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Original

Effect of palm kernel cake in the nutrition for tilapia fry (*Oreochromis niloticus*)

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ABSTRACT

Objective. To determine the response of the productive indicators when including palm (*Elaeis guineensis*) kernel cake (PKC) in diets for the nutrition of tilapia fry (*Oreochromis niloticus*). **Material and methods.** Three hundred sex-reversed males of tilapia (4.89±0.09 g) were used and distributed according to a completely random design for 60 days, in three replicates per treatment (20 fish per replicate). The PKC was used to formulate five diets isoproteic (30.64%), isolipidics (7.38%) and isoenergetic (11.84 MJ kg^{-1} of feed), control (T0), 5% (T5); 10% (T10); 15% (T15), and 20% (T20). **Results.** Fish fed T0, T5, and T10 treatments did not show statistical differences among groups (p>0.05), but yes with the T15 and T20 in the overall nutrient digestibility, growth, and body composition. However, the inclusion of up to 20% PKC in the diet decreased the feed cost. There is a high dependency degree between the neutral detergent fiber (%) and the apparent dry digestibility (%) and apparent protein digestibility (%) (R^2 =0.732 and R^2 = 0.774; p<0.000), respectively. **Conclusions**. The palm kernel cake can be used up to 10% on tilapia fry diets without affecting apparent nutrient digestibility, growth, and whole-body nutritional contents. The progressive inclusion of PKC in the diets decreased the feed cost for more profitable tilapia culture.

Keywords: Aquaculture; feeding; fish; protein (*Source; CAB*).

RESUMEN

Objetivo. Determinar la respuesta de los indicadores productivos al incluir palmiste (*Elaeis guineensis*) en dietas para la nutrición de alevines de tilapia (*Oreochromis niloticus*). **Material y métodos.** Se utilizaron 300 machos masculinizados de tilapia (4.89±0.09 g) y se distribuyeron bajo un diseño completamente al azar con tres repeticiones por tratamiento (20 peces por repetición).

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Se utilizó palmiste para formular cinco dietas isoproteicas (30.64%), isolipídicas (7.38%) e isoenergéticas (11.84 MJ kg^{-1} de alimento), control (T0), 5% (T5); 10% (T10); 15% (T15) y 20% (T20) para alimentar los juveniles de tilapia durante 60 días. **Resultados.** Los peces alimentados con los tratamientos T0, T5 y T10, no mostraron diferencias significativas (p>0.05), pero sí con T15 y T20 en la digestibilidad de los nutrientes, el crecimiento y la composición del cuerpo. La inclusión de palmiste hasta el 20% de la dieta, disminuyó el costo del alimento. Se observó un alto grado de dependencia entre el contenido de fibra detergente neutro (%), la digestibilidad aparente de la materia seca (%) y la digestibilidad aparente de la proteína (%) (R^2 = 0.732 y R^2 = 0.774; p<0.000), respectivamente. **Conclusiones.** El palmiste se puede usar hasta el 10% en dietas para alevines de tilapia, sin afectar la digestibilidad aparente de los nutrientes, el crecimiento y el contenido nutricional en todo el cuerpo. La inclusión progresiva de palmiste en las dietas, disminuyó el costo del alimento, para un cultivo de tilapia más rentable.

Palabras clave: Acuicultura; alimentación; peces; proteína (*Fuente: CAB*).

INTRODUCTION

Aquaculture is an opportunity to provide sustainable and quality food for the growing population worldwide. Tilapia (*Oreochromis niloticus*) is among the main species produced worldwide after carp. This aquaculture species has rapid growth, suitable reproductive conditions in captivity, easy adaptation, and various diseases resistance. Also, Tilapia is a well-accepted fish in the international market due to its nutritional and organoleptic characteristics (1,2). However, the main problem in tilapia production is the high price and instability of the raw materials used to formulate diets for this species (1).

Therefore, it is necessary to find new ingredients available for the daily manufacture of feedstuff (3). The palm kernel cake (PKC) is an oil palm (*Elaeis guineensis* Jacq) by-product, a production that is increasing in Asia, America, Africa, and Europe (4). The PKC is a vegetable source of crude protein between 12 to 21%. Besides, it has a high content of neutral detergent fiber (55 to 65%) and raw fiber (14 to 30%), which limits its use in animal formulations (5,6,7).

Moreover, the PKC has a low price and high availability in many tropical countries, being an alternative protein source for ruminants, poultry, and pigs (5,6,7). Although PKC has been used in fish feeding (8,9), however, the optimal levels of PKC inclusion for tilapia diets have not been thoroughly investigated due to variations in tilapia species, feeding habits (omnivore or herbivore), stage of culture, physical-chemical parameters of water, as well as differences in the nutritional characteristics of the PKC, product to the origin of the palm, environmental influence, and oil extraction process (chemical or mechanical) (4,5,6,7). Therefore, this research aimed to determine the response of the productive indicators when including palm kernel cake (PKC) in diets for the nutrition of tilapia fry (*O. niloticus*).

