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Apparent and true digestibility of palm oil (*Elaeis guineensis*), chicken oil, and Sacha inchi oil (*Plukenetia volubilis*) with three inclusion levels in diets for broiler chickens

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Abstract

With the intention of evaluating the fecal and ileal digestibility of crude palm oil (*Elaeis guineensis*), chicken oil, and Sacha inchi oil (*Plukenetia volubilis*) at inclusion levels of 3%, 6%, and 9%, a total of 480 female Ross 308 broiler chickens were used. Digestibility was assessed at 21 days of age for both the diets and the fat sources. Total collection or the indicator method with chromium oxide was used for fecal digestibility, while the indicator method was used for ileal digestibility. The inclusion of the three levels of the evaluated sources was based on the substitution method of the core composed of corn and soybean. A fat-free diet was used to estimate the true digestibility of fat in the evaluated sources. The experiment was conducted in a 3*3 factorial arrangement. The treatments with the sources and inclusion levels were randomly assigned. Each treatment had six repetitions with eight birds per repetition. The results showed that the apparent digestibility of fat in the experimental diets was affected by the source and the interaction between the source and inclusion level. Only in the fecal digestibility obtained through the total collection technique, the inclusion level of the source in the diet did not have an effect. In the digestibility of the evaluated sources, it was determined that as the inclusion level of the source increased, the true digestibility of the source also increased.

Keywords: Palm oil; Chicken oil; Sacha inchi; Broiler; Digestibility coefficient; True digestibility

1. Introduction

In the poultry industry, the cost of including energy-providing ingredients is high due to the sector's low autonomy in production, access, and price regulation of cereals. Cereal prices depend on significant factors such as geopolitics or climate, which results in higher consumer prices. In this context, the evaluation of alternative feed options that offer solutions to nutritionists in designing competitive diets without compromising performance indices becomes important. Fats and oils, as sources of high energy concentration, are alternatives to consider as partial substitutes for cereals. Digestibility is one of the available options for nutritional evaluation of ingredients. It measures the disappearance of chemical fractions, nutrients, and energy of ingredients in the gastrointestinal tract (GIT). Part of this disappearance can be considered to be due to or explained by absorption, but not everything that disappears does so through absorption. Digestibility is an expression of the interaction between animal conditions, primarily referring to the gastrointestinal tract (GIT), food characteristics, the adopted evaluation method, and the use of additives such as emulsifiers for fats and oils. Digestibility, therefore, reflects the interaction of these components.

In any digestibility study of fats or oils, whether ileal or fecal, the gastrointestinal tract (GIT) contributes fatty acids to the ileal or fecal contents. Estimating these contributions and including them in the correction of digestibility estimation transforms it into true digestibility. In birds, there are limited studies to estimate the endogenous fat contributions from the GIT2. In a study conducted by Tancharoenrat *et al* (2014)[20], it was reported that ileal endogenous losses of fat and fatty acids (FA) were 1714 and 825 mg/kg of ingested dry matter, respectively. The main identified endogenous

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saturated FAs in the ileal contents were palmitic and stearic acid, while the unsaturated FAs were oleic, linoleic, and arachidonic acid (Carew *et al*., 1972)[3]. In digestibility studies, two strategies for collecting ileal contents or excreta can be chosen: total or partial collection. In the partial collection of excreta or in the collection of contents in the terminal ileum, the inclusion of an indicator is mandatory, which can be internal or external. In summary, in digestibility studies, there are several options: fecal or ileal, apparent or true, with total or partial collection, with or without the use of indicators (Ajuyah et *al.,* 1996)[1] and (Jallier *et al*., 2003)[8.]

Multiple factors affect the digestibility of fats and fatty acids (FAs). Katongole *et al* (1980); Jallier *et al* (2003)[8] and Tancharoenrat *et al* (2013)[21] indicated that bird age, type of fat, and diet composition an important play a role. Meanwhile, Díaz & Ceroni da Silva (2006)[5] and Ortiz *et al* (2008)[14] referred to factors such as chain length of FAs, degree of unsaturation, melting point, and composition of triacylglycerols (TAG) FAs as factors affecting digestibility. For over 40 years, it has been known that young chickens have a lower capacity to absorb fat from corn oil and tallow. In the case of corn oil, this capacity increased from 84% to 95% between the first and second week of life by Tancharoenrat *et al* (2013)[21]. The increase was more pronounced for tallow, which went from 40% to 79% between the first and second week of life (Carew *et al*., 1972)[3].

