

## Effect of sow age on the apparent total tract digestibility of nutrients in the diet

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### Abstract

The objective of this research was to evaluate the effect of sow age on apparent total tract digestibility of nutrients and the concentration of metabolizable energy in the diet. The experiment was carried out on 20 gestating sows, divided into two groups: Group I - 10 sows in first pregnancy ( $131 \pm 4.5$  kg) and Group II - 10 sows in fourth pregnancy ( $225 \pm 8.2$  kg). Sows in the two groups were fed identical diets for sows during early pregnancy. The total collection of faeces began on day 30 of pregnancy and lasted eight days. Sows in the fourth pregnancy had greater digestibility coefficients of dry matter (4.1 percentage units), organic matter (3.4 percentage units), crude protein (5.5 percentage units) and crude fibre (6.2 percentage units) than sows in the first pregnancy. The total tract digestibility of ether extract, starch and sugars was not affected by pig age. The metabolizable energy, determined according to the content of digestible nutrients, in the sow diet in fourth pregnancy was 0.7 MJ/kg higher than in the diet of sows in their first pregnancy. Results of this research indicate that sow age should be considered when formulating diets during early pregnancy.

**Keywords:** Digestibility, gestation, metabolizable energy, nutrients, age of sow

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### Introduction

The apparent total tract digestibility of nutrients in pigs could be affected by many factors, among others the age and body weight of animals. Adult pigs have a more developed and larger gastro-intestinal tract with residence time of ingesta being longer than in growing pigs (Varel, 1987; Low, 1993). The slow passage rate of digesta through the large intestine supports extensive fermentation of fibre and encourages bacterial growth (Mosenthin, 1998). The number of cellulolytic bacteria in the large intestine of adult sows is 6.7 times greater than in growing pigs (Varel, 1987). This results in a greater capacity of sows to digest fibrous components and other nutrients compared with young pigs (Fernandez *et al.*, 1986; Varel, 1987; Noblet & Shi, 1993; Shi & Noblet, 1993a; b; Le Goff & Noblet, 2001; Jørgensen *et al.*, 2007).

Digestibility of energy is the sum of the energy digestibility of protein, lipids and carbohydrates. The effect of pig age on the increased digestibility of these nutrients is due mainly to the greater rate of degradation of the fibre fraction in the large intestine (Jørgensen *et al.*, 1995; Urriol *et al.*, 2010). This leads to an increase in the digestibility of energy in older pigs compared with younger ones (Le Goff & Noblet, 2001; Wilfart *et al.*, 2007; Le Gall *et al.*, 2009).

The effects of age and body weight (BW) on apparent total tract digestibility of nutrients and energy has been demonstrated in many experiments on growing pigs and adult sows (Fernández *et al.*, 1986; Noblet & Shi, 1993; Le Goff & Noblet, 2001; Le Gall *et al.*, 2009; Lowell *et al.*, 2015). The objective of this research was to evaluate the effect of age in gestating sows on the apparent total tract digestibility of nutrients and the concentration of metabolizable energy (ME) in the diet of sows during early pregnancy.

### Materials and Methods

A total of 20 gestating sows of the same genetic origin (Polish Large White × Polish Landrace) was used in this experiment. Three days before artificial insemination, sows were weighed and allotted to two groups, depending on age/BW: Group I - 10 sows in first pregnancy ( $131 \pm 4.5$  kg) and Group II - 10 sows in the fourth pregnancy ( $225 \pm 8.2$  kg). At the fifth week of pregnancy, each sow was placed in an individual metabolism cage (0.9 x 2.3 m), equipped with a feeder and a nipple drinker.

The experimental diet was formulated according to recommendations for the nutrient requirements for sows during early pregnancy of the Polish Standards of Pig Feeding (2014). The feed ingredients of the experimental diet are presented in Table 1. From insemination and during the experimental period, the sows received a diet of 2.8 kg per day in two equal meals at 07:30 and 17:00. During the experimental period, there were no refusals. The animals had ad libitum access to water for the entire experiment.

