LYSOFORTE®: a flexible tool in animal nutrition

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Lysoforte is a unique biosurfactant which is highly enriched in lysophospholipids. Lysophospholipids are a class of chemical compounds derived from phospholipids which occur in lecithins. Phospholipids contain two fatty acid residues combined with glycerol. Partial hydrolysis of the phospholipids, which removes one of the fatty acid groups, yields lysophospholipids as shown in Figure 1.

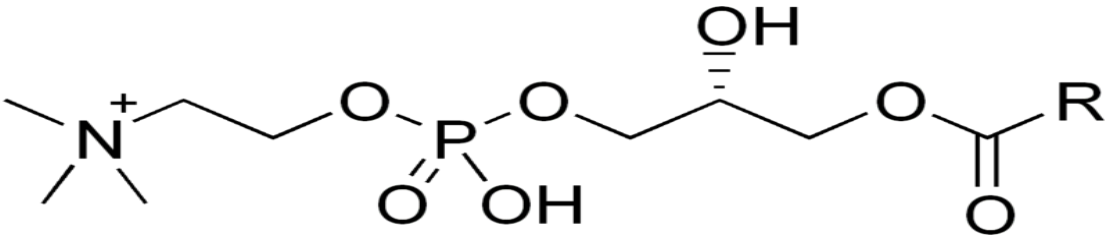

Figure 1. General chemical structure of lysophosphatidylcholine where R = fatty acid residue

Lysophosphatidylcholine

Among the group of lysophospholipids, lysophosphatidylcholine (LPC) is a particularly well known molecule in biology and physiology. Several studies have been carried out demonstrating the influence of LPC on:

Lipid absorption, metabolism and lipoprotein output and metabolism by caco-2 cells (Nakano, *et al.*, 2009a)

Intestinal brush border protein turnover enhancement (Nakano, *et al.*, 2009b)

Improvement of intestinal absorption of Vitamins A and E (Noh and Koo, 2001)

Prevention and treatment of sepsis and microbial infections (Yan *et al.*, 2004)

Absorption of carotenoids from the digestive tract and supporting a simple diffusion mechanism for carotenoids absorption by the intestinal epithelium (Sugawara *et al.*, 2001)

Fat metabolism and absorption

Fat is an important and expensive nutrient in animal feeds and therefore the metabolism and absorption of fat is of great economic significance in maintaining profitable animal production. The rate and efficiency of fat absorption (Figure 2) is influenced by the average size of the emulsion droplets. This leads to the formation of micelles which can be absorbed through the wall of the gastrointestinal tract. The concentration of fatty acids required to form a micelle is important and is described as the "critical micellar concentration." Lysoforte can influence both the emulsion droplet size and the formation of micelles.

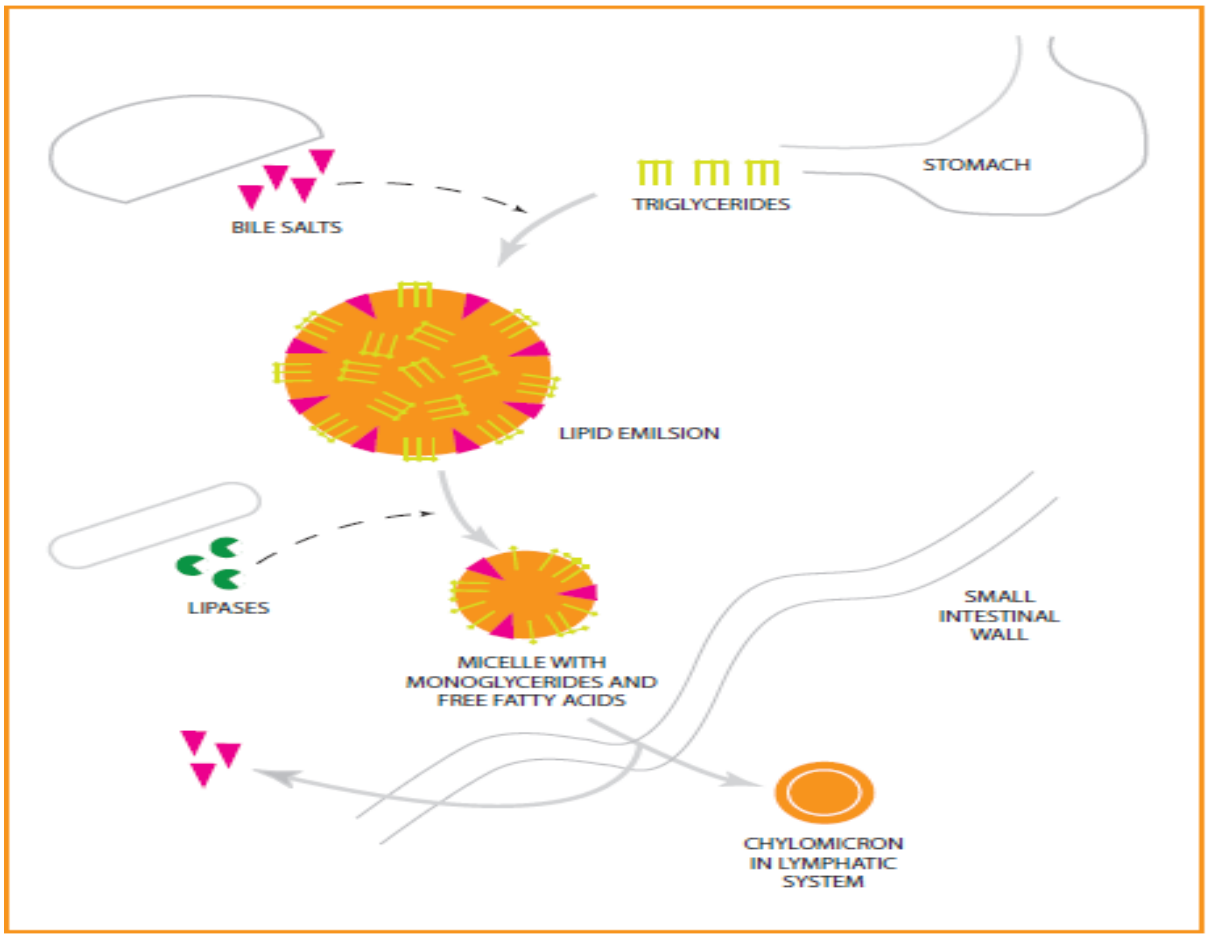

Figure 2. Digestion and absorption of fat in the gastrointestinal tract.