MATERIALS AND METHODS

Experimental diets. PKC composition shown in Table 1 was used to formulate five diets isoproteic (30.64%, crude protein), isolipidic (7.38%, crude lipid), and isoenergetic (11.84 MJ kg^{-1} of feed) (Table 2). For the preparation of the diets, the research was considered (10,11). Poultry by-product meal (PBM) and cornmeal (CM) were reduced proportionally as a consequence of the inclusion of PKC (Table 2). The feed was weighed with a digital balance (± 0.01g, FX-2000i A&D Weighing). For the preparation of the diets, the PBM, CM, soybean meal (SBM), and PKC (primary ingredients) were ground and sieved (250 μm) and mixed to obtain a homogeneous dough (Table 2). The remainder, soybean oil, DL-Methionine, L-Lysine HCL, sodium chloride, mineral and vitamin premixes, bentonite, and monocalcium phosphate, were mixed into a homogeneous was obtained and slowly added to the rest of the ingredients. The warm distilled water (300 ml kg^{-1} of the diets) was added to each dietary treatment. The wet mixture was room temperature extruded using a meat grinder (Hakka #8 Brothers, USA), with 2 mm outlet diameter pellets. The diets were dried at 60 °C in a convection oven (BINDER, Model ED 56, Germany) to a constant weight and stored in plastic bags at -2°C (11) until their use in the feeding test.

Table 1. Chemical composition (%, as-dry basis) of palm kernel cake (PKC).

Nutrient contents	Concentration
DM (%)	93.90±0.11
CP (%)	16.78±0.12
CL (%)	7.16±0.07
Ashes (%)	5.12±0.09
CF (%)	18.79±0.10
NDF (%)	57.49±0.66
ADF (%)	36.37±0.22
DAL (%)	9.50±0.13
Phosphorus (%)	0.58±0.02
Calcium (%)	0.26±0.01
Potassium (%)	0.77±0.03
Magnesium (%)	0.28±0.01
Copper (mg/kg)	33.41±0.51
Sulfur (%)	0.21±0.01
Zinc (mg/kg)	45.60±2.16
Manganese (mg/kg)	171.91±4.36
Iron (mg/kg)	332.67±4.16

Mean ± Standard deviation (SD). Dry matter (DM), crude protein (CP), crude lipid (CL), crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF) and detergent acid lignin (DAL).

Fish and treatments. Sex reversed male tilapia fry (*O. niloticus*) were received from the Cacharí Farm Station, Ministry of Aquaculture and Fisheries, Los Ríos Province, Ecuador. Thirty hundred tilapia with an average weight, 4.89±0.09 g. The tilapias were randomly distributed in 15 circular tanks (120 L). Twenty fish was assigned to each tank (five treatments with three replicate). The feeding study was conducted over a 60-day. Before the experiment, the tilapia were acclimatized for two weeks to laboratory conditions and fed tilapia (CP =31% and CL =6.10%).

Experimental conditions. Filtered freshwater (50 microns mesh) was maintained during the bioassay and maintained at 28.0°C. A stainless-steel thermostat with a sensor was used in each tank. Continuous aeration was promoted using a double outlet aerator. All fish from each tank were fed their respective diets (8.00, 12:00, and 16:00 h), apparently satiation. In the bioassay, the fish were weighed every 15 days (13). To remove feed and feces residues from the experimental, daily at 7:00 am were siphoned. The photoperiod of 12 h light and 12 h dark were maintained. The temperature (28.0ºC), dissolved oxygen (6.3 mg L^{-1}), and pH (7.2) of water were recorded daily, using a Portable Multiparameter Meter, Orion Star A3290 (Thermo Scientific). The temperature, dissolved oxygen, and pH were within acceptable limits for tilapia growth (14).

Table 2. Formulation and nutritional composition (%, as-fed basis) of diets.

Components	T0	T5	T10	T15	T20	
PKC	-	5.00	10.00	15.00	20.00	
PBM	25.00	23.00	21.00	19.00	17.00	
SBM	32.18	34.08	36.04	37.94	39.82	
CM	33.84	28.94	23.97	19.05	14.16	
Soybean oil	2.00	2.00	2.00	2.00	2.00	
L-Lysine HCL	0.02	0.01	-	-	-	
DL-Methionine	0.26	0.27	0.29	0.31	0.32	
Premixture[1]	2.00	2.00	2.00	2.00	2.00	
Sodium chloride	0.20	0.20	0.20	0.20	0.20	
Monocalcium phosphate	2.00	2.00	2.00	2.00	2.00	
Bentonite	2.50	2.50	2.50	2.50	2.50	
Nutritional composition (%)						
DM	92.54	92.63	92.75	92.86	92.96	
CP	30.64	30.60	30.68	30.62	30.66	
CL	6.92	7.10	7.47	7.69	7.74	
CF	1.99	2.85	3.71	4.56	5.42	
Calculated values						
DE (MJ Kg^{-1} of feed)	12.06	11.92	11.85	11.75	11.61	
CP DE^{-1} (mg PC MJ^{-1})	25.41	25.71	25.85	26.08	26.39	
CF PKC CF $Total^{-1}$ (%)	-	30.91	47.59	58.00	65.09	
NDF (%)	5.28	7.75	10.19	12.64	15.11	
ADF (%)	2.36	4.02	5.67	7.33	8.99	
Essential amino acids (g 100g^{-1}MS)						[2]
Lysine	1.43	1.43	1.44	1.46	1.47	1.43
Valine	1.34	1.34	1.34	1.34	1.34	0.78
Leucine	2.25	2.22	2.19	2.15	2.12	0.95
Histidine	0.83	0.81	0.79	0.76	0.74	0.48
Arginine	1.66	1.69	1.72	1.74	1.77	1.18
Threonine	1.12	1.19	1.19	1.18	1.17	1.05
Isoleucine	1.18	1.18	1.19	1.19	1.19	0.87
Methionine	0.73	0.73	0.73	0.73	0.73	0.73
Phenylalanine	1.09	1.09	1.08	1.07	1.07	1.05
Tryptophan	0.31	0.32	0.32	0.33	0.33	0.28

