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THE IMPORTANCE OF FEED PARTICLE SIZE: From Milling Efficiency to Gizzard Function – Part II

Building on the biological principles presented in [Part I](#), this article examines how feed manufacturing practices determine particle size distribution and, ultimately, nutritional outcomes. From grinding and mixing to pelleting and real-time monitoring, it highlights how aligning processing technology with nutritional objectives can transform particle size from a routine production parameter into a strategic tool for improving feed quality, digestive efficiency and poultry performance.

FROM MILL TO MOUTH: HOW PROCESSING SHAPES NUTRITION

Between formulation and ingestion, feed undergoes a series of technological transformations that shape its physical structure and ultimately its nutritional value. At this stage, the causal chain becomes explicit: processing parameters define particle structure, which in turn drives physiological responses in the animal.

The first and most decisive control point is grinding. Mill settings such as tip speed, screen size, roll gap, throughput, and energy input determine not only the target particle size, but also the shape and dispersion of the particle size distribution (Figure 3).

Targeting a lower D50 generally entails increased specific energy input and is frequently accompanied by a higher proportion of fines, altered particle morphology, and greater dispersion within the particle size distribution. Conversely, coarser settings may preserve structural integrity but reduce surface area available for enzymatic action. Thus, grinding should not be viewed as a simple size-reduction step, but as a structural engineering process that defines how feed particles will interact with water, enzymes, and the gastrointestinal tract.

Once ground, particles become part of a dynamic system in which transfer, conveying, and mixing may induce segregation. Differences in particle size,

density, and shape can lead to de-mixing during conveying, bin filling, discharge, and mixing itself, particularly in mash feeds. Mixing improves homogeneity up to a point, after which additional mixing provides limited benefit and may even promote

re-segregation when particle size distributions are highly heterogeneous. While mixing conditions influence the final coefficient of variation (CV), the stability of homogeneity is largely governed by particle size distribution (Figure 4).

