



The effects of Sepiolite-SPLF on piglet and heavy pig production

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ABSTRACT

In order to evaluate the effects of Sepiolite for Pig Liquid Feeding (Sepiolite-SPLF) on piglet and heavy pig production, two separate trials have been performed. In the first trial a total of 319 piglets from 32 litters was used. From the 6th day of life piglets belonging to 16 litters received a complementary feed containing Sepiolite-SPLF at 1% (Group B); the remaining piglets were fed a complementary feed without sepiolite addition (group A). At weaning (26 days of life), according to the dietary treatment of the suckling period, 80 piglets were homogeneously allocated to two groups fed up to 30 kg body weight a diet containing or not containing Sepiolite-SPLF at 1% (group B and Group A, respectively). In the second trial 330 barrows of the initial body weight of 60 kg were used. Animals were homogeneously allocated to two groups: a control group traditionally fed a soybean-maize based diet and a sepiolite group in which Sepiolite-SPLF was added at 1% (Group B). Pigs were slaughtered at about 170 kg body weight. In both trials daily weight gain, feed intake and pigs' health were recorded.

Weaned piglets on the sepiolite diet showed a highly significant ($P < 0.01$) reduction of diarrhea score (1.55 vs. 2.03 points). At slaughtering the dietary inclusion of sepiolite resulted in a higher uniformity-degree of pigs as it was demonstrated by a higher ($P < 0.05$) frequency of carcasses in the central class comprised between 133 and 145 kg (52% vs. 35%).

Key words: Pig, Sepiolite-SPLF, Health, Growth, Slaughtering parameters

RIASSUNTO

EFFETTI DELLA SEPIOLITE-SPLF SULLA PRODUZIONE DEL SUINETTO E DEL SUINO PESANTE

Con la finalità di valutare gli effetti della Sepiolite for Pig Liquid Feeding (Sepiolite-SPLF) sulle prestazioni produttive del suinetto e del suino pesante italiano sono state allestite due diverse sperimentazioni. In una prima ricerca sono stati utilizzati 319 suinetti, derivanti da 32 scrofe, ripartiti in due tesi sperimentali ognuna delle quali comprendeva 16 nidiate. Dal sesto giorno di vita i suinetti appartenenti alla tesi B (Sepiolite-SPLF) hanno ricevuto un alimento prestarter che conteneva l'additivo in ragione dell'1% mentre i restanti animali fungevano da controllo (gruppo A). Allo svezzamento (avvenuto al 26° giorno di vita), rispettando il trattamento alimentare effettuato nel periodo dell'allattamento, 80 suinetti sono stati omogeneamente assegnati a due tesi sperimentali nell'ambito delle quali una riceveva un mangime additivato con SPLF all'1% (tesi B). La prova ha avuto termine al raggiungimento dei 30 kg di peso vivo. Nella seconda prova sono stati utilizzati 330 suini del peso vivo medio iniziale di 60 kg. Gli animali sono stati ripartiti in due gruppi nell'ambito dei quali uno era alimentato con mangime contenente Sepiolite-SPLF in ragione dell'1% (tesi B). L'alimento è stato somministra-

to in forma liquida. In entrambe le sperimentazioni sono stati registrati gli incrementi ponderali giornalieri, i consumi alimentari e lo stato sanitario degli animali.

Nel post-svezzamento i suinetti che avevano assunto l'additivo hanno presentato una riduzione altamente significativa ($P < 0.01$) della severità dei fenomeni diarroici (1.55 vs 2.03 punti). In sede di macellazione i suini appartenenti al gruppo Sepiolite-SPLF hanno presentato un maggior grado di uniformità ponderale, come indicato da una frequenza significativamente ($P < 0.05$) più elevata di carcasse nella classe centrale di peso compresa fra i 133 ed i 145 kg (52% vs 35%).

