The Philippine Journal of Fisheries 25(2): 41-56 July-December 2018
DOI: 10.31398/tpjf/25.2.2018A0008

Growth performance and cost efficiency of tilapia (*Oreochromis niloticus*) and milkfish (*Chanos chanos*) fed extruded floating and non-floating feeds reared in net cages in Taal Lake

Frederick B. Muyot*[1], Maria Theresa M. Mutia[1], Paul John H. Caunan[1]
[1]*National Fisheries Research and Development Institute-Freshwater Fisheries Research and Development Center, Butong, Taal, Batangas, Philippines*

ABSTRACT

This study evaluated the growth and cost efficiency of tilapia (*Oreochromis niloticus*) and milkfish (*Chanos chanos*) fed three feed types used in cage farming in Taal Lake, Batangas, Philippines to serve as baseline information for cage aquaculture regulations. *O. niloticus* and *C. chanos* were reared in net cages fed three feed treatments: extruded floating feed (EFF), slow-sinking feed (SSF), and sinking feed (SF). Growth performance, feed conversion ratio (FCR), yield, and cost efficiency were compared at harvest. Results of the study showed that EFF had significantly higher mean weight gain, absolute growth and specific growth rate, biomass harvest, percentage good size fish, and FCR than SF in both *O. niloticus* and *C. chanos* ($P<0.05$), but had no significant difference with SSF in terms of growth parameters ($P>0.05$). FCR and biomass harvest were significantly higher in EFF than SF in *O. niloticus* ($P<0.05$) but were not statistically different in *C. chanos* ($P>0.05$). Survival rate was not significantly different among feed types ($P>0.05$) in both species. Net profit was significantly higher in EFF than the other feed types ($P<0.05$). At the same volume of fish production in the lake, the use of extruded floating feeds in cages lessened the feed cost by 17.91-29.44% for higher net returns and decreased feeds use by 19.64-30.0%, which could minimize negative impacts on the lake water environment. The results of the study revealed the comparative advantage of floating feeds over slow-sinking feeds and sinking feeds and is therefore recommended as the ideal feed type for cage farming in the lake.

E-mail address: *fredbmuyot@yahoo.com**
Received: *October 2, 2018;* Accepted: *December 28, 2018*

Keywords: *extruded floating feeds, slow sinking feeds, sinking feeds, growth performance, cage aquaculture*

1. INTRODUCTION

The Philippines ranked 11th among aquaculture producing countries in the world in 2015 with a production of 781,798 metric tons valued at US$ 1.87B (FAO 2017). Milkfish (*Chanos chanos*) and tilapia (*Oreochromis niloticus*) are the 2nd and 3rd among cultured species produced in the country with a combined production of 657,133 metric tons in 2016 (BFAR Fisheries Profile 2016) with a percentage share of 82.51% of aquaculture production excluding seaweeds. Among culture environments in the country, inland waters, particularly lakes, are rapidly becoming the major source of production for aquaculture with 97,568 metric tons production in 2016 (BFAR Philippines Fisheries Profile 2016) representing 12.25% of the national aquaculture production. Taal Lake, the third largest lake in the country, is one of the important freshwater inland waters because of the rapid development and expansion of cage aquaculture. It is now a major producer of *O. niloticus* and *C. chanos* in the country with 72,393 metric tons of O. niloticus and 12,880 metric tons C. chanos produced in 2016 (BFAR Philippine Fisheries Profile 2016; PSA 2016). This represents about 6.07% of the total aquaculture production in the country and specifically, 27.95% of *O. niloticus* and 3.24% *C. chanos*.

The rapid development of cage aquaculture in inland waters such as Taal Lake has led to a significant contribution to fisheries production. However, the large volume of production in these aquatic environments also reflects the high volume of feeds used for rearing fish, a major concern for Taal Volcano Protected Landscape-Protected Landscape Management Board (TVPL-PAMB), the management board overseeing Taal Lake and its watershed. Feeds is a major input in intensive cage culture system which is one of the potential contributors of organic loading in the lake. When improperly managed by fish farmers and left unchecked and unregulated by appropriate authorities, feeds may lead to degradation of water quality of the lake and result in fish kills. White (2013) stated that poor feed quality and poor feeding strategy have major influences on the environmental impact for shore-based and open-water farming system. Several studies have shown that increased production of cultured species fed artificial diets resulted in higher levels of ammonia and decreased dissolved oxygen level (Jescovitch 2017; Mmochi et al. 2002) and may affect fish culture. It is therefore important that the impact of aquaculture feeds in the environment be minimized through the use of efficient, environment-friendly diets, and employing optimum feeding strategies (Tacon and Forster 2003; White 2013).

As feed is the main input in cage aquaculture that may affect lake water quality, specific guidelines in the TVPL Management Plan in its Unified Rules and Regulation for Fisheries (URFF) Section 6 stated that *extruded floating feeds must be employed in cage aquaculture in the lake* (TVPL 2010). Extruded feeds are known to be efficient and contribute less to water quality degradation. The use of extruded feeds in aquaculture is known to be more environment-friendly and efficient than conventional pressed sinking pellets (Ammar 2008; Ammar et al. 2008; Robert et al. 1993; Venou et al. 2003; Hilton et al. 1981). Moreover, in the case of inland water aquaculture such as in lakes, such type of feeds is more appropriate to sustain fish production and minimize contribution to water quality degradation (Johnsen and Wansvik, 1991). Extruded feeds occur in floating, slow-sinking, and sinking feeds. Each type of extruded feeds is effective for specific species of fish depending on their feeding habits (Xie et al. 2018). At present, the majority of cage farmers in Taal Lake are using sinking and slow-sinking feeds while the extruded floating feed is a relatively recent introduction in cage aquaculture in the area. Although the use of extruded floating feeds is known to perform better in land-based farms, there has been some hesitation on its application in cages for various reasons such as broken sizes in harvested fish, wastage of feeds due to strong waves, and feeds cost. Studies on extruded floating feeds in Taal Lake are lacking and as such, comparative evaluation of extruded floating and non-floating feed types commercially available for *O. niloticus* and *C. chanos* cage aquaculture is therefore needed to supplement the hypothesis on the relative efficiency of extruded floating feeds over the commonly used non-floating feeds.

This study was conducted to evaluate the growth performance and cost efficiency of extruded floating, extruded slow-sinking, and pressed sinking feeds for *O. niloticus* and *C. chanos* reared in net cages and to serve as baseline information for the policy implementation on the use of extruded floating feeds in Taal Lake. The results of the study may also be useful to policy management regulators of other inland waters in the country, as well as in other parts of the world.

