Effects of the water-feed ratio and of a rheological sepiolite on some physical parameters of liquid feed and performances of pigs.

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Abstract

This study evaluated the effects of the water-feed ratio (WFR) and of a rheological sepiolite (Splf, Tolsa SA) on physical parameters of the liquid diet, reliability of liquid feeding systems and performances in growing-finishing units. In exp.1 (23 to 115 kg), 48 pigs per group received *ad lib* a diet mixed with water in a ratio of 2.8:1 l/kg, or the same diet with 1 % Splf at 2.8:1 or 2.2:1 l/kg. In exp.2 (27 to 69 kg), 36 pigs per group were fed *ad lib* in a 2x2 factorial study: inclusion or not of 1% Splf and WFR (2.7:1 or 2.35:1 l/kg).
From d0 to d21 in exp.1, pigs receiving Splf at a 2.8 or 2.2:1 ratio had higher intakes (FI: respectively 1.64 and 1.64 vs. 1.59 kg/d; $p<0.05$) and daily gains (ADG: 796 and 798 vs. 772 g/d; $p <0.05$), as feed conversion ratio was not affected. From d0 to d47, FI (2.08 and 2.11 vs. 2.04 kg/d; $p<0.01$) and ADG (897 and 905 vs. 886 g/d; not significant) stay higher. From d0 to d15 in exp.2, FI were equal for all diets and ADG of Splf treatments (783 vs. 759 g/d) did not differ statistically. From d0 to d43, ADG and FCR were unchanged by WFR and were slightly but not significantly improved by Splf (ADG: 992 vs. 974 g/d). It was concluded that rheological properties of Splf increased water retention by diet, setting of particles in suspension, fluidity of the liquid mixture, facilitated accuracy of the distribution and a lower WFR, and improved performances of growing pigs.

Keywords: pigs, young growers, liquid feed, sepiolite, water feed ratio.

Introduction

Liquid feeding of growing-finishing pigs is a largely widespread technique in Europe. Advantages of liquid feeding include a fully automated preparation and distribution of different feeds for fattening pigs and its potential to use maize, whey or wet by-products from food industry. The distribution of feed by liquid systems is based on curves adapted to the needs of the animals and adjusted by changing the dosing percentage after daily inspection of the troughs.
One problem in the management of liquid feeding is that, in the purpose to avoid refusals and to prevent digestive disorders, many pig farmers use in practice low curves and apply only falling changes of the dosing percentage (Guillou and Landeau, 2005; EDE Bretagne, 2006). Moreover, the pigs, when fed with a liquid feed seem to be more sensitive to palatability factors or use of raw materials as rapeseed meal (Sommer, 2005; MLC, 2005). As a consequence, some farmers restrict in excess the pigs. Additionally, for younger pigs (20-35 kg) daily volumes of liquid and feed to be ingested appear relatively large and some difficulties to reach the potential intakes could appear.
A study has been undertaken to evaluate if the water to feed ratio (WFR) and the inclusion of a rheological sepiolite could help to boost and regularize the voluntary feed intake of pigs, especially young growers, fed liquid feed.
A large range of water to feed ratios is used by farmers and its effects on biological performances are discussed for many years. A higher dry matter concentration reduce the effluent output (Chosson *et al.*, 1988; Smolders and Hoofs, 2000). It could also have no adverse effects on eating behaviour as voluntary water use is lower for pigs fed *ad libitum* than for pigs restricted (Massabie, 2001). Sepiolite, a clay mineral which belongs to the groups of phyllosilicates, is well-known for its technological and nutritional properties and registered as a feed additive. Splf® is a product with rheological properties containing 60 to 95 % of pure sepiolite and obtained by micronisation in wet process by company TOLSA (Madrid, Spain). It has been demonstrated that the inclusion of Splf® facilitated the distribution of liquid feeds with low water to feed ratios (LeTreut and Guillou, 2003; Lizardo *et al.*, 2005).

Materials and methods

Experimental facility

Two experiments were performed at the Swine Research Centre of Ifip - Institut du porc (Villefranche de Rouergue, France) using two hundred and eighty-eight pigs of both sex and crossbred ((LW x LD) x P76). The liquid feeding facility contained 24 pens of 6 animals situated on both sides of the central corridor. In front of the pen, a trough with six eating places was present. Pens (2.30 x 1.90 m) had fully slatted floors. Environmental temperature was maintained between 22 and 26 °C.

The liquid feeding equipment was an automatic supply system (Asserva, Lamballe, France) comprising a square mixing/weighing tank of low capacity (500 l) divided into an internal positioning water vat and a mixing compartment. The tank was made of stainless steel and equipped with a 3-point weighing system. Mixing of dry meal and water was carried out during 180 seconds by recycling runs by an internal pump and two agitators.
The system also included a centrifugal pump, a rinse water tank and two separate ring circuits with two feeding valves per trough making it possible to distribute two distinct diets to the same trough. The correct feed amount was weighted and pumped into the circuit as a column, with water as a positioning liquid. As positioning water was weighted prior to the distribution, the system did not stop when the mixing compartment was empty so there was neither waiting time nor sedimentation during the feeding cycle. When no feeding cycle was active, all the circuits were filled with water. The mixing zone between the positioning water and the feed column was eliminated and not re-used to prepare a new feed. For both circuits, the lengths between the pump and the 1st valve, and between the pump and the last valve were of 11 m and 33 m respectively.
All experimental diets were in meal form and were initially produced at the Ifip manufacturing unit. Before the experiments, pigs received a dry feed during the post-weaning periods.

Experimental design

Experiment 1
The pigs were introduced to the experiment at an average body weight of 22.7 kg (SD =1.8). They were blocked on body weight and sex and randomly allocated to three groups: a control group (2.8C) which was fed *ad libitum* a liquid feed prepared with water and the basal diet in a ratio of 2.8:1 (l/kg), and two sepiolite groups (2.8S and 2.2S) which were fed the basal diet with 1 % Splf® at a dilution ratio of 2.8:1 or 2.2:1 l/kg. Each group comprised 4 pens of 6 barrows and 4 pens of 6 females.

Table 1 – Ingredient composition of the basal diets in experiment 1 (percentage on as fed basis).

Live weight range	23 - 36	36 - 66	66 - 115
Wheat	30.9	15.0	15.0
Barley	29.7	46.5	53.5
Peas	12.5	18.8	12.9
Rapeseed meal	12.0	11.0	10.0
Soybean meal	10.6	5.8	6.0
Vegetable oil	0.7	0.0	0.0
Limestone	1.04	1.04	1.35
Dicalcium phosphate	1.08	0.61	0.22
Lysine 50 %	0.350	0.230	0.170
Methionine 40 %	0.090	0.065	0.000
Threonine 30 %	0.240	0.155	0.025
Salt	0.30	0.30	0.30
Premix [a]	0.50	0.50	0.50

[a] Premix provided per kilogram of complete diets: Cu, 10 mg; Fe, 80 mg; Mn, 40 mg; Zn, 100 mg; Co, 150 µg; I, 0.3 mg; Se, 0.2 mg; vitamin A, 6,250 UI; vitamin D3, 1,250 UI; vitamin E, 18 mg; vitamin K, 0.6 mg; vitamin B1, 1.2 mg; vitamin B2, 3.8 mg; pantothenic acid, 9 mg; vitamin B6, 3 mg; vitamin B12, 25µg; vitamin PP, 12 mg and choline, 0.3 mg.

