Feeding of sows with organic diets containing peas or faba beans during gestation and lactation

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Abstract

The objective of this study was to examine the influence of pea and faba beans in the organic feeding of gilts and sows and phasing the lactation and gestation feeding on pregnant and lactating sows. The lactation feeding was phased by giving the sows more protein (rape seed expeller) at the last half of lactation (from 3 weeks lactation to weaning). The feeding of gestation was phased by replacing a part of the gestation feed with lactation feed at the last third of gestation.

Experiment was carried out with 84 sows. The experiment was focused on sow feeding during lactation (n=74 sows) as only a small number of the sows (n=23) had results from the gestation period. MTT's sow unit was closed at the end of 2013. The results from the gestation period have been calculated and reported but the data was too small to draw conclusions.The sows were divided to three experimental groups: control (19.7% peas on lactation diet), experimental group 1 (19.7% pea and rapeseed expeller 3.4% after 21st day of lactation) and experimental group 2 (16.4% faba beans and rapeseed expeller 3.6% after 21st day of lactation). The diets contained also organic barley, wheat, oats and protein and mineral concentrate. The sows of different parity were located in the treatment groups: 1st parity, 2nd to 6th parity and 7th parity onwards.

Live weight and condition changes, fat measurements and the piglets weight development was studied using 100% organic diets. Milk samples were taken from a total of 24 sows. Samples were analyzed for dry matter, lactose, protein and fat concentrations.

The daily net energy intake of the sows was similar during the 21 days of lactation but from day 22 to weaning the NE intake was higher in the experimental groups 1 and 2 (103.8 MJ and 100.3 MJ/d) than in the control group (96.5 MJ/d). During lactation the sows lost 11.6 kg, 15.6 kg and 13.6 kg body weight in control group and the experimental groups 1 and 2 respectively. Total loss of body weight from farrowing to weaning, back and side fat changes (109th day of farrowing to weaning) were not affected by dietary treatment. The litter weight at weaning tended to be higher in the experimental groups 1 and 2 (161.2 kg and 154.6 kg) than in the control group (147.8 kg). In conclusion, the performance and production results of the sows with high daily energy intake were similar in diets containing peas and faba beans. The supply of additional protein feed had no effect on sow performance but tended to increase litter weight at weaning.

Keywords:

sow, piglet, lactation, pea, faba beans, organic production, condition score, fat measurement,

Herneen ja härkäpavun käyttö emakoiden vaiheistetussa luomuruokinnassa

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Tiivistelmä

Tutkimuksessa selvitettiin herneen ja härkäpavun käytön sekä ruokinnan vaiheistamisen vaikutuksia emakon ja porsaiden tuotantotuloksiin luonnonmukaisella ruokinnalla. Imetysajan ruokinta vaiheistettiin antamalla emakoille rypsipuristetta neljännestä imetysviikosta vieroitukseen. Tiineysajan ruokinta vaiheistettiin korvaamalla osa tiineysrehusta imetysrehulla viimeisen tiineyskolmanneksen aikana.

Kokeessa oli 84 ensikkoa ja -emakkoa. Tutkimuksessa keskityttiin emakoiden imetysruokintaan (n= 74 eläintä), koska Hyvinkään tutkimussikalan lopettamisen takia vain 23 emakolla oli tietoa tiineysajalta ja sen jälkeisestä imetyksestä. Emakot jaettiin kolmeen koeryhmään: kontrolli (19.7 % hernettä imetysrehussa), koeryhmä 1 (19.7 % hernettä imetysrehussa + rypsipuriste 3.4 % 22. imetyspäivästä alkaen) ja koeryhmä 2 (16.4 % härkäpapua + 3.6 % rypsipuristetta 22. imetyspäivästä alkaen). Lisäksi rehuissa oli viljaa ja luonnonmukaista täydennysrehua. Ryhmiin otettiin eri porsimakerran emakoita: ensikot, 2. – 6. porsimakerta ja ≥ 7. porsimakerta.

Kokeessa mitattiin elopaino emakoilta ja imeviltä porsailta, kylki- ja selkäsilava emakoilta sekä arvioitiin emakoiden kuntoluokka. Kokeessa analysoitiin 24 emakon maidon kuiva-aine-, laktoosi-, valkuais- ja rasvapitoisuudet 1 päivä porsimisesta, 21 päivää porsimisesta ja vieroitusviikolla.

Päivittäisessä energiansaannissa ei ollut eroa ruokintaryhmien välillä ensimmäisten kolmen viikon imetyksen aikana, mutta neljännestä imetysviikosta vieroitukseen koeryhmien 1 ja 2 päivittäinen energiansaanti oli suurempi (103.8 NE MJ/d ja 100.3 NE MJ/d) kuin kontrolliryhmällä (96.5 NE MJ/d). Emakot menettivät painoaan imetyksen aikana keskimäärin 11.6 kg, 15.6 kg ja 13.6 kg (kontrolli, koeryhmät 1 ja 2). Imetyksen aikaisessa painonmenetyksessä ei ollut tilastollisesti eroa eri ruokintaryhmien välillä. Porsaiden pahnuepaino vieroituksessa oli koeryhmillä 1 ja 2 (161.2 kg ja 154.6 kg) suurempi kuin kontrolliryhmällä (147.8 kg). Tulos oli vain suuntaa-antava (p=0.10).

Tulosten mukaan emakoiden tuotantotulokset olivat samanlaiset hernettä ja härkäpapua sisältävillä ruokinnoilla. Emakoiden luomurehujen syöntikyky oli suuri. Lisävalkuaisen annolla imetyksen viimeisinä viikkoina ei kuitenkaan ollut vaikutusta emakoiden tuotantotuloksiin, mutta se paransi suuntaa-antavasti pahnueen vieroituspainoa.

Avainsanat:

emakko, porsaat, herne, härkäpapu, luomutuotanto, imetys, kuntoluokka, silavamitat

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1 Introduction

In organic piglet production the length of lactation period is at least 40 days (Evira, 2014). In the conventional production the lactation is often in the range 21 to 28 days and rarely longer than 35 days. The extended lactation sets many challenges on the sows' feeding in organic production. However, the effects of extended lactation on nutritional requirements, performance and feed intake of the sows have been seldom studied. Sows should not lose body weight and condition. The extended lactation also requires that the sows must be in good body condition at farrowing. Excessive body weight loss can have an unfavourable effect on the sow's estrous cycle which can lengthen the time from weaning to pregnancy. For the first litter sows, weight loss during lactation can have a negative effect on the size of the next litter. In organic piglet production with long lactation period it is crucial that the sows have good feed intake and mothering ability.

In organic production the energy and amino acid levels of lactation feed are not necessarily as high as the recommended levels for conventional production. The main challenge is finding protein sources for the lactating sows. Organic lactation diets often contain feed ingredients with anti-nutritive substances which can negatively affect diet palatability when they are used in large amounts.

1.1 Legumes for sows

Legumes and rapeseed are the most potential domestic protein sources for organic monogastric animals in Finland and in Northern Europe (Partanen et al. 2001, 2003, 2006). However, the current information is from 1970-1990s (Buron & Gatel 1992, Etienne 1977, Etienne et al. 1976, Gatel et al. 1988, Suomi, 1985) and the cultivars have developed after that. Both peas and faba beans are good sources of protein but like other legumes their content of the sulphur containing amino acids methionine and cysteine is low. Rapeseed expeller from organic oil production is a good source of methionine and cysteine in diets containing peas or faba beans for sows. Peas and faba beans contain a number of anti-nutritive factors which can impair protein digestion and affect the palatability of the diets. Maximum inclusion rate of faba beans for lactating sows has been as low as 15% of DM (Buron & Gatel 1992) which is lower than recommendations for peas for lactatiog sows. More updated research is needed on the suitability of legumes, especially faba beans, for sows feeding.

1.2 Phase feeding of lactating sows

The sows' nutrition can be set closer to the requirements by phase feeding. The sow's requirement of protein and amino acids are different during gestation and lactation. At the beginning of the gestation when the foetuses' nutritional requirements are small, the sow's need of protein remains low. During the last third of gestation the foetuses grow fast and the sow's energy and protein needs are growing exponentially (Walker & Young, 1992). The optimal amino acid ratio in the diet is different in the beginning and the end of gestation. Kim et al. (2009) suggest that the need of standardized ileal digestible threonine and leucine at the beginning of gestation are 79% and 88% of the amount of lysine, and at the end 71% and 95%. The need of valine in relation to lysine only changes from 65% to 66% during the gestation time. Levesque et al. (2011) stated that the need of threonine grows at the end of the gestation, depending on how many times the sow has farrowed. For the sow's second farrowing the amount of threonine in relation to lysine should be 47% in the beginning and 72% at the end of the gestation. For the sows third farrowing the respective threonine to lysine ratios should be 61% and 95%. The Danish recommendation for ideal amino acid pattern for sows according to Tybirk et al. (2014) is presented in Table 1.

Table 1. Suggested ideal ratios for standardised ileal digestible amino acids for sows, relative to propotion of lysine (Tybirk et al. 2014).

	SID Met	SID Met +Cys	SID Thr	SID Try	SID Ile	SID Leu	SID His	SID Phe	SID Phe +Tyr	SID Val
Ideal AA pattern in gestation	0.48	0.97	0.91	0.30	0.91	0.79	0.36	0.58	1.09	1.06
Ideal AA pattern in lactation	0.32	0.60	0.65	0.20	0.56	1.15	0.39	0.55	1.13	0.76

At the last phase of lactation, 21 days after farrowing, the optimal amino acid ratio in the feed is affected by the sow's weight loss in the preceding of weeks of lactation. For example the requirement of threonine in relation to lysine is the lowest, 59%, for the sows who have not lost body weight at all (Kim et al. 2009).

