Model for nutrient flow estimation in gestating second parity Large White sows

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SUMMARY

The purpose of the study was to estimate the nutrient flow in different body fractions, in phase-fed second parity Large White sows after mating and during gestation, by developing a model based on data from previous experiments and on theoretical coefficients. The trial used 16, second parity, pregnant Large White sows selected randomly, with 171 ± 20 kg average initial body weight. After mating, the animals were assigned randomly to 3 homogenous groups: group C, whose dietary compound feed had a protein level according to the norms calculated by mathematical modelling; group L, whose dietary protein level was 10% lower compared to C diet; group H, whose dietary protein level was 10% higher compared to C diet. A total of 4 sows have been slaughtered in the beginning of the trial to determine reference values for the body composition. The different dietary protein level of the three groups was the variable; the feeding norm and the feed intake were changed gradually, but similarly among the groups. The gain of protein was 13.03 kg for group L, 11.67 kg for group C and 12.52 kg for group H. the decrease of the dietary protein level was accompanied by the 4.18% decrease of the energy intake compared to H diet and 2.65% compared to C diet. The protein level increased 1.34 times, 2 days before parturition compared to the post-mating period, with a stronger increase for L diet. Overall body fractions, lipid content was 1.05 times lower in group L, 1.14 times lower in group C and 0.7 times lower in group H. In conclusion, protein restriction can be advantageous in terms of economy, environment protection and production. On the contrary, the surplus of protein may lead to waste and it doesn't justify.

Keywords: model, pregnant sows, metabolism, protein

INTRODUCTION

Feeding reproductive sows is the most costly critical element in farm management. The proper feeding of the sows is important for the production of large litters and for a long productive life. *Precision* feeding is a challenge, the key to the establishment of a state of physical and physiological comfort, which h leads to optimal performance, good health state and proper animal welfare. In pregnant sows development we must ensure, on the one hand, the maintenance requirements and, on the other hand, the requirements for foetuses, uterus and mammary gland. Nutrients in excess contribute to the constitution of sow's body reserves (Dourmand et al. 2008, NRC, 1998). Reproductive sows are restrictively fed during gestation and are generally fed ad libitum during lactation (Guillemet et al., 2010). The nutrient requirements for pregnant sows have been reviewed during the recent years (Kim, 2009, NRC, 2012) based on the growth models, but questions still persist regarding the interrelation between feed characteristics, feed intake and animal response, implications of the managerial practices applied to reproductive sows on their subsequent reproductive cycles. The protein requirements of pregnant sows include the requirement for maintenance, protein from the maternal tissue and the foetus (NRC, 1998). The studies on pregnant sows' metabolism and nutrition are rather elaborate (Burlacu et al. 2002, Noblet, Dourmad and Etienne 1990, Tuitoek et al. 1997, Ji et al. 2005, Goodband et al, 2013), but necessary in order to optimise their performance (Hansen and Kebreab, 2013). McPherson et al., (2004), and Ji et al., (2006), showed that foetus weight, their protein content and the mammary gland protein content increase 5, 18 and/or 27 times during the final 45 days of gestation. This gain in foetal weight and protein retention shows that the protein/amino acids requirements must be higher during late pregnancy than in early gestation. Moehn and Ball, (2013) showed that a single-phase feeding throughout gestation is incorrect because the requirements are different in early and late gestation, and feeding in two phases (early and late gestation) is rather impracticable. However, during the successive reproduction cycles, the body reserves of the sow fluctuate with the rate of the succeeding pregnancy and lactation stages. Most effects of the feeding on the reproductive performance seem to be associated with the extreme variations of the body reserves (Dourmand et al., 1996, 2008). Phase feeding is a solution to supply appropriate nutrients to cover nutritional requirement of the pregnant sows (Burlacu et al. 2002, Moehn et al., 2011). However, Soto (2011) claims that the adjustment of the feed intake during late gestation is enough to cover the increased requirement of nutrients, while Kusina et al. (1999) and Kleisiary (2007) highlighted the need to increase continually the protein concentration of the feed in late gestation. On the background of the controversial literature opinions, we undertook to estimate the flow of nutrients in different body fractions, in phase-fed second parity Large White sows after matting and during gestation, by developing a model on the basis of data from previous experiments and also using theoretical coefficients.