Poultry by-product meal (PBM), cornmeal (CM), soybean meal (SBM).
[1]Premix, composition per kg: vitamin D3: 200.000 IU. vitamin A: 1200.000 IU. vitamin K3: 2400 mg. vitamin E: 12000 mg. vitamin B1: 4800 mg. vitamin B2: 4800 mg. vitamin B12: 4800 mg. vitamin B6: 4000 mg. pantothenic acid: 12000 mg. folic acid: 1200mg. biotin: 48 mg. vitamin C: 48000 mg. Niacin: 24000 mg. Choline: 65000 mg. Cu: 600 mg. Mg: 4000 mg. Zn: 6000 mg. I: 20 mg. Fe: 10000 mg. Se: 20 mg. Co: 2 mg.
[2]Essential amino acid requirements of tilapia (*O. niloticus*) according to NRC (14).

Apparent digestibility. For the apparent digestibility test, feces were collected: 8:00 and 17:00 h. The intact feces were siphoned manually and individually stored (per experimental unit) at −20°C until analyzed.

The apparent digestibility coefficients (ADC) were calculated according to Araiza et al (15):

$$\text{ADG (\%)} = 100 - \left[100 \text{ x } \left(\left(\frac{\%\text{MD}}{\%\text{MF}}\right) \text{x} \left(\frac{\%\text{NF}}{\%\text{ND}}\right)\right)\right]$$

Where:
MD = marker in the diet
MF = marker in feces
NF = nutrient in feces
ND = nutrient in the diet

Growth parameters. All fish were individually weighed (± 0.01g, FX-2000i A&D Weighing) according to Devic et al (16):
Specific growth rate (SGR):

$$\text{SGR (\%/day)} = 100 \text{ x } \left[\frac{(\text{logn MFBW} - \text{logn MIBM})}{\text{days}}\right]$$

Average daily gain (ADG):

$$\text{ADG (g/day)} = \frac{(\text{MFBW} - \text{MIBM})}{\text{days}}$$

Feed conversion ratio (FCR):

$$\text{FCR} = \frac{\text{FCO}}{\text{LWG}}$$

Protein efficiency rate (PER):

$$\text{PER} = \frac{\text{LWG}}{\text{PI}}$$

Feed efficiency rate (FER):

$$\text{FER} = \frac{\text{LWG}}{\text{FCO}}$$

Protein retention (PR):

$$\text{PR (\%)} = 100 \text{ x } \left[\frac{(\text{FBP} - \text{IBP})}{\text{PI}}\right]$$

Survival (SUR):

$$\text{SUR (\%)} = 100 \text{ x } \left(\frac{\text{FFN}}{\text{IFN}}\right)$$

Where:
Natural logarithm (logn)
Mean final body weight (MFBW, g)
Mean initial body weight (MIBW, g)
Feed consumed (FCO, g)
Live weight gain (LWG, g)
Protein intake (PI, g)
Final body protein (FBP, g)
Initial body protein (IBP, g)
Final fish number (FFN)
Initial fish number (IFN)

Chemical analysis. At the beginning of the bioassay, 35 fish were taken for whole-body analysis (75.08% moisture, 14.65% CP, 3.69% CL). At the end of the bioassay, five fish were taken from each tank (15 fish/treatment) at random and stored at -20 ° C until analysis. Samples of fish, feeds, and feces were analyzed for chemical composition, according to AOAC (17). Detergent acid lignin (DAL), acid detergent fiber (ADF), and neutral detergent fiber (NDF) were characterized, according to Van Soest et al (18). The digestible energy (DE) was theoretically estimated according to Ramanathan et al (19) from the conversion factors of 4.25 animal protein, 8.0 for lipids, 2.0 (legume), 3.8 vegetable protein, and 3.0 kcal g^{-1} for carbohydrates (non-legume). According to the technique validated by Van Keulen and Young (20), the acid-insoluble ash (AIA) as the internal marker was determined in diets and feces. Sulfur (S) and phosphorus (P) were analyzed by visible spectrophotometry-colorimetry using a Spectronics-USA spectrophotometer, model Genesys, USA, 2006, digital range: 325 to 1100 nm. Magnesium (Mg), calcium (Ca), copper (Cu), potassium (K), zinc (Zn), iron (Fe), and manganese (Mn) were analyzed by atomic absorption, GBC Scientific Equipment, equipment-XplorAA Dual, Australia, 2014. All chemical analyses were performed in triplicate.