Parole chiave: Suino, Sepiolite-SPLF, Salute, Accrescimento, Parametri di macellazione

Introduction

Sepiolite is a clay mineral which belongs to the group of phyllosilicates. Chemically it is a hydrated magnesium silicate $\text{Si}_{12}\text{Mg}_8\text{O}_{30}(\text{OH}_2)_4(\text{OH})_4$ with structural units made of two parallel layers of silicon tetrahedra and a layer of magnesium octahedra in between. But, unlike other phyllosilicates, Sepiolite has a characteristic chain-like structure. Consequently, alternate hollow channels are produced, which confer to sepiolite its characteristic capillary arrangement. Owing to these structural characteristics, sepiolite has specific physical-chemical properties such as high porosity and surface area, strong absorptive power, high structural stability, no swelling behavior in water, chemical inertia and strong capacity to form stable suspensions at low concentrations.

Sepiolite is a feed additive (E-562) used as a binder and anti-caking agent at 2% in all feeds for all animal species.

Beside its well-known technological properties as a pellet binder (Angulo *et al.*, 1995; Angulo *et al.*, 1996), sepiolite shows interesting effects from a nutritional and environmental point of view, particularly with regard to pigs and to other non-ruminants. It has been demonstrated by several authors (Castaing, 1989; Parisini *et al.*, 1993; Tortuero and Rioperez, 1993; Castaing, 1994; Magnin and Escribano, 1996; Castaing and Noblet, 1997; Parisini *et al.*, 1999), that the inclusion of a 2% sepiolite additive in a basal pig grower diet improved nutrient utilization and determined a higher lean meat yield without having any adverse effect on animal performance. Some *in-vitro* studies (Cabezas *et al.*, 1991) have shown that pancreatic enzymes can be absorbed over the surface of sepiolite, forming complexes which are active over a range of different digestive pH. This is particu-

larly relevant in the case of pancreatic amylase which is normally very intolerant to differing pH values. Although the sepiolite-enzyme derivatives are less active than the native enzymes, the profile of the plot of enzymatic activity versus pH is complementary to that of native enzymes. These findings may help to explain the positive action of the addition of sepiolite to the feed, as it favors the hydrolysis of the feed components.

Chickens fed a diet containing sepiolite showed a reduction of transit time of *digesta* (Tortuero *et al.*, 1992) which might correspond to better nutrient utilization; this mechanism has also been described for pigs (Melcion, 1995). Recently, Ouhida *et al.* (2000) have demonstrated a positive effect of sepiolite on the OM digestibility of broiler chicken diets of different viscosities.

Owing to its great surface area and porosity, sepiolite can absorb NH_4^+ molecules produced from deamination of proteins or urea hydrolysis along the alimentary tract of pigs and, afterwards, from excreta during storage (Bueno *et al.*, 1984; Canh *et al.*, 1996); these results are also of interest with regard to human and to pig health, and from an environmental point of view (reduction of the impact of intensive pig breeding).

Furthermore it is worth noting that certain clays (i.e. bentonite, sepiolite and zeolites) can effectively reduce the detrimental effects of microtoxin-contaminated diets (Phillips *et al.*, 1988; Lindemann *et al.* 1993; Schell *et al.* 1993a and 1993b; Ramos *et al.*, 1996).

Sepiolite can be industrially processed to develop strong rheological properties; thus it can be used as a suspending agent. The early laboratory tests on "rheological" Sepiolite for Pig Liquid Feeding (SPLF) were conducted by Escribano *et al.* (1995) who found a reduced sedimentation when SPLF was dispersed into the water prior to the

Table 1. Physical-chemical properties of the Sepiolite-SPLF used in the experiments (source: TOLSA, Madrid, Spain).