MATERIAL AND METHODS

To draw up this model we sued experimental data from a previous trial conducted in the experimental farm of INCDBNA – Balotesti, whose protocol is described below. The trial used 16, second parity gestating Large White sows, of 171 ± 20 kg average initial body weight, selected randomly. The sows were kept in common stalls, while at the time of meals the sows were introduced in individual pens, for single feeding. The animals had free access to the water both in the common stalls and in the individual pens. We monitored body weight evolution by individual weighing at the beginning of the trial and before slaughter. After mating, the animals were assigned randomly to 3 homogenous groups, which received a compound feed with the same energy content, but with different protein levels (Table 1), as follows: control group (C diet), whose compound feed had a protein content according to the norms calculated by mathematical modelling by Burlacu et al., (2002); group L (L diet), whose dietary protein level was 10% lower compared to C diet; group H (H diet), whose dietary protein level was 10% higher compared to C diet. A total of 4 sows have been slaughtered in the beginning of the trial to determine reference values for the body composition. Twelve sows were slaughtered 2 days before parturition. The right side of each eviscerated carcass, previously weighed, was cut in 3 fractions according to the French procedure (Desmoulin, 1988): muscle (intramuscular fat included); subcutaneous and perirenal adipose tissue and skeleton. Each resulting fraction was weighed. Samples of meat and fat, organs (heart, liver, kidneys, spleen and lung) with blood and viscera, bones, skin, hair, uterus, placenta, mammary gland and foetuses were collected. The bones were kept in autoclave for 16h at 1.5 atm. and ground thereafter. Two piglets from each sow were ground entirely and assayed for chemical composition.

The chemical composition of the collected samples was determined using methods standardized according to Commission Regulation (EC) no. 152 (2009). The gross energy was determined by burning in the calorimetric bomb, in oxygen atmosphere, at a pressure of about 25 atm.

The formulation and calculation of the compound d feeds was done using a software based on the mathematical model for energy and protein metabolism simulation in sows, developed by Burlacu et al. (2002) on the basis of the functions and parameters described by the literature and on data from own experiments. The nutrient requirement for the different stages of gestation was covered by an increasing intake of feed (Table 1). The feeding value of the studied dietary ingredients has been determined in advance. The compound feeds formulations consisted of barley and peas during the first 80 days of gestation, to which partially hulled sunflower meal was added afterwards. All diets were supplemented with salt, dicalcium phosphate, calcium carbonate, choline premix and mineral and vitamin mixtures.

Table 1. Calculated nutrient composition using equations according to mathematical model (g/ day)[1]

Calculated nutrient composition (g/ day)									
Pregnancy period (days)	CP level (diets)	ME (MJ/day)	CP (g)	CP/kg DM	DCP[2] (g)	DCP /kg DM	Pm (g)	Pr+PG (g)	Dig. lysine (g)
0 - 20	L	30.36	325.28	14.62	240.00	10.73	102.28	33.00	10.00
	C		326.00	15.71	270.53	11.96	124.00	40.00	12.12
	H		387.00	17.15	306.54	13.57	154.95	50.00	15.15
21-40	L	30.60	326.07	14.34	243.89	10.42	102.40	32.80	9.95
	C		362.27	15.48	273.84	11.70	128.00	41.00	12.44
	H		398.53	16.88	310.65	13.28	155.60	59.20	14.92
41-60	L	31.02	345.73	14.10	249.93	10.15	104.25	27.00	11.84
	C		392.33	15.52	291.00	11.75	131.00	46.00	13.13
	H		422.56	17.37	335.50	13.82	169.20	66.60	14.42
61-80	L	31.75	360.25	14.10	262.16	10.15	105.45	33.80	8.42
	C		415.88	15.60	303.70	11.84	133.00	57.00	14.11
	H		440.33	16.34	347.88	13.56	165.60	71.05	17.61
81-90	L	32.30	418.31	15.47	299.71	11.09	135.00	51.10	10.97
	C		465.95	16.88	350.00	12.68	135.00	73.00	15.15
	H		512.60	18.49	401.89	14.49	135.00	94.90	18.82
91-100	L	33.00	433.80	15.41	312.07	11.05	136.00	58.50	11.20
	C		482.03	17.37	367.16	13.23	136.00	90.00	17.23
	H		530.00	19.37	421.52	15.40	136.00	117.00	22.39
101-114	L	33.92	470.70	15.90	344.22	11.55	137.00	84.50	13.48
	C		523.18	18.16	405.48	14.08	137.00	130.00	20.74
	H		581.11	20.71	473.40	16.87	137.00	169.00	26.96
Average	L	31.60	370.68	14.69	270.67	10.63	113.29	42.20	10.65
	C		409.95	16.17	312.54	12.29	131.12	62.54	14.48
	H		452.02	17.75	358.54	14.21	153.82	82.65	17.82

