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The Impact of Particle Size Distribution on Extruded Pet Food Performance, Quality and Palatability

Implications for Manufacturers, Retailers and Regulatory Stakeholders

Executive Summary

Particle size distribution (PSD) is a foundational variable in extruded pet food systems that directly i**nfluences processing performance, product quality and animal preference.** While often treated as a secondary specification, PSD plays a central role in how ingredients hydrate, cook and ultimately form the structure and texture of the finished product.

This paper consolidates two stages of research. The first establishes the fundamental relationship among ingredient particle size, extrusion stability and die design constraints. The second applies those principles through improved grinding practices, demonstrating measurable improvements in process efficiency, product integrity and palatability.

The results show that tighter control of PSD—particularly reducing large particle outliers and improving overall uniformity—**can enable more stable processing, improved texture, reduced waste and significantly higher animal preference.** At the same time, PSD must be managed within an optimal range to avoid unintended process and safety challenges.

The findings presented are based on original research using specific formulations and processing conditions at the time and should be validated using the reader's own systems.including Walmart, Kroger, Whole Foods and Target — are strengthening clean-label standards that make artificial flavor removal a cost of doing business. As a result, natural flavors derived from botanical extracts, fermentation-derived ingredients and enzymatically treated natural compounds are rapidly becoming **the new industry standard.**

1. Introduction

Extrusion is a highly interactive process where ingredient properties, formulation design and processing conditions converge to define final product performance. Among these variables, particle size distribution is often specified but not fully optimized, despite its influence across nearly every stage of the process.

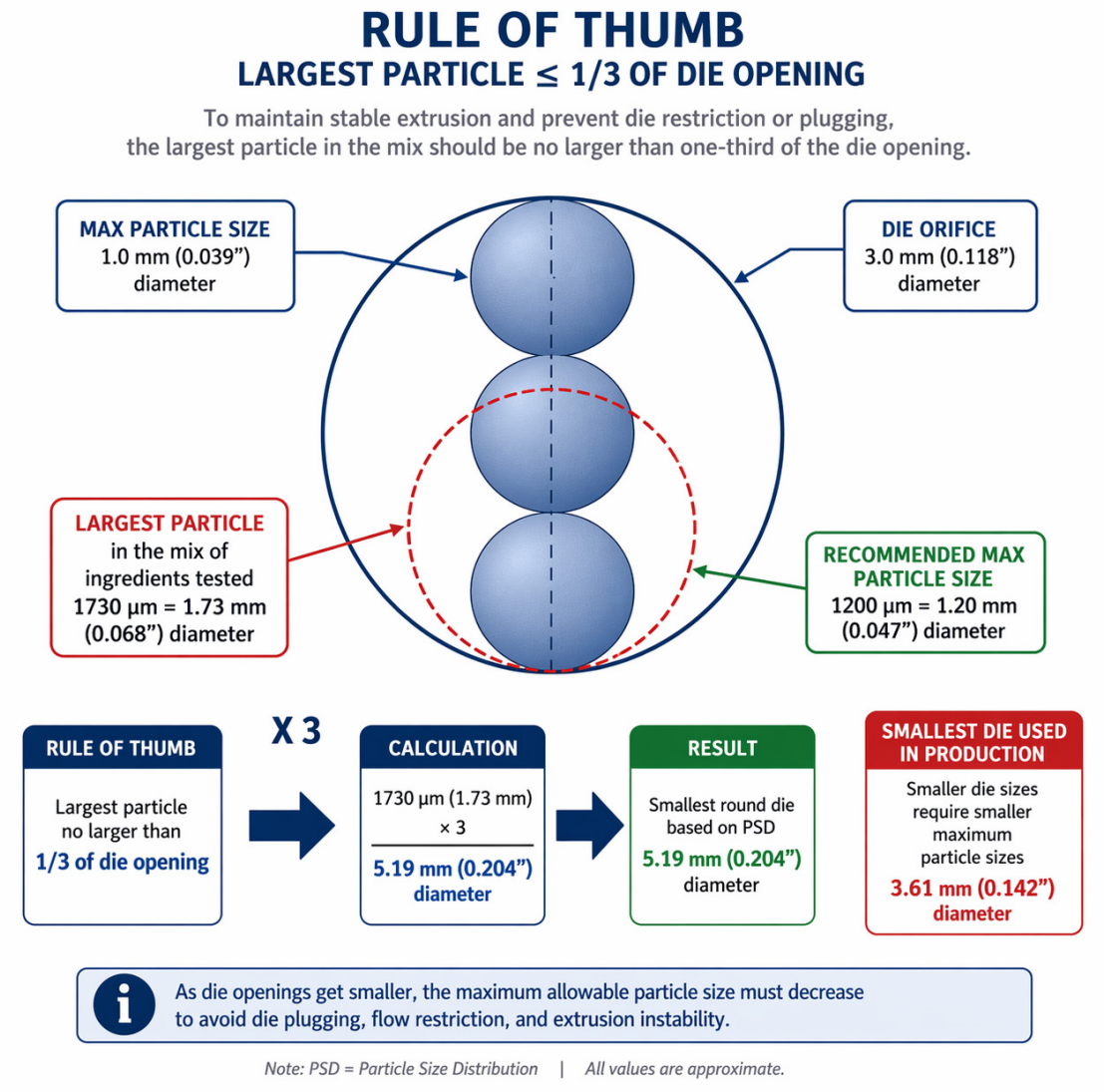
As product expectations evolve—requiring improved texture, palatability and more precise product forms—PSD becomes increasingly important as both a constraint and an opportunity within the extrusion system.