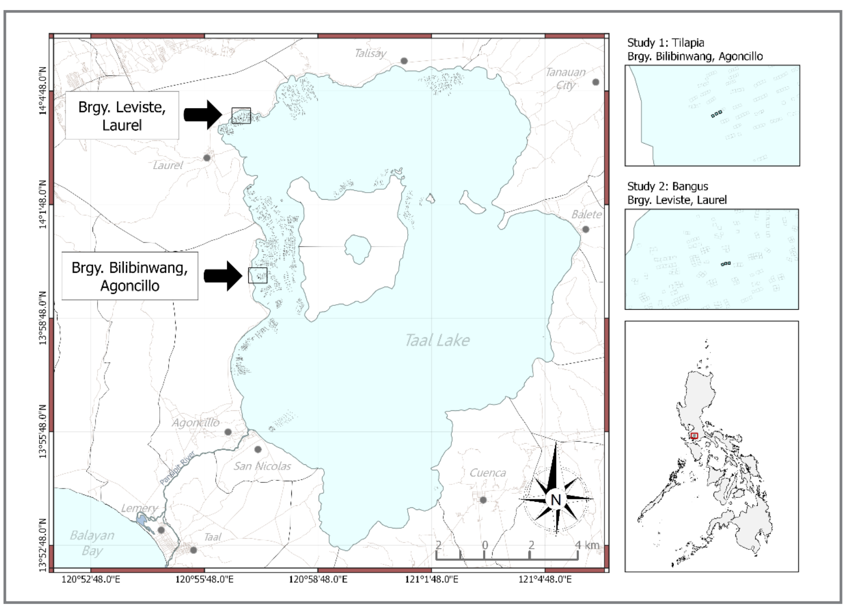

Figure 1. Map showing the experimental site for the tilapia (*Oreochromis niloticus*) and the milkfish (*Chanos chanos*) study.

2. MATERIALS AND METHODS

The study is composed of two sub-studies: Study 1 for tilapia (*Oreochromis niloticus*) and Study 2 for milkfish (*Chanos chanos*). Each study was conducted separately in two experimental sites located in cage aquaculture zones in Taal Lake, Batangas, specifically Brgy. Bilibinwang, Agoncillo, Batangas for the tilapia study and Brgy. Leviste, Laurel, Batangas for the milkfish study (Figure 1). In the tilapia Study, *O. niloticus* was reared as single species in the experimental cages. Similarly, C. chanos was reared in monoculture in the Milkfish Study experimental site. The experimental period was eight months for *O. niloticus* and ten months for *C. chanos* from May 2016 to March 2017 upon reaching a marketable size of 250-350 g for tilapia and 300-400 g for milkfish. This study is a collaborative project between National Fisheries Research and Development Institute (NFRDI), Department of Environment and Natural Resources-Protected Areas Superintendent (DENR-PASu), and Bureau of Fisheries and Aquatic Resources Region 4A (BFAR 4A).

2.1 Experimental design

The experiment was conducted in a randomized complete block design with three replications (Figure 2). Three feed types were compared: (1) extruded floating feed; (2) extruded slow-sinking feed; and (3) pressed sinking feed; all of which were manufactured and procured from one commercial aquaculture feed company, Santeh Feeds. Each of the three modules represented one block-replications while each of the three cage nets in the module served as the experimental units or treatments. Each of the three feed types was assigned randomly to the three cage nets in one module. All feed types were represented in each of the block modules.

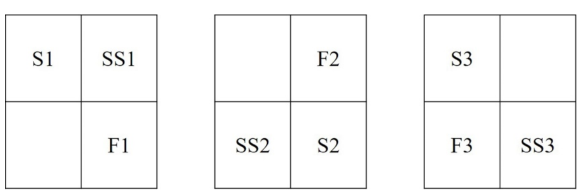

Figure 2. Experimental set up of feeding experiment for O. niloticus and C. chanos study.

In each of the sub-studies, nine units of floating type bamboo-framed cages measuring 4 m x 4 m were constructed and installed with net cages made of polyethylene net measuring 4 m x 4 m x 5 m (depth). Cages were situated at about 500 m from the lakeshore with a depth of 12-15 m. The nine cages were divided into three modules with each module having three cages constructed adjacent to each other. Each module was installed 10 m apart and moored to the bottom of the lake by sandbags supported by polyethylene rope no. 10.

In the tilapia study experimental site, a total of 36,000 *O. niloticus* size 14 fingerlings BFAR Strain with a mean weight of 1.7±0.17 g (mean length of 4.9±0.10 cm) procured from a private hatchery in Binangonan, Rizal were stocked randomly into the nine cage nets at an equal stocking density of 50 fish•m^{-3} (4,000 fingerlings per cage net). In the milkfish study experimental site, a total of 10,080 *C. chanos* fingerlings with a mean weight of 9.27±1.21g (mean length of 8.63±0.42 cm) purchased from a private nursery farm near the experimental site in Brgy. Leviste, Laurel, Batangas were equally distributed among nine cage nets at a density of 14 fish•m^{-3} (1,120 fish per cage net).

2.2 Feeding of fish

Fish were fed two times a day at 8:00 AM and 3:00 PM at a pre-determined feeding rate which ranged from 3-5% body weight depending on the size of the fish. For each feed type, three feed sizes were utilized, namely starter, grower, and finisher, which were used based on the fish size at rearing period. The actual amount of feeds consumed per feeding period were recorded for the computation of the feed conversion ratio. Net cages were regularly cleaned and scrubbed to prevent fouling of nets and to provide good water circulation. Bamboo raft cage and cage nets were regularly monitored for any damages and immediately repaired when needed. Replacement of cage nets was done every 2-3 months, with each replacement net having larger mesh size (B-net PE net, size 17 PE net, size 14 PE net, and size 10 PE net).

2.3 Data collection

Growth performance. Growth evaluation of the fish was conducted every month by collecting 30 random samples from each cage net replicates to determine the growth performance. Weight (in grams) and standard length (in cm) of individual fish were measured. The weight gain, absolute growth, and specific growth rate were computed following the formula:

Weight gain (g) =	Final weight – Initial weight
Absolute growth (g/day) =	Final weight – Initial weight / no. rearing days
Specific growth rate =	(ln final weight – ln initial weight) * 100/ no. rearing days (%/day)

Survival, Biomass Harvested and Size Distribution. At the end of the experiment, all fishes were harvested from each cage net treatment replicate and weighed. Tilapia were harvested on April 6-10, 2017 and milkfish on April 1-5, 2017. Harvested fish were individually classified according to size by contracted harvester-buyer and bulk weighed by size class. The total weight of fish harvested per size class per feed treatment was recorded for the determination of size distribution harvested fish, expressed in percentage composition of fish per size class per feed treatment. From each of the size class, a random sample of 30 fishes was collected and measured individually to determine the mean weight and length of each size class. The total number of harvested fish, survival rate, and biomass harvested were computed based on the formula:

Actual no. of fish harvested = (*Total weight of harvested fish at Size A/Mean weight of Size A*) + (*Total weight of harvested fish at Size B/Mean weight of Size B*) + … + (*Total weight of harvested fish at Size E/Mean weight of Size E*)

Survival rate = *No. of fish harvested/Initial no. fish stocked* x 100

Biomass harvested = *total weight harvested from 3 cage nets of each feed treatment* / 3 cage nets

Feed Conversion Ratio and Feeds consumed. At the end of the experiment, the feed conversion ratio and total feeds consumed were computed as follows:

Feed conversion ratio = *Total feeds consumed* / T*otal volume of fish harvested*

Total feeds consumed = *Total recorded feed consumption per feed treatment*

Cost analysis. A simple cost analysis of the three feed treatments was done to assess the cost efficiency of the feed types used in the feeding experiment. The computations for the cost analysis were as follows:

Fixed cost = *depreciated cost cage + depreciated cost nets*

Operating cost = *fingerling cost + feed cost _ repair & maintenance cost + miscellaneous cost*

Total cost = *fixed cost + operating cost*

Sales = *Biomass harvest* x *market price of fish*

Net income = *Sales – total cost*

Proximate analysis. Proximate nutrient analysis was conducted for both feeds and fish. About 100 g sample of each feed type at the start of the experiment and 100 g fish harvested after the experiment was sent to NFRDI Integrated Laboratory, Quezon City for proximate analysis of crude protein, crude fat, ash, and moisture and to SGS Laboratory, Makati City for crude fiber. Both laboratories used the standard method for proximate nutrient analysis (AOAC 1990).

