



Whole-cereal utilization in swine feeding systems: balancing agronomic yield and nutritional output

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Abstract. This mini-review examines the integration of whole cereal utilization in swine feeding systems, with a focus on reconciling agronomic productivity and nutritional efficiency. Cereals, recognized for their high yield per unit area, offer opportunities for whole-crop use (including grain and vegetative fractions) to enhance biomass recovery. However, such strategies introduce trade-offs between increased field yield and reduced dietary energy density due to elevated fiber content. Evidence from studies on corn, sorghum, and wheat systems indicates that moderate inclusion levels of whole-crop silages can sustain acceptable growth performance in pigs, while excessive inclusion negatively affects digestibility, carcass traits, and nutrient utilization. Fiber composition emerges as a critical determinant of energy and phosphorus digestibility, interacting with starch availability and processing methods. Furthermore, harvest timing significantly influences the balance between biomass yield and nutritive value, with intermediate maturity stages generally optimizing both parameters. Overall, the review highlights that strategic management of inclusion rates, harvest timing, and processing technologies is essential to maximize the efficiency of whole cereal systems in pig production.

Keywords: agronomic yield, corn, digestibility, fiber content, harvest timing, sorghum, starch availability, swine nutrition, whole cereals, whole crop silage.

Introduction. Cereals are among the crops with the highest productivity per unit area (Tiwari et al 2011; Pandey & Tiwari 2012; Syafruddin, 2017; Aedin et al., 2019; Guta & Marin, 2020; Pandey et al., 2026). Using whole cereals (grain plus vegetative fractions or whole-ear/whole-plant silages) links field productivity with pig performance. The studies below allow a structured discussion of yield–quality trade-offs, fiber–digestibility relationships, and harvest timing, with emphasis on corn and sorghum whole-crop uses and on grain composition effects.

The aim of this mini-review is to critically evaluate the use of whole cereals in swine feeding systems by integrating agronomic and nutritional perspectives. Specifically, the study seeks to: (i) analyze the trade-offs between biomass yield and nutritional value associated with whole-crop utilization; (ii) assess the impact of fiber content and composition on nutrient digestibility and energy utilization in pigs; and (iii) identify optimal harvest strategies that balance field productivity with feed efficiency. Through this approach, the review aims to provide a conceptual framework for improving the sustainability and performance of cereal-based feeding systems in pig production.

Agronomic Yield vs. Nutritional Value. Whole-plant or whole-ear systems increase biomass harvested per hectare, but dilute energy and protein with fibrous fractions. Whole-ear corn silage (grain + cob + some husk) had lower dietary P and similar neutral detergent fiber (NDF) to grain-based controls, with comparable metabolizable energy (ME) per kg dry matter (DM) and no loss in average daily gain up to 30% dietary inclusion, although carcass leanness and P retention decreased (Zanfi et al., 2014). Whole-plant corn

silage replacing grain up to about 7.5-12.5% of diet DM reduced final body weight and net protein utilization at the highest inclusion, but moderate levels maintained growth and improved some intestinal morphology indices (Ma et al., 2024). Ensiled whole-grain sorghum supported efficient energy and P utilization when fermented at optimal DM, allowing reduced mineral P supplementation (Puntigam et al., 2021). For ruminants, biomass-type sorghum maximized DM yield but had the lowest ME, whereas grain-type sorghum gave lower yield but clearly higher silage energy value, illustrating the classic biomass–nutritive value trade-off (Terler et al., 2021) (Table 1, Figure 1). Under agrivoltaic shading, whole-crop durum wheat biomass showed somewhat reduced yield but improved fiber digestibility and protein, allowing more flexible harvest for forage quality (Prà et al., 2024; Cheţan et al 2025).

Table 1

Examples of whole-crop vs grain-focused systems

<i>System / material</i>	<i>Main agronomic advantage</i>	<i>Main nutritional constraint or effect in pigs</i>	<i>Sources</i>
Whole-ear corn silage (15-30% diet DM)	Higher field biomass per ha than grain	Similar ME and average daily gain (ADG); lower carcass leanness, P retention at 30%	Zanfi et al., 2014
Whole-plant corn silage (5-15% diet DM)	Utilizes entire plant, lowers feed cost	High inclusion ↓ body weight (BW), ADG, energy, protein digestibility	Ma et al., 2024
Ensiled whole-grain sorghum (variable DM)	One harvest, long-term storage	Lower DM at ensiling (≈70% DM) ↑ energy and P digestibility	Puntigam et al., 2021
Biomass vs grain sorghum (ruminants)	Biomass types: maximal DM yield	Grain types: higher ME; optimum at dough stage	Terler et al., 2021
Whole-crop durum wheat under agrivoltaics	Co-produce feed + electricity, stable Ca:P	Slight yield penalty; ↑ digestible NDF and protein	Prà et al., 2024

