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

Poultry diets may be formulated to identical nutrient specifications, yet their biological performance can differ markedly due to one often-overlooked factor: feed structure. This first part explores how particle size distribution influences digestive physiology, gizzard development, gut health and feeding behaviour, demonstrating why particle size should be regarded not merely as a milling parameter, but as a critical nutritional characteristic that bridges feed manufacturing and animal performance.

Poultry feed formulation has reached a high level of precision, yet differences in bird performance persist despite identical nutrient specifications. Increasing evidence suggests that these discrepancies are not explained solely by nutrient composition, but also by feed structure, particularly particle size distribution.

This paper examines how grinding, mixing, handling, and pelleting shape feed structure and, in turn, influence digestive physiology, gut health, nutrient utilization, and feeding behavior in poultry. Particular attention is given to particle size distribution—not only its average value, but its overall profile—and its role in feed homogeneity, segregation, and digestive function.

The effects of pelleting on particle size are discussed, together with the need for appropriate measurement methods in finished feeds. Finally, the paper advocates a more integrated approach in which particle size is defined, measured, and managed as a nutritional parameter. Emerging tools for real-time monitoring and process control are highlighted as key enablers of this transition.

Ultimately, particle size should be viewed not as a by-product of grinding, but as a functional feed attribute that must be aligned with nutritional objectives.

ONE FORMULA, TWO OUTCOMES

Two feed mills may produce the same broiler diet on paper, using identical ingredient compositions and meeting the same nutrient and energy specifications. Yet, under commercial conditions, bird performance can differ substantially. Broilers fed from one mill may achieve faster growth, convert feed more efficiently, and superior gastrointestinal development compared with those receiving feed from the other mill. The difference lies not in the formulation matrix itself, but in the extent of feed processing and the resulting physical structure of the finished feed.

Modern poultry nutrition is built on precision. Nutritionists formulate diets to meet biological requirements with increasing accuracy, while feed technologists design processes to ensure throughput, efficiency, and pellet quality. Both disciplines ultimately pursue the same objective: delivering nutrients to the animal in the most effective way. Yet between formulation and feeding, a critical transformation occurs. During grinding, mixing, conditioning, and pelleting, feed is not only processed—it is structurally redefined.

This transformation governs how nutrients are accessed, digested, and utilized by the bird. It shapes how feed is perceived, selected, retained, and broken down in the gastrointestinal tract. Feed structure, and particularly particle size distribution, thus emerges as the missing link between what is formulated and what is biologically expressed.

Despite its importance, this link remains insufficiently integrated into both nutritional formulation and feed manufacturing practices. Particle size is still too often treated as a secondary parameter, reduced to equipment settings or a single analytical value. This paper explores how particle size reduction and feed processing shape both technological outcomes and biological responses and argues for a more integrated approach in which particle size is considered a functional parameter of nutrition.

DEFINING FEED PARTICLE SIZE

Feed particle size (PS) is often reduced, in practice, to a single number: the median diameter, commonly expressed as D50. While useful, this simplification hides a much richer reality. Particle size is not a single point, but a distribution. Two feeds with the same D50 may behave very differently in the animal if one contains a high proportion of fine particles and the other a wider spread including coarse fractions.

Understanding particle size therefore requires moving beyond a single value and considering the full particle size distribution, including its shape, its extremes, and its consistency over time. Characterizing this distribution requires a standardized series of sieves. A set including 100, 200, 500, 800, 1000, 1600, 2000, and 3150 µm provides a practical framework for describing feed granulometry. Beyond D50, the geometric standard deviation (GSD), which reflects dispersion, together with the proportion of each particle fraction, are essential descriptors of feed structure.

From a processing perspective, the properties of the raw materials set the starting particle size. Milling then reduces these particles to smaller sizes, so the final particle size is determined by the milling

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operation. Depending on plant design, ingredients may be ground together after dosing (post-grinding) or individually before mixing (pre-grinding), the latter offering greater flexibility to tailor particle size distributions to nutritional objectives.

Particle size is shaped primarily by the choice of grinding technology and operating conditions. Hammer mills generally produce broader distributions with a higher proportion of fines, whereas roller mills generate more uniform particles with fewer fines. Beyond equipment selection, screen size, tip speed, throughput, specific energy input, and equipment wear all influence the final distribution. Raw material properties such as hardness, moisture content, fiber structure, and fat level further contribute to grinding behavior and particle size variability.

