Scientific Annals of Polish Society of Animal Production - Vol. 11 (2015), No 3, 33-43

Effect of the level of feeding of pregnant sows on their body condition and blood parameters*

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The aim of the study was to determine the effect of the level of feeding of sows during pregnancy (days 41-70) on their body condition and biochemical and hormonal blood parameters during gestation and after weaning of the piglets. The observations included 16 F_1 sows (PL x PLW), assigned at random to a control group (K) or experimental group (D) and fed individually with complete mixtures with the recommended nutritional value for pregnant and suckling sows. From days 41 to 70 of gestation the sows in group D received a 30% larger feed ration (0.7 kg/head/day) than the animals in group K, which received a standard ration. Blood samples were collected (*v. cava cranialis*) three times from all sows: at mating, on day 70 of gestation and at weaning of the piglets (day 35). The following biochemical parameters were determined: ALB, TP, ALP, GLU, CHOL, TG, CREA, UREA, the hormones GH and INS, and Fe. The temporary 30-day feeding of pregnant sows with an increased feed ration (by 30%) had a positive effect on body weight gain and fat and protein reserves in the sows. The sows fed more during the gestation period were in better breeding condition after rearing of their progeny than the moderately fed sows. The increased feed ration led to compensatory growth, indicating the expediency of applying a higher level of nutrition for sows during this physiological period. The experimental factor caused changes in the level of growth hormone and alkaline phosphatase on the 70th day of gestation in comparison with the mating period. A decrease in the concentration of GH (by 20%) and ALP was recorded in the sows in group D with respect to group K, while differences remained stable between the groups for the remaining biochemical parameters and insulin. No statistically confirmed differences were found in biochemical parameters, hormones or Fe between the groups, which indicates that the change in the feeding level made it possible to maintain the homeostasis of the organism.

KEY WORDS: sows / nutrition / blood / biochemical parameters / hormones

***The study was conducted under a grant from the Ministry of Science and Higher Education. Registration number for the research project: N N311 082639.**

The productivity of sows has been changing over the years. Today's sows give birth to and rear more offspring and produce more milk, and their full somatic maturity is linked to a high body weight. This means that their maintenance and production demand is greater [21, 22]. Therefore the nutritional requirements for pregnant and lactating sows must be continually verified experimentally. An important element of comprehensive evaluation is testing of the body condition of sows and their biochemical blood indices [29]. The results obtained may signal disturbances of homeostasis due to dietary errors. Nutritional deficiencies in pregnant females may be one of the reasons for the phenomenon of IUGR, which has negative consequences during the postnatal period and adulthood in many animal species, including pigs [16, 23, 25, 26]. The morphological and biochemical blood indices tested can be used to assess the state of the body by comparing them with reference values [9, 27, 33, 34, 35]. They are analysed and evaluated in relation to the quantity and quality of feed in the diet, as well as sex, age, physiological state, health, and housing conditions [3, 4, 7, 11, 15, 19, 24, 35]. A proper level of feed is conducive to optimization of protein and energy reserves, expressed as the value of characteristics measured in live animals—the thickness of the backfat and longissimus dorsi muscle, and homeostasis of the organism of sows [1, 28, 29].

The aim of the study was to determine the effect of the size of the feed ration for sows during days 41-70 of pregnancy on their body condition and biochemical and hormonal blood parameters during gestation and after weaning of the piglets.

Material and methods

Consent for the experiment was obtained from the third Local Ethics Committee. During the experiment 16 F_1 sows (Polish Landrace x Polish Large White), randomly assigned to the control (K) or experimental group (D), were individually fed complete mixed rations with the recommended nutritional value for pregnant and lactating sows [21]. The sows in group K during the first period of pregnancy (days 1 to 90) and the final period (days 91 to 110) received 2.3 kg and 3.2 kg, respectively, of the feed. The sows in group D were fed a similar diet, but from days 41 to 70 of gestation they received a 30% larger feed ration, i.e. 0.7 kg more per day than the sows in group K. During the perinatal period the amount of feed was varied: 2.0 kg/sow/day from days 111 to 114 (LP mixture for pregnant sows + wheat bran), 0.5-1.0 kg bran on the day of parturition, and an average daily ration increased by 1.0 kg (LK mixture for lactating sows) for 3-4 days after farrowing. During lactation the sows were fed according to recommendations in Swine Feeding Standards [21].

After insemination the sows were kept in individual pens for three weeks, and from the fourth week were kept in a group pen (solid floor with shallow litter), where they remained until the 104th day of gestation. Ten days before parturition they were transferred to farrowing pens divided into three sections, where they stayed with their offspring for 35 days after farrowing. The animals' housing was in compliance with zootechnical and hygiene standards [30].

