Studies on the material circulation in a closed ecological recirculating aquaculture system, CERAS

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Long-term self-sustained habitation in closed environments requires water-gas recycling, waste treatment, and food production, based on biological and physico-chemical processes. In the field of food production, edible higher plant productions primarily have been studied. As a next step, supplying a principal source of animal protein will be needed to extend the food variety for inhabitants in the future.

Accordingly, we have proposed that fish culture is applicable to the production of food containing rich animal protein in closed habitats for example, space stations, lunar or mars bases. We have developed a fish culture system which introduces an artificial food chain consisting of aquatic organisms such as phytoplankton, zooplankton, and fish. It is called the Closed Ecological Recirculating Aquaculture System (CERAS), which is applied to the concept of a closed ecological system (CES). In particular, the aim of the CERAS is to establish an aquatic controlled ecological system with an artificial food chain including gas exchange to maintain the balance between respiration and photosynthesis by the organisms.

In this paper, our studies on the material circulation in CERAS with an artificial food chain: waste material excreted by tilapia *Oreochromis niloticus* - *Chlorella vulgaris* - water flea, *Moina macrocopa* - tilapia larvae are introduced.

Initially, we designed and constructed a completely gas closed fish rearing system with an algal culture system for a multiple purposes to determine the relationship between biomass production of the microalga and the oxygen generation by the microalga. The experiment of gas exchange between *C. vulgaris* and *O. niloticus* was successfully run for 14 days.

C. vulgaris was cultured by using aquacultural waste excreted by *O. niloticus* for a culture media as the first step of a food chain. The culture media was prepared from a mixture of diluted wastewater and solid waste which was digested with concentrated sulfuric acid and hydrogen peroxide under heat soaking. The culture was comparable to algal growth observed in synthetic media and successful in the nutrient removal from the medium. The percentages of nitrogen and phosphorus removal from the medium were 75.2% and 71.9%, respectively.

As a next step of the food chain, tank culture of *M. macrocopa* was carried out to determine the biomass conversion, nitrogen and phosphorus retention when it was fed on *C. vulgaris*. As a result of the culture, the percentages of biomass conversion rate, nitrogen and phosphorus retentions were 20.4%, 24.9% and 17.0%, respectively.

In the third step, a feeding trial with *O. niloticus* larvae and juveniles fed only *M. macrocopa* was conducted for a month. The fish grew normally under the exclusive feeding of *M. macrocopa* through the period for the trial. From the result, the biomass conversion, nitrogen and phosphorus retention were calculated. The values were 25.4%, 27.3% and 45.3%, respectively.

The production of *O. niloticus* larvae and juveniles was postulated as that the fish rearing is started with the larvae at first feeding with a body weight of 10mg wet weight and conducted until attaining to a body weight of 5.0g. The results show that the culture period required for the growth of larval *O. niloticus* until the desired body weights were 53 days and the required biomass for the fish culture of *M. macrocopa* and *C. vulgaris* were calculated 3.75g and 19.6g dry weight, respectively. In the production of *C. vulgaris*, 34g of oxygen can be reproduced. Conversion rate of nitrogen and phosphorus between the all of process were estimated 5.12% and 5.54%, respectively.

The results provide the relationship between the biomass production and oxygen balance, which can be one of the basic data for the establishment of our envisioned system.