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Effect of dietary supplementation of lysophospholipids on productive performance, nutrient digestibility and carcass quality traits of broiler chickens

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ABSTRACT
An experiment was carried out to evaluate productive performance, nutrient digestibility and carcass quality traits of broiler chickens fed diets supplemented with an exogenous emulsifier based on lysophospholipids prepared by enzymatic conversion of soy lecithin. One thousand seven hundred and fifty-five one-day-old male Ross 308 chicks were randomly divided into three experimental groups of nine replications each: control group (CON) fed a corn–soybean basal diet, and two groups fed CON diet supplemented with constant (1 kg/ton) or variable (1–1.5 kg/ton) level of emulsifier (CONST and VARI, respectively). At the end of the trial (42 d), birds receiving the emulsifier had a statistically significant ($p < 0.05$) lower feed conversion rate compared to the control. Body weight and daily weight gain were only slightly influenced by lysophospholipids supplementation, while mortality and feed intake resulted similar among the groups. No statistically significant effect of the emulsifier was observed on nutrient digestibility as well as slaughtering yields, skin pigmentation and incidence of foot pad dermatitis. The results obtained in this study suggest that the use of an emulsifier based on lysophospholipids improves feed efficiency while showed limited effect on carcass quality traits.

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Broiler; carcass quality; digestibility; emulsifier; productive performance

Introduction
Lipids are water-insoluble compounds and their digestion is due to the synergic action of bile salts and pancreatic lipase. Since lipids digestion takes place in an aqueous environment in small intestine, bile salts ensure emulsification of dietary fats allowing pancreatic lipase to hydrolyse the triglycerides present on water–oil interface, with production of 2-monoglycerides and free fatty acids (Leeson & Summers 2001). Furthermore, bile salts play a key role in the formation of mixed micelles which are subsequently absorbed by the mucosa cells in the small intestine (Krogdahl 1985). Hybrid chickens used in intensive broiler production require an adequate dietary source of energy and protein to express their genetic potential. In order to achieve these requirements, great amounts of animal fats and vegetable oils are usually added to broiler diets to increase their energy content (Blanch et al. 1996). However, several factors can affect lipids digestion, both related to the animal characteristics such as bird age (Krogdahl 1985; Tancharoenrat et al. 2013), genetic strain (Katongole & March 1991), secretion and activity of digestive enzymes (Nitsan et al. 1991; Nir et al. 1993; Noy & Sklan 1995), microflora status (Maisonnier et al. 2003), and to the diet composition such as type of fat used as lipid supplement (Tancharoenrat et al. 2014), ratio of unsaturated to saturated fatty acids in the diet (Ketels & De Groote 1989), presence of pentosans (Choct & Annison 1992) and dietary fibre (Jiménez-Moreno et al. 2009). Therefore, given the considerable amount of lipids in broiler diet, the use of exogenous emulsifiers may support bile salts in both emulsion and micelle formation process, determining a positive effect on lipids digestibility and productive performance. Lysophospholipids are mono-acyl derivatives of phospholipids resulting from the action of phospholipase A1 or A2, which hydrolyse respectively the ester bond at sn-1 and sn-2 position (Joshi et al. 2006). Presenting a single fatty acid, these compounds are characterised by higher hydrophilic–lipophilic balance and thus a better oil–water emulsification capacity than the corresponding phospholipids (Schwarzer & Adams 1996). Lysophospholipids show a lower critical micelle...
concentration than bile salts and lecithin (Zubay 1983) and form smaller micelles compared to phospholipids (Mine et al. 1993). On the other hand, lysophospholipids are mentioned to improve gut permeability to macromolecules like proteins and dextrans (Tagesson et al. 1985), regulate the activity of several enzymes (Shier et al. 1976; Tagesson et al. 1985), influence the formation of protein channels (Lundbaek & Andersen 1994) and cause epithelial cells hypertrophy in broiler duodenum (Khonyoung et al. 2015). Despite some studies report the positive or partially positive effects of lysophospholipids in broilers (Schwarzer & Adams 1996; Melegy et al. 2010; Zhang et al. 2011; Jansen et al. 2015), pigs (Dierick & Decuypere 2004; Zhao et al. 2015) and veal calves (Sabbioni et al. 1997), the data found in literature do not allow to obtain a clear indication about their efficacy, due to the different composition of the basal diet used. Furthermore there are no indications concerning the needs to adapt the level of inclusion of lysophospholipids according to the increasing fat content of diets in the different feeding phases.