Economic analysis. The cost of the experimental diets was calculated in United States dollars (USD). Then, the analysis of the cost-benefit ratio was calculated by multiplying the costs of the diet by the FCR and thus obtaining the savings for the concept of feeding the experimental diets with the control group (T0), in the production of one kg of tilapia, according to Palupi et al (21) and Mansour et al (22).

Statistical analysis. Each treatment consisted of three replicate, according to a completely randomized design. Data obtained from the productive indicators including the PKC in the tilapia diets, were performed with analysis of variance (ANOVA). In addition, Duncan´s multiple range test was used to determine differences between means. Also, a quadratic regression analysis was performed for the level of ADF (%) in diets and ADMS (%), and APD (%).

All analyzes were performed according to the statistical software IBM SPSS version 23 (2014).

RESULTS

The apparent dry matter digestibility and apparent protein digestibility were significantly similar ($p<0.05$) among T0, T5, and T10, while T15 and T20 showed the lowest values (Table 3). Furthermore, there is a high dependency degree between the neutral detergent fiber (%) and the apparent dry digestibility (%) and apparent protein digestibility (%) ($R^2=0.732$ and $R^2=0.774$; $p<0.000$), respectively (Figure 1, 2).

Table 3. Results of apparent digestibility coefficients (%) for DM, CP, CL of tilapia nutrition with PKC in the diet.

Variables (%)	T0	T5	T10	T15	T20	SEM±	P
ADMD	76.16^{a}	74.91^{ab}	73.06^{ab}	71.74^{bc}	69.78^{c}	0.704	0.006
APD	89.75^{a}	88.83^{a}	87.39^{ab}	85.80^{bc}	83.76^{c}	0.650	0.003
ALD	85.03^{a}	83.52^{a}	81.28^{ab}	79.82^{ab}	75.93^{b}	1.043	0.021

a.b.c Letters differ in the same row ($p<0.05$). ±SEM: standard error. ADMD = Apparent dry matter digestibility. APD = Apparent protein digestibility. ALD = Apparent lipid digestibility.

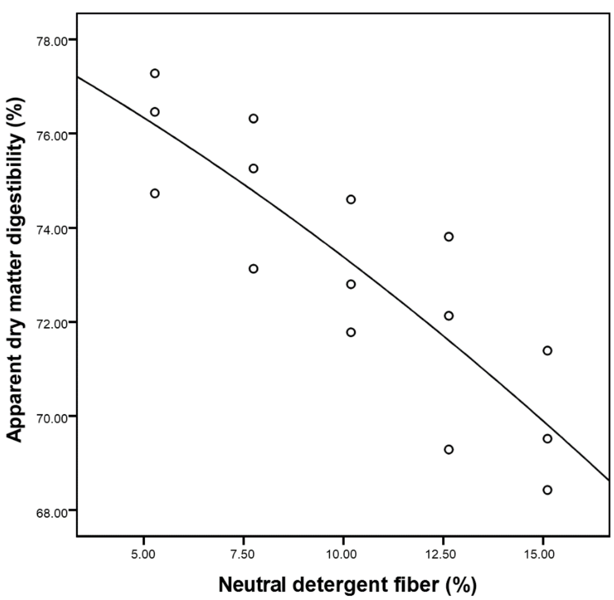

Figure 1. Apparent dry matter digestibility (%) and neutral detergent fiber (%) in diets. $y=78.77 -0.43x -0.01x^2$ $R^2=0.732$ ($p<0.000$).

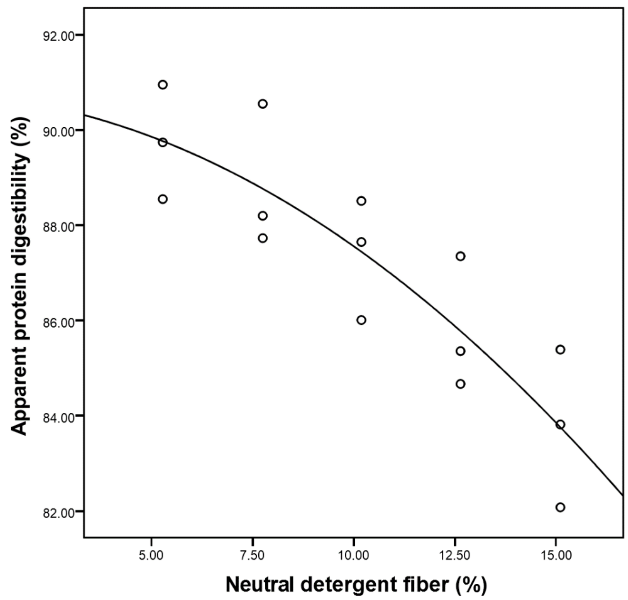

Figure 2. Apparent protein digestibility (%) and neutral detergent fiber (%) in diets. $y=90.76 -0.04x -0.03x^2$ $R^2 =0.774$ ($p<0.000$).

