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Original article

Effects of dietary fibre on metabolism and performance in sows

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Abstract

The etiology of Postpartum dysgalactia syndrome (PDS) includes stress on preparturition and constipation associated with low water intake or low fiber intake. The aim of this study was to investigate the effects of a raw crude fibre concentrate (Arbocel®) on sow's metabolism and performance.

100 sows from a farm suffering from PDS, were divided into two groups, with equal distribution of their parity (1 to 5 parity): a) T1 group (control group): 50 sows were fed with regular gestation feed (GF), pre-farrowing feed (PFF), and lactation feed (LF), b) T2 group: 50 sows were fed with regular GF, PFF and LF supplemented with topdress Arbocel® from 104th day of gestation until 7th day of lactation). Health parameters [faeces score (FS), PDS score (PDSS), body condition score (BCS)], performance parameters and liter characteristics were recorded. Blood samples were collected from 25 sows / group (5 sows per parity) 24 h after birth of last piglet and on 14th day of lactation for the evaluation of insulin, leptin and ghrelin levels in the serum, using commercial ELISA kits.

In T2 group, BCS at farrowing (p<0.001), FS (p=0.001) and PDSS (p=0.003) were improved significantly. The number of piglets stillborn and dead due to crushing decreased (p=0.001), while the number of liveborn (p=0.016) and weaned piglets (p=0.001) increased in T2 group. Moreover, in T2 group, the BW of piglets at weaning was higher (p<0.001). A significant increase of insulin (p=0.032) and leptin (p=0.032) levels in serum was noticed in T2 group 24 h after farrowing. In conclusion, the supplementation of extra crude fibre in breeding stock with PDS problems due to nutritional imbalance has beneficial effects on their health and performance.

Key words: insulin, ghrelin, leptin, fibre, dysgalactia, pig

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Introduction

The modern hyperprolific sow and her numerous offspring appear to be a challenge to the producer in terms of reproductive performance of the herd (van Nieuwamerongen et al. 2014). Nutrition is considered a major factor in the reproductive management of the hyperprolific sow. During late pregnancy, one common practice in feeding sows aims to reduce the amount of feed offered and increase the energy of the ration in preparation for the upcoming metabolic changeover into lactation and farrowing (Farmer et al. 2014). This practice aims mainly to ensure that sows receive enough energy during late pregnancy to satisfy upcoming milk production (Decaluwé et al. 2014). High backfat values were associated with increased duration of farrowing (Oliviero et al. 2010). However, the reduction of the volume and fibre content of sow feeds can have negative effects, including increased stereotypic behaviour (Ramonet et al. 1999). As sows approach farrowing, severe constipation is common because the intestine is less active approaching parturition (Kamphues et al. 2000).

Postpartum dysgalactia syndrome (PDS), is characterized by insufficient colostrum and milk production during the first days after farrowing (Papatsiros et al. 2007, Martineau et al. 2012). The etiology of PDS includes stress before and after parturition and constipation associated with low water intake or low fiber intake (Maes et al. 2010, Papadopoulos et al. 2010, Martineau et al. 2012, Kirkden et al. 2013). In European Union, animal welfare legislation (EC 2001) imposes the provision of high-fibre diets to pregnant sows to improve sow welfare.

Addition of crude fibre in the sow diet has beneficial effects on the gut health; however, the effects on metabolism are not clear. Adding more fibre to sow diets during pregnancy (especially during the period prior to farrowing) prevents constipation, increases water intake and feed intake during lactation, improves the duration of farrowing as well as milk intake and performance of piglets (Danielsen and Vestergaard 2001, Oliviero et al. 2009, Quesnel et al. 2009, Peltoniemi et al. 2016). Crude fibre may also influence the energy metabolism of the sow (Le Goff and Noblet 2001).

The aim of the present study was to investigate the effects of top-dress application of a raw crude fibre concentrate (Arbocel®) on sow's metabolism and performance in a commercial breeding stock with PDS problems due to nutritional imbalance.

