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Evaluation of Fermented Copra Meal as Replacement of Soybean Meal in the Diet of Hybrid Saline-tolerant Tilapia (*Oreochromis niloticus* × *O. mossambicus*) Reared in Seawater

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Abstract | A 60-day feeding trial was performed to assess the effects of replacing soybean meal (SBM) with fermented copra meal (FCM) on growth, feed utilization, survival, and enzyme activity of hybrid saline-tolerant tilapia (*Oreochromis niloticus* x *Oreochromis mossambicus*) juveniles. Soybean meal was replaced with fermented copra meal at 25%, 50%, 75% and 100% (by weight). Five iso-nitrogenous (at 38% CP) and iso-lipidic (at 5% CL) formulated diets were fed to hybrid tilapia juveniles (0.42 g ± 0.07) following a complete randomized statistical design. Weight gain, specific growth rate (SGR), protein efficiency ratio (PER) and protein retention (PR) showed no significant differences up to 50% FCM replacement. Significantly decreasing growth performance indices and feed conversion ratio (FCR) relative to the full soybean meal control were observed in 75% and 100% FCM replacement levels ($P < 0.05$). Carcass composition did not differ significantly in all treatments ($P < 0.05$). High survival was observed in all treatments and feed intake showed no significant difference among treatments. Protease and amylase activities was significantly reduced at 75% and 100% FCM inclusion which can be linked to the reduction in growth and feed utilization in the present study. Results of the study showed that fermented copra meal can replace soybean meal up to 50% in the diet of hybrid saline tilapia without compromising growth, feed utilization, and survival.

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Introduction

Soybean meal contains the highest plant protein content and has the best essential amino acid profile making it widely adapted as a primary source of protein in fish diet formulations (Kokou *et al.*, 2016). However, as the animal growing industry sector expands the demand for soybean meal has also risen. Consequently, the cost of soybean meal in the global market has significantly increased

(FAO, 2023). The increase in soybean meal price has spurred research interests in alternative sources of dietary proteins to replace soybean meal in aquatic animal feeds. Microbial fermentation of plant-based biomass has shown promising potential as a cheap and sustainable alternative protein source in aquatic feed formulations.

Fermented copra meal also referred to as protein-enriched copra meal is a product of solid-state fermentation which allows the bioconversion of copra meal to a highly digestible and high protein biomass ideal as an alternative feed ingredient to replace soybean meal. Copra meal is originally processed from by-products of coconut oil extraction and has been incorporated into livestock and fish diets. However, the high fiber content of copra meal when used as feed is known to inhibit digestion and impede nutrient absorption resulting in growth suppression in monogastric animals (Jurairat *et al*., 2022). There have been several technological innovations done attempting to reduce the fiber contents of copra meal and to improve its protein composition but were met with limited success. Also, it has been reported that fermentation of copra meal with a selected group of microbes, that produces cellulose and mannan hydrolyzing enzymes, has decreased the fiber content of this biomass (Pham, 2017). Kraikaew *et al.* (2020) also reported that enzymes with endo-B-D-mannanase activity can be used to decrease the fiber contents of agricultural biomass byproducts such as copra meal to improve its digestibility and feed value. Moreover, it was shown that fermentation of palm kernel meal using different cellulosic fungi (Sundu *et al*., 2021) and cellulosic bacteria (Alshelmani *et al*., 2021) could improve the feed value of this biomass. This fermented biomass has been reported to replace soybean meal in about 15-20% of broiler chicken diets. However, most of these earlier works were focused on the chemical aspect of fermentation specifically on the details of the fermentation process and information on the evaluation of the feed value and effects of these fermented biomass to the physiology of cultured aquatic animals has been scarce.

Tilapia is one of the major food fish species that are widely cultivated in tropical regions. The unique characteristic of tilapia facilitated its continued growth and in 2022 despite the increase in price due to inflation tilapia production globally was predicted to increase to about 2-4% (Globefish, 2023). Recently the global production of tilapia has exhibited a positive trend as genetic selection has improved. New tilapia strains exhibiting fast growth, disease resistance, and high salinity tolerance have been introduced in industrial-scale production. With the introduction of salinity-tolerant strains, tilapia production is no longer limited to freshwater environments and production in sea cages opens an unlimited opportunity for future expansion. However, as tilapia production intensifies and expands, it is envisioned that feeds and feed ingredients will be the major limiting factor in the growth of the tilapia industry (Guerrero, 2019). The industry requires a sustainable and economically viable feed ingredient to support the growth of the tilapia industry.

