Development of a decision support tool for precision feeding of pregnant sows

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Abstract

Nutritional studies indicate that nutrient requirements for pregnancy largely differ among sows and according to the stage of pregnancy, whereas in practice the same diet is generally fed to all sows from a given herd. In this context, the availability of new technologies for high throughput phenotyping of sows and their environment, and of innovative feeders that allow the distribution of different diets, offers opportunities for a renewed and practical implementation of prediction models of nutrient requirements, in the perspective of improving feed efficiency and reducing feeding costs and environmental impacts. The objective of this study was thus to design a decision support tool that could be incorporated in automated feeding equipment. The decision support tool was developed on the basis of InraPorc® model. The optimal supply for a given sow is determined each day according to a factorial approach considering all the information available on the sow: genotype, parity, expected prolificacy, gestation stage, body condition (i.e. weight and backfat thickness), activity and housing (i.e. type of floor and ambient temperature). The approach was tested using data from 2500 pregnancies on 540 sows. Energy supply was calculated for each sow to achieve, at farrowing, a target body weight established based on parity, age at mating and backfat thickness (18 mm). Precision feeding (PF) with the mixing of two diets was then simulated in comparison with conventional (CF) feeding with a single diet. Compared to CF, PF reduced protein and amino-acid intake, N excretion and feeding costs. At the same time, with PF, amino acid requirement was met for a higher proportion of sows, especially in younger sows, and a lower proportion of sows, especially older sows, received excessive supplies. This project has received funding from the European Union's Horizon 2020 research and innovation programme, grant agreement No 633531. The data

used for the simulations were issued from a project conducted within the AgriInnovation Program from Agriculture and Agri-food Canada.

Keywords: sow, gestation, precision feeding, decision support tool

Introduction

Nutrient requirements for pregnant sows largely differ among animals according to their body condition at mating, their parity, their expected reproductive performance, their stage of pregnancy, their physical activity and the housing conditions (Dourmad et al., 2008). In practice, the feeding level of pregnant sows is to some extent adapted to take account of these variations, but generally the same diet is fed to all sows from a given herd. Moreover, the group housing of pregnant sows, for welfare issues, makes it sometime difficult to feed each animal individually, especially when sows are raised in small groups with a common feeding trough. Conversely, the group housing of pregnant sows also favoured the development of innovative technologies allowing the distribution of feed individually, for sows raised in large groups, using automated electronic feeders and animal identification.

The objective of this study was thus to design a decision support tool to be incorporated in automated feeding equipment, as already developed for fattening pigs (Cloutier et al., 2015), and to test it using a set of data already available from an experimental farm.

Development of the decision support tool

Description of the general approach

The description of the general approach is illustrated in Figure 1. The final objective is to send a command to the automated feeder to proceed with feed distribution. This command informs the feeder with the amount of each of the different diets, generally two diets differing in their nutrient content, to be fed to a given sow over a given day or period.