Materials and Methods

All procedures during this clinical study were performed according to the Code of Practice for the Conduct of Clinical trials for Veterinary Medical Products and the Guide for the Care and Use of Agricultural Animals in Research and Teaching and the animals were maintained in accordance with National and European animal Welfare requirements (OECD 2000, EMEA 2001, European Council 2003, FASS 2010). All animal procedures regarding animal care and handling were approved by the Ethical Committee of the Faculty of Veterinary Medicine, School of Health Sciences, University of Thessaly (Approval number 44/21.06.2017).

Trial farm: Capacity/Facilities

One farrow-to-finish swine herd, consisting of approximately 650 sows (commercial hybrids Landrace x Large White, Topigs), with its own feed mill, participated in the study. Based on farm records, the mean number of total born piglets, per sow, per year was 34.73 and the mean number of weaned piglets, per sow, per year 27.14. During the last 12 months prior the trial, the farm suffered from PDS problems at a prevalence of 45%, including mainly agalaxia, pyrexia and constipation.

All gilts/sows were ear-tagged and were housed in the mating-pregnancy building. Gilts in the farm were served during their 2nd oestrus. After weaning, sows were housed in pens of 5 animals. One week prior to farrowing, the sows were moved from the gestation unit to the farrowing house in groups of 9-11 animals in order to fill one farrowing room. All pens were equipped with commercial farrowing crates, including nipple drinkers and separate removable feeders for the sows and the piglets. No enrichment material (e.g. straw) was used in sows before and after parturition. At weaning sows were moved to the breeding stock house and were penned separately in individual cages with slatted floors. Piglets were weaned at 28±3 days of age and around 350-380 weaners were moved weekly into the flat deck unit, grouped in pens of 25 pigs.

The feed provided to the farm animals was home-mixed and was (depending on the season of the year) a corn/barley/wheat - soybean based meal (Tables 1a,b). The drinking water was provided to animals throughout automatic system. In farrowing crates there was a nipple per sow and a nipple for piglets, in individual stalls a nipple per sow, in pens of weaning stage a nipple per 10 weaners and in pens of growing/finishing stage a nipple per 40 animals. Housing facilities had fully automated temperature and humidity control sys-

Table 1a. Composition of gestated and lactated sows' diet.

Composition (ingredients) (%)	Gestation Feed-GF	Pre-farrowing feed-PFF*	Lactation feed-LF**
Corn	32.95	25.5	25.0
Barley	20.0	32.8	30.8
Wheat bran	27.5	24.5	20.0
Soybean	14.0	10.0	14.5
Soybean oil	2.2	2.1	3.0
Fish meal	-	1.0	2.5
Premix of vitamins/minerals	1.25	1.25	1.25
Limestone	1.10	1.0	1.6
Sodium Bicarbonate	0. 6	-	0.4
Monocalcium phosphate	0.4	0.55	0.65
Sodium chloride	-	0.65	0.3
Citric acid	-	0.65	-

*110th day of gestation to 3rd day post-farrowing
** 4th-7th day post-farrowing

Table 1b. Calculated analysis of gestated and lactated sows' diet.

Analysis	Gestation Feed-GF	Pre-farrowing feed-PFF*	Lactation feed-LF**
NE (Kcal/Kg)	2217.093	2202.759	2298.608
Crude protein (%)	14.773	14.327	16.846
Crude Fat (%)	4.811	4.612	5.541
Crude Ash (%)	5.531	5.680	6.190
Crude Fibre (%)	5.155	5.034	4.164
Lysine (g/kg)	7.621	8.155	10.058
Methionine+Cystine (g/kg)	5.518	6.084	6.744
Calcium (g/kg)	9.151	9.293	1.0
Total Phosphorus (g/kg)	5.356	5.494	5.832
Available Phoshorus (g/kg)	3.574	3.817	4.074

*110th day of gestation to 3rd day post-farrowing
** 4th-7th day post-farrowing

tem, as well as automated feeding. The flow of the nipples was checked every day, while the quality of water was checked monthly for chemical and microbiological risk factors. The detailed feed composition is shown in Table 1 and the feeding schedule in Table 2. During lactation period, on the days that the feed amount was up to 6 kg, this was provided in 3 meals only during the summer period, otherwise in 2 meals. Piglets received part creep feed and a liquid milk supplement during lactation period.

