Implementation of nutrient kinetics concept in formulation of pig's starter feed

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ABSTRACT

Objective: To compare a conventional starter feed (Milkiwean®) with a starter feed formulated under the concept of digestion and absorption kinetics of nutrients (Milkiwean Kinetio®) in piglets.

Methodology: A total of 440 piglets (initial body weight 6.4±0.83 kg and 22 days of age) were randomly assigned following a completely randomized design. The experimental treatments consisted of evaluating two starter diets: Milkiwean® and Milkiwean Kinetio®.

Results: Pigs fed the standard diet exhibited greater body weight gain, final body weight, and feed intake (P=0.08); however, feed conversion ratio was significantly improved with Milkiwean Kinetio® (P=0.001). Additionally, the cost per kilogram of pork produced was lower with Milkiwean Kinetio®.

Implications: Further research is needed on the synchronization of digestion and absorption of nutrients from dietary ingredients used in pig production.

Findings/Conclusions: Formulating pig diets based on the kinetics of nutrient digestion and absorption has the potential to enhance nutrient utilization.

Keywords: digestion kinetics, absorption kinetics, pigs

Citation: Martínez-Aispuro, J. A., Soni-Guillermo, E., Martínez-Aispuro, M., Morales-Ortigoza A., Figueroa-Velasco, J. L., Pérez-Sato, M., Pérez-Martínez J., & Castro González, N. P. (2025). Implementation of nutrient kinetics concept in formulation of pig's starter feed. *Agro Productividad*. https://doi.org/10.32854/wj9ecz19

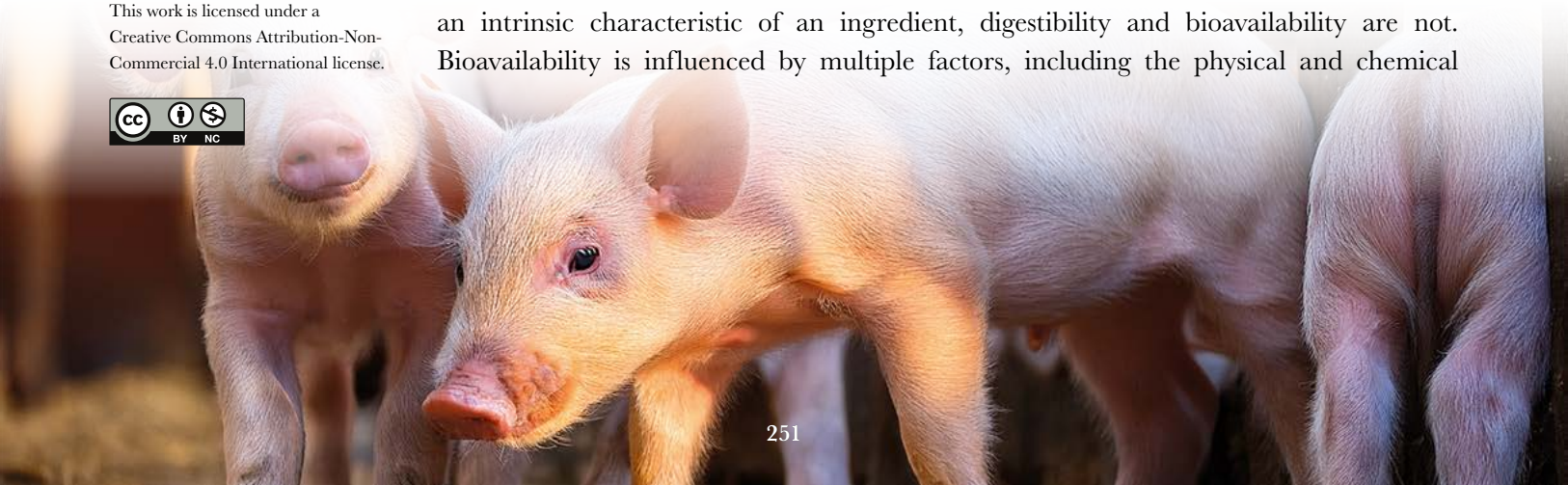
Academic Editor: Jorge Cadena Iñiguez
Associate Editor: Dra. Lucero del Mar Ruiz Posadas
Guest Editor: Daniel Alejandro Cadena Zamudio

Received: July 11, 2025.
Accepted: August 12, 2025.
Published on-line: September XX, 2025.