2. Ingredient Particle Size AS A PROCESSING CONSTRAINT AND ENABLER

Particle size distribution governs how materials hydrate, mix and cook during extrusion. Variability in particle size introduces inconsistency in conditioning behavior, which can lead to instability in extrusion performance and reduced process efficiency. **Tighter PSD control—particularly targeting all particles below approximately 1000 microns—enables more uniform hydration and improved cooking efficiency**. A critical engineering relationship exists between particle size and die geometry. The largest particle must be small enough to pass through the die opening, leading to a widely applied rule (see figure 1).

To maintain stable extrusion and prevent die restriction or plugging, the largest particle in the system should not exceed approximately one-third of the die opening dimension. As die sizes decrease, allowable particle size must decrease proportionally to maintain process stability. Failure to meet this relationship can limit product design flexibility, increase the risk of die plugging and introduce variability into the extrusion process.

FIGURE 1. RELATIONSHIP BETWEEN INGREDIENT PARTICLE SIZE AND DIE OPENING GEOMETRY



3. Application of PSD Control Through Grinding Strategy

To address PSD variability, a secondary grinding approach was implemented in which the fully blended ingredient system was reprocessed to improve distribution uniformity. This whole-batch grinding method significantly reduced the dominant particle size and transformed the distribution into a more homogeneous profile. With improved PSD, hydration behavior became more consistent, enabling more efficient starch gelatinization and creating a more stable relationship between process conditions and product structure.

