5. SUMMARY

In the present study, two different sets of experiments were conducted, one on protein to carbohydrate ratio and second on protein to lipid ratio at constant protein to energy ratio (23.0 mg KJ⁻¹). All the experiments were carried out with statistically designed replicates. Each set consisted of 20 test diets (F1 to F20 and D1 to D20), four dietary protein levels, 25, 30, 35 and 40% were selected. At each protein level five carbohydrate levels (0, 5, 10, 15, and 20%) and five lipid levels (0, 4, 8, 10 and 15%) were tested. The test diets were formulated and prepared using purified ingredients such as casein, gelatin, dextrin, cellulose, carboxymethylcellulose, cod liver oil and vitamin mineral mix. With a view to find out the optimum salinity required for better growth performance and nutrient digestibility, the diets in each series were tested on the fish at 5, 15 and 30 ppt salinities for a period of 21 days.

The present investigation yielded valuable information on the effect of carbohydrate and lipid supplementation in diets at constant protein to energy ratio (23.0 mgKJ⁻¹) on growth and nutrient metabolism in mullet M. cephalus as a function of rearing salinities (5, 15 and 30 ppt). The results are summarized below.

1. Experimental diets containing 25 to 40% protein (at 5% interval) were taken. In one set carbohydrate was varied from 0 to 20% and in another set lipid was varied from 0 to 15%, keeping the protein to energy ratio constant (23.0mg KJ⁻¹).
2. Growth (% increase) of *M. cephalus* fed with test diets increased with increase in carbohydrate or lipid levels at the tested salinities. The increase was more pronounced in fish fed with low protein diet (25 and 30%) than that of those fed with high protein diet (40%). Irrespective of the rearing salinities, the growth (% increase) of *M. cephalus* also increased with increase in dietary protein level. Fish reared at 15 ppt salinity registered the maximum growth (% increase) of 77.80 ± 3.34% or 70.52 ± 2.89% fed with 40% protein having 20% carbohydrate or 15% lipid in the diet. Statistical analysis (Two way ANOVA) for the data on growth (% increase) of *M. cephalus* inferred that the variations in carbohydrate, lipid supplementation and rearing salinities were statistically significant (P<0.01 to <0.001). As F-ratio was concerned except for those fish fed with 35 and 40% protein diets supplemented with carbohydrate, the influence of nutrient supplementation on growth (% increase) was more than the rearing salinities.

3. The trend observed in the Specific Growth Rate (SGR) of *M. cephalus* fed with 25 to 40% protein diets supplemented with either carbohydrate or lipid was more or less similar to that obtained for growth (% increase) at the tested rearing salinities. Data on multiple comparison (SNK test) revealed that the variation in SGR between the experimental diets fed fish at the tested protein levels and rearing salinities was statistically significant (P<0.05) for the majority of the diets.

4. Food consumption of *M. cephalus* fed with test diets was increased with increase in carbohydrate or lipid levels in the diets at the tested salinities. On the other hand, it decreased with increase in protein content of the diets. However, food consumption of *M. cephalus* fed all the carbohydrate
supplemented diets was more at 15 ppt salinity than those reared at 5 or 30 ppt salinity. In the case of fish fed with lipid supplemented diets, the food consumption was minimum at 15 ppt salinity when compared to those reared at 5 or 30 ppt salinity.

5. Food Conversion Efficiency (FCE) of *M. cephalus* fed with test diets increased with increase in carbohydrate as well as lipid level in the diets. It has also shown an increasing trend with increase in protein level in the diets at the tested salinities. FCE of *M. cephalus* was maximum (31.05 ± 2.27%) for those fed with 40% protein diet having 20% carbohydrate. Similarly, it was also maximum (29.40±1.26%) for those fish fed with 40% protein diet having 15% lipid reared at 15 ppt salinity. Critical analysis of the data on mean of *M. cephalus* as a function of carbohydrate or lipid supplementation at the tested protein levels and salinities with multiple range test (SNK test) revealed that the variation between mean FCE for majority of the feeds was statistically significant (P < 0.05).

6. The Feed Conversion Ratio (FCR) of *M. cephalus* increased with increase in dietary carbohydrate and lipid levels at the tested protein levels and rearing salinities. It was low for those fish reared at 5 and 30 ppt salinities and high at 15 ppt salinity. The maximum FCR of 3.21± 0.13 or 3.40 ± 0.14 was shown by the fish fed with 40% protein having either 20% carbohydrate or 15% lipid reared at 15 ppt salinity.