Digestibility vs. Fiber Content. In grain-based diets, higher fiber (NDF, acid detergent fiber (ADF), non-starch polysaccharides (NSP)) consistently reduces available energy, whereas starch improves it (Rosenfelder-Kuon et al., 2017; Wafar et al., 2021). Across corn, wheat and rice samples, DE and ME were negatively associated with NDF and ADF and positively with starch; prediction equations show ADF and starch as key levers for energy value (Wafar et al., 2021). Ileal starch digestibility in cereals was generally high (≈92-97%) but decreased with increasing soluble and insoluble NSP, making low-fiber triticale superior in ileal digestible starch content to barley and wheat (Rosenfelder-Kuon et al., 2017).

When whole-plant fractions are included, total fiber rises and energy efficiency tends to fall. In whole-plant corn silage diets, increasing silage from 5 to 15% of the diet progressively reduced digestibility of DM, crude protein (CP), fat and gross energy and worsened feed conversion at the highest level (Ma et al., 2024). Whole-ear corn silage at up to 30% of dietary DM maintained overall energy balance but lowered P digestibility and carcass lean content (Zanfi et al., 2014).

Cereal fiber type also modulates mineral utilization. Barley cultivars rich in fermentable fiber (amylose, β-glucan) had lower apparent and standardized P digestibility than lower-fermentable cereals, even though total tract release of P from phytate was higher; fermentation increased phytate hydrolysis but also endogenous losses (Heyer et al., 2022). In fermented whole-grain sorghum, lower ensiling dry matter markedly improved apparent total tract digestibility (ATTD) of energy and P, again linking fiber–starch matrix properties with nutrient recovery (Puntigam et al., 2021). High-fiber ingredients in general depress energy digestibility in pigs but can be partially compensated by processing (e.g. extrusion, particle size reduction) and by enzyme use, especially xylanases and related carbohydrases that improve ATTD of DM, CP and gross energy (GE) in cereal-based diets (Rojas & Stein, 2017; Torres-Pitarch et al., 2019; Zhang et al., 2023).

