

The Missing Half of Nutrition:

Why Delivery Matters as Much as Formulation

The livestock industry has become exceptionally good at formulating diets. Better ingredients, improved genetics and more precise formulation have transformed animal nutrition over the past half-century. Yet two animals consuming the same diet can still perform very differently. The challenge has expanded beyond formulation. Nutrients still need to survive manufacturing and digestion before reaching the site where they can be effectively absorbed and utilised.

For decades, nutrition research focused on what went into the feed. Far less attention was given to what happens after feed is consumed, where digestive processes, interactions among nutrients and biological variability all influence how much of a nutrient is ultimately used by the animal. The importance of that process is becoming harder to ignore. Ingredient costs remain volatile (Morciani, 2026), sustainability expectations are tightening (Place, 2024), heat stress is becoming a more persistent production challenge (Mangan & Siwek, 2024) and antibiotics are steadily being withdrawn from feed (European Medicines Agency, 2021). At the same time, sensors, biological monitoring and AI-driven analytics provide a much clearer picture of what happens inside the animal (Michelena *et al.*, 2025).

Together, these changes are shifting attention from formulation alone toward nutrient delivery: whether nutrients reach the right place, at the right time and in a form the animal can effectively use. Encapsulation has emerged as one of the more established responses, attracting investment across the industry rather than from any single company. A growing body of published research suggests that nutrient delivery is becoming an important part of precision nutrition.

Why 'More' Stopped Working

The traditional response to unpredictable nutrient losses has been to over-formulate: adding more vitamins or minerals than the animal needs as a hedge against pelleting losses, storage instability and gastric degradation. That insurance is not free. Every percentage point of surplus adds cost without guaranteeing a return, and margins designed solely to offset degradation accumulate quickly across the volumes handled by a commercial feed mill. The pattern is not specific to any one company's technology: reviews of trace mineral bioavailability more broadly note that cheaper inorganic sources are also less bioavailable, which has historically encouraged higher inclusion rates simply to compensate (Byrne & Murphy, 2022).

Over-formulation also carries biological and environmental trade-offs. Less bioavailable nutrient sources can increase mineral excretion without a corresponding improvement in animal performance, while excess nutrients that are not absorbed simply represent additional cost and environmental burden (van Rensburg, 2025). In addition, excess nutrients can result in bacterial blooms, particularly among pathogenic bacteria. None of this implies that vitamins and minerals were oversupplied out of carelessness; it reflects a genuine engineering challenge. For many years, over-formulation was

the most practical way to compensate because more precise delivery systems did not exist.

The Delivery Problem

A better solution is to address two challenges simultaneously. Vitamins vary considerably in stability and pelleting and extrusion add further losses through heat and pressure (Wedegaertner *et al.*, 2020). Manufacturing is half of the problem. The second half starts once the feed is eaten: a nutrient that survives milling intact still must get past stomach acid, then be released at the point in the intestine where it can be absorbed rather than consumed by competing microflora further down the gut. In weaned pigs, lipid matrix microencapsulation delivered close to 42% of an encapsulated compound specifically to the mid-jejunum (Choi *et al.*, 2020) and in broilers, a separate research group found more than 60% of an encapsulated marker compound reached the lower intestine using a different encapsulation approach entirely (Abdelli *et al.*, 2021). Surviving manufacturing and being released in the right place are two different engineering problems and technology must solve both to be useful in practice.

A Broader Industry Response

Encapsulation is not a single technique but a family of approaches applied to very different nutrients. Vitamins, trace minerals, amino acids, organic acids, essential oils, enzymes and even live probiotics have all been protected for targeted release, although the objective varies by nutrient and species. Rumen-protected amino acids, for example, solve a different problem than delayed-release trace minerals in monogastrics, even though both rely on the same principle: protecting nutrients until they reach the point where they can be used most effectively.

As pharmacological zinc oxide is phased out across the EU and medically important antibiotics face growing restrictions elsewhere, feed formulators are being asked to achieve more, through biological efficiency rather than simply higher inclusion rates (All About Feed, 2026). That challenge has accelerated investment across the industry. Companies including Adisseo, Alltech, Balchem, Kemin, Jefe and Novus (alphabetically listed) are all developing encapsulation or protected-delivery technologies, each using different technical approaches to improve nutrient stability, targeted release and utilisation, with Jefe reported in Canada as making exceptional investments.