The present study was conducted to evaluate fermented copra meal as a replacement for soybean meal in the diet of saline-tolerant hybrid tilapia (*Oreochromis niloticus* x *O. mossambicus*) reared in seawater.

Materials and Methods

Diet preparation

Fermented copra meal registered as PECM® was used in this study. PECM® is a commercialized product of the University of the Philippines Los Banos and is produced through the solid-state fermentation of copra cake with *Aspergillus niger*. Detailed fermentation is described in the work of Hatta and Sundou (2009) and Pham (2017). Five iso-nitrogenous and iso-lipidic diets were formulated containing different levels of FCM. Diet ingredients and composition analysis of the diets are shown in Table 1. Dietary treatments were formulated to substitute soybean meal with FCM, by weight, at different levels 25%, 50%, 75%, and 100%, respectively. Formulated diet with full soybean meal as the main protein source was used as the control treatment. All dry ingredients were mixed in a mechanical mixer until homogenous, and then oil and wheat flour were added. The moist mash was passed through a laboratory scale cold extruder. The feed pellets formed were then collected, oven-dried for 24 hours, stored in airtight containers and kept at 4°C in a refrigerator until feeding.

Growth trial

Juvenile hybrid saline-tolerant tilapia at day 21-old were purchased from a local tilapia hatchery and reared in the University of the Philippines-Visayas Multi-species Hatchery, Miagao, Iloilo, Philippines.

Table 1: *Diet composition and pproximate analysis, (% dry matter), of control, 25%, 50%, 75% and 100% FCM replacement levels of soybean meal.*

Ingredients	Control (g 100g^{-1})	25% (g 100g^{-1})	50% (g 100g^{-1})	75% (g 100g^{-1})	100% (g 100g^{-1})
Sardine meal	15.00	15.00	15.00	15.00	15.00
Soybean meal defatted	47.00	35.25	23.50	11.75	0.00
Fermented copra meal	0.00	11.75	23.50	35.25	47.00
Soybean Oil	1.50	1.50	1.40	1.00	1.00
Wheat flour	24.70	24.70	25.80	26.30	27.00
Vitamin premix[1]	2.50	2.50	2.50	2.50	2.50
Trace mineral premix[2]	0.50	0.50	0.50	0.50	0.50
Rice bran	11.50	11.50	10.50	10.40	9.70
Proximate analysis (% dry matter)					
Protein	38.29 ± 0.88[a]	38.05 ± 0.65[a]	37.94 ± 0.88[a]	37.7 ± 0.55[a]	37.12 ± 0.40[a]
Lipid	5.46 ± 0.22[a]	5.55 ± 0.07[a]	5.61 ± 0.04[a]	5.75 ± 0.10[a]	5.90 ± 0.14[a]
Fiber	7.64 ± 0.05[a]	7.70 ± 0.04[a]	7.75 ± 0.06[a]	7.95 ±0.07[a]	8.13 ±0.06[a]
Ash	8.35 ± 0.28[a]	8.39 ± 0.37[a]	8.61 ± 0.28[a]	8.79 ±0.30[a]	9.19 ± 0.40[a]
NFE	40.26± 0.13[a]	40.26± 0.02[a]	40.31± 0.18[a]	39.81± 0.12[a]	39.66± 0.20[a]

[1]Vitamin premix (mg/kg Diet): Vitamin A (7.2), D3 (2.68), E (16), B1 (160), B2 (160), B6 (100), B12 (40), niacin (800), calcium pantothenate (400), biotin (0.8), folic acid (36), and ethoxyquin (10). All chemicals used were obtained from Merck- Sigma Aldrich Inc., Darmstadt, Germany. [2]Trace mineral premix (mg/kg diet): iron (800), manganese (200), zinc (800), copper (80), iodine (36), cobalt (0.4 mg), and selenium (4). All chemicals used were obtained from Merck-Sigma Aldrich Inc., Darmstadt, Germany. Sardine meal, proximate composition (% dry matter), protein (57.5), lipid (10.0), ash (28.5), fiber (0.1), Nitrogen free extract (3.9). Rice bran, proximate composition (% dry matter), protein (18.7), lipid (15.9), ash (8.8), fiber (5.8), Nitrogen free extract (50.8). Soybean meal, proximate composition (% dry matter), protein (47.8), lipid (3.2), ash (5), fiber (7), Nitrogen free extract (37). Rice bran, Sardine and Soybean meals were obtained from Pacifica Agrivet Supplies, Inc. Philippines.