Lysoforte stimulates the absorption of both unsaturated and saturated fatty acids

Lysoforte stimulates the absorption of saturated fatty acids by living cells

Lysoforte improves the absorption of saturated fatty acids, stearic acid (Figure 3) and palmitic acid (Figure 4). This is especially important in young animals that frequently have difficulty metabolising saturated fatty acids. Here the uptake of radioactively labelled stearic and palmitic acid molecules by living cells was greater in the presence of Lysoforte compared to another emulsifier, lecithin. Both stearic and palmitic acids are significant feed components. Palm oil for example has 48% palmitic acid. Both stearic and palmitic acids are major components of palm fatty acid distillate.

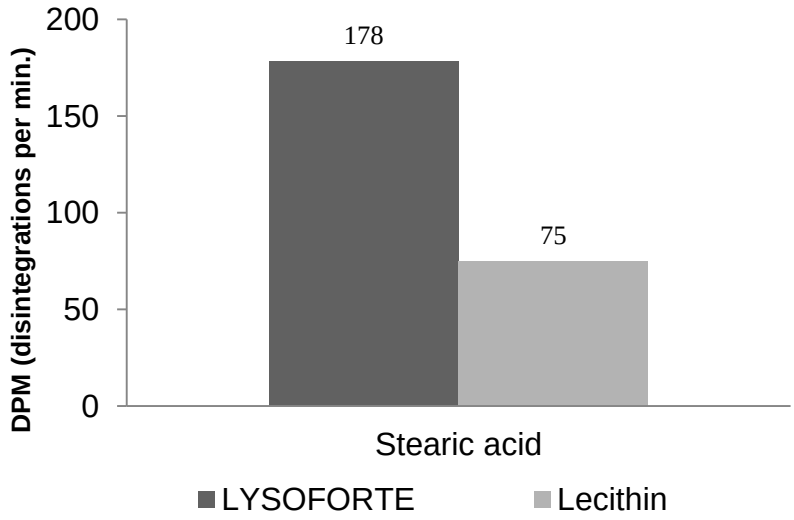

Figure3. Influence of Lysoforte on the absorption of stearic acid by living cells.

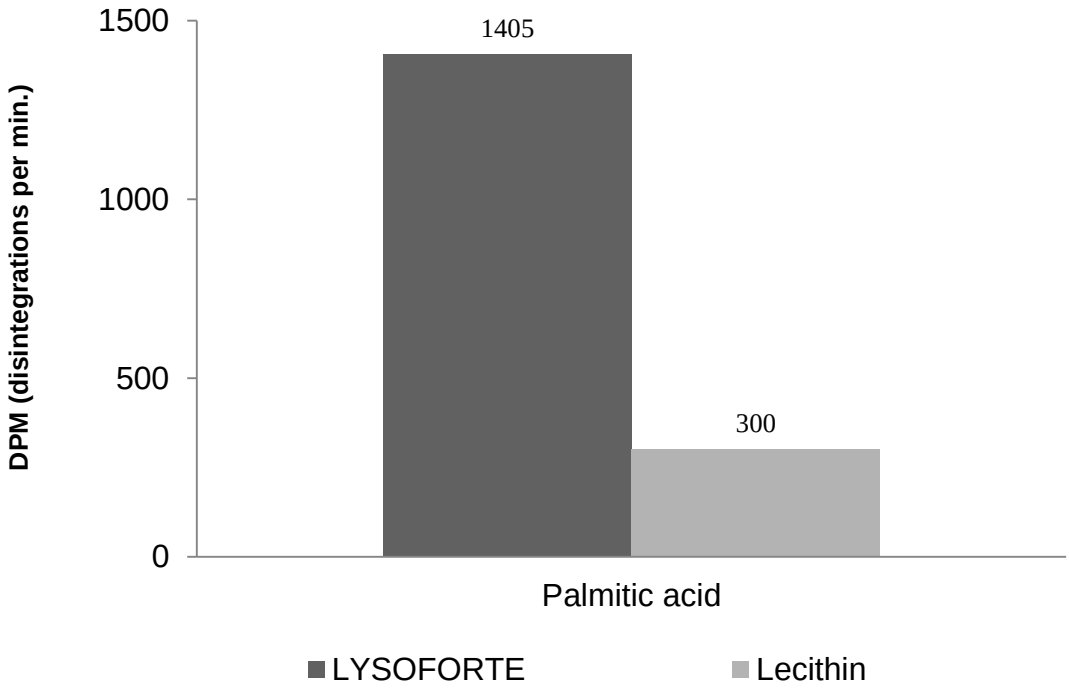

Figure 4. Influence of Lysoforte on the absorption of palmitic acid by living cells.

Lysoforte stimulates the absorption of linoleic acid, an unsaturated fatty acid, by living cells.

Unsaturated fatty acids are also an important nutrient in all animal diets and Lysoforte has been shown to improve the absorption of these fatty acids. Lysoforte stimulated the absorption of linoleic acid as shown in Figure 5. Linoleic acid is of interest particularly in laying hens as it affects egg size. Vegetable oils are a good source of Linoleic acid. Soya oil has 54%, rice bran oil has 40% and sunflower seed oil has 68% Linoleic acid.