It can be stated that in their early days of life, chickens have anatomical, physiological, and biochemical limitations for the complete digestion of fats and subsequent absorption of fatty acids (FAs). These limitations are associated with the lower production and concentration of pancreatic lipase (PL) and the deficient enterohepatic circulation of bile salts by Ashild *et al* (1985)[2], factors that lead to poor emulsification of fats and micelle formation, which is an essential prerequisite for proper FA absorption regardless of the maturity of intestinal villi (Wu & Ravindran, 2004)[23]. Noy & Sklan (1998)[13] and Ortiz *et al* (2008)[14] indicated that the secretion of PL, trypsin, and pancreatic amylase increased 20 to 100 times between day 4 and 21 of age, with PL showing the slowest increase in activity by Noy & Sklan (1998)[13]. Similarly, in young birds, the synthesis of fatty acid-binding protein (FABP), a protein carrier for FAs, is insufficient but increases after the fourth week of life (Tancharoenrat *et al*., 2013)[21]. FABP binds to FAs, preferably unsaturated long-chain FAs. In birds, FABP is highly concentrated in the proximal portion of the intestine and decreases towards the distal part (Ashild *et al*., 1985)[2]; (Díaz & Ceroni da Silva, 2006)[5]; (Osorio & Flórez, 2011)[15] and Ravindran *et al*., 2016)[16].

The objective of this study was to determine the apparent and true ileal and fecal digestibility of fat from palm oil (*Elaeis guineensis*), chicken oil, and Sacha inchi oil (*Plukenetia volubilis*) at inclusion levels of 3%, 6%, and 9% using the total collection and indicator techniques.

2. Material and methods

2.1. Location

The experiment was conducted at the San Pablo Agricultural Station, which belongs to the National University of Colombia, Medellín Campus. It is located in the municipality of Rionegro, 52 km away from Medellín, the capital of the Antioquia department, Colombia. The farm is situated at an altitude of 2100 meters above sea level (m.a.s.l.), with coordinates 6°07'51.3"N and 75°27'19.1"W. According to the Holdridge (1978)[7] life zone classification system, the station is located in the very humid lower montane forest life zone (bmh-MB). The average temperature ranges from 12 to 18°C, and the annual rainfall is approximately 2280 mm. The relative humidity is around 75.5% during the night and early morning hours.

2.2. Animals and Housing

A total of 480 female Ross 308 broiler chicks from a commercial hatchery were used in the study. An experimental poultry house measuring 126 m2 was used, with an east-west orientation, natural ventilation, and curtain management. The chicks were housed in a cement floor pen within this poultry house for the first 12 days of age. The pen provided constant heating to maintain an average temperature of 30°C. The chicks had ad libitum access to water and were fed a commercial diet formulated for their age. They also received vaccinations against infectious bronchitis, Newcastle disease, and infectious bursal disease (Gumboro). At 12 days of age, the chicks were transferred to another poultry house and housed in 60 cages of a horizontal battery system, with each cage measuring 0.7 m in length, 0.75 m in width, and 0.6 m in height. Heating was provided using gas heaters, and ventilation was managed through curtains to maintain the appropriate temperature for the age of the chicks. During the two additional days in the battery cages, the chicks were fed the same commercial diet they had been consuming in the floor pen. From day 14 to 21 of age, the chicks were fed the experimental diets.

2.3. Diets

To estimate the endogenous fat contributions from the gastrointestinal tract, a fat-free diet (FFD) was used. This information was used to estimate the true fecal and ileal digestibility of the fat from the evaluated sources. The proximate and nutritional composition of the fat-free diet is shown in Table 1.

Table 1 Proximate composition of the fat-free diet

Ingredient	**kg/100 kg of diet**
Maltodextrin	71.70
WPC-80 (Whey Protein Concentrate 80%)	20.00
Carboxymethylcellulose	3.50
Monodicalcium phosphate	1.50
Calcium carbonate	0.30
Sea salt	0.50
Commercial chromium oxide	0.50
Mineral and vitamin premix1	2.00
TOTAL	100
Chemical composition of fat-free diet (g/kg Dry matter)	
Moisture and other volatile matter	5.70
Fat content	0.35
Nitrogen content	1.70
Calcium	0.68
Phosphorus	0.15

[1] Vitamin A 11,000,000 IU, Vitamin D 2,500,000 IU, Vitamin E 12,000 mg, Vitamin K 3,000 mg, Thiamine 1,300 mg, Riboflavin 5,000 mg, Niacin 60,000 mg, Pantothenic acid 11,100 mg, Pyridoxine 2,000 mg, Biotin 50 mg, Vitamin B12 11 mg, Folic acid 600 mg, Choline chloride 60% 500,000 mg, Zinc 76,000 mg, Manganese 76,000 mg, Copper 8,000 mg, Iron 60,000 mg, Iodine 800 mg, Selenium 300 mg, Antioxidant 100,000 mg, Maximum moisture 5%.