Fish were acclimated to the experimental conditions for 2 weeks before the feeding trial. The experimental fish (0.46g ± 0.03) were stocked in a 50-L rectangular plastic container at 20 fish per replicate container. The trial was performed following a complete randomized design with five treatments run in four replicates per treatment. Feeding was done by "ad libitum" four times daily (8 am, 11 am, 2 pm, 5 pm) for 8 weeks. Uneaten diets were collected before the provision of the next ration. The collected uneaten feeds are dried and weighed and values are used in the calculation of the total feed intake. The experimental setup is a continuous flow system, with a flow rate of 100 ml/min, that received sea water coming from a reservoir, continually supplied with seawater by an electric pump. Salinity was maintained at 30-35 ppt and aeration was supplied in each tank. Total fish biomass sampling was performed every 10 days.

Proximate analysis

Analyses of the diets and carcass total protein, lipid, moisture, and ash were determined following the standard analytical method of AOAC (1995). Moisture content was quantified by drying on an oven at 105°C. Crude protein was determined by the Kjeldahl distillation method. Crude lipid was analysed by Bligh and Dyer (1995). Ash content was determined by combusting the samples in an electric furnace at 550°C for 6 hours. Crude fiber was quantified by gravimetric determination following a sequential acid and base digestion.

Digestive enzyme analysis

Digestive tracts were dissected and homogenized in respective enzyme buffers, sodium-calcium acetate buffer (pH 7.5) for protease assay, and citrate-phosphate buffer (pH 7.0) for amylase and lipase assay. The homogenates were centrifuged (4,000 rpm, 15 mins, 4°C) and the supernatants were collected and used as the crude digestive enzymes in the assays.

Protease activity was assayed according to the method of Folin and Ciocalteu (1927) using casein as a substrate. Amylase activity assay was done following the method of Bernfield (1955) using buffered starch as substrate. Lipase activity assay was determined based on the method described by Borlongan (1990). Protein concentration (mg ml^{-1}) was determined using Bradford method using bovine serum albumin (BSA) as protein standard (Bradford, 1976).

Calculations and statistical analysis

Growth performance, survival and feed utilization were calculated as follows:

Weight gain (%) = (final weight –initial weight) × 100/ initial weight

Survival (%) = 100 × (final number of fish) / (initial number of fish)

Specific growth rate (SGR, % day^{-1}) = 100 × (Ln final Wt – Ln initial Wt)/days of culture

Feed conversion ratio (FCR) = Feed consumed (g, dry weight) / weight gain (g, wet weight)

Protein Efficiency Ratio (PER) = (Final weight – Initial weight) / dietary protein intake

Protein Retention Efficiency = [(final protein in carcass × final weight carcass, dry basis) - (initial protein carcass × initial weight carcass, dry basis)] / [(total feed intake, dry basis) × crude protein]

Results were expressed as means ± standard error of means. Statistical analyses were carried out in SPSS 16. Data was analyzed using one-way analysis of variance (ANOVA) using Tukey's test of multiple comparisons at 95% significance level.

Results and Discussion

Growth performance

Table 2 presents growth and feed utilization after 60 days of rearing. Survival was high (93-100%) and not affected by the dietary treatments ($P < 0.05$). Weight gain and specific growth rate were found similar in fish fed with control diet and diets with 25% and 50% FCM replacements. However, significant reduction was observed at 75% and 100 % SBM replacement with FCM ($P < 0.05$). Feed intake did not significantly differ in all treatments which indicate that acceptability of diet was similar in the duration of the experiment. Feed conversion ratio significantly increased at 75% and 100% SBM replacement with FCM. Consequently, protein efficiency ratio and protein retention showed no significant difference between control, 25% and 50% levels of FCM replacement but significantly decreased at 75% and 100% levels of replacement.