Therefore, a trial was conducted to evaluate the effects of lysophospholipids prepared by enzymatic conversion of soy lecithin supplemented either at a constant dose or at variable one according to the lipid content of the diets, on productive performance, nutrient digestibility and carcass quality traits of broiler chickens.

Materials and methods

Birds and poultry house

One thousand seven hundred and fifty-five one-day-old male Ross 308 chicks were weighed, randomly divided into three groups and distributed in 27 pens of 6 m² each (65 birds/pen, 11 birds/m²). Each group was composed of nine replications, for a total of 585 birds per group. The distribution of pens inside the poultry house was done in randomised blocks in order to minimise any environmental effects. Each pen was equipped with 10 nipples and two circular pan feeders to ensure at least 2 cm/bird of front space. The pen floor was covered with chopped straw (2 kg/m²) and the environment was conditioned and equipped with artificial light. Birds received 23L:1D from 0 to 7 d and for the last 3 days of life, and 18L:6D for the remaining days (European Commission 2007).

Diets

The feeding program was composed of four phases: starter (from 0 to 12 d), grower I (from 13 to 26 d), grower II (from 27 to 36 d) and finisher (from 37 to 42 d). A common corn–soybean basal diet (Table 1) has been used to prepare the experimental diets. The basal diet was supplemented either with a constant amount (1 kg/ton) of an emulsifier (Lipidol Ultra, Andres Pintaluba, Spain, containing 6% of a standardised mixtures of lysophosphatidylcholine, lysophosphatidylethanolamine, lysophosphatidylinositol and lysophosphatidic acid) from 0 to 42 d (CONST) or increasing amounts of it depending on the level of dietary lipids (1 kg/ton from 0 to 26 d and 1.5 kg/ton from 27 to 42 d; VARI). Control diet (CON) was represented by the basal diet without emulsifier addition.

At the beginning of every feeding phase, feeds were weighed and stocked in an individual and clearly labelled bin provided for each pen. Feed was manually distributed from the bin to the feeders two times a day. Water and feed were provided for ad libitum consumption.

Productive performance

At housing and at the end of each feeding phase (12, 26, 36, 42 d), number and weight of birds present in each pen were recorded, as well as the weight of residual feed. Number, age and weight of birds died during the trial were recorded in order to calculate the mortality percentage. On the basis of these measurements, daily weight gain, feed intake and feed conversion rate and cumulative feed conversion rate were calculated on a pen basis and corrected for mortality.

Apparent digestibility

From 19 to 23 d of trial, faecal samples from each box (nine per group for a total of 27 boxes) were collected to evaluate the apparent digestibility of dry matter, crude fat and crude protein. Titanium dioxide, added to both the grower I and grower II diets (3 kg/ton), was used as indigestible marker to evaluate nutrient digestibility. Litter was covered by a plastic sheet to avoid the contact between faeces and the underlying materials. Faeces were collected with care twice a day (morning and afternoon), put in a plastic container and extraneous materials were carefully removed. Samples were mixed in order to obtain a homogeneous pool per pen/day and subsequently frozen at −20°C. Proximate analysis was conducted on both feed and faecal samples to evaluate the content of dry matter, crude fat and crude protein. Moisture was determined in duplicate according to the Association of Official Analytical Chemists procedure (AOAC 1990). Crude protein were determined by the standard Kjeldahl copper
Catalyst method as described in AOAC (1990). Crude fat were determined using the Soxhlet method (AOAC 1990), which allows to extract the ethyl-ether soluble substances present in the sample. The amount of titanium dioxide was determined by a spectrophotometric analysis, according to the procedure proposed by Myers et al. (2004). Briefly, a sample of 1 g either of feed or faeces was put in a glass tube with 13 ml of H2SO4 96% (CAS: 7664-93-9, EC: 231-639-5, Carlo Erba Reagents s.r.l., Milano, Italy), 3.5 g of K2SO4 and 0.4 g of CuSO4. Samples were digested in a macro-Kjeldahl apparatus (Gerhardt Kjeldatherm) for 2 h at 420 °C.