Targeting a lower D50 generally requires higher specific energy input and is frequently accompanied by a greater proportion of fines and increased dispersion within the particle size distribution. Consequently, particle size should not be viewed solely through its average value, but through the overall balance between mean size, distribution width, and process efficiency.

Particle size is therefore a measurable, traceable, and repeatable technological outcome. When properly defined and monitored, it becomes a genuine feed quality attribute, comparable to pellet durability or moisture content. More than a by-product of grinding, it is a parameter that can be deliberately targeted, controlled, and optimized.

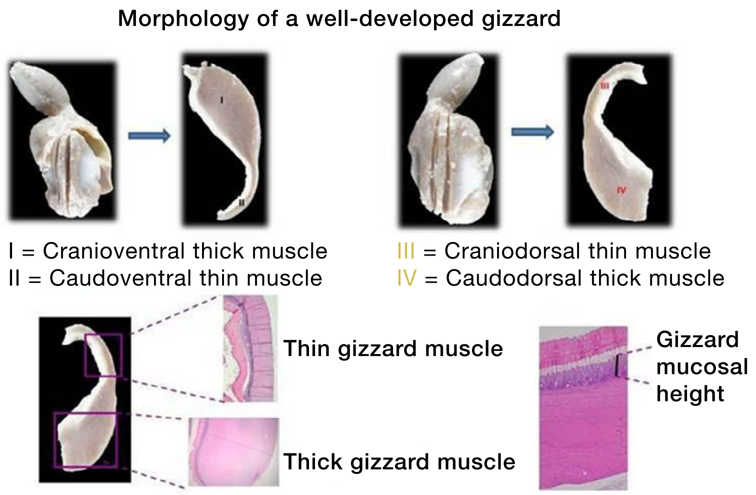
THE ANIMAL'S PERSPECTIVE

During feed manufacturing, most ingredients, particularly cereal grains, are ground prior to incorporation into the final diet. Grinding reduces particle size and alters the physical characteristics of ingredients, improving blending ability and homogeneity, reducing segregation during handling, and facilitating the pelleting process. Particle size reduction is also believed to enhance the accessibility of digestive enzymes to substrates due to the increased surface area of feed particles. However, excessively fine particles may adversely affect the development and functionality of the foregut, particularly the proventriculus and gizzard, which play a critical role in regulating intestinal health and nutrient utilisation. Feeding coarser particles has been associated with improved foregut development, enhanced gut motility, and better digestive function, contributing to overall gut health. Nevertheless, results from studies evaluating the effects of feed particle size on upper gastrointestinal tract development remain inconsistent. These discrepancies are largely attributed to confounding factors, particularly feed form (mash vs. pellets), which can mask or modify the biological effects of particle size.

The influence of feed particle size on gizzard development is well documented. The gizzard possesses a remarkable capacity to mechanically reduce feed particles to a relatively uniform size, regardless of initial particle dimensions. Early work by O'Dell et al. (1959) demonstrated that birds fed purified diets composed predominantly of fine particles exhibited an enlarged proventriculus and a reduced gizzard size compared with birds fed diets containing coarser particles. Diets consisting of fine particles were also shown to pass more rapidly through the gastrointestinal tract (135 vs. 165 minutes). Additionally, birds consuming finely ground diets exhibited increased water intake, likely to facilitate feed ingestion, resulting in a pendulous crop. These observations highlight the physiological consequences of excessive particle size reduction on foregut function.

Hetland et al. (2002) demonstrated in broilers that, irrespective of the original feed structure, the majority of digesta particles measured less than 0.04 mm in diameter upon leaving the gizzard. These findings highlight the gizzard's critical role in regulating particle size before digesta enters the small intestine. Gizzard weight in broilers is positively correlated with feed particle size when diets are offered in mash form. Broilers fed mash diets containing coarsely ground particles exhibit prolonged digesta retention time in the gizzard, leading to enhanced gizzard development. Increased grinding ac-