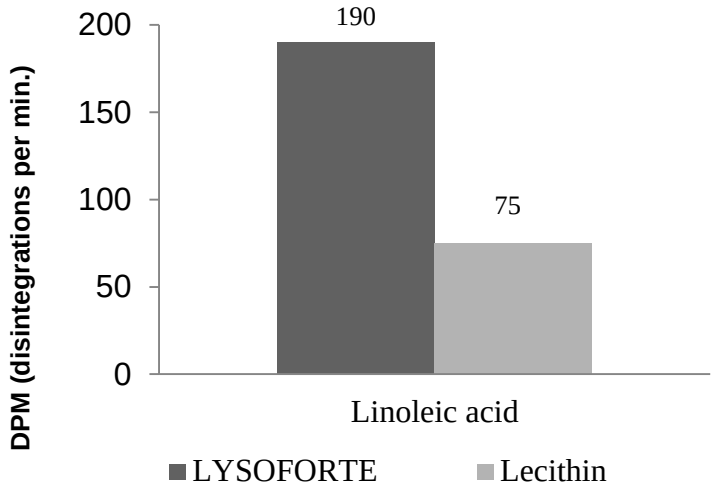

Figure 5. Influence of Lysoforte on the absorption of Linoleic acid by living cells.

Lysoforte increases fat digestibility and improves apparent metabolizable energy (AME) in broiler diets

An AME trial was carried out at the Monogastric Research Centre, Massey University, New Zealand, in 2008, on 28-day old, male Ross 308 broilers.

The birds were fed maize soybean meal diets with three different fat sources. The ME of normal diets was maintained at 12.76 MJ (3050 kcal) /kg and reduced ME diets were obtained by the reducing the added fat level by 1% and replacing it with fine sand. Lysoforte dry was added to the feeds at 500 g/tonne. The fat sources and Lysoforte dry addition are shown in Table 1.

Table 1. Fat sources and Lysoforte dry addition in broiler feeds

Treatment no.	Fat source	Added fat quantity (%)	Feed ME	Lysoforte dry (g/tonne)
1	Tallow	3.80	Normal	0
2	Tallow	2.80	Reduced	0
3	Tallow	2.80	Reduced	500
4	Palm oil	3.20	Normal	0
5	Palm oil	2.20	Reduced	0
6	Palm oil	2.20	Reduced	500
7	Rice bran oil	3.47	Normal	0
8	Rice bran oil	2.47	Reduced	0
9	Rice bran oil	2.47	Reduced	500

Addition of Lysoforte dry to a reduced ME diet improved the measured AME to close to the normal values (Table 2). While the AME of all feeds was improved by Lysoforte, the effect was greater for the more saturated fats. The AME of the tallow-based feed improved by 0.36 MJ (87 kcal)/ kg. The palm oil-based feed was improved by 0.41KJ (98 kcal)/kg and the rice bran oil-based feed was improved by 0.34 MJ (81 kcal)/kg.

Table 2. AME determined in broiler diets with various fat sources and Lysoforte dry

Fat source	Diet formulation		
	Normal ME, MJ (kcal)/kg (	Reduced ME, MJ (kcal)/kg (	Reduced ME + Lysoforte dry MJ (kcal)/kg (
Tallow	12.91[a] (3085)	12.48[b] (2982)	12.84[a] (3069)
Palm oil	12.86[a] (3073)	12.29[b] (2937)	12.70[a] (3035)
Rice bran oil	12.87[a] (3076)	12.40[b] (2964)	12.74[a] (3045)

[a, b] denotes a statistically significant difference (P<0.05)

Lysoforte stimulates the absorption of fat-soluble nutrients

The effect of Lysoforte dry on vitamin E absorption in broiler breeder's eggs in a commercial facility

Broiler breeder hens (Cobb 500 x Cobb 500) were raised in a two-house commercial facility located in Canton, GA, USA. The initial hen body weight was around 3380g and they were 30 to 33 weeks old. Vitamin E was added to diets as tocopherol acetate at 20.7mg/kg feed. Lysoforte™ dry was added at a rate of 500g/ton of feed. The experimental period lasted 12 weeks and Lysoforte was added only for the first 4 weeks. Forty eggs were randomly collected from the eggs collection room at 6 different time points, for a total of 240 eggs.

The various egg characteristics are shown in Table 3. A 4 week treatment with Lysoforte significantly improved the egg parameters measured.

Table 3. Effect of Lysoforte® dry on breeders eggs when fed diets for 4 weeks in a 12 weeks trial

Experimental Period	Egg parameters (g/egg)			
	Shell egg weight	Sample weight	Total dry matter	Total moisture
Initial Baseline*	59.85±0.66[c]	53.03±0.60[c]	13.71±0.18[cd]	40.10±0.46[c]
Week 1 (Lysoforte)	62.13±0.66[b]	55.04±0.60[bc]	14.23±0.18[c]	40.80±0.46[bc]
Week 2 (Lysoforte)	63.92±0.66[ab]	56.73±0.60[ab]	14.83±0.18[b]	41.89±0.46[ab]
Week3 (Lysoforte)	63.86±0.66[b]	56.34±0.60[ab]	14.84±0.18[b]	41.49±0.46[abc]
Week 4 (Lysoforte)	62.71±0.66[b]	55.60±0.60[bc]	14.14±0.18[c]	41.45±0.46[abc]
Final Baseline**	65.76±0.66[a]	57.80±0.60[a]	15.39±0.18[a]	42.40±0.46[a]

[a-c] denotes a statistically significant difference (P<0.05)

*Baseline eggs collected at day 0 of trial, right before feeding hens with Lysoforte®

**Final baseline eggs collected at week12 of the study, 8 weeks after the elimination of Lysoforte® from the diets.

n=10

There was an improvement in the amount of vitamin E deposited in breeder eggs for the first three weeks of the trial, statistically significant on week 3 (Figure 6). Also at 12 weeks there remained an increased vitamin E content in the eggs compared to the initial values.