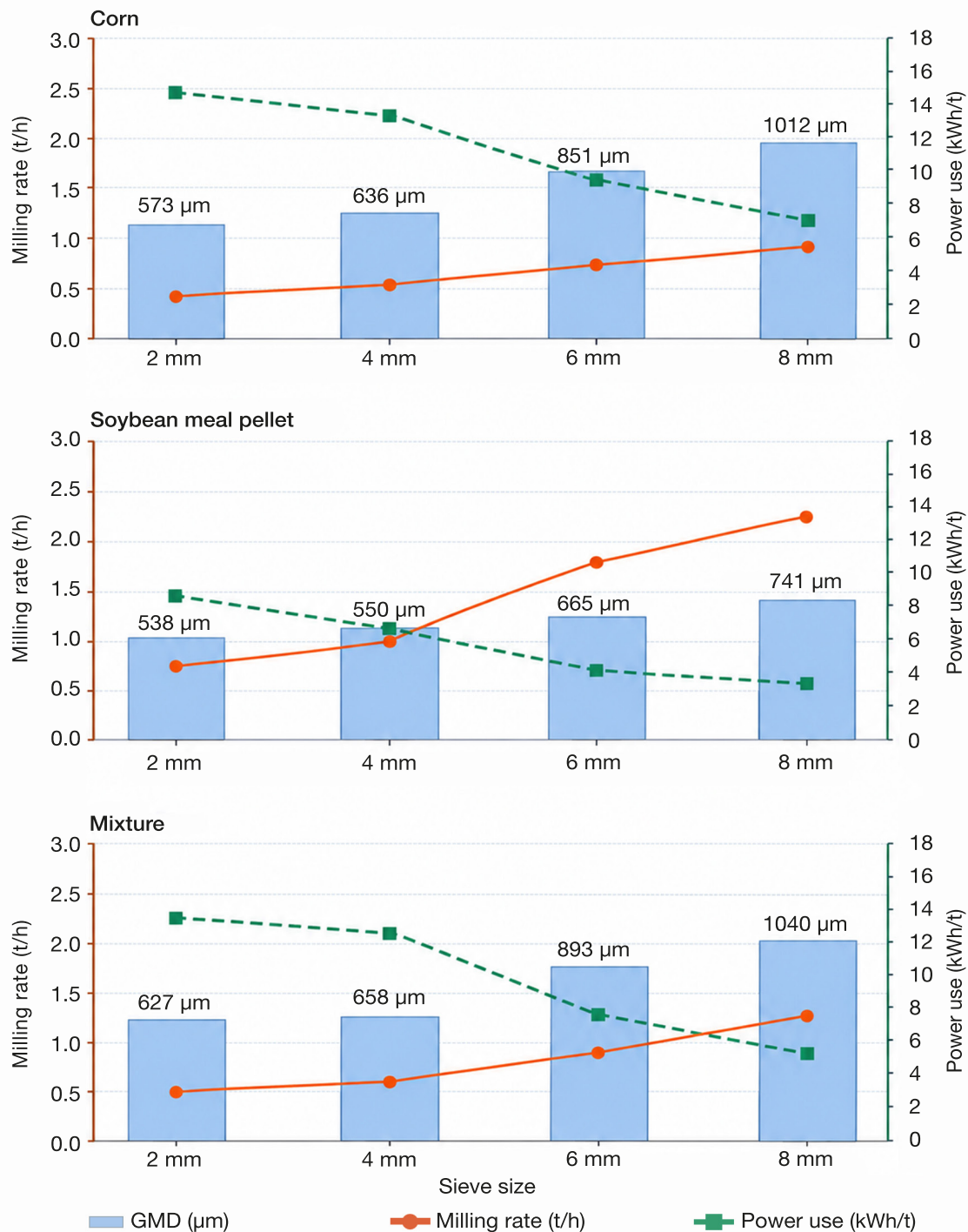


Figure 3. Geometric mean diameter (GMD) of feed particles and energy consumption during milling with different sieves. **Source:** Carina Scherer, Univ. of West Parana, poster WPC Bahia 2012.

Importantly, segregation does not stop at the mixer. During storage, transport, and feed delivery, particles continue to redistribute under gravity and movement. Consequently, the particle size distribution consumed by the bird may differ from that measured at the feed mill. Birds may further amplify these differences through selective feeding, creating additional variability in nutrient intake.

Together, grinding and post-grinding handling demonstrate how technological decisions propagate throughout the feed chain. Feed homogeneity is not created in the mixer; it is largely determined by the particle size distribution established during grinding.

Figure 4 illustrates the typical relationship between mixing time and feed homogeneity (expressed as CV), highlighting the influence of particle size distribution. Homogeneity improves rapidly during the initial mixing phase, then reaches a plateau. In the case of heterogeneous particle size distributions, extended mixing may even lead to re-segregation and a subsequent increase in CV, which might not be problematic in terms of performance.

As discussed earlier, while pelleting transforms mash diets into macro-particles in the form of pellets, it simultaneously reduces the size of the micro-particles that constitute the intact pellet. Abdollahi et al. (2011), using wet sieving techniques, demonstrated

that passage through the pellet die reduced particles larger than 2.0 mm and increased the proportion of particles smaller than 0.075 mm. Similarly, Amerah et al. (2007) reported that pelleting reduced the proportion of particles larger than 1.0 mm while increasing the fraction of fine particles smaller than 0.075 mm in coarsely ground diets.

Fine grinding is commonly favoured by the feed industry to achieve high pellet physical quality; however, additional particle size reduction during pelleting is unavoidable, resulting in a high proportion of fine particles inside the pellets in the final feed. This feed structure compromises gizzard development, leading to elevated gizzard pH and reduced digesta retention time, both of which are physiological constraints to optimal digestion. A negative correlation between relative gizzard weight and gizzard pH has been reported, and birds fed pelleted diets generally exhibit higher gizzard pH than those fed mash diets. In finely ground pelleted diets, the gizzard functions primarily as a transit organ rather than an effective grinding organ, ultimately impairing nutrient digestion and utilisation (Figure 5).