Subsequently, 10 ml of H2O2 30% (CAS: 7722-84-1, EC: 231-765-0, Carlo Erba Reagents s.r.l., Milano, Italy) and distilled water were added and the liquid was filtered to remove the precipitate. The aqueous phase was read at 410 nm with an UV/Vis Spectrophotometer (Jasco model 7800). A standard curve has been previously prepared using solutions containing 0, 2, 4, 6, 8 and 10 mg of TiO2 to calibrate the spectrophotometer. Finally, the amount of titanium dioxide detected was used to assess the apparent digestibility of the nutritional components according to the following formula, obtained by a modification of those used by Kluth & Rodehutscord (2006):

\[
\text{Apparent digestibility (\%)} = \left( \frac{\text{TiO}_2 \text{ feed}}{\text{TiO}_2 \text{ faeces}} \times \frac{\text{Nutrient faeces}}{\text{Nutrient feed}} \right) \times 100
\]

where TiO2 feed and TiO2 faeces are the respective concentration of titanium dioxide detected in feed and faeces, while nutrient feed and nutrient faeces represent the quantity of the specific nutrient (dry matter, crude protein, crude fat) respectively in feed and faeces.

### Carcass traits

At the end of the trial (42 d), broilers were subjected to a total feed withdrawal of 12 h and slaughtered in a commercial slaughterhouse. Eviscerated yield, as well as the percentage of breast, legs and unseparated wings, was measured on all the slaughtered birds. During the slaughtering process, a foot of each bird was removed from each bird.

### Table 1. Ingredients and composition of basal diet.

| Ingredients, g/100 g | Starter (0–12 d) | Grower I (13–26 d) | Grower II (27–36 d) | Finisher (37–42 d) |
|---------------------|------------------|--------------------|----------------------|---------------------|
| Corn                | 32.22            | 37.10              | 37.62                | 40.89               |
| Wheat               | 15.00            | 15.00              | 15.00                | 15.00               |
| Sorghum             | 5.00             | 5.00               | 5.00                 | 5.00                |
| Soybean oil         | 2.53             | 2.51               | 3.43                 | 3.61                |
| Soybean meal        | 21.93            | 18.73              | 14.73                | 11.55               |
| Expanded soybean    | 10.00            | 10.00              | 15.00                | 15.00               |
| Pea                 | 3.00             | 3.00               | 3.00                 | 3.00                |
| Sunflower           | 3.00             | 3.00               | 3.00                 | 3.00                |
| Corn gluten         | 3.00             | 2.00               | 0.00                 | 0.00                |
| Lysine sulphate     | 0.57             | 0.53               | 0.40                 | 0.37                |
| DL-methionine       | 0.29             | 0.31               | 0.33                 | 0.30                |
| L-threonine         | 0.12             | 0.11               | 0.09                 | 0.07                |
| Calcium carbonate   | 0.57             | 0.52               | 0.55                 | 0.56                |
| Dicalcium phosphate | 1.40             | 0.93               | 0.61                 | 0.51                |
| Sodium chloride     | 0.33             | 0.29               | 0.27                 | 0.19                |
| Sodium bicarbonate  | 0.00             | 0.05               | 0.08                 | 0.08                |
| Premix vit.-min.1   | 0.44             | 0.38               | 0.34                 | 0.24                |
| Choline             | 0.10             | 0.10               | 0.10                 | 0.06                |
| Enzymes             | 0.18             | 0.18               | 0.18                 | 0.18                |
| Phytase             | 0.10             | 0.10               | 0.10                 | 0.10                |
| Butyric acid        | 0.20             | 0.15               | 0.00                 | 0.00                |
| Xanthophylls        | 0.00             | 0.00               | 0.18                 | 0.17                |

Proximate composition

|                | Starter (0–12 d) | Grower I (13–26 d) | Grower II (27–36 d) | Finisher (37–42 d) |
|----------------|------------------|--------------------|----------------------|---------------------|
| Dry matter, %  | 88.42            | 88.19              | 87.95                | 87.97               |
| Crude protein, %| 22.52            | 20.69              | 19.23                | 17.92               |
| Total lipid, % | 6.34             | 6.40               | 8.09                 | 8.35                |
| Crude fiber, % | 3.02             | 2.97               | 3.01                 | 2.96                |
| Ash, %         | 5.37             | 4.74               | 4.43                 | 4.19                |
| Lysine, %      | 1.38             | 1.27               | 1.18                 | 1.08                |
| Met.-Cyst., %  | 0.99             | 0.93               | 0.87                 | 0.81                |
| Ca (total), %  | 0.82             | 0.66               | 0.58                 | 0.53                |
| P (total), %   | 0.62             | 0.53               | 0.47                 | 0.44                |
| AME, kcal/kg   | 3050             | 3100               | 3200                 | 3250                |

Provided the following per kg of diet: vitamin A (retinyl acetate), 13,000 U; vitamin D3 (cholecalciferol), 4000 U; vitamin E (DL-α-tocopheryl acetate), 80 U; vitamin K (menadione sodium bisulfite), 3 mg; riboflavin, 6.0 mg; pantothenic acid, 6.0 mg; niacin, 20 mg; pyridoxine, 2 mg; folic acid, 0.5 mg; biotin, 0.10 mg; thiamine, 2.5 mg; vitamin B12, 20 μg; Mn, 100 mg; Zn, 85 mg; Fe, 30 mg; Cu, 10 mg; I, 1.5 mg; Se, 0.2 mg; ethoxyquin, 100 mg.