[1]Vitamin mineral premix added at 1% in the diet, contained the following (/kg feed): 9,000 UI of vitamin A; 1,500 UI of vitamin D3; 50.00 UI of vitamin E; 2 mg of vitamin K_3; 1.50 mg of vitamin B1; 5.20 mg of vitamin B2; 15.00 mg of niacin; 8.10 mg of vitamin pantothenic acid; 2.00 mg of vitamin B6; 0.10 mg of biotin B7; 0.50 mg of folic acid; 0.03 mg of vitamin B12; 39.00 mg of Mn; 100.00 mg of Fe; 15.00 mg of Cu; 100.00 mg of Zn; 0.30 mg of I; 0.22 mg of Se; 0.25 mg of Co; 60 mg of antioxidant (oxitec).
[2]D = digestible; based on composition of the ingredients and on the digestibility coefficients determined by INCDBNA Balotesti

The compound feed was calculated and fed by stage of gestation (every 20 days up to 80 days, and every 10 days thereafter, until the end of gestation).

The average daily compound feed intake was calculated as weighted average, being differentiated by stage of gestation depending on the composition of the compound feed (2.4 kg at the start of gestation, gradually increasingly to 2.7 kg at the end of gestation).

Calculations and statistical analysis

The monofactorial experimental design (One way Anova) was:

$$X_{ij} = \mu + \alpha + e_{ij.}$$

The different dietary protein level was the variable, while the other nutrients had similar levels in all groups; the feeding norm and the feed intake changed progressively, but similarly among the groups. The results were expressed as mean values and SE.

We used the following equations to calculate the average amount of protein ingested and used at digestive and metabolic levels by the sows:

- Total initial protein = GN initial x 0.148
- Total final protein = GN final x 0.179;
- Retained protein (Pr) = Pt final – Pt initial;
- Protein for maintenance (Pm) = $\frac{\text{Pt}\, initial + \text{Pt}\ final}{2} \times 0.004$
- Digestible protein (DP) = DCP – (Pt final – Pt initial);
- ME = DE – (EU + E deamination)

RESULTS AND DISCUSSION

Animal performance

The average daily compound feed intake throughout the entire gestation period was 2.76 kg /sow/day for group L, 2.77 kg /sow/day for group C and 2.74 kg /sow/day for group H.

As response of ingested nutrients metabolisation we determined body weight evolution throughout gestation (Table 2). Starting from the initial body weight of 174 ± 26 kg in L diet group, 167 ± 17 kg in C diet group and 172 ± 26 kg in H diet group, the animals reached the end of gestation with rather the same average body weight: 235± 21 kg in L diet group, 224± 12 kg in C diet group and 232 ± 19 kg in H diet group.

Table 2 shows the effect of the dietary protein level on the average daily weight gain during the period of gestation. Table data show that the weight gain was 60 kg in H diet group, 57 kg in C diet group and 61 kg in L diet group.

The maternal gain, obtained by deducting progeny weight, was rather close in groups H and L (46 and 41 kg, respectively), and 35 kg in C diet group.

The regression coefficients between the gross and net weight are shown in Table 2.

Table 2. Body weight evolution and weight gain of the sows during gestation

Specification*	Crude protein level %		
	L diet	C diet	H diet
Initial gross weight - kg	174 ± 26	167 ± 17	172 ± 26
Initial net weight - kg	167 ± 25	160 ± 16	165 ± 25
Regression coefficient between gross and net weight	0.96	0.96	0.96
Gross weight at the end of gestation (with piglets) - kg	235 ± 21	224 ± 12	232 ± 19
Net weight at the end of gestation (with piglets) - kg	230 ± 20	220 ± 12	228 ± 18
Regression coefficient between gross and net weight	0.97	0.97	0.97
Gross weight at the end of gestation (without piglets) - kg	220 ± 23	202 ± 9	215 ± 18
Net weight at the end of gestation (without piglets) - kg	215 ± 23	198 ± 8	210 ± 17
Regression coefficient between gross and net weight	0.97	0.97	0.97
Overall gain throughout gestation - kg	61	57	60