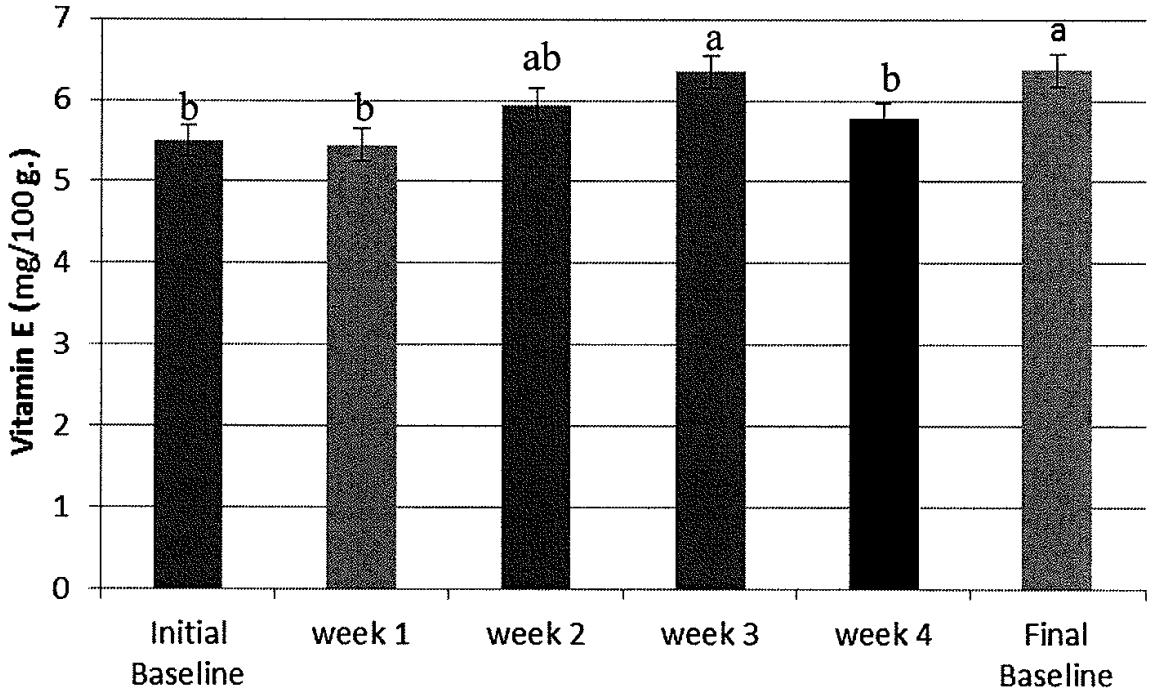

Figure 6. Effect of Lysoforte® on vitamin E deposition in broiler breeder eggs

a, b, c, denotes a statistically significant difference (P<0,05).

Lysoforte improves nutrient digestibility

Effect of lysophospholids on nutrient digestibility in broilers

This trial was conducted at Poznan University of Life Sciences (Poland-2010) on the Ross 308 broiler strain. Two different feeds were used, high density (HD) and low density (LD). Treatments scheme is shown in Table 4.

Table 4. Treatments

Treatment	Test product	Test product inclusion rate kg/tonne feed	Route of administration
Positive Control (HD)	No	-	Mash
Positive Control + Lysoforte Booster	Yes	0.25	Mash
Positive Control + Lysoforte Booster	Yes	0.50	Mash
Negative Control (LD)+ Lysoforte Booster	Yes	0.50	Mash

The diets were based on maize, soja meal, wheat and soy oil, feed formulations were designed so that HD feed had 0.20 MJ apparent metabolizable energy (47 kcal)/kg more than the LD feed.

As shown in Table 5, animals treated with Lysoforte Booster dry showed a better digestibility rate for all the nutrients tested; this improvement was statistically significant for crude fat and nitrogen retention and, finally, also AMEn of treated groups was significantly increased.

Table 5 Digestibility of dry matter, NDF, crude fat, nitrogen retention and AMEn level

	DM	ODM	CF	CFi	NDF	N	AMEn
Positive Control (HD)	69.7	71.5	85.1b	27.9	21.2	87.9b	2988b
Pos. Control + Lysoforte Booster 250g/tonne	71.0	72.9	87.8a	29.8	23.5	89.3a	3128a
Pos. Control + Lysoforte Booster 500g/tonne	72.8	74.6	88.1a	33.1	28.4	90.3a	3158a
Neg. Control (LD)+ Lysoforte Booster 500g/tonne	71.8	73.6	87.0ab	31.8	25.5	89.6a	3186a
SEM	0.414	0.403	0.337	0.888	0.952	0.190	18.34
P	0.353	0.298	0.135	0.658	0.400	0.001	0.017

DM – dry mater
ODM - Organic dry mater
NDF – neutral detergent fibre
CF – crude fat
CFi- crude fibre
N – nitrogen retention
AMEn – apparent metabolisable energy corrected to zero nitrogen balance
SEM – standard error of the mean
P – probability
abc - means in the row with different letters are significantly different at $p \leq 0,05$

Lysoforte improves carcass characteristics

Dietary fortification with a natural biosurfactant, lysolecithin in broilers (Melegy, T *et al.* 2010)

In this trial a total of 996 day old broiler chicks (Cobb 500) were weighed individually and randomly assigned into four groups with three replicate per group for 83 birds per replicate.

Birds of Group I, (positive control) were fed on the basal diet recommended by Cobb breeding company. The diets were corn-soybean meal- based (Table 6).

Birds of Group Il, (negative control) were fed a low nutrient density test diet. Diets were corn-soybean meal-based and were lower in added oil and in synthetic amino acids (L-Lysine and DL-methionine). The ME of these diets was approximately 0.14 MJ (35 Kcal)/kg lower than the control diets (Table 6).

Birds of Group III were fed on the negative control diet with Lysoforte Booster added at the rate of 250 g/tonne of feed from day one until slaughter (40 days).

Birds of Group IV were fed on the negative control diet with Lysoforte Booster added at the rate of 500 g/tonne of feed from day one until slaughter (40 days).

Table 6. Broiler feed compositions and calculated analysis.