To estimate the digestibility of the fat from the evaluated oils, a reference diet without the inclusion of any oil or fat source was used, along with nine diets corresponding to the three oils and the three inclusion levels. The proximate and nutritional composition of these diets is recorded in Table 2.

Table 2 Proximate and nutritional composition of the diets with the employed sources

Ingredient (kg/100 kg diet)	**Experimental diets**								
	Palm oil			**Chicken oil**			**Sacha inchi oil**		
Corn kernel and soybean cake	92.10	89.10	86.20	92.10	89.10	86.20	92.10	89.10	86.20
Source evaluated	2.90	5.90	8.80	2.90	5.90	8.80	2.90	5.90	8.80
Phosphorus source	1.7								
Calcium carbonate	1.5								
Chromium oxide	0.5								
Sea salt	0.3								
L-Lysine HCL 99% (Alys® 99)	0.3								
DL-Methionine	0.25								

L-Threonine 98.5%.	0.2								
Vitamin and mineral premix[1]	0.25								
Total	100								
Chemical composition of the experimental diets (g/kg Dry Matter)									
	3%	**6%**	**9%**	**3%**	**6%**	**9%**	**3%**	**6%**	**9%**
Moisture and other volatile matter	13.2	12.7	11.4	12.0	11.6	11.3	11.7	11.3	11.11
Fat content	6.69	9.73	12.2	7.24	9.38	12.47	6.44	9.53	12.46
Nitrogen	3.25	3.00	3.00	3.20	3.00	2.90	3.00	3.10	2.75
Calcium	1.16	1.26	1.15	1.25	1.06	1.08	1.18	1.14	1.12
Phosphorus	0.65	0.75	0.78	0.79	0.80	0.80	0.85	0.70	0.73

[1]Vitamin A 11,000,000 IU, Vitamin D 2,500,000, Vitamin E 12,000 mg, Vitamin K 3,000 mg, Thiamine 1,300 mg, Riboflavin 5,000 mg, Niacin 60,000 mg, Pantothenic acid 11,100 mg, Pyridoxine 2,000 mg, Biotin 50 mg, Vitamin B12 11 mg, Folic acid 600 mg, Choline chloride 60% 500,000 mg, Zinc 76,000 mg, Manganese 76,000 mg, Copper 8,000 mg, Iron 60,000 mg, Iodine 800 mg, Selenium 300 mg, Antioxidant 100,000 mg, Maximum humidity 5%.

The diets were prepared in the Concentrate Laboratory located at the same agricultural station. They were provided in the form of flour and at levels that ensured a constant presence of feed in the feeders. Each week, the remaining feed in the feeder was weighed to estimate the diet consumption.

2.4. Laboratory analysis

In the last three days of the experimental period, excreta collection was carried out. On the final day, the birds from each repetition were sacrificed, and the contents of the distal ileum were collected as described by Tancharoenrat *et* al (2014)[20]. Both the excreta and ileal contents were grouped by repetition and frozen for subsequent chemical analysis. The cervical dislocation technique was used for euthanasia, taking care not to apply pressure to the abdominal region to avoid accidentally extracting the ileal content. This technique was approved by the ethics committee of the National University of Colombia, Medellin campus, under code CEMED-006 (2016).

Analysis of certain parameters of oil quality was conducted at the Food Science Laboratory of the Faculty of Sciences, National University of Colombia, Medellin campus. Regarding the fatty acid profiles, analysis was performed at the Instrumental Analysis Laboratory of the same faculty. Fatty acids were evaluated using an Agilent Technologies gas chromatograph, model 6890N®. The sample underwent a procedure using hexane, and the obtained extract was treated following the methodology NTC 4967 (2014) for the preparation of fatty acid methyl esters.

