Micro -algae biomass as an alternative resource for fishmeal and fish oil in the production of fish feed

In recent years, intense efforts have been made to find new, alternate and sustainable aquatic feed ingredients, primarily in anticipation of an increasing world population and predicted insufficient fishmeal supply which is a critical component of aquaculture feed. Now it is becoming increasingly evident that the continued exploitation of industrial fish as a resource fish feed will ultimately become both environmentally and economically unsustainable. Microalgae are at the base of the entire aquatic food chain and play a major role in the diet of aquatic animals such as fish. Microalgae main applications for aquaculture are related to nutrition, being used as a sole fresh feed or an additive, e.g. source of pigment. Algae produce almost all nutritive compounds which are required for fish. The diverse biochemical composition of microalgae represents them as a promising candidate for the formulation of fish feed. The nutritional composition of microalgae depends on the species, environmental conditions and growth medium composition. Microalgae for use in aquaculture should be non-toxic and possess the essential nutritive constituents, in a reasonable price. Photosynthetic production of algae either in outdoor or indoor photobioreactor systems is costly since cultures must be maintained at low densities. Consequently, large volumes of media must be processed to recover small quantities of algae, and since most algal cells are minuscule, unspecific expensive harvesting processes must be employed. Strategies such as cultivation of microalgae on low price growth media, selection of microalgae capable of growing on such media and produce biomass with desired chemical composition and development of specific harvest and downstream processing represent basic solutions to improve the applicability of microalgae biomass as a fish feed ingredient. Moreover, storage of the algae biomass at optimum conditions minimise the deterioration of valuable compounds. This project has employed the strategies mentioned above to provide a clear concept for the cultivation, processing and the storage of microalgae biomass intended to be used as a fish feed ingredient. A pre-gasified industrial process water with high concentration of ammonia and free from toxic compounds, representing effluent from a local biogas plant was used as a low price growth medium. Therefore, the biomass production benefits from low cultivation price and also from valorization of the nutrients. Screening of various microalgae species has been extensively done to find proper microalgae capable of growing on industrial process water and producing a biomass containing high levels of protein, long-chain polyunsaturated fatty acids (LC PUFA), and bioactive compounds such as natural antioxidants. Effects of growth media composition/concentration and cultivation time on the nutritional composition of the biomass, variations in proteins, lipid, fatty acid composition, amino acids, tocopherols, and pigments were evaluated. Among all studied species including Nannochloropsis salina, nannochloropsis limnetica, Chlorella sorokiniana, Chlorella vulgaris, Chlorella pyrenoidosa, Desmodesmus sp. and Arthrospira platensis, the microalgae Chlorella pyrenoidosa grew well on the industrial process water, efficiently valorized the compounds in the growth medium (ammonia and phosphorous) and produced reasonable amounts of the biomass (6.1 g/L). The resulting biomass included very high levels of protein (65.2±1.30% DW) as well as promising amino acid and carotenoid compositions. Chlorella pyrenoidosa was selected as a source of proteins and amino acids while lacking LC PUFA’s. The microalgae Nannochloropsis salina which was grown on a mixture of standard growth medium and industrial process water produced a biomass containing high eicosapentaenoic acid (C20:5 n-3, as 44.2% ± 2.30% of total fatty acids), representing a rich source of LC PUFA. Data from laboratory scale experiments were translated to large scale and both of these species have been successfully cultivated in flat panel photobioreactor systems. Chromatographic methods were developed and employed for characterising algal biomass at both pre- and post-harvest stages and were based on the analysis of fatty acids (gas-liquid chromatography) and pigments (high-performance liquid chromatography). These methods represented rapid, routine and reliable control measures to verify the variations in the purity of the biomass the microalgae biomass during cultivation, and its quality during the processing and storage. In this study, a new downstream process set up, which included cross flow microfiltration by SiC (0.1µm) ceramic membranes, heat treatment (75°C&15 seconds) for inactivation of enzymes, up concentration by bowl centrifuge at 6500 x 500 g and finally drying by the novel swirl(spin) flash dryer was developed. This processing concept was specifically designed and tested on microalgae samples as a fish feed ingredient. The process aimed at reducing the energy consumption and minimizing deterioration of value-added bioactive compounds such a carotenoids, and LC PUFA. The method has been tested in the laboratory and large scales. Energy consumption per kg of the product was evaluated as 2.2 KWh, which was estimated as 28% lower than known current processing technologies which are being applied to microalgae. The swirl flash dryer was specifically designed to handle microalgae paste like feeds. Analysis of the pigment and fatty acid composition also revealed that the drying technique had profound adverse effects on the quality of microalgae biomass. As the final part of the study, effects of the storage time (0-56 days), storage temperature (5°C, 20°C and 40°C) and the packaging conditions (under vacuum or ambient pressure) on a high LC PUFA biomass from Nannochloropsis salina was investigated. The storage time and temperature strongly influenced the oxidation reactions, which resulted in deterioration of bioactive compounds such as carotenoids, tocopherols and LC PUFA. The study revealed that the oxidation reactions, which led to the creation of primary and secondary products, occurred mainly during the first days of storage. The storage of freeze-dried microalgae at a low temperature (e.g. 5°C) was found to be more efficient than in oxygen-reduced storage conditions such as vacuum packaging. This project provides imperative data covering all aspects of utilisation of algae biomass as a fish feed ingredient. These findings reveal new opportunities and open new doors toward research, processing and quality control in the microalgae industry.

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