The sow's milk production in affected by genotype, parity, litter size and weight, piglets vitality and temperature of the environment (Ètienne et al. 2000). Milk production is dependent on the sow's ability to eat and on the feed palatability. Sufficient feed intake ensures adequate transfer of the nutrients from feed to milk production and can prevent excessive use of the sow's tissue storages to compensate for a low feed intake (Libal, 1991).

It has been possible to decrease the nitrogen flow in the manure by a phased gestation feeding (Clowes et al. 2003), and phasing of the lactation feeding could be a possibility to maintain the sows condition and strain the environment less.

1.3 Milk composition

The sow's milk production after farrowing is very low but grows exponentially during the first nine days of lactation. After that milk production still increases (Noblet & Etienne, 1986). The composition of milk also changes during the lactation. At the beginning, three days after farrowing, the content of fat in milk is 11% and the content of protein is 6.5%, but 7 days after farrowing the contents of fat and protein have decreased to 8% and 5.1%. These levels are maintained until the end of the third week of lactation. The content of lactose in sow milk is 4% at the beginning and increase to 5% on the first week of lactation and remains at that level until the end of third week of lactation (Dourmad et al. 1998). Too low intake of protein from the lactation feed increases the sow's weight loss and deteriorates the growth of the piglets. The sow's metabolism cannot quite compensate the missing protein from body storages and transform it to the milk for the piglets (Quesnel et al. 2005). There is very little information on the effect of long lactation, adapted in organic production, on milk composition at the end of lactation period.

2 Materials and methods

2.1 Aim of the study

The aim of this experiment was to study the effects of phase feeding during lactation and gestation and the effects of peas and faba beans in the organic feeding of gilts and sows on the feed intake, weight and condition changes of sows and their piglets and composition of the sow milk.

2.2 Experimental design and animals

The experiment was conducted according to a 3 x 3 factorial design. The first examined factors were the dietary treatment and the parity of the sow. The lactation feeding was phased by providing the sows supplemental protein during the late lactation (4th lactation week to weaning). The gestation feeding was phased by replacing part of the gestation diet with lactation diet during the last third of gestation. The three experimental treatments were as follows:

1) Control, cereal-pea-rapeseed expeller based diets for gestation and lactation, no phase feeding (**Control**)
2) Phase feeding by supplementing cereal-pea-rapeseed expeller based diets with rapeseed expeller in lactation and with lactation diet in gestation (**Experimental group 1**)
3) Phase feeding by supplementing cereal-faba bean-rapeseed expeller based diets with rapeseed expeller in lactation and with lactation diet in gestation (**Experimental group 2**)

The experiment began on the 109th day of gestation and continued during lactation, subsequent gestation and lactation. The lactation lasted at least 40 days after both farrowings. The experiment ended, when the sow was weaned after the second lactation.

The parity of the sow was grouped as follows:

1) First parity
2) 2nd to 6th parity
3) 7th parity onwards

The experiment was performed on the MTT's experimental farm in Hyvinkää (16.11.2012 – 16.7.2013). A total of 74 Finnish Landrace and Finnish Landrace and Yorkshire crossbred sows from the three parity groups were randomly allotted to the dietary treatment groups (Tables 2 and 3). The original aim was to use 90 sows in the experiment, 30 sows in each dietary treatment. As MTT's sow unit was closed down in 2013, the number or gestating and second lactation sows remained small. Therefore, the focus of this report is on the effects of dietary treatment and parity during the first lactation in the trial.

Table 2. The breed distribution of the sows in the treatment groups during the first lactation period.

	Control	Experimental group 1	Experimental group 2	
Yorshire x Finnish Landrace	13	12	13	38
Finnish Landrace	12	14	10	36
Total	25	26	23	74

Table 3. Distribution of the experimental sows by parity during the first lactation period.

	Control	Experimental group 1	Experimental group 2
1st litter	9	10	9
2nd litter	2	2	1
3rd litter	4	4	3
4th litter	4	2	3
5th litter	2	1	2
6th litter		2	
7th litter	2	3	3
8th litter		1	2
9th litter	1		
10th litter		1	
11th litter	1		
Total	25	26	23

2.3 Housing

The sows were moved to the farrowing unit around the 100th day of gestation. They were housed in compartments for 8 sows in individual pens (2.9 m x 2.0 m) with a farrowing crate (2.4 m x 0.85 m). The farrowing crate was used on farrowing day and opened one day after farrowing, and the sows had a possibility to turn and move. The farrowing pens had slatted dunging area (38% of total area was slatted floor). The piglets had laying area with solid floor, equipped with a nest, an infrared heating lamp and dry feeder. At weaning the sows were moved to gestation compartment and were housed in groups of 7 – 8 animals. Total area per sow was 2.36 m^2 which included 0.60 m^2 slatted floor. Wood shavings were used as bedding material for lactating and gestating sows.

The size of the litters was balanced so that there were be 8-10 piglets in the gilt litters and 10-12 piglets in the litters of the older sows three days after farrowing. The minimum of the litter size was 7 piglets for the gilts and 8 piglets for the older sows. Maximum litter size for the older sows was 14.

2.4 Experimental diets and feeding

2.4.1 Sows

All pigs in the experiment were fed with 100% organic diets.

The composition of organically produced feed ingredients used in this experiment was analysed for the ICOPP database of organic feedstuffs (Kyntäjä et al. 2014, Tables 4, 5 and 6).

Table 4. Analyzed chemical content (g/kg DM) of organically produced feed ingredients.

		Barley	Wheat	Oats	Rape seed expeller	Peas	Faba beans
Dry matter	%	85.9	88.1	86.5	90.7	83.7	83.5
Ash		30	22	34	70	35	45
Crude protein		112	137	117	340	224	320
Crude fat (HCl)		21	23	63	163	24	17
Crude fibre		53	31	88	105	43	82
NFE		784	787	698	321	675	535
Starch		670	707	564	23	601	456
Sugars		33	37	21	99	65	45
NDF		223	141	271	249	124	144
ADF		63	32	100	160	51	88
ADL		10	0	21	43	0	0

Table 5. Analyzed mineral content of organic feed ingredients.

		Barley	Wheat	Oats	Rape seed expeller	Peas	Faba beans
Ca	g/kg DM	0.4	0.3	0.6	7.5	0.6	1.0
P	g/kg DM	4.3	4.3	4.3	12.8	5.6	8.0
Phytic acid	g/kg DM	11.3	11.6	10.5	34.5	11.7	22.3
Phytate P/total P	%	0.74	0.76	0.68	0.76	0.58	0.79
Phytase	U/kg DM	1261	1449	118	< 0,0	22	< 0,0
Mg	g/kg DM	1.3	1.5	1.3	4.9	1.3	1.5
S	g/kg DM	1.3	1.4	1.5	5.1	1.8	2.0
K	g/kg DM	5.7	4.8	5.7	12.2	11.8	13.0
Na	g/kg DM	0.04	0.02	0.04	0.06	0.02	0.04
Fe	mg/kg DM	66	42	153	107	73	65
Cu	mg/kg DM	4.3	4.6	5.0	5.8	9.1	16.9
Zn	mg/kg DM	37.5	36.5	34.3	56.6	41.5	57.8
Mn	mg/kg DM	11.9	30.0	29.5	39.7	5.1	11.0
Se	mg/kg DM	0.011	0.011	0.015	0.035	0.012	0.012

Table 6. Analyzed amino acid content (g/16gN) of organic feed ingredients.

	Barley	Wheat	Oats	Rape seed	Peas	Faba beans
Lys	3.7	2.6	5.1	6.3	7.8	6.2
Thr	3.4	2.8	3.9	4.9	4.2	3.5
Met	2.1	1.9	2.2	2.4	1.4	0.9
Cys	2.0	2.0	2.8	2.1	1.7	1.1
Ile	3.5	3.4	4.5	4.5	4.6	4.1
Val	4.8	4.2	5.7	5.7	5.1	4.6
Leu	6.6	6.5	8.4	7.7	7.8	7.4
Phe	4.5	4.3	5.8	4.5	5.3	4.2
Tyr	3.4	3.1	4.1	3.8	4.2	3.7
His	2.2	2.3	2.7	2.9	2.7	2.6
Arg	5.2	4.8	8.3	6.9	8.4	10.0
Ala	4.2	3.4	5.4	5.0	4.7	4.0
Asp	6.6	5.2	10.1	9.1	12.6	10.9
Glu	20.4	28.9	21.4	18.0	17.8	16.5
Gly	4.1	4.0	5.4	5.6	4.9	4.2
Ser	3.9	4.5	5.5	4.7	5.4	4.7
Pro	8.8	9.3	5.5	6.0	4.5	4.1

Table 7 lists the feeds used for sows during the trial and table 8 shows the feeding plan and schedule for the treatments groups (Control, Experimental group 1 and Experimental group 2).

The basal feeds for lactation and gestation were mixed and pelleted in MTT's feed mill in Jokioinen. Basal feeds containing pea (LP) were given to the sows in control group and experimental group 1 and basal feeds containing faba beans (LFB) were given to the sows in experimental group 2. In lactation, basal feed was supplemented with organic protein and mineral concentrate (C) in all treatment groups. In addition, the feeding of the sows in experimental groups 1 and 2 was supplemented with rapeseed expeller from lactation day 22 to weaning. From weaning to insemination, all sows were fed with basal feed and concentrate (max. for 7 days). During the first 76 days of gestation, all sows were fed with the basal gestation feed only, during days 77-108 the sows in control group were given basal feed and the feeding of the sows in experimental groups was supplemented with lactation feed and concentrate. On gestation day 109 the sows in all groups were switched to the lactation feeding (basal lactation feed + concentrate).

Table 7. Organic feeds for sows in different treatments groups.