AME: apparent metabolizable energy.
was collected and subjected to a macroscopic analysis to evaluate the incidence of foot pad lesions, scored in three classes according to the method proposed by Ekstrand et al. (1998): 0 = no lesion, 1 = mild lesion (<0.8 cm), 2 = severe lesion (>0.8 cm). Moreover, lesion score was calculated according to the formula in the Commission of the European Communities (2005). The number of feet in class 0 did not contribute to the score, while the number of feet in class 1 was multiplied by 0.5 and the number in class 2 was multiplied by 2. Finally, the scores were added and the total was divided by the sample size and multiplied by 100.

Skin pigmentation was measured 24-h postmortem in 280 randomly selected carcasses per experimental group. The CIE (1978) system colour profile of lightness (L*), redness (a*) and yellowness (b*) was detected by a reflectance colorimeter (Minolta Chroma Meter CR-300, Minolta Italia S.p.a, Milano, Italy) using illuminant source C. A standard white ceramic tile was used to calibrate the colorimeter throughout the study and colour was measured in triplicate on the ventral pterylae.

Statistical analysis
The data were analysed using a one-way ANOVA, considering the dietary inclusion of the emulsifier as the independent variable. Means were separated by Student Newman–Keuls test using SAS statistical package (SAS 1988). Prior to analysis, mortality data were submitted to arcsine transformation. Moreover, the data regarding the frequency distribution of foot pad lesions were analysed using chi-square test. Differences were considered statistically significant at $p \leq 0.05$ level.

Results and discussion
Productive performance
The effects of the emulsifier on productive performance are shown in Table 2. The addition of the emulsifier does not statistically improve final body weight (2617 vs. 2643 vs. 2643 g, respectively for CON, CONST and VARI groups) and daily weight gain of broilers (61.3 vs. 61.9 vs. 61.9 g/bird/d, respectively for CON, CONST and VARI groups). These observations are partially in contrast with Melegy et al. (2010) who reported that the use of an emulsifier based on lysolcithin at the dosage of 0.25 or 0.5 kg/ton of feed significantly improves these productive parameters.

The emulsifier does not affect the feed intake as birds consumed a similar daily amount of feed (116.7 vs. 116.0 vs. 115.5 g/bird/d, respectively for CON, CONST and VARI groups), while Zaefarian et al. (2015) found a significant increase in feed consumption in broilers fed diets containing 3.5 kg/ton of lysophospholipids. No effect of emulsifiers on feed intake was previously reported by Guerreiro Neto et al. (2011), Aguilar et al. (2013) and Zhang et al. (2011) who used respectively a casein, a nonionic and lysophosphatidylcholine emulsifier.

Birds receiving diets supplemented with the emulsifier presented a significantly lower feed to gain ratio compared to CON (1.871 and 1.875 vs. 1.913 respectively for VARI, CONST and CON; $p < 0.05$) and this result confirms the data found by Melegy et al. (2010). This aspect may be related to the ability of lysophospholipids to ensure a better emulsion of dietary lipids.

Table 2. Productive performance of CON, CONST and VARI groups in each feeding phase and in the whole period of trial (0–42 d).

