

Article

Soybean Oil Replacement by Palm Fatty Acid Distillate in Broiler Chicken Diets: Fat Digestibility and Lipid-Class Content along the Intestinal Tract

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Simple Summary: Palm fatty acid distillate is a by-product of palm oil refining. It is of both environmental and economic interest to include it in the diets of broiler chickens. However, its high saturation degree and acidity level limit its use. This study aimed to assess the effect of replacing soybean oil with increasing levels of palm fatty acid distillate on the utilization of fat by broilers. Dietary fat hydrolysis was mostly affected by the age of the bird and including palm fatty acid distillate mainly affected the absorption process. The replacement of soybean oil by palm fatty acid distillate reduced the total fat utilization, and in starter chicks delayed the site of fatty acid absorption. As the age increased, the digestibility of saturated fatty acids improved, and, above all, it improved the free fatty acid utilization. Therefore, the potential inclusion of palm fatty acid distillate for broiler feeds depends on the age of the bird. It would not be recommended to include this by-product in starter feeds. However, for the grower-finisher phase, blending palm fatty acid distillate with soybean oil (1:3, w/w) could be a suitable alternative, that does not have negative repercussions for either fatty acid absorption or growth performance.

Table S1. Lipid-class content according to different intestinal segments and excreta in 11- and 35-day-old broiler chickens.

Item	Intestinal Segment and Excreta ¹				<i>p</i> -Values		
	Upper Jejunum	Lower Jejunum	Upper Ileum	Lower Ileum	Excreta	SEM	P
11-day-old broiler chickens							
TAG	0.44 ^a	0.35 ^{ab}	0.26 ^b	0.28 ^b	0.32 ^b	0.022	<0.001
DAG	1.83 ^a	0.88 ^{bc}	0.68 ^{bc}	0.63 ^c	1.05 ^b	0.097	<0.001
MAG	0.18 ^{ab}	0.18 ^{ab}	0.15 ^b	0.22 ^a	0.16 ^b	0.014	0.004
FFA	15.22 ^a	8.70 ^b	7.67 ^b	7.64 ^b	8.93 ^b	0.913	<0.001
35-day-old broiler chickens							
TAG	0.21 ^a	0.22 ^a	0.13 ^{bc}	0.09 ^c	0.16 ^{ab}	0.015	<0.001
DAG	1.58 ^a	0.60 ^b	0.18 ^c	0.15 ^c	0.17 ^c	0.062	<0.001
MAG	0.25 ^a	0.20 ^{ab}	0.13 ^c	0.17 ^{bc}	0.12 ^c	0.015	<0.001
FFA	10.06 ^a	5.29 ^b	2.60 ^c	2.54 ^c	2.78 ^c	0.417	<0.001

¹ Values are pooled means of 30 replicates from chickens fed diets at 11-day-old ($n = 150$) or 35-day-old ($n = 150$). TAG = triacylglycerols; DAG = diacylglycerols; MAG = monoacylglycerols; FFA = free fatty acids. SEM = standard error of the mean. *p*-Values were obtained from univariate ANOVA conducted for each age to study whether the intestinal segment (or excreta) affected the lipid-class content. a–c: means in a row not sharing a common letter are significantly different ($p < 0.05$).

Table S2. Lipid-class content in the lower ileum according to different fat sources in the diet in 11- and 35-day-old broiler chickens.

Item	Dietary Treatments ¹										<i>p</i> -Values									
	11-day-old broiler chickens					35-day-old broiler chickens					S6		S4-PA2		S2-PA4		PA6		P6	
	S6	S4-PA2	S2-PA4	PA6	P6	S6	S4-PA2	S2-PA4	PA6	P6	SEM	P	SEM	P	SEM	P	SEM	P	SEM	P
TAG	0.32	0.29	0.27	0.33	0.19	0.09	0.11	0.09	0.07	0.07	0.020	<0.001	0.044	0.015	0.029	0.001	0.051	0.006	0.021	0.002
DAG	0.64	0.60	0.76	0.71	0.45	0.14	0.17	0.11	0.18	0.17	0.069	<0.001	0.052	<0.001	0.072	<0.001	0.032	<0.001	0.071	0.021
MAG	0.23	0.25	0.25	0.23	0.15	0.13	0.14	0.21	0.21	0.15	0.014	<0.001	0.036	0.051	0.027	0.384	0.027	0.483	0.019	1.000
FFA	3.02	5.23	8.78	12.70	8.47	0.87	1.32	2.77	4.82	2.92	0.252	<0.001	0.290	<0.001	0.443	<0.001	0.212	<0.001	0.574	<0.001

¹Values are pooled means of 6 replicates from chickens fed diets supplemented with 6% of soybean oil (S6), palm fatty acid distillate (PA6), palm oil (P6), or oil blends with 4% soybean oil and 2% palm fatty acid distillate (S4-PA2) or 2% soybean oil and 4% palm fatty acid distillate (S2-PA4). TAG = triacylglycerols; DAG = diacylglycerols; MAG = monoacylglycerols; FFA = free fatty acids. SEM = standard error of the mean. *p*-Values were obtained from univariate ANOVA conducted for each dietary treatment to study whether the age affected the lipid-class content ($n = 12$). $p < 0.05$ was considered significant.