Chemical analysis		Mineralogical analysis		Physical properties	
SiO ₂	60.7%	sepiolite	>85%	apparent density	> 400g/l
Al ₂ O ₃	2.6%	associated minerals	<15%	wet particle size	>5 μ < 10%
Fe ₂ O ₃	0.8%			dry particle size	<75 μ <20% >850 μ <2%
CaO	0.4%			ion exchange capacity	25 meq/100g
MgO	24.0%			BET surface	195 m ² /g
K ₂ O	0.6%			Cowles Viscosity (*)	> 30,000 cP
Na ₂ O	0.1%			Syneresis	0 %

BET = exchange surface area

(*) Cowles viscosity refers the viscosity of a clay suspension prepared with a Cowles stirrer

addition of a 22% dry matter meal-feed. Hoppenbrock and Latka (1996) reported a reduction in sedimentation when SPLF was added at 0.75%. Hoppenbrock *et al.* (1998) found that the addition of 1% SPLF reduced sedimentation and separation of meal-feed by maintaining feed particles homogeneously suspended.

The aim of the present trials was to evaluate the effects of sepiolite SPLF on heavy pigs performances over their whole production cycle, i.e. from birth to slaughtering (at about 170 kg body weight) with particular regard to animals' health, growth and slaughtering parameters and the quality of carcasses and meat.

Material and methods

Trial on piglets from birth to post-weaning

The experiments were conducted under the guidelines of the Ministry of Agricultural and Forestry Policies (MiPAF, Italy) implementing Council Directive 91/630/EEC on pig protection and utilized 319 piglets deriving from 32 Large White sows. Sows were homogeneously chosen on the basis of sires' genetic (Landrace boars) and farrowing order (on average four parity-dams).

Litters were allotted to two experimental groups:

- Group A (control) in which piglets from 16 litters received a feed without Sepiolite-SPLF;
- Group B (SPLF) in which piglets from the

remaining 16 litters received the same feed as Group A but containing Sepiolite-SPLF at 1%.

The main physical-chemical properties of SPLF used in the present trials are shown in Table 1.

Pre-starter feed (Table 2) was offered as meal from the 6th day of life up to weaning. Weaning took place on the 26th day of life.

During the suckling period the following data were recorded: number of piglets born per sow; average live weight at birth per litter; number of piglets weaned per sow; mortality; health and diarrhea score with points awarded on a 1-to-4 scale (1 indicating a normal consistency of feces and 4 indicating severe diarrhea; to perform this classification the number of pigs in each litter and feces consistency were used); number of piglets whose weaning weight was less than 6 kg ("under-weight" piglets).

After weaning, 80 male piglets were randomly chosen according to the dietary treatment of the previous phase and placed in 16 post-weaning cages each containing 5 animals. Forty piglets received a feed containing SPLF at 1% (Group B). Feed was offered *ad libitum* in pellet form. To meet the piglets' requirements and in accordance with INRA (1989) recommendations, two different formulations were used from 27 to 52 and from 53 to 80 days of life (Table 2). The trial ended on the 80th day of life, when piglets attained a body weight (BW) of about 30 kg.

Piglets were individually monitored for: weight

Table 2. Chemical composition of the diets.

Type of feed		Prestarter	Starter		Grower-finisher
Age of the pigs	d	6-26	26-52	53-80	130-slaughter
Analyzed values:					
Dry matter	%	88.42	89.72	88.97	23.50
Crude protein	% DM	21.90	21.44	19.69	17.16
Ether extract	"	7.53	5.17	5.38	4.96
Crude fiber	"	4.11	4.60	4.63	4.55
Ash	"	7.55	7.07	6.81	4.61
Calcium	"	1.29	1.10	1.08	0.89
Phosphorus	"	0.94	0.69	0.67	0.39
Calculated values (on a DM basis):					
DE	kcal/kg	3840	3726	3747	3685
Lysine	%	1.65	1.48	1.23	0.87

at weaning; weight at 52 days of life and at the end of the trial; average daily gain; feed intake; feed conversion rate; mortality (and causes); diarrhea incidence and diarrhea score measured as described above.

During the post weaning period 4 samples of feces per thesis (in all 24 samples) were collected every two weeks (33, 47, 61, 75 days of life) to determine fecal dry matter by freeze-drying.