Ingredient	Control diets		Experimental diets	
	Starter	Grower-Finisher	Starter	Grower-Finisher
Yellow corn	55.78	60.40	56.57	61.23
Soybean meal (44% CP)	29.19	23.83	29.19	23.83
Corn gluten meal (60% CP)	7.50	7.50	7.50	7.50
Soya-oil	3.04	4.10	2.29	3.35
Sodium chloride	0.35	0.35	0.35	0.35

Sodium Bicarbonate	0.04	0.06	0.04	0.06
L-Lysine	0.20	0.18	0.15	0.13
DL-Methionine	0.06	0.07	0.04	0.05
Monocalcium phosphate	1.76	1.55	1.76	1.55
Limestone	1.81	1.66	1.81	1.66
Broiler premix	0.30	0.30	0.30	0.30
Total	100	100	100	100
Calculated analysis				
ME: MJ (Kcal) /kg	12.76 (3050)	13.28 (3175)	12.62 (3015)	13.14 (3140)
Crude protein (%)	22.00	20.00	22.00	20.00
Fat (%)	6.33	7.35	5.61	6.63
Crude fibre (%)	3.45	3.15	3.45	3.15
Lysine (%)	1.28	1.10	1.24	1.06
Methionine (%)	0.50	0.48	0.48	0.46
Met+Cys (%)	0.89	0.84	0.87	0.82
Calcium (%)	1.00	0.90	1.00	0.90
Total phosphorus (%)	0.81	0.74	0.81	0.74
Available phosphorus (%)	0.50	0.45	0.50	0.45

As shown in Table 7, dressing percentage and breast muscle yield for the negative control with Lysoforte treatment were similar to the values seen in the positive control. This indicates that Lysoforte supplementation in a low density diet compensated for the reduced nutrient supply and still gave good growth performance. At the same time, the addition of Lysoforte Booster dry "on top" on the negative control diet improved significantly ($p < 0,05$) dressing yield.

Table 7. Carcass traits of slaughtered birds at the end of the experiment. Values are means ± SD

Parameter (%)	Positive control	Negative control with Lysoforte Booster (g/tonne)			*P* value
		0	250	500	
Dressing	76.12^{ab} ± 3.0	75.66^{b} ± 1.0	76.78^{a} ± 1.4	77.01^{a} ± 1.9	0.019
Breast muscle	28.20 ± 2.1	27.55 ± 1.6	28.20 ± 1.2	28.13 ± 1.3	0.36
Thigh yield	41.36 ± 2.1	42.03 ± 1.2	42.53 ± 0.8	42.54 ± 1.1	0.051
Liver index	3.10^{a} ± 0.4	2.80^{ab} ± 0.5	2.68^{b} ± 0.3	2.72^{b} ± 0.4	0.004
Spleen index	0.24 ± 0.07	0.21 ± 0.04	0.24 ± 0.036	0.25 ± 0.4	0.10

Heart index	0.71 ± 0.17	0.70 ± 0.13	0.72 ± 0.10	0.73 ± 0.11	0.864

a, b denotes a statistically significant difference (P<0.05)

Feed reformulation with Lysoforte is cost-effective

SAC broiler performance trial uk, 2010

In this trial, two groups of broilers, Ross 308 males and females, were tested to assess Lysoforte efficacy on diets lowered in energy by decreasing added soy oil. The trial period was 40 days. Each group comprised 344 broilers - 184 males (4 pens x 46 birds) and 160 females (4 pens x 40 birds). There were four feeding phases: Starter (0-10 days), Grower (10-25 days), Finisher (25-35 days) and Withdrawal (35-40 days). Feed was rationed for the starter phase (360g/male, 340g/female) and fed ad libitum during the other phases. Starter feeds were produced as crumbs. Grower, finisher and withdrawal feeds were produced as pellets (3mm). Lysoforte was added at 500 g/tonne in all 4 phases.

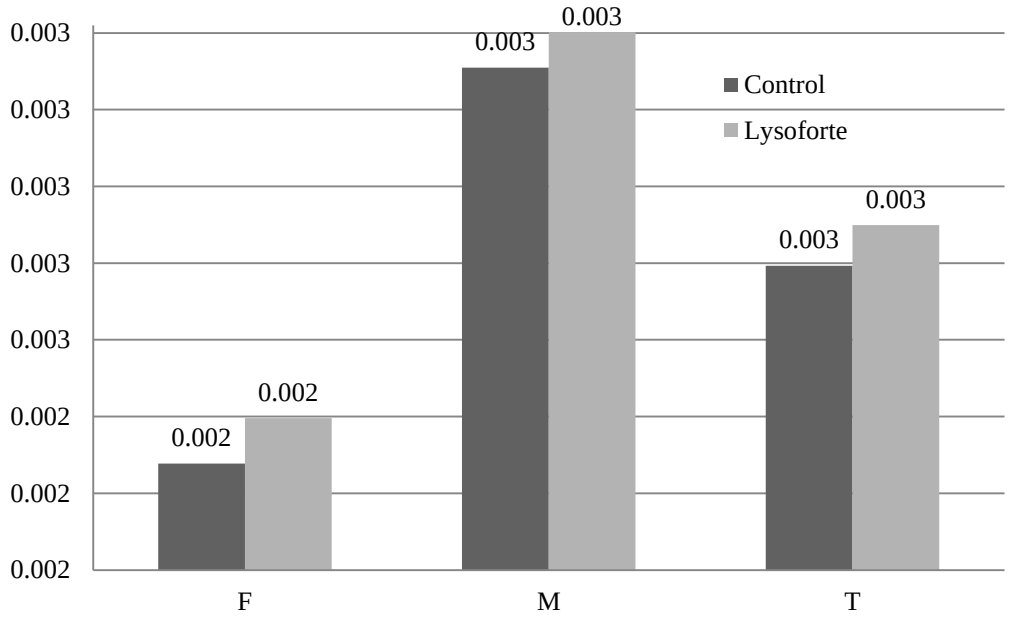

Figure 7. Average body weight (kg) at 40 days. F=females; M=males; T=total population