*Net weight calculated as difference between final body weight and digestive content

Prediction of the average amount of protein

The literature has data on the nutrient requirement by reproductive categories that are regularly reviewed, but the scientific information relies on standard conditions, so that there are differences between the different systems and areas. Furthermore, the data on nutrient flow are rather scarce because of the difficulty to set up such experiments. This fact is more so important as the new European regulations impose major restrictions regarding the trials on animals, while their genotype underwent important changes. In this study, starting from the compound feeds formulations calculated and used with the purpose of validating the model under farm conditions, we estimated the protein and energy flow using the above-mentioned equations (Table 3). Thus, the ingested amount if crude protein was 1.09 times higher in group H com pared to group C and 1.19 times higher compared to group L. The values for the initial total body protein were close: 24.7 kg for L diet group, 23.7 kg for C diet group and 24.37 kg for H diet group.

The protein gain was 13.03 kg for L diet group, 11.67 kg for C diet group and 12.52 kg for H diet group. The decrease of the protein level was accompanied by the decrease of the energy intake, which was 4.18% lower compared to H diet and 2.65% compared to C diet.

Table 3. Prediction of the average amount of protein and energy ingested and used at the digestive and metabolic levels by the sows

Items*	Crude protein level %		
	L diet	C diet	H diet
Total crude protein ingested–kg/100 kg	41.96	46.10	50.31
Total crude protein ingested –kg /100 kg DM	31.52	34.38	37.50
Total initial body protein – kg	24.70	23.70	24.37
Total final body protein – kg	37.73	35.37	36.89
Metabolisable energy – MJ/day*	32.99	33.89	34.43

*equations by Burlacu et al. 2002

Protein and lipid deposition

The protein pools cover conceptus, i.e. uterus, placenta and fluids, mammary and foetus, and maternal protein (Moehn and Ball, 2013). Protein deposition depends mainly on the energy supply and maximum potential protein deposition. In growing pigs, this is generally described by a linear-plateau relationship between protein deposition and ME intake (van Milgen et al., 2008).Williams et al. (1985) suggested a similar relationship for pregnant sows.

Figure 1 estimates the protein flow according to the mathematical model of Burlacu et al. (2002). According to this model, at 114 days of gestation, 46% of the available protein is used for maintenance, while 43% of the available protein is retained or used for gestation.

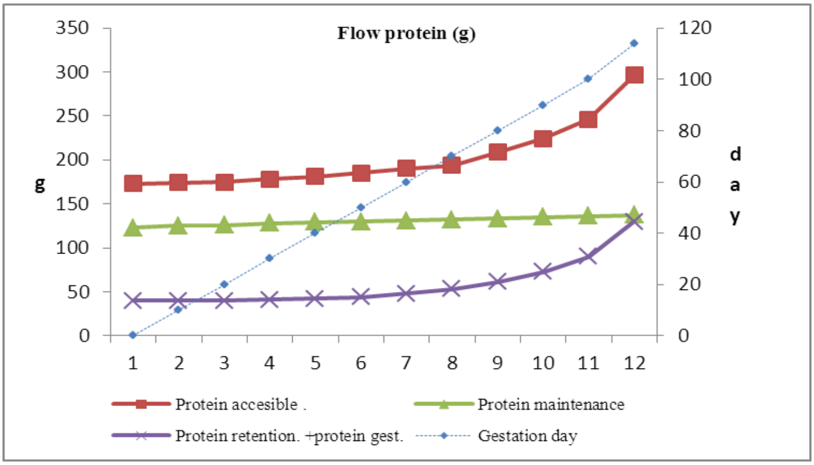

Figure 1. Protein flow depending on day of gestation, according to the mathematical model (Burlacu et al., 2002)