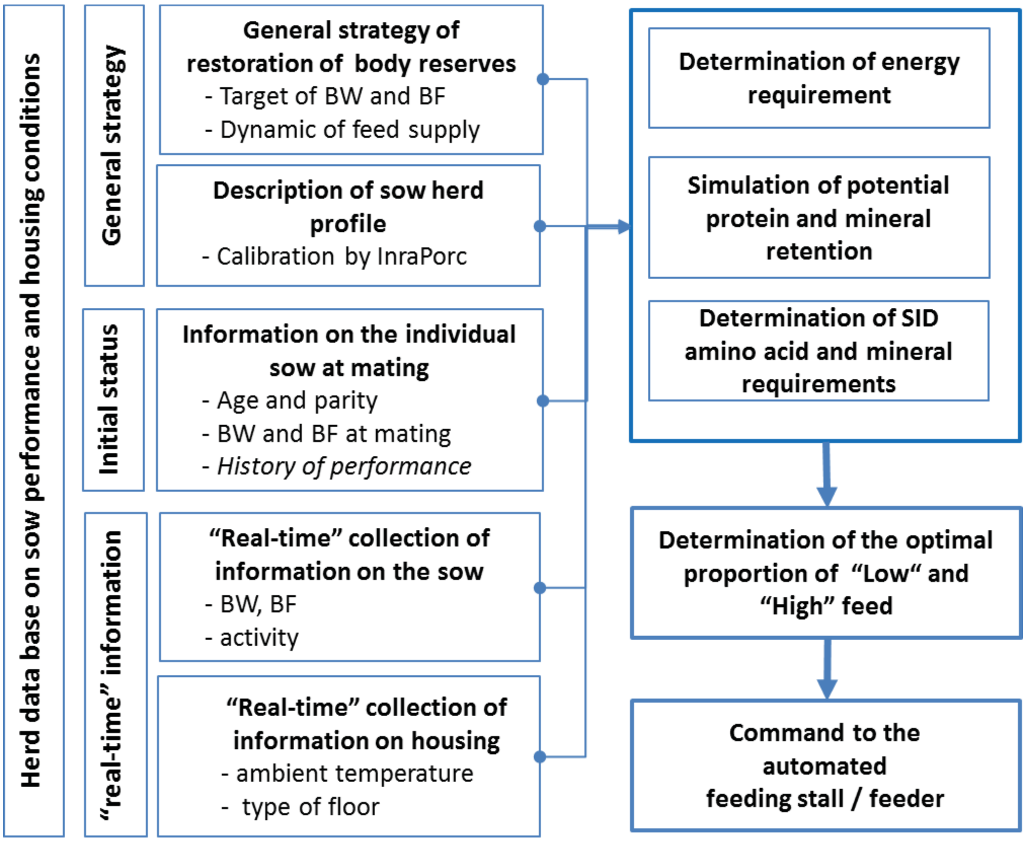

Figure 1. General description of the approach

To take that decision, the decision support system (DSS) uses information relative to the individual sow to be fed, her housing conditions and the general feeding strategy in the farm. This information is stored in a herd database that will not be described in detail in this paper. Different types of information are stored in this database: (i) the description of herd profile and performance, and the general strategy of management of sow body reserves, as described in InraPorc tool (Dourmad et al., 2008), (ii) information about each individual sow at mating, especially their age, parity, body weight (BW) and backfat thickness (BF), and their history of performance, and (iii) real time data collected either automatically by different sensors about the sows (e.g. BW, physical activity, feeding or drinking activity…) or their environment (ambient temperature, humidity…).

From the available information, which may vary according to the equipment available on the farm and the data management system, the DSS build the "best guess" decision to be transmitted to the automated feeder. This involves mainly two steps: (i) the determination of energy, amino acid and mineral requirements and (ii) the determination of the amount and composition of the ration to be fed. This ration is prepared from the mixing of different diets, generally two diets, available in the automated feeder.

Determination of energy and amino acid requirements

Energy and nutrient requirements are determined according to a factorial approach. Metabolizable energy (ME) requirement is calculated as the sum of the requirements for maintenance, physical activity and thermoregulation, growth and constitution of body reserves, and development of foetuses and uterine contents (Table 1, eq. 1).

Table 1. Main equations describing nutrient utilization (from Dourmad et al., 2008)

Energy utilisation	$ME = ME_m + ER_c / k_c + ER_m / k_m$	[1]
	ME_m : ME for maintenance	
	ER_c : energy retention in conceptus	
	ER_m: energy retained in maternal tissues	
	$k_c = 0.50$ efficiency of ME retention in conceptus	
	$k_m = 0.77$ efficiency of ME for maternal	
ME for maintenance and effect of activity and ambient temperature	in thermoneutral conditions	
	$ME_m = 440$ kJ.BW$^{-0.75}$.d^{-1} (for 240 min.d^{-1} standing activity)	[2]
	physical activity = 0.30 KJ. kg BW$^{-0,75}$.d^{-1}.min^{-1} standing	[3]
	below lower critical temperature (LCT)	
	In individually housed sows	
	LCT = 20°C and HP increases by 18 kJ.kg BW$^{-0.75}$.d^{-1}.°C^{-1}	[4]
	In group-housed sows	
	LCT = 16°C and HP increases by 10 kJ.kg BW$^{-0.75}$.d^{-1}.°C^{-1}	[5]
Energy retention	ERc : Energy in conceptus (kJ)	
	$Ln(ERc) = 11.72 - 8.62\ e^{-0,0138\ t} + 0.0932$ Litter size	[6]
	ERm : Energy in maternal tissues (MJ)	
	$ER_m = 13.65$ BW gain + 45.94 BF gain	[7]
Nitrogen retention	NR : total N retention (g.d^{-1}),	
	NR_c: N in conceptus (g)	
	$Ln(6.25\ NR_c) = 8.090 – 8.71\ e^{-0,0149\ t} + 0.0872$ Litter size	[8]
	$NR = 0.85\ (d(NR_c)/dt – 0.4 + 45.9\ (t/100) – 105.3\ (t/100)^2 + 64.4\ (t/100)^3 + a\ (ME - ME_{mm})\ )$	[9]
	where a = f(BW at mating) and $ME_{mm} = ME_m$ at mating	
SID lysine requirement g/d	SID Lys = 0.036 x BW$^{-0.75}$+ 6.25 NR x 0.065 /0.65	[10]