The pregnant sows ate individually at a computer-controlled feeding station (the ration was programmed according to the design of the experiment). Lactating sows received feed three times a day, and the suckling piglets received a pre-starter mixture (ad libitum). The mothers and their offspring had constant access to water (automatic water troughs).

Body weight and the thickness of the backfat and *longissimus dorsi* muscle in the sows were measured three times: at mating, on day 70 of gestation and at weaning (35th day of lactation). Body weight was measured with an electronic weighbridge. Backfat and lean meat were measured with a Piglog 105 scanner, according to methods for performance evaluation of livestock animals [6].

From the sows of each group blood was collected three times from the cranial vena cava: on the day of mating, on day 70 of gestation and on the day of weaning. The blood samples were centrifuged (10 min, 3,500 rpm), and the serum was stored at –20ºC. Biochemical indices were determined in an Accent 200 biochemical analyser (Cormay) using level 1 multicalibrators, HP and HN sera and reagents for Cormay assays. The following were determined: albumin (ALB), total protein (TP), alkaline phosphatase (ALP), glucose (GLU), cholesterol (CHOL), triglycerides (TG), creatinine (CREA), urea (UREA), and iron (Fe). The growth hormone level was tested as well (GH) (Cormay assays). Insulin (INS) was determined with a Canberra Packard gamma-Cobra II counter, using hormones marked with I^{125}.

The results were analysed statistically using the SPSS Statistics 21 software package. Normality of distribution was tested by the Shapiro-Wilk test. Differences between groups were tested with the Mann-Whitney U test.

Results and discussion

At mating the sows from groups K and D did not differ in backfat thickness, the height of the loin eye (measured at point P_4M, i.e. behind the last rib, between the thoracic and lumbar vertebrae, 8 cm from the midline of the spine) or body weight (Tab. 1). Changes

Table 1
Fat and protein reserves in sows

Traits	Groups	Mating day	Changes with respect to mating day (%)	
			70th day of pregnancy	last day of lactation
P_2 (mm)	K	17.6	+ 29.3	+ 11.5
	D	17.6	+ 13.0	+ 24.4
P_4 (mm)	K	18.9	+ 28.3	– 4.0
	D	19.3	+ 11.1	+ 16.1
P_4M (mm)	K	51.1	+ 13.5	+ 9.4
	D	52.2	+ 17.9	+ 8.8
Body weight (kg)	K	139.4	+ 14.3	+ 21.3
	D	140.6	+ 21.1	+ 25.5

Groups: K – control, D – experimental

in fat and protein reserves (P_4M) during the study period, as well body weight, were more favourable in the group D sows. The increased feed ration caused intensive growth in the sows, which demonstrates that increased feeding for sows during this physiological period is advisable [22]. Sows receiving the larger feed ration during the period from days 41 to 70 of gestation had better body condition after rearing their progeny than the sows fed a moderate diet.

Table 2 presents the results of the blood tests in the sows. At mating the concentrations of GLU, Fe and GH were markedly higher, and ALB, TP, ALP, UREA and INS slightly higher in group D than in group K. The levels of the remaining indicators, i.e. CHOL, TG

Table 2
Biochemical and hormonal blood indicators

Indicators	Units	Groups		P
		K	D	
1	**2**	**3**	**4**	**5**
	Mating			
Albumin (ALB)	mmol · l^{-1}	3.28	3.42	0.161
Total protein (TP)	mmol · l^{-1}	56.86	60.50	0.195
Alkaline phosphatase (ALP)	mmol · l^{-1}	119.38	127.88	0.130
Glucose (GLU)	mmol · l^{-1}	5.77	6.61	0.645
Cholesterol (CHOL)	mmol · l^{-1}	2.66	2.74	0.721
Triacyloglycerides (TG)	mmol · l^{-1}	0.52	0.51	0.574
Creatinine (CREA)	μmol · l^{-1}	148.12	152.75	0.798
Urea (UREA)	mmol · l^{-1}	6.61	7.03	0.574
Iron (Fe)	μmol · l^{-1}	22.64	27.75	0.328
Growth hormone (GH)	U · l^{-1}	0.11	0.13	0.442
Insulin (INS)	U · l^{-1}	34.67	37.01	0.878
	70th day of pregnancy			
Albumin (ALB)	mmol · l^{-1}	3.88	3.95	0.721
Total protein (TP)	mmol · l^{-1}	57.71	61.22	0.279
Alkaline phosphatase (ALP)	mmol · l^{-1}	169.75	153.13	0.328
Glucose (GLU)	mmol · l^{-1}	6.76	8.00	0.279