Water Quality. Dissolved oxygen, temperature, and pH were monitored daily at 9:00 AM and 4:00 PM. Dissolved oxygen and temperature were measured using YSI Pro 20 portable DO meter and pH was monitored using Eutech Instruments pH 700. Ammonia, nitrate, and nitrite were monitored once a week using LaMotte Smart 3 colorimeter and total phosphorus was measured using Shimadzu UV Spectrophotometer UV-1800.

2.4 Statistical Analysis

Results were presented as means ± standard error of the mean (SEM). Levene's test (F-max test) was used to test the homogeneity of variance. After confirming homogeneity of variances, analysis of variance (ANOVA) was employed using a univariate general linear model to determine significant differences among treatment effects. Tukey HSD and Scheffe were used to determine specific treatment mean differences. Percentage data were arcsine-transformed prior to ANOVA. Statistical significance was compared at the 5% probability level. All computations and analysis were carried out using the SPSS version 20.

3. RESULTS

The results presented in this study are consolidated data from the two experimental sites of the two sub-studies conducted.

3.1 Growth performance

The average increase in weight of tilapia (*Oreochromis niloticus*) at periodic sampling during

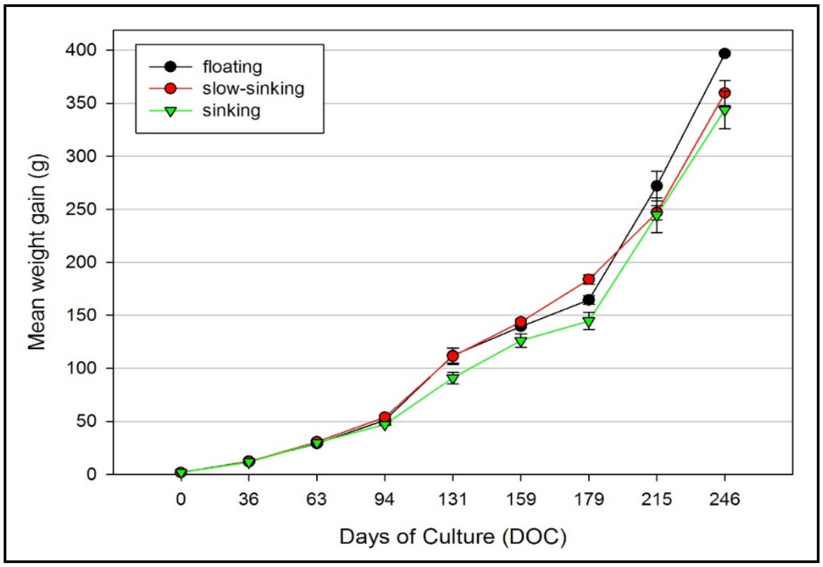

Figure 3. Mean body weight of tilapia (g) fed floating, slow-sinking, and sinking feeds during the 246 days of culture (DOC).

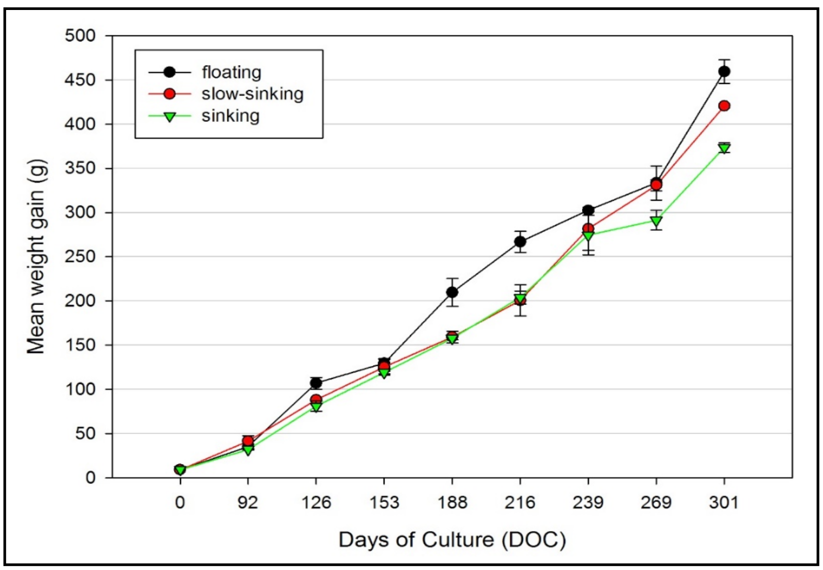

Figure 4. Mean body weight of milkfish (g) fed floating, slow-sinking, and sinking feeds after 301 days of culture (DOC)

the study is presented in Figure 3. Final mean weight gain after 246 days of culture was 396.63±1.84 g, 359.57±11.58 g, and 343.60±17.91 g for extruded floating, slow-sinking, and sinking feeds, respectively. Analysis of variance showed a significant difference in mean weight gain (P<0.05) among feed treatments. Mean weight gain was significantly higher in *O. niloticus* fed extruded floating feed than sinking feeds. No significant difference in mean weight gain was detected between *O. niloticus* fed extruded floating and slow-sinking feeds nor between slow-sinking feeds and sinking feed treatments. At four months rearing period, *O. niloticus* had a mean weight gain of 112.03±7.17 g in extruded floating feed treatment, 111.25±7.69 g in slow-sinking feed, and 90.77±5.40 g in sinking feed treatment with no statistical difference between treatments (P>0.05).

Figure 4 shows the average increase in weight of milkfish *C. chanos* during the study. After 301 days of culture, the final mean weight gain of *C. chanos* fed extruded floating, slow-sinking, and sinking feed type was 459.23±13.48 g, 420.53±1.60 g, and 373.46±5.41 g, respectively. Mean weight gain was significantly different among feed treatments (P<0.05) with extruded floating and slow-sinking feeds attaining significantly higher mean weight gain than sinking feeds. Mean weight gain was not statistically different between *C. chanos* fed extruded floating and slow-sinking feeds. At four months rearing period, mean weight gain was 106.88±6.67 g in extruded floating, 88.05±1.52 g in slow-sinking, and 81.00±5.90 g in sinking feed treatment, with extruded floating feeds having significantly higher weight gain than the other two treatments (P<0.05).