**Table 1** Composition of experimental diet for sows during early pregnancy

Ingredients (%)	
Wheat	15.00
Barley	30.00
Triticale	10.00
Oats	15.00
Wheat bran	20.00
Soybean meal (47% CP)	7.50
Lysine	0.10
DL-methionine	0.05
L-threonine	0.05
Limestone	0.66
Vitamin-mineral premix*	0.50
Dicalcium phosphate	0.74
Sodium chlorate	0.40
Total	100.0

\*Provided per kilogram of complete diet: vitamin A, 15000 IU; vitamin D<sub>3</sub>, 1800 IU; vitamin E, 60 mg; vitamin K, 1.5 mg; vitamin B<sub>1</sub>, 1.5 mg; vitamin B<sub>2</sub>, 6 mg; vitamin B<sub>6</sub>, 4 mg; vitamin B<sub>12</sub>, 25 mg; niacin, 40 mg; pantothenic acid, 16 mg; folic acid, 2 mg; biotin, 60 mg; choline chloride, 300 mg; Ca, 1.5 g; 300 mg; Fe, 80 mg; Mn, 40 mg; Zn, 80 mg; Cu, 15 mg; I, 0.5 mg; Co, 0.5 mg; Se, 0.3 mg.

On day 30 of pregnancy, the sows were placed in the metabolism cages. The experiment lasted 12 days and consisted of four days for adaptation to the metabolism crates, followed by eight days of total collection of faeces. Faeces were collected daily from each sow in a bucket. Collection began at 07:30 in the morning on day 1 and ceased at 07:30 in the morning of day 9 of the collection period. Buckets were emptied once daily. The faeces were weighed and homogenized and a subsample (15% total faeces) was stored at -20 °C. The frozen daily subsamples were then thawed and bulked together per sow. The content of crude protein was determined in the thawed samples. Other samples of faeces were oven-dried and finely ground for chemical analyses.

The basic chemical composition of diet and faeces samples was determined by standard methods (AOAC, 2007), namely dry matter by drying at 105 °C to constant weight; ether extract by Soxhlet extraction with diethyl ether; crude ash by incineration in a muffle furnace at 580 °C for 8 h; crude protein (N×6.25), using the Kjeldahl method with the Büchi Distillation Unit B-324 (Büchi Labortechnik AG, Switzerland) and, Weende crude fibre on a ANCOM 220 fibre analyser (ANKOM Technology, USA). Starch content was determined with the Ewers polarimetric method (EEC, 1972), and the content of sugars was measured by the Luff-Schoorl method (BIPEA, 1976). Amino acids in the diet were determined on a Beckman 6300 amino acid analyser (Beckman Instruments Corp., Palo Alto, Calif, USA). Before analysis, samples were hydrolyzed with 6 M HCl for 24 h at 110 °C [method 982.30 E(a); AOAC, 2007]. Sulphur-containing amino acids (methionine and cystine) were determined as Met sulfone and cysteic acid after cold performic acid oxidation overnight before hydrolysis [method 982.30 E(b); AOAC 2007]. Tryptophan was determined after NaOH hydrolysis for 22 h at 110 °C [method 982.30 E(c); AOAC, 2007]. Phosphorus was measured by the vanadium-molybdenum colorimetric method (Cavell, 1955) and calcium by emission spectrometry on a Buck Scientific 210 VGP atomic absorption spectrophotometer.

Nitrogen-free extract (NFE) was calculated as:

$$\text{NFE (\%)} = 100 - \% (\text{moisture} + \text{ash} + \text{crude protein} + \text{ether extract} + \text{crude fibre}).$$

The apparent total tract digestibility (ATTD) of nutrients in the diet was calculated using the following formula:

$$\text{ATTD (\%)} = [\text{nutrient in feed} - \text{nutrient in faeces} / \text{nutrient in feed}] \times 100.$$

The ME concentrations in the diets were calculated using the formula (Jentsch *et al.* 2003):

$$\text{ME (MJ/kg)} = 0.0205 \text{ dCP} + 0.0398 \text{ dEE} + 0.0173 \text{ dST} + 0.0160 \text{ dSU} + 0.0147 \text{ dNFR}.$$

where dNFR is digestible N-free residua [dNFR = dOM – (dCP + dEE + dST+ dSU)

dCP is digestible crude protein

dEE is digestible ether extract

dST is digestible starch

dSU is digestible sugars

dOM is digestible organic matter content in g/kg feed.

The results are presented as arithmetic means ( $\bar{x}$ ) and standard deviation (SD). The data were subjected to a one-way analysis of variance (ANOVA). The significance of difference (*P*) between means was determined by using paired t-tests. Statistical data analysis was carried out using Statistica software (Statistica PL, version 10).

## Results

The analysed chemical composition of the diet used in the study is given in Table 2, and the amino acids content in Table 3. The levels of organic matter, crude protein and crude fibre in the diet were 836.3, 145.8 and 76.5 g/kg, respectively. The indispensable amino acids were at levels that met or exceeded the estimated requirements for sows during early pregnancy (Polish Standards of Pig Feeding, 2014).