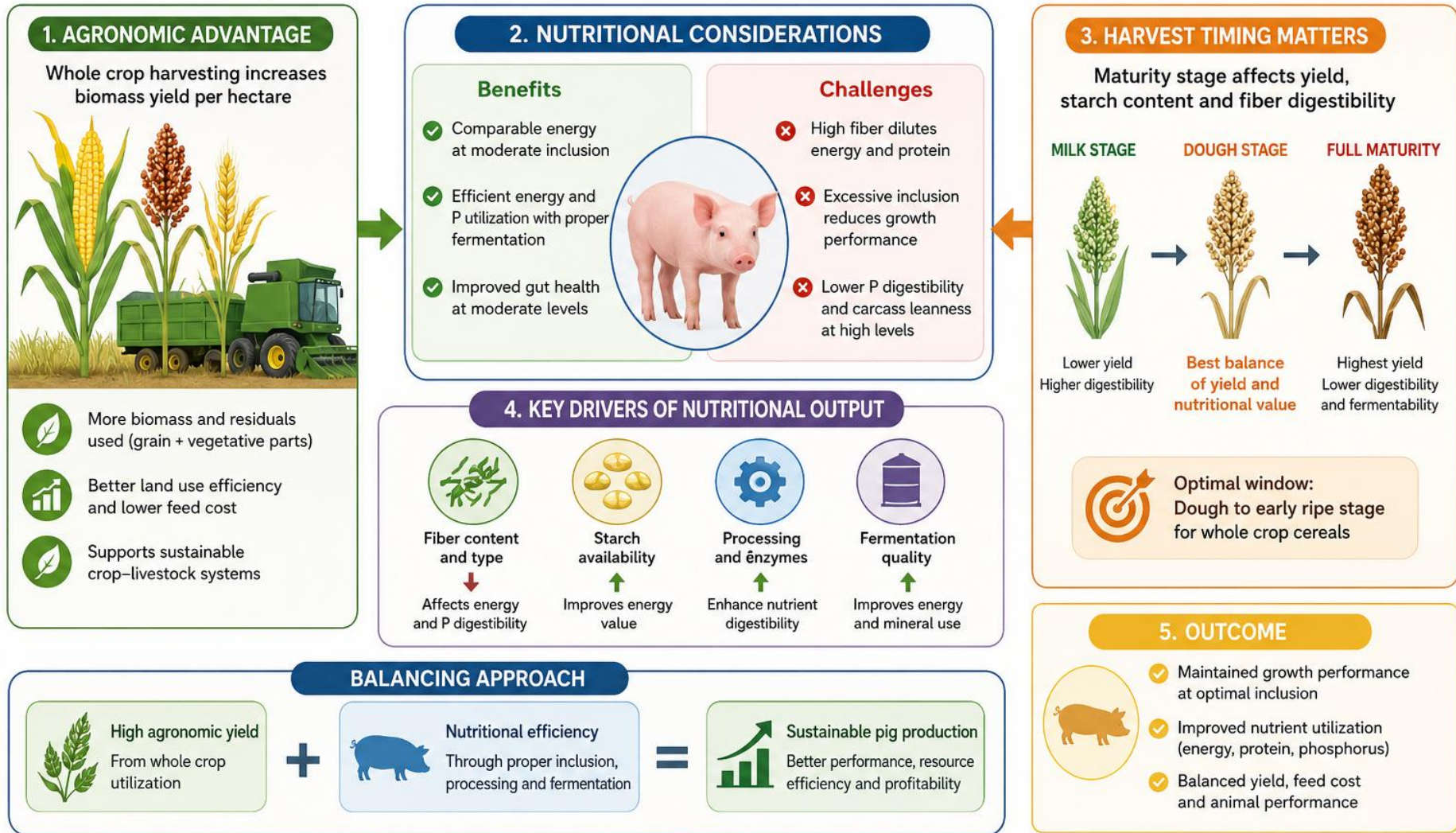


Figure 1. Whole-cereal utilization in swine feeding systems: balancing agronomic yield and nutritional output.

Optimization of Harvest Timing. For cereals harvested as whole crops, maturity stage at cutting governs starch accumulation, fiber composition and thus the balance between field yield and digestibility. In sorghum for ruminants, DM yield increased from late milk to dough stage and then plateaued, while ME of whole-crop silage rose between late milk and dough but declined at full maturity; grain-type sorghum at dough stage optimally combined yield and nutritive value (Terler et al., 2021). Sorghum stalk silage harvested at the ripe stage had the highest DM, relative feed value and in vitro digestibility, as well as a favorable fermentation microbiota, compared with milk or dough stages (Zhao et al., 2025).

For whole-grain sorghum silages destined to pigs, different harvest dates created silages with 70-81% DM. Pigs fed silage made from earlier, lower-DM harvests showed higher ATTD of energy and nutrients, particularly P, than those fed late-harvest, very dry silage, suggesting that too-mature grain (high DM) compromises fermentability and nutrient extraction (Puntigam et al., 2021). In small-grain grasses for dairy, harvesting at soft dough rather than boot stage increased DM yield by 107-205% but also increased fiber and undegraded NDF and reduced CP, so ration formulation software did not consistently prefer one maturity stage under varying price scenarios (Ferreira et al., 2025). This illustrates that optimal harvest timing depends on economic context and the targeted animal response.

In pig-adapted systems, extrapolating these data suggests that intermediate maturity (dough to early ripe) for whole-crop cereals may best reconcile agronomic yield with acceptable starch concentration and fiber digestibility, while avoiding the sharp declines in nutrient digestibility observed with very high whole-crop inclusion levels in pig diets (Zanfi et al., 2014; Puntigam et al., 2021; Ma et al., 2024).

Conclusions. The use of whole cereals in swine feeding systems represents a viable strategy to enhance overall agricultural efficiency by linking crop yield with animal production. However, this approach is inherently constrained by the inverse relationship between fiber content and nutrient digestibility. While moderate inclusion of whole-crop materials can maintain acceptable growth performance, high inclusion levels compromise energy availability, protein utilization, and carcass quality. Fiber type and physicochemical properties play a central role in modulating nutrient recovery, particularly for energy and phosphorus, and can be partially mitigated through processing technologies and enzyme supplementation. Harvest timing further influences the nutritional profile of whole-crop cereals, with intermediate maturity stages offering the most favorable compromise between yield and digestibility. Ultimately, optimizing whole cereal utilization in pig systems requires a systems-level approach that integrates agronomic practices, feed formulation, and technological interventions to achieve both economic and biological efficiency.

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