In the Chemical and Bromatological Analysis Laboratory of the National University of Colombia, the diets, unconsumed feed collected from the feeders, excreta, and ileal contents were dried in a forced-air oven at 60 °C for 72 hours. They were then ground, passed through a 1 mm sieve, and subjected to laboratory analysis. The diets and feed leftovers were analyzed for moisture and other volatile matter content (thermogravimetric method at 105°C ± 2°C; ISO-6496, 1992) to estimate the dry matter intake. The diets were also analyzed for crude protein content using the Kjeldahl method (ICONTEC, 2022; NTC - 4657), fat content with prior hydrolysis using HCl (ICONTEC, 2001), calcium and chromium (Atomic absorption spectrometry), and phosphorus (UV-VIS spectrometry). The ileal contents and excreta samples were analyzed for moisture and other volatile matter content, fat content with prior hydrolysis using HCl, and chromium content. The chromium content of the chromium oxide used as an indicator was also analyzed.

2.5. Estimation of digestibility

2.5.1. Of the diets

The estimation of the apparent fecal digestibility of dietary fat (AFDFD) and ileal digestibility (AIDFD) was conducted according to the following model:

% AFDFD (total collection technique) = [(fat intake - fecal fat) / fat intake)] *100

% AFDFD (indicator technique) = [(dietary fat - (fecal fat * FI)) / dietary fat] *100

% AIDFD (indicator technique) = [(dietary fat - (ileal fat content * FI)) / dietary fat] *100

Where FI represents the indigestibility factor of the indicator, which is estimated as the ratio of % Cr Diet / % Cr Feces.

The chromium content of the chromium oxide used was 897.94 g/100 g of the sample.

2.5.2. Of the oils

For each oil and substitution level, the apparent fecal digestibility (AFDAoil) or ileal digestibility (AIDAoil) was estimated according to the following model:

AFDAoil or AIDAoil = (AFDRAoil or AIDRAoil - ((AFDR or AIDR * RDA))/A

Where:

AFDA oil or AIDA oil represents the apparent fecal or ileal digestibility of the diet containing the evaluated oil.

AFDRA oil or AIDRA oil represents the apparent fecal or ileal digestibility of the reference diet.

AFDR or AIDR represents the apparent fecal or ileal digestibility of the reference diet.

RDA corresponds to the percentage of the reference diet in the diets that contained the evaluated oils.

A is the substitution level of the evaluated oils.

2.6. Statistical Analysis

The experiment was conducted in a setup with three oil sources and three inclusion levels per source. The diets resulting from the interaction of these two factors were randomly assigned. Each diet had six replicates with eight birds per replicate. The analysis of variance for the studied variables was performed using the General Linear Model (GLM) procedure. Mean comparisons were conducted using the SNK test. All statistical analyses were carried out using SAS Version 9 software.

3. Results and Discussion

For palm oil, the values obtained for both the evaluated quality parameters and the determined levels of fatty acids are either close to or within the records of the Colombian Technical Standard 431 (ICONTEC, 2017)[12]. These values were compared with studies conducted by Chiu *et al* (2002)[4] and information from the Spanish Federation for the Development of Animal Nutrition. They reported an iodine value of 79.1 for chicken oil, which is higher than the value recorded in this study (12.9); equal for the saponification values, the value obtained in the analyses is similar to value of 196.9.

Table 3 presents the results of the analysis for some quality parameters and the fatty acid profile of each evaluated fat source.

Table 3 Results of the analysis for some quality parameters and fatty acid profile of the evaluated fat sources

Parameter	**Palm oil**	**Chicken oil**	**Sacha inchi oil**
Peroxide value (mEq.oxygen/kg sample)	1.2	8.5	3.5
Saponification index (mg KOH/g sample)	208.3	194.1	207.7
Iodine value (g of I^2/ 100 g of sample)	55.9	12.9	140.4
Acid number (% oleic acid)	3.5	1.4	0.6
FATTY ACIDS (g AG/100 g sample)			
C16:0 Palmitic	35.41	18.66	4.26
C18:0 Stearic	3.75	5.46	2.96

C18:1 Oleic	36.68	30.64	9.29
C18:2 n6 Linoleic	7.91	21.15	33.91
C18:3 n3 Linolenic acid	1.3	2.8	54.23

In the samples of chicken oil, differences were identified in the total saturated fatty acids compared to Chiu *et al* (2002)[4] publication, which was close to 60%, while in this study, it was 54.5%. The chicken fat samples showed contents between 45% and 50% of oleic and linoleic acids by Chiu *et al* (2002)[4]; Liu *et al* (2014)[10] and Ming & Sotero (2002)[11]. Based on this information, it can be considered that the fatty acids in this fat are monounsaturated. Due to its high content of palmitic acid, palm oil can be classified as a source of saturated fatty acids, while Sacha inchi oil, with over 90% of unsaturated acids, is considered a polyunsaturated source. The lipid profile of palm oil falls within the parameters reported by NTC 431 (2011)[12], and the Sacha inchi profile shows similar data to those reported by Gutiérrez *et al* (2011)[6] and Liu *et al* (2014)[10].