The growing industry interest is supported by published research. Across pigs and poultry, encapsulated minerals, organic acids, botanicals and essential oils have maintained or improved performance while supporting gut health or reducing reliance on medicated feed under both research and commercial conditions (All About Feed, 2026; Blair *et al.*, 2025; Johnson *et al.*, 2023; Pham *et al.*, 2020; Samuels, 2024). Although the technologies differ, the overall direction is consistent: improving nutrient utilisation through protected, targeted delivery.

One well-documented example is Jefe Matrix Technology (JMT), which uses a patented lipid matrix to protect vitamins and trace minerals during feed manufacture and digestion before releasing them progressively in the intestine through

lipase activity. Across several independent poultry studies, JMT has maintained or improved performance under reduced inclusion levels, although responses have varied depending on the production system and outcome measured (Ferket *et al.*, 2018; Dewez, 2024; Malheiros *et al.*, 2025a; Malheiros *et al.*, 2026). Using substantially lower levels of vitamins, minerals and amino acids has the potential to revolutionise current practices around premix and animal feeding.

Gut Health and Antibiotic Stewardship

One explanation is that encapsulated nutrients reduce the amount of unabsorbed substrate reaching the hindgut, potentially limiting opportunities for less desirable bacteria to proliferate. Independent studies using encapsulated organic acids, essential oils and protected vitamin and mineral programmes have reported improved gut-barrier function and favourable shifts in the gut microbiota (Johnson *et al.*, 2023; Pham *et al.*, 2020; Wedegaertner, 2020).

Improving nutrient utilisation may help support intestinal health and complement antimicrobial stewardship, alongside the biosecurity, vaccination and management practices that remain the primary tools for antibiotic-free production (Shannon & Hill, 2019). This is a role that encapsulated nutrient delivery systems can play.

Beyond Feed Formulation

The implications of nutrient delivery extend beyond feed efficiency. Improved trace mineral bioavailability has been associated with better egg production, antioxidant status and reproductive performance in broiler breeders compared with conventional inorganic mineral sources (Wang *et al.*, 2019; Malheiros, 2021; Malheiros *et al.*, 2025b). At the same time, maintaining performance at lower inclusion rates may reduce mineral excretion, an increasingly important consideration as environmental regulations tighten in many livestock-producing regions (Alltech, 2025).

Precision nutrient delivery does not eliminate biological variability; it changes where that variability appears. Nutrient release still depends on digestive physiology, including lipase activity, which varies among animals and even between breeds (Liu *et al.*, 2021). Research evaluating lipid-matrix encapsulation illustrates how these biological differences can influence nutrient release and animal responses, reinforcing that nutrition remains an interaction between the feed and the animal rather than the formulation alone (Wedegaertner, 2020).

A recent presentation at the Poultry Science Meeting in Toronto, Canada, by Dr Ferket described the biological and economic inefficiencies of over-supplementation, what he calls the 'hidden cost of asynchronous nutrition', specifically the timing and kinetics of nutrient absorption. This is the future of feeding, beyond precision nutrition.

What Does this Mean for Industry?

That variability is why the practical takeaway is not that every premix should be switched overnight inclusion rate and delivery form are now two separate levers rather than one. Encapsulation technologies can improve feed mill handling by reducing moisture uptake and improving flowability during storage (Wedegaertner *et al.*, 2020), but improvements in animal performance remain dependent on species, genetics, production system and diet. The practical approach is to validate results under an operation's own conditions rather than assume published findings will transfer directly.

Stepping back, the pattern is bigger than any one technology. Encapsulation illustrates a broader shift toward

treating nutrient delivery as an integral part of nutrition rather than an afterthought. Important questions remain about how consistently these responses translate across species and commercial production systems, particularly under antibiotic-free conditions and when better delivery produces measurable changes in gut biology. Answering them will help identify where encapsulation creates the greatest biological and economic value.

Even so, waiting for perfect certainty is rarely how industries move forward. Other areas of animal health have already rewarded companies willing to invest early in emerging technologies; artificial intelligence provides a recent example (Connolly & Ulloa, 2026). Precision nutrient delivery appears to be following a similar trajectory. For decades, competitive advantage came from deciding what belonged in the ration. The next opportunity may lie in ensuring those nutrients complete the journey.

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