To determine the optimal microstructure of pelleted diets, particle size distribution must be measured using a wet sieving technique (Svihus et al., 2025). As described by Lentle et al. (2006), a representative sample (200 g) of each diet is divided

Effect of mixing time and particle size distribution on feed homogeneity

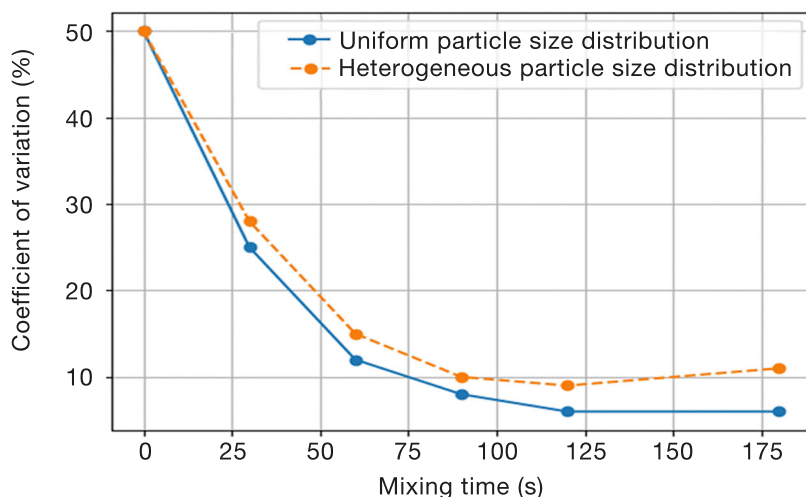


Figure 4. Conceptual representation of the effect of mixing time on feed homogeneity (CV) under different particle size distributions. The curves are constructed from typical values reported in the literature (Gomes et al., 2022; Behnke, 1996) and illustrate general trends rather than a single experimental dataset.



Figure 5. Well-developed and functional gizzard in birds fed coarsely ground wheat-based diets in mash form (Left) vs. Under-developed gizzard in birds fed finely ground wheat-based diets in pellet form. Source: Poultry Research Team, Massey University, New Zealand.

into two sub-samples. One sub-sample is dried at 80 °C in a forced-draft oven for 72 h to determine dry matter content. The second sub-sample is soaked in water (100 g feed in 400 ml water) and allowed to hydrate for 1 h prior to sieving. Hydrated samples are washed for 5 min through a stack of six stainless steel sieves with aperture sizes of 2.0, 1.0, 0.5, 0.212, 0.106, and 0.075 mm. Material retained on each sieve is transferred onto pre-weighed filter papers, dried in a forced-draft oven at 80 °C for 24 h, and reweighed. Particle size distribution is expressed as the proportion of total recovered dry matter retained on each sieve. Particles larger than 1.0 mm are present in the digestive tract in much lower proportions than in the diet, indicating their selective retention in the gizzard for mechanical grinding. In contrast, particles smaller than 1.0 mm show similar proportions in the diet and duodenal contents, reflecting more rapid passage. This pattern underscores the key role of coarse particles in stimulating gizzard activity (Svihus et al., 2025). Particles exceeding 1.0 mm, and particularly those greater than 2.0 mm, are the most effective in promoting gizzard development and function, especially when the overall proportion of coarse material in the diet is low (Naderinejad et al., 2016). From a practical standpoint, the use of sieves smaller than 1.0 mm may be of limited relevance, as such fine particles contribute little to gizzard development. Instead, emphasis should be placed on

characterizing the coarse fraction (> 1.0 mm). This is particularly important when applying the wet sieving method. In addition to 1.0 mm and 2.0 mm sieves, the inclusion of a coarser sieve (approximately 3.0-4.0 mm) is recommended to quantify very coarse particles, such as minimally ground cereal fractions (Svihus et al., 2025).