**Table 2** Chemical composition of experimental diet for sows during early pregnancy

Chemical composition	(g/kg)
Dry matter	887.0
Ash	50.7
Organic matter	836.3
Crude protein	145.8
Ether extract	33.8
Crude fibre	76.5
Nitrogen-free extract	583.6
Starch	397.1
Sugars	33.5
Calcium	7.95
Phosphorus	5.99

The data presented in Table 4 indicate the effect of sow age on the apparent total tract digestibility of dry matter, organic matter, crude protein and crude fibre. Sows in the fourth pregnancy had greater digestibility coefficients of dry matter (*P* <0.05), organic matter (*P* <0.05) and crude protein (*P* <0.01) than sows in the first pregnancy. However, the most pronounced difference between sows in the fourth and first pregnancy was in the digestibility of crude fibre (+ 6.2 percentage units; *P* <0.01). There was no significant effect of sow age on the apparent total digestibility tract of other nutrients.

**Table 3** Amino acid composition of experimental diet for sows during early pregnancy

Amino acids	(g/kg)
Indispensable amino acids	
Arginine	8.31
Histidine	3.67
Isoleucine	4.81
Leucine	9.53
Lysine	6.84
Methionine	2.57
Phenylalanine	6.59
Threonine	5.30
Tryptophan	1.81
Valine	6.71
Dispensable amino acids	
Alanine	6.87
Aspartic acid	10.98
Cystine	2.45
Glutamic acid	29.21
Glycine	7.06
Proline	9.62
Serine	6.23
Tyrosine	4.29
Total amino acids	132.85

**Table 4** Mean ( $\pm$  SD) of apparent total tract nutrient digestibility (%) by gestating sows

Nutrients	Sow age		P
	first pregnancy $\bar{x} \pm SD$	fourth pregnancy $\bar{x} \pm SD$	
Dry matter	74.3 $\pm$ 1.8	78.4 $\pm$ 1.5	<0.05
Organic matter	77.8 $\pm$ 1.6	81.2 $\pm$ 1.3	<0.05
Crude protein	76.8 $\pm$ 2.4	82.3 $\pm$ 2.1	<0.01
Ether extract	73.8 $\pm$ 4.4	75.6 $\pm$ 4.1	NS
Crude fibre	26.6 $\pm$ 3.3	32.8 $\pm$ 2.9	<0.01
Nitrogen-free extract	84.0 $\pm$ 1.8	86.1 $\pm$ 1.3	NS
Starch	97.9 $\pm$ 1.7	98.7 $\pm$ 2.1	NS
Sugars	98.2 $\pm$ 1.4	99.1 $\pm$ 1.5	NS

SD: standard deviation.

NS: not significant.

Differences in nutrient digestibility between sows in first and fourth pregnancy resulted in a higher content of digestible dry matter (5.5%,  $P < 0.05$ ), digestible organic matter (4.4%;  $P < 0.05$ ), digestible protein (8.0%;  $P < 0.01$ ), and digestible crude fibre (25.0%;  $P < 0.01$ ) in the diet of sows the fourth pregnancy than in the first pregnancy (Table 5). Consequently, the metabolizable energy content in the diet of sows in the fourth pregnancy was 0.7 MJ/kg higher ( $P < 0.01$ ) than in the diet of sows in the first pregnancy.

**Table 5** Comparison of the content of digestible nutrients and metabolizable energy in sow diet in the first and fourth pregnancies

Item	Sow age		Fourth pregnancy relative to first pregnancy (%)	P
	first pregnancy $\bar{x} \pm \text{SD}$	fourth pregnancy $\bar{x} \pm \text{SD}$		
Digestible nutrients (g/kg)				
Dry matter	659.0 ± 13.0	695.4 ± 11.3	105.5	<0.05
Organic matter	650.6 ± 12.3	679.1 ± 11.0	104.4	<0.05
Crude protein	112.0 ± 3.6	120.9 ± 3.1	108.0	<0.01
Ether extract	24.9 ± 2.1	25.8 ± 1.7	103.6	NS
Crude fibre	20.4 ± 2.6	25.5 ± 2.1	125.0	<0.01
Nitrogen-free extract	489.6 ± 9.4	501.9 ± 7.9	102.6	NS
Starch	388.0 ± 5.9	391.5 ± 7.2	100.9	NS
Sugars	32.6 ± 0.5	33.0 ± 0.6	101.2	NS
Metabolizable energy (MJ/kg)	11.8 ± 0.5	12.5 ± 0.4	105.9	<0.01

SD: standard deviation.