| Treatments | CON | CONST | VARI |
|------------|-----|-------|------|
| No. replications | 9 | 9 | 9 |
| Body weight, g/bird | | | |
| 0 | 41.1 | 41.5 | 41.4 | 0.14 | ns |
| 12 | 300.0 | 303.5 | 303.8 | 3.02 | ns |
| 26 | 1115 | 1129 | 1121 | 10.91 | ns |
| 36 | 2012 | 2029 | 2028 | 15.17 | ns |
| 42 | 2617 | 2643 | 2643 | 16.46 | ns |
| Daily weight gain, g/bird/d | | | |
| 0–12 | 21.6 | 21.8 | 21.9 | 0.26 | ns |
| 13–26 | 58.2 | 59.0 | 58.4 | 0.72 | ns |
| 27–36 | 89.5 | 90.0 | 90.4 | 1.06 | ns |
| 37–42 | 100.1 | 102.3 | 102.5 | 1.23 | ns |
| 0–42 | 61.3 | 61.9 | 61.9 | 0.36 | ns |
| Feed intake, g/bird/d | | | |
| 0–12 | 34.1 | 34.5 | 33.8 | 0.52 | ns |
| 13–26 | 104.0 | 103.7 | 102.0 | 0.92 | ns |
| 27–36 | 180.4 | 177.7 | 178.6 | 1.01 | ns |
| 37–42 | 207.6 | 205.8 | 207.6 | 1.00 | ns |
| 0–42 | 116.7 | 116.0 | 115.5 | 0.41 | ns |
| Feed conversion rate | | | |
| 0–12 | 1.583 | 1.579 | 1.541 | 0.02 | ns |
| 13–26 | 1.791 | 1.759 | 1.745 | 0.02 | ns |
| 27–36 | 2.019 | 1.976 | 1.979 | 0.02 | ns |
| 37–42 | 2.077 | 2.013 | 2.029 | 0.02 | ns |
| 0–42 | 1.913 | 1.875 | 1.871 | 0.01 | <0.05 |
| Mortality, % | | | |
| 0–12 | 0.17 | 0.00 | 0.19 | 0.01 | ns |
| 13–26 | 0.34 | 0.34 | 0.39 | 0.02 | ns |
| 27–36 | 0.52 | 0.00 | 0.58 | 0.02 | ns |
| 37–42 | 0.34 | 0.00 | 0.00 | 0.01 | ns |
| 0–42 | 1.37 | 0.34 | 1.16 | 0.03 | ns |

CON: control diet; CONST: control diet +1 kg/ton of lysophospholipids emulsifier; VARI: control diet +1–1.5 kg/ton of lysophospholipids emulsifier. ns: not significant.

a,bDifferent letters in the same row denote significant difference among the treatments.

cSE of arc sin transformation of mortality data.
and form small liposomes that are absorbed with high efficiency by the animal (Reynier et al. 1985).

In this experiment, mortality percentage was very low in all the experimental groups and no significant difference among the groups emerged. Schwarzer & Adams (1996) observed that the dietary supplementation of lysophospholipids seems to play a positive effect on mortality of broilers. Similar results were also reported by Melegy et al. (2010), while other authors did not observe significant difference due to the use of emulsifiers (Roy et al. 2010; Aguilar et al. 2013; Zaefarian et al. 2015).

Regarding the effect of inclusion level of the emulsifier, no significant difference emerged between CONST and VARI groups for all the considered productive parameters. Also Zhao et al. (2015) did not found significantly differences in productive performance of weanling pigs administering diets containing 0.5 or 1 kg/ton of an emulsifier based on lysophospholipids.

The effect of the emulsifier in the different feeding phases was not statistically significant for all the considered productive parameters. On the contrary, Zhang et al. (2011) stated that the use of lysophosphatidylcholine significantly improves body weight gain in broiler chickens from 1 to 21 days.

**Apparent digestibility**

Table 3 shows the apparent digestibility of dry matter, crude fat and crude protein evaluated from 19 to 24 d.

| Samples/group | CON | CONST | VARI | SE | Probability |
|---------------|-----|-------|------|----|-------------|
| DM, %         | 60.5| 61.3  | 60.6 | 1.71| ns          |
| CF, %         | 59.4| 61.5  | 62.1 | 2.22| ns          |
| TF, %         | 59.7| 62.9  | 62.5 | 1.40| ns          |

CON: control diet; CONST: control diet +1 kg/ton of lysophospholipids emulsifier; VARI: control diet +1–1.5 kg/ton of lysophospholipids emulsifier. ns: not significant.

Table 3 shows the apparent digestibility of dry matter, crude fat (CF) and crude protein (CP) evaluated from 19 to 24 d.

showing a possible synergistic effect. Also Zhang et al. (2011) reported no significant effect of lysophosphatidylcholine on digestibility of dry matter and crude proteins in broiler chickens from 14 to 17 and from 35 to 38 days of trial. Nevertheless, these authors stated that the use of lysophosphatidylcholine in broiler diets significantly improves the apparent digestibility of fatty acids as C16:0, C18:1 n9 and C18:1 n7 from 14 to 17 days and C18:2 and C18:3 n3 from 35 to 38 days.

As for productive performance, groups receiving the emulsifier obtained comparable results in terms of nutrient digestibility. Similarly, Zhao et al. (2015) observed no significant difference on nutrient digestibility in weanling pigs fed diets containing two different levels of lysophospholipids.