Table 2 – Calculated and analysed nutrient content of the diets in experiment 1 (as fed basis, g /kg) [a].

Live weight range	23 – 36		36 - 66		66 - 115	
Sepiolite level	0%	1%	0%	1%	0%	1%
Dry matter	874 (881)	875 (878)	872 (884)	873 (881)	875 (887)	877 (886)
Crude protein	180 (184)	178 (180)	165 (167)	163 (166)	159 (156)	158 (156)
Crude fibre	48 (54)	48 (49)	52 (55)	51 (55)	52 (52)	51 (54)
Starch	400 (411)	396 (404)	417 (435)	413 (435)	430 (442)	426 (448)
Fat	23 (23)	23 (20)	16 (17)	16 (16)	17 (19)	16 (15)
Ash	58 (50)	67 (59)	52 (47)	61 (55)	51 (47)	60 (47)
Calcium	8.5	8.4	7.9	7.8	8	7.9
Total phosphorus	6.4	6.3	5.5	5.4	4.7	4.7
NE, MJ/kg	9.2	9.1	9.0	8.9	9.1	9.0
Total lysine	10.9 (11.0)	10.8 (10.7)	9.8 (9.9)	9.7 (10.0)	8.8 (8.9)	8.7 (8.4)
Ileal digestible lysine	9.25	9.16	8.12	8.04	7.25	7.18
Lys d / EN (g/MJ)	1.00	1.00	0.90	0.90	0.80	0.80

[a] In parenthesis the analysed content of specific nutrients is given.

The basal diets were relatively complex with barley, wheat, peas, rapeseed and soybean meal as base components and were formulated according to the nutrient requirement of pigs (Ifip, 2000) into three live weight ranges diets: starting phase was from 23 to 36 kg (day 1 to 18), growing phase from 36 to 66 kg (day 18 to 50) and finishing phase from 66 to 115 kg (day 50 to slaughtering). The ingredient composition of the basal diets is presented in Table 1 and the calculated and analysed nutrient

content is shown in Table 2. The diets contents were balanced for net energy and ileal amino acids with 1.0, 0.9 and 0.8 g ileal digestible lysine per MJ NE for starting, growing and finishing phases.
After 5 days of adaptation, Splf® was incorporated in the rate of 1 % by dilution of the basal diet at the time of the preparation of liquid feed. Thereafter (Day 9), Splf®was premixed in the feed meal.

Experiment 2
The one hundred and forty-four pigs weighed on average 27.3 kg (SD = 2.7) and were used in a 2 x 2 factorial arrangement. The experimental groups used during starting and growing phases (from 27 to 69 kg) were: a control group (2.7C) which was fed *ad lib* a liquid feed produced by mixing water with the basal diet in a ratio of 2.7:1, a group (2.7S) which was fed the basal diet with 1 % Splf® at a same dilution ratio of 2.7:1 l/kg, and two others groups (2.35C and 2.35S) which were fed the basal diet added or not with Splf® mixed with water at a dilution ratio of 2.35:1 l/kg. Pigs were blocked and randomly allocated to groups so that sex and body weight were equally distributed. Each group comprised 3 pens of barrows and 3 pens of females, with 6 animals per pen.
The basal diets were relatively simple with wheat, maize, soybean meal as base components and were formulated according to the nutrient requirement of pigs (Ifip, 2000) into three live weight ranges diets: starting phase was from 27 to 38 kg (day 1 to 15), growing phase from 38 to 68 kg (day 15 to 43) and finishing phase from 68 to 116 kg (day 43 to slaughtering). The ingredient composition of the basal diets is presented in Table 3 and the calculated and analysed nutrient content is shown in Table 4. The diets contents were balanced for net energy and ileal amino acids with 1.0, 0.9 and 0.8 g ileal digestible lysine per MJ NE for starting, growing and finishing phases.
Splf® was incorporated at the level of 1 % by dilution of the basal diet at the time of the mixture of feed meal. At the end of the growing period (68 kg), sepiolite treatment was stopped while dilution treatment continued. The pigs were all fed the basal finishing phase diet, at a dilution ratio of 2.7:1 or 2.35:1.

Table 3 - The ingredient composition of the basal diets in experiment 2 (percentage on as fed basis).

Live weight range	27 - 38	38 - 68	68 - 116
Wheat	54.3	58.8	64.1
Maize	20.0	20.0	20.0
Soybean meal	21.9	17.5	13.0
Limestone	1.00	1.30	1.00
Dicalcium phosphate	1.50	1.10	0.70
Lysine	0.325	0.330	0.330
Methionine	0.050	0.040	0.025
Threonine	0.095	0.090	0.080
Salt	0.30	0.30	0.30
Premix [a].	0.50	0.50	0.50

[a] Premix : see Table 1.

Table 4 - Calculated and analysed nutrient content of the diets in experiment 2 (as fed basis, g /kg) [a].

Diets	Experimental period				Post-experiment
Live weight range	27 - 38		38 - 68		68 - 116
Sepiolite level	0%	1%	0%	1%	0%
Dry matter	883 (875)	884 (876)	885 (880)	886 (880)	883 (880)
Crude protein	186 (186)	184 (182)	171 (172)	169 (166)	156 (155)
Crude fibre	29 (34)	29 (34)	28 (33)	28 (33)	31 (28)
Starch	463 (472)	459 (472)	492 (504)	488 (498)	524 (532)
Fat	20 (15)	20 (14)	20 (17)	20 (15)	20 (19)
Ash	56 (44)	65 (51)	53 (42)	62 (50)	44 (53)
Calcium	9,2	9	9,2	9,1	7,1
Total phosphorus	6,3	6	5,4	5,4	4,6
Net energy (MJ/kg)	9,95	9,85	10,05	9,96	10,03
Total lysine	11,0 (10.9)	10,9 (11.0)	10,0 (9.7)	9,9 (9.7)	8,9 (9.2)
Ileal digestible lysine	10,00	9,90	9,04	8,95	8,03
Lys. d. / EN (g/MJ)	1.01	1.01	0.90	0.90	0.80

[a] In parenthesis the analysed content of specific nutrients is given.