NS: not significant.

## Discussion

The experimental diet contained high levels of crude fibre. The early pregnancy of sows is the recommended period for feeding fibrous diets because their nutrient requirements in this period are lower than in those of growing pigs and lactating sows. Furthermore, dietary fibre can improve embryo survival (Jindal *et al.*, 1996) and ovulation rate (Cox *et al.*, 1987), ultimately increasing the litter size of sows at birth.

The current studies demonstrated that apparent total tract digestibility of dry matter, organic matter, crude protein and crude fibre were greater in sows in the fourth pregnancy than in the first pregnancy. Greater digestibility of dietary energy, N and fibre in multiparous sows than in nulliparous sows was also observed by Renteria-Flores *et al.* (2008). Other studies have shown that the apparent total tract digestibility of energy and several nutrients in adult sows was greater than in growing pigs (Fernández *et al.*, 1986; Le Goff & Noblet, 2001; Le Gall *et al.*, 2009; Lowell *et al.*, 2015).

The increased digestibility of nutrients by sows in the fourth pregnancy compared with sows in the first pregnancy might be the result of differences in age, body weight and time of adaptation to a high fibre diet. The body weight of pigs increases with age, correlating with larger, more developed intestinal tracts and thus greater intestinal volume (Brunsgaard, 1997; Le Goff & Noblet, 2001; Landgraf *et al.*, 2006). Additionally, a longer period of feeding a diet rich in fibre allows for an increase in the gastrointestinal tract of the pigs (Bridges *et al.*, 1986; Rijnen *et al.*, 2001). It could be assumed that in the current study the sows in the fourth pregnancy had greater gastrointestinal tracts owing to greater body weight and longer feeding time of a diet high in fibre than the sows in first pregnancy. Increased gastrointestinal tract volume may influence digestibility through a slower transit time of digesta and greater contact of endogenous enzymes and microbial populations and more absorption of nutrients in the small and large intestines (Fernández *et al.*, 1986; Low, 1993; Le Goff *et al.*, 2002). However, the improvement of digestibility with age results mainly from a larger microbial population and more extensive fermentation in the large intestine (Shi & Noblet 1993a; b; Urriol *et al.*, 2010).

The improved digestibility of crude fibre is particularly noticeable with age (Le Goff & Noblet 2001; Lowell *et al.*, 2015), which agrees with the results of this study. Shi & Noblet (1993a) reported that fermentation of crude fibre in the large intestine is roughly 25% greater in sows than in growing pigs. Fermentation of crude fibre in the large intestine of pigs yields volatile fatty acids that can generate about 25% of the total digestible energy derived from the diet of sows (Shi & Noblet, 1993b). This value in multiparous sows is likely to be higher than in nulliparous sows owing to their greater ability to digest fibrous feed ingredients.

These results indicate that the total tract digestibility of ether extract, starch and sugars is not dependent on the age of pigs, which is consistent with previous reports (Le Goff & Noblet 2001; Serena *et al.*,

2008). These nutrients are digested mainly in the small intestine (Lin *et al.*, 1987) with several differences between growing and adult pigs.

The value of ME of the diet of sows in fourth pregnancy was greater than that of the diet of sows in first pregnancy (Table 5). This suggests that the ability of sows to degrade and utilize the fibre fraction in the large intestine improves with age. Therefore, sow age should be considered when formulating and estimating the energy value of diets of sows during early pregnancy. An increase in the value of metabolizable energy in diet, depending on the age of the pig, was observed by other authors (Le Goff & Noblet, 2001; Lowell *et al.*, 2015).

## Conclusions

Apparent total tract digestibility of dry matter, organic matter, crude protein and crude fibre was greater in sows in the fourth pregnancy than in the first. Consequently, the value of metabolizable energy, determined according to the content of digestible nutrients, in the diet of sows in the fourth pregnancy was greater than in the diet of sows in the first. Therefore, sow age must be considered when formulating and estimating the energy value of diets for sows during early pregnancy, because multiparous sows have greater ability to digest fibre fraction in the large intestine than nulliparous sows.

## Authors' Contributions

E.J. and A.P. were responsible for experiment conception and design, supervision of project, interpretation of results and wrote the manuscript. W.B., M.K. and A.S. participated in perform the research, collating the result and statistical analysis of data. A. K-S. and B.M. were responsible for supervision and perform the research. All authors were involved in discussing and interpreting the results.

## Conflict of Interest Declaration

None of the authors have any conflict of interest to declare.

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