ME requirement for maintenance is calculated according to BW (eq. 2) and modulated according to physical activity (eq. 3), and ambient temperature depending on housing conditions (eq. 4 and 5). The cumulated amount of energy retained in sow body reserves over pregnancy (ER_m) is determined according to the amount of energy in maternal body at mating and the targeted amount after farrowing. These amounts are calculated from sow BW and BF according to the equations proposed by Dourmad et al (1997) (eq. 7). The corresponding metabolizable energy (ME) requirement is calculated from ER_m and the efficiency of energy retention in maternal tissues (k_m). ME requirement for conceptus is calculated according to energy retention in conceptus (ER_c, eq. 6) and the efficiency of energy retention in conceptus (k_c).

Total nitrogen retention (eq. 9) is calculated as the sum of N retained in conceptus (eq. 8) and the nitrogen retained in maternal tissues. Standardized ileal digestible (SID) lysine requirement is the calculated assuming 6.5% lysine in retained protein (NR x 6.25) with an efficiency of retention of 65% (eq.10).

Utilisation of the decision support system (DSS)

<u>Description of the database</u>

A database issued from an experimental farm (Table 2) was used to simulate the utilization of the DSS. This database contains the data from 2511 gestating sows with information about their body condition at mating (i.e. body weight, BW, and backfat thickness, P2) and at farrowing. These data were used to calibrate InraPorc parameters for this phenotype. Litter size at farrowing averaged 14.1 for a mean piglet birth weight of 1.48 kg. Sows BW at mating increased from 163 to 251 kg from parity 1 to parity 8, whereas P2 tended to be higher in first and second parity and then remained rather constant.

Table 2. Description of the data base

Parity	n° sows	Average Litter size	Average Piglet weight, g	Average at mating		Average target after farrowing[2]	
				BW[1], kg	P2[1], mm	BW[1], kg	P2[1], mm
1	392	13.3	1405	163	16.9	203	18
2	389	13.5	1557	192	15.9	227	18
3	413	14.1	1523	211	15.0	243	18
4	384	14.9	1480	227	14.4	255	18
5	335	15.0	1472	234	14.1	260	18
6	253	14.8	1438	241	14.1	263	18
7	187	13.9	1445	246	14.6	265	18
8	158	13.6	1455	251	14.9	267	18
all	2511	14.1	1478	214	15.2	244	18

[1]BW sows net body weight; P2 sows backfat thickness
[2]A target of BW is calculated for each sow according to BW and age at mating. The same target of P2 is used for all sows.

Determination of energy and lysine requirement

A target of maternal BW (i.e. total BW minus uterus contents) was calculated for each sow according to her age and BW at mating (Table 2). Target of P2 at farrowing was fixed to 18 mm for all sows according to the usual recommendation for this farm.

The DSS was then used to calculate the average ME and feed requirement over pregnancy (Table 3). Average ME requirement varied according to parity, from 31 to 36.8 MJ /d, and it was highly variable between sows with a coefficient of variation of about 7%.

Table 3. Calculated ME (MJ/d) and SID lysine requirement (g/kg feed) and supplies per parity, and % of low nutrient density feed (L) and % of reduction of lysine in precision feeding (PF) compared to conventional feeding (CF) strategy.

			Av. lysine req		Lysine supply in PF strategy[1]		
Parity	ME MJ/d	Feed. kg/d	30 d	114 d	Average g/kg feed	L feed	Reduction PF vs CF,%
1	31.0	2.4	3.63	6.23	4.01	67	17%
2	34.0	2.6	3.20	5.80	3.62	78	24%
3	35.5	2.7	2.91	5.41	3.32	85	28%
4	36.4	2.8	2.68	5.14	3.09	89	30%
5	36.8	2.8	2.59	5.09	3.02	89	31%
6	36.6	2.8	2.52	4.92	2.91	91	32%
7	35.9	2.7	2.48	4.79	2.83	92	33%
8	35.7	2.7	2.44	4.72	2.77	93	33%
all	35.0	2.7	2.89	5.38	3.28	84	27%

