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# Seaweed mariculture provides feed, green energy production, bioremediation

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## South Africa provides template for other coastal African nations to meet their aquaculture potential



The South African seaweed aquaculture industry has developed steadily and could be used as a guide by other coastal nations to further their aquaculture potential.

Seaweed or macroalgae are compound names for large multicellular marine algae, including brown, green and red algae. Over 20 commercial seaweed species make macroalgae the second most-cultured species of aquatic organisms after finfish, with more than 92 percent of its production coming from mariculture. Most of this production is for direct or indirect human consumption.

When talking about algae, much of the recent interest has been in microalgae, especially for biofuel production. The attributes of macroalgae seem to be overlooked.

## Macroalgae

Macroalgae have a higher photosynthetic efficiency (the fraction of light energy converted into chemical energy during photosynthesis in plants and algae) (6 to 8 percent) than that of terrestrial plants (1.8 to 2.2 percent). Under cultivation, macroalgae grow rapidly and synthesize large amounts of carbon/energy reserves. They also utilize non-arable land, non-potable water and wastewater.

Seaweed can remove excess nutrients such as sodium, potassium, calcium, magnesium, chloride, iodine and bromine from industrial agriculture effluent and reduce coastal eutrophication. Major metallic pollutants also taken up by seaweeds are lead, chromium, mercury, uranium, selenium, zinc, arsenic, cadmium, gold, silver, copper and nickel, of which cadmium is highly absorbed among others in combine, states with sulphur, chlorine and oxygen.

## South African industry

South Africa's seaweed industry has been in existence for over 60 years. It currently is based on the following macroalgal species: *Ulva* species, *Porphyra* species, *Ecklonia maxima*, *Laminaria pallida*, *Gracilaria gracilis*, *Gracilariopsis longissima*, *Gelidium abbottiorum*, *G. pteridifolium*, *G. pristoides*, *G. capense* and *Plocamium corallorhiza*.

These have been used commercially as feedstock for phycocolloid production and for the production of abalone feed and several commercial plant-growth stimulants used in the agricultural sector. In the last seven years, macroalgae have been developed as a feedstock for biofuel production.



*Ulva armoricana* works well in culture due to its high growth rate, ease of harvesting and resistance to contamination by other algal species.

## Green energy, bioremediation

The green seaweed *Ulva armoricana*, the main species of *Ulva* grown in South Africa, is currently the country's largest aquaculture product by weight. It is grown on a large scale with a corresponding capacity for large-scale production of methane biogas. *U. armoricana*'s growth rate, ease of harvesting, resistance to contamination by other algal species and minimal production loss make it preferable to microalgae and other macroalgae for large-scale renewable energy production.

The authors' findings have further proven that biotransformation of *Ulva* to liquefied petroleum gas is viable and economically feasible as clean fuel (Table 1). Results from land-based, paddlewheel flow-through cultivation systems with *Ulva armoricana* have shown that it is efficient at nutrient extraction and heavy metal accumulation (Table 2).

## Amosu, Composition and biogas yield, Table 1

Element	Biogas
Methane	53%
Carbon dioxide	47%
Hydrogen	1%
Hydrogen sulfide	325 ppm
Ammonia	75 ppm
Water	3° C (Dew point)
Gas yield	77.4 normal m <sup>3</sup> /t fresh matter
Gas yield	691.0 normal m <sup>3</sup> /t dry matter

Table 1. Composition and biogas yield from *Ulva armoricana*.

## Amosu, Heavy metals and nutrient composition, Table 2

Heavy Metal/Nutrient	Experiment Seawater (0 fertilizer)	Experiment Double Fertilizer Ratio	Experiment Quadruple Fertilizer Ratio	Standards South Africa Permissible Limit (mg/kg) (Lettuce)	Standards FAO/WHO Permissible Limit (mg/kg)
Cadmium	0.639 ± 0.023 <sup>a</sup>	1.166 ± 0.360 <sup>b</sup>	0.845 ± 0.566 <sup>b</sup>	0.1	0.20
Copper	4.619 ± 1.193 <sup>a</sup>	5.676 ± 1.367 <sup>a</sup>	4.687 ± 1.148 <sup>a</sup>	30.0	0.10
Lead	Not detected	Not detected	Not detected	0.5	0.30
Zinc	18.640 ± 4.814 <sup>a</sup>	20.244 ± 2.011 <sup>a</sup>	22.158 ± 8.991 <sup>a</sup>	40.0	.015-.030*
% Nitrogen	2.122 ± 0.862 <sup>a</sup>	3.220 ± 0.494 <sup>b</sup>	2.350 ± 1.039 <sup>b</sup>	–	Good manufacturing practices