Carcass composition

The proximate whole-body composition of experimental fish at the start and end of the experiment are presented in Table 3. Protein and lipid contents in carcass showed no significant difference among the treatments (P > 0.05). Also, no significant difference was observed among treatments in terms of ash content and moisture. From the results of the study, carcass composition was not significantly affected by the diet composition.

Digestive enzyme activities

Specific enzyme activities of experimental treatments are shown in Figures 1, 2, 3. Protease and amylase enzyme activities were significantly higher in the control, the 25%, and the 50% FCM levels as compared

Table 2: *Growth performance of hybrid saline tilapia (O. niloticus × O. mossambicus) juvenile fed with different fermented copra meal replacement levels.*

	T1 (Control)	T2 (25% FCM)	T3 (50% FCM)	T4 (75% FCM)	T5 (100% FCM)
Survival (%)	95 ± 2.89[a]	93.75 ± 3.75[a]	98.75 ± 1.25[a]	100 ± 0.00[a]	100 ± 0.00[a]
Weight gain (%)	847 ± 32.40[a]	773 ±47.60[ab]	761 ± 18.70[ab]	681 ± 18.40[b]	530 ± 12.90[c]
Feed intake (g fish^{-1})	5.64 ± 0.09[a]	5.40 ± 0.20[a]	5.37 ± 0.09[a]	5.44 ± 0.06[a]	5.72 ± 0.04[a]
SGR (% day^{-1})	3.75 ± 0.07[a]	3.60 ± 0.09[a]	3.59 ± 0.04[a]	3.42 ± 0.04[b]	3.07 ± 0.03[c]
Feed conversion ratio	1.69 ± 0.05[a]	1.64 ± 0.02[a]	1.68 ± 0.01[a]	1.96 ± 0.02[b]	2.61 ± 0.03[c]
Protein efficiency ratio	2.47 ± 0.09[a]	2.51 ± 0.12[a]	2.36 ± 0.03[a]	1.99 ± 0.02[b]	1.49 ± 0.02[c]
Protein retention	24.2 ± 1.20[a]	24.0 ± 0.77[a]	23.9 ± 0.26[a]	20.5 ± 0.24[b]	16.26 ± 0.21[c]

Table 3: *Carcass composition (% dry weight) of hybrid saline tilapia (O. niloticus x O. mossambicus) juvenile fed with different FCM levels after 60 days growth trial.*

	Initial	Control	25%FCM	50%FCM	75%FCM	100%FCM
Protein (%)	43.84 ± 0.32	61.83 ± 0.90[a]	62.53 ± 0.86[a]	62.89 ± 0.94[a]	63.12 ± 0.57[a]	63.27 ± 0.94[a]
Lipid (%)	22.28 ± 0.38	23.39 ± 0.16[a]	23.41 ± 0.06[a]	23.41 ± 0.02[a]	23.63 ± 0.13[a]	24.58 ± 0.08[a]
Ash (%)	4.76 ± 0.20	4.91± 0.15[a]	5.34 ± 0.38[a]	5.02 ± 0.30[a]	5.88 ± 0.13[a]	6.03 ± 0.25[a]

to the treatments at 75% and 100% FCM replacement levels. The protease and amylase enzyme activities in the control, the 25%, and the 50% FCM levels were statistically similar. No significant differences were recorded in the protease and amylase activities in the 75% and 100% FCM replacement groups. Specific enzyme activity for lipase showed no significant difference among treatments.

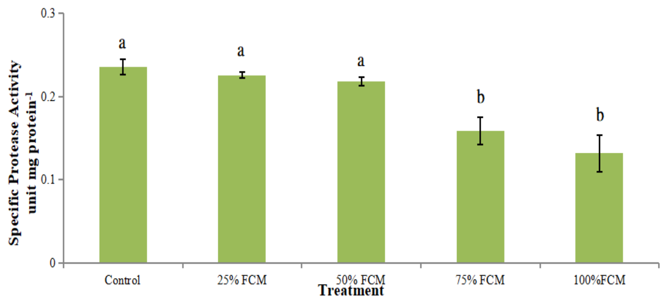

Figure 1: *Effect of replacing soybean meal with different FCM levels on specific protease activity of hybrid saline tilapia (Oreochromis niloticus x O. mossambicus) juvenile. Data are expressed as mean ± SE. Bars assigned different superscripts were significantly different (P < 0.05).*