Trial on growing-finishing pigs

This trial used 330 Landrace x Large White barrows, with an initial BW of about 60 kg.

Pigs were homogeneously allocated to two experimental groups each containing 11 replications of 15 animals fed as follows:

- Group A (control) in which pigs received a maize/soybean diet;

- Group B in which pigs received the same feed as Group A but added (in the mixing tank) with sepiolite-SPLF at 1.02% (so that sepiolite replaced all the other ingredients at 1%).

All the pigs received a water-diluted feed (23.5% dry matter) the chemical composition of which is shown in Table 2. Pigs were fed twice a day and feed was offered at the rate of 9% of the metabolic body weight ($BW^{0.75}$) up to a maximum of 3.0 kg (on a dry matter basis) per head, per day. Chemical analyses of feed were performed accord-

ing to ASPA methods (Martillotti *et al.*, 1987). During the growing-finishing phase initial and final weights, feed intake and health status were recorded.

Pigs were slaughtered at about 170 kg BW. On a total of 200 pigs the following data were collected, in accordance with ASPA directions (1996): carcass weight, dressing out percentage, lean meat yield (by Fat-o-Meater), pH (at 45' and at 24 hours *post-mortem*) and color of *Semimembranosus* muscle; this latter was assessed according to L*a*b* method (McLaren, 1980) by Minolta CR-200 colorimeter.

Samples of subcutaneous fat were taken (in the overhanging area of *Biceps Femoris* muscle) from 20 thighs per group deriving from the right side to determine the fatty acid composition by gas chromatograph (HRGC 8560 Series Mega 2 gas chromatograph; Fisons Instruments, Milan, Italy).

Statistics

All the data obtained from both trials were submitted to analysis of variance by using the model:

$$y_{ij} = \mu + \alpha_i + \epsilon_{ij}$$

Were: y_{ij} = dependent variable; α_i = effect of the diet ($i = 1-2$); ϵ_{ij} = error contribution.

To compare data from mortality, diarrhea score and carcass classification, a chi-square test was used.

Table 3. Performance of the suckling piglets.

Groups		A (Control)	B (SPLF)	RMSE
Parity order of the sows	n.	3.81	4.25	1.63
Litters	"	16	16	-
Born/litter	"	9.69	10.25	2.69
Weight at birth	kg	1.45	1.44	0.28
Weaned/litter	n.	8.44	9.06	1.89
Weight at weaning	kg	8.03	7.87	0.78
Weight gain/litter	"	53.72	56.60	11.94
Mortality	%	11.54	11.28	1.70
Underweight piglets (BW at weaning <6kg)	"	3.7	1.4	-
Diarrhea score ¹	point	1.20	1.17	0.15

¹ Diarrhea score: 1=normal; 2=mild; 3=medium; 4=severe.

Evaluation of feed homogeneity

Liquid feed was collected monthly from the mixing tank and from three equidistant troughs (initial, middle and final troughs) along the delivery system of the barn (the length of the barn was of 55 m) and analyzed for dry matter (by freeze-drying) and protein content according to ASPA methods (Martillotti *et al.*, 1987).

Results and discussion

Suckling and weaned piglets

Data concerning the productive performances of suckling piglets are shown in Table 3. The addition of SPLF did not result in any significant ($P>0.05$) modification in either the health status or of the productive parameters of the piglets. A slight reduction of diarrhea score corresponded to a lower number of underweight piglets and a slight reduction in mortality rate.

The growing parameters of piglets in the post-weaning phase (7 to 30 kg BW) are shown in Table 4. As in the previous phase, also during this second period no significant differences were appreciable between groups. On the whole, growing parameters, either with respect to daily weight gain or feed conversion rate, could be regarded as highly satisfactory and they could be ascribable to the good hygienic farming conditions (including feed quality). These results agree with those reported by Parisini *et al.* (1993 and 1999), Magnin and

Escribano (1996) and Castaing and Noblet (1997) who found a non-significant improvement of growing parameters of young pigs receiving sepiolite at 2%. It is worth noting that in the above mentioned experiments "traditional" sepiolite was used instead of the "rheological" Sepiolite-SPLF.