% Phosphorus	1.789 ± 0.082 <sup>a</sup>	1.711 ± 0.318 <sup>a</sup>	1.700 ± 0.269 <sup>a</sup>	–	2,200.00

Figures in the same row with the same superscript are not significantly different ( $P > 0.05$ ).

\*Australia's recommended leaf nutrient concentrations.

Table 2. Result of *U. armoricana* experimental heavy metals and nutrient composition.

## Feed production

When grown as a feedstock, there was no suggested metal contamination of tissues, so *Ulva* could be used as a plant stimulant, in feed formulations for livestock and for the food industry. Studies with *Ulva* in abalone, *Haliotis midae*; sea urchins, *Tripneustes gratilla*; and African mud catfish, *Clarias gariepinus*; showed that with an *Ulva*-enriched diet, growth could be increased, or there was no significant difference ( $P < 0.05$ ) in the feed-conversion ratios among the fish or abalone when substituting *Ulva* for a protein component across the different experimental diets.

The experimental fish, urchins and abalone were able to utilize *Ulva*-enriched diets better than non-enriched diets, as well as the all-seaweed diets. This suggested that protein-enriched *Ulva* species have the potential to be successful as fish feed, particularly if the diets include *Ulva* grown with enriched nutrient, and are good substitutes for protein in formulated commercial feeds.

## Acidification mitigation

Most of the current macroalgae aquaculture occurs in integrated multi-trophic aquaculture (IMTA) systems with seaweed and abalone. One of the positive side effects of seaweed/abalone co-cultivation is that the seaweed is able to alter seawater pH to make it more beneficial for abalone.

Toxicity tests for pH were conducted to assess the health of *Ulva* grown under extreme pH conditions. Findings showed increasing carbon dioxide concentrations decreased water pH (4.71 to 6.67), which caused a significant inhibition in growth and led to different sporulation responses, especially when the medium was not enriched. However, the *Ulva* was able to tolerate and increase pH in integrated systems, which had positive benefits for abalone.

Additional benefits from seaweed-farming activities include capturing atmospheric and dissolved carbon dioxide during growth to assist in climate change mitigation. The energy supply in South Africa is primarily coal-based. South Africa is therefore a carbon dioxide-intense economy, with the country's major energy requirement sourced from fossil fuels. South Africa has among the highest per-capita emissions of greenhouse gases in the world.

It is widely accepted that increases in carbon dioxide, largely caused by human-induced emissions from the burning of fossil fuels and other activities, result in global warming, ocean acidification and climate change. Ocean acidification represents an extremely serious environmental hazard, particularly for shellfish aquaculture. Evidence suggests the South African abalone industry will be influenced by ocean acidification. However, IMTA systems that incorporate *Ulva* and abalone could potentially mitigate this effect.



Most of South Africa's macroalgae aquaculture occurs in integrated multi-trophic systems, where the seaweed alters seawater pH to make it more beneficial for the abalone.

## Perspectives

Despite the fact that South Africa is currently not Africa's largest seaweed aquaculture producer, the country has the highest regional seaweed diversity and one of the richest in the world. As a third-world country with many first-world technologies, South Africa provides many important lessons for less-developed coastal African nations.

The South African seaweed aquaculture industry is well researched and has developed steadily due to the increasing demand for abalone feed that has seen the need for sustainable production of seaweed in IMTAs.

Presently, the South African seaweed industry provides raw materials for other sectors of the economy, as well as the potential for bioremediation of both the atmospheric and aquatic environments. It provides a template that could be used by other coastal African nations to further their undeveloped aquaculture potential.

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