7. The whole body composition of *M. cephalus* was significantly varied by the experimental diets as well as rearing salinities. The variation in whole body protein content of *M. cephalus* fed with both carbohydrate and lipid
supplemented diets were much pronounced at all the protein levels and salinities. Statistical analysis (Two-way ANOVA) revealed that the whole body protein content of *M. cephalus* was more significantly (*P* < 0.001) influenced by rearing salinity than by the carbohydrate or lipid levels in the diets. On the other hand, the influence of carbohydrate and lipid levels in diets on whole body carbohydrate and lipid content of *M. cephalus* was statistically more significant (*P* < 0.001) than the independent influence of rearing salinities.

8. Similarly the biochemical composition of faeces in *M. cephalus* fed with test diets also significantly varied at different salinities. The variation in carbohydrate and lipid contents in faeces was high and it was low for protein content. Two-way ANOVA test revealed that the faecal protein content of *M. cephalus* was more significantly (*P* < 0.001) influenced by rearing salinities than that of carbohydrate or lipid levels in the diets. In contrast, the faecal carbohydrate and lipid contents of *M. cephalus* were more significantly influenced (*P* < 0.001) by carbohydrate and lipid levels in the diets than that of rearing salinities.

9. The dietary carbohydrate and lipid levels as well as the rearing salinities also influenced the nutrient metabolism in *M. cephalus*. Irrespective of the rearing salinity, the protein consumption of *M. cephalus* increased with increase in dietary carbohydrate or lipid levels. The protein consumption of *M. cephalus* fed with 25 to 40% protein diet (having 0 to 20% carbohydrate) was maximum at 15 ppt salinities, compared to those fish reared at other salinities (5 or 30 ppt). On the other hand, *M. cephalus* fed with test diets having 0 to 15% lipid content and reared at low and higher salinities (5 or 30 ppt) exhibited
low protein consumption. Whereas, the fish fed with high protein levels (35 and 40%), the protein consumption was more in 5 and 30 ppt salinities when compared to 15 ppt salinity.

10. The carbohydrate consumption of *M. cephalus* increased with increase in dietary carbohydrate levels and decreased with increase in dietary lipid. But fish fed with carbohydrate supplemented diets showed a decrease in carbohydrate consumption rate with increase in dietary protein level. In contrast, this trend was reverse for those fish fed with lipid supplemented diets. Moreover, the carbohydrate consumption of *M. cephalus* fed with carbohydrate supplemented diet was maximum at 15 ppt salinity and minimum for those reared at 5 and 30 ppt salinities. But for the fish fed with lipid supplemented diet, the carbohydrate consumption was maximum at low rearing salinity of 5 ppt. At the tested salinities a significant (P<0.01) positive correlation coefficient was obtained for the relationship between carbohydrate consumption of *M. cephalus* and that of carbohydrate levels in the diets.

11. Similarly, the lipid consumption of *M. cephalus* showed a decreasing trend with increase in dietary carbohydrate and it was vice-versa with increase in lipid level in the diets at the tested protein levels. But, when this parameter was increased with increase in dietary protein level for those fish fed with carbohydrate supplemented diets, it showed a reverse trend for lipid supplemented diets fed groups. A significant (P < 0.05) negative correlation coefficient was obtained for the relationship between dietary lipid consumption and that of dietary carbohydrate level. But a significant positive correlation co-efficient was obtained for the relationship between lipid consumption of *M. cephalus* and dietary lipid level.
12. The nutrient digestibility co-efficient of *M. cephalus* fed with tested diets and reared at selected salinities was estimated by indirect marker method using chromic oxide (Cr$_2$O$_3$) as an inert marker (5%). Of the tested nutrients, the protein digestibility co-efficient of *M. cephalus* was decreased with increase in carbohydrate or lipid level in the test diets. For the fish fed with test diets the protein digestibility co-efficient showed an increasing trend with increase in dietary protein level. Despite, a more obvious variation was found in protein digestibility co-efficient of *M. cephalus* fed with high protein diets supplemented with either carbohydrate or lipid; the variation in protein digestibility co-efficient for those fish which received low protein diet was not much varied. At the selected salinities the difference in protein digestibility co-efficient of *M. cephalus* fed either with carbohydrate or lipid supplemented diets did not deviate much.

13. The carbohydrate digestibility co-efficient of *M. cephalus* fed with test diets decreased with increase in carbohydrate or lipid levels and it also showed a decreasing trend with increase in dietary protein density. The trend observed in the lipid digestibility co-efficient of *M. cephalus* fed with experimental diets reared at tested salinities was more or less same to that of the values recorded for carbohydrate digestibility co-efficient.