Agro Productividad, 18(9) supplement. September. 2025. pp: 251-256.

INTRODUCTION

Traditional systems for evaluating the nutritional value of feed ingredients have primarily relied on dietary inclusion rates, determined by nutrient concentrations and their digestibility coefficients. However, these approaches do not adequately account for differences in the rate, extent, and timing of nutrient digestion and fermentation throughout the gastrointestinal tract [1]. While nutrient composition can be considered an intrinsic characteristic of an ingredient, digestibility and bioavailability are not. Bioavailability is influenced by multiple factors, including the physical and chemical



structure of the nutrient, the source ingredient, the diet in which it is incorporated, and the animal's physiological capacity to degrade, absorb, and utilize those nutrients. Consequently, the extent to which ingested nutrients are digested and utilized depends on the interaction between diet composition and the animal's metabolism [2]. An emerging approach to assessing the nutritional value of feed ingredients involves analyzing the digestion kinetics of starch, fiber, and proteins in pigs [3]. Understanding the dynamics of nutrient digestion enables the development of more precise formulation strategies that enhance nutritional efficiency, reduce the incidence of digestive disorders such as diarrhea, and decrease nutrient excretion into the environment [2]. Currently, commercial products have been developed incorporating the concept of nutrient degradation kinetics into their formulations. One such example is Milkiwean Kinetio®, which differs from its standard counterpart (Milkiwean®) by being designed under the principle of sequential nutrient digestion potentially leading to significantly improved nutrient utilization. Within this context, the aim of the present study was to compare the productive performance of weaned pigs fed a standard starter feed versus one formulated based on the concept of nutrient digestion and absorption kinetics (Milkiwean Kinetio®).

MATERIALS AND METHODS

The study was conducted at the commercial pig farm "Villa Rica," located in the municipality of Zapopan, Jalisco, Mexico. The region has a warm sub-humid climate, with an average annual temperature of 20.5 °C and an average annual rainfall of 943 mm. Animal management was carried out in accordance with the technical specifications for the production, care, and use of laboratory animals, complying with the provisions of the Mexican Official Standard NOM-062-ZOO-1999 (SAGARPA, 2001).

The experiment involved a total of 440 newly weaned piglets (220 castrated males and 220 females), the offspring of Large White×Hampshire crosses, with an average initial body weight (BW) of 6.4±0.83 kg and an average age of 22 days. The animals were housed in group pens (10 pigs per pen) equipped with nipple drinkers and hopper-type feeders, with *ad libitum* access to feed and water. Throughout the experimental period, no clinical signs of respiratory or digestive diseases were observed. The piglets were randomly assigned to two treatments, balancing initial body weight and sex across 44 pens. The treatments involved the evaluation of two starter feeds for weaned pigs, both developed by Trouw Nutrition, Mexico: T1: standard Milkiwean® and T2: Milkiwean Kinetio®. The experimental period lasted 29 days.

Milkiwean® is a pelleted starter feed (2.5 mm) structured in four phases: Phase 0: days 21-23 of age, 6-6.5 kg BW, estimated dry matter intake (DMI): 0.5 kg. Phase 1: days 24-32 of age, 6-9 kg BW, estimated DMI: 2.75 kg. Phase 2: days 33-39 of age, 9-11.2 kg BW, estimated DMI: 3.0 kg and Phase 4: days 40-49 of age, 11.2-16 kg BW, estimated DMI: 6.25 kg.

Milkiwean Kinetio®, on the other hand, is a starter feed formulated under the concept of digestion kinetics. It incorporates ingredients that provide a balanced mix of protein and starch sources with varying digestion rates (rapid, slow, and resistant), as well as fibers with different fermentation rates (rapid, slow, and resistant).

Response variables

The following productive variables were evaluated: average daily gain (ADG), cumulative weight gain (CWG), average daily feed intake (FI), cumulative feed intake (CFI), feed conversion ratio (FCR), and final body weight (FBW). Additionally, an economic analysis was conducted based on the relationship among dry matter intake (DMI), feed conversion ratio (FCR), and average daily gain (ADG).