Liquid feeding

Fresh liquid feeds were provided twice a day in two similar portions (14 meals per week). The pigs were fed a real *ad libitum*. Each meal was monitored and the amount of feed was daily adjusted. Feed was supplied so that there was no feed leftover, although the animals could not clean up the troughs. As a refusal appeared, the increase of the feeding level was stopped, and sometimes reductions in the daily ration were carried out. The changes from a phase diet to the subsequent phase were carried out without adaptation period.
During the finishing period, a limitation to 3.100 kg of the feeding level was applied for the barrows from day 64 (average weight of 79 kg) for Exp. 1, and from day 59 (average weight of 84 kg) for Exp. 2. The females remained fed *ad libitum*.
In Exp. 1, no additional water was available. In Exp. 2, during the finishing period, i.e. after the end of the sepiolite supplementation, an additional water supply was given via a separate distribution corresponding to 1 l /pig/day for groups 2.35 from d 44 to 70, then, from d 71, to 2 l and 1 l/pig /day for groups 2.35 and groups 2.7 respectively so that the total water amount was approximately equal among groups.

Parameters measured

Pigs were individually weighed at the beginning of each period of the experiments, then at two weeks intervals. The health of the animals was monitored regularly and any medication and veterinary intervention was recorded. Feed intakes per pen were recorded daily during the trials. The percentage of days with a reduction of the feed ration (refusals) was calculated.
The pigs were slaughtered in two batches per experiment when individual pigs reached 110 kg: on day 98 and day 113 for Exp. 1, and day 91 and day 100 for Exp. 2. Backfat and muscle thickness were measured and the lean meat percentage was calculated. Carcass weight was estimated by multiplying by 0.975 the weight of the hot, eviscerated carcass 45 m after slaughter. The dressing percentage was calculated as carcass weight/ live weight ratio.

The metering precision of the system was periodically monitored as described by Albar *et al.* (1987). The accuracy of the distribution to the diaphragm valves was controlled by derivation of the drop pipe at every feeding valve and weighting of the quantity of feed programmed by the computer. In order to control the precision of the water to feed mixing and the homogeneity of the liquid feed among the valves, samples of the liquid feed were then taken along the different pipes and analysed for dry matter content. In Exp. 2, the technological quality of liquid feed was also estimated by the fluidity. This method described by Escribano et al. (2005) evaluates the homogeneity of the liquid feed and its ability to maintain solid particles of feed suspended. Fluidity is defined as the quantity of liquid feed which runs out by gravity on a level inclined with 4.5 ° during a fixed time (1.5 m). Measurements were taken at the laboratory for the starting feed and at the time of the distribution by the liquid feeding system for growing and finishing feeds.

Statistical analysis

Measures of the quality of liquid feeds were interpreted using the GLM procedure of SAS.
Measures of growth, feed intake, and feed efficiency were analysed with pen mean as the experimental unit, using proc GLM. Carcass characteristics were analysed with pig as the experimental unit. Data of Exp. 1 were analysed with a model that included effects of block, dietary treatment, sex, and interactions. Means were compared using Tukey test. Data of Exp. 2 were analysed with a model that included effects of block, water-feed ratio, sepiolite level, sex, and interactions. Only the effects of dietary treatments and sex are presented here. In addition treatment means were separated using Tukey and t tests.

Results

In general the analysed composition of the diets (Tables 2 and 4) agreed well with the calculated composition, although the analysed ash contents were somewhat lower than calculated.
There were no major health problems with the pigs in both experiments. No differences were found in mortality or frequency of individual treatments among the groups within each experiment. In Exp. 1, 2 pigs died and 4 pigs were removed from experiment. In Exp. 2, 1 pig was culled and 1 pig was removed from test.

Technical quality of the liquid feed

Accuracy of the distribution
The precision of the distribution to each trough was checked 8 times during Exp. 1 and 4 times during Exp. 2 (Table 5). For Exp. 1, the quantity of liquid feed programmed by trough was on average 26.2, 27.4 and 23.6 kg and that really distributed 26.4, 27.8 and 23.8 kg for 2.8C, 2.8S and 2.2S groups respectively. The average deviation, as absolute value, between the quantity programmed by the computer and that really measured was 472, 428 and 404 grams, i.e. less than 1.5 % of the programmed quantity. For Exp. 2, the programmed quantity was 27.8, 28.5, 25.4 and 25.8 kg and that really distributed was 28.1, 28.8, 25.4 and 25.9 kg for 2.7C, 2.7S, 2.35C and 2.35S groups respectively. The deviation, as absolute value, between the programmed and measured quantities was 369, 377, 272 and 283 grams, i.e. less than 1.5 % of the quantity programmed by valve. On the whole, the precision of the distribution is satisfactory and not modified by the treatment.

Table 5 - Effect of diet treatment on precision of the distribution to the troughs [a]

Exp.1	2.8C	2.8S	2.2S	Effect of treatment
Total no. of troughs weighted	72	72	72	
Average quantity / trough (kg)	26.39 ± 6.54	27.76 ± 6.66	23.77 ± 5.66	***
DTC [b], kg	0.24 ± 0.61	0.30 ± 0.45	0.21 ± 0.48	ns
DTC [b], absolute value as %	1.81 ± 1.69	1.56 ± 1.12	1.72 ± 1.40	ns

Exp.2	2.7C	2.7S	2.35C	2.35S	Effect of treatment
Total no. of troughs weighted	19	24	24	24	
Average quantity / trough (kg)	28.06 ± 6.83	28.75 5±.77	25.41 ± 4.72	25.87 ± 5.50	***
DTC [b], kg	0.24 ± 0.35	0.22 ± 0.38	0.03 ± 0.33	0.07 ± 0.36	ns
DTC [b], absolute value as %	1.32 ± 0.70	1.36 ± 0.75	1.11 ± 077	1.13 ± 0.87	ns

[a] Results are given as means ± SD for 8 valves per group, each valve being controlled 9 times (Exp.1) and for 6 valves per group, each valve being controlled 4 times (Exp.2). The data of exp1 were not normally distributed but are presented as means ± S.D. to enhance interpretation.
[b] DTC = Difference between quantities weighted at the trough and operated by computer.

Reliability of the liquid feed distributed
In Table 6, the regularity of the liquid feed distributed among troughs is presented. In Exp.1, standard deviation and coefficient of variation of the WFR calculated within a controlled feeding cycle were lower for 2.2S treatment ($p < 0.001$). Within a feeding cycle, the difference of WFR between the tank and the pipes was unaffected by diet treatment ($p > 0.05$). But when calculated as absolute value, this difference has a lower SD among troughs for 2.2S feed ($p < 0.01$) than for other feeds. In Exp. 2, as there was fewer controls, it was not possible to evaluate the

regularity among troughs within a distribution. Pooled data showed no effects of feed on variation of the WFR value and on WFR difference between tank and pipes among troughs.

