Use of dietary palm random esterified acid oils with different physicochemical properties in broiler chicks

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Abstract

The aim of this trial was to study the effect of mono- (MG) and diacylglyceride (DG) content, and the effect of fatty acid (FA) positional distribution within the glycerol molecule among different palm random esterified acid oils on growth performance and FA apparent absorption in broiler chickens at early ages.

For this purpose, 96 1-day-old female broiler chicks of Ross 308 strain were randomly distributed into 24 cages. The 4 treatments used were the result of a basal diet supplemented with 6% of palm native oil (PN), palm totally esterified acid oil (PE), palm esterified acid oil low MG and DG (PEL) and palm esterified acid oil high MG and DG (PEH).

As MG and DG content of the oils increased (PE < PEL < PEH), the percentage of solid fat content increased and, in parallel, the ADFI, the ADG, and the final BW decreased (linear, $P < 0.01$), but no differences were found for FCR. No differences were obtained for FA apparent absorption. On the other hand, no effect was observed for the predicted different FA positional distribution within the glycerol molecule between PN and PE treatments.

Introduction

Random esterified acid oils (EO) are obtained from the random chemical esterification of free fatty acids with glycerol (by-products from oil refinement and biodiesel production, respectively). These fat sources, in comparison with their respective native oil, have the same fatty acid (FA) composition, but new physicochemical properties (BERRY, 2009). Their different proportions of mono- (MG), di- (DG) and triacylglycerides (TG), and their different FA positional distribution within the glycerol molecule can give physiological advantages in lipid digestion and absorption processes. For example, it has been reported that MG and DG are emulsifying agents, able to improve fat digestibility and, consequently, the overall digestibility of the diet by enhancing lipase performance and micelle formation (GARRETT et al., 1975). However, as the random chemical esterification process generates fats with complex blends of TG, DG and MG, melting occurs over a wider temperature range, which can negatively affect the digestion and absorption processes of these new fats (BERRY, 2009). Also, it has been found that the random chemical reesterification process of palm native oil increases the proportion of palmitic acid in the TG sn-2 position, which has been related to an increased absorption of this FA due to its easier incorporation into micelles as a 2-MG, compared to its free FA form (MU et al., 2005).

Since the impact of each of these factors is unknown, the aim of this trial was to study the effect of MG and DG content of different palm EO, and the effect of FA positional distribution within the glycerol molecule on growth performance and FA apparent absorption in broiler chickens at early ages.

Material and Methods

96 1-day-old female broiler chicks of Ross 308 strain were randomly distributed into 24 cages (4 animals per cage and 6 replicates per treatment) until 13 days of age. Feed consumption and weight gain were measured weekly to calculate growth performance traits.

From day 7 to 10, a balance study was carried out using the total excreta collection method (BOURDILLON et al., 1990). The 4 treatments used were the result of a wheat and soybean-meal based diet, supplemented with 6% of: palm native oil (PN), palm totally esterified acid oil (PE), palm esterified acid oil low MG and DG (PEL) and palm esterified acid oil high MG and DG (PEH). These experimental fats were delivered by SILO S.p.a., (Firenze, Italy), and allowed assessment of the effect of MG and DG content among EO (PE < PEL < PEH), and the effect of FA positional distribution within the glycerol molecule (PN vs. PE).

Experimental fats were characterized by differential scanning calorimetry (Perkin-Elmer Diamond calorimeter) in order to study their melting profile, nuclear magnetic resonance (^{13}C NMR, 500 MHz, $CDCl_3$, 298 K) in order to know their lipid fraction composition (TG, 1,2-DG, 1,3-DG, 1-MG, 2-MG and FFA), gas chromatography (direct transesterification according to the method of SUKHIJA et al. (1988) and injection in HP 6890) in order to analyze their total FA composition, and adiabatic calorimetry (IKA-Kalorimeter system C4000), in order to know their gross energy content.

Regarding the statistical analysis, the effect of FA positional distribution within the glycerol molecule (PN vs. PE) was analyzed by t-test, and the effect of MG and DG content among EO (PE, PEL and PEH) was assessed by one-way analysis of variance (ANOVA). When ANOVA was significant, values were analyzed for linear and quadratic contrasts (with glycerol to FA ratio as a quantitative factor). All statistical analysis were performed using SAS software.

Results and Discussion

In relation to the characterization of the experimental fats (Table 1), it was observed that all palm oils presented a similar FA profile. On the other hand, as MG and DG content of EO increased (PE: 13.8, PEL: 53.7 and PEH: 83.9 mol %), the glycerol to FA ratio also increased (PE: 0.35, PEL: 0.43 and PEH: 0.58 mol/mol) and, subsequently, the gross energy content decreased (PE: 9,299, PEL: 9,223 and PEH: 8,948 kcal/kg).