Animals

A hundred sows of a farm suffering from PDS, were allocated randomly to one of two groups, taking into account the equal distribution of sows, according to their parity (1 to 5 parity): a) T1 group: 50 sows of the control group were fed with regular gestation-GF, pre-farrowing-PFF, and lactation-LF feed, b) T2 group: 50 sows were fed with regular GF, PFF and LF supplemented with topdress Arbocel® from day 104 of gestation until 7th day of lactation) (Table 2). At admission, ear tags of the animals were recorded, while cross fostering was allowed only among litters of the same experimental group. Animals of both groups were in the same room or in identical rooms.

Experimental product

Arbocel® (J. Rettenmaier & Söhne GmbH and Co KG) is HPC-fibrillated crude fibre concentrate made from lignocellulose with a crude fibre content of more than 65%. Arbocel® was distributed as top-dress (once per day in morning meals) and the total quantity that each sow received was 500 grams.

Table 2. Feeding schedule in gestated and lactated sows (values obtained from obtained from NRC 2012).

TIME	FEED		
	Gestation Feed GF	Pre-farrowing feed PFF	Lactation feed LF
Up to 1-week pre-farrowing	2.5-3 kg (2 meals)	-	-
1-week pre-farrowing	-	2.5-3 kg (2 meals)	-
2 days pre-farrowing	-	1.5-2 kg (2 meals)	-
1-day pre-farrowing	-	1-1.5 kg (1 meal)	-
1st -3rd day of farrowing	-	1/1.5/2 kg (1/2/2 meals)	
4th day post-farrowing to weaning	-	-	2.5 kg plus 0,4 kg/piglet (3 meals)

Collection of blood samples

Blood samples were collected from 25 sows/group (5 sows per parity from parity 1 to parity 5), at first 24 hours of lactation and on 14th day of lactation (4 hours after meal) in order to evaluate the levels of insulin, leptin and ghrelin in serum. Blood samples were collected from the same 10 sows each period via vena cava puncture, 4 hours after morning meal.

Recorded parameters

The following parameters were recorded (blinded) by a different person than the person responsible for the group allocation.

Sow body condition parameters

Condition of the sows was assessed on farrowing and weaning days, based on parameters of body condition score (BCS) and body weight (BW). The body condition of the sows was assessed both visually and by means of backfat measurements on farrowing and weaning days. Before performing the backfat measurements, the BCS of the sow was assessed by the same person visually with a numerical rating of 1 to 5 (Muirhead and Alexander 1997). Score 1 was used for extremely thin sows, score 5 for extremely fat ones. Backfat measurements were performed using the P2 method (Lean-Meater® Series 12, serial number 63597, Renco Corporation Minneapolis USA). The point of measurement was marked on each sow to guarantee that the same spot was investigated during the subsequent measurements.

Health status parameters

Data relative to health status parameters were recorded:

a) Constipation score (according to Oliviero et al. 2009): 0 = absence of faeces, 1 = dry and pellet--shaped (unformed), 2 = between dry and normal (pellet-shaped and formed), 3 = normal and soft, but firm and well formed, 4 = between normal and wet; still formed, but no firm, 5 = very wet faeces, unformed and liquid.
b) PDS score (0 = no clinical signs, 1 = medium; body temperature of the sow >39.0°C on day 1 postpartum and clinical signs in the sow or suckling piglets, 2 = severe; body temperature of the sow >39.5°C on day 1 postpartum and clinical signs in the sow and suckling piglets), 3 = acute; body temperature of the sow >40.5°C on day 1 postpartum and clinical signs in the sow and suckling piglets.

Performance parameters

Reproductive parameters (gestation length in days, duration of lactation in days, weaning to service interval in days) and litter characteristics (number of totally born, liveborn, stillborn, dead due to crushing from their mother, fostered and weaned piglets), as well as BW of piglets at weaning.