A 100% survival of tilapia fed the different experimental diets was obtained. The inclusion of 5% and 10% PKC was not statistically different from the control, although T15 and T20 markedly depressed the MFBW and SGR ($p<0.05$). However, ADG up to 5% inclusion of PKC in the diet was not significantly affected (Table 4).

Table 4. Results of growth and survival of tilapia (*O. niloticus)* nutrition with PKC in the diets.

Variables	T0	T5	T10	T15	T20	SEM±	P
MIBW (g)	4.82	4.85	4.93	4.97	4.87	0.089	0.985
MFBW (g)	31.82^{a}	29.80^{ab}	28.23^{ab}	25.45^{bc}	22.71^{c}	0.702	0.000
ADG(g day^{-1})	0.45^{a}	0.42^{ab}	0.39^{bc}	0.34^{cd}	0.30^{d}	0.016	0.001
SGR(%day^{-1})	3.36^{a}	3.03^{ab}	2.91^{ab}	2.73^{b}	2.58^{b}	0.092	0.041
SUR (%)	100.0	100.0	100.0	100.0	100.0		

a.b.c.d Letters differ in the same row ($p<0.05$). ±SEM: standard error. Mean initial body weight (MIBM, g). Mean final body weight (MFBW, g). Average daily gain (ADG, g/day). Specific growth rate (SGR, %/day). Survival (SUR, %).

Likewise, the dietary treatments T5 and T10 resulted in similar FCR, FER, PER, and PR (%) ($p>0.05$) than the control. However, it was observed that treatments T15 and T20 negatively affected the measured indicators ($p<0.05$), with the lowest results for T20 (Table 5).

Table 5. Feed efficiency of tilapia nutrition with PKC in the ration.

Variables	T0	T5	T10	T15	T20	SEM±	P-
FCR	1.55[a]	1.61[ab]	1.66[abc]	1.77[bc]	1.84[c]	0.035	0.026
FER	0.65[a]	0.62[ab]	0.60[abc]	0.57[bc]	0.54[c]	0.012	0.023
PER	2.11[a]	2.03[ab]	1.97[abc]	1.85[bc]	1.78[c]	0.041	0.031
PR (%)	37.13[a]	34.76[a]	32.71[ab]	28.30[bc]	25.64[c]	1.253	0.002

[a.b.c] Letters differ in the same row (p<0.05). ±SEM: standard error. Feed conversion ratio (FCR). Feed efficiency rate (FER). Protein efficiency rate (PER). Protein retention (PR, %).

The moisture value in the tilapia was statistically (p<0.05) higher in treatments T15 and T20, related to T0, T5, and T10. However, protein levels increased statistically (p<0.05) in treatments T0, T5, and T10, concerning the groups that consumed the highest amount of PKC (T15 and T20) (Table 6). The CL content was similar in the treatments.

Table 6. Results of whole-body nutritional contents (%, wet weight) of tilapia fed of PKC in the ration.

NC (%)	T0	T5	T10	T15	T20	SEM±	P
Moisture	73.11[c]	73.84[bc]	74.61[bc]	75.74[ab]	76.93[a]	0.444	0.018
CP	17.14[a]	16.73[a]	16.28[ab]	15.18[bc]	14.44[c]	0.311	0.006
CL	5.45	5.32	5.00	4.36	3.60	0.281	0.193

Nutrient contents (NC). Crude protein (CP). Crude lipid (CL).

Regarding the economic analysis, table 7 shows a reduction in the costs of the diets and the cost per kg of tilapia as the KPC increased in the diet.

Table 7. Economic analysis in the tilapia nutrition with PKC in the diet.

Variables	T0	T5	T10	T15	T20
Cost/kg diets (USD)	0.72	0.69	0.66	0.63	0.60
FCR	1.55	1.61	1.66	1.77	1.84
Cost/kg tilapia (USD)	1.116	1.111	1.096	1.115	1.104
Utility / T0 (USD)	-	0.005	0.020	0.001	0.012
Relative (%)	-	0.46	1.83	0.08	1.08

FCR: Feed conversion ratio.

DISCUSSION

PKC can be utilized as an alternative vegetable source of protein in the nutrition of tilapia, substitutes animal and vegetable conventional protein sources in formulations, due to its high availability and low cost. However, there is a variation in the chemical composition of the PKC, depending on the factors related to the African palm (*Elaeis guineensis* Jacq.) cultivation methods and oil extraction process (4). In the present study, the nutritional characteristics of the PKC are within the values reported by other authors (5,6), and the CP stands out (16.78%) and CL of 7.17%, although high values of CF (18.79%) and NDF (57.49%) (%, as-dry basis) (Table 1).