In both *O. niloticus* and *C. chanos* studies, feed treatments showed significant effects (P<0.05) on the mean values of absolute growth and specific growth rate (Figure 5). In *O. niloticus* study, absolute growth and specific growth rate were higher in extruded floating feed treatment (1.61±0.007 g/day and 2.22±0.002%/day) than the sinking feed treatment (1.40±0.073 g/day and 2.16±0.021%/day). Growth in slow-sinking feed treatment (1.46±0.047 g/day and 2.18±0.01%/day) did not differ significantly from extruded floating feed and sinking feed treatments. For *C. chanos* study, absolute growth and specific growth rate was statistically higher (P>0.05)

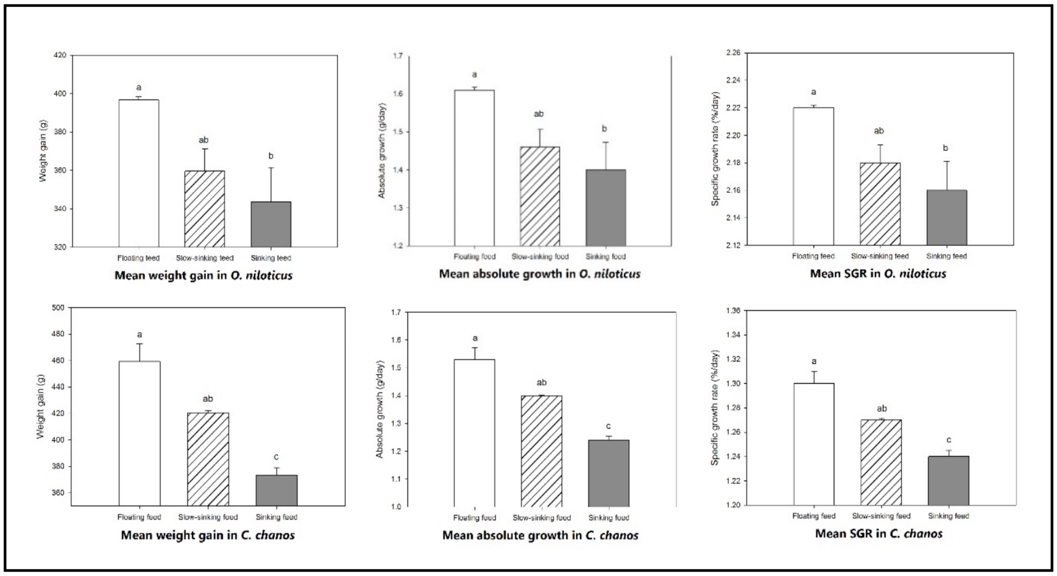

Figure 5. Mean (±SEM) weight gain, absolute growth, and specific growth rate of O. niloticus and C. chanos fed extruded floating, slow-sinking, and sinking feeds

in extruded floating feed type (1.53±0.043 g/day and 1.30±0.01%/day) and slow-sinking feed treatment (1.40±0.003 g/day and 1.27±0.001%/day) than sinking feed type (1.24±0.015 g/day and 1.24±0.005%/day). Growth was not significantly different between extruded floating treatment and slow-sinking feed treatment (P>0.05).

3.2 Percentage Survival, Biomass Harvested and Size Distribution at Harvest

Statistical analysis showed no significant difference in survival rate (P>0.05) in both *O. niloticus* and *C. chanos* studies (Table 1). The survival rate in *O. niloticus* study ranged from 38.77±2.8% to 42.25±1.41% and 77.78±3.05% to 81.97±3.92% in *C. chanos* study. Highest survival rate was achieved by *O. niloticus* fed extruded feeds and *C. chanos* fed slow-sinking feeds. Lowest percentage survival was attained by sinking feed treatment in both species. Gradual mortalities were recorded in *O. niloticus* experimental fish during the study. The affected fish exhibited inappetence for 1-2 weeks and eventually died with a very thin body and exhibited swirling swimming behavior. Mortalities in both *O. niloticus* and *C. chanos* were also noted during low levels of dissolved oxygen levels in the experimental site.

While the percentage survival did not differ between feed treatments, the results of total harvest of experimental fish after the study period (Table 1) showed significant difference in the biomass harvest (P<0.05) between feed treatments in both *O. niloticus* and *C. chanos* studies as a result of the significant difference in the mean weight gain. Biomass harvested was highest in *O. niloticus* fed extruded floating feeds at 991.33±29.36 kg which was significantly higher than *O. niloticus* fed slow-sinking and *O. niloticus* fed sinking feeds with 828.00±16.92 kg and 731.00±20.26 kg, respectively. However, no significant difference was detected in biomass harvested between slow-sinking and sinking feed treatments. For *C. chanos,* biomass harvest in extruded floating feed treatment (702.17±13.18 kg) was significantly higher than sinking feed treatment (572.33±14.19 kg) but was not statistically different from slow-sinking feed treatment (678.17±30.31 kg). Biomass harvest did not differ significantly between slow-sinking and sinking feed treatments.

Moreover, results of the size distribution at harvest showed significantly higher percentage (P<0.05) of good-sized fish (250 g and larger in *O. niloticus* and 300 g and larger in *C. chanos*) in extruded floating feed treatments than the other two feed types for both *O. niloticus* study (Table 2a) and *C. chanos* study (Table 2b). Sinking feed treatment attained the lowest percentage of good-sized fish in both species. Mean percentage of good sized harvested fish for extruded floating, slow-sinking, and sinking feed treatment was 84.01±2.51%%, 66.78±6.67%, and 55.41±7.30%, respectively for *O. niloticus*, and 84.46±5.58%, 72.80±0.80%, and 64.12±9.66%, respectively for *C. chanos.*

Table 1. Mean values (±SEM) of survival rate and biomass harvested of tilapia and milkfish fed three feed types reared in experimental cages.

Treatment		Survival Rate (%)	Biomass harvested (kg)
A. Tilapia			
	Floating feed	45.25±1.41a	991.33±29.36a
	Slow-sinking feed	41.80±2.01a	828.00±16.92b
	Sinking feed	38.77±2.82a	731.00±20.26b
B. Milkfish			
	Floating feed	77.92±1.41a	702.17±22.4613.18a
	Slow-sinking feed	81.97±3.92a	678.17±30.31ab
	Sinking feed	77.78±3.05a	572.33±14.19b

*In a column, means followed by a common letter are not significantly different at 5% level by Tukey HSD and Scheffe; ± indicates standard error of the mean (SEM)

Table 2a. Size distribution of harvested tilapia fed three feed types after 246 days of culture.

Treatment	**Total Good Size, medium to jumbo (%)**	**Jumbo >500g**	**Big 350-500g**	**Medium 250-350g**	**Small 200-250g**	**Reject <200g**
Floating feeds	84.01±2.51a	22.40	23.80	37.80	12.15	3.84
Slow-sinking feeds	66.78±6.67b	8.72	26.97	31.09	26.32	6.91
Sinking feed	55.41±7.30c	6.32	17.80	31.28	38.10	6.49

Table 2b. Size distribution of harvested milkfish fed three feed types after 246 days of culture.