3.1. Apparent digestibility of the dietary fat

Table 4 presents the results of the apparent digestibility coefficients of the experimental diets' fat.

Table 4 Values of apparent digestibility coefficients of the experimental diets' fat

Fat source	**Fecal digestibility**		**Ileal digestibility**
	Total collection technique	**Indicator technique**	
Oil source	P<0.01	P<0.01	P<0.01
Palm	80.31[b]	74.94[b]	76.61[b]
Chicken	86.36[a]	78.37[a]	84.45[a]
Sacha inchi	88.04[a]	78.47[a]	86.03[a]
Dietary oil level	P>0.05	P<0.01	P<0.05
3	84.44	56.62[c]	80.81[b]
6	84.89	80.68[b]	82.09[a,b]
9	85.38	94.48[a]	84.19[a]
Source * Level of inclusion (%)	P<0.05	P<0.01	P<0.01
Palma. 3	81.80[c]	53.66[f]	77.99[d]
Palm. 6	80.15[c,d]	78.92[d]	77.16[d]
Palma. 9	78.96[d]	92.25[b]	74.69[d]
Chicken. 3	85.04[b]	61.55[e]	82.79[c]
Chicken. 6	85.80[b]	78.62[d]	83.60[b]
Chicken. 9	88.25[a]	94.94[a]	86.94[b]
Sacha inchi. 3	86.48[a]	54.64[f]	81.65[c]
Sacha inchi. 6	88.72[a]	84.51[c]	85.52[b]
Sacha inchi. 9	88.92[a]	96.26[a]	90.04[a]
Coefficient of Variation (%)	2.65	2.00	4.11
Root MSE	2.65	2.00	2.65
Pr>F	<0.0001	<0.0001	<0.0001

[a, b, c] Different letters within the same column indicate significant differences (P<0.05).

The results show that the statistical analysis model used was significant for all three expressions of digestibility, and the coefficient of variation for digestibility was low. Only in fecal digestibility obtained through the total collection technique, there was no effect of the inclusion level of the fat source in the diet. However, for the other expressions of digestibility, there was an effect of the source, inclusion level, and the interaction between these two factors.

Regarding the interactions, the fecal digestibility values obtained through the total collection technique showed less variation (ranging from 78.96% to 88.92%) compared to fecal digestibility using the indicator technique (ranging from 53.66% to 96.26%) or ileal digestibility (ranging from 74.69% to 90.04%). It is observed that fecal digestibility estimated using the indicator technique generated the lowest value, and the highest value corresponded to diets with 3% palm oil and 9% Sacha inchi. The comparison of average digestibility values across the three expressions (fecal using both techniques and ileal) shows no specific trend, which can be interpreted as a reflection of the source, inclusion level, and the digestibility expression itself.

The comparison of average fecal and ileal digestibility values estimated using the indicator does not show any specific trend based on the oil source, inclusion level, or the interaction between these factors. In this comparison, three situations arise: in some cases, the values are similar, in others, fecal digestibility is higher than ileal digestibility, and in others, ileal digestibility is higher. However, the total collection technique tends to generate higher fecal digestibility values compared to the indicator technique.