The nutritional characterization of the diets when PKC was included showed that they were isoproteic (30.64% CP), which coincides with the CP requirements for tilapia fry (12), besides, a similar contribution of essential amino acids profile that satisfy the requirements for this species (12).

The apparent digestibility of nutrients showed that up to 10% inclusion of PKC in the diet, ADMD (%) and APD (%), is not affected. However, higher levels of PKC in the diet (15-20%) caused a reduction in the digestibility of the nutrients (Table 3). In other studies with 30% PKC in the diet for tilapia (*O. niloticus*), the digestibility of DM, CP, and CL was affected (8,9).

In turn, Obirikorang et al (10) demonstrated that the daily gastrointestinal emptying pattern of tilapia (*O. niloticus*) fed 30% PKC in the diet had shorter retention times of feed and higher feces volume was obtained (p<0.05) versus the control group. They point out that the high volume of fecal matter obtained is related to the high dietary levels of non-digestible fiber in the diet, in addition to concern on water quality, especially aquaculture ponds (10).

According to Maas et al (23), increasing the levels of dietary on-starch polysaccharides (NSP) tilapia (*O. niloticus*) resulted in a negative correlation among the digestibility of CP, CL, and energy (p<0.001). In this study, when NDF (%) was increased in the diet (Table 2), a reduction in the ADM (%) and APD (%) was observed (regression coefficients, of 0.732 and 0.774; p<0.000, respectively), resulting in a decrease of nutrient availability (Figure

1,2). Furthermore, by increasing the NSP in the tilapia (*O. niloticus*) diets, it resulted in a significant reduction ($p<0.05$) of the apparent digestibility of energy and CP (32).

When a diet is formulated, the use of carbohydrates must be taken with caution. By increasing the insoluble non-starch polysaccharides, the rate of passage of chyme in the intestine is increased, which could result in a deterioration of intestinal physiology, increasing fecal content, and reducing the absorption rate of fish nutrients (25).

PKC has no toxic elements or lethal anti-nutritional factors (8,9), one should consider that the survival was 100% after two months of tilapia cultivation (Table 4).

It was shown that the inclusion of 5% and 10% PKC in the diets did not significantly affect the productive indicators of the *O. niloticus* (Table 4 and 5), considering that both treatments had similar nutrient contributions in the diets. However, negative results were observed in the growth indicators when PKC increased from 15 to 20% in the diet. Probably for the increase in crude fiber (4.6 and 5.4%) and neutral detergent fiber (12.6 and 15.1%) in treatments T15 and T20, respectively. In this sense, Obirikorang et al (9) found that the inclusion of PKC from 18 to 36% in the diet negatively affected the performance of juvenile tilapia (*O. niloticus*). In addition, those authors did not supplement diets with essential amino acids, which could cause an amino acid imbalance in the ration, with a reduction in the growth of tilapia (9).

The tilapia (*O. niloticus*) is defined as an omnivore fish, able to digest a great variety of nutrients, with a positive impact on its cultivation (25,26,28). However, it has been reported that carbohydrate addition in higher amounts of its optimal levels could reduce growth (25,29).

Maas et al (23) demonstrated that as the CF in the tilapia diet increases from 0 to 16%, in parallel, the digestibility of carbohydrates decreases from 90 to 30%, respectively, impacting the efficiency indicators. In this sense, those authors obtained a significant positive correlation coefficient ($r=0.50$, $p<0.010$) accordingly to the level of non-starch polysaccharides in the diets (%). In addition, figure 1 shows a significant high regression coefficient ($R^2=0.732$, $p<0.000$) between the neutral detergent fiber content (%) in the diets and the ADMD (%), as a result of the affected performance of tilapia.

Nutrient retention in the whole body of fish reflects suitable digestibility of nutrients. The present research results indicate that the moisture of the tilapia body increased (T15 and T20) significantly ($p<0.05$) as PKC increased in the diet. At the same time, the CP value decreased when the PKC levels in the diets were 15 and 20%, as previously reported (21,30).

On this topic, Adjanke et al (31) found that the inclusion of PKC up to 10% in the diet did not affect the moisture and the crude protein of the whole body of tilapia (*O. niloticus*).

The result presented here confirms that a gradual PKC increase in diets for tilapia up to 20%, reduces the cost (Table 7), due to the low price and high availability of this ingredient. Thus, the use of PKC as an alternative vegetable protein promotes economic gains for tilapia culture during the phase of the present study.

In conclusion, the PKC can be used up to 10% on tilapia fry (*O. niloticus*) diets without affecting apparent nutrient digestibility, growth, and whole body nutritional contents. Furthermore, the progressive inclusion of PKC in the diets decreased the feed cost for more profitable tilapia culture.

Conflict of interests

The authors state that there is no conflict of interest due to the publication of the current work.