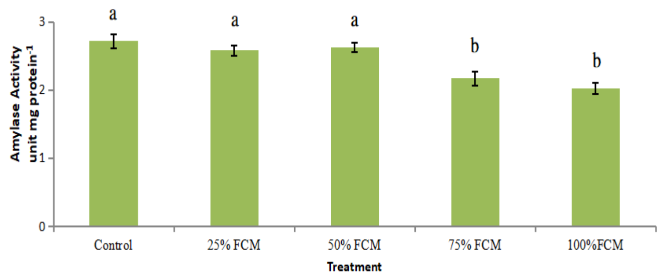

Figure 2: *Effect of replacing soybean meal with different FCM levels on amylase activity of hybrid saline tilapia (Oreochromis niloticus x O. mossambicus) juvenile. Data are expressed as mean ± SE. Bars assigned different superscripts were significantly different (P < 0.05).*

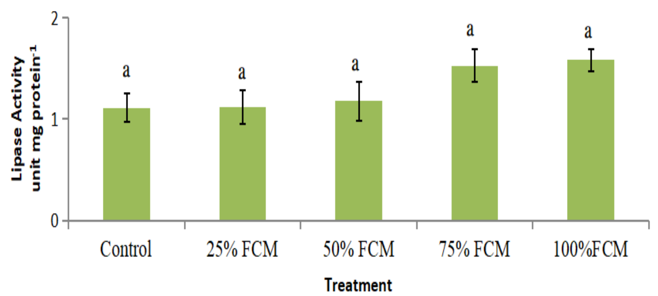

Figure 3: *Effect of replacing soybean meal with different FCM levels on lipase activity of hybrid saline tilapia (Oreochromis niloticus x O. mossambicus) juvenile. Data are expressed as mean ± SE. Bars assigned different superscripts were significantly different (P < 0.05).*

The current study assessed the growth, survival, feed conversion and digestive enzyme activities of hybrid saline tilapia (*O. niloticus* x *O. mossambicus*) fed formulated diets with fermented copra meal replacing soybean meal at dietary levels of 0%, 25%, 50%, 75%, and 100%. Results indicate that FCM can substitute up to 50% of soybean meal without causing a significant reduction in growth and FCR of hybrid saline tilapia (*O. niloticus* x *O. mossambicus*). Weight gain, PER, and SGR showed no significant difference with the control, the 25%, and 50% FCM replacement levels. The findings of the present study observed a higher replacement level of soybean meal with FCM as compared to the reports done in earlier works. Olude *et al.* (2008) reported that soaked copra meal could only replace 30% of soybean in the formulated feeds of *O. niloticus* without compromising growth and nutrient utilization. Similarly, the report of Mukhopadhyay and Ray (1999) has shown that 30% and 40% of fermented sesame seed meal as replacement SBM is optimum in the formulated diet of Indian carp (*Labeo rohita*).

Also, Deng *et al.* (2015) has demonstrated that rubber seed meal could only replace SBM at 10-30% in the diet without affecting the growth performance of the hybrid tilapia (*O. niloticus* x *O. aureus*). Moreover, a recent report of Chatvijitkul (2016) showed that lipid-extracted distillers dried grains could replace 30% of SBM diets of hybrid tilapia (*O. niloticus* x *O. aureus*). Similar studies on SBM replacement with plant-based proteins has demonstrated that 20–30% dietary SBM could be replaced with biofloc meal (Mabroke *et al.*, 2019), Leucaena meal (Pratiwy *et al.*, 2020) and peanut meal (Silva *et al.*, 2017) without causing growth reduction in Nile tilapia (*O. niloticus*).