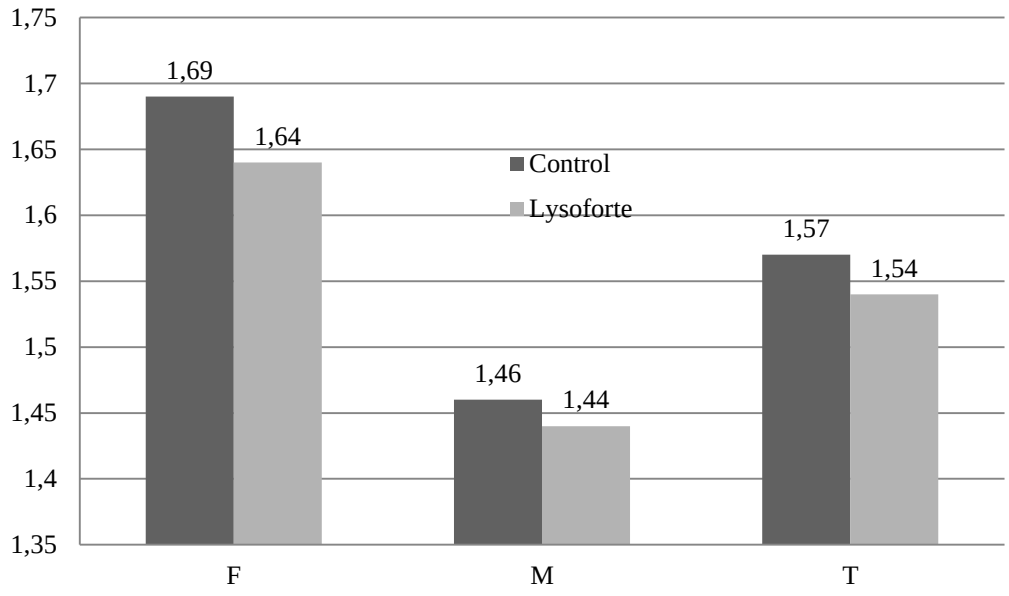

Figure 8. FCR standardized at 2.5 Kg. F=females; M=males; T=total population

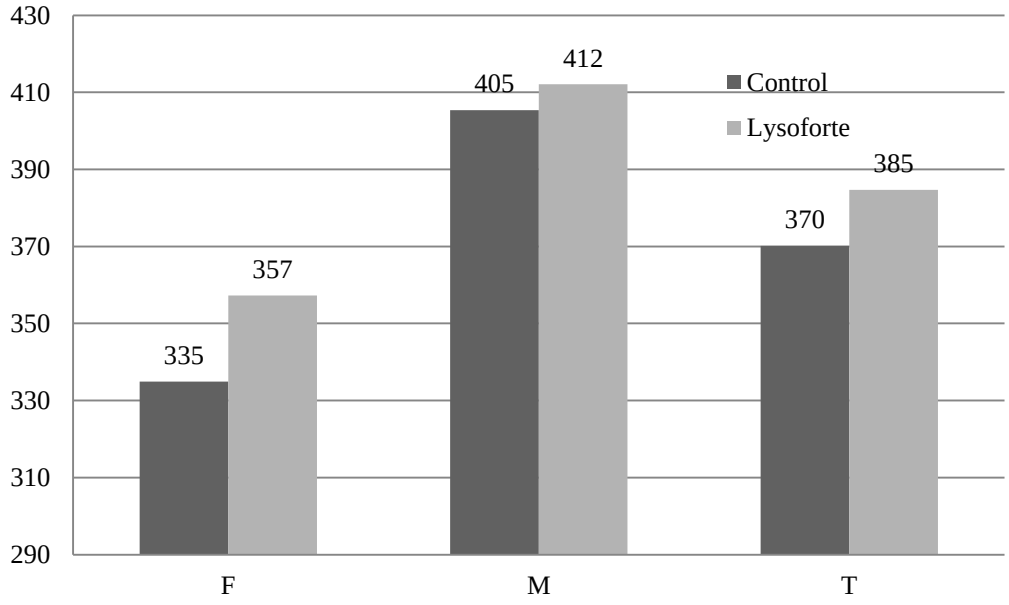

Figure 9. European Production Efficiency Factor (EPEF) at 40 days. F=females; M=males; T=total population

This trial confirmed that, through the application of Lysoforte Booster dry nutritional matrix in broiler feed reformulation process, it is possible to achieve the same (or better) zootechnical performance with a lower feed cost, increasing production profitability.

Effect of Lysoforte Booster dry inclusion in the diet on the animal performance of growing pigs - 2013

The trial was performed at the Schothorst research centre, the Netherland. In total, 360 pigs (180 boars and 180 gilts allocated together) entered the experiment with a starting body weight of approximately 26 kg and ended at approximately 55 kg of body weight. The pigs were randomly assigned to three treatments: (1) Positive Control (PC): pigs received the standard grower diet; (2) Negative control diet (NC): formulated to contain around -70 kcal/kg NE, keeping the SID (Standard Ileal Digestible) Lysine/NE ratio constant; and (3) Lysoforte

supplemented diet (LYS): NC diet supplemented with 500 g Lysoforte Booster dry/ton feed. The diets fed to the pigs were pelleted. The diet composition and analysis are shown in Tables 8 and 9, respectively.

Table 8. Growing pigs diet composition (%).

	PC	NC	LYS
Barley	25.00	25.00	25.00
Maize	20.00	16.18	16.18
Wheat	15.00	15.00	15.00
Soybean meal 47%	11.33	9.58	9.58
Rapeseed meal	7.50	7.50	7.50
Wheat middlings	6.81	6.81	6.81
Cane molasses	5.00	5.00	5.00
Maize gluten feed	-	4.84	4.84
Palm kernel meal	2.84	4.03	4.03
Palm oil	2.10	1.67	1.67
Premix, Vitamins, Amino acids, Phytase, Limestone	4.42	4.39	4.34
Lysoforte Booster Dry	-	-	0.05

Table 9: Growing pigs nutrient analysis of the diets.