Treatment	**Total Good Size, 3/1 to jumbo (%)**	**Jumbo (%) >500g**	**2/1 (%) 450-500g**	**5/2 (%) 400-450g**	**3/1 (%) 350-400g**	**4/1 (%) 250-300g**	**5/1 (%) 200-250g**
Floating feed	84.46±5.58a	4.79	20.01	29.55	30.11	14.10	1.44
Slow-sinking feed	72.80±0.80b	-	4.58	32.75	35.47	25.22	1.98
Sinking feed	64.12±9.66c	-	8.31	14.37	41.44	30.21	5.67

3.3 Feed Conversion Ratio and Feeds Consumed

Analysis of variance indicated significant differences in feed conversion ratio (P<0.05) in both *O. niloticus* and *C. chanos* studies (Table 3). Feed conversion ratio ranged from 1.39±0.03 to 1.99±0.07 in *O. niloticus* and 1.79±0.04 to 2.41±0.11 in *C. chanos*. Lowest FCR was achieved by extruded floating feed treatments for both *O. niloticus* and *C. chanos* while highest in sinking feed treatment. In both species, FCR of fish fed extruded floating feed was significantly lower than fish fed sinking feed. No significant difference was detected between FCR of *O. niloticus* fed slow-sinking and sinking feed, between *C. chanos* fed extruded floating and slow-sinking feeds, and between *C. chanos* fed slow-sinking and sinking feeds.

Mean weight of total feeds consumed by experimental fish during the study period (Table 3) was not statistically different between feed treatments (P>0.05) in *O. niloticus* study which ranged from 1375.85±6.29 kg to 1454.75±113.86 kg. However, a significant difference was detected in the mean weight feed consumption of *C. chanos* study (P<0.05). *C. chanos* fed extruded floating feed consumed significantly higher mean weight of feed consumed (1256.01±5.06 kg) than *C. chanos* fed slow-sinking (1380.40±4.89 kg) and sinking feeds (1401.90±6.12 kg). Feed consumption between slow-sinking and sinking feed treatments was not statistically different.

Table 3. Mean values (±SEM) of feeds consumed and feed conversion ratio of tilapia and milkfish fed three feed types reared in experimental cages.

Treatment		Feeds consumed (kg)	Feed conversion ratio
A. Tilapia			
	Floating feed	1375.85±6.29a	1.39±0.03c
	Slow-sinking feed	1371.42±79.8a	1.66±0.07ab
	Sinking feed	1454.75±113.86a	1.99±0.11a
B. Milkfish			
	Floating feed	1256.01±5.06b	1.79±0.04b
	Slow-sinking feed	1380.40±4.89a	2.03±0.01ab
	Sinking feed	1401.90±6.12a	2.41±0.07a

*In a column, means followed by a common letter are not significantly different at 5% level by Tukey HSD and Scheffe; ± indicates standard error of the mean (SEM)

Table 4a. Cost analysis of tilapia cage farming comparing floating, slow-sinking, and sinking feeds at 8 months culture period.

		Floating feeds	**Slow-sinking feeds**	**Sinking feeds**
A. Fixed cost				
	Cage (depreciated)	12,000	12,000	12,000
	Nets (depreciated)	9,000	9,000	9,000
B. Operating cost				
	Fingerlings	22,500	22,500	22,500
	Feeds	402,408.70	399,531.55	399,263.15
	Labor	28,000	28,000	28,000
	Repair & maint.	5,000	5,000	5,000
	Miscellaneous	10,000	10,000	10,000
C. Total cost		488,980.70	486,031.55	485,763.15
D. Sales		703,356.25	593,867.70	529,586.88
E. Net income		214,447.60	107,836.00	43,823.73

Note: All costs were calculated for a 10 m x 10 m x 10 m standard sized cage allowed in Taal Lake using data generated from the study

3.4 Cost and Returns, Cost Efficiency and Decreased Volume of Feeds Used

Simple cost and returns for *O. niloticus* cage farming were calculated for a 10 m x 10 m x 10 m standard size net cage allowed in Taal Lake using data generated from the study after 246 days (8 months) as shown in Table 4a. Cost analysis showed that the net income is highest in the cage using floating feeds with PHP 214,447.60 (USD 4,288.95) followed by slow-sinking feeds with PHP 107,836.00 (USD 2,156.72) and lowest in sinking feeds with PHP 43,823.73 (USD 876.47). At about four months rearing period (131 days), cost analysis showed that expected volume of harvest and sales of fish (Table 4b) is still low. Net returns in extruded floating feed treatment, slow-sinking, and sinking feed treatment was PhP 6,021.48, -PHP 11,442.72 and -PHP 3,302.66, respectively. Mean weight of fish at this stage is less than 150 g. Harvesting of fish at this period is not yet economically viable.

The estimated total required feeds and feed cost for each feed type for a regular sized 10 m x 10 m x 10 m cage is shown in Table 5. Based on the estimate, to reach the targeted yield of 5 tons of tilapia a total of 10,000 kg feeds would be needed if conventional sinking feeds will be used. At the same biomass at harvest, 7,000 kg is needed when floating feeds is used and 8,500 kg feeds when slow-sinking feeds are used. A decrease in feed cost from PHP 314,500.00 to PHP 221,900.00 (USD 6,290 to USD 4,438) would be achieved when floating feeds is used instead of sinking feeds. A decrease in feed cost by PHP 92,600.00 (USD 1,852) will be attained, thereby increasing the income by 29.44%. Moreover, this will lessen the number of

Table 4b. Cost analysis of tilapia cage farming comparing floating, slow-sinking, and sinking feeds at 4 months culture period.

		Floating feeds	Slow-sinking feeds	Sinking feeds
A. Fixed cost				
	Cage (depreciated)	12,000	12,000	12,000
	Nets (depreciated)	9,000	9,000	9,000
B. Operating cost				
	Fingerlings	22,500	22,500	22,500
	Feeds	35,103.90	42,750.60	32,332.14
	Labor	16,000	16,000	16,000
	Repair & paint	5,000	5,000	5,000
	Miscellaneous	5,000	5,000	5,000
C. Total cost		104.603.90	112,250.60	85,832.14
D. Sales		110,625.38	100,807.88	82,529.48
E. Net income		6,021.48	(11,442.72)	(3,302.66)

Note: All costs were calculated for a 10 m x 10 m x 10 m standard sized cage allowed in Taal Lake using data generated from the study

Table 5. Estimated feed requirements and feed cost in rearing tilapia and milkfish using the three feed types with values of FCR and feed price from the study as basis for computations

Treatment		Target Biomass at harvest (kg)	FCR based on study	Total feeds requirements (kg)	Price of feeds per kg (PhP)	Total Feeds Cost (PhP)
A. Tilapia						
	Floating feed	5,000	1.4	7,000	31.70	221,900.00
	Slow-sinking feed	5,000	1.7	8,500	31.45	267,325.00
	Sinking feed	5,000	2.0	10,000	31.45	314,500.00
B. Milkfish						
	Floating feed	5,000	1.8	9,000	31.70	285,300.00
	Slow-sinking feed	5,000	2.03	10,450	31.03	324,263.50
	Sinking feed	5,000	2.41	11,200	31.03	347,536.00

Note: Feed amount and feed cost were calculated for a 10 m x 10 m x 10 m standard sized cage allowed in Taal Lake using data generated from the study

feeds used by 30%. This is mainly due to the relative efficiency of floating feeds as feeds for tilapia as reflected by the lower FCR.