Results suggest that FCR increased with increasing FCM replacement of SBM. Feed conversion ratio was found significantly higher in treatments with 75% and 100% FCM dietary inclusion (*P < 0.05*) while no significant difference between control, 25%, and 50% FCM levels were observed. Moreover, an increase in FCR in the diet was accompanied by a reduction in specific growth rates. Similar observation was reported in previous studies when increasing the substitution of soybean meal by plant-based proteins such as biofloc meal (Mabroke *et al.*, 2019), Leucaena meal (Pratiwy *et al.*, 2020), and peanut meal (Silva *et al.*, 2017) in *O. niloticus* diet. The limitation in the inclusion of plant-based ingredients in fish feed has been attributed to the high content of anti-nutrients that affect the digestive physiology of fish (Paranamana *et al.*, 2014). The higher replacement level of soybean meal with FCM in the present study could have been due to the fermentation of copra meal. Copra meal, a by-product of the coconut oil processing industry is known to have low feed value. However, Sundu *et al*. (2009) has shown that its nutrient digestibility and its amino acid profile could be improved by fermentation. The solid-state fermentation using selective microbial agents has been also shown to remove major anti-nutrients present in copra meal, such as tannins and phytic acids (Hatta and Sundou, 2009; Kraikaew *et al*., 2020), and may explain the high inclusion level of this ingredient as observed in the present study.

Result of the present study also suggests that the protein efficiency ratio decreased with increasing SBM replacement levels. Dietary inclusion of FCM higher than 75% replacement significantly reduced specific growth rate and protein efficiency ratio in the diet of hybrid saline tilapia ($P < 0.05$). Similar to our findings, Sun *et al*. (2015) reported significant PER reduction at highest SBM substitution level of 24% with fermented cottonseed meal in the diet of black sea bream. Mabroke *et al*. (2019) also observed body protein reduction of Tilapia in the treatment with a higher than 30% SBM substitution by Biofloc meal in the diet. Recent study by Deng *et al*. (2015) observed PER reduction at 40% rubber seed meal or the highest SBM substitution level used in the study of hybrid tilapia (*Oreochromis niloticus* x *O. aureus*) diet. All of these works indicated that nutrient digestion and absorption are linked with the high content of anti-nutrients in these ingredients used to replace the soybean meal.

Further, results of the present study suggest that the growth inhibition and decrease in protein efficiency ratio in fish maintained with higher replacement of soybean meal with FCM, at 75% and 100%, is not associated with decreased feed intake. Feed intake values showed no significant differences in all treatments with FCM and the control diet indicating that FCM inclusion did not affect diet palatability. Similar to our results, earlier reports also suggest that palatability is not affected by SBM substitution with plant protein sources such as rubber seed meal in Nile tilapia (Deng *et al*., 2015), hydrolyzed feather meal in hybrid tilapia (Zhang *et al*., 2014) and fermented cottonseed meal in black sea bream (Sun *et al*., 2015). Thus, it is most likely that growth depression observed at high dietary inclusion of FCM could not be associated with feed intake or palatability of the diet but could be associated with factors present at high FCM replacement levels in the diet of hybrid saline-tolerant tilapia.

In the present study, the inhibition of digestive enzyme activities further supports the inhibitory effects of higher replacement levels of soybean meal with FCM in hybrid tilapia. Digestive enzyme activities have been used as an efficient quantitative index in the evaluation of the nutrient quality in a formulated diet (Rungruangsak-Torrissen, 2014). Moreover, it has been previously documented that enhanced digestive enzyme activities have been associated with feed nutrient availability, efficient nutrient utilization, and enhanced growth in juvenile tilapia (Montoya-Mejía *et al*., 2017). Digestive protease activity of hybrid saline-tolerant tilapia in the present study was inhibited at inclusion levels of FCM at 75% and 100% FCM levels. This suggests that protease inhibitors might be present in FCM which can cause negative effects at high inclusion in the diet of hybrid saline-tolerant tilapia juvenile. Protease inhibitors are common anti-nutrient substances in many plant-based ingredients and have been reported to be associated with depressed growth in animals fed diets containing significant amounts of plant-based ingredients (Berilis *et al*., 2017; Prabu *et al*., 2017; Silva *et al*., 2017). In earlier works, it has been shown that a decrease in digestive protease has been associated with a decreasing protein efficiency ratio, specific growth rate, and increasing feed conversion ratio as reported in hybrid tilapia *Oreochromis niloticus* x *O. aureus* (Lin and Luo, 2011). Moreover, digestive amylase activity shows that the inclusion of FCM from 25-50 % showed no significant reduction in the amylase activity of tilapia hybrid, however, higher inclusion (at 75 and 100%) leads to a significant reduction in the activity of amylase.