The efficacy of lysophospholipids on nutrient digestibility is dependent on several factors. Differences in basal diet, especially in sources, composition and inclusion rate of dietary fats and emulsifier could lead to different responses (Zhang et al. 2011; Zaefarian et al. 2015; Zhao et al. 2015). Jansen et al. (2015) reported that the effect of lysophospholipids on nutrient digestibility strongly depends on the fat sources used in broiler diets. In fact, while a statistically significant improvement was observed when lysophospholipids were added to diets containing pig lard, only slight improvement was detected when the emulsifier was included in diet containing soybean oil, being the latter characterised by a high digestibility rate. On the contrary, Zhang et al. (2011) found no significant interactions between fat sources (soybean oil, tallow and poultry fat) and lysophosphatidylcholine on nutrient digestibility in broilers. Conflicting results about the effect of lysophospholipids on digestibility were also recorded in swine. Zhao et al. (2015) stated that lysophospholipids improve nutrient digestibility in weanling pigs fed a low energy diet using beef tallow as fat source. Similarly Dierick and Decuypere (2004) reported a positive effect on digestibility of non-lipids fraction in diet for growing pigs enriched with 4% of animal fats. On the contrary, Xing et al. (2004) observed a linear reduction in the digestibility of dry matter, gross energy and crude proteins when a quantity of 0.1% of lysolecithins was added to diet for piglets till 28 days after weaning. However, the same authors observed a better digestibility of fats using 0.02% of lysolectithin as dietetic supplement for 10 days weaned piglets. Also Soares and Lopez-Bote (2002) observed a different effect of lecithin on fat digestibility depending on the source of dietary fats: the stronger positive effect was detected in diet containing lard respect to those containing soybean oil. Therefore, we suppose that the lack of emulsifier effects on nutrient digestibility
observed in our trial may be attributable to the use of soybean oil as lipid source in our diets. In fact, considering the data reported in pigs by Dierick and Decuypere (2004), the use of a highly digestible lipid source, such as soybean oil, may have determined little room for the action of the emulsifier and limited its effectiveness.

Carcass traits

No differences were observed among the experimental groups regarding the eviscerated yield (68.4, 68.7 and 68.3% respectively for CON, CONST and VARI), as well as for the percentage of breast (30.1, 30.2, 30.1%), legs (43.1, 43.1, 43.1%) and unseparated wings (19.1, 19.2 and 19.3%). Similarly, Melegy et al. (2010), Guerreiro Neto et al. (2011) and Aguilar et al. (2013) stated that the dietary use of emulsifiers did not affect carcass yield of broilers, and also Schwarzer and Adams (1996) observed similar slaughter yields in pigs fed diets added with or not an emulsifier based on lysophospholipids.

As for skin pigmentation, values of lightness (L*), redness (a*) and yellowness (b*) resulted similar, showing no significant differences among the groups (Table 4). Skin pigmentation is a relevant quality parameter for poultry industry, since both carcass and meat colour could strongly influence the consumer’s choice. Pigmentation is affected by several factors, including quantity, bioavailability and dietary source of pigments (Sirri et al. 2010). Sugawara et al. (2001) reported that lysophosphatidylcholine improves carotenoids absorption by human intestinal cells; however there are no other evidence in literature regarding chicken skin pigmentation.

The results of the evaluation of foot pad dermatitis are reported in Table 5. The percentage of birds that show no lesion (class 0) was similar in the different groups, as well as for the percentage of birds with mild (class 1) or severe (class 2) lesions and thus the Lesion Score resulted similar in the three groups. Foot pad lesions are an important parameter to evaluate the welfare status and rearing condition of broiler chickens. Several factors, with particular regard to litter characteristics, are involved in the onset of this injury (Mayne 2005; Meluzzi et al. 2008). It is widely known that nitrogen and fat excretion tend to reduce litter’s quality and increase the incidence of food pad lesions. Although no significant difference was observed in this trial, the use of an emulsifier that improves the retention of dietary fats and proteins may have a positive effect on the development of these lesions particularly when raw materials with low digestibility rates are included.

Conclusions

The supplementation of an emulsifier based on lysophospholipids determined a significant improvement of feed conversion rate of broiler chickens, while showed limited effects on the other productive parameters. The positive response of the emulsifier on feed efficiency might be related to a cumulative effect on nutrient digestibility although no significant result was detected when each of those was considered singularly.

The use of two different doses of emulsifier led to the same results for all the considered productive parameters and for nutrient digestibility showing that the lower dose could be the more suitable solution for feed formulation.

Therefore, from the results obtained in this experiment, the use of an emulsifier based on lysophospholipids represents a potential solution to improve feed efficiency of broiler chicken.