Table S3. Feed apparent metabolizable energy value and apparent fatty-acid digestibility coefficients in the lower ileum according to different fat sources in the diet in 11- and 35-day-old broiler chickens.

Item	Dietary Treatments ¹										<i>p</i> -Values									
	11-day-old broiler chickens					35-day-old broiler chickens					S6		S4-PA2		S2-PA4		PA6		P6	
	S6	S4-PA2	S2-PA4	PA6	P6	S6	S4-PA2	S2-PA4	PA6	P6	SEM	P	SEM	P	SEM	P	SEM	P	SEM	P
AME, kcal/kg ²	3348	3340	3074	2760	3014	3364	3379	3212	3121	3279	24.64	0.656	30.21	0.381	23.86	0.002	35.64	<0.001	31.27	<0.001
<i>FA digestibility</i>																				
TFA	0.79	0.73	0.65	0.41	0.62	0.92	0.92	0.82	0.76	0.84	0.011	<0.001	0.011	<0.001	0.019	<0.001	0.012	<0.001	0.022	<0.001
SFA	0.69	0.55	0.47	0.18	0.49	0.90	0.90	0.71	0.64	0.78	0.011	<0.001	0.023	<0.001	0.018	<0.001	0.016	<0.001	0.026	<0.001
MUFA	0.76	0.74	0.71	0.56	0.74	0.93	0.93	0.88	0.88	0.93	0.010	<0.001	0.011	<0.001	0.022	<0.001	0.012	<0.001	0.026	<0.001
PUFA	0.83	0.83	0.79	0.68	0.75	0.93	0.93	0.87	0.85	0.83	0.011	<0.001	0.011	<0.001	0.026	0.050	0.021	<0.001	0.028	0.056

¹Values are pooled means of 6 replicates from chickens fed diets supplemented with 6% of soybean oil (S6), palm fatty acid distillate (PA6), palm oil (P6), or oil blends with 4% soybean oil and 2% palm fatty acid distillate (S4-PA2) or 2% soybean oil and 4% palm fatty acid distillate (S2-PA4). AME = apparent metabolizable energy, TFA = total fatty acids, SFA = saturated fatty acids, MUFA = monounsaturated fatty acids, PUFA = polyunsaturated fatty acids, SEM = standard error of the mean. *p*-Values were obtained from univariate ANOVA conducted for each dietary treatment to study whether the age affected the feed AME values, and the FA digestibility results (*n* = 12). *p* < 0.05 was considered significant.

Table S4. Contribution of each intestinal segment to FA absorption according to the age of the chicken.

Item	Age (days) ¹		<i>p</i> -Value	
	11	35	SEM	Age
Upper jejunum				
TFA	48.25	45.93	5.542	0.577
Palmitic	41.33	49.70	4.742	0.234
Stearic	-	-	-	-
Oleic	51.71	60.56	4.272	0.168
Linoleic	47.50	35.14	6.472	0.138
Lower jejunum				
TFA	36.24	37.85	5.09	0.735
Palmitic	39.38	36.87	4.753	0.521
Stearic	52.89	65.55	4.783	0.069
Oleic	33.00	29.31	3.957	0.342
Linoleic	37.68	40.06	5.283	0.872
Upper ileum				
TFA	5.52	12.36	1.299	<0.001
Palmitic	6.40	9.55	1.755	0.293
Stearic	18.80	24.73	3.863	0.380
Oleic	7.27	7.50	1.076	0.999
Linoleic	6.92	19.44	1.683	<0.001
Lower ileum				
TFA	9.99	3.86	1.206	<0.001
Palmitic	12.89	3.88	1.882	<0.001
Stearic	28.32	9.72	3.590	<0.001
Oleic	8.02	2.62	1.040	<0.001
Linoleic	7.90	5.36	0.984	0.089

¹Values are means of 30 replicates from chickens fed diets at 11-day-old or 35-day-old. TFA = total fatty acids. SEM = standard error of the mean. *p*-Values were obtained from univariate ANOVA conducted for each intestinal segment to study whether the age affected the FA absorption ($n = 60$). $p < 0.05$ was considered significant.