ALIGNING NUTRITION AND TECHNOLOGY: SPEAKING THE SAME LANGUAGE

To optimize poultry performance, nutritionists and feed technologists must share common targets and metrics. Historically, particle size has often been specified indirectly through equipment settings, such as screen size, rather than through measurable physical outcomes.

A more integrated approach consists of translating nutritional objectives into structural feed targets. Rather than prescribing a specific grinding configuration, nutritionists and technologists should define the particle size distribution most likely to support desired physiological responses, such as improved gizzard development or nutrient utilization.

This shared language relies on metrics that are meaningful to both disciplines. Beyond traditional descriptors such as GMD and GSD, more integrative concepts have emerged to describe feed structure in functional terms. Although not yet standardized, the notion of a "feed structure score" reflects the ability of a feed to stimulate digestive function and is supported by studies demonstrating the combined effects of particle size distribution, feed form, and coarse particles on gizzard development and nutrient digestibility (Abdollahi et al., 2013, 2018; Svihus et al., 2014, 2025). Complementary indicators such as gizzard scores and process KPIs further strengthen the connection between technological execution and nutritional response.

Ultimately, grinding profiles should be formulated rather than simply applied. When nutritional objectives and technological parameters are aligned, feed structure becomes a deliberate component of feed design rather than an incidental consequence of processing.

FUTURE PERSPECTIVES: MANAGING PARTICLE SIZE FOR AN OPTIMAL NUTRITION

Looking ahead, managing particle size for optimal nutrition will require a more integrated and data-driven approach, where feed structure is continuously monitored and actively controlled rather than periodically verified. One of the most promising developments lies in the emergence of at-line and on-line particle size monitoring systems capable of providing rapid feedback directly from the production process. Compared with traditional sieve analysis, these technologies offer faster and more representative assessment of particle size distribution, enabling early detection of deviations caused by raw material variability, equipment wear, or process drift.

Technologies based on laser diffraction and dynamic image analysis are increasingly being adapted to industrial feed manufacturing. Beyond measuring D50 or complete granulometric profiles, modern imaging systems can also characterize particle morphology and shape, providing a more comprehensive description of feed structure. Although challenges remain regarding representative sampling and operation in dusty environments, recent advances in automation, image processing, and artificial intelligence are rapidly improving the feasibility of real-time particle characterization in feed mills.

The broader opportunity lies in shifting from controlling grinding settings to controlling particle size outcomes. In such a framework, particle size distribution becomes a true process variable, continuously adjusted to achieve nutritional objectives. Combined

with process analytics and predictive models, these technologies could support more adaptive manufacturing systems capable of responding dynamically to raw material variability and desired animal responses.

At the same time, advances in monitoring must remain connected to biological relevance. Studies have shown that maintaining a proportion of coarse particles in pelleted diets can preserve gizzard function despite the particle size reduction associated with pelleting. Naderinejad et al. (2016) reported that relatively low proportions of particles larger than 2 mm were sufficient to stimulate hydrochloric acid secretion and maintain gizzard acidity at levels comparable to those observed in mash-fed birds. Coarse particles in pelleted diets have also been associated with increased gizzard development, improved nutrient digestibility, and enhanced energy utilization. Beyond these physiological benefits, coarser grinding generally reduces grinding energy requirements, illustrating how nutritional and technological objectives can converge.

More broadly, the evolution of poultry nutrition over the past decades has favoured highly digestible and nutrient-dense diets, often at the expense of physical structure. While nutritional precision has increased dramatically, feed structure has progressively become a neglected dimension of diet formulation. The evidence reviewed in this paper suggests that restoring adequate feed structure, particularly through appropriate particle size distribution in the final feed, can contribute significantly to digestive function, gut health, and nutrient utilization.

Ultimately, particle size should no longer be regarded as a simple by-product of grinding or a specification linked to a screen size. It is a functional attribute of feed, connecting manufacturing decisions to digestive physiology. Future feed mills will increasingly be required not only to formulate nutrients, but also to formulate structure. In this vision of structural nutrition, particle size is managed with the same level of precision and strategic importance as the nutrient composition itself.

References are available upon request.

