Using seaweed cultivation to remediate by-products from ethanol production

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Venus Shell Systems grows seaweed in land based tanks which require the addition of nutrients and sunlight for growth. The seaweed produced is of a very high quality and can be used for various food and medical applications. As it grows the seaweed consumes organic nutrients (predominantly nitrogen based), carbon dioxide and trace elements. The project is concerned with how these nutritional needs might be met by the waste byproducts (retentate) of a large ethanol distillery and at the same time enable safe and efficient disposal of this retentate at a low cost or even profitably. Currently the retentate from the ethanol distillery is disposed of by irrigating pasture for cattle. This has become a limiting factor because of the finite land area available and the relatively poor conversion of the nutrients into marketable biomass (beef). Seaweed growth in tanks has a significantly higher nutrient conversion rate than grazing cattle (up to 20 times higher) and so requires less area to dispose of the same amount of retentate. However, growing seaweed has a higher setup and maintenance cost associated with it. If necessary, extra nutrients required for seaweed growth can be supplied from other sources.

The study group divided the project into a number of smaller more manageable parts concentrating on different aspects of the proposal around scale and feasibility, weather factors and modelling growth. The seaweed's need for nutrient was matched to both current retentate output from the ethanol plant and a projected future production. The system was considered both in steady state and with variable conditions. Models were founded upon some supplied growth and nutrient values for the particular seaweed of interest to Venus Shell Systems. It was noted that these values vary with different strains and species of seaweed. There is potential to grow a variety of seaweeds to meet different market needs and also in order to more exactly meet retentate consumption requirements.

On a short time scale (order of weeks to month) the seaweed growing conditions in the tanks are relatively consistent. By monitoring the pH levels in the tanks, the carbon dioxide concentration is maintained at optimal growth levels. The carbon dioxide available from the ethanol production is in large quantities and calculations showed that it can be considered limitless for the quantities of seaweed and retentate under consideration. The tanks are continually mixed by the introduction of the carbon dioxide gas flow and so can be considered homogeneous without depth variation. The seaweed is regularly harvested to maintain the optimal growing density. However, on a longer seasonal timescale there is variability of temperature and light which significantly impact the growth rates of the seaweed.

One subgroup worked on matching the ethanol plant output directly to seaweed growth and , used spreadsheets to handle the different quantities of retentate components involved. They sought to take up all the nitrogen supplied by the ethanol plant and as much of the other trace elements in the retentate as possible. A basic production and financial model was created using the current quantity of retentate from ethanol production. The study demonstrated the feasibility of consuming all available nitrogen in less than a tenth of the land area currently required for grazing cattle. Other trace elements could also be consumed in a fraction of this area. For the proposed expansion of the ethanol plant more land for tanks is required and the group were advised that this is available. For the model in this case, additional trace elements would need to be added for seaweed nutrition. The project involves very large quantities of seaweed but apparently there is a demand and even larger quantities are used by some of the current or projected fish farming food production units. The financial model built around the estimates appeared to be viable but it would be a large and costly undertaking.

The differences in growth rates between summer (high) and winter (low) were an added complication that was included in the analysis. The area covered by tanks has to be assigned to use all the retentate during the slower growing winter months which means there is excess tank capacity during the summer months. To fully utilise the investment in tank infrastructure additional nutrients would be needed to be added during the summer. This was costed and found to be viable.

The variation in seaweed growth with season is due to both temperature and light. As well as seasonal and diurnal variation there will be variation due to cloudy days. Using data obtained from the Bureau of Meteorology a study was made of the local distribution of these to ascertain the probability distribution of consecutive cloudy days. This would then impact on the short term growth rates of the seaweed and hence would need to be included in a risk assessment. A long run of cloudy days would require extra tank capacity to buffer the retentate that is not being used due to the slower growth.

To allow for changes in the system with time, various models of seaweed growth were built using differential equations. These capture key quantities present including masses of seaweed, nitrogen and carbon dioxide. Using steady state solutions, without time variation, and comparison with current operating data, it should be possible to determine some of the model parameters. Once the key parameters are obtained, these models could in the future guide optimising the ‘finishing’ of the seaweed, in which different seaweed products are obtained by adjusting the carbon:nitrogen ratio.