	Feed	**Treatment group**
Lactation feeds		
LP	Basal lactation feed containing peas	Control, Exp.1
LFB	Basal lactation feed containing faba beans	Exp. 2
C	Protein and mineral concentrate for sows	Control, Exp. 1, Exp. 2,
RSE	Rape seed expeller	Exp. 1, Exp. 2
Gestation feeds		
GP	Basal gestation feed containing peas	Control, Exp 1
GFB	Basal gestation feed containing faba beans	Exp 2
LP	Lactation feed containing peas	Control, Exp.1
LFB	Lactation feed containing faba beans	Exp. 2
C	Protein and mineral concentrate for sows	Control, Exp. 1, Exp. 2

Exp.: Experimental group

Table 8. The feeding plan and schedule.

	Day in the trial	Control	Phase feeding with peas (Exp 1)	Phase feeding with faba beans (Exp 2)
Start of the experiment at 109th pregnancy day	-7	LP + C	LP + C	LFB + C
Farrowing	1			
Lactation week 1 - 3	1 - 21	LP + C	LP + C	LFB + C
Lactation week 4 – until weaning	22 - 42	LP + C	LP + C + RSE	LFB + C + RSE
Pregnancy				
Insemination	1	LP + C	LP + C	LFB + C
Pregnancy week 1 - 10	7 - 76	GP	GP	GFB
Pregnancy week 11 - 16	77 - 108	GP	GP + LP + C	GFB + LFB + C
5 days before farrowing	109 - 116	LP + C	LP + C	LFB + C
Farrowing	1			
Lactation week 1 - 3	1 - 21	LP + C	LP + C	LFB + C
Lactation week 4 – until weaning	22 - 42	LP + C	LP + C + RSE	LFB + C+ RSE[6]

LP	Basal lactation feed containing peas
LFB	Basal Lactation feed containing faba beans
C	Protein and mineral concentrate for sows
GP	Basal gestation feed containing peas
GFB	Basal gestation feed containing faba beans
RSE	Rape seed expeller

The composition of experimental diets for lactating sows is presented in Table 9 and the composition of organic protein and mineral concentrate for sows (Rehux Oy Tarvasjoki, Finland) in Table 10. Diets were optimized for standardized ileal digestible amino acids (SID) based on Danish recommendations for pregnant and lactating sows (Tybirk et al. 2014). Conclusions from the work of Kim et al. (2009) were also been taken into account.

Lactation diet of the control group contained 0.67 g SID lysine/MJ NE, calcium 0.92 g/MJ NE and digestible phosphorus 0.32 g/MJ NE during the whole lactation. For experimental groups 1 and 2 the amount of SID lysine, calcium and digestible phosphorus were the same as in the control group for the first 21 days of lactation. From lactation day 22 to weaning the amount of SID lysine was 0.71 g/MJ NE and amount of calcium and digestible phosphorus were similar to the first 21 days of lactation. Digestible protein was in all lactation feeds was 13.10 – 14.27 g/MJ NE (Table 9.).

In the beginning of the trial, from the 109th day of gestation, the lactation feeds were gradually mixed with standard gestation. At the gestation day 112 the feed was totally switched to experimental lactation feeding.

From lactation day 3 to weaning, all sows were fed according to their individual feed consumption and feed was given three times per day.

Table 9. Feed ingredients and calculated chemical composition of basal lactation feeds and lactation diets.

	Basal feeds		Experimental diets			
Treatment Group	LP Control, Exp 1	LFB Exp 2	LP+C Control, Exp 1	LFB+C Exp 2	LP+C+RSE Exp 1	LFB+C+RSE Exp 2
Lactation days			0 - weaning (control) 0 – 21 (Exp 1)	0 - 21	22 - weaning	22 - weaning
Feed ingredient						
Oats, %	14.8	10.5				
Wheat, %	44.1	47.9				
Barley, %	10.5	13.9				
Rape seed expeller, %	9.3	9.3				
Peas, %	19.7					
Faba beans, %		16.4				
Vegetable oil, %	1.4	1.9				
Vitamin mix (ADE forte[1]), %	0.03	0.05				
Mineral mix (Sika hiven[2]), %	0.21	0.18				
C, %			14.2	14.12	14.5	13.9
LP, %			85.8		82.2	
LFB, %				85.9		82.5
RSE, %					3.4	3.6
Calculated chemical composition						
Dry matter, %	87.2	87.4	87.8	87.9	87.9	88.0
Crude protein, %	14.4	15.4	15.0	15.8	15.5	16.4
Crude fat, %	5.1	5.3	5.1	5.3	5.4	5.6
Crude fibre, %	4.8	5.1	4.3	4.5	4.5	4.7
Net energy, MJ/kg	9.67	9.66	9.49	9.48	9.48	9.48
Digestible crude protein	12.20	13.09	13.11	13.88	13.53	14.27
SID lys	0.59	0.59	0.68	0.68	0.71	0.71
SID met	0.25	0.24	0.29	0.28	0.30	0.30
SID met+cys	0.49	0.49	0.55	0.54	0.57	0.57
SID thr	0.43	0.44	0.47	0.48	0.50	0.51
SID try	0.13	0.14	0.15	0.16	0.15	0.16
SID val	0.58	0.62	0.63	0.66	0.66	0.69
Calcium, g/MJ	0.12	0.12	0.92	0.91	0.95	0.92
Digestible phosphorus, g/MJ	0.16	0.16	0.32	0.32	0.33	0.33
Vitamin A (*1000 IU)/MJ	0.14	0.18	1.29	1.32	1.31	1.30
Vitamin D3 (*1000 IU)/MJ	0.02	0.02	0.25	0.25	0.25	0.25
Vitamin E, mg/MJ	2.01	2.12	5.37	5.38	5.38	5.32

LP Basal lactation feed containing peas
LFB Lactation feed containing faba beans
C Protein and mineral for lactating sows, the composition is presented in Table 10.
RSE Rape seed expeller

[1] The ADE vitamin mixture ADE Forte supplied per kg of feed: 2000 IU of vitamin A, 200 IU of vitamin D_3, 3.2 mg of vitamin E, 2.9 mg as α-tocopherol, 32 µg of Se.

[2] The organic mineral-vitamin mixture Sika-Hiven supplied per kg of feed: 1.1 g of Ca, 0.65 g of P, 0.46 g of digestible P, 0.1 g of Mg, 90 mg of Na, 14 mg of Fe, 1 mg of Cu, 10 mg of Mn, 22 mg of Zn, 0.12 mg of I, 0.1 mg of Se, 3000 IU of vitamin A, 500 IU of vitamin D_3, 25 mg of vitamin E 3a700, 22.7 mg as α-tocopherol, 0.15 mg of vitamin K, 0.5 mg of vitamin B_1, 1 mg of vitamin B_2, 0.75 mg of vitamin B_6, 25 µg of vitamin B_{12}, 0.45 mg of biotin, 6 mg of niacin, 0.3 mg of folic acid, and 4 mg of pantothenic acid.

Table10. Feed ingredients and calculated chemical composition of organic protein and mineral concentrate (C) for lactating sows.

Feed ingredient	Concentrate for lactating sows
Oats, dehulledd, %	65.6
Fish meal, %	14.2
Premix, %	2.0
Salt, %	2.7
Limestone, %	9.3
Monocalcium phosphate, %	6.2
Chemical composition, calculated	
Dry matter, %	91.3
Crude protein, %	18.4
Crude fat, %	5.1
Crude fibre, %	1.4
Net energy, MJ/kg	8.37
Digestible crude protein, g/MJ	19.4
SID lys, g/MJ	1.19
SID met+cys, g/MJ	0.92
SID thr, g/MJ	0.76
SID try, g/MJ	0.26
SID val, g/MJ	1.02
Calcium, g/MJ	6.46
Phosphorus, g/MJ	2.56
Digestible phosphorus, g/MJ	1.58
Sodium, g/MJ	1.34
Zinc, mg/MJ	75.3
Selenium, mg/MJ	0.22
Vitamin A (*1000 IU)/MJ	9.26
Vitamin D3 (*1000 IU)/MJ	1.85
Vitamin E, mg/MJ	28.7

After weaning the sows were fed with basal lactation feeds and concentrate twice daily for seven days according the Finnish feeding standards. Pregnant sows were fed according the Finnish feeding standards (MTT 2013). Feed allowance was based on the sow's condition scoring (Appendix I.)
At gestation the sows were feed twice a day.

The sows in the control group were fed with basal gestation feed containing peas (GP) for the whole gestation period. Sows in experimental group 1 and 2 were fed with basal gestation feeds GP and GFB for the 0 – 76 gestation days. From gestation day 77 to day 108 the diet of experimental groups 1 and 2 was a mixture of basal gestation diet and lactation diet in ratio 52:48 and 51:49 (Table 11). Diets for the last third of gestation were planned by implementing the results of Pettigrew and Yang (1997), Kim et al. (2009) Clowes et al. (2003) and Ji et al. (2005).

All sows were also fed with dried hay daily. In lactation, the sows got a handful of hay twice a day. In gestation the amount of hay was larger than in lactation, approximately 0.5 kg per sow per day. The intake of hay was not included in the feed and energy intake calculations.

Table 11. Feed ingredients and calculated chemical composition of the basal gestation feeds and diets.