Table 6 - Effect of diet treatment on deviation of the WFR at the distribution

Exp. 1 [a]	2.8C	2.8S	2.2S		R2	Effect of treatment
Total no. of pipes controlled	48	48	48			
WFR by tank	2.81	2.79	2.22			
mWFR [b]	2.78[b]	2.83[b]	2.29[a]		0.91	***
sdWFR [b]	0.12[b]	0.11[b]	0.03[a]		0.78	***
cvWFR % [b]	4.4[b]	4.0[b]	1.3[a]		0.75	***
mWFR_ dif [b]	-0.03	0.04	0.08		0.54	ns
mWFR_ dif abs value [b]	0.12	0.14	0.08		0.49	ns
sdWFR_diff abs value [b]	0.09[b]	0.09[b]	0.03[a]		0.67	**
Exp.2 [c]	**2.7C**	**2.7S**	**2.35C**	**2.35S**	**R2**	**Effect of treatment**
Total no. of pipes controlled	6	9	9	9		
WFR by tank [c]	2.67 ± 0.02	2.67 ± 0.01	2.34 ± 0.02	2.33 ± 0.02		
WFR to pipes [c]	2.76 ± 0.10	2.69 ± 0.09	2.39 ± 0.05	2.39 ± 0.11	0.90	(***)[d]
WFR diff [c]	0.09 ± 0.09	0.02 ± 0.09	0.06 ± 0.06	0.05 ± 0.10	0.60	ns
WFR diff abs value [c]	0.09 ± 0.09	0.06 ± 0.06	0.06 ± 0.06	0.09 ± 0.06	0.62	ns

[a] Eight feeding cycles have been monitored. [b] For each feeding cycle controlled, average water feed ratio (mWFR), standard deviation (sdWFR), and coefficient of variation (cvWFR) among 6 troughs were calculated. Within a feeding cycle, average difference of WFR between feed mixed in tank and that sampled in pipe was also calculated as baseline value (mWFR_dif) or as absolute value (mWFR_dif abs val) as well as its standard deviation (sdWFR_dif abs val). Means within a row without a common superscript letter differ ($p < 0.05$). [c] Results have been pooled for Exp. 2 and are presented as means ± SD of average water feed ratio (WFR) and average difference of WFR between tank and trough calculated as baseline value (mWFR_dif) or as absolute value (mWFR_dif abs val). [d] The data was not normally distributed.

Fluidity

When mixed with a lab mixer at a 2.35:1 WFR, the starting phase basal feed reached a high fluidity (93 %) after a setting time of 5 m, that diminished to 37 % after 10 m of rest in the test-tube (Table 7). With sepiolite the high fluidity of 2.35S kept on after 10 m. When mixed at 2.7:1 WFR, fluidity of the 2.7C liquid feed was definitely lower after 5 m (53 %) or 10 m (42 %) of rest. Sepiolite increased the fluidity of 2.7S to 97 % for a 5 m setting time, but did not maintained it after 10 m (54%). Samples taken at the time of the distribution in the drop pipes indicated a lower fluidity of basal 2.35C feeds than found at the laboratory in connection with a slightly longer setting time, but mixing by the tank could as well have been less strong. Sepiolite increased the fluidity values for 2.35S diets, whereas for 2.70S vs. 2.70C the variation was moderate.

Table 7 - Fluidity of liquid feeds with low or standard WFR and with or without sepiolite added in Exp. 2

Code	2.70C		2.70S		2.35C		2.35S	
Laboratory a								
Setting time (m)	5	10	5	10	5	10	5	10
Fluidity %	53	42	97	54	93	37	95	94
Industrial scale b								
Phase diet	growing	finishing	growing	finishing	growing	finishing	growing	finishing
Fluidity %	55.8 ± 6.0	61.1 ± 3.9	58.7 ± 3.2	69.1 ± 3.9	55.7 ± 3.5	71.0 ± 6.3	79.7 ± 11.5	92.5 ± 2.7

[a] values determined for 2 samples (2.35 WFR) or 1 sample (2.70 WFR) of starting phase feed per setting time group.

[b] results presented as means ± SD for 4 to 6 samples per phase diet (6 to 8 minutes of setting in the test-tube).

Pig performances

Experiment 1

The effect of dietary treatment on pig performance is presented in Table 8.

Pigs offered the two feeds supplemented with sepiolite had a significantly higher feed intake (+3.1% for 2.8S; +3.4 % for 2.2S; $p < 0.05$) during the period from d 1 to 22 than pigs offered basal diet. During the growing period, feed intake was higher for pigs fed the 2.2S diet (+4.0%; $p < 0.05$) than for pigs fed the basal diet, whereas that found for pigs receiving 2.8S treatment was intermediate (+1.6%).

Feed intakes were similar for the whole finishing period (d 48 to harvest), although during the period from d 48 to 62, it was significantly higher ($p < 0.01$) for pigs offered 2.2S than for pigs offered either 2.8C or 2.8S. At day 62 (average weight 79 kg), ad lib feeding of castrated males was stopped in order to prevent the possibility of a FCR degradation. For all treatments the distribution of feed was then restricted at 3.1 kg/d, whereas females continued to be fed at lib. During the d 62 to 77 and d 62 to harvest periods, intakes did not differ among treatments but the restriction applied to 2.2S barrows has been more drastic than for other males.

For all periods, the percentage of days with a decrease of the intake was not influenced by the dietary treatment.

In the period from d 1 to 22, sepiolite significantly improved ADG ($p < 0.05$) for both 2.8S pigs (3.1%) and 2.2S pigs (3.4%). During the growing period, ADG for pigs offered 2.2S feed was slightly, not significantly improved (1.4%; $p > 0.10$). During the latter finishing period, barrows fed 2.2S had a not significantly lower ADG (-4.7%; $p > 0.10$) than males fed other diets, whereas females were not concerned (+1.2 %).

Figure 1. Daily intake in Exp.1

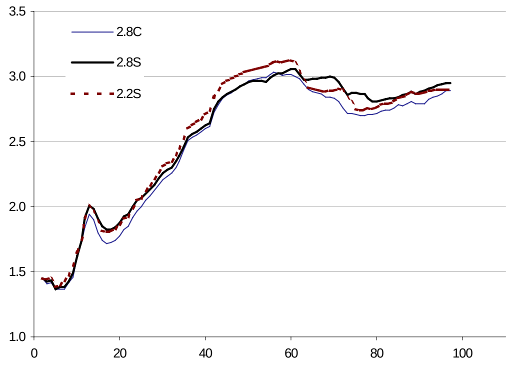
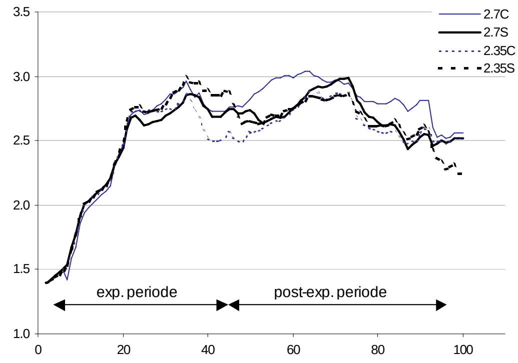


Figure 2. Daily intake in Exp.2



There were no significant effects of WFR and inclusion of sepiolite to the diets on FCR.