The comparison between PN and PE oils, showed that both oils had similar glycerol to FA ratio (PN: 0.32 and PE: 0.35 mol %) and, subsequently, a similar gross energy content (PN: 9,307 and PE: 9,298 kcal/kg). However, PN presented a higher percentage of free fatty acids (FFA) than PE.

Table 1: Characterization of the experimental palm oils[1]

	PN	PE	PEL	PEH
Lipid fractions[2] (mol %)				
TG	46.9	86.2	46.3	16.2
DG	19.2	13.8	44.4	46.5
1,2-DG	2.3	1.7	9.7	14.1
1,3-DG	16.9	12.1	34.7	32.4
MG	2.8	0.0	9.3	37.4
1-MG	2.8	0.0	9.3	35.0
2-MG	0.0	0.0	0.0	2.3
FFA	31.0	0.0	0.0	0.0
Glycerol:Fatty acid ratio	0.32	0.35	0.43	0.58
Fatty acid composition (%)				
C16:0	44.5	44.9	40.7	43.3
C18:0	4.2	4.5	8.0	4.4
C18:1-n9 *cis*	38.4	39.5	39.5	39.0
C18:2-n6 *cis*	10.2	8.7	7.9	8.9
C18:3-n3 *cis*	0.3	0.1	0.2	0.3
Others	2.6	2.3	3.2	4.0
Gross energy (kcal/kg)	9,307	9,298	9,223	8,947

[1]PN: Palm native oil; PE: Palm totally esterified acid oil; PEL: Palm esterified acid oil low MG and DG; PEH: Palm esterified acid oil high MG and DG.
[2]TG: Triacylglycerides; DG: Diacylglycerides; MG: Monoacylglycerides; FFA: Free fatty acids.

Furthermore, the melting profile of the oils determined by differential scanning calorimetry (Figure 1) showed how, as MG and DG content of EO increased, oils started to melt earlier and finished to melt later, expanding their melting range (PE: -20 to 40, PEL: -35 to 45, and PEH: -50 to 50 ºC) due to their complex blends of MG, DG and TG. However, the comparison between PN and PE showed that both oils had the same melting profile and the same melting range, but PN started and finished to melt earlier than PE (PN: -25 to 35 and

PE: -20 to 40 ºC). This difference is related to the optimized crystallization behavior of EO, since the random chemical esterification process generates more stable crystalline forms (BERRY, 2009).

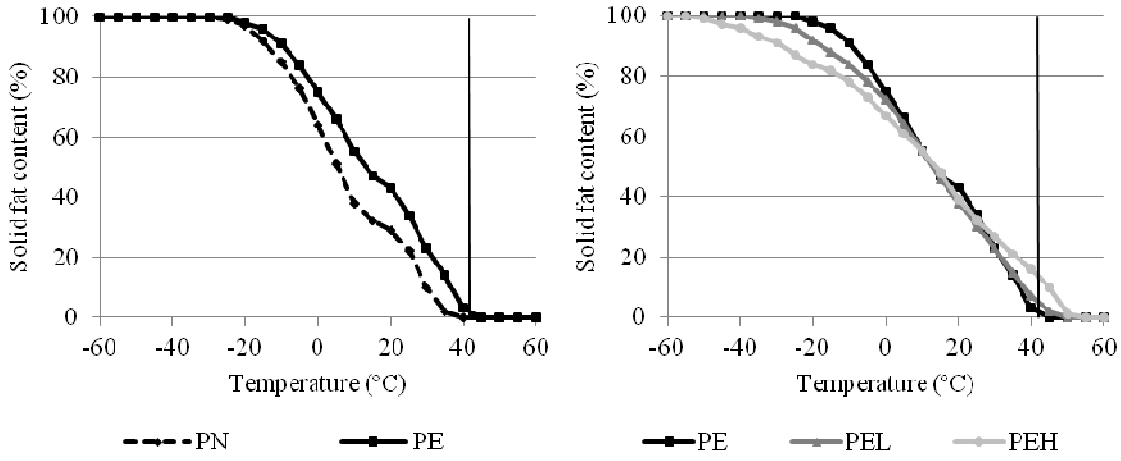

Figure 1: Solid fat content of the experimental palm oils measured at different temperatures

Regarding growth performance traits (Table 2), differences were only found for MG and DG effect. As MG and DG content increased, the average daily feed intake, the average daily gain, and the final body weight decreased (linear, $P < 0.01$), but no differences were found for feed conversion ratio ($P > 0.05$). These results are in agreement with those obtained by KAMPHUIS et al. (2003), who observed that women fed a high-DG diet showed an improved appetite control, due to an increased fat oxidation, and MENG et al. (2004), who observed that rats fed a high-DG diet resulted in a significant reduction in body weight gain, due to an increased intestinal fat oxidation.