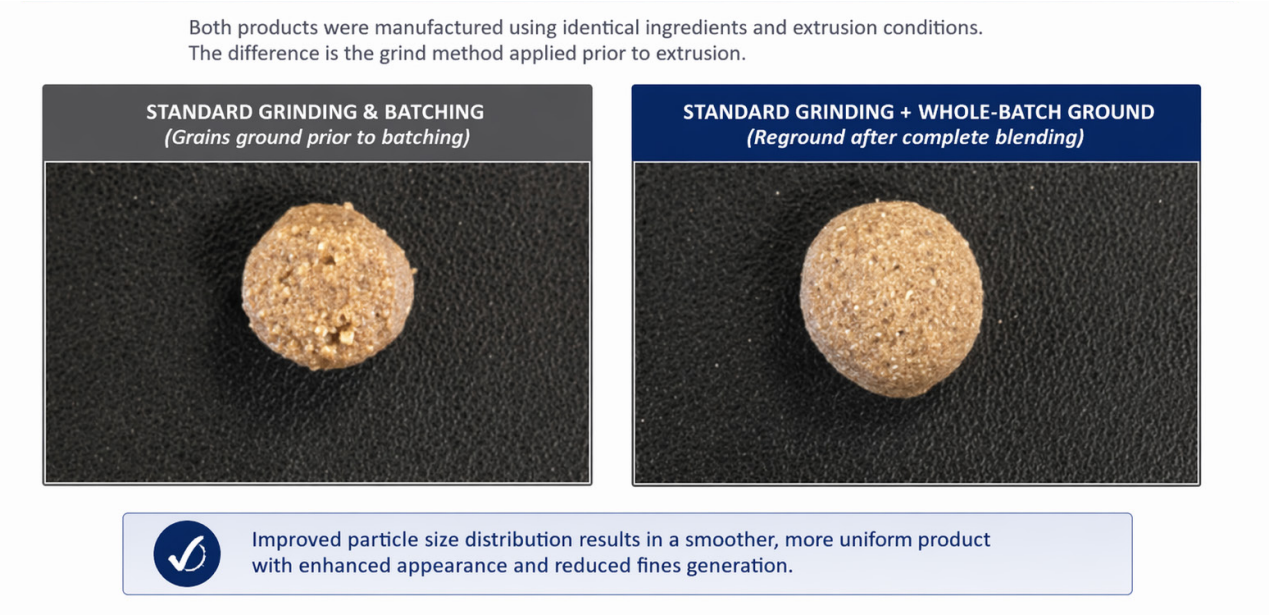
This validates the fundamental conclusion that PSD control is a practical and effective lever for improving extrusion performance.

4. Impact on Product Quality and Performance

Improvements in PSD translated directly into measurable differences in finished product quality. Texture became more consistent and aligned with desired feeding characteristics. Products manufactured with tighter PSD also demonstrated significantly improved durability, including a substantial reduction in broken pieces and fines during handling and packaging. Palatability results further reinforced these improvements. Products produced with a finer and more uniform PSD showed strong preference outcomes in feeding studies, indicating a direct connection between particle size, structure and feeding response.

Products produced with improved particle size distribution exhibit a smoother, more uniform structure and enhanced

FIGURE 2. VISUAL COMPARISON OF PRODUCTS PRODUCED WITH STANDARD GRINDING VS. WHOLE-BATCH GROUND PSD



visual quality. These improvements occur despite identical formulations and extrusion conditions, with the only variable being the grinding method applied before processing.

This comparison illustrates how PSD influences not only internal product structure but also visible qualityand consistency.

5. Integrated Understanding: FROM INGREDIENT TO OUTCOME

The combined research establishes a clear progression from ingredient characteristics to product performance. Improved particle size uniformity leads to consistent hydration and cooking behavior, which enhances extrusion stability and allows for better control of texture development.

The result is a finished product that is more uniform, more durable and more palatable. PSD therefore acts as a critical bridge linking ingredient preparation, process execution and final product outcomes.

6. Practical Application

From a practical standpoint, PSD should be treated as a primary design variable. Improving distribution uniformity and reducing large particle outliers can significantly enhance process stability and product consistency. At the same time, reducing particle size beyond an optimal range can introduce unintended consequences. Extremely fine particles may create challenges related to dust generation, ingredient handling and flowability, as well as potential safety concerns associated with airborne particulate.

In addition, overly fine PSD can alter hydration behavior and lead to undesirable product structure or density changes. For these reasons, PSD optimization should be approached as a balanced system design challenge rather than simply driving toward the smallest possible particle size. Grinding strategies, ingredient functionality and extrusion conditions must be aligned to achieve the desired outcome without introducing downstream risks.

7. Limitations and Validations

The findings presented are based on specific ingredient systems and processing environments evaluated during the original research. Variations in raw materials, equipment design and operating conditions may influence outcomes. All recommended changes should be validated through controlled testing using the reader's own formulations and production systems before implementation.

Particle size distribution is one of the most influential and controllable variables within extrusion-based pet food systems. When properly managed, it enables improvements in process efficiency, product integrity and palatability.

8. Conclusion

However, optimal performance requires balancing PSD reduction with practical considerations related to safety, handling and functionality. When approached as a system-level design variable, PSD provides a powerful opportunity to enhance both technical performance and product differentiation.