Carcass characteristics were calculated for 138 pigs slaughtered with an average weight of 115.7 kg. Differences in mean values for body weight and dressing percentage were not influenced by sepiolite or WFR. An interaction on lean meat percentage was observed ($p<0.05$) between the effects of treatment and sex. Male pigs offered 2.2S had a better lean meat percentage than 2.8S male pigs, whereas lean meat percentage of females offered 2.2S was lower than 2.8C females ($p=0.07$).

Table 8 - Effect of water-feed ratio and inclusion of sepiolite on pig performances in Exp.1 [a]

	Liquid feeding treatment			Sex		Statistical significance [b]			
	2,8C	2,8S	2,2S	Barrows	Females	RMSE	Treatment	Sex	T x S_x
Weight [c], kg									
Day 1	22.7	22.7	22.7	22.8	22.7				
Day 22	39.0^{a}	39.4^{ab}	39.5^{b}	39.2	39.4	0.3	*	ns	ns
Day 48	64.4^{a}	64.8^{ab}	65.4^{b}	64.7	65.0	0.9	*	ns	ns
Live BW at slaughter	114.2	115.6	114.7	114.4	115.2	4.2	ns	ns	ns
Carcass weight	90.2	91.1	90.2	90.3	90.7	3.8	ns	ns	ns
Dressing Percentage	77.0	76.9	76.7	77	76.8	1.4	ns	ns	ns
Lean Meat Percentage	60.2	59.6	60.3	58.8	61.3	2.1	ns	***	T x S_x*
Daily Feed Intake [c], kg/d									
Day 1 to 22	1.59^{b}	1.64^{a}	1.64^{a}	1.64	1.61	0.03	*	*	ns
Day 22 to 48	2.40^{b}	2.44^{ab}	2.49^{a}	2.46	2.42	0.05	*	ns	ns
Day 48 to harvest	2.86	2.93	2.91	3.03	2.77	0.07	ns	***	ns
Day 1 to harvest	2,49^{b}	2,55^{a}	2,55^{a}	2.61	2.45	0.04	*	***	ns
Days with ration reduction, as %									
Day 1 to 22	26.2	21.4	19.6	21.8	23.0	6.8	ns	ns	ns
Day 22 to 48	0.0	0.5	1.0	0.0	1.0	1.4	ns	ns	ns
Day 48 to harvest	16.3	10.0	14.0	7.0	19.8	4.9	ns	***	ns
Daily Gain [c], g/d									
Day 1 to 22	772^{b}	797^{a}	798^{a}	788	790	18	*	ns	ns
Day 22 to 48	984	986	998	987	992	20	ns	ns	ns
Day 48 to harvest	876	875	860	881	859	39	ns	ns	ns
Day 1 to harvest	879	884	881	885	877	21	ns	ns	ns
Feed conversion, kg/kg									
Day 1 to 22	2.06	2.06	2.06	2.08	2.04	0.02	ns	**	ns
Day 22 to 48	2.44	2.47	2.50	2.50	2.44	0.05	ns	*	ns
Day 48 to harvest	3.26	3.35	3.39	3.44	3.23	0.13	ns	ns	ns
Day 1 to harvest	2.83	2.89	2.90	2.95	2.80	0.06	ns	***	ns

[a] Values in the table are presented as least-square means and root mean square error (RMSE) for eight pens of 6 pigs each, except for carcass characteristics for which data are LSmeans for 48 pigs per treatment.
[b] From analysis of variance including the effects of block, liquid feeding treatment (T), sex (S_x), and interactions. Statistical significance: *** $P < .001$, ** $P < .01$, * $P < .05$, not significant (ns) $P > .05$.
[c] Within a row, treatment values not followed by the same superscript differ ($P > .05$).

Experiment 2

In Table 9, the effects for WFR and type of diet are presented. During the period from d 1 to 15, daily feed intake progressed rapidly and was unaffected by treatment and sex. During periods from d 15 to 43 and d 1 to 43, there was an interaction ($p < 0.05$) between the effects of sepiolite and sex. In both periods, the inclusion of sepiolite into the diet tended to improve feed intake for the males ($p = 0.08$) whereas such effects were not observed for the females. A lower WFR did not result in a higher feed intake during the starting and growing periods. But in the

Table 9 - Effect of water-feed ratio and inclusion of sepiolite on pig performances in Exp.2 [a]

WFR	2.7		2.35		Sex		Statistical significance [c]				
Sepiolite [b]	0%	1%[S]	0%	1%[S]	Barrows	Females	RMSE[a]	WFR	S_p	S_x	Int.
Weight, kg											
Day 1	27.3	27.3	27.3	27.3	27.1	27.5					
Day 15	37.9	38.3	38.0	38.2	37.6	38.6	0.5	ns	t	***	ns
Day 43	68.4	68.7	68.4	69.3	69.0	68.3	1.8	ns	ns	ns	ns
Live weight at slaughter	116.4	116.5	115.9	114.1	115.8	115.7	5.3	t	ns	ns	ns
Carcass weight	93.0	93.4	93.0	91.9	92.9	92.7	4.2	ns	ns	ns	ns
Dressing Percentage	77.9	78.2	78.3	78.5	78.3	78.1	1.4	ns	ns	ns	ns
Lean Meat Percentage	59.7	59.4	60.2	60.6	58.8	61.2	2.4	*	ns	***	ns
Daily Feed Intake [d], kg/d											
Day 1 to 15	1.57	1.60	1.59	1.59	1.59	1.58	0.03	ns	ns	ns	ns
Day 15 to 43	2.68	2.62	2.61	2.71	2.74	2.58	0.10	ns	ns	**	S_p x S_x*, W x S_x^t
Day 1 to 43	2.31	2.28	2.27	2.34	2.35	2.25	0.08	ns	ns	**	S_p x S_x*, W x S_x^t
Day 43 to 59	2.85^a	2.70^{ab}	2.57^b	2.71^{ab}	2.86	2.56	0.11	*	ns	***	W x S_p**
Day 43 to harvest	2.85	2.71	2.63	2.69	2.85	2.59	0.10	*	ns	***	W x S_p*
Days with ration reduction [d], as %											
Day 1 to 15	2.4	0.0	0.0	0.0	1.2	0.0					
Day 15 to 43	14.9	16.1	21.4	14.9	12.8	20.8	6.1	ns	ns	*	ns
Day 43 to 59	9.4^a	18.8^{ab}	12.5^a	27.1^b	15.1	18.8	10.7	ns	*	ns	ns
Day 43 to harvest	14.6^a	21.1^b	19.7^b	22.5^b	18.2	20.7	3.8	t	*	ns	ns
Daily Gain [d], g/d											
Day 1 to 15	753	788	760	777	748	792	39	ns	t	*	ns
Day 15 to 43	1095	1084	1088	1114	1127	1063	54	ns	ns	*	ns
Day 1 to 43	977	985	978	1001	999	972	42	ns	ns	ns	D x S_x^t
Day 43 to 59	1014^a	919^b	966^{ab}	911^b	976	929	42	ns	***	*	ns
Day 43 to harvest	939	896	887	874	909	889	53	t	ns	ns	ns
Feed conversion [d], kg/kg											
Day 0 to 15	2.09	2.04	2.09	2.06	2.13	2.00	0.08	ns	ns	**	ns
Day 15 to 43	2.45	2.42	2.44	2.45	2.45	2.43	0.09	ns	ns	ns	ns
Day 1 to 43	2.37	2.31	2.35	2.35	2.37	2.32	0.06	ns	ns	t	ns
Day 43 to 59	2.82^{ab}	2.95^{ab}	2.68^a	2.98^b	2.95	2.77	0.17	ns	**	*	ns
Day 43 to harvest	3.03	3.03	2.99	3.15	3.17	2.93	0.14	ns	ns	**	ns