1	2	3	4	5
Cholesterol (CHOL)	mmol · l^{-1}	2.55	2.74	0.161
Triacyloglycerides (TG)	mmol · l^{-1}	0.63	0.61	0.645
Creatinine (CREA)	µmol · l^{-1}	164.00	154.87	0.878
Urea (UREA)	mmol · l^{-1}	6.65	6.61	0.959
Iron (Fe)	µmol · l^{-1}	23.25	27.46	0.505
Growth hormone (GH)	U · l^{-1}	0.15	0.12	0.442
Insulin (INS)	U · l^{-1}	31.48	34.61	0.844
	Weaning			
Albumin (ALB)	mmol · l^{-1}	3.15	3.14	0.878
Total protein (TP)	mmol · l^{-1}	46.63	48.87	0.798
Alkaline phosphatase (ALP)	mmol · l^{-1}	119.50	122.38	0.505
Glucose (GLU)	mmol · l^{-1}	7.83	7.77	0.645
Cholesterol (CHOL)	mmol · l^{-1}	2.60	2.66	0.998
Triacyloglycerides (TG)	mmol · l^{-1}	0.55	0.62	0.574
Creatinine (CREA)	µmol · l^{-1}	144.75	161.37	0.279
Urea (UREA)	mmol · l^{-1}	7.03	6.81	0.574
Iron (Fe)	µmol · l^{-1}	26.25	27.32	0.645
Growth hormone (GH)	U · l^{-1}	0.13	0.12	0.574
Insulin (INS)	U · l^{-1}	33.07	37.24	0.645

Groups: K – control, D – experimental
P>0.05 – not statistically significant

and CREA, were similar. On the 70th day of gestation increased levels of GLU, Fe and INS were noted in group D as compared to group K, together with a significantly reduced level of growth hormone (GH) and markedly reduced ALP, with slight deviations (±) in the remaining biochemical indicators. During the weaning period the level of Fe, GH and GLU was higher and that of GH lower in group D than in group K; the concentrations of the other indicators tested were similar. Similar tendencies of changes in most of the indicators were observed, except for GH and ALP after the period when the 30% greater feed ration was used.

The mean values for the biochemical indicators in the blood of the sows (e.g. CREA, UREA, TG, and Fe) were within the normal ranges for the species, production group and phase of the reproductive cycle [33]. This indicates normal homeostasis of the organism of the animals studied and their good health, and confirms that their housing and diet were appropriate.

Increased feed consumption by sows causes an increase in the concentration of IGF--I and UREA in the blood plasma [20, 31]. The embryos of sows fed *ad libitum* have been shown to have elevated concentrations of urea and insulin-like growth factor in their plasma, allantois and amnion, as well as larger livers [20]. These results confirm the hypothesis that increased feed intake by pregnant sows affects the environment of the placenta on both the mother's and the embryo's side. Similar results were obtained by Hoving et al. [13], who found that the UREA concentration was higher in sows receiving a 30% larger feed ration than in the control. A higher INS concentration may signal the onset of anabolic processes. It may also indicate that the protein contained in the feed is of low biological value [10], so that not all amino acids are utilized by the body; this exacerbates deamination processes and the production of greater quantities of urea. In the present study, the UREA level did not vary significantly between groups or periods of the experiment. Korniewicz et al. [15], who reduced the level of protein in feed for sows by 10% or 20%, reported changes in biochemical blood indices, including reduced total protein, globulins and urea and increased total and LDL cholesterol.

In the present study a lower insulin level was noted in the sows on the 70th day of pregnancy than at mating. The reduction in INS activity was greater in group K (9.2%) than in group D (6.5%). The INS concentration was greater in the group D sows than in group K in the three periods of the experiment, by 6.75%, 9.94% and 12.61%, respectively. On the 70th day of gestation, when the INS concentration was higher in the blood of the experimental sows, the GH level was 20% lower in the group D sows than in group K. The differences between groups and between experimental periods in groups were not significant ($P>0.05$). The reduction in GH concentration in the present study is typical of various animal species fed intensively [12, 18]. Increased supply of nutrients to the body increases the release of somatostatin from the hypothalamus, which exacerbates its negative effect on the synthesis and release of GH. A relatively high INS level may stimulate the hypothalamus to sense glucose, which reduces the production and secretion of GH [2]. A reduced level of GH is one of the characteristics of compensatory growth, which in the present study seemed to be beneficial. Analysis of the role of growth hormone in reproduction, including at the level of very early pregnancy, implantation, and placental development, seems to confirm this [14]. Growth hormone is effective in stimulating muscle growth and inhibiting adipose tissue hyperplasia in the postnatal period [25]. Circulating in the bloodstream, the maternal growth hormone GH also plays a role in the prenatal growth and development of the offspring. Administration of GH to sows from early pregnancy until its middle stage increases foetal growth, irrespective of the status of the mother (multiparous or primiparous), the