Similarly, for *C. chanos,* the use of floating feeds entailed lesser volume of feed used and lower feed cost making it more efficient compared to slow-sinking and sinking feeds. From a total volume of 11,200 kg feeds for sinking feed type with a value of PHP 347,536.00 (USD 6,950.72), the volume of feeds decreased to 9,000 kg with the use of floating feeds with a value of PHP 285,300.00 (USD 5,706). This translates to a decrease in the use of feeds by 2,200 kg feeds (19.64%) and lower feed cost by PHP 62,236.00 (USD 1,244.72) or 17.91%.

3.5 Proximate Analysis

Proximate analysis of the three feed types used for *O. niloticus* and *C. chanos* studies is presented in Table 6. Results of ANOVA showed no significant difference (P>0.05) in the mean crude protein and crude fiber between feed types in both *O. niloticus* and *C. chanos* studies. Moisture content was also not statistically different among different *C. chanos* feed types (P>0.05). However, significant differences were detected in the mean crude fat and ash of the three feed types in the two species (P<0.05) and in the mean percentage moisture of *O. niloticus* (P<0.05). In *O. niloticus* feed types, slow-sinking feed had the highest

Table 6. Proximate analysis (±SEM) of floating, slow sinking, and sinking tilapia and milkfish feeds compared in the study

Treatment		Protein (%)	Fiber (%)	Fat (%)	Moisture (%)	Ash (%)
A. Tilapia						
	Floating feed	29.52±1.29a	5.21	5.02±0.14bc	9.50±0.10b	9.23±0.03c
	Slow-sinking feed	31.81±0.10a	6.19	9.20±0.31a	8.17±0.17c	10.88±0.04a
	Sinking feed	30.90±0.52a	4.49	6.22±0.41b	10.88±0.40a	10.74±0.03ab
B. Milkfish						
	Floating feed	32.21±0.08a	5.17	3.31±0.07c	10.85±2.27a	10.11±0.10b
	Slow-sinking feed	32.28±0.14a	4.82	5.49±0.29b	8.18±0.10a	10.70±0.03a
	Sinking feed	31.90±0.10a	4.44	7.62±0.23a	11.33±0.06a	10.04±0.04bc

*In a column, means followed by a common letter are not significantly different at 5% level by Tukey HSD and Scheffe; ± indicates standard error of the mean (SEM)

Table 7. Proximate analysis (±SEM) of harvested tilapia and milkfish fed with floating, slow-sinking, and sinking feeds compared in the study

Treatment		Protein (%)	Fiber (%)	Fat (%)	Moisture (%)	Ash (%)
A Oreochromis niloticus						
	Floating feed	19.47±0.31a	<0.10	0.85±0.11b	78.44±0.062a	1.31±0.03a
	Slow-sinking feed	19.29±0.81a	<0.10	0.53±0.09c	80.57±0.58a	1.27±0.05a
	Sinking feed	19.34±0.22a	<0.10	1.30±0.07a	79.32±0.58a	1.19±0.01a
B. Chanos chanos						
	Floating feed	21.93±0.39a	<0.10	2.18±0.32b	70.96±0.36a	1.29±0.05a
	Slow-sinking feed	22.07±0.37a	<0.10	2.57±0.30a	72.55±0.34a	1.36±0.03a
	Sinking feed	20.74±0.44a	<0.10	1.83±0.06bc	72.11±0.25a	1.31±0.03a

*In a column, means followed by a common letter are not significantly different at 5% level by Tukey HSD and Scheffe; ± indicates standard error of the mean (SEM)

mean crude fat and ash while moisture content was highest in sinking feed. For *C. chanos* feed types, the highest mean percentage fat was noted in sinking feeds and the highest mean percentage ash in slow-sinking feeds. Protein content ranged from 29.52±1.29 to 31.81±0.10% in *O. niloticus* and 31.90±0.10 to 32.28±0.14% in *C. chanos.*

Results of the proximate analysis of fish flesh of harvested *O. niloticus* study and *C. chanos* study (Table 7) showed that the different feed treatments have significant effect on the body crude fat ($P<0.05$) but not on crude protein, crude fiber, ash, and moisture ($P>0.05$) with *O. niloticus* fed sinking feeds and *C. chanos* fed slow-sinking feeds having significantly higher fat content than fish fed with any other feed types.

3.6 Water Quality

Results of statistical analysis of water parameters of experimental cages (Table 8) showed that mean readings of all parameters did not differ significantly between treatments ($P>0.05$) in experimental sites in both *O. niloticus* and *C. chanos* studies. All parameters were within optimum levels except for dissolved oxygen which was less than the 5.0 mg•li^{-1} optimum. Comparing the experimental cages which lie within the cage aquaculture zone and the open water non-cage area about 200 meters away, mean readings of dissolved oxygen level were significantly higher in the non-cage zone than the cage area ($P<0.05$). The non-cage area had mean dissolved oxygen reading of 4.925±0.020 mg•li^{-1} in *O. niloticus* study area and 4.622±0.026 mg•li^{-1} in *C. chanos* site. Low levels of dissolved oxygen (<4.0 ppm) were recorded for one to two times in a month in both *O. niloticus* and *C. chanos* cage sites which caused poor appetite and gradual mortality in the experimental fish. DO levels even dropped to below 2.5 mg•li^{-1} during the month of August. Inappetence and mortalities were recorded during this period.

Table 8. Mean readings of water parameters in O. niloticus and C. chanos experimental cages.