Statistical analysis

The experimental design was completely randomized, with two treatments and 22 replicates per treatment; each pen was considered an experimental unit. Prior to analysis, the Shapiro-Wilk and Levene's tests were applied to verify data normality and homogeneity of variances, respectively. Subsequently, an analysis of variance (ANOVA) was performed using the GLM procedure of the Statistical Analysis System (SAS, 2010; Cary, NC, USA), with a significance level of $P \leq 0.10$. Mean comparisons between treatments were conducted using Tukey's test ($P \leq 0.10$). Initial body weight was included as a covariate in the statistical model ($P \leq 0.10$) to adjust for potential initial effects on the productive variables evaluated.

RESULTS AND DISCUSSION

Table 1 presents the results of the productive performance of pigs during the starter phase. Final body weight (FBW), average daily gain (ADG), and cumulative weight gain (CWG) were higher in pigs fed the standard Milkiwean® diet ($P=0.08$). Similarly, both daily and total dry matter intake (DMI) throughout the experimental period were significantly greater with the use of the standard Milkiwean® feed ($P=0.001$). However, despite the Milkiwean Kinetio® treatment showing lower ADG and reduced feed intake, it

Table 1. Productive performance of starter pigs fed with two starters.

Item	T1: Milkiwean	T2: Milkiwean Kinetio	SE	P
Initial number of pigs	220	220		
Final number of pigs	217	218		
Mortality, number	3	2		
Initial body weight, kg/pig	6.42	6.41	0.83	-
Final body weight, kg/pig	15.87	15.45	0.16	0.08
ADG, kg	0.330	0.310	0.01	0.08
Cumulative ADG, kg	9.45	9.03	0.16	0.08
Daily DMI, kg	0.410	0.370	0.01	0.001
Total DMI, kg	11.78	10.70	0.20	0.001
DMI Phase 0, kg	0.51	0.50		
DMI Phase 1, kg	2.79	2.78		
DMI Phase 2, kg	3.04	3.03		
DMI Phase 3, kg	5.43	4.39		
Feed Conversion Ratio	1.25	1.18	0.01	0.001

T: Treatment; SE: Standard Error; ADG: Average Daily Gain; DMI: Dry Matter Intake.

exhibited a significantly improved feed conversion ratio (FCR) compared to the standard feed (P=0.001), suggesting a higher nutrient utilization efficiency in this group.

The breakdown of feed cost and consumption per phase is detailed in Table 2. The price per kilogram of both feeds was similar; however, due to the higher intake observed in the group fed the standard Milkiwean® diet, the cumulative feeding cost began to diverge starting from Phase 3. The total feed cost over the entire period was higher for the standard Milkiwean® diet ($8.271 USD) compared to Milkiwean Kinetio® ($7.652 USD).

When the total feeding cost is related to the weight gain achieved, the cost per kilogram of pork produced was lower with Milkiwean Kinetio® ($0.847 USD/kg) than with the standard feed ($0.875 USD/kg), indicating greater economic efficiency of the digestion kinetics-based treatment. It is important to note that the nutritional value of feed ingredients is not strictly additive, as it is influenced by complex interactions between the diet and the animal. Nevertheless, conventional feed formulation and evaluation practices often assume nutrient additivity and rely on static nutritional values, largely due to the lack of more precise tools [4].

To advance toward more realistic models, it is essential to consider the dynamic processes of digestion, metabolism, and specific interactions between diet and animal physiology. In this context, models have been developed that integrate parameters such as digestive kinetics, variability in feed intake, enzymatic digestion, hydrolysis, and nutrient absorption providing a more robust framework for understanding the complex nutritional processes occurring in pigs [2]. The composition and origin of feed ingredients directly influence their physicochemical properties, which in turn affect nutrient degradability and solubility both for individual ingredients and for the diet as a whole. This variability impacts nutrient absorption along the gastrointestinal tract [5]. Currently, physicochemical properties of nutrients or diets such as solubility, viscosity, and pH are not routinely considered in feed formulation, despite being determined by the specific composition of the ingredients used. Although existing digestive models can provide detailed insights to support post-

Table 2. Feed cost of starter pigs fed with two starters.