On the other hand, no differences were observed for the FA positional distribution effect ($P > 0.05$), according to the results obtained in broiler chickens by other authors (LIN et al., 2010 and SMINK et al., 2008), whose studies did not find growth performance improvements despite the increased proportion of SFA located in the sn-2 position of TG.

Table 2: Growth performance according to different dietary palm oils

	Dietary treatments[1]				SEM[2]	*P*-values			
	PN	PE	PEL	PEH		FA positional distribution effect PN *vs.* PE	MG and DG effect PE *vs.* PEL *vs.* PEH		
Glycerol:Fatty Acids	0.32	0.35	0.43	0.58					
Item[3]							ANOVA	linear	quadratic
BW at 0 d (g)	46.6	46.6	46.6	46.6	0.06	1.000	1.000	-	-
ADFI (g/bird per d)	32.9	33.8	32.4	30.8	0.65	0.393	0.003	0.001	0.618
ADG (g/bird per d)	24.1	23.8	22.6	22.1	0.64	0.843	0.019	0.009	0.281
FCR (g/g)	1.37	1.42	1.43	1.40	0.028	0.242	0.692	-	-
BW at 13 d (g)	359	357	342	337	9.1	0.911	0.021	0.012	0.193

[1]Diets with 6% of palm native oil (PN), palm totally esterified acid oil (PE), palm esterified acid oil low MG and DG (PEL) or palm esterified acid oil high MG and DG (PEH).
[2]SEM: Standard error of the mean of 6 observations per treatment (the experimental unit is the cage).
[3] BW: Body weight; ADFI: Average daily feed intake; ADG: Average daily gain; FCR: Feed conversion ratio.

The effects of treatments on the apparent digestibility are presented in Table 3. No differences were observed among EO ($P > 0.05$), in agreement with the results obtained in rats by other authors (MENG et al., 2004 and TAGUCHI et al., 2001), although we observed a systematic numerical decrease in the FA apparent digestibility, as MG and DG content

increased. These findings may be explained as a consequence of the counteraction of the beneficial effect that can exert MG and DG as emulsifying agents, by the detrimental effect that may have the increased solid fat content of EO at chicken's body temperature (PE: 1, PEL: 6 and PEH: 16 % at 41.5ºC), as its MG and DG content increased.

On the other hand, the FA apparent absorption results for PN and PE treatments, were neither significantly different ($P > 0.05$), in agreement with SMINK et al. (2008), but in contrast with our initial hypothesis and the results from LIN et al. (2010), who found an increase in the apparent absorption of total FA, saturated FA, monounsaturated FA and polyunsaturated FA. Thus, in this study seems that changing the FA positional distribution within the glycerol molecule had no benefit on FA apparent absorption, even in contrast with a PN with a substantial FFA content, which is well known that can compromise its fat digestibility (WISEMAN et al., 1991).

Table 3: Fatty acid apparent absorption (%) according to different dietary palm oils

	Dietary treatments[1]				SEM[2]	*P*-values	
	PN	PE	PEL	PEH		FA positional distribution effect	MG and DG effect
Glycerol:Fatty Acids	0.32	0.35	0.43	0.58		PN *vs.* PE	PE *vs.* PEL *vs.* PEH
Item[3]							
Total FA	53.8	47.9	47.5	38.9	5.05	0.490	0.296
SFA	44.9	39.0	41.1	31.5	4.89	0.463	0.261
C16:0	46.6	40.8	41.8	32.7	4.79	0.461	0.254
C18:0	31.9	25.3	27.3	17.1	5.48	0.466	0.294
MUFA	61.5	54.9	53.9	43.8	5.47	0.485	0.228
C18:1-n9 *cis*	62.2	55.7	54.6	45.3	5.34	0.479	0.256
PUFA	58.6	53.6	51.2	45.8	4.94	0.548	0.466
C18:2-n6 *cis*	58.3	53.2	50.7	45.2	4.99	0.546	0.456
C18:3-n3 *cis*	63.9	58.5	57.1	52.6	4.11	0.430	0.528

[1]Diets with 6% of palm native oil (PN), palm totally esterified acid oil (PE), palm esterified acid oil low MG and DG (PEL) or palm esterified acid oil high MG and DG (PEH).
[2]SEM: Standard error of the mean of 6 observations per treatment (the experimental unit is the cage).
[3]FA: Fatty acids; SFA: Saturated FA; MUFA: Monounsaturated FA; PUFA: Polyunsaturated FA.

Conclusions

Increasing the MG and DG content of palm esterified acid oils had no effect on feed conversion ratio, in accordance to the similar FA apparent absorption, although animals achieved lower final body weights, due to their lower feed intake.

The changes in the FA positional distribution within the glycerol molecule between palm native oil and palm totally esterified acid oil had no effect on FA apparent absorption, and animals achieved the same performance results.

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