Mean individual weight of tilapia subjected to open and greenhouse ponds increased over the 60 days of the experiment (Figure 3). Fish growth was similar within the first 30 days after which there was differential growth pattern among the treatments. On the 60th day, there was significant difference ($p<0.02$) in the mean size of the groups with the fish under open pond being significantly smaller than in greenhouse. There were no significant differences ($p > 0.05$) between *hapas* within treatments. Adding time as a factor into the ANOVA to compare the growth trajectories of the different groups showed significant effects of time ($p<0.0001$), greenhouse ($p<0.0004$) and interaction between the two factors ($p<0.0001$).

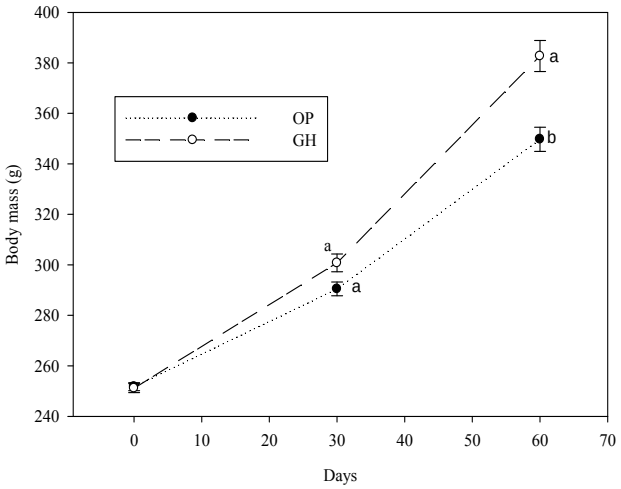

Figure 3: Mean body mass (±S.D) of fish reared under open and inside greenhouse ponds. Significant differences are indicated with superscripted letters (Tukey's test, $p < 0.05$). OP= open pond, GH=greenhouse.

Mean individual weight of tilapia subjected to different levels of crude protein increased over the 60 days of the experiment (Figure 4). At the termination of the experiment, fish under LCP15 treatment recorded significantly ($p<0.05$) smaller weights as compared to HCP30. However, there was no significant difference ($p > 0.05$) in the mean body mass of the groups exposed to MCP25 and HCP30.

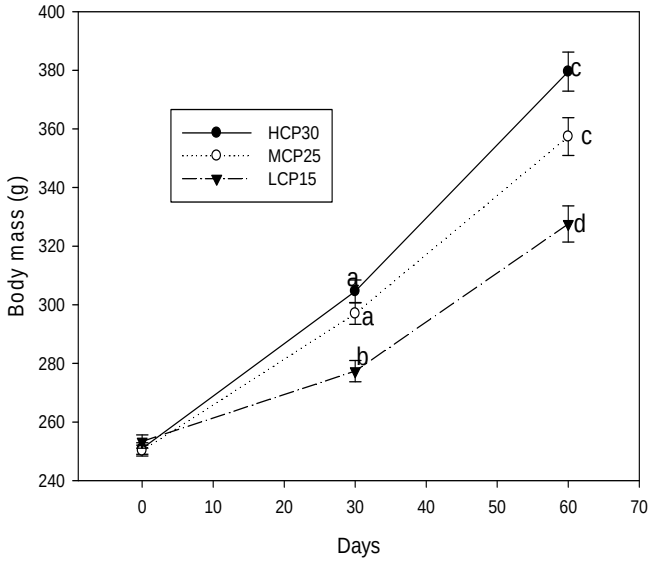

Figure 4: Mean body mass (±S.D) of fish reared under different levels of crude protein. Significant differences are indicated with superscripted letters (Tukey's test, $p < 0.05$).

3.4 Fecundity

Table 3 indicates the main effects of dietary crude protein and greenhouse on spawning frequency during the sampling period. Greenhouse had significantly higher ($p < 0.002$) number of eggs than open pond. Notably, HCP30 gave significantly higher ($p < 0.001$) number of eggs as compared to LCP15. However, HCP30 was not significantly different ($p>0.05$) from MCP25 in terms of number of eggs produced. The results of the present study indicated that in greenhouse, majority of the eggs were either in stage 2 or stage 3 of development while in open pond, they were all at stage 1 of development (Table 3). Spawning frequency was shorter for greenhouse (30 days) than the open pond (60 days). Notably, spawning frequency was shorter for HCP30 as compared to LCP15. Greenhouse and dietary crude protein did not interactively or independently affect the stage of development. However, dietary crude protein and greenhouse had a strong interactive effect of on fecundity and spawning frequency of Nile tilapia.

Table 3: The main effects of crude protein and greenhouse on fecundity of Nile tilapia.

Treatments	*Fecundity/ Female*	*Stage of development*	*Spawning frequency (days)*
CP (%)			
L15	405.76±4.12[a]	1	60
M25	1029.76±1.22[b]	2	30
H30	1036.84±3.12[b]	3	30
Cover			
GH	1198.59±0.15[a]	3	30
OP	618.66±1.23[b]	1	60
Interactions			
L15 x GH	*	ns	*
L15 x OP	ns	ns	ns
M25 x GH	**	ns	**
M25 x OP	ns	ns	ns
H30 x GH	**	ns	**
H30 x OP	ns	ns	ns

Values are means ± SD; values within the same column without a common superscript are significantly different ($p < 0.05$*). Significant level of differences: ns,* $p > 0.05$*; *,* $p \leq 0.05$*; **,* $p \leq 0.01$*.* OP= open pond, GH=greenhouse, CP= crude protein