14. Irrespective of the dietary protein levels and rearing salinities, the protein production of *M. cephalus* fed with experimental diets showed an increasing trend with increase in carbohydrate or lipid levels in the diets. A significant (P<0.01) positive correlation co-efficient was obtained for the relationship between protein consumption and production of *M. cephalus* fed with either carbohydrate or lipid supplemented diets. At the tested salinities, the
maximum protein production was recorded for those fish reared at 15 ppt salinity than those reared at 5 or 30 ppt salinity.

15. The carbohydrate production of \textit{M. cephalus} fed with carbohydrate supplemented diets registered an increasing trend. But in those fish fed with lipid supplemented diets, the carbohydrate production was decreased with increase in dietary lipid. Among the chosen salinities, the carbohydrate production of \textit{M. cephalus} was maximum at 15 ppt salinity when compared with those reared at 5 or 30 ppt salinity. The correlation co-efficient obtained for the relationship between carbohydrate consumption and production was statistically significant (P<0.01) and positive for both carbohydrate and lipid supplemented diet fed fish.

16. For the fish fed with carbohydrate supplemented diets, the lipid production was decreased with increase in carbohydrate level in the diets; but increased with increase in lipid level in the diets. The correlation co-efficient obtained for the relationship between lipid consumption and production of \textit{M. cephalus} fed with carbohydrate or lipid supplemented diet was positive and significant (P<0.01). The maximum lipid production was recorded in those fish reared at 15 ppt salinity fed with either carbohydrate or lipid supplemented diets.

17. The Nutrient Efficiency Ratio (NER) i.e., protein, carbohydrate and lipid of \textit{M. cephalus} fed with test diets at the selected salinities varied with variation in non-protein nutrient source in the test diets. At 25% protein diet fed fish, the Protein Efficiency Ratio (PER) was increased with increase in carbohydrate level in the diets. A similar increase in trend was also observed for the Lipid Efficiency Ratio (LER) of \textit{M. cephalus} fed with the same protein diet. On the
other hand, the Carbohydrate Efficiency Ratio (CER) of *M. cephalus* showed a decrease in trend with increase in carbohydrate level in the diets at the tested protein level. More or less a similar trend was observed in the NER of *M. cephalus* fed with other test diets with higher protein levels.

18. Again, the PER of *M. cephalus* fed with lipid supplemented diets increased with increase in lipid levels in the diets. Similarly the CER of *M. cephalus* also showed an increasing trend with increase in lipid levels in the test diets. But the LER of *M. cephalus* decreased with increase in lipid levels in the diets at all the tested proteins. The NER of *M. cephalus* fed with test diets reared at selected salinities showed the maximum values at the salinity level of 15 ppt. Below and above this level the NER was relatively less. Two way analysis of variance for the data on NER of *M. cephalus* inferred that the influence of nutrient source and rearing salinities on NER was statistically more significant (P < 0.05 to < 0.001).

19. Data on Productive Protein Value (PPV) of *M. cephalus* fed with test diets reared at tested salinities showed an increasing trend with increase in carbohydrate or lipid level. It also showed an increasing trend with increase in protein density in the diets. The correlation co-efficient obtained for the relationship between PPV and protein consumption of *M. cephalus* fed with either carbohydrate or lipid supplemented diets was positive (r = 0.671 to 0.998) and statistically significant (P < 0.05 to 0.001). At the tested salinities, the PPV of *M. cephalus* fed with test diets was maximum at 15 ppt salinity and minimum at 5 and 30 ppt salinities.
20. The Productive Carbohydrate Value (PCV) of *M. cephalus* fed with test diets decreased with increase in carbohydrate or lipid levels at the chosen salinities. But, it increased with increase in protein densities in the diet. Fish fed with carbohydrate supplemented diets showed a significant (P < 0.01) negative (r = -0.933 to -0.998) correlation coefficient for the relationship between productive carbohydrate value and carbohydrate consumption. On the other hand a significant (P < 0.01) positive correlation coefficient (r = 0.903 to 0.993) was obtained for the relationship between PCV and dietary carbohydrate consumption for those fish reared on lipid supplemented diets. The trend on PCV obtained in *M. cephalus* reared at chosen salinities was similar to that of the value recorded for PPV.

21. The Productive Lipid Value (PLV) of *M. cephalus* fed with test diets reared at tested salinities increased with increase in dietary carbohydrate or lipid levels. It also increased with increase in protein density in the diets. At the tested dietary protein levels and rearing salinities a significant (P < 0.01) positive correlation coefficient (r = 0.840 to 0.992 or r = 0.869 to 0.989) was obtained for the relationship between PLV and lipid consumption of *M. cephalus* fed with either carbohydrate or lipid supplemented diets. Among the tested salinities, the maximum PLV was recorded for those fish fed with 40% protein with 20% carbohydrate or 15% lipid diets at 15 ppt salinity.