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REFERENCES

1. Tacon AG. Trends in global aquaculture and aquafeed production: 2000–2017. Rev Fish Sci Aquac. 2020; 28(1):43-56. https://doi.org/10.1080/23308249.2019.1649634

2. Kord MI, Srour TM, Omar EA, Farag AA, Nour AAM, Khalil HS. The immunostimulatory effects of commercial feed additives on growth performance, non-specific immune response, antioxidants assay, and intestinal morphometry of Nile tilapia, *Oreochromis niloticus*. Front Physiol. 2021; 12(627499):1-12. https://doi.org/10.3389/fphys.2021.627499

3. Pinho SM, David LHC, Goddek S, Emerenciano MG, Portella MC. Integrated production of Nile tilapia juveniles and lettuce using biofloc technology. Aquacult Int. 2021; 29(1):37-56. https://doi.org/10.1007/s10499-020-00608-y

4. Qureshi SS, Nizamuddin S, Baloch HA, Siddiqui TH, Mubarak NM, Griffin GJ. An overview of OPS from oil palm industry as feedstock for bio-oil production. Biomass Conv Bioref. 2019; 9:827-841. https://doi.org/10.1007/s13399-019-00381-w

5. Son AR, Hyun Y, Htoo JK, Kim BG. Amino acid digestibility in copra expellers and palm kernel expellers by growing pigs. Anim Feed Sci Technol. 2014; 187(2014):91-97. https://doi.org/10.1016/j.anifeedsci.2013.09.015

6. Botello AL, Martínez YA, Cotera MB, Morán CM, Ortega MO, Pérez KC, et al. Growth performance, carcass traits and economic response of broiler fed of palm kernel meal (*Elaeis guineensis*). Cuba J Agric Sci. 2020; 54(4):1-12. http://cjascience.com/index.php/CJAS/article/view/986

7. de Melo Lisboa M, Silva RR, da Silva FF, de Carvalho GGP, da Silva JWD, Paixão TR, et al. Replacing sorghum with palm kernel cake in the diet decreased intake without altering crossbred cattle performance. Trop Anim Health Pro. 2021; 53(1):1-6. https://doi.org/10.1007/s11250-020-02460-x

8. Obirikorang KA, Amisah S, Fialor SC, Skov PV. 2015. Digestibility and postprandial ammonia excretion in Nile tilapia (*Oreochromis niloticus*) fed diets containing different oilseed by-products. Aquacult Int. 2015; 23(5):1249-1260. https://doi.org/10.1007/s10499-015-9881-z

9. Obirikorang KA, Amisah S, Agbo NW, Adjei-Boateng D, Adjei NG, Skov PV. Evaluation of Locally available Agroindustrial By-products as Partial Replacements to Fishmeal in Diets for Nile Tilapia (*Oreochromis niloticus*) Production in Ghana. J Anim Nutr. 2015; 1(1-2):1-9. https://doi.org/10.21767/2572-5459.100002

10. Obirikorang KA, Amisah S, Fialor SC, Skov PV. Effects of dietary inclusions of oilseed meals on physical characteristics and feed intake of diets for the Nile Tilapia, *Oreochromis niloticus*. Aquacult Rep. 2015; 1(2015):1-7. http://dx.doi.org/10.1016/j.aqrep.2015.01.002

11. Thongprajukaew K, Rodjaroen S, Tantikitti C, Kovitvadhi U. Physicochemical modifications of dietary palm kernel meal affect growth and feed utilization of Nile tilapia (*Oreochromis niloticus*). Anim Feed Sci Technol. 2015; 202(2015):90-99. https://doi.org/10.1016/j.anifeedsci.2015.01.010

12. National Research Council (NRC). Nutrient Requirement of Fish. Committee on Animal Nutrition, Board of Agriculture, National Research Council. National Academic Press: Washington, D.C. USA; 1993. https://www.nap.edu/catalog/2115/nutrient-requirements-of-fish

13. He JY, Han B, Tian LX, Yang HJ, Zeng SL, Liu YJ. The sparing effect of cystine on methionine at a constant TSAA level in practical diets of juvenile Nile tilapia *Oreochromis niloticus*. Aquac Res. 2016; 47(6):2031-2039. https://doi.org/10.1111/are.12657

14. Makori AJ, Abuom PO, Kapiyo R, Anyona DN, Dida GO. Effect of water physic-chemical paramaters on tilapia (*Oreochromis niloticus*) in earthen ponds in Teso North Sub-County, Busia County. J Fish Aquat Sci. 2017; 20(30):1-10. https://doi.org/10.1186/s41240-017-0075-7

15. Araiza MAF, Hernández LHH, Velázquez EAR, Reyes MLE. Effect of the substitution of fish oil with a mixture of plant-based oils in diets of rainbow trout (*Oncorhynchus mykiss* Walbaum) fingerlings on growth, phosphorus and nitrogen excretion. Isr J Aquacult-Bamid. 2015; 67(2015):1-9. https://doi.org/10.46989/001c.20681

16. Devic E, Leschen W, Murray F, Little DC. Growth performance, feed utilization and body composition of advanced nursing Nile tilapia (*Oreochromis niloticus*) fed diets containing Black Soldier Fly (*Hermetia illucens*) larvae meal. Aquacult Nutr. 2018; 24(1):416–423. https://doi.org/10.1111/anu.12573