Levels of insulin, leptin and ghrelin in serum

Serum levels of insulin, leptin and ghrelin were measured using the enzyme-linked immunosorbent assay (ELISA). Insulin and leptin were measured using the commercial Sandwich-ELISA Porcine LEP (Leptin) ELISA and Porcine INS (Insulin) ELISA Kits (Elab science Biotechnology Co. Ltd, China), respectively and according to the manufacturer's protocol. Ghrelin was measured using the competitive immunoassay commercial Porcine Ghrelin ELISA Kit (AB clonal, MA 01801, United States) according to the manufac-

Table 3. Sow body condition and health status parameters per group (mean±sd).

Parameters	Groups		P-value
	T1	T2	
BW at farrowing (Kg)	227.70±30.13	225.40±27.69	0.626
BW at weaning (Kg)	211.90±29.53	209.10±28.81	0.554
Backfat at farrowing	14.61±0.60	14.03±0.37	<0.001
Backfat at weaning	12.68±0.56	12.23±0.58	<0.001
BCS at farrowing	4.04±0.60	3.54±0.64	<0.001
BCS at weaning	2.74±0.59	2.86±0.35	0.149
Faeces score (FS)	2.28±0.88	2.82±0.69	0.001
PDS score (PDSS)	1.28±1.03	0.68±0.76	0.003

Table 4. Performance parameters (reproductive parameters and litter characteristics) per group (mean±sd).

Parameters	GROUPS		P-value
	T1	T2	
Reproductive parameters (days)			
Gestation length	114.92±1.62	116.56±1.52	<0.001
Duration of lactation	29.06±2.83	26.42±1.59	<0.001
Weaning to service interval	6.64±2.70	5.44±1.10	0.001
Litter characteristics (piglets)			
Total born	15.02±2.78	15.28±2.79	0.690
Stillborn	2.36±1.65	1.3±1.19	0.001
Liveborn	12.64±2.90	13.96±2.38	0.016
Fostered (given)	1.18±1.39	1.4±1.59	0.542
Fostered (received)	1.4±2.22	0.78±1.29	0.413
Dead piglet (crushing)	1.02±0.96	0.2±0.62	0.001
Weaned	11.64±1.43	12.7±1.29	0.001
BW at weaning	7.18±0.41	7.59±0.39	<0.001

turer's protocol. All samples were measured in duplicate and the median of each result was used.

Statistical analysis

Data of laboratory tests (insulin, leptin and ghrelin) were subjected to Mann-Whitney test to determine any significant differences between groups. The statistical analysis was done with SPSS v.21 (IBM Inc., Chicago, Illinois) and the significance level was set at $p<0.05$. Data of recorded parameters are expressed as mean±standard deviation and normality was evaluated using the Shapiro-Wilk test. Comparisons were performed using the nonparametric Mann-Whitney U test. Statistically significant differences were considered at $p<0.05$ levels. All analyses were performed using the IBM SPSS software version 25 (IBM Corp, Armnok, NY, USA).

Results

Sow body condition and health status parameters

Data relative to sow body condition and health status parameters (BW of sows at farrowing and at weaning, backfat and BCS at farrowing and at weaning, faeces and PDS scores) are presented in Table 3. No statistically significant differences were observed regarding BW at farrowing and at weaning in sows, as well for BCS at weaning. However, the parameters of BCS at farrowing ($p<0.001$), FS ($p=0.001$) and PDSS ($p=0.003$) were significantly improved in T2 group.

Performance parameters

Performance parameters (reproductive parameters and litter characteristics) are shown in Table 4. The gestation length was higher ($p<0.001$), while the duration of lactation periods ($p<0.001$), as well as the weaning to service interval ($p=0.001$) were lower in T2 group

Table 5. Median values of insulin, leptin and ghrelin in serum of sows (ng/ml) per group at 24 h and 14 days after farrowing.