Feed	GP	GFB	GP +C+LP	GFB+ C+LFB
Treatment Group	Control and Exp 1	Exp 2	Exp 1	Exp 2
Pregnancy days	0 - 76	0 - 76	77-108	77-108
Feed ingredient				
Oats, %	40.00	41.7		
Wheat, %				
Barley, %	50.7	50		
Rapeseed expeller, %	2.00	2.00		
Peas, %	3.93			
Faba bean, %		2.83		
Vegetable oil, %				
Vitamin mix (ADE forte)[1], %	0.11	0.15		
Mineral mix (Sika hiven)[2], %	1.50	1.50		
Salt, %	0.34	0.34		
Limestone, %	1.04	1.04		
Monocalcium phosphate, %	0.42	0.41		
GP[1], %			52.0	
GFB[2], %				51.0
C[3], %			6.8	6.9
LP[4], %			41.2	
LFB[5], %				42.1
Chemical composition, calculated				
Dry matter, %	86.6	86.6	87.3	87.2
Crude protein, %	10.3	10.5	13.0	13.1
Crude fat, %	3.5	3.5	4.3	4.4
Crude fibre, %	6.6	6.8	5.5	5.7
Net energy, MJ/kg	8.53	8.48	8.99	8.97
Digestible crude protein, g/MJ	9.19	9.35	11.60	12.13
SID lys, g/MJ	0.43	0.43	0.55	0.55
SID met+cys, g/MJ	0.44	0.44	0.50	0.48
SID thr, g/MJ	0.33	0.33	0.41	0.41
SID try, g/MJ	0.11	0.11	0.13	0.14
SID val, g/MJ	0.49	0.50	0.57	0.59
Calcium, g/MJ	0.81	0.81	0.86	0.87
Phosphorus, g/MJ	0.67	0.67	0.74	0.76
Digestible phosphorus, g/MJ	0.28	0.28	0.30	0.31
Vitamin A (*1000 IU)/MJ	0.86	0.97	1.08	1.29
Vitamin D3 (*1000 IU)/MJ	0.12	0.13	0.20	0.20
Vitamin E, mg/MJ	7.22	7.44	6.42	7.34

GP	Gestation feed containing peas
GFB	Gestation feed containing faba beans
C	Protein and mineral for lactating sows
LP	Basal lactation feed containing peas
LFB	Lactation feed containing faba beans

[1] The ADE vitamin mixture ADE Forte supplied per kg of feed: 2000 IU of vitamin A, 200 IU of vitamin D_3, 3.2 mg of vitamin E, 2.9 mg as α-tocopherol, 32 µg of Se.

[2]The organic mineral-vitamin mixture Sika-Hiven supplied per kg of feed: 1.1 g of Ca, 0.65 g of P, 0.46 g of digestible P, 0.1 g of Mg, 90 mg of Na, 14 mg of Fe, 1 mg of Cu, 10 mg of Mn, 22 mg of Zn, 0.12 mg of I, 0.1 mg of Se, 3000 IU of vitamin A, 500 IU of vitamin D_3, 25 mg of vitamin E 3a700, 22.7 mg as α-tocopherol, 0.15 mg of vitamin K, 0.5 mg of vitamin B_1, 1 mg of vitamin B_2, 0.75 mg of vitamin B_6, 25 µg of vitamin B_{12}, 0.45 mg of biotin, 6 mg of niacin, 0.3 mg of folic acid, and 4 mg of pantothenic acid.

2.4.2 Piglets

All piglets were given organic piglet feed (Table 12) which was mixed in Hyvinkää experimental station. The diet was in meal form. The creep feeding of the piglets was begun at approximately at the age of ten days.

Table 12. Feed ingredients and calculated chemical composition of organic piglet feed.

Feed ingredient	Organic piglet feed
Oats, %	10.0
Wheat, %	32.2
Barley, %	10.0
Rapeseed expeller, %	11.3
Peas, %	24.0
Protein and mineral concentrate (C), %	12.0
Limestone, %	0.3
Salt, %	0.1
Chemical composition, calculated	
Dry matter, %	87.4
Crude protein, %	16.1
Crude fat, %	4.2
Crude fibre, %	4.5
Net energy, MJ/kg	9.2
Digestible protein, g/MJ	14.5
SID lys, g/MJ	0.79
SID met+cys, g/MJ	0.59
SID thr, g/MJ	0.53
SID try, g/MJ	0.16
SID val, g/MJ	0.71
Calsium, g/MJ	0.95
Phosphorus, g/MJ	0.76
Digestible phosphorus, g/MJ	0.33
Vitamin A (*1000 IU)/MJ	1.02
Vitamin D3 (*1000 IU)/MJ	0.2
Vitamin E, mg/MJ	4.38

2.5 Measurements and analyses

All sows were weighed at the gestation day 109, one day after farrowing, 21 days after farrowing and at weaning. Sows which were fed experimental diets at gestation were weighed at gestation day 77.

Back fat and side fat thickness of the sows was measured at the gestation day 109, 21 days after farrowing and at weaning with Renco Lean Meter (S.E.C. Repro, Ange-Gardien-de-Rouville, Quebec, Canada). Back fat was measured 3-5 cm from the last rib towards the head. Side fat was measured from both sides of the sow, 5-8 centimeter from the last rib down from the backbone. Condition score of each sow was estimated at the gestation day 109 and at weaning (Appendix I).

The piglets were weighed one day after birth, at the age of 21 days and at weaning.

2.6 Milk samples

Milk samples were collected from 24 sows. Milk samples were taken from the same sows 3 days after farrowing, 21 days after farrowing and in weaning week. An intramuscular Oxytocin injection (1 ml) was given to the sows before taking the milk sample.

Samples were analyzed for dry matter, lactose, protein and fat concentration by Milko-Scan 133 B which was calibrated for the sow milk before measurements.

2.7 Feed samples

Feed ingredients were analysed before mixing the feeds (Kyntäjä et al., 2014).

Feed samples were taken from every feed batch. Feed analyses of proximate composition included dry matter, ash, crude protein (N*6.25) and crude fibre. Amino acid analysis included all amino acids except tryptophan.

References to the principal methods used in the chemical analyses and are given in Appendix II.

2.7 Statistical analysis

The data were statistically analyzed by SAS® for Windows (version 9.3) using the MIXED procedure. In the analysis of data on the first lactation period, the effects of treatment and parity and interaction of treatment and parity were included in the statistical model. The data on the gestation and the second lactation period was small and only the effect of treatment could be included in the statistical model. When the F-test was significant, differences between the treatments were identified with Tukey's test. The normality of the residuals was evaluated by the UNIVARIATE procedure of SAS®.

3 Results

3.1 Chemical composition of the experimental feeds

The analyzed chemical composition of the experimental feeds is presented in Table 13.

Table 13. Analyzed chemical composition of experimental diets.

	LP	LFB	C	GP	GFB	RSE	Piglet feed
Analysed chemical composition,							
Dry matter, g/kg	873	873	890	877	873	916	877
g/kg DM							
Ash	32	33	178	60	56	70	58
Crude protein	157	164	211	114	118	340	177
Crude fibre	53	58	27	69	69	163	53
Amino acids, g/kg DM							
Essential							
Arginine	9.5	10.9	12.9	7.2	7.4	23.6	11.4
Histidine	3.8	4.0	4.5	2.7	2.7	10.0	4.4
Isoleucine	5.8	6.2	8.3	4.2	4.3	15.4	6.9
Leucine	10.8	11.8	17.0	8.2	8.3	26.3	12.8
Lysine	7.4	7.6	12.3	5.1	5.0	21.3	9.8
Methionine	3.0	3.0	5.4	2.4	2.5	8.0	3.4
Phenylalanine	7.3	7.5	9.9	5.7	5.7	15.1	8.4
Threonine	5.8	6.1	8.8	4.4	4.4	16.8	7.3
Valine	7.4	8.0	11.0	6.0	6.0	19.5	8.9
Non-essential							
Alanine	6.3	6.8	11.8	5.2	5.2	16.9	7.9
Aspartic acid	12.7	13.5	18.6	9.2	9.4	30.8	15.9
Cystine	3.2	3.2	3.7	2.8	2.8	7.2	3.4
Glutamic acid	33.7	36.8	36.4	23.6	23.6	61.1	35.9
Glycine	7.0	7.5	11.2	5.4	5.5	18.9	8.5
Proline	10.9	9.1	10.8	8.6	8.4	20.4	11.4
Serine	7.4	8.0	9.9	5.5	5.6	16.1	8.8
Tyrosine	5.0	5.5	7.5	4.0	4.1	12.8	6.1

LP	Basal lactation feed containing peas
LFB	Basal lactation feed containing faba beans
C	Protein and mineral concentrate for lactating sows
GP	Gestation feed containing peas
GFB	Gestation feed containing faba beans
RSE	Rape seed expeller

Calculated SID amino acid ratios in relation lysine in the experimental diets are presented in Table 14. The calculations are based on the analyzed amino acid composition of the feeds and the calculated SID of amino acids in experimental diets.

Table 14. Calculated SID amino acids ratios in experimental lactation and gestation diets, in relation to of SID lysine.

	LP+C	LP+C+RSE[6]	LFB+C	LFB+C+RSE	GP	GP+LP+C	GFB	GFB+LFB+C
met:lys	0.45	0.44	0.44	0.44	0.51	0.47	0.54	0.48
met+cys:lys	0.87	0.86	0.86	0.85	1.09	0.96	1.13	0.96
tre:lys	0.76	0.76	0.78	0.78	0.85	0.80	0.87	0.81
val:lys	1.00	1.00	1.06	1.05	1.21	1.09	1.23	1.12
arg:lys	1.36	1.35	1.50	1.47	1.56	1.44	1.64	1.55
his:lys	0.52	0.52	0.54	0.54	0.57	0.54	0.58	0.55
ile:lys	0.80	0.80	0.84	0.83	0.87	0.83	0.91	0.86
leu:lys	1.56	1.54	1.64	1.61	1.73	1.63	1.79	1.70
phe:lys	1.02	1.00	1.04	1.01	1.21	1.10	1.23	1.10

LP	Basal lactation feed containing peas
LFB	Lactation feed containing faba beans
C	Protein and mineral concentrate for lactating sows
GP	Gestation feed containing peas
GFB	Gestation feed containing faba beans
RSE	Rape seed expeller

3.2 1st lactation period

The results of first lactation period results include data from 74 gilts and sows which started the experiment from the 109th day of gestation. The first lactation period ended at weaning.