Parameters	Oreochromis niloticus cages				Chanos chanos cages			
	Floating	Slow-sinking	Sinking	Non-cage area	Floating	Slow-sinking	Sinking	Non-cage area
Dissolved oxygen (mg•li-1)	4.069 ±0.123b	4.019 ±0.135b	3.919 ±0.167b	4.93 ±0.020a	3.523 ±0.042b	3.57 5±0.045b	3.544 ±0.036b	4.622 ±0.026a
Temperature (oC)	30.40 ±0.007a	30.45 ±0.014a	30.43 ±0.013a	30.31 ±0.003b	31.18 ±0.018a	31.20 ±0.007a	31.20 ±0.007a	31.15 ±0.020a
pH	7.9167	7.9167	7.9167	7.9167	7.7667	7.7667	7.7667	7.7667
Transparency (cm)	1.699 ±0.015	1.696 ±0.009	1.781 ±0.013	1.756 ±0.003	1.912 ±0.013	1.909 ±0.008	1.914 ±0.008	1.905 ±0.002
Ammonia (mg•li-1)	3.479 ±1.210	3.454 ±1.140	3.512 ±1.311	3.262 ±0.727	4.1839 ±1.783	4.1976 ±1.886	4.3452 ±2.156	4.1844 ±1.479
Nitrate (mg•li-1)	0.8268 ±0.533	0.8368 ±0.633	0.9012 ±0.493	0.8553 ±0.776	0.7154 ±0.269	0.8078 ±0.398	0.7367 ±0.481	0.6365 ±0.534
Nitrite (mg•li-1)	0.0050 ±0.009	0.0070 ±0.01	0.0063 ±0.013	0.0052 ±0.089	0.0050 ±0.009	0.0053 ±0.023	0.0049 ±0.012	0.0068 ±0.012
Total Nitrogen (mg•li-1)	2.9092 ±2.129	2.8095 ±2.412	2.9113 ±2.228	2.9550 ±2.855	2.6285 ±2.071	2.7123 ±3.189	2.8731 ±2.110	2.9942 ±2.532
Phosphate (mg•li-1)	1.8286 ±0.084	1.923 ±0.094	1.789 ±0.093	1.8283 ±0.083	1.8643 ±0.067	1.9645 ±0.071	1.8761 ±0.083	1.8442 ±0.069
Hardness (mg•li-1)	266.67 ±11.55	267.86 ±10.65	271.87 ±12.77	266.67 ±11.547	276.0 ±16.73	289.0 ±14.93	281.7 ±14.52	280.0 ±14.14
Alkalinity (mg•li-1)	220.0 ±20.0	225.0 ±25.5	228.0 ±18.9	220.0 ±20.0	240.0 ±14.14	245.4 ±23.97	251.8 ±19.22	225.0 ±10.0

*In a row, means followed by a common letter are not significantly different at 5% level by Tukey HSD and Scheffe; ± indicates standard error of the mean (SEM)

4. DISCUSSION

Feed is a major input in cage aquaculture comprising of 70-80% of operating cost which limits the profitability of culture operations. It is also used in cage aquaculture in significant volume with serious implications on lake water quality in case of feeds wastage, hence, selection of appropriate feed type is important. Since the start of cage aquaculture in inland waters such as Taal Lake in Batangas, Philippines, sinking feeds and slow-sinking feeds had been used traditionally for feeding fish but in recent years, extruded floating feeds had been introduced commercially. While some cage operators are now using floating feed types, a significant number of fish cage farmers still use sinking feeds with the basic assumptions that it results in better growth and size distribution at harvest. Extruded floating feed has been shown to exhibit better growth performance in several species (Aba et al. 2012; Ammar 2008; Chebbaki et al. 2010; Lee et al. 2016; Hematzade et al. 2013) but had shown no significant difference in some species (Limbu 2015; Misra et al. 2002). Whether floating or sinking feed type provides better culture performance and cost efficiency on *O. niloticus* and *C. chanos* reared in net cages remain to be validated.

Results of the present study indicated that extruded floating and extruded slow-sinking feeds had better growth performance than sinking feed for both *O. niloticus* and *C. chanos*. These results agree with the study of Ammar et al. (2008) and Abou-Zied (2015) which found a significantly better performance of *O. niloticus* fed extruded feeds over non-extruded feeds. Extruded floating feeds also performed better compared to non-extruded feeds in other species such as *Oncorhynchus mykiss* (Aba et al. 2012; Hematzade et al. 2013); *Sparus aurata* (Ammar 2008), *Dicentrarchus labrax* (Ammar 2008; Chebbaki et al. 2010), *Mugil cephalus* (Ammar 2008), and *Anguilla japonica* (Lee et al. 2016). The higher growth in fish fed extruded floating feed may be attributed to the efficiency of the feed type and lesser energy spent on feeding by the cultured fish. Extruded feeds are more efficient due to its higher digestibility and facilitate the inactivation and/or destruction of the heat-labile anti-nutritional factors (Delgado and Reyes-Jaquez 2018). Swimming is a very energy-demanding activity, and the energy expenditure of swimming at a fast speed during feeding may affect the weight gain of fish. In this study, the higher weight gain in fish fed floating feed type may be explained by the feeding behavior of *O. niloticus* and *C. chanos* on this feed type where fish feed effortlessly on the water surface with less swimming effort, therefore exerting low energy in feeding. The conserved energy of the fish was translated into fish flesh, thereby achieving more weight gain at harvest. In contrast, fish feeding on slow-sinking and sinking feeds were exerting more energy by dart swimming after the sinking feeds, hence, losing more energy in feeding that resulted in lesser weight gain.

Proximate analysis of the feeds used in the study showed crude protein, fiber, fat, moisture, and ash to be in the range required by both species. Among these parameters, only fat content was significantly different between feed treatments with higher fat content in sinking feeds than extruded floating feeds. In several species, the protein sparing effects of lipids had been reported (Orire and Sadiku 2011; Li et al. 2012; Hasan and Khan 2013; Yigit et al. 2002; Kikuchi et al. 2000) with higher levels of lipids in feeds resulting to higher weight gain in fish. This is in contrast with the results of this study which showed that fish fed on lower lipid level extruded floating feeds attained a higher growth rate than fish fed on sinking feed with higher lipid content. This may be attributed to the characteristics of the feed type and the manner in which fish exert energy to grab the feed. In floating feed type, fish exerted less energy to capture the feed due to its floating nature leading to conserved energy for growth. In the process, however, the decreased feeding activity resulted in higher body fat in fish. On the other hand, feeding on sinking feed type spent high energy in capturing food, thus, leaving less energy for growth resulting in lower weight gain.

The survival rate in the present study did not differ between feed treatments in both species but was relatively low in *O. niloticus* in comparison to percentage survival achieved in other studies at more than 85% (Abou-Zied 2015; Ammar et al. 2008). The low survival rate may be attributed to the low mean dissolved oxygen levels in the experimental sites during the study period, which is typical of the dissolved oxygen level in the cage zones in Taal Lake (Querijero and Mercurio 2016). During these periods of low dissolved oxygen, inappetence, and mortality were recorded. Furthermore, gradual mortalities not related to low dissolved oxygen was also observed in *O. niloticus*. These were characterized by inappetence, disoriented, swirling swimming behavior, exophthalmia, and bent bodies that eventually die with very thin bodies. These clinical symptoms are similar with Streptococcal infection in *O. niloticus* described in the study of Sun et al. (2016), Pretto-Giordano et al. (2010), Asencios and Chaupe (2016), and Najiah et al. (2012). Such bacterial infection is normally correlated with high bacterial load in the water and high stocking density usually practiced in cage aquaculture. Although periodic mortality in *O. niloticus* was in few numbers, it occurred frequently over long periods until the harvest results to high accumulated mortality leading to low survival at the end of the study. On the other hand, the survival rate was high in *C. chanos* which is comparable to percentage survival attained in the study of Manomaitis and Cremer (2006). Few mortalities, however, were also recorded in *C. chanos* in all of the feed treatments which occurred at the later stage of the experiment and were noted to be caused by puncturing of the eye of the affected fish by other fishes during feeding activity.