[1]in CF feeding strategy lysine content was constant and equal to 4.8 g/kg feed

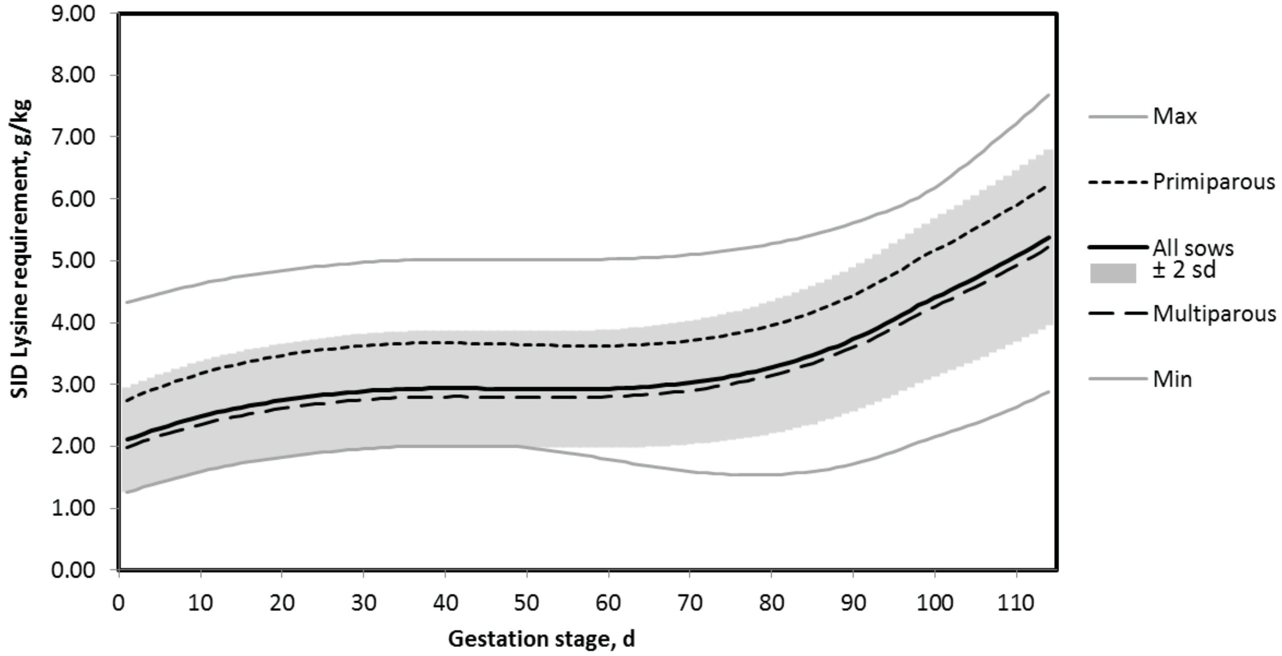

Figure 2. Evolution of SID lysine requirement (g/kg feed) of primiparous (mean), multiparous (mean) of all sows (mean ± 2sd) sows, and minimum and maximum requirement, according to gestation stage.

The dynamic of SID lysine requirement, expressed in g/kg feed, according to gestation stage is presented in Figure 2. Average SID lysine requirement increases with gestation stage with a large variability among sows, the highest value being 3-fold higher that the lowest. The requirement is also affected by sows parity with much higher values in primiparous than in multiparous sows.

<u>Evaluation of a precision feeding strategy</u>

These simulated data were used to evaluate the interest of precision feeding. A conventional 1-phase feeding strategy (CF) was compared to a precision feeding (PF) strategy consisting in the mixing of two diets with either a low (L) or a high (H) nutrient content. SID lysine content was assumed to 4.8, 3.0 and 6,0 g/kg feed and protein content to 14%; 9% and 16% in diets CF, L and H, respectively.

On average the level of incorporation of L diet in the PF strategy was 84%, the value being lower in first parity sow (67%). The level or incorporation of L diet decreased with gestation stage from almost 100% in the first week to less than 30% in the last week.