3.2.1 Sow weight and fat measures

The effect of dietary treatments on sow weight and fat measures is shown in Table 15. During the first lactation in the trial the sows lost 11.6 kg (4.3% of live weight at 1st day after farrowing), 15.6 kg (5.7% of live weight on 1st day after farrowing) and 13.6 kg (5.1% of live weight at 1st day after farrowing) body weight in the control group and the experimental groups 1 and 2, respectively. Total loss of body weight from farrowing to weaning, back and side fat changes (from 109th day of gestation to weaning) were not affected by dietary treatments.

Table 15. Effect of dietary treatments on sow weight and fat measures.

	Control	Experimental group 1	Experimental group 2	SEM	p treatment
sows, n	25	26	23		
Live weight, kg					
109th day of gestation	292.5	294.7	287.6	4.23	0.46
1st day after farrowing	271.0	273.9	269.3	3.94	0.70
21st day of lactation	265.4	269.1	265.0	4.37	0.76
at weaning	259.5	258.9	255.7	4.79	0.83
Live weight change during lactation, kg					
109th d of gestation - 1st day after farrowing	-21.4	-20.2	-18.3	1.74	0.42
1st day after farrowing – 21st day of lactation	-5.63	-6.02	-4.30	2.18	0.83
21st day of lactation - weaning	-6.01	-9.60	-9.29	1.84	0.31
Farrowing - Weaning	-11.6	-15.6	-13.6	3.24	0.67
Back fat, mm					
109th day of gestation	17.8	17.9	18.4	0.62	0.78
21st day of lactation	15.4	15.1	15.5	0.51	0.85
At weaning	13.5	13.2	13.6	0.64	0.91
Back fat change during lactation, mm					
109th d of gestation - 21st day of lactation	-2.40	-2.75	-2.82	0.35	0.66
21st day of lactation - weaning	-1.87	-1.86	-1.94	0.47	0.99
109th d of gestation - weaning	-4.27	-4.61	-4.76	0.61	0.84
Side fat, mm					
109th day of gestation	14.6	14.6	14.3	0.62	0.94
21st day of lactation	12.6	12.2	12.3	0.51	0.84
At weaning	11.4	10.7	11.0	0.49	0.64
Side fat change during lactation, mm					
109th d of gestation - 21st day of lactation	-1.96	-2.42	-2.01	0.41	0.67
21st day of lactation - weaning	-1.25	-1.48	-1.33	0.28	0.83
109th d of gestation - weaning	-3.22	-3.90	-3.34	0.55	0.62

Body weight at 109th day of gestation, 1st day after farrowing, 21st day of lactation and weaning were affected by parity of the sow (Table 16). Body weight change from 109th day of gestation to first day of lactation was also affected by parity ($p<0.001$). There was no effect of parity on back or side fat changes during lactation. The first parity sows tended to lose less weight less (5.08 kg) than the older sows (2nd – 6th parity: 9.93 kg and >6th parity: 9.90 kg) from 21st day of lactation to weaning ($p=0.06$).

Table 16. Effect of parity on sow weight and fat measures.

	Parity of the sow				
	1	2−6	>6	SEM	p treatment
sows, n	28	32	14		
Live weight, kg					
109th day of gestation	229.7[a]	308.1[b]	337.0[c]	5.18	**0.001**
1st day after farrowing	215.0[a]	285.4[b]	313.8[c]	4.82	**0.001**
21st day of lactation	211.0[a]	277.2[b]	311.4[c]	5.35	**0.001**
At weaning	205.5[a]	267.2[b]	301.5[c]	5.87	**0.001**
Live weight change during lactation, kg					
109th day of gestation - 1st day after farrowing	-14.0[a]	-22.7b[c]	-23.2[c]	2.10	**0.001**
1st day after farrowing - 21st day of lactation	-5.26	-8.26	-2.42	2.63	0.17
21st day of lactation - weaning	-5.07[a]	-9.93[b]	-9.90[ab]	2.22	*0.06*
Farrowing - Weaning	-10.3	-18.2	-12.3	3.91	0.11
Back fat, mm					
109th day of gestation	17.8	18.9	17.4	0.77	0.17
21st day of lactation	15.1	15.9	15.1	0.63	0.28
At weaning	12.9	13.8	13.7	0.79	0.47
Back fat change during lactation, mm					
109th day of gestation - 21st day of lactation	-2.69	-2.96	-2.32	0.43	0.45
21st day of lactation - weaning	-2.16	-2.12	-1.4	0.56	0.51
109th d of gestation - weaning	-4.85	-5.01	-3.72	0.73	0.30
Side fat, mm					
109th day of gestation	14.2	15.0	14.3	0.75	0.47
21st day of lactation	12.2	12.4	12.5	0.61	0.91
At weaning	10.7	11.3	11.1	0.59	0.59
Side fat change during lactation, mm					
109th day of gestation - 21st day of lactation	-1.96	-2.65	-1.78	0.49	0.21
21st day of lactation - weaning	-1.52	-1.08	-1.47	0.34	0.38
109th d of gestation - weaning	-3.47	-3.74	-3.25	0.66	0.81

The effect of dietary treatment on body condition scores of sows is shown in Table 17. When the experiment started, the sows in experimental group 2, were slightly thinner than the sows in control and experimental group 1. The proportion of sows with a moderate condition score 3 was 43.5% in experimental group 2, 36.0 % in control group and 29.9% in experimental group 1. At weaning, however, the proportion of sows with condition scores 3 and 4 was higher in the control group (60.0%) compared to that of in experimental groups 1 and 2 (38.5% and 43.3%). The effect of parity on condition scores of sows is presented in table 18. The proportion of sows with moderate condition score were on the same level at farrowing (34.3 – 35.7 %) in all groups, but at weaning the proportion of sows in condition scores 1 and 2 were higher in first parity sows (67.9 %) than in older sows (2nd – 6th parity: 43.4 % and more than 6th parity: 42.8 %)

Table 17. Effect of dietary treatments on condition score of the sows.

	Control		Experimental group 1		Experimental group 2	
	n[1]	%[2]	n	%	n	%
Body condition score on 109th of gestation						
Score 3	9	36.0	7	29.9	10	43.5
Score 4	14	56.0	17	65.4	9	39.1
Score 5	2	8.0	2	7.7	4	17.4
Body condition score at weaning						
Score 1	4	16.0	3	11.5	4	17.4
Score 2	6	24.0	13	50.0	9	39.1
Score 3	13	52.0	9	34.6	7	30.4
Score 4	2	8.0	1	3.9	3	13.0

[1]n=number of sows within condition score.
[2]%=percentage distribution within condition score.

Table 18. Effect of parity on condition score of the sows.

	Parity of the sow					
	1		2-6		>6	
	n[1]	%[2]	n	%	n	%
Condition score on 109th of gestation						
Score 3	10	35.7	11	34.4	5	35.7
Score 4	16	57.1	16	50.0	8	57.1
Score 5	2	7.1	5	15.6	1	7.1
Condition score at weaning						
Score 1	7	25.0	3	9.4	1	7.1
Score 2	12	42.9	11	34.4	5	35.7
Score 3	7	25.0	15	46.9	7	50.0
Score 4	2	7.1	3	9.4	1	7.1

[1]n=number of sows within conditioning score.
[2]%=percentage distribution within conditioning score.

There were 2 sows having shoulder ulcers in first lactation period. One of those sows belonged to first experimental group and the other one the second experimental group.

3.2.2 Piglet performance

There was no effect of dietary treatment to weight of the piglets from birth to weaning (Table 19). The litter weight at weaning tended to be higher in the experimental groups 1 and 2 (161.2 kg and 154.6 kg) than in the control group (147.8 kg) (p=0.10). There was a significant effect of dietary treatment to the weaning age of piglets. Control group was weaned 1.5 days earlier than sows in treatment group 1 and 1.9 days earlier than treatment group 2. The sows were weaned in groups which resulted in variation of weaning age of the litters.

Table 19. Effect of dietary treatments on piglet performance.

	Control	Experimental group 1	Experimental group 2	SEM	p treatment
sows, n	25	26	23		
Litter size					
Total born*	13.7	12.4	13.0	0.66	0.35
Live born*	12.0	11.3	11.6	0.64	0.72
At 21 day of age	10.4	10.4	10.5	0.29	0.98
At weaning	10.3	10.4	10.3	0.29	0.95
Live weight of the piglet, kg					
Total born	1.72	1.79	1.71	0.05	0.45
Live born	1.75	1.82	1.73	0.06	0.45
At 21 day of age	7.23	7.61	7.22	0.18	0.19
At weaning	14.4	15.6	15.1	0.42	0.14
Litter weight at weaning, kg	147.8^{a}	161.2^{b}	154.6^{ab}	4.47	*0.10*
Weaning age, day	42.5^{a}	44.0^{b}	44.4^{b}	0.48	**0.01**

*litters were balanced at the age of one day

The parity significantly affected the litter size at farrowing, at the 21 days of age and at weaning and litter weight at weaning (Table 20). There was a significant effect of parity on the weaning age of piglets ($p<0.05$). Gilts were weaned 1.2 days earlier than 2 – 6 parity sows and 1.8 days earlier than over 6 parity sows. Group weaning of the litters may be the main reason for the different weaning ages.

Table 20. Effect of the sow's parity on piglet performance.

	Parity of the sow				
	1	2−6	>6	SEM	p treatment
sows, n	28	32	14		
Litter size					
Total born*	11.0^{a}	13.2^{ab}	14.9^{b}	0.79	**0.0004**
Live born*	10.4^{a}	12.0^{ab}	12.6^{b}	0.77	**0.04**
At 21 day of age	9.40^{a}	10.9^{ab}	11.0^{b}	0.35	**0.0001**
At weaning	9.40^{a}	10.8^{ab}	10.8^{b}	0.35	**0.0001**
Piglet live weight, kg					
Total born	1.78^{ab}	1.81^{a}	1.63^{b}	0.07	*0.08*
Live born	1.79	1.84	1.67	0.07	0.11
At 21 day of age	7.54	7.52	6.99	0.22	*0.09*
At weaning	14.8	15.7	14.6	0.50	0.12
Litter weight at weaning, kg	137.3^{a}	168.5a^{bc}	157.7^{c}	5.41	**0.0001**
Weaning age, day	42.6^{a}	43.8^{b}	44.4^{b}	0.58	**0.02**

*litters were balanced at the age of one day

3.2.3 Feed and energy intake in lactation

The effect of dietary treatments on feed and energy intake of the sows in lactation is presented in Table 21. There was no difference between treatments in feed intake during the first three weeks of lactation (6.52 – 6.71 kg DM/day) but after that the feed intake was higher in experimental groups 1 and 2 (9.58 kg DM/day and 9.27 kg DM/day) than in control (8.91 kg DM/day).