3.2. True digestibility of the evaluated fat sources

Table 5 Values of the true digestibility coefficients of the evaluated fat sources

Oil source	**Level of inclusion**	**True fecal digestibility**		**True ileal digestibility**
		Total collection technique	**Indicator technique**	
Palm	3	46.02[c]	53.66[c]	53.82[c]
	6	75.09[b]	78.92[b]	75.92[b]
	9	94.84[a]	92.25[a]	91.42[a]
Average		71.98	74.94	73.72
C.V (%)		2.94	2.41	6.15
Root MSE		2.11	1.80	4.53
Pr>F		P<0.01	P<0.01	P<0.01
Chicken	3	53.52[c]	61.55[c]	61.46[c]
	6	75.09[b]	78.92[b]	75.92[b]
	9	94.84[a]	92.25[a]	91.42[a]
Average		75.47	78.37	77.37
C.V (%)		3.24	2.06	2.94
Root MSE		2.45	1.61	2.27
Pr>F		P<0.01	P<0.01	P<0.01
Sacha inchi	3	46.64[c]	54.64[c]	54.29[c]
	6	81.59[b]	84.51[b]	82.35[b]
	9	97.33[a]	96.26[a]	95.48[a]
Average		75.19	78.47	77.38
C.V (%)		1.73	1.46	3.18
Root MSE		1.30	1.14	2.46
Pr>F		P<0.01	P<0.01	P<0.01

[a, b, c] Different letters within the same column indicate significant differences (P<0.05).

The results show that for the three evaluated sources and expressions of true digestibility, the statistical analysis model used was significant, with low coefficients of variation. There is also consistency in the effect of inclusion level on fat digestibility in all three sources. The digestibility coefficient increased with the inclusion level of the fat source in the reference diet.

Rostagno *et al* (2011) reported true digestibility coefficients for some fat sources using literature data to estimate fat digestibility coefficients in birds. The reported values were above 99% for palm oil and 94% for chicken oil. These studies used different methodologies, and when compared, they did not show significant differences Rostagno *et al*., 2011). In the present study, palm oil showed values above 90% using all three evaluation methods, but at a 9% inclusion level, similar to chicken oil. Smink *et al* (2008)[19] evaluated apparent fecal digestibility using the total collection method for palm oil with 4% inclusion in the starter diet and 8% in the finisher diet, resulting in digestibility values of 56.5% and 77.5% respectively. When comparing these results with other sources rich in polyunsaturated fatty acids (PUFAs) such as hydrolyzed and crude sunflower oil or hydrolyzed palm oil, it was confirmed that sources rich in saturated fatty acids (SFAs) are less digestible than sources rich in PUFAs.

Table 5 presents the results of the true digestibility coefficients of the evaluated fat sources.

Evidence from Wiseman (1984)[22] showed that broilers fed with a commercial fat mixture in a basal fat-free (semisynthetic) diet exhibited a negative and nonlinear response in ME values to increasing fat inclusion levels ranging from 10 to 100 g/kg, with 10 g/kg increments. These negative effects were particularly evident for SFAs and in young birds (Wiseman, 1984)[22].

Skrivan *et al* (2018)[18] evaluated ileal digestibility using chromium oxide as an indicator for rapeseed oil, palm oil, and lard with 6% inclusion in a reference diet through substitution and did not report statistical differences between these sources. However, the highest concentration of total PUFAs was present in the diet supplemented with rapeseed oil, and the highest concentration of SFAs was found in the palm oil-supplemented diet. Nevertheless, the highest digestibility of total fatty acids was observed in birds fed with lard, while the lowest digestibility was observed in birds supplemented with palm oil. These results are similar to the present study, where chicken oil and Sacha inchi did not show significant differences but had higher values compared to palm oil, which showed the lowest values.

4. Conclusion

In general, there was an interaction for the three coefficients of digestibility, which means that one factor depends on the other, indicating that the digestibility of fat depends on its inclusion, as observed in the experiment. Only in the fecal digestibility obtained through the total collection methodology, there was no effect of the inclusion level of the source in the diet.

The apparent and true digestibility of the experimental diets in the three methods used shows an increase in digestibility as the inclusion level increases. This can be important for nutritionists as it allows them to adjust the energy value and evaluate the production cost of the formulated diets as the inclusion level of these sources increases in diet design.

Based on the digestibility results of this study, it can be concluded that the three methods used to evaluate the true digestibility of palm oil, chicken oil, and Sacha inchi oil show that the digestibility increases as the inclusion level increases.

Compliance with ethical standards

Acknowledgments

Administrative office agrarian centers of Universidad Nacional de Colombia (CEAGRO)

Disclosure of conflict of interest

There is not any interest conflict.

Statement of ethical approval

All processes within the experimental analysis were carried out according to the guidelines proposed by "The international guiding principles for biomedical research involving animal" (CIMOS and ICLAS 2012). The present project had the endorsement of the committee of ethics in animal experimentation of the Universidad Nacional de Colombia Sede Medellín CMED-006 as of March 17, 2016.

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