17. Official Methods of Analysis (AOAC), 19th edn. Association of Official Analytical Chemists, Gaithersburg, Maryland, USA. 2012. https://www.techstreet.com/standards/official-methods-of-analysis-of-aoac-international-19th-edition-2012?product_id=1881941

18. Van Soest PJ, Robertson JB, Lewis BA. Methods for Dietary Fiber, Neutral Detergent Fiber, and Nonstarch Polysaccharides in Relation to Animal Nutrition. J Dairy Sci. 1991; 74(10):3583–3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2

19. Ramanathan G, Ramalakshmi P, Gopperundevi B, Suresh JI. Production Characterization and Aqua Feed Supplementation of Astaxanthin from *Halobacterium salinarium*. Int J Curr Microbiol App Sci. 2015; 4(3):56-63. https://www.ijcmas.com/vol-4-3/G.Ramanathan,%20et%20al.pdf

20. Van Keulen J, Young BA. Evaluation of acid insoluble ash as a natural marker in ruminant digestibility studies. J Anim Sci. 1977; 44(2):282-287. https://doi.org/10.2527/jas1977.442282x

21. Palupi ET, Setiawati M, Lumlertdacha S, Suprayudi MA. Growth performance, digestibility, and blood biochemical parameters of Nile tilapia (*Oreochromis niloticus*) reared in floating cages and fed poultry by-product meal. J Appl Aquaculture. 2019; 32(1):1-18. https://doi.org/10.1080/10454438.2019.1605324

22. Mansour AT, Allam BW, Srour TM, Omar EA, Nour AAM, Khalil HS. The Feasibility of Monoculture and Polyculture of Striped Catfish and Nile Tilapia in Different Proportions and Their Effects on Growth Performance, Productivity, and Financial Revenue. J Mar Sci Eng. 2021; 9(6):1-14. https://doi.org/10.3390/jmse9060586

23. Maas RM, Verdegem MC, Wiegertjes GF, Schrama JW. Carbohydrate utilisation by tilapia: a meta-analytical approach. Rev Aquacult. 2020; 12(2020):1851-1866. https://doi.org/10.1111/raq.12413

24. Haidar MN, Petie M, Heinsbroek LTN, Verreth JAJ, Schrama JW. The effect of type of carbohydrate (starch vs. non-starch polysaccharides) on nutrients digestibility, energy retention and maintenance requirements in Nile tilapia. Aquaculture. 2016; 463(2016):241-247. https://doi.org/10.1016/j.aquaculture.2016.05.036

25. Chen JX, Feng JY, Zhu J, Luo L, Lin SM, Wang DS, et al. Starch to protein ratios in practical diets for genetically improved farmed Nile tilapia *Oreochromis niloticus*: Effects on growth, body composition, peripheral glucose metabolism and glucose tolerance. Aquaculture. 2020; 515(2020):734538. https://doi.org/10.1016/j.aquaculture.2019.734538

26. Kamalam BJ, Medale F, Panserat S. Utilisation of dietary carbohydrates in farmed fishes: new insights on influencing factors, biological limitations and future strategies. Aquaculture. 2017; 467(2017):3-27. https://doi.org/10.1016/j.aquaculture.2016.02.007

27. Boonanuntanasarn S, Jangprai A, Kumkhong S, Plagnes JE, Veron V, Burel C, et al. Adaptation of Nile tilapia (*Oreochromis niloticus*) to different levels of dietary carbohydrates: New insights from a long term nutritional study. Aquaculture. 2018; 496(2018):58-65. https://doi.org/10.1016/j.aquaculture.2018.07.011

28. Boonanuntanasarn S, Kumkhong S, Yoohat K, Plagnes JE, Burel C, Marandel L, et al. Molecular responses of Nile tilapia (*Oreochromis niloticus*) to different levels of dietary carbohydrates. Aquaculture. 2018; 482(2018):117-123. https://doi.org/10.1016/j.aquaculture.2017.09.032

29. Kabir KA, Verdegem MCJ, Verreth JAJ, Phillips MJ, Schrama JW. Dietary non-starch polysaccharides influenced natural food web and fish production in semi-intensive pond culture of Nile tilapia. Aquaculture. 2020; 528(2020):1-10. https://doi.org/10.1016/j.aquaculture.2020.735506

30. Magouz FI, Dawood MA, Salem MF, Mohamed AA. The effects of fish feed supplemented with Azolla meal on the growth performance, digestive enzyme activity, and health condition of genetically-improved farmed tilapia (*Oreochromis niloticus*). Ann Anim Sci. 2020; 20(3):1029-1045. https://doi.org/10.2478/aoas-2020-0016

31. Adjanke A, Tona K, Ble CM, Toko II, Gbeassor M. Effect of dietary inclusion of palm kernel meal on feed intake, growth and body composition of Nile Tilapia, *Oreochromis niloticus* reared in concrete tanks in Togo. Int J Fish Aquat Stud. 2016; 4(5):642-646. https://www.fisheriesjournal.com/archives/2016/vol4issue5/PartI/4-4-51-784.pdf