Table 21. Effect of dietary treatments on feed and energy intake of sows during lactation.

	Control	Experimental group 1	Experimental group 2	SEM	p treatment
sows, n	25	26	23		
Length of gestation, d	116.9	117.3	117.0	0.35	0.63
Length of lactation, d	42.2[a]	44.0[b]	44.4[b]	0.47	**0.004**
Total feed intake, kg DM					
109th day of gestation - farrowing	16.3	17.3	16.5	0.77	0.60
Farrowing – 21st day of lactation	137.0	141.3	138.5	2.27	0.38
21st day of lactation - weaning	189.5[a]	220.6[b]	216.7[b]	6.21	**0.001**
Farrowing - weaning	326.5[a]	361.9[b]	355.2[b]	7.31	**0.002**
Feed intake, kg DM per day					
Farrowing – 21st day of lactation	6.52	6.71	6.60	0.10	0.41
21st day of lactation - weaning	8.91[a]	9.58[b]	9.27[ab]	0.19	**0.04**
Farrowing - weaning	7.72[a]	8.21[b]	7.99[ab]	0.13	**0.03**
Total energy intake of NE, MJ					
109th day of gestation - farrowing	142	153	145	8.32	0.60
Farrowing – 21st day of lactation	1485	1525	1500	24.7	0.49
21st day of lactation - weaning	2054[a]	2392[b]	2345[b]	67.5	**0.001**
Farrowing - weaning	3538[a]	3917[b]	3845[b]	79.0	**0.002**
Total energy intake of NE, MJ per day					
Farrowing – 21st day of lactation	70.7	72.5	71.4	1.15	0.52
21st day of lactation - weaning	96.5[a]	103.8[b]	100.3[ab]	2.06	**0.04**
Farrowing - weaning	83.7[a]	88.9[b]	86.5[ab]	1.43	**0.03**

Total feed and energy intake from farrowing to 21st day of lactation, from 21st day of lactation to weaning and in the whole lactation period were significantly affected by parity of sows (Table 22). Some interactions in feed intake between dietary treatments and parity of sow were found but they could be explained by the variation in feed intake of individual sows in relatively small parity groups (Table 23). Consumption of experimental feeds during lactation is presented in table 24.

Table 22. Effect of parity on feed and energy intake of sows in lactation.

	Parity of the sow				
	1	2−6	>6	SEM	p treatment
sows, n	28	32	14		
Length of gestation, d	117.6[a]	117.1[ab]	116.5[b]	0.42	*0.07*
Length of lactation, d	42.3[a]	43.8[b]	44.5[b]	0.57	**0.004**
Total feed intake, kg DM					
109th day of gestation - farrowing	17.6	17.0	15.5	0.93	0.17
Farrowing - 21st day of lactation	134.2[a]	140.8[b]	141.9[ab]	2.75	**0.02**
21st day of lactation - weaning	186.7[a]	214.9[b]	225.2[b]	7.50	**0.0001**
Farrowing - weaning	320.9[a]	355.7[b]	367.0[b]	8.85	**0.0001**
Feed intake, kg DM per day					
Farrowing – 21st day of lactation	6.38[a]	6.70[b]	6.76[b]	0.13	**0.01**
21st day of lactation - weaning	8.76[a]	9.43[b]	9.56[b]	0.23	**0.004**
Farrowing - weaning	7.58[a]	8.11[b]	8.24[b]	0.16	**0.006**
Total energy intake of NE, MJ					
109th day of gestation - farrowing	157	150	134	10.1	0.17
Farrowing - 21st day of lactation	1447[a]	1525[b]	1537[ab]	29.9	**0.01**
21st day of lactation - weaning	2025[a]	2327[b]	24538[b]	81.6	**0.0001**
Farrowing - weaning	3472[a]	3852[b]	3975[b]	95.6	**0.0001**
Total energy intake of NE, MJ per day					
Farrowing – 21st day of lactation	69.0[a]	72.6[b]	73.2[b]	1.39	**0.008**
21st day of lactation - weaning	95.0[a]	102.1[b]	103.5[b]	2.50	**0.005**
Farrowing - weaning	82.0[a]	87.9[b]	89.3[b]	1.73	**0.0005**

Table 23. Interaction between treatment and parity on feed and energy intake of sows in lactation.

	Control			Experimental group 1			Experimental group 2			SEM	p interaction parity x treatment
Parity	1	2-6	>6	1	2-6	>6	1	2-6	>6		
sows, n	9	12	4	10	11	5	9	9	5		
Total feed intake, kg DM											
Farrowing - 21st day of lactation	134.4	144.7	131.8	137.8	143.8	142.3	130.2	133.8	151.6	5.11	*0.009*
21st day of lactation - weaning	173.1	212.7	182.7	191.8	229.3	240.8	195.3	202.8	252.0	14.0	**0.01**
Farrowing - weaning	307.6	357.4	314.5	329.6	373.1	383.1	325.5	336.6	403.5	16.4	**0.003**
Total energy intake of NE, MJ											
Farrowing - 21st day of lactation	1457	1568	1428	1475	1558	1542	1410	1449	1642	55.6	**0.01**
21st day of lactation - weaning	1876	2305	1980	2085	2482	2608	2113	2195	2727	151.8	**0.02**
Farrowing - weaning	3333	3873	3408	3560	4040	4150	3524	3644	4368	177.8	**0.003**

Table 24. Consumption of experimental feeds during lactation.

	Control		Experimental group 1		Experimental group 2	
sows, n	25		26		23	
		CV		CV		CV
Feed intake, kg DM from farrowing to 21st day of lactation	138.9	8.27	141.2	6.97	136.3	9.56
LP	119.1	8.31	120.9	6.96		
LFB					116.7	9.62
C	19.9	8.12	20.3	7.09	19.6	9.37
Feed energy intake of NE, MJ from farrowing to 21st day of lactation	1506	8.27	1523	7.27	1476	9.57
LP	1319	8.31	1339	6.96		
LFB					1292	9.62
C	186.8	8.12	183.5	21.25	184.1	9.37
Feed intake, kg DM from 21st day of lactation to weaning	193.6	17.4	217.1	16.13	210.5	15.51
LP	165.8	17.47	179.5	16.2		
LFB					174.1	15.48
C	27.9	17.02	30.3	15.85	29.2	15.85
RSE			7.4	16.69	7.2	15.65
Feed energy intake of NE, MJ from 21st day of lactation to weaning	2098	17.41	2354	16.12	2278	15.51
LP	1836	17.47	1992	16.16		
LFB					1927	15.48
C	262	17.02	284.5	15.85	275.2	15.85
RSE			77.6	16.69	76.2	15.65
Feed intake, kg DM from farrowing to weaning	332.6	12.25	358.3	10.91	346.8	12.53
LP	284.8	12.32	300.4	10.83		
LFB					290.7	12.47
C	47.7	11.89	50.6	10.76	48.8	12.6
RSE			7.4	16.69	7.2	15.65
Feed energy intake of NE, MJ from farrowing to weaning	3604	12.25	3877	10.94	3754	12.53
LP	3155	12.32	3331	10.82		
LFB					3219	12.47
C	448.8	11.89	468.1	13.69	459.0	12.6
RSE			77.6	16.69	76.4	15.65

LP	Basal lactation feed containing peas
LFB	Lactation feed containing faba beans
C	Protein and mineral concentrate for lactating sows
RSE	Rape seed expeller

CV: coefficient of variation, %

3.2.4 Feed intake of piglets

There was no effect of dietary treatment of the sow on the creep feed consumption of piglets during lactation period. The piglets from control group ate 10.5 NE MJ per piglet while experimental groups 1 and 2 consumed 10.1 NE MJ and 11.7 NE MJ. The piglets also had access to sow's feeding trough and most of them used to eat the sow's feed to some extent. However, the consumed feed amount could not be registered.

3.3 2nd lactation period

3.3.1 Animals the gestation and 2nd lactation period

The gestation period and the second lactation period was performed with 23 sows. A total of 13 sows continued experiment after the first weaning and there were also sows which started the experiment from insemination (n=10). The breed distribution of experimental animals is presented in Table 25 and the number of sows by parity is shown in Table 26.

Table 25. The breed distribution of the sows in the treatment groups during gestation and second lactation.

	Control	Experimental group 1	Experimental group 2	
Yorshire x Finnish Landrace	4	2	5	11
Finnish Landrace	5	5	2	12
Total	9	7	7	23

Table 26. Distribution of experimental sows by parity during gestation and second lactation.

	Control	Experimental group 1	Experimental group 2
2nd litter		3	1
3rd litter	2		2
4th litter	2		
5th litter	3	2	1
6th litter			
7th litter	1	1	
8th litter		1	1
9th litter	1		2
12th litter	1		
Total	9	7	7

3.3.2 Sow weight and fat measures

Live weight, live weight change, back fat or side fat were not affected by feeding treatment (Table 27). The effect of dietary treatment on condition scores of sows is shown in Table 28.

Table 27. Effect of dietary treatments on sow weight and fat measures.

