Results and Discussion

Although IPF estimations are in average accurate (Remus et al., 2020; Hauschild et al., 2020), and results in SID Lys efficiency of utilization greater than conventional methods (Pomar et al., 2021), there are several limitations in this and similar factorial methods. The SID Lys requirements are the sum of maintenance (e.g. body renewal, digestive losses) and growth requirements (Lys efficiency of utilization and PD rate). However, Lys efficiency of utilization can vary by more than 50% between pigs with the same genetic background and age. Similarly, finishing pigs with the same body weight have different body fat content (Salgado et al., 2020). Body lipid synthesis and degradation are regulated by complex mechanisms, but are mainly driven by blood glucose concentration and insulin secretion. Yet, insulin secretion varies by 40% and more among pigs of similar genetic background, weight, and feed. Also, pigs with greater PD present lower transcript abundance related to genes associated with protein turnover, oxidative stress and immune system activation (Remus et al., 2022). Hence, actual mathematical models used for precision nutrition are limited by their ability to represent all these sources of between animal variation and by the scarcity of real-time relevant farm data needed to precisely estimate in real-time the amount of each nutrient that each pig needs at a given time to express it full growth potential. Grey-box models integrating artificial intelligence able to handle complex and dynamic data, associated with more comprehensive mechanistic models, are needed advance precision nutrition.

Conclusion and implications

Although precision nutrition can significantly improve nutrient efficiency by providing each pig with the required amount of each nutrient in real-time, it relies on the utilization of sound nutritional concepts and comprehensive biological models. New models are needed to further develop actual precision nutrition systems integrating the observed variation among animals. Developing new feeding systems can only be achieved by developing a new way of thinking and solving problems.

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14. SNAPIG: a model to study nutrient digestion and absorption kinetics in growing pigs based on diet and ingredient properties

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Introduction

The nutritional value of feed ingredients for pigs is known to be affected by the kinetics of nutrient digestion, which in turn is affected by diet × animal interactions. Although current feed evaluation systems provide invaluable tabular values regarding the chemical composition and nutrient digestibility of feedstuffs, interactions between ingredients and between the diet and animal are not accounted for in predicted nutritional values. To aid future predictions of the nutritional value of diets and feed ingredients, an *in-silico* nutrient-based mechanistic digestion model (SNAPIG) was developed. The model objective was to predict nutrient digestion and absorption kinetics in the gastrointestinal tract of pigs fed diets varying in feed ingredients, nutrient composition, and physicochemical properties.

Material and methods

The model was developed using AcslX (Aegis Technologies Group, Inc.). It simulates the process of nutrient digestion, representing nutrient passage, hydrolysis and absorption, and endogenous secretions along the stomach, proximal and distal small intestine, and caecum/colon, using the time unit of hour. The model comprises 48 pools representing gastrointestinal protein, starch, fat, non-starch polysaccharide, hydrolysis products, endogenous secretions, and microbial biomass. Nutrient hydrolysis kinetics vary with feed ingredient origin, and parameters were estimated from *in vitro* assay data. Feed protein, starch, and fat were differentiated in (enzymatically) degradable and undegradable fractions and specific hydrolysis rates were estimated according to their feed ingredient origin. Based on *in vivo* studies,

Table 1
Model evaluation parameters of the digestion model for growing pigs, presenting goodness of fit of observed (obs) v. predicted (pred) postprandial time of peak (TOP, h) and area under the curve[2] (AUC, % of ingested) of nutrients absorbed from the intestine.