Parameter	Groups		P-value
	T1	T2	
24 h after farrowing			
Insulin	0.19	1.55	0.032
Leptin	0.13	2.53	0.032
Ghrelin	48.24	53.90	NS
14 days after farrowing			
Insulin	0.19	0.19	NS
Leptin	0.27	1.00	NS
Ghrelin	52.22	33.52	NS

NS: not significant

Table 6. Median values of insulin, leptin and ghrelin in serum of sows (ng/ml) in the same group at 24 h and at 14 days after farrowing.

Parameter	TIME		P-value
	24 h after farrowing	14 days after farrowing	
T1 group			
Insulin	0.19	0.19	NS
Leptin	0.13	0.27	NS
Ghrelin	48.24	52.22	NS
T2 group			
Insulin	1.55	0.19	NS
Leptin	2.53	1.00	NS
Ghrelin	53.90	33.52	NS

in comparison to T1 group. The number of stillborn piglets and dead piglets due to crushing decreased (p=0.001), while the number of liveborn (p=0.016) and weaned piglets (p=0.001) increased in T2 group. There was no significant difference between the groups regarding the number of fostered piglets that sows give or receive. Moreover, the BW of piglets at weaning was higher (p<0.001) in T2 group in comparison to T1 group.

Laboratory examinations

Levels of insulin, leptin and ghrelin in serum (24 h and 14 days after farrowing)

Data relative to median values of insulin, leptin and ghrelin in serum at 24 h after farrowing (24 h after birth of last piglet) and 14 days after farrowing between groups are shown in Table 5. Due to hemolysis of most of the samples, it was not possible to determine insulin levels in all samples, as the erythrocytes release endopeptidases, which degrade the insulin. A significant increase of insulin (p=0.032) and leptin (p=0.032) levels in serum was noticed in T2 group 24 h after farrowing. However, there was no significant difference between groups, for ghrelin levels in serum 24 h after farrowing. Finally, no significant differences were noticed in median values of insulin, leptin and ghrelin between groups 14 days after farrowing.

Comparison of median values between 24 h and 14 days after farrowing

Median values of insulin, leptin and ghrelin in the same group 24 h and at 14 days after farrowing are presented in Table 6. No significant differences were noticed in both groups.

Discussion

Our results indicated that a high-fibre diet of sows from day 104 of gestation and during lactation has beneficial effects on their reproductive parameters and litter characteristics (Table 4). Gestation length was higher (ranged in more normal lengths, >115 days) and the duration of lactation period was lower in T2 group in comparison to T1 group. The difference in the duration of lactation period is due to the differences of gestation length, as all sows were weaned on the same day. The increase of gestation length in T2 group is important for modern genetic lines, as allowing piglets to stay *in utero* extra days leads to improved birth weight and colostrum antibodies levels in the sow (Pinilla et al. 2008, Kraeling and Webel 2015). Moreover, in our study feeding of sows with high-fibre diet lead to a decrease of the number of stillborn piglets at birth and increase of the number of liveborn and weaned piglets. The advantages of increased fibre in the feed of sows, during gestation, on their health and behaviour are well known (Meunier-Salaun et al. 2001).

Stereotypic (van der Peet-Schwering et al. 2003) and aggressive behaviour incidents (Danielsen and Vestergaard 2001) are fewer when using high-fibre gestation diets. In our trial, we noticed that most sows belonging to the group of high-fibre rations (T2 group) had lower duration of farrowing and less dead piglets due to crushing. Prolonged duration of farrowing is considered as one of the complications of the confinement stress (Oliviero et al. 2010). The death of live-born piglets can also be related to sow's behaviour. It can result due to low attention of the sow towards the piglets, which increases the risk of crushing (Grandinson et al. 2003), or from sow's nervousness combined with aggressiveness and further infanticide. It is possible that lower mortality of suckling piglets due to crushing in T2 group in comparison to T1 group could be related to the beneficial effects of a high-fibre diet on the welfare status of sows during parturition period.