Facing similar mortality rates in both groups (regardless of the dietary treatment, mortality rate was very low), piglets receiving SPLF showed a highly significant ($P<0.01$) reduction in diarrhea score (1.55 vs. 2.03). In particular, a global reduction of the total number of intestinal troubles was observed (43 vs. 65) together with a different allocation of diarrhea occurrences in the four classes of diarrhea intensity. Piglets receiving SPLF showed, in fact, a significant ($P<0.05$) reduction of severe (13.3 vs. 25.4%) and medium (17.8 vs. 31.7%) forms which corresponded to a relative significant ($P<0.01$) increase in the occurrences of mild diarrhea (68.9 vs. 42.9%). Although differences in mean values were not significant, piglets receiving SPLF showed a higher dry matter content of feces; this latter effect, that in the present experiment was obtained by adding SPLF at 1%, was also observed in weaning piglets by using clinoptilolite at 2% (Malagutti *et al.*, 2002; Sardi *et al.*, 2002) and on growing pigs either by using clinoptilolite at 4% (Malagutti *et al.*, 1997) or phillipsite at 2% (Benatti *et al.*, 1994). From a general standpoint, these positive results could be related to the physiology of the intensive-bred

Table 4. Productive parameters of the weaned piglets.

Groups		A (Control)	B (SPLF)	RMSE
Cages	n.	8	8	-
Piglets	"	40	40	-
Initial weight (26 d of age)	kg	7.21	7.49	1.14
Intermediate weight (52 d of age)	"	13.65	13.66	1.97
Final weight (80 d of age)	"	30.65	30.70	3.56
ADG 26-52 d	g/d	248	237	32.15
ADG 53-80 d	"	607	609	48.16
ADG 26-80 d	"	434	430	50.11
FCR 26-52 d	g/g	1.54	1.52	0.14
FCR 53-80 d	"	1.84	1.82	0.17
FCR 26-80 d	"	1.74	1.71	0.14
Mortality rate	%	0.05	0.02	-
Diarrhea score ¹	point	2.03A	1.55B	0.23
Total cases of diarrhea	n.	63	45	-
Mild intensity	%	42.9A	68.9B	-
Medium intensity	"	31.7b	17.8a	-
Severe intensity	"	25.4b	13.3a	-
Fecal dry matter	%	30.78	31.34	3.72

ADG= average daily gain; FCR= feed conversion rate

¹ Diarrhea score: 1=normal; 2=mild; 3=medium; 4=severe.

A, B=P<0.01; a, b=P<0.05.

Table 5. Productive parameters of the growing-finishing pigs.

Groups		A (Control)	B (SPLF)	RMSE
Pigs	n.	165	165	-
Pens	"	11	11	-
Initial body weight	kg	62.78	64.22	7.32
Final body weight	"	161.18	163.56	14.80
Average daily gain	g/d	800	808	100.13
Feed intake	kg/d	2.57	2.53	0.01
Feed conversion rate	kg/kg	3.66	3.57	0.45

young pig that is particularly exposed to clinical and sub-clinical troubles. In this framework sepiolite could have improved the intestinal "health status" by favoring enzyme activity and/or by binding noxious substances along the gastrointestinal tract as suggested by Parisini *et al.* (1999).

Growing-fattening pigs

Data concerning the trial on growing-fattening pigs are displayed in Table 5.

The addition of SPLF to liquid feed resulted in a slight, non significant ($P>0.05$) improvement of growth parameters (i.e. avg. daily weight gain and feed conversion rate). Nevertheless it is worth noting that sepiolite, which replaced all other nutrients at 1%, has no caloric value and has high ash content. Our results agree with those reported by Hoppenbrock *et al.* (1998) who found a tendency ($P<0.1$) toward an improvement in ADG and FCR in SPLF-treated pigs (100 kg BW).