	Control	Experimental group 1	Experimental group 2	SEM	p treatment
sows, n	9	7	7		
Live weight, kg					
109th day of gestation	312.8	305.7	325.4	8.89	0.31
1st day after farrowing	286.9	287.4	303.7	9.69	0.38
21st day of lactation	282.3	279.4	292.6	11.53	0.70
At weaning	274.6	273.3	286.6	13.7	0.74
Live weight change during lactation, kg					
109th day of gestation - 1st day after farrowing	-25.8	-18.3	-21.6	4.58	0.47
1st day after farrowing - 21st day of lactation	-4.61	-8.07	-11.1	4.09	0.50
21st day of lactation - weaning	-7.72	-6.07	-5.93	3.59	0.91
Farrowing - Weaning	-12.3	-14.1	-17.1	5.94	0.84
Back fat, mm					
109th day of gestation	17.3	17.7	19.0	1.35	0.64
21tst day of lactation	14.6	15.7	16.6	1.22	0.47
At weaning	13.6	13.7	14.6	1.12	0.78
Back fat change during lactation, mm					
109th day of gestation - 21st day of lactation	-2.78	-2.00	-2.43	0.63	0.66
21st day of lactation - weaning	-1.00	-2.00	-2.00	0.49	0.22
109th d of gestation - weaning	.3.78	-4.00	-4.43	0.73	0.80
Side fat, mm					
109th day of gestation	14.2	15.2	15.2	1.12	0.74
21st day of lactation	12.3	13.4	13.1	1.06	0.75
At weaning	11.4	12.2	12.1	0.98	0.79
Side fat change during lactation, mm					
109th day of gestation - 21st day of lactation	-1.89	-1.86	-2.14	0.56	0.92
21st day of lactation - weaning	-0.94	-1.14	.1.00	0.37	0.92
109th d of gestation - weaning	-2.83	-3.00	-3.14	0.64	0.94

Table 28. Effect of dietary treatments on condition scores of the sows.

	Control		Experimental group 1		Experimental group 2	
	n[1]	%[2]	n	%	n	%
Condition score on 109th day of gestation						
Score 2	0	0.00	0	0.00	2	28.6
Score 3	6	66.7	3	42.9	2	28.6
Score 4	2	22.2	3	42.9	3	42.9
Score 5	1	11.1	1	14.3	0	0.00
Condition score at weaning						
Score 1	1	11.1	0	0.00	2	28.6
Score 2	4	44.4	3	42.9	3	42.9
Score 3	2	22.2	3	42.9	2	28.6
Score 4	2	22.2	1	33.3	0	0.00

[1]n=number of sows within conditioning score.
[2]%=percentage distribution within conditioning score.

3.3.3 Piglet performance

There was no effect of dietary treatment to piglet performance (Table 29).

Table 29. Effect of dietary treatments on piglet performance.

	Control	Experimental group 1	Experimental group 2	SEM	p treatment
sows, n	9	7	7		
Litter size					
Total born	13.9	12.4	12.7	1.38	0.70
Live born	12.4	11.0	11.0	1.33	0.64
At 21 day of age	10.7	10.6	10.4	0.37	0.89
At weaning	10.7	10.6	10.4	0.37	0.89
Live weight, kg					
Total born	1.73	1.85	1.87	0.10	0.51
Live born	1.74	1.89	1.92	0.10	0.35
At 21 day of age	6.78	7.44	7.69	0.34	0.13
At weaning	13.3	14.6	14.2	0.54	0.22
Litter weight at weaning, kg	142.2	153.9	148.1	7.53	0.52
Weaning age, d	41.3	41.3	41.4	0.74	0.99

3.3.4 Feed and energy intake in gestation

There were dietary effects on total energy intake from insemination to 76th day of gestation and also on total energy intake from insemination to 109th day of gestation. However, this could be explained by the variation in feed intake of individual sows in small treatment groups (Table 30). Consumption of experimental feeds during gestation is presented in Table 31.

Table 30. Effect of dietary treatments on feed and energy intake in gestation.

	Control	Experimental group 1	Experimental group 2	SEM	p treatment
sows, n	9	7	7		
Length of gestation, d	116.1	116.6	116.9	0.43	0.42
Total feed intake, kg DM					
Insemination – 76th day of gestation	213.3^{ab}	200.8^{a}	226.7^{b}	7.09	*0.06*
77th day of gestation - 109th day of gestation	87.3	81.5	90.3	3.69	0.25
Insemination - 109th day of gestation	300.7^{ab}	282.3^{a}	317.0^{b}	9.52	*0.06*
Total energy intake, MJ					
Insemination – 76th day of gestation	2075^{ab}	1953^{a}	2209^{b}	75.1	**0.05**
77th day of gestation - 109th day of gestation	850	833	924	36.8	0.20
Insemination - 109th day of gestation	2925^{ab}	2787^{a}	3133^{b}	92.4	**0.05**

Table 31. Consumption of experiment feeds during gestation.

	Control		Experimental group 1		Experimental group 2	
sows, n	9		7		7	
		CV		CV		CV
Feed intake, kg DM Insemination – 77th day of gestation						
GP	213.3	10.41	200.8	9.58		
GFB					226.7	5.32
Feed energy intake of NE, MJ Insemination – 77th day of gestation						
GP	2075	10.41	1954	9.58		
GFB					2209	5.00
Feed intake, kg DM 77th day of gestation – 109th day of gestation						
GP	87.3	12.82	44.8	8.07		
GFB					48.7	12.57
LP			31.1	8.70		
LFB					35.8	11.09
C			5.65	1.54	5.8	8.59
Feed energy intake of NE, MJ 77th day of gestation – 109th day of gestation						
GP	849.6	12.82	435.5	8.07		
GFB					473.2	12.57
LP			344.7	8.70		
LFB					396.2	11.09
C			53.1	1.54	54.8	8.59
Feed intake, kg DM Insemination – 109th day of gestation						
GP	300.7	10.71	245.6	8.54		
GFB					275.4	4.73
LP			31.1	8.70		
LFB					35.8	11.09
C			5.65	1.54	5.82	8.59
Feed energy intake of NE, MJ Insemination – 109th day of gestation						
GP	2925	10.71	2389	8.54		
GFB					2682.4	4.39
LP			344.7	8.70		
LFB					396.2	11.09
C			53.1	1.54	54.8	8.59

GP	Gestation feed containing peas
GFB	Gestation feed containing faba beans
LP	Basal lactation feed containing peas
LFB	Lactation feed containing faba beans
C	Protein and mineral concentrate for lactating sows

CV: coefficient of variation, %

3.3.5 Feed and energy intake in lactation

Feed and energy intake of sows were not affected by feeding treatment (Table 32). Consumption of experimental feeds during gestation is presented in Table 33.

Table 32. Effect of dietary treatments on feed and energy intake of sows in lactation.

	Control	Experimental group 1	Experimental group 2	SEM	p treatment
sows, n	9	7	7		
Length of lactation, d	41.3	41.3	41.4	0.74	0.99
Total feed intake, kg DM					
109th d of gestation - farrowing	14.9	15.9	16.5	0.89	0.42
Farrowing - 21st day of lactation	137.2	146.3	141.3	3.96	0.25
21st day of lactation - weaning	197.9	215.2	203.3	14.0	0.65
Farrowing - weaning	335.1	361.5	344.6	16.6	0.50
Total energy intake of NE, MJ					
109th d of gestation - farrowing	154.5	167.7	179.1	10.6	0.24
Farrowing - 21st day of lactation	1487	1586	1530	42.8	0.25
21st day of lactation - weaning	2144	2329	2200	151	0.65
Farrowing - weaning	3631	3915	3731	179.2	0.50

Table 33. Consumption of experiment feeds during lactation.

	Control		Experimental group 1		Experimental group 2	
sows, n	9		7		7	
		CV		CV		CV
Feed intake, kg DM from farrowing to 21st day of lactation	137.2	9.79	146.3	6.62	141.3	3.88
LP	117.4	9.69	125.3	6.63		
LFB					120.9	3.93
C	19.8	10.47	21.1	6.62	20.4	3.64
Feed energy intake of NE, MJ from farrowing to 21st day of lactation	1487	9.79	1586	6.63	1530	3.89
LP	1300.6	9.69	1387.8	6.63		
LFB					1339	3.93
C	186.3	10.47	198.0	6.62	191.7	3.64
Feed intake, kg DM from 21st day of lactation to weaning	197.9	26.03	215.2	12.10	203.3	8.88
LP	169.2	25.84	177.8	12.07		
LFB					167.9	8.90
C	28.8	27.18	30.0	11.98	28.4	8.70
RSE			7.3	13.81	7.1	11.20
Feed energy intake of NE, MJ from 21st day of lactation to weaning	2144	26.00	2329	12.10	2200	8.88
LP	1874	25.84	1970	12.07		
LFB					1859	8.90
C	270.4	27.18	282.4	11.98	266.8	8.70
RSE			76.8	13.81	74.9	11.20
Feed intake, kg DM from farrowing to weaning	335.1	18.07	361.5	9.20	344.6	5.84
LP	286.6	17.90	303.1	9.13		
LFB					288.8	5.84
C	48.6	19.10	51.1	9.11	48.8	5.62
RSE			7.3	13.81	7.1	11.20
Feed energy intake of NE, MJ from 21st day of lactation to weaning	3631	18.04	3915	9.20	3731	5.84
LP	3175	17.90	3358	9.13		
LFB					3197	5.84
C	456.6	19.00	480.4	9.12	458.4	5.62
RSE			76.8	13.81	74.9	11.20

LP Basal lactation feed containing peas
LFB Lactation feed containing faba beans
C Protein and mineral concentrate for lactating sows
RSE Rape seed expeller
CV: coefficient of variation, %

3.3.6 Feed intake of piglets

There was no effect of dietary treatment of sow on the creep feed consumption of piglets. The piglets ate 12.5 NE MJ, 15.6 NE MJ and 11.4 NE MJ (control experimental groups 1 and 2) organic piglet feed during lactation period.