	PC	NC	LYS
NE value kcal/kg	2300	2231	2231
SID Lys/NE, g/Mcal	3.82	3.82	3.82
Crude protein, g/kg	159.81	160.44	160.44
Crude fat, g/kg	54.14	50.61	50.61
U/S ratio	1.89	2.00	2.00
Crude fibre, g/kg	42.97	48.16	48.16
SID Lys, g/kg	8.79	8.51	8.51
SID Met, g/kg	2.89	2.79	2.79
SID M+C, g/kg	5.34	5.23	5.23
SID Thr, g/kg	5.63	5.50	5.50
SID Trp, g/kg	1.63	1.58	1.58
Total Ca, g/kg	7.00	7.00	7.00
Digestible P, g/kg	2.48	2.40	2.40

The differences in final BW of the pigs were significantly higher for the pigs fed the positive control diets and Lysoforte Booster dry diets compared with pigs fed the negative control diet (P=0.037) (Figure 10). Also, there was a tendency for a higher average daily growth (ADG) for the pigs fed the positive control and Lysoforte Booster dry diets compared with pigs fed the negative control diet (*P*=0.091).

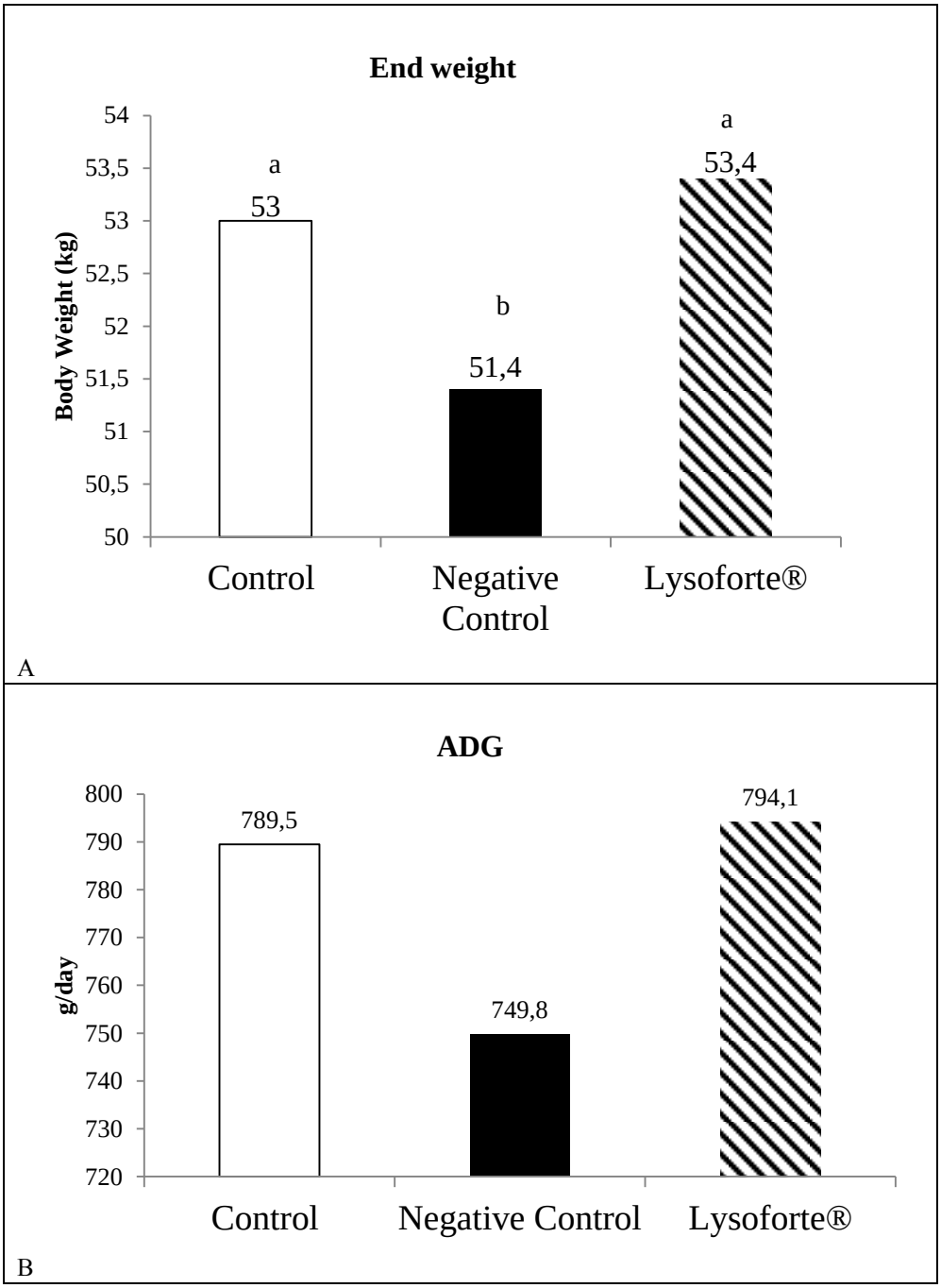

Figure 10. End weight (kg) and Average Daily Gain (ADG-g/day) of growing pigs assigned to the three treatment groups. Superscripts a,b within the same graph indicate significant differences between treatments (P<0.05).

It is evident from the results that growing pigs fed the reformulated diet supplemented with Lysoforte Booster dry were able to perform equally to the pigs from the positive control group. The challenge imposed with the reformulation diet was not only the -70kcal/kg NE gap, but also a lower concentration of SID amino acids (*e.g.* Lysine, Methionine).

Based on the economic parameters of this trial a benefit of 0,76 €/pig, compared to positive control diet, was achieved in animals fed the reformulated diet with Lysoforte Booster dry. Moreover, the ROI of Lysoforte Booster dry was 20.5 vs. Negative Control.