Nutrient	Variable	Obs (SD)	Pred (SD)	R-sq	RMSPE[1] (%)	ECT[1] (%)	ER[1] (%)	ED[1] (%)	CCC[1]	Cb[1]
Glucose	TOP	56 (20)	44 (15)	0.25	39	31	4	65	0.38	0.8
	AUC	63 (20)	69 (30)	0.41	39	6	52	42	0.58	0.9
Amino acids	TOP	58 (34)	61 (11)	0.03	60	1	3	96	0.09	0.6
	AUC	63 (13)	83 (2)	0.03	40	69	0	27	-0.02	0.1
Protein	AID	70 (5)	78 (5)	0.67	12	88	0	12	0.34	0.4
Fat	AID/AFD	82 (15)	86 (4)	0.30	16	6	8	86	0.27	0.5

[1] RMSPE = root mean square prediction error (as % of observed mean), ECT = error of overall bias, ER = error due to deviation of the regression slope from unity, ED = error due to disturbance (i.e. random error), CCC = Lin's concordance correlation coefficient, Cb = bias correction faction, AID = apparent ileal digestibility, AFD = apparent faecal digestibility.
[2] Area under the curve calculated based on observed sampling time (varying from 5 to 12h).

the passage of digesta solids and liquids from the stomach was modelled as a function of nutrient solubility and by diet viscosity, diet solubility, and feed intake. Results were evaluated against independent literature data on nutrient absorption from studies with (portal) blood measurements in pigs (12 studies, 32 dietary treatments for glucose; 8 studies, 15 dietary treatments for amino acids).

Results and Discussion

Model evaluation focussed on the prediction of glucose and amino acid absorption kinetics (Table 1). The predicted time of peak (44 ± 15 *vs.* 56 ± 20 min after meal) and extent (69 ± 30 *vs.* 63 ± 20% of intake) of glucose absorption after a meal, compared with observed values, were adequate (RMSPE = 39%). For amino acids, the mean, but not the variation in time of peak could be predicted (61 ± 11 *v.* 58 ± 34 min, RMSPE = 60%). Although net portal appearance is the closest estimation for amino acid absorption from the gut, the absorption kinetics of amino acids can be affected by gut metabolism, which is not represented in the model. The extent of small intestinal protein digestion was slightly over-predicted (70 ± 5 *v.* 78 ± 5 %, RMSPE = 12%), while variation among diets and ingredients was well predicted. To improve model calibration, a more extensive observational dataset is required. Ideally, such a dataset should cover data regarding the net portal appearance of amino acids in pigs fed diets, including 'slow' and 'fast' *in vitro* degradable protein sources, and also includes passage kinetics of digesta and the extent of ileal protein digestibility.

Conclusion and implications

In conclusion, results show SNAPIG can predict variation in nutrient digestion kinetics in pigs fed diets varying in feed ingredient composition and physicochemical properties. The use of SNAPIG enables the identification of knowledge gaps in pig nutrition concerning feedstuff properties and its consequences on digestion kinetics. To further improve the evaluation of both feed nutritional value and pig growth, a post-absorptive metabolism model was also developed. The coupled digestion and metabolism model (called DyNAMPIG) will allow such evaluation.

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15. Behavioural analysis of the fasting substrate conversion for energy utilization in growing pigs using within-day kinetics in the DyNAMPig model

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Introduction

Homeostasis of metabolite pools in pigs is challenged when confronted with a rapid post-absorptive influx of nutrients. Physiological mechanisms that buffer this influx are key in overcoming this challenge, e.g. by storing excess absorbed glucose as glycogen. On the other hand, utilization of these body stores for energy in between meals ensures energy is available during fasting by providing oxidizable substrates (glucose, fatty acids). With our current development of an *in-silico* nutrient-based post-absorptive metabolism model using within-day kinetics (DyNAMPig), a representation of these mechanisms is included to accommodate predictions of the post-absorptive metabolic fate of nutrients in growing pigs. Here, we present a showcase of the conversion of body stores to metabolite pools in between meals.

Material and methods

Principles for nutrient partitioning were adapted from the pig growth model developed by Halas et al. (2004) and modified to accommodate within-day kinetics of nutrient metabolism. Body components (protein, fat) and metabolites (glucose, glycogen, fatty acids, acetyl-CoA