4. Discussion

Greenhouse water showed uniform water temperature through out the day and night. Consistent with other studies [16, 20, 27] this could probably be due to transmission of solar radiation by greenhouse and absorption by water. The *hapas* in open condition showed lower water temperatures due to continuous heat losses from the *hapas* to the ambient through conduction, convection, evaporation and radiation [43-44]. Generally fish do not like any kind of changes in their environment. Any changes add stress to the fish and the larger and faster the changes, the greater the stress. So the maintenance of temperature in pond culture by use of greenhouse becomes very essential for fish culturist/hatchery operators for getting maximum yield and fingerlings

The greenhouse treatment showed increased water temperature of average 7.82 ^{0}C above the open pond condition, suggesting that water temperature can be increased significantly in ponds by use of greenhouse in a tropical climatic condition similar to those of the study area. The results of the present study concur with those of several other studies, which indicate that greenhouse could increase the water temperature in fish culture [4, 20, 27, 30, 36, 41, 45, 50]. Crude protein did not have any significant effect on water quality. Notably, there were no significant interactive effects of crude protein and greenhouse on water quality parameters suggesting that the effect of different levels of dietary crude protein on water quality is independent of the temperature (as a result of greenhouse) of the rearing water.

We observed that fish under greenhouse had elevated consumption and activity. This could possibly be as a result of elevated water temperature as a result of greenhouse effect. Many researchers have associated elevated food ingestion with temperature [9, 22, 38, 47]. This could be due to additional energy required to offset higher metabolic cost associated with higher temperature in order to maintain desired growth rates [6, 26]. This could have resulted into high ingestion rate of fish under greenhouse condition. Low oxygen in the morning in greenhouse resulted to increased ventilation. Consistent with other studies [13, 19], this could be a reaction to low oxygen by increasing the rate of water flow through the gills.

In this research, with regards to the dietary crude protein level, fish fed with high dietary protein gained significantly higher WG % and SGR while those fed with low dietary protein got low WG % and SGR. This could be because protein intake was high at high dietary protein level and the main component in diet which influences growth is protein. However, the present results are different from the results of El-Saidy and Gaber [17] who found no significant increase on growth performance at high dietary protein level (30%) compared to the low one (25%). It could be due to the size of the fish they used as it is known that the protein requirement varies with size and stage of development [46].

Several studies have established that at higher temperature, growth performance increases due to the presence of suitable conditions that enhance enzymatic response of fish physiological functions [5, 15, 25, 35]. Studies on several fish species have prevailed that with increase in water temperature, the growth rate increases at higher levels and decreases at lower levels [12, 48]. In this study, prevailing higher water temperature inside greenhouse showed higher growth rate in comparison with open condition possibly due to increased metabolism [34-35]. Similar findings have been reported by Josiah et al., [27] and Mohapatra [37] who found better growth of *Clarias gariepinus* and *Labeo rohita* in greenhouse. In open pond condition, growth rate was markedly dropped due to poor ingestion

There was a strong interactive effect of crude protein and greenhouse on growth of Nile tilapia, suggesting that the effect of crude protein on growth performance of Nile tilapia under culture conditions strongly depends on the environmental temperatures. The overall specific growth rate (SGR) of the fish in the present experiment (1.16 **%** day^{-1}) for fish reared under greenhouse condition was good in comparison to what is reported in other studies on tilapia. It was higher than the 0.4%day^{-1} reported by Liti et al [31] for slightly larger tilapia (500 g) and slightly less than the 1.3 % day^{-1} reported by Liti et al. [32] for slightly smaller fish (25 g). However, all these studies had recorded poor growth rate values during the first period (from day 1 to day 30). It is not clear why this case occurs. However, it is possible that the fish had not fully acclimated to the *hapas* before the experiment commenced. In contrast, the growth rate subsequent growth periods were very good and therefore, the overall growth performance was good under greenhouse condition as compared to open pond.

There was a strong interactive effect of greenhouse and dietary crude protein on fecundity and spawning frequency of Nile tilapia. Numerous studies have demonstrated that reproductive performance and egg quality are influenced by nutrients and environmental factors like temperature [14, 18]. Proteins and lipids are the main components of egg yolk and play an important role in fish reproduction. Furthermore, proteins are a major source of amino acids and are a reservoir of materials used for early stages of embryogenesis. Therefore, formulated feed for broodfish should contain sufficient amounts of crude protein. Because the metabolism of fish is affected by temperature and other environmental factors [21], it is often assumed that environmental conditions e.g. temperature may have a significant effect on feeding activity. In the present study, interactive influence of temperature and dietary crude protein could have enhanced feeding frequency of fish resulting in higher protein intake in the higher dietary protein level resulting to high production of eggs and spawning frequency

5. Conclusion and Recommendations

In conclusion, this study demonstrates that there is a strong interactive effect of greenhouse and dietary crude protein on growth performance, fecundity and spawning frequency of Nile tilapia. However greenhouse and dietary crude protein does not have a strong independent or interactive effect on the stage of development of the egg. Greenhouse can raise

water temperature with an average of 7.82 ^{0}C above the open pond conditions in a tropical climatic condition similar to those of the study area. The current study suggests that the recommended maximum level of dietary crude protein level to maintain the welfare and maximum growth of Nile tilapia is between 25-30 % with a maximum advantage of greenhouse culture. However farmers need to watch out for excessive algal bloom under greenhouse possibly by not fertilizing ponds under greenhouse.

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