Table 6. Slaughtering parameters and meat quality of heavy pigs.

Groups		A (Control)	B (SPLF)	RMSE
Pigs	n.	100	100	-
Carcass weight	kg	139.1	139.7	12.59
Dressing out	%	81.5	81.7	2.85
Carcass classification:				
< 133 kg	%	33	26	-
133-145 kg	"	35a	52b	-
>145 kg	"	32	22	-
Lean meat (F-o-M)	"	48.2	48.1	3.27
Meat quality:				
pH at 45' SM muscle		6.7	6.6	0.20
pH at 24 h SM muscle		5.6	5.6	0.13
Thigh color (SM muscle):				
L*		47.5	47.2	3.62
Hue		0.4	0.4	0.09
Chroma		10.1	10.2	1.89
Fatty acid relative composition ¹ :				
C 16:0	%	19.99	20.01	1.18
C 18:0	"	14.80	14.05	0.85
C 18:1	"	44.19	43.80	1.79
C 18:2	"	12.32	13.47	1.32
Saturated fatty acid	"	36.63	35.94	1.94
Unsaturated fatty acid	"	63.36	64.06	1.87
UFA/SFA		1.74	1.79	0.06

SM = Semimembranosus

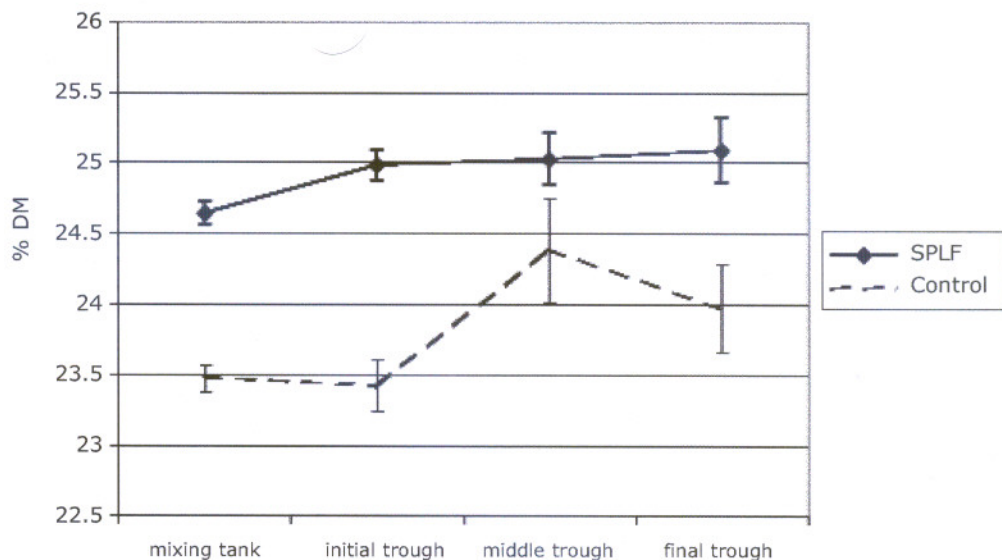
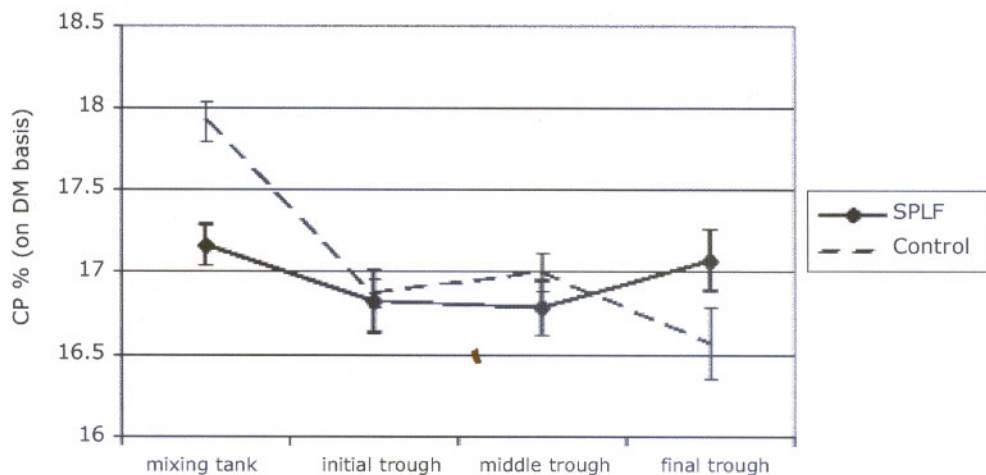
¹Analyses were performed on the subcutaneous fat of 20 thighs per group.