Similar to these earlier findings, results in the present study indicate that the significant inhibition of the digestive protease and amylase activities at 75% and 100% FCM replacement of soybean meal is also associated with decreased protein efficiency ratio, protein/lipid retentions and consequently suppression of specific growth rate and weight gain of the hybrid saline-tolerant tilapia. It is tempting to speculate that anti-nutritional factors (ANF's) in the form of enzyme inhibitors, particularly in protease and amylase, may be present in FCM and may explain the inhibition of enzyme activities at higher soybean meal replacement with FCM. Anti-nutritional factors (ANF's) are known to interfere with the digestive enzymes in the gastro-intestinal tract and inhibit digestion and absorption (Wilson, 2003; Berilis *et al*., 2017). Limitations on the inclusion levels of plant ingredients for most fish species are said to be due to the presence of anti-nutritional factors (ANFs) which impair the utilization of nutrients resulting in reduced growth, nutrient utilization, and feed efficiency (Prabu *et al*., 2017). Earlier report has shown that unprocessed copra meal contains non-starch polysaccharides (NSP's) in the form of water-soluble galactomannans and water-insoluble mannan oligosaccharides (Knudsen, 1997). Galactomannan as an antinutrient was shown to increase the digestive nutrient viscosity that impairs intestinal nutrient absorption in carp (Hossain *et al*., 2001), decreased feed conversion efficiency in tilapia, (Hossain *et al*., 2003), and reduced intestinal glucose uptake in rainbow trout, (Storebakken, 1985). These NSP's may have caused the decrease in amylase and protease digestive enzyme activities associated with the growth depression of tilapia as observed in higher replacement of soybean meal (> 50%) with FCM in the present study.

However, the anti-nutrients present in fermented copra meal were not evaluated in the present study but this aspect could be a good subject for future investigations. Furthermore, there was no significant difference detected in carcass composition in all treatments. The proximate analysis data of this study indicated that moisture, protein, lipid, and ash content of whole-body composition in saline tilapia hybrid fingerlings were not affected by the dietary FCM replacement levels.

Conclusions and Recommendations

The present study concluded that fermented copra meal can replace soybean meal up to 50% dietary inclusion without causing negative effects on growth performance, survival, feed utilization and digestive enzyme activities of saline-tolerant tilapia hybrid (*Oreochromis niloticus* x *O. mossambicus*). Growth based on weight gain, protein efficiency ratio, specific growth rate, and feed utilization reduction was prominent in 75% and 100% FCM replacement of soybean meal. Feed intake did not show significant difference among treatments therefore dietary inclusion of FCM did not affect palatability of the diet. However, enzyme activity revealed that protease and amylase activities were inhibited at 75% and 100% FCM replacement of soybean meal. The reduced growth performance of fish-fed diet at high replacement level of soybean meal with FCM (75% and 100%) is associated with the inhibition of digestive protease and amylase enzyme activities. In conclusion, the result of this study indicates that fermented copra meal could be used to replace up to 50% of soybean meal without adversely affecting the overall growth performance and feed conversion ratio of hybrid saline-tolerant tilapia.

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Novelty Statement

The present work describes the use of a biotechnologically-generated and sustainable high-protein feed ingredient, produced by the fermentation of copra meal as a substitute for soybean meal in the diet of seawater-cultured tilapia. This ingredient can replace 50 % of imported soybean meal in the formulated diet of tilapia. This feed ingredient can lower the reliance of aquaculture on the use of imported soybean meal and may lower the production cost.

Author's Contribution

Pia Amabelle M. Flores, Connie Fay Komilus and Rex Ferdinand M. Traifalgar: Designed and formulated the conceptual framework of the study
Pia Amabelle M. Flores, and Emelyn Joy Mameloco: Participated in the conduct of the experiment, gathering of data and analysis of the samples.

Rex Ferdinand M. Traifalgar, Pia Amabelle M. Flores, Connie Fay Komilus and EmelynJoy Mameloco: Performed the statistical data analysis and writing of the manuscript.
All authors have read, agreed and have approved the final manuscript for publication

Conflict of interest
All authors have declared no conflict of interest.

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