[a] Values in the table are presented as least-square means and root mean square error (RMSE) for six pens of 6 pigs each, except for carcass characteristics for which data are LSmeans for 36 pigs per treatment.
[b] From day 43, sepiolite treatment was stopped [S].
[c] From analysis of variance including the effects of block, water feed ratio (WFR or W), sepiolite (S_p), sex (S_x), and interactions. Statistical significance: *** P < .001, ** P < .01, * P < .05, t (tendency) P < .12, ns (not significant) P > .12.
[d] Within a row, treatment values not followed by the same superscript differ (P > .05).

growing period, an interaction tended to be observed (p = 0.09) between the effects of WFR and sepiolite. Feed intake tended to be increased by sepiolite for pigs that were given a 2.35:1 WFR liquid feed (+4%, p = 0.10) whereas it was unaffected for 2.7:1 pigs (p > 0.10).

At the end of the experimental period (day 43), supplementation with sepiolite was stopped and all groups received a finishing phase diet. Feed intake for 2.7C pigs was similar in the periods from d 30 to 43 (2.84 ±0.19 kg/d) and d 43 to 59 (2.85 ±0.22 kg/d), whereas for 2.7S pigs it decreased slightly by 2.5% from 2.77 (±0.26) to 2.70 (±0.18) kg/d. Moreover, in spite that from day 45 pigs fed with 2.35:1 WFR received an additional distribution of water once a day, feed intake reduced stronger by 4% for 2.35C (from 2.69 ±0.22 to 2.57 ±0.14 kg/d) and by 6% for 2.35S (2.90 ±0.33 to 2.71 ±0.22 kg/d). As a consequence, in the d 43 to 59 period, feed intake was decreased by the 2.35:1 WFR (p < 0.05), but there was also an interaction (p < 0.01) between the dilution ratio and the ulterior effect of sepiolite. For the whole post-experimental period the lower dilution ratio decreased the feed intake of pigs (p<0.05) and the interaction between WFR and sepiolite occurred. In the periods from d 43 to 59 and d 43 to harvest, day percentage with a reduction of the ration was higher for pigs no more proposed sepiolite feed (p<0.05), and there was a tendency (p= 0.06) for 2.35:1 WFR to enhance it from d 43 to harvest.

During the period from d 1 to 15, the inclusion of sepiolite in the diets tended to improve the ADG (+3% and +2% for 2.7S and 2.35S compared to basal diets respectively; p=0.12). In the growing period, ADG was high (1095 g/d) and did not differ significantly among treatments. The end of the SPLF supplementation had a transient negative effect on ADG of former sepiolite pigs during the d 43 to 59 period (p <0.001), which was not observed for the later periods. During the total post-experimental period, a low WFR ratio tended to decrease the daily gain (p = 0.11).

No differences in feed conversion were observed.

142 pigs were slaughtered at an average weight of 115.7 kg. Differences in mean values for carcass characteristics were not influenced by sepiolite. As a consequence of a lower FI in the latter period, the lower WFR increased the lean meat percentage (p<0.05).

Discussion

Technical quality of the liquid feed

WFR reduction and sepiolite supplementation had an impact on the fluidity rates measured in Exp. 2 at laboratory or in the facility, implying that such a liquid feed has a better flow capacity with less residual in the pipe. A programme of work at Hauss Düsse Research Centre in Germany had previously showed that the addition of Splf® reduce sedimentation and separation of liquid feed by maintaining feed particles suspended (Hoppenbrock and Lakta, 1996; Hoppenbrock *et al.*, 1998). An interactive effect between WFR diminution and sepiolite supplementation on viscosity and segregation of the liquid feed was also reported (Hoppenbrock *et al.,* 1998). Relatively little information exists regarding the optimal structure of liquid feed. Escribano *et al.* (2005) have recently proposed a synthetic index of the liquid feed technical quality based on fluidity and water retention capacity. They showed that these criteria were mostly influenced by particle size and composition of diets as well as mixing time, mixing speed and WFR. A detailed analysis of these parameters should be the subject of an increasing interest.

In our liquid feeding system, the basal accuracy of the distribution was excellent so that WFR or sepiolite had no effects but a reduced variation of WFR among troughs within each distribution cycle for 2.2S in Exp.1. With other liquid feeding designs (higher distances, less homogeneously suspended feed), these factors can result in a better quality of the liquid feed. A greater homogeneity among troughs of WFR was also measured at a research level (Sardi *et al.*, 2004) as well as at commercial farms level (LeTreut and Guillou, 2003) with a Splf® supplementation.

As a consequence of the better homogeneity of the liquid feeding among pens, a better uniformity of carcasses in weight or lean mean rate can be observed with sepiolite supplementation (LeTreut and Guillou, 2003; Sardi *et al.*, 2004).

Sepiolite

Experiments 1 and 2 studied the effects of the inclusion of sepiolite in liquid feed.

In Exp. 1, a better voluntary feed intake appeared as a result of the sepiolite inclusion, especially during the initial period. Such an increased feed intake as an outcome of sepiolite was not found over the same period in Exp. 2. A higher initial weight of the pigs (27.3 kg) than in Exp. 1 (22.7 kg), a higher energy concentration of the basal diet as well as the non inclusion of raw materials of supposed low palatability had probably facilitated the adaptation to liquid feeding for pigs in Exp. 2. During the growing period, the advantage of sepiolite on feed intake kept on in Exp. 1 but appeared more obvious when dilution rate was low. In Exp. 2, feed intake tended to be increased by sepiolite for male pigs over the same period which was not observed for females.

Although pigs had excellent performance regardless of dietary treatment in both experiments, the sepiolite improved or tended to improve daily gain during the initial periods which was not found for the subsequent growing periods.

In both experiments, the feed conversion ratios were unchanged in spite of a slight decrease of the energy level of diets added with 1% of SPLF. This was not surprising considering that Castaing and Noblet (1997) demonstrated that the reduction of the net energy value, despite the increase in the ash content of diet, was not higher than the rate of supplementation in sepiolite, i.e. a decrease of 1 % in the present study.

No comparable data relating to the effect of sepiolite on the voluntary feed intake of liquid feed has been found in previous studies. In other experiments on sepiolite in liquid feeding, pigs were fed according to scale. Our results are thus consistent with better ADG and FCR previously reported in growing-finishing (Hoppenbrock *et al.*, 1998) or finishing experiments (Sardi *et al.*, 2003; Lizardo *et al.*, 2005).