3.4 Milk composition

Milk samples were taken from a total of 24 sows (control group: 9 sows, experimental group 1: 8 sows and experimental group 2: 7 sows). Milk samples were taken from 19 sows in first lactation period and from 5 sows from second lactation period.

Dietary treatment did not affect dry matter, lactose or fat content of milk. The dietary treatment affected protein concentration at the 21st day of lactation and at the last week of lactation. The protein content in sow milk was lower in the experimental group 1 than in the control group. The milk protein content in experimental group 2 did not differ from the results of the other groups.

Table 34. Effect of dietary treatment on milk composition.

	Control	Experimental group 1	Experimental group 2	SEM	p treatment
sows, n	9	8	7		
Dry Matter, %					
1st day of lactation	21.3	19.9	20.7	0.71	0.33
21st day of lactation	18.8	19.8	18.9	0.71	0.55
At the last week of weaning	18.7	18.6	18.4	0.36	0.88
Lactose concentration, %					
1st day of lactation	5.03	5.15	5.16	0.08	0.35
21st day of lactation	5.52	5.55	5.59	0.06	0.69
At the last week of lactation	5.68	5.61	5.67	0.05	0.49
Protein concentration, %					
1st day of lactation	6.20	5.70	5.73	0.20	0.11
21st day of lactation	5.03[a]	4.55[b]	5.07[a]	0.11	**0.004**
At the last week of lactation	5.57[a]	5.02[b]	5.29[ab]	0.14	**0.02**
Fat concentration, %					
1st day of lactation	8.72	8.18	8.75	0.69	0.78
21st day of lactation	7.55	8.94	7.52	0.63	0.18
At the last week of lactation	6.99	7.33	6.72	0.33	0.42

4 Conclusions

The feed intake of sows was very good in the present study. There was no difference between treatments in feed intake during the first three weeks of lactation (6.52 – 6.71 kg DM/day) but after that the sows in experimental groups 1 and 2 which were given supplemental protein had higher feed intake (9.58 kg DM/day and 9.27 kg DM/day) than the sows in the control group (8.91 kg DM/day).

The present study demonstrated that sows fed *ad libitum* with diets containing relatively high amount of pea or faba beans, did not lose excessively body weight during long lactation. The performance and production results of the sows with high daily energy intake were similar in diets containing peas and faba beans. However, the results of this experiment are mainly from only one lactation period and therefore it is not possible to draw any conclusions about the long-term effects of the use of faba bean for sows.

The composition of the control lactation diet used in the present study was optimized according to Tybirk et al (2014) and it fulfilled the recommended amino acid levels for lactating sows. It might be that the differences in dietary amino acid ratios were too small to show any effects to sows performance. The number of animals in the experiment was also smaller than planned. There were no effects of phase feeding on the performance results during lactation. The higher litter weight at weaning with phase feeding could demonstrate that the sows may have used use the supplemental protein for milk production and not for reserves of their own body. The results of condition scoring at weaning support this observation. The condition score of control sows at weaning was better than that of sows in experimental groups 1 and 2. The proportion of sows with condition score 3 (=good) and 4 (=very good) was higher in control group (60.0%) than in experimental groups 1 and 2 (38.5 % and 43.3%).

Even though the litter weight at weaning tended to improve by supplemental protein feeding of the sow during the late lactation, it should be estimated if this improvement leads to improved economical profitability. The sows given supplemental protein also consumed more feed than the sows in the control group.

The protein content of milk was 12 to 20% lower on the 21st day of lactation in all treatment groups than the protein content in milk on the first day after farrowing, but a slow return to earlier levels was noted during the last week of lactation. The fat content of milk was also dropped in every treatment groups from farrowing (8.18 – 8.75 %) to the last week of lactation (6.72 – 7.33%). These figures are in the line with average reported in the study of Klobasa et al. (1987). However the amount of milk samples was rather low.

In conclusion, the present study shows that high feed intake of lactating sows can be maintained by feeding organic diets with peas and faba beans. Supplemental protein during the last half of the lactation in the form of rapeseed expeller had a slight positive effect on litter weight but had no effect on sow condition at weaning.

5 References

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7 Appendix

I Finnish energy requirements of sows in gestation (MTT 2012).

The energy requirements of swine are presented as megajoules (MJ) net energy (NE) per day. Also feed energy concentration is presented as MJ NE per kg or per kg dry matter. Previously the energy value was pesented as feed units (FU), but megajoules will gradually replace feed units. One feed unit equals 9.3 MJ NE.

The aim of presenting the energy requirements is to improve the fertility, longevity and welfare of sows by adequate feeding so that great weight changes during the production cycle are avoided. This is achieved by using condition scoring and modifying feeding during gestation on individual or group basis. The condition scoring is conducted on all sows at insemination (for gilts at insemination after the first farrowing) and at weaning.

There are 5 condition scores: thin (1), moderate (2), good (3), very good (4) and fat (5). The condition score of a sow should not be less than 3.5 at insemination and not less than 3 at weaning. This is possible if the sow does not loose more than 10-15 kg weight during lactation. Some sows are genetically low-fat and mobilise body reserves during lactation, and this target may not apply to them.

Feeding pregnant sow according to the condition

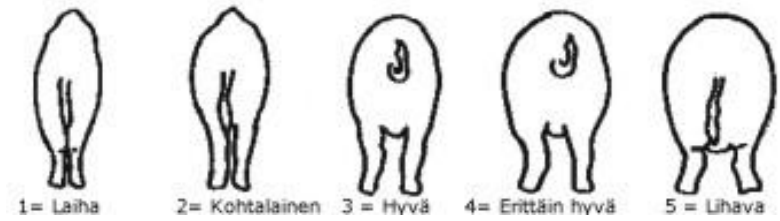
Actions on thin sows must be taken immediately after weaning. If the reason for thinness is a sickness, or the animal is in a very poor condition, it is slaughtered. The weaning can also be done earlier (25 days after farrowing), and in that case the piglets are left in the farrowing pen and transferred to weaning department together with other litters. If weight loss during lactation was due to large litter size or low feed intake, the first heat after weaning is passed and the sow is fed with lactation feed at a rate of 32.6 MJ NE/day (3.5 FU/day) until the next heat. Hay is also given as a stimulus. If the sow does not start cycling, it is slaughtered. If it becomes pregnant, but the condition score remains below 2 at insemination, the feeding must be considered individually.

Sows in other condition scores (score 2-5 at insemination):

	MJ NE / sow / day*			
Condition score at insemination	2 - moderate	3 - good	4 - very good	5 - fat
1st week after insemination	22.3	22.3	22.3	22.3
Weeks 2-13 of gestation	29.8	26.0	22.3	22.3
Weeks 14-16 of gestation, if condition did not raise	29.8	26.0	22.3	22.3
5 days before farrowing	16.7	16.7	16.7	16.7

*If sows are kept in a loose-house system and move a lot, feed allowance can be raised by 1.9 - 3.7 MJ NE/day (0.2 - 0.4 FU/day). If sows move very little, the allowance can be reduced by 0.9 MJ NE/day (0.1 FU/day).

Condition score of sows:



1= thin 2=Moderate 3=Good 4=Very Good 5=Fat

II References for analytical methods used

Dry matter (DM)

DM content was determined by drying samples at 105°C for 20 h.

Ash

Ashing at 600°C for 2 h or alternatively at 510°C for 16 h. Official method AOAC-942.05 (Association of Official Analytical Chemists, USA).

Ether extract (crude fat) after acid hydrolysis (EE)

Acid hydrolysis with 3 M HCl and ether extraction according to the accredited in-house methods No. 4.21 and 4.22 by Soxcap-Soxtec-Analyzer. Official Method AOAC-920.39 (Association of Official Analytical Chemists, USA) Fat (Crude) or Ether Extract in Animal Feed and Foss Tecator Application Note AN 390).

Nitrogen (Crude protein) by Kjeldahl method

Accredited in-house methods 1120, 1122 and 1125 Kjeldahl; Official method AOAC-984.13 (Association of Official Analytical Chemists, USA) using Cu as a digestion catalyst and using Foss Kjeltec 2400 Analyzer Unit (Foss Tecator AB, Höganäs, Sweden). Crude protein value was achieved by multiplying the nitrogen content by correction factor 6.25.

Crude fibre

by Fibertec 2023 FiberCap system (Foss Tecator AB, Höganäs, Sweden). EEC 92/89, ASN 3802. The determination of crude fibre in feed according to EEC standard using the FiberCap 2021/2023 system.

Neutral detergent fibre (NDF)

NDF Method (Method 6) : Neutral Detergent Fiber in Feeds - Filter Bag Technique (for A200 and A200I) using 25 microns nylon bags (F57, ANKOM Technology) and ANKOM 220 Fiber Analyzer (ANKOM Technology, 2052 O'Neil Road, Macedon NY 14502). Detergent solution was made according to Van Soest, P.J., Robertson, J.B. and Lewis, B.A. 1991. Methods for dietary fibre, neutral detergent fibre and nonstarch polysaccharides in relation to animal nutrition. Journal of Dairy Science, 74: 3583-3597. Sodium sulfite was used in NDF-detergent solution and α-amylase in case of samples containing starch. NDF is expressed without containing residual ash.

Acid Detergent fibre (ADF)

ADF Method (Method 5) : Acid Detergent Fiber in Feeds - Filter Bag Technique (for A200 and A200I) using 25 microns nylon bags (F57, ANKOM Technology) and ANKOM 220 Fiber Analyzer (ANKOM Technology, 2052 O'Neil Road, Macedon NY 14502). Detergent solution was made according to Robertson, J.B. and Van Soest, P.J. 1981. The detergent system of analysis and its application to human foods. In: James, W.D.T. and Theander, O. (eds.). The Analyses of dietary Fibre in Foods. New York, NY, Marcell Dekker. p. 123-158.

Acid Detergent Lignin (ADL)

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