Nutrient reduction in aquaculture waste by macroalgae production

Danish marine finfish aquaculture wants to increase production and follow the trend of increasing world wide demand for finfish, but restrictions are based on environmental concerns. The demand on seaweeds are also increasing on the market due to its content of vitamins, minerals, gelling agents etc. as well as its potential use for environmental friendly biofuel. Furthermore, seaweeds (macroalgae) assimilate nutrients and can therefore bioremediate wastes in seawater. Linking finfish and seaweed aquaculture together, the seaweed can convert the nutrient waste from the fed aquaculture production into a valuable product and when harvested the environmental footprint from the finfish production will be smaller. This led to the aim of this Ph.D.-project: “Nutrient reduction in aquaculture waste by macroalgae production”. In this study the three red macroalgae containing gelling agents; Chondrus crispus, Furcellaria lumbricalis and Gracilaria vermiculophylla, were investigated as candidates for polyculture acting as biofilters near two fish farms in the inner Danish waters. In addition, the biofilter potential of C. crispus was investigated in outdoor tank cultures receiving fish effluent or seawater. Furthermore, the sporulation method was examined on C. crispus to only get the most valuable life phase and reduce labor intensity. Finally, thalli of C. crispus were cultivated in a bubble column photobioreactor in the laboratory to examine growth and open up the “black box” of growth in between inocula- and end-biomass with on-line growth measurements. In the field near the two fish farms, the highest specific growth rates were C. crispus 0.018±0.006 d-1, F. lumbricalis 0.011±0.004 d-1 and G. vermiculophylla 0.039±0.007 d-1. Results showed a small increase in biomass and a decrease in the specific growth rates of the three macroalgae, while the epibios biomass increased during the deployment periods. Decrease of specific growth rates of C. crispus with distance and increase with feed use underline the importance of the nutrient source originating from the fish farm for algal growth. The slow growth of the investigated macroalgal species, however, makes the production of algal biomass too small to reduce the nutrient waste from the fish farms significantly. The biomass of C. crispus cultivated in outdoor tanks reduced nutrients in the received fish effluent and seawater. The biomass increased up to 110 % during 27 days of experiment with specific growth rates of 0.03 d-1 reached in the flow-through cultures and 0.01 d-1 in the batch cultures. Only the seaweed in the flow-through culture with fish effluent had nitrogen content higher than the critical level for growth and furthermore were not bleached, which indicated non-limited growth with respect to nutrients. Whole thalli of C. crispus cultivated in the photobioreactor with nonlimiting temperature, light and carbon dioxide supply reached a specific growth rate of 0.095 d-1 and contamination was kept at a low level, while fragments of freshly formed thalli reached growth rates of 0.12 d-1 without contaminants and epiphytes. On-line data of carbon dioxide addition from the closed system reflected photosynthetic activity, and these results revealed lag-phases and existence of several exponential growth phases in one of the experiments. Germination of the most valuable tetraspores of C. crispus in the photobioreactor and in the field was successful. The specific growth rate of sporelings in the photobioreactor was 0.065 d-1 and sporelings reached an average length of 1.1±0.1 cm in 119 days. In the field, sporelings reached a maximum length of 1.5 cm with low growth of epibios during four months. In conclusion, the investigated species either grow too slowly to be used for polyculture or as a biofilter near Danish fish farms and/or they cannot be sold as a product due to the high degree of epibios coverage. The bubble column photobioreactor method is well suited to characterize the growth of C. crispus and the on-line data identifies the different growth phases during an experiment. This identification is not possible in the commonly used method in which specific growth rate depends on beginning and end biomass. Further studies could give more information about variables importance for macroalgal growth. However, this method is expensive and needs attention and not suitable for large-scale production of C. crispus unless the produced biomass is for, e.g., high value secondary metabolites. The species Saccharina latissima has in recent studies showed applicability as the future seaweed for polyculture or biofilter in Danish offshore marine fish farming with well known sporulation method, high growth rate and biomass production and low epibios. However, the value of the seaweed biomass is low, but the bioremediation effect is the most important right now for the offshore marine fish farmers in order to maintain their licenses to produce finfish.