In Exp. 1, the improvement of the lean meat rate for the male pigs receiving the 2.2S treatment can be explained by the higher growth during the starting period and by the feed restriction during the finishing period. Carcass quality was unchanged for 2.8S . On the contrary, a trend to improve lean meat percentage was found in 2 of 3 experiments reported by Hoppenbrock *et al.* (1998). Furthermore, sepiolite has previously been shown to increase the lean meat rate for pigs fed dry diets according to scale (Parisini *et al.*, 1993; Castaing, 1994) or *ad libitum* (Magnin and Escribano, 1996).

Water to feed ratio.

The effect of WFR had been tested in Exp. 2. There was no benefit of a lower dilution ratio on voluntary feed intake and performance during the first weeks. Pigs of 2.7C and 2.7S groups have ingested up to 38 kg BW daily quantities of liquid feed (5.8 and 5.9 kg/d respectively) that did not seem to excess the maximum ingestion capacity of young growers, which was estimated about 5 kg by Jost *et al.* (1986). Pigs of 2.35C and 2.35S groups have ingested 5.3 kg/d. In Exp. 1, average daily volumetric intakes up to 39 kg were 6.0, 6.2 and 5.2 kg/d for 2.8C, 2.8S and 2.2S groups respectively.

The optimal WFR in liquid feeding had been discussed for many years, but few studies focussed on the adaptation of young growers previously fed dry during the initial period up to 36-38 kg. Previous studies have shown that weaner pigs accept well a wide range of WFR as high as 5.0:1 l/kg (Geary *et al.*, 1996). But in practice, commercial producers who are providing liquid feeding to piglets are using WFR from 1.8 to 2.5:1 l/kg.

In growing-finishing, some studies have underlined the interest of a higher dilution ratio than 3:1 l/kg in fattening performance (Brooks and Carpenter, 1990). Other results discussed the advantage of a lower WFR to limit the effluent output. A recent study showed that varying the dry matter concentration of liquid feed has negligible effect on the digestibility of nutrients for growing pigs (Thompson *et al.*, 2004), and several bibliographical

reviews (Albar and Latimier, 1987; Courboulay, 1992) concluded that a WFR from 2.2 to 3.5:1 l/kg do not result in performance differences.
However, in Exp. 1, as a consequence of the experimental design, pigs were not given free access to water via drinkers and the limitation of the daily feed intake from day 62 could have result in insufficient water consumption by barrows beyond 79 kg. During the finishing period, the water intakes for the 2.2S pigs (respectively 6.6 and 6.1 litres/day for castrated males and females) were slightly below the minimal quantities observed in unrestricted supply of water under dry feed housing conditions in our research centre (Massabie, 2001). Although sepiolite feeding can reduce nitrogen excretion (Cahn *et al.*, 1996; Castaing and Noblet, 1997), the water requirement for castrated males is enhanced by a greater protein catabolism and thus a greater amount of water excreted in urine, accordingly (Thulin and Brumm, 1991; Albar and Granier 1996). In lack of any other clinical sign (tail-biting), the non significant and slight decrease of performance for 2.2S barrows during the finishing period can be considered as resulting of a small insufficient water intake by pigs (Massabie, 2001).
Even if the additional water intake of liquid fed finishing pigs is so low that it does not justify an extra drinker, a motivation for water exist (Vermeer and Kuijken, 2007) and, for ethical reasons, the European regulation imposed a permanent access to sufficient quantity of water.

Combination of Sepiolite and WFR.
The effects on feed intake of a lower WFR combined with sepiolite supplementation were contrasted in our experiments. In the starting periods, there were no interactive effects between sepiolite and WFR, suggesting that it is not useful to reduce the dilution ratio when sepiolite is added for liquid fed young growers.
On the contrary, during the growing periods, some interactions on feed intake occurred or tended to appear. In both experiments, the best performances were found for pigs offered liquid feed with sepiolite at a lower dilution rate, although most of the differences were too small to reach statistical significance. At the end of the growing period, the sepiolite added liquid feed when given with a same basal WFR resulted in small and non significant body weight improvements by 0.5 and 0.3 kg in Exp. 1 ($p > 0.10$) and Exp. 2 ($p > 0.10$) respectively, compared to the basal diet and standard WFR. But when given with a lower WFR, these increases were by 1.1 kg in Exp. 1 ($p < 0.05$) and 0.9 kg in Exp. 2 ($p > 0.10$).
Information is still lacking to understand this interaction. Our results are partly consistent with findings of LeTreut and Guillou (2003) who found similar feed intake and not significant improvement by 2% on ADG and FCR for pigs provided ad libitum a 2.3:1 WFR 0.8% sepiolite liquid feed versus a 2.8:1 WFR basal diet from 35 to 80 kg. Geier *et al.* (2000) observed significant lower consumption for the pigs, particularly the males, fed according to a curve with a 2.4:1 WFR 1 % sepiolite liquid feed in comparison with a 2.7:1 WFR basal diet resulting also in a better FCR and a reduction of the fattening period.
Additionally, the performances obtained during the post-experimental period in Exp. 2 have to be analysed taking into account the management of liquid feeding. The use of sepiolite was stopped at the time of the passage to finishing diet from day 43. Furthermore, the WFR of liquid feeds were maintained but the pigs of 2.35 treatment received daily from day 45 an additional quantity of water. As sepiolite improved the retention coefficients of nutrients (Parisini *et al.*, 1999) and the viscosity of liquid diet, its withdrawal could be responsible of the sudden drop in ADG and FCR for 2.7S and 2.35S groups. These changes could also have altered the appetite of the pigs and increased the frequency of refusals during a few days. From day 55 consumption and growth had progressed again. This result support the need for applying an adaptation over a few days at the time of the any modification of the characteristics of the liquid feed.

Conclusions

It can be concluded from our study that the use of a rheological sepiolite increase setting of particles in suspension, fluidity and viscosity of the liquid mixture. As the distribution accuracy of our liquid system was already good, it was not possible from this study to determine how these properties, in practice, result on the reliability of a commercial system.
In liquid feeding, a lower water feed ratio does not increase the voluntary feed intake and performances of young growers. The results of experiment 1 indicate that inclusion of 1 % of Splf sepiolite can improve voluntary feed intake of young growers of low initial weight fed with raw components as rapeseed meal or peas.
It was also concluded that there is an interesting potential for a combined use of sepiolite and low water feed ratio to improve voluntary feed intake and daily gain of growers. Information is lacking to determine why this interactive effect was found neither for young growers nor finishers. Further studies should verify whether the effects found are mainly associated with the fluidity value of the liquid feed.
Another implication of this study is that performance of finishers can be adversely affected by a sudden change in the liquid feeding as the withdrawal of sepiolite or the increase of the water intake, and an adaptation period should be managed each time an adjustment is done. Lastly, when a low water to feed ratio is used, an additional supply of water should be provided for finishing pigs.