size of the litter, or reduced feeding [32]. As GH is not able to cross the barrier of the placenta and does not increase its weight, Tung et al. [32] hypothesized that its effect on foetal growth may be due to improved placental structure or function. Testing the effect of GH administration to multiparous and primiparous sows on placental function, they found that administration of the hormone did not affect its size or structure. It did, however, increase the growth of the foetus by improving transport of nutrients through the placenta, thereby supplying them to the foetus, as well as increasing the growth and differentiation of the trophoblast, which may improve growth conditions for the foetuses within the uterus.

The present study found a marked increase in GLU content in the blood of the sows at weaning in comparison with the mating stage. Changes between the 70th day of gestation and mating day were 3.87 percentage points greater in group D than in group K, which may have been a consequence of the temporarily increased feeding level in the experimental sows. However, in the sows completing the rearing of their progeny the results in the groups were comparable, which suggests that the differences in the GLU level in the cycle may have been due to physiological changes in the bodies of the sows rather than to a modification of the feeding level in early gestation. Norms for GLU in the blood of pigs range from 3.0 to 5.6 mmol/l [34]. The results of the present study are consistent with those of other researchers [17, 35]. A study by Rekiel et al. [27] showed that after three weeks of lactation the level of GLU decreased as compared to the level noted in late pregnancy. In contrast, Kudlač et al. [17] and Žvorc et al. [35] found a higher blood level of GLU in lactating sows than in pregnant ones. Hoving et al. [13], comparing biochemical blood indicators of sows receiving feed rations of different size between days 3 and 35 of gestation (sows in the control received 2.5 kg/sow/day, while the experimental group received a 30% larger ration), found that on day 15 of gestation the GLU and INS levels before lactation were not significantly varied between the experimental and control groups. These researchers also found no differences between groups in the concentration of IGF-1. The concentration of non-esterified fatty acids (NEFA) was lower in group D than in group K (149.5 ±9.2 vs. 182.4 ±11.9 μm/l, P=0.04). The 30% larger feed ration for sows in the first period of gestation caused a lower concentration of NEFA, without affecting the level of progesterone, LH or IGF-1. Certain fluctuations in GLU during the reproductive cycle are a normal physiological phenomenon [34].

In groups K and D an elevated cholesterol level was noted as compared to norms in all three periods of the experiment [34]. In group K the CHOL concentration ranged from 2.55 to 2.66 mmol · l^{-1}, and in group D from 2.66 to 2.74 mmol · l^{-1}. An elevated CHOL level may be caused by kidney, liver or pancreas dysfunction or by a diet overly rich in fats [34]. The feed given to the experimental sows was not supplemented with oil. The higher CHOL level in the group D sows as compared to group K (at mating: +3.01%, 70th day of gestation: +7.45%, at weaning: +2.31%) may indicate that the dietary modification affected its content in the blood of the animals. According to Farmer et al. [8], a change in the feeding level can be expected to lead to changes in indicators of energy and protein metabolism.

The higher CHOL level in the blood of the group D sows as compared to group K (70th day of gestation) was probably due to greater synthesis of saturated acids [5], which are activators of 3-hydroxy-3-methylglutaryl coenzyme A reductase, which controls cholesterol synthesis in the liver.

To sum up, the temporary, 30-day use of a 30% larger feed ration in the diet of sows had a positive effect on body weight gain and fat and protein reserves in the body. The sows fed the increased rations during gestation had better body condition after rearing their offspring than the sows fed the moderate diet. The increased feed ration led to compensatory growth, which justifies its use in the diet of sows during this physiological period. The experimental factor caused changes in the level of growth hormone and alkaline phosphatase on the 70th day of pregnancy in comparison with the mating period. A decrease was noted in the concentrations of GH (by 20%) and ALP in the experimental sows in comparison with the control, while the differences between groups for the remaining biochemical indicators tested and for insulin remained stable. No statistically confirmed differences were noted between groups for biochemical indices, hormones or Fe, which suggests that the change in diet preserved homeostasis in the organism.

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