Figure 1

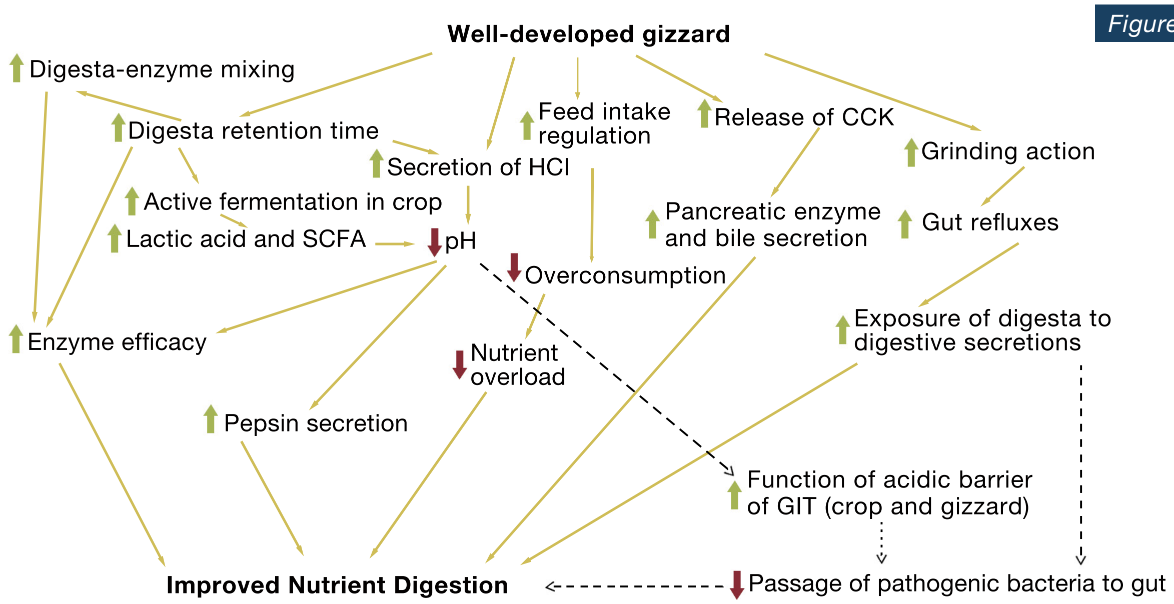


Source: Adapted from Abdollahi et al. 2019. J Anim Physiol Anim Nutr. 103:146–161.

tivity within the gizzard stimulates hypertrophy of the gizzard musculature, which is characterized by well-developed myelinated muscle fibres (Figure 1).

Enhanced gizzard function has been associated with increased pancreatic enzyme secretion, mediated in part by elevated cholecystokinin release (Svihus, 2014), as well as improved gastrointestinal tract motility. A well-developed gizzard generates stronger reverse peristaltic contractions, thereby enhancing the mechanical breakdown of feed and promoting increased proteolysis by pepsin, trypsin, and other endogenous proteases in the small intestine. Gabriel et al. (2003) reported that the inclusion of larger feed particles enhanced pepsin activity in the proventriculus, reinforcing the role of feed particle size in modulating digestive enzyme activity and protein digestion efficiency. Collectively, these physiological adaptations contribute to more efficient digestion and improved nutrient utilisation (Figure 2).

Figure 2



Source: Adapted from Abdollahi and Ravindran, The Perfect Pellet: Issues and Challenges, 14th European Poultry Conference, 2014, Stavanger, Norway.

A well-developed gizzard also plays a critical role in regulating gastrointestinal microbial ecology by acting as a physiological barrier against pathogenic bacteria entering the distal gastrointestinal tract. Enhanced gizzard function is associated with increased hydrochloric acid secretion and lower pH in the digestive tract, creating an antimicrobial environment that suppresses acid-sensitive pathogens. Studies have shown that birds fed coarse mash diets exhibit increased populations of beneficial Lactobacillus spp. in the caeca, whereas finely ground and pelleted diets are associated with reduced lactic acid bacteria counts. Increased inclusion of coarse particles has also been linked to higher Lactobacillus and Bifidobacterium populations and reduced counts of pathogenic or opportunistic bacteria such as Clostridium, Campylobacter, and Bacteroides spp. In contrast, finely ground feed particles pass more rapidly through the gizzard, limiting exposure to acidic conditions and proteolytic enzymes. The resulting influx of undigested material into the small intestine may promote dysbiosis and facilitate the proliferation of pathogens such as Clostridium perfringens and Escherichia coli. Collectively, these findings suggest that feed particle size influences gut microbiota through two primary mechanisms: enhanced antimicrobial action mediated by a functional gizzard and the promotion of competitive exclusion via increased colonisation of commensal bacteria.