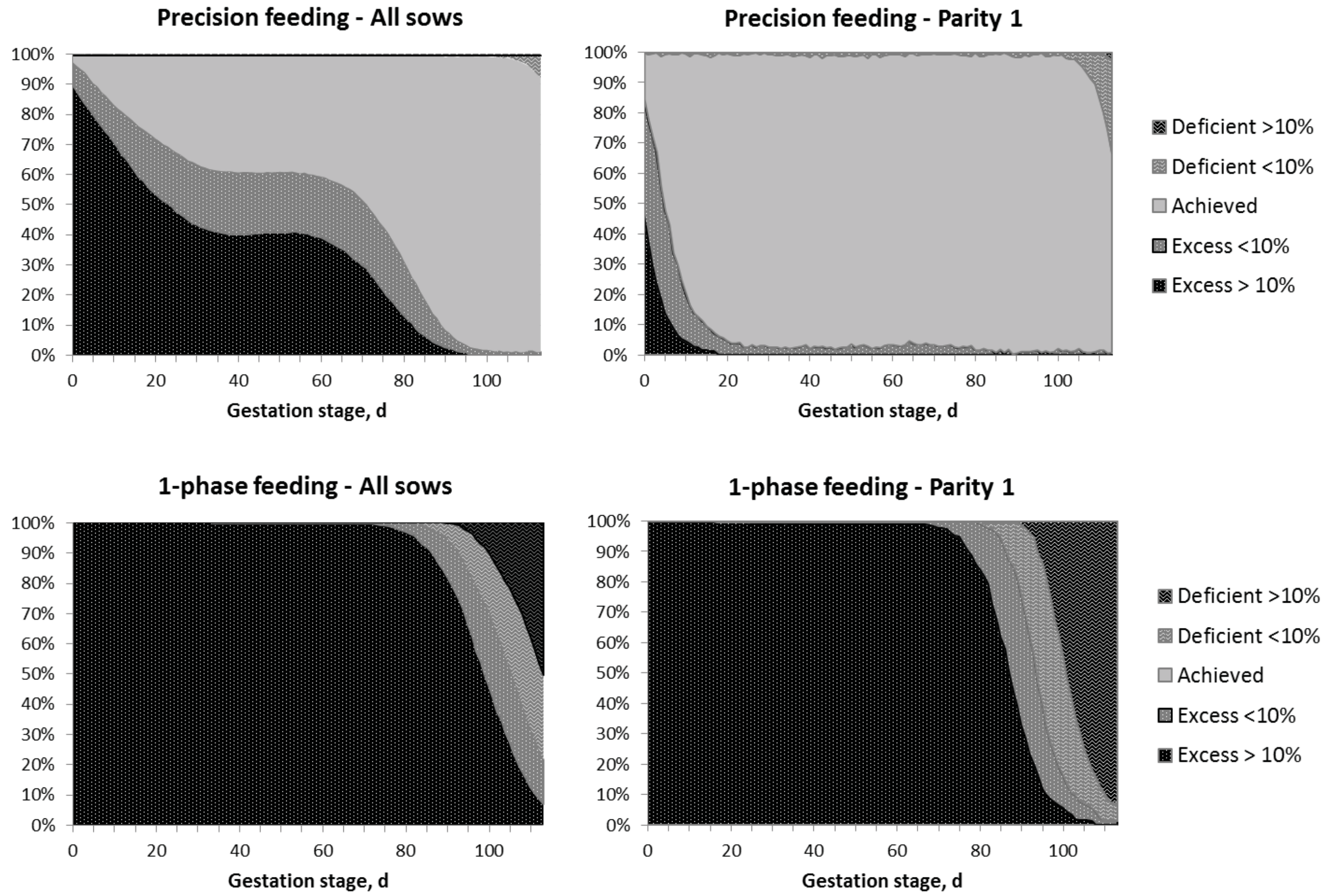

Figure 3. Effect of the feeding strategy (1-phase vs precision feeding) during gestation on the proportion of sows (among all sows or among first-parity sows) that received adequate, deficient or in excess lysine supplies.

Compared to the 1-phase strategy, PF strategy resulted in 27% decrease in total SID lysine supply and 28% decrease in total crude protein supply. Moreover, the proportion of sows that were underfed in the last two weeks of lactation decreased from more than 60% with 1CF to less than 5% with PF. For first parity sow the difference was even more marked, with almost all primiparous sows receiving deficient diets over the last 10 days of pregnancy with CF, compared to about 10% with PF (Figure 3). Conversely the proportion of sows that were overfed was drastically reduced (Figure 3).

Conclusions

The results from this study indicate that, in the same way as in fattening pigs (Pomar et al., 2009), precision feeding of gestating sows appears a win-win strategy which allows improving nutritional supplies of sows whilst reducing total protein supply and consequently reducing N excretion. The effect on feeding cost was not evaluated but it may be expected that it will also be reduced (Dourmad et al., 2009). The DSS developed in this study allows adapting the amount and composition of feed to each sow according to her body condition at mating and expected prolificacy, and to stage pregnancy. This DSS will also allow taking account of information collected by sensors during gestation, such as BW, backfat thickness or physical activity, on the environment, such as ambient temperature.

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