Item	T1: Milkiwean	T2: Milkiwean Kinetio
Feed cost, $ USD/kg*		
Milkiwean Phase 0	$1.030	$1.068
Milkiwean Phase 1	$0.823	$0.834
Milkiwean Phase 2	$0.669	$0.671
Milkiwean Phase 3	$0.629	$0.630
Cost of feed consumed, $ USD/kg*		
Milkiwean Phase 0	0.525	0.534
Milkiwean Phase 1	2.296	2.319
Milkiwean Phase 2	2.034	2.033
Milkiwean Phase 3	3.416	2.766
Total feeding cost, $/pig	$8.271	$7.652
Cost per kg of pork produced, $ USD	$0.875	$0.847

*Only includes the cost of raw materials, packaging, and manufacturing. T: Treatment.

absorptive metabolic models and predict the nutritional value of pig diets, they still have significant limitations. In particular, they are unable to simulate variation in nutrient absorption kinetics originating from diets with identical nutrient profiles but differing ingredient sources. Incorporating dietary factors such as feed viscosity, nutrient solubility, feed intake levels, and differentiation between gastric emptying of solids and liquids would allow for the development of more realistic models that simulate the transit and digestion of each ingredient within the stomach [4]. Within the scope of precision swine nutrition, significant advances can be achieved through the assessment of digestion kinetics of dietary chemical components, also considering circadian behavior, gastrointestinal microbiota, and the functional properties of dietary ingredients [2,6]. Beyond the quantitative content of nutrients or metabolites, the rates of digestion and fermentation are crucial for understanding the timing of nutrient release along the gastrointestinal tract. This information is critical for predicting the post-absorptive appearance of nutrients and their metabolic effects [7]. Information on protein digestion kinetics can be used to develop strategies that synchronize the supply of energy and protein, thereby improving protein retention and utilization efficiency in pigs [8]. This is particularly relevant because, even when amino acids are absorbed, they may not always be fully bioavailable or available at the right time for metabolic utilization [5]. The postprandial appearance of amino acids and peptides in the bloodstream is associated with the kinetics of free amino acid and di-/tripeptide release during digestion. Therefore, ingredients can be classified as sources of rapidly digestible protein such as wheat gluten or plasma protein and slowly digestible protein such as soybean meal, canola meal, or black soldier fly larvae [8]. In weaned piglets, whose gastric conditions include a relatively high pH, it is advisable to select protein sources with greater solubility at this pH, as higher solubility accelerates protein degradation. Rapidly digestible proteins reduce the risk of diarrhea by minimizing the amount of undigested protein available to pathogenic bacteria in the large intestine. Starch digestion kinetics also has significant effects on productive response. It has been observed that pigs fed higher proportions of resistant or slowly digestible starch exhibit longer intervals between meals and more prolonged feeding patterns compared to those fed rapidly digestible starch [9]. This kinetic behavior is influenced by starch characteristics such as the amylose-to-amylopectin ratio, particle size, processing method, and interactions with other dietary components. Based on the rate and extent of enzymatic digestion, starch can be classified as rapidly digestible, slowly digestible, or resistant [10]. It is worth noting that gastric starch digestion is often underestimated, which can lead to overestimation of the starch fraction reaching the small intestine, thereby affecting the accuracy of *in vitro* models [10]. Given that starch is the primary quantitative macronutrient in pig diets, it may also alter the digestion kinetics of other nutrients, such as proteins and minerals. In swine diet formulation, the concept of fiber degradation and fermentation kinetics is applied to improve gastrointestinal health, digestive system development, and digesta transit. Proper characterization of dietary fiber fractions is essential, as they can influence the production of short-chain fatty acids, lactate, gases, and the composition of the intestinal microbiota [11]. Poorly fermentable fibers tend to support intestinal epithelial regeneration and improve fecal quality, while highly fermentable fibers serve as substrates for intestinal

bacteria, promoting digestive health benefits. However, excessive fermentable fiber may induce osmotic imbalances and intestinal disorders [12].

CONCLUSION

Based on the results obtained in this study, it can be concluded that formulating starter diets for pigs based on the concept of nutrient digestion kinetics has the potential to optimize dietary nutrient utilization. This strategy enhances feed efficiency and reduces production costs, while promoting a more precise and sustainable approach to swine nutrition.

ACKNOWLEDGMENTS

The authors express their gratitude to the Knowledge Generation and Application Line "Technological Innovation and Food Quality in Livestock" of the Colegio de Postgraduados, as well as to Trouw Nutrition Mexico for their collaboration in the development of this study.

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