Improving litter uniformity through higher feed digestibility: new possibilities for Lysoforte use

Lysoforte Booster dry in sows during lactation: influence on feed efficiency and piglets weight at weaning - 2012

The current trial evaluated the effect of Lysoforte Booster dry added to sow lactation feed (500 g/tonne of feed) on sow and piglet performance. A total of 62 lactating sows were included in the experiment. The facility contained 7 farrowing rooms, each one with 10 farrowing cages. The farrowing cage floor, trough, drinkers and size were in accordance with actual animal welfare EU regulation. In each farrowing room the sows were split into 2 groups: CON (Control) and LYS (standard diet supplemented with 500 g/tonne Lysoforte), with the same average number of parity between the groups. Piglets were weaned after 26 days. The sows received a standard lactation diet, which had crude protein 16.90%, crude fat 4.50%, fiber 5.87%, and as a pure fat source soya and palm oil (1.83% and 0.50% respectively). The measured parameters were: litter size, litter weight , and piglet weight initially and at weaning. Daily weight gain of piglets, piglet mortality, total sow feed consumption during lactation, and daily sow feed consumption were also measured. Results are shown in Tables 10.

Table 10. Litter and piglet performance results from the two treatment groups CON and LYS.

Parameter	CON	LYS
Litter size at birth (n°)	11,3	11,4
Litter size weaning (n°)	10,8	10,7
Piglets mortality (%)	4,19	5,88
Litter initial weight (kg)	20,6	20,7
Litter weight weaning (kg)	76,3	78,0
Average piglet initial weight (kg)	1,82	1,82
Average piglet weight at weaning (kg)	7,07	7,38
Average daily weight gain of piglets (g/day)	206	217
Coefficient Variation of litter initial weight (%)	18,52	18,93
Coefficient Variation of litter weight at weaning (%)	20,55	12,75

Conclusively, piglet and litter weight at weaning were numerically improved by the addition of Lysoforte at 500 g/tonne of feed in lactation sow diets. An improvement of 8% in litter uniformity at weaning was noted in the Lysoforte supplemented group when compared to the control group. The sow feed intake was not influenced by dietary treatments, while sow efficiency (sow output) improved numerically. These findings indicate an improved feed utilization in lactating sows after on top Lysoforte supplementation is likely. This is of high importance in a period of negative energy balance, which is the lactation period in sows.

Lysoforte effectiveness also on unconventional source of feed fats and oils

Efficient application of Lysoforte Booster in Growing Turkeys - 2013

The trial objective was to investigate the effects of dietary supplementation of a natural absorption enhancer added on top on feed in the first two growing stages and after feed reformulation in the remaining growth stages till slaughter in the diets of growing turkeys. The experimental trial took place in the facilities of Moorgut Kartzfehn GmbH & Co. KG (Germany), at the test farm Kartzfehn Nord. In total, 960 day old male BUT 6 turkeys were used. The turkeys were randomly divided into two treatments: Control- standard 6-phase-diet according to Kartzfehn recommendations and Lysoforte- standard 6-phase-diet with reduced amounts of fat in phases 3 to 6 and supplemented with 500 g Lysoforte Booster Dry per ton of feed. Specifically, the amount of total fat in phases 1 and 2 was 5.9% for both treatments, and Lysoforte Booster Dry was added on top in the treatment group. In phase 3 the amount of total fat was 6.6% in the Control and 5.9% in the Lysoforte, in phase 4 7.7% in the Control and 6.8% in Lysoforte, in phase 5 8.5% in Control and 7.3% in Lysoforte, and in phase 6 10.1% in Control and 8.8% in Lysoforte. As a result of the reformulation, a lower ration cost was achieved, which approximately ranged from 2-3 €/ton of feed. The performance results of the trial are shown in Table 11.

Table 11. Average values of performance parameters of the two treatment groups Control and Lysoforte. (NS=not significant differences)

Parameter	Control	Lysoforte	*P* value
Weight after phase 1 (kg)	0,271	0,315	<0.001
Weight after phase 3 (kg)	4,39	4,82	<0.001
Weight after phase 4 (kg)	9,21	10,15	<0.001
Weight after phase 5 (kg)	13,36	14,72	0.006
Live Weight (kg, 147 days)	22,27	22,21	NS
Live Weight corr. (kg)	22,45	22,4	NS
SD	1,65	1,71	NS
CV%	7,37	7,67	NS
Daily Gain (kg)	0,153	0,152	NS
FCR1	2,74	2,73	NS
Mortality (%)	16,46	18	NS
Foot pad score (average)	1,235	1,089	NA

Mortality (also including culled animals, missorted hens and for any reason treated animals) was not different between treatments: 16.46% in Control and 18.00% in Lysoforte. The footpad condition was evaluated according to a scoring-system of Hocking *et al.* (2008) after slaughter.

The Lysoforte group exhibited higher weights at all intermediate phases, while at slaughter, the weights were similar to the control. This may be attributed to more efficient digestion and absorption of dietary fat in the Lysoforte group, especially in the earlier stages of growth. As discussed above, the ending body weight was the same for both treatments. It is plausible that earlier weight differences were ameliorated in the last growth stage (with less favourable feed conversion rate) or that the random weight of turkeys in the intermediate phases (25% of the population) could not represent the total population trend. Still the overall growth performance and feed conversion was similar for both treatments, and based on the fact that reformulation resulted in lower diets cost, it can be conjectured that Lysoforte can be effectively used in turkey diets with acid oil as the main oil source. Finally, the better foot pad scoring could be attributed to drier faeces, most probably due to better fat digestion in the Lysoforte group.

Conclusions

Lysoforte is suitable for multiple species and has been successfully tested in broilers, layers, turkeys, pigs and fish.

Lysoforte is a very versatile feed ingredient and can be used to achieve many different goals. It has been successfully tested and applied in monogastric nutrition to improve:

Weight gain, FCR and EPEF

Digestibility of feed nutrients

Production profitability (feed reformulation)

Pellet quality

Absorption of fat soluble vitamins and carotenoids

Resistance of animals to heat stress

Meat and carcass quality of broilers

Egg weight

References available on request to the author: mauro.dibenedetto@kemin.com

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