The culture period to achieve market size in this study, eight months for *O. niloticus* and ten months for *C. chanos*, is relatively longer in comparison to the rearing of these species in other culture areas which may last for 4-6 months (Manomaitis and Cremer

2006; Abu-Zied 2015; Ammar et al. 2008). This may be related to the periodic low levels of oxygen in the experimental cage areas that caused inappetence of fish during this adverse water condition, therefore reducing the growth rate of the experimental fish. At the optimum level of dissolved oxygen, a specific growth rate in *O. niloticus* may reach 3.8%/day (Makori et al. 2017) in comparison with the SGR in this study which ranged 2.16-2.22%/day at lower mean readings of dissolved oxygen. In the works of Tran-Duy et al. (2011), fish tended to reduce the energy requirements for maintenance as DO level declined. Feed intake in *O. niloticus* drops at below 5.5 mg•li-1 dissolved oxygen in >200 g fish and at 3 mg•li-1 for <100 g fish with growth and metabolism adversely affected. Similarly, growth rate increased at a higher level of dissolved oxygen and lower growth at lower than optimum level was shown in the study on *O. niloticus* by Makori et al. (2017) and Abdel-Tawwab et al. (2015) and Tran-Duy et al. (2008).

Furthermore, the comparable feeds consumption but lower feed conversion ratio in O. *niloticus* and *C. chanos* fed floating feed than fish fed sinking indicated the efficiency of the former over the latter feed type. In this study, the corresponding increase in weight at a lesser feed intake happened with fish fed floating feed type, similar with the results of Abu-Zied (2015) on O. niloticus fed extruded floating and extruded sinking feed. FCR is lower at floating feed type while inverse results occurred with sinking feed diets. FCR was also found to be better in fish fed extruded floating feed than sinking feeds and non-extruded feeds in other species (Aba et al. 2012; Ammar et al. 2008; Chebbaki et al. 2010; and Lee et al. 2016).

Biomass harvested in *O. niloticus* and *C. chanos* fed floating feeds was expectedly higher in floating feed treatments compared to sinking feeds as a result of the higher weight gain at final harvest with similar survival rate which is similar with the results of Abou-Zied (2015) and Ammar et al. (2008). Similar weight gain and percentage survival in slow-sinking and sinking feed treatments resulted in similar biomass harvested in the two feed types. Contrary to the usual notion of cage farmers in Taal Lake that floating feeds will result in broken size with a large number of small-sized fish at harvest, the result of this study showed that the use of floating feeds in *O. niloticus* and *C. chanos* cage culture results in higher percentage of good marketable size at harvest. In the floating feed treatment, the majority of the fishes had an equal opportunity of feeding at the water surface, thus, resulting in a higher number of good sizes. At a very high fish density, however, this efficiency of floating feeds may decrease because the fish stocks may not be able to feed effectively at the water surface as a result of over-crowding. Appropriate stocking density must, therefore, be employed to assure the efficiency of the feed type. For fish fed sinking feed, the high percentage of smaller sized fish may be attributed to the inability of these fishes to compete with other faster swimming fishes while feeding after the sinking feeds. Fish in slow-sinking feed treatment had more good sized fish than sinking feed treatment because of better opportunities for feeding on slow-sinking feeds.

Cost analysis in the study showed fish fed floating feed had the highest profit and lowest in fish fed sinking feed. This is similar to the results of Abou-Zied (2015) for *O. niloticus* reared in earthen pond with net returns of EGP 38,475 (USD 2,146.14) for floating feed and EGP 21,300 (USD 1,188.12) for sinking feed and with Ammar et al. (2008) with EGP 14,538.25 (USD 810.95) and EGP 10,779.55 (US$D601.29) for floating and sinking feed, respectively. The major difference in the net returns between the feed types is a result of the higher biomass harvested with lower FCR in the floating feed and slow-sinking type than in the sinking feed treatment. Moreover, the efficiency of the floating feed is also reflected in the higher volume of harvest at a lower feed cost. The higher biomass and lower feeds consumption and FCR of tilapia fed floating feed indicates the relative advantage of extruded floating feeds than sinking feeds used by cage farmers in Taal Lake. By using extruded floating feed instead of sinking feeds for *O. niloticus* culture, there will be a 35.61% increase in biomass harvest and a 30.15% decrease in FCR. In *C. chanos*, the use of floating feeds resulted in an increase in biomass harvest by 22.69% and a decrease in FCR by 25.73%. While floating feed type and slow-sinking feed are both extruded feeds, the use of floating feeds has relatively better growth performance and lower FCR compared to slow-sinking feeds. About 9.0% to 10.26% increase in weight gain was achieved using floating type compared to slow-sinking feed in both *O. niloticus* and *C. chanos*. FCR was also lower by 11.82% to 16.27%. Mean weight of fish at 4 months period is less than 150 g, thus harvesting the fish at this stage is not economically viable due to very low or even negative net returns.

5. CONCLUSION

The use of extruded floating feeds revealed comparative advantage over commonly used sinking feeds and slow-sinking feeds with higher weight gain and biomass harvest, lower feed conversion ratio, and better size distribution at harvest. With extruded floating feeds, *O. niloticus* could attain 398.33 g in 246 days with an FCR of 1.39 while *C. chanos* could achieve 468.5 g in 301 days with an FCR of 1.8. The use of extruded floating feeds could decrease the use of feeds in cages by 30% in *O. niloticus* and by 19.4% in *C. chanos* at the same level of fish production in the lake, therefore minimizing the impact on the lake water environment. It could also lessen the feed cost by 29.44% in *O. niloticus* and 17.91% in *C. chanos* thus, higher net returns is attained. In effect, using extruded floating feeds in cage aquaculture does not only increase the profitability of the operations through the lower feed cost and higher biomass of harvest but also lessens the volume of feeds used in cage operations. By eliminating the use of sinking feeds, wastage of feeds due to sinking nature of the feeds is therefore prevented. However, appropriate stocking density should be followed to achieve the best results when using extruded floating feeds. Proper feeding management is also needed to avoid wastage of feeds and achieve maximum feed utilization. Based on the results of this study, it is therefore recommended that cage aquaculture such as Taal Lake utilize extruded floating feeds for a sustainable aquaculture production at higher net returns while minimizing negative impacts on the lake environment. Further study on proper feeding practices is also recommended to assess the appropriate methods for feeding using floating feeds.

6. ACKNOWLEDGMENT

The authors express their deepest gratitude to their collaborating partners, Department of Environment and Natural Resources-Protected Areas Superintendent (DENR-PASu), Bureau of Fisheries and Aquatic Resources-Region 4A (BFAR-4A), and the local government units of Agoncillo, Batangas and Laurel, Batangas. The authors are also thankful to the anonymous reviewers of this paper. Special thanks to Ma. Lourdes Merilles for the figures and proofreading. Sincerest gratitude is also extended to Pedro del Mundo and Rosario del Mundo for their unwavering support to the project. Finally, the authors would like to acknowledge the efforts of their fish cage caretakers, Demetrio Artista, Maximo Masicat, and Doroteo Miranda.

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