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Disclosure statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.
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References

Aguilar YM, Becerra JC, Bertot RR, Peláez JC, Liu G, Hurtado CB. 2013. Growth performance, carcass traits and lipid profile of broiler chicks fed with an exogenous emulsifier and increasing levels of energy provided by palm oil. J Food Agric Environ. 11:629–633.

AOAC. 1990. Official methods of analysis. 15th ed. Association of Official Analytical Chemists, Washington, DC, USA.

Blanch A, Barroeta AC, Bauells MD, Serrano X, Puchal F. 1996. Utilization of different fats and oils by adult chickens as a source of energy, lipid and fatty acids. Anim Feed Sci Technol. 61:335–342.

Choc M, Annison G. 1992. The inhibition of nutrient digestion by wheat pentosans. Br J Nutr. 67:123–132.

CIE. 1978. Recommendations on uniform color spaces, color differences, equations. Psychometric color terms. CIE Publication 15, Suppl. 2. Comm. Int. de l’Eclairage, Colorimetry, Paris, France.

Commission of the European Communities. 2005. Laying down minimum rules for the protection of chickens kept for meat production. COM Proposal 221 final.

Dierick NA, Decuyperse JA. 2004. Influence of lipase and/or emulsifier addition on the ileal and faecal nutrient digestibility in growing pigs fed diets containing 4% animal fat. J Sci Food Agric. 84:1443–1450.

Ekstrand C, Carpenter TE, Andersson I, Algers B. 1998. Influence of lipase and/or emulsifier addition on the ileal and faecal nutrient digestibility in growing pigs fed diets containing 4% animal fat. J Sci Food Agric. 84:1443–1450.

European Commission. 2007. Council Directive 2007/43/EC of 28 June 2007 laying down minimum rules for the protection of chickens kept for meat production. Off. J. L182:19–28. (12/07/2007).

Guerrero Neto AC, Pezzato AC, Sartori JR, Mori C, Cruz VC, Fascina VB, Pinheiro DF, Madeira LA, Gonçalvez JC. 2011. Emulsifier in broiler diets containing different fat sources. Rev Bras Cienc Avic. 13:119–125.

Jansen M, Nuyens F, Buyse J, Leleu S, Van Campenhout L. 2015. Interaction between fat type and lyssolecithin supplementation in broiler feeds. Poult Sci. 94:2506–2515.

Jiménez-Moreno E, González-Alvarado JM, González-Serrano A, Lázaro R, Mateos GG. 2009. Effect of dietary fiber and fat on performance and digestive traits of broilers from one to twenty-one days of age. Poult Sci. 88:2562–2574.

Joshi A, Paratkar SG, Thorat BN. 2006. Modification of lecithin by physical, chemical and enzymatic methods. Eur J Lipid Sci Technol. 108:363–373.

Katongole JBD, March BE. 1980. Fat utilization in relation to intestinal fatty acid binding protein and bile salts in chicks of different ages and different genetic sources. Poult Sci. 59:819–827.

Ketels E, De Groote G. 1989. Effect of ratio of unsaturated to saturated fatty acids of the dietary lipid fraction on utilization and metabolizable energy of added fats in young chicks. Poult Sci. 68:1506–1512.

Khonyoung D, Yamauchi K, Suzuki K. 2015. Influence of dietary fat sources and lyssolecithin on growth performance, visceral organ size, and histological intestinal alteration in broiler chickens. Livest Sci. 176:111–120.

Kluth H, Rodehutscord M. 2006. Comparison of amino acid digestibility in broiler chickens, turkeys, and Pekin ducks. Poult Sci. 85:1953–1960.

Krogdahl A. 1985. Digestion and absorption of lipids in poultry. J Nutr. 115:675–685.

Leeson S, Summers JD. 2001. Nutrition of the chicken. 4th rev. ed. Ithaca, NY: University Books, M.L. Scott and Associates.

Lundbaek JA, Andersen OS. 1994. Lysophospholipids modulate channel function by altering the mechanical properties of lipid bilayers. J Gen Physiol. 104:645–673.

Maisonnier S, Gomez J, Brée A, Berri C, Baëza E, Carré B. 2003. Effects of microflora status, dietary bile salts and guar gum on lipid digestibility, intestinal bile salts, and histomorphology in broiler chickens. Poult Sci. 82:805–814.

Mayne RK. 2005. A review of the aetiology and possible causative factors of foot pad dermatitis in growing turkeys and broilers. World Poultry Sci J. 61:256–267.