References

Albar J. and Latimier P., 1987. Etude d’un système de distribution séquentielle d’aliment en engraissement : le turbomat. In Journée porc 4ème SIMAVIP, (eds EDE Bretagne-Pays de Loire ITP), pp. 59-71. Institut Technique du porc, Paris, F.

Albar J., Chosson C. and Granier R., 1987. Proposition d’une méthode de diagnostic des installations de distribution de soupe dans les porcheries. TechniPorc, 10 (2), 53-72.

Albar J. and Granier R., 1996. The effects of dietary protein content on water intake, the volume of slurry produced and nitrogen output in growing-finishing pigs. Journées Rech. Porcine en France, 28, 257-266.

Brooks P.H. and Carpenter J.L., 1990. The water requirement of growing-finishing pigs – theorical and practical considerations. In Recent advances in animal nutrition 1990. pp. 115-136. Butterworths, London, UK.

Cahn T.T., Jongbloed A.W., Aarnink A.J.A., Mroz Z., Alvarez A. and Escribano F., 1996. Effect of sepiolite (Exal®) in pig diets on ammonia emission from slurry. Conference at the 47th EAAP Annual Meeting, Lillehammer, Norway, 6pp.

Castaing J., 1994. Effect of sepiolite 'Exal' according to crude fibre and fat contents of feed for fattening pigs. Journées Rech. Porcine en France, 26, 199-206.

Castaing J. and Noblet J., 1997. Effect of addition of sepiolite on digestive utilization of feed and performance in growing pigs. Journées Rech. Porcine en France, 29, 213-220.

Courboulay V., 1992. Abreuvement et rejets. Conference at the ITP session: Conduite alimentaire et protection de l'environnement, St-Didier, France, 21-22 octobre 1992. Institut Technique du Porc, Paris, France. 16pp.

Chosson C., Granier R., Maigne A., Bouby A. and Mongin J.P., 1988. Réduction du volume de lisier produit par un porc à l'engrais. Techniporc, 11 (5), 27-41.

Escribano F., Lizardo R., Matas N. and Sánchez M., 2005. El uso de sepiolita en alimentación porcina : nutrición y seguridad. Mundo ganadero, 16 (12), 48-52.

EDE Bretagne, 2006. Alimentation en soupe: surveiller animaux, matériel et courbe d'alimentation. Atout Porc Bretagne, 34, 4-5.

Geary T.M., Brooks P.H., Morgan D.T., Campbell A. and Russell P.J., 1996. Performance of weaner pigs fed ad libitum with liquid feed at different dry matter concentrations. J. Sci. Food Agric., 72 (1),17-24.

Geier U., Oster A. and Gómez G., 2000. Wirkung des Sepiolit-Produktes SPLF auf Mast- und Schlachtleistung bei wachsenden Schweinen. Retrieved Aug. 8, 2007 from http://www.landwirtschaft-mlr.baden-wuerttemberg.de/servlet/PB/menu/1034707/index.html 10pp.

Guillou D. and Landeau E., 2005. Gestión de planes nutricionales en la alimentación liquida : limites y ventajas. Mundo ganadero, 16 (12), 54-58.

Hoppenbrock K.H. and Latka S., 1996. In Annual report of LZ Haus Düsse 1996, 50-51. Haus Düsse, Bad Sassendorf, D.

Hoppenbrock K.H., Latka S., Bonekamp B., Alvarez A., Ihnen T. and Escribano F., 1998. Sepiolite-splf effect on performance in liquid feeding systems. Conference at the 49th EAAP Annual Meeting, Warsaw, Poland, 10pp.

Jost M., Künzler, R. and Schwab P., 1986. Affouragement liquide des porcins, mais comment ?. Le Menu Bétail (CH), 5 septembre 1986, 391-397.

LeTreut Y. and Guillou D., 2003. La incorporacion de aditivos con propiades reologicas en el alimento liquido mejora los rendimientos zootecnicos. Conference at the Jornadas de alimentacion liquida del ganado porcino, 2 octubre 2003, IRTA, Reus, Spain. 10pp.

Lizardo R., Gómez G., Escribano F. and Brufau J., 2005. Interés de la incorporación de sepiolita con propiedades reológicas en los alimentos líquidos para porcino. Conference at the Jornadas AIDA, 11-12 mayo 2005, Zaragoza, Spain. 4 pp.

Magnin M. and Escribano F., 1996. Performance and carcass quality of pigs fed practical diets with 2% Exal from weaning to slaughter. Conference at the 47th EAAP Annual Meeting, Lillehammer, Norway, 5pp.

Massabie P., 2001. L'abreuvement des porcs. TechniPorc, 24 (6), 9-14.

MLC, 2005. Focus on liquid feeding for pigs. Notes from the BPEX Workshop, 22/02/05, Nothants, UK. Meat and Livestock Commission Technical Division, Stotfold, UK, 25pp.

Parisini P., Sardi L., Panciroli A. and Coppa C., 1993. Effetti della sostituzione con Sepiolite di parte del mangime nell'alimentazione del suino pesante. In 10th Nat. Congr. ASPA, 459-464. Ass. Sci. di Prod. Anim., Padova, I.

Parisini P., Martelli G., Sardi L. and Escribano F, 1999. Protein and energy retention in pigs fed diets containing sepiolite. Anim. Feed Sci. Technol., 79 (1-2), 155-162.

Sommer W., 2005. Rapskuchen – der neue Stern an Fütterungshimmel ? Schweinezucht und schweinemacht, 5/2005, 26-31.

Smolders M. and Hoofs A., 2001. Extra drinkwater bij brijvoer aan vleesvarkens. Varkens praktijkonderzoek, april 2001, 13-14.

Sardi L., Martelli G., Scipioni R. and Parisini P., 2003. The effects of Sepiolite-SPLF on heavy pigs fed liquid diets. Ital. J. Anim. Sci., 2 (S1), 367-369.

Sardi L., Martelli G., Escribano F., Parazza P. and Parisini P., 2004. The effects of Sepiolite-SPLF on piglet and heavy pig production. Ital. J. Anim. Sci., 3, 225-234.

Thompson E., Wiseman J. and Gill B.P., 2004. Physico-chemical aspects of liquid feed: the effect on component digestibility in growing/finishing pigs of 1) dietary dry matter concentration and 2) dietary fineness of grind. In 2004 Brit. Soc. Anim. Sci. Annual Meeting: Pig research Features, BSAS, UK, p.41.

Thulin A. J. and Brumm M. C., 1991. Water: The forgotten nutrient. In Swine Nutrition (eds E.R. Miller, D.E. Ullrey and A.J. Lewis), pp. 315-324. Butterworth-Heinemann, Stoneham, MA, USA.

Vermeer H. and Kuijken N., 2007. Motivation for additional water intake in dry or liquid fed finishing pigs. Book of abstracts of the 58th EAAP Annual Meeting, p.278.