Feeding of sows with a high-fibre diet during the period preceding parturition has beneficial effect on gut function (e.g. lower constipation frequency), duration of farrowing (Oliviero et al. 2009) and backfat (Guillemet et al. 2007). In our study, in the group that received extra dietary fibre (T2 group), the parameters of backfat and BCS at farrowing was improved in comparison t o T1 group. In addition, the faeces score in T2 group ranged between normal values, indicating a significant decrease of constipation incidents. Previous studies showed that constipation at farrowing could be avoided by increasing the amount of dietary fibre during the last phase of pregnancy (Tabeling et al. 2003, Oliviero et al. 2009). Dietary fibres are also known to reduce sow digestive disorders such as constipation (Wenk 2001, Tabeling et al. 2003) as well as excessive body fat at farrowing, that has been shown to lead to longer parturition length and increased losses of piglets (Bilkei Papp 1990). Our results for backfat and BCS at farrowing agree with a previous study (Guillemet et al. 2007), which reported that sows fed the high-fibre diet gained less backfat during gestation in comparison to sows with a control diet. Based on our results, the administration of extra fibre in the diet of sows before farrowing may lead to a faster farrowing process, less backfat at farrowing, fewer constipation incidents, resulting in a lower number of stillborn piglets in comparison to T1 group.

The incidence of postparturition disorders in sows is affected by the farrowing duration (Tummaruk and Sang-Gassanee 2013). Moreover, the constipation in sows on the day of farrowing results in reduced appetite on day 1 postpartum and the incidence of sows with fever on day 1 postpartum is higher in sows with constipation (Pearodwong et al. 2016). In our study, we noticed that the incidences of PDS and constipation were lower in T2 group in comparison to T1 group. Generally, PDS is characterized by insufficient colostrum and milk production during the first days after farrowing (Martineau et al. 2012). The lower frequency of PDS incidents in the T2 group, during our study, had possible beneficial effects on their colostrum and milk intake in piglets, resulting in an increased number of weaned piglets.

Insulin assists the movement of glucose in the bloodstream into the cells to provide energy and its levels usually increase after feeding (Vieira et al. 2010). Leptin is a mediator of the long-term regulation of the energy balance, suppressing food intake and thereby inducing weight loss in pigs (Barb et al. 2005, Berthoud 2005). It serves as an endocrine messenger from the body to the brain and elsewhere to communicate the nutritional status of the body, which in turn influences feeding behavior, metabolism, and energy balance in most animal species (Keisler et al. 1999). Ghrelin is a fast-acting hormone that plays a role in increased appetite and therefore feeding initiation (Klok et al. 2007). In the current study, insulin and leptin levels results were significantly increased in serum 24 h after farrowing in T2 group, but no significant difference was noticed in ghrelin levels between groups (Table 5). Insulin levels usually increase after feeding in situations of appropriate nutritional status, while is low in sows and cattle that are nutritionally compromised (Lucy 2008). When an animal with optimal body condition is fed, insulin and leptin levels normally increase, while the concentration of circulating ghrelin decreases (Brown 2011). In our study, we noticed a significant increase of insulin and leptin levels in serum 24 h after farrowing in the T2 group (Table 5). However, our results contrast with Quesnel et al. (2009), as they noticed that the greater appetite of lactating sows fed a high-fibre diet during gestation may be partly explained by decreased secretion of leptin and does not seem to be related to changes in glucose and insulin metabolism. Moreover, the results of our study regarding leptin levels and BCS at farrowing contrast with De Rensis et al. (2005), who observed a positive relationship between blood leptin level in sows and their backfat thickness.

The feed intake of sows during lactation, on the other hand, appears as a key factor in enhancing gonadotropin secretion and follicle development throughout lactation period; however, these effects of feeding become more evident towards the end of lactation (Kauffold et al. 2008). In the current study, the supplementation of extra fibre in sows during late gestation and lactation has possible beneficial effects on the reproductive performance (weaning-to-service interval).

Conclusions

In conclusion, the supplementation of extra fibre in sows suffered from PDS, during last stage of gestation and lactation has beneficial effects on their health status and performance parameters. Moreover, the increase of insulin and leptin levels in serum of sows 24 h after farrowing could be correlated with an optimal body condition and improvement of metabolic status.

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