Melegy T, Khaled NF, El-Bana R, Abdellatif H. 2010. Dietary fortification of a natural biosurfactant, lyssolecithin in broiler. Afr J Agric Res. 5:2886–2892.

Meluzzi A, Fabbri C, Folegatti E, Sirri F. 2008. Survey of chicken rearing conditions in Italy: effects of litter quality and stocking density on productivity, foot dermatitis and carcass injuries. Br Poult Sci. 49:257–264.

Mine Y, Chiba K, Tada M. 1993. Effect of phospholipids on conformational change and heat stability of ovalbumin. Circular dichroism and nuclear magnetic resonance studies. J Agric Food Chem. 41:157–161.

Myers WD, Ludden PA, Nayigihugu V, Hess BW. 2004. Technical note: a procedure for the preparation and quantitative analysis of samples for titanium dioxide. J Anim Sci. 82:179–183.

Nir I, Nitsan Z, Mahagna M. 1993. Comparative growth and development of the digestive organs and of some enzymes in broiler and egg type chicks after hatching. Br Poult Sci. 34:523–532.

Nitsan Z, Ben-Avraham G, Zoref Z, Nir I. 1991. Growth and development of the digestive organs and some enzymes in broiler chicks after hatching. Br Poult Sci. 32:515–523.

Noy Y, Sklan D. 1995. Digestion and absorption in the young chick. Poult Sci. 74:366–373.

Reynier MO, Lafont H, Crotte C, Sauve P, Gerolami A. 1985. Sensory evaluation of lipid bilayers. J Gen Physiol. 104:645–673.

Roy A, Haldar S, Mondal S, Ghosh TK. 2010. Effects of supplemental exogenous emulsifier on performance, nutrient metabolism, and serum lipid profile in broiler chickens. Vet Med Int. 2010. Article ID 262604.

Sabbioni A, Superchi P, Bonomi A, Bonomi BM, Taglietti P, Passeri B. 1997. Effetti dell’associazione di lissolecitina e lipasi sui parametri produttivi dei vitelli a carne bianca. Proc. 51st Congr. SISVet, Bologna, Italy, 51:387–388.

SAS. 1988. Guide for personal computers. Version 6.03 edition. Cary, NC, USA: SAS Inst. Inc.
Schwarzer K, Adams CA. 1996. The influence of specific phospholipids as absorption enhancer in animal nutrition. Lipid/Fett. 98:304–308.
Shier WT, Baldwin JH, Nilsen-Hamilton M, Hamilton RT, Thanassi NM. 1976. Regulation of guanylate and adenylate cyclase activities by lysolecithin. Proc Natl Acad Sci U S A. 73:1586–1590.
Sirri F, Petracci M, Bianchi M, Meluzzi A. 2010. Survey of skin pigmentation of yellow-skinned broiler chickens. Poult Sci. 89:1556–1561.
Soares M, Lopez-Bote CJ. 2002. Effects of dietary lecithin and fat unsaturation on nutrient utilisation in weaned piglets. Anim Feed Sci Technol. 95:169–177.
Sugawara T, Kushi M, Zhang H, Nara E, Ono H, Nagao A. 2001. Lysophosphatidylcholine enhances carotenoid uptake from mixed micelles by Caco-2 human intestinal cells. J Nutr. 131:2921–2927.
Tagesson C, Franzen L, Dahl G, Weström B. 1985. Lysophosphatidylcholine increases rat ileal permeability to macromolecules. Gut. 26:369–377.
Tancharoenrat P, Ravindran V, Zaefarian F, Ravindran G. 2013. Influence of age on the apparent metabolisable energy and total tract apparent fat digestibility of different fat sources for broiler chickens. Anim Feed Sci Technol. 186:186–192.
Xing JJ, Van Heugten E, Li DF, Touchette KJ, Coalson JA, Odgaard RL, Odle J. 2004. Effects of emulsification, fat encapsulation, and pelleting on weanling pig performance and nutrient digestibility. J Anim Sci. 82:2601–2609.
Zaefarian F, Romero LF, Ravindran V. 2015. Influence of high dose of phytase and an emulsifier on performance, apparent metabolisable energy and nitrogen retention in broilers fed on diets containing soy oil or tallow. Br Poult Sci. 56:590–597.
Zhang B, Haitao L, Zhao D, Guo Y, Barri A. 2011. Effect of fat type and lysophosphatidylcholine addition to broiler diets on performance, apparent digestibility of fatty acids, and apparent metabolizable energy content. Anim Feed Sci Technol. 163:177–184.