Poultry are highly sensitive to feed particle size and can distinguish textural differences through mechanoreceptors in the beak from an early age. Birds consistently show a preference for larger particles, and this preference intensifies as they mature. Feed particle size, together with dietary nutrient density, is a primary determinant of voluntary feed intake (FI), with numerous studies demonstrating that changes in particle size alone, without altering diet composition, can significantly influence FI in poultry. Feed selection behaviour further indicates that birds preferentially consume coarse particles, leaving behind fines, underscoring feed particle size as a key driver of feeding behaviour and intake regulation in poultry.

Studies evaluating the effects of feed particle size on FI in broilers fed mash diets have produced inconsistent results, largely due to the influence of multiple confounding factors, including grain type and cultivar, endosperm hardness, particle size characteristics (mean size, uniformity, and distribution), grinding method, and bird age. Amerah et al. (2007) reported that broilers fed coarsely ground wheat mash diets (7-mm screen) consumed approximately 13% more feed than those fed medium-ground diets (3-mm screen), resulting in significant improvements in weight gain and feed efficiency. Yasar (2003) demonstrated that the negative effects of soluble non-starch polysaccharides (NSP) in wheat-based diets were exacerbated by fine grinding. Reducing screen size from 7.0 to 6.0, 5.0, and 4.0 mm progressively increased ileal digesta viscosity (from 7.3 to 18.3 cP), which was associated with reduced FI. This effect was attributed to increased solubilisation of NSP following fine grinding, leading to slower digesta passage rate and consequent suppression of feed intake. Nir et al. (1994) demonstrated that, irrespective of cereal type (maize, wheat, or sorghum), mash diets with a medium particle size, corresponding to a GMD of 966–1266 µm, resulted in the highest FI and optimal growth performance.

However, when diets are pelleted or crumbled, differences in pre-pelleting particle size often result in similar broiler performance outcomes. This convergence in performance is largely attributed to the pelleting process, which tends to homogenize particle size distribution, effectively minimizing structural differences created by grinding intensity (Abdollahi et al., 2011). Particle size reduction during pelleting is thought to occur because larger particles are preferentially fractured under the compressive forces generated by the narrow gap between pellet rollers and the die, as well as the frictional forces within the die channels.

It is noteworthy that the optimal feed microstructure may vary with bird age. During the starter phase, broilers are assumed to have an incompletely developed gizzard, which may limit their tolerance for large feed particles compared with later grow-out phases. Several studies have reported negative effects of high inclusion levels of coarsely ground maize particles in mash diets fed to young birds, an effect commonly attributed to the limited grinding capacity of an immature gizzard. In contrast, when diets are provided in pelleted form, even during the starter phase, broilers exhibit a high tolerance for coarse particles. These findings indicate that pelleting process largely mitigates the negative effects of coarse particles observed in mash diets and allows the inclusion of coarser grains even in young broilers. Therefore, and based on the available literature, responses observed in broilers fed mash diets differing in particle size cannot be directly extrapolated to pelleted or crumbled diets, as particle size differences are largely reduced during the pelleting process. In broilers fed pelleted or crumbled diets, the inclusion of coarsely ground grain does not appear to depress FI and may, in fact, improve feed utilisation. From a feed manufacturing perspective, coarse grinding offers additional advantages, including substantial energy savings with wider grinder screen openings and increased mill throughput.

References are available upon request.

About Dr. Reza Abdollahi

Dr. Reza Abdollahi is currently affiliated with the Monogastric Research Centre, at Massey University as an Adjunct Professor of Poultry Nutrition. He is also the founder of "A2Z Poultry Feed DynamikZ", an international independent research and consultancy firm. Dr Abdollahi is a globally recognized poultry nutrition expert with over 28 years of experience across academia, research, and industry, with an extensive track record in feed formulation, nutrient utilisation, and commercial poultry performance optimisation.

About Marc Perel

An engineer specializing in feed manufacturing technologies, Marc Perel is the founder of FeedSphere Solutions©, an independent consulting firm serving the global animal nutrition industry. With more than 30 years of international experience and projects spanning over 400 production sites in 45 countries, he provides expert guidance on feed manufacturing, process optimization, and industrial performance, helping companies implement practical, unbiased solutions tailored to their operational needs.