Table 4 shows the animal response in terms of nutrient (protein and lipid) retention in different organs, after mating (as reference values) and 2 days before parturition. For the calculation of the total protein content we took into consideration the chemical composition related to the net weight. The highest protein and lipid content was observed in the muscles and fat. Thus, the average protein level after mating was 17.7% DM in these fractions, compared to 3.64% DM in viscera and blood, 3.03% DM in the skin and hair, and 2.18% DM in bones. Irrespective of the type of treatment, as expected, two days before farrowing, the protein level increased compared to the post-mating period, irrespective of the organ. In the muscles and fat, the increase was 14.4% for L diet group and 7.2% for H diet group, which supports the mathematical model showing that a higher amount of protein is retained on the background of the protein limitation. A similar trend was noticed for the placenta and liquid. The protein restriction caused, however, a lower protein level in the viscera and blood (by 22.9% compared to C diet, and by 12.26 % compared to H diet), in bones (by 7.4% compared to C diet), in the uterus (by 22.3% compared to C diet and 32.9% compared to H diet) and in the litter (by 17.83% compared to C diet and 2.5% compared to H diet). Overall body fractions, the protein level increased 1.34 times two days before farrowing compared to the post-mating period, the increase being higher for L diet group.

Table 4. Proteic and lipid level in various body fractions after mating (as reference values) and 2 days before parturition (% DM)

Items*	After mating		Before parturition					
			Treatment					
			L diet		C diet		H diet	
	Protein	Lipid	Protein	Lipid	Protein	Lipid	Protein	Lipid
Muscle and fat	17.70 ± 1.00	56.06 ± 17.56	21.89 ± 3.08	42.99 ± 3.83	20.26 ± 3.11	37.10 ± 9.96	18.99 ± 3.49	46.44 ± 10.10
Viscera and blood	3.64 ± 0.35	2.66 ± 0.20	3.75 ± 0.94	1.39 ± 0.34	4.61 ± 1.10	2.70 ± 1.84	4.21 ± 0.63	1.76 ± 0.58
Skin and hair	3.03 ± 0.67	4.71 ± 0.59	3.43 ± 0.96	4.91 ± 0.63	3.27 ± 1.41	5.15 ± 1.49	3.61 ± 1.28	3.91 ± 1.61
Bones	2.18 ± 0.30	2.61 ± 0.58	2.83 ± 0.64	2.52 ± 0.59	3.04 ± 0.90	2.74 ± 0.74	2.72 ± 0.76	2.86 ± 0.77
Mammary gland			0.84 ± 0.13	2.95 ± 0.43	0.79 ± 0.09	2.59 ± 0.70	0.97 ± 0.16	2.22 ± 0.44
Uterus			0.94 ± 0.16	0.13 ± 0.07	1.15 ± 0.20	0.52 ± 0.50	1.25 ± 0.23	0.33 ± 0.29
Litter			1.57 ± 0.39	0.34 ± 0.24	1.85 ± 0.36	0.21 ± 0.05	1.61 ± 0.45	0.43 ± 0.20
Placenta and liquid			0.16 ± 0.06	0.02 ± 0.01	0.13 ± 0.03	0.02 ± 0.01	0.14 ± 0.02	0.02 ± 0.01
Total	25.84	58.43	35.44 ± 4.53	55.28 ± 3.00	35.13 ± 4.85	51.07 ± 8.80	33.53 ± 3.55	58.00 ± 11.58

*Calculation using previous experimental data obtained in INCDBNA Balotesti (Habeanu et al., data not published).

The lipid level was 3.17 times higher compared to the protein level in the muscles and fat, while in the other body fractions the values were rather close to those of the post-mating period. While the protein level increased in the muscles and fat compared to the post-mating period, the lipid level decreased irrespective of the treatment. Overall body fractions, the lipid level was 1.05

times lower in L diet group, 1.14 times in C diet group and 0.7 times in H diet group. The results obtained by processing the experimental data are in agreement with the results determined by mathematical modelling (Burlacu et al., 2002). In terms of practice, a protein surplus is not economically beneficial and doesn’t lead to better animal performance, having an adverse environmental impact. The possible explanation is that protein retention in pigs has a maximal level given by the response plateau genotype, beyond which any additional dietary protein or energy amount means wasting.

CONCLUSIONS

This study proposes a model for nutrient (protein and lipids) flow estimation in gestating multiparous sows, based on experimental data obtained under conditions specific to our area and on theoretical values obtained by mathematical modelling. According to our data, protein restriction can be economically profitable, with environmental and production benefits. On the contrary, the excess of protein may lead to wasting and is not justified. These results are valid under the conditions in which the dietary formulations are adjusted periodically to meet the feeding requirements. The research must be continued so as to acquire new data on amino acids and fatty acids, because of the scarce literature data in these “areas”.

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