a, b=P<0.05.

At slaughtering (Table 6) no significant differences were observed between the groups concerning dressing out percentage, lean meat yield and meat (pH and color) and subcutaneous fat (fatty acids relative composition) quality. These results are only partially consistent with those reported by Hoppenbrock *et al.* (1998) and Castaing *et al.* (1998; unpublished data cited by Hoppenbrock *et al.*, 1998) who found a higher lean meat yield and a reduction of backfat thickness of growing pig (100 kg BW) on SPLF-diets.

The addition of SPLF resulted in a higher uniformity-degree of pigs as it was demonstrated by a higher (P<0.05) frequency of carcasses in the central class comprised between 133 and 145 kg (52% vs. 35%). This result could be attributable to a bet-

ter homogeneity (i.e. lower sedimentation of solid particles) of SPLF-added liquid feed, as shown in Figures 1 and 2. A higher DM content in the mixing tank (due to sepiolite addition) was in fact followed by a better homogeneity of the liquid feed along the whole delivery system, whilst the dry matter content of feed without sepiolite addition was inconstant (figure 1). Similarly the protein content of liquid feed with the SPLF additive showed fewer variations along the whole delivery system (figure 2). Thus, it could be supposed that all the pigs were allowed to ingest a feed characterized by a constant nutrient supply (otherwise, due to meal sedimentation, differences in the composition of the liquid-feed are commonly observable both among pens within the same barn and

Figure 1. Dry matter content of liquid feed supplied to heavy pigs (mean values \pm SD).Figure 2. Crude protein (CP) content of liquid feed supplied to heavy pigs (mean values \pm SD).

among what pigs receive within the same pen).

From a practical standpoint a higher degree of uniformity in the carcasses can be considered as a highly positive effect because it facilitates the processing of carcasses, including the curing of thighs (Scipioni *et al.*, 2003).

In addition to these findings, and apart from any experimental scheduling or modeling, people

from the farm-staff were asked about their impressions on the management of SPLF-treated and untreated pigs. On a subjective basis (i.e. degree of the animals' dirtiness/cleanliness inside the same pen), pigs receiving SPLF were found to be cleaner and it cannot be excluded that this fact was related to a possible higher consistency of their feces. Considering that the degree of cleanli-

ness of the pigs can influence the quality of meat (Hansen *et al.*, 1994; Maw *et al.*, 2001), further research (e.g. by getting a "dirtiness/cleanliness score") is needed to elucidate this possibility.

Conclusions

From the present experiments it can be concluded that Sepiolite-SPLF replacing at 1% all other nutrients in the piglets' diet could reduce diarrhea intensity in the post-weaning period. With respect to heavy pigs, the addition of sepiolite resulted in a higher degree of uniformity in the animals at slaughtering as it was demonstrated by a higher frequency of carcasses in the central BW class. This effect, which can be considered as highly favorable from a technological standpoint, was probably due to an improvement of the homogeneity (i.e. reduction of sedimentation) of the liquid feed due to the rheological properties of Sepiolite-SPLF. The addition of SPLF did not result in any adverse effect on growing and slaughtering performances of growing-finishing pigs and no significant differences were observed with regard to ADG, FCR, lean meat yield, meat and fat quality.

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