, however, measures every transition in that explanation, so the chain should not be represented as a continuous experimental trace.

The distinction between nutrient delivery and nutrient sufficiency is especially important. The review establishes a route by which fish-system effluent can contribute nutrients to the plant unit [1]. In contrast, the lettuce study involving iron and iron-plus-potassium supplementation shows that examining plant function and water nutrients can expose limitations of an existing nutrient supply [4]. The trials involving recirculating aquaculture water also relate solution composition to plant response [5]. These findings are compatible: a solution may carry aquaculture-derived nutrients while its composition still limits plant performance. A beneficial plant response cannot, on its own, quantify the feed-derived contribution or identify which earlier transformation produced a particular nutrient.

There is also an asymmetry in what the evidence says about different nutrients. The fish-metabolism sources specifically support ammonia production and excretion associated with nitrogen metabolism [2], [3], while the system review specifically supports conversion of ammonia to nitrate and delivery of effluent towards plants [1]. The supplementation study concerns measured nutrient conditions and responses involving iron and potassium [4]. It does not establish that these elements follow the same release or conversion route as nitrogen. Accordingly, the nitrogen chain can be described mechanistically, whereas the evidence here supports a more limited conclusion for other nutrients: their availability in the plant-facing solution must be assessed rather than inferred from the nitrogen pathway.

V. Practical Implications and Limitations

A sound interpretation of feed-derived plant nutrition must keep origin, transport and plant response separate. The fish reviews explain why ammonia can enter the water following dietary nitrogen metabolism [2], [3]. The aquaponics review explains how effluent and biological filtration connect that release to a nitrate-containing input for the plant unit [1]. The practical implication is an explanatory one: neither feed input nor fish excretion alone specifies the nutrient composition presented to plants. Any claim about that composition also depends on the intervening water and filtration stages. The supplied evidence supports the existence and direction of this principal route, but not a quantified balance of feed input against nutrient uptake.

Plant measurements are necessary to interpret the endpoint, yet their evidential role has limits. The aquaponic supplementation study measures nutrient conditions and lettuce responses, showing that plant performance can reveal a limitation of the nutrient environment [4]. Comparisons involving recirculating aquaculture water likewise examine nutrient concentrations and lettuce growth [5]. Neither study, as used here, directly traces an identified portion of feed through fish release, filtration and plant uptake. It would therefore overstate their findings to assign a measured plant response specifically to a quantified feed-derived nutrient flow. The studies are strongest as evidence about the resulting

solution and plant response, not as substitutes for a complete pathway measurement.

The most useful validation would connect observations that the existing sources examine separately. Fish-side measurements would need to be related to the forms of nitrogen present after biological filtration and to the water entering the plant unit; plant-facing measurements would then need to be interpreted without treating a response as proof of origin. This need follows from the different evidential boundaries of the fish-metabolism reviews [2], [3], the aquaponics pathway review [1], and the nutrient and lettuce studies [4], [5]. Until those transitions are measured together, the supported conclusion is a causal account of the main route, not a complete allocation of each feed nutrient or an assurance of nutrient sufficiency.

VI. Conclusion

Feed-derived nitrogen can reach the plant side of an aquaponic system through a connected sequence: fish metabolism produces ammonia that is excreted into water, fish-system effluent carries nutrients towards the plant unit, and biological filtration converts ammonia to nitrate [1], [2], [3]. This explains why plant nutrition depends on transformations between feeding and delivery, rather than on feed composition alone. Studies measuring aquaculture-water nutrients and lettuce responses further show why the condition of the plant-facing solution must be considered independently of the existence of that pathway [4], [5].

The account remains deliberately narrower than a complete nutrient budget. The accepted evidence links fish nitrogen release to system-level transport and conversion, but does not continuously trace every feed-derived nutrient into plant tissue [1], [2], [3]. Plant-response studies illuminate possible limitations of the supplied solution without closing that tracing gap [4], [5]. Work that observes these successive stages together would provide a stronger basis for distinguishing nutrient delivery, chemical transformation and plant uptake.

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References

[1] V. Lobanov, H. Monsees, F. Latrille, G. Pate, and A. Joyce, "Coupled vs. decoupled aquaponics: Evidence, mechanisms, and methodological gaps in the productivity hypothesis," *Aquacultural Engineering*, 2026.

[2] Q. Wang, Z. Xu, and Q. Ai, "Arginine metabolism and its functions in growth, nutrient utilization, and immunonutrition of fish," *Animal Nutrition*, 2021.

[3] S. I. Dolomatov, P. V. Shekk, W. Zukow, and M. I. Kryukova, "Features of nitrogen metabolism in fishes," *Reviews in Fish Biology and Fisheries*, 2011.

[4] E. Tsoumalakou, E. Mente, K. A. Kormas, N. Katsoulas, N. Vlahos, P. Kapsis, and E. Levizou, "Precise monitoring of lettuce functional responses to minimal nutrient supplementation identifies aquaponic system's nutrient limitations and their time-course," *Agriculture*, 2022.

[5] B. Delaide, S. Goddek, J. Gott, H. Soyeurt, and M. H. Jijakli, "Lettuce (lactuca sativa l. var. sucrine) growth performance in complemented aquaponic solution outperforms hydroponics," *Water*, 2016.