Technical upscaling of seaweed cultivation

Proseaweed Dossier (project AF-16202)

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Introduction: current production

The use of seaweeds goes back centuries, even not thousands of years. Already some 2000 years ago, Romans wrapped roots with seaweeds in order to establish healthy crops, whereas in Asia/China coastal villagers were used to collect seaweeds not only for food and feed, but also for medicinal purposes. During the industrial evolution, techniques became available to extract specific compounds with gelating properties, like e.g. carrageen and agar-agar, whereas more recently, intact and seaweeds extracts have attracted the attention of the agricultural, pharmaceutical and cosmoceutical industry. Still, the use of seaweed extracts or specific seaweed compounds as bio-stimulants remains underexploited, partly due to regulatory constraints [1-5].

Even though recognised as a potential alternative crop for traditional arable crops and specific applications like e.g. pharmaceuticals and cosmoceuticals, and the fact that an exponential increase of seaweed productivity to 30 million tonnes of fresh weight has been achieved worldwide the last 2 decades (FAO, 2016), seaweed farming is still in its infancy. Worldwide, land use based arable farming productivity still exceeds that of seaweeds by a factor ~ 50.000, and only relatively few large scale seaweed farms, especially off-shore, nowadays exist. Worldwide, over more than 10.000 species of seaweed are known to science at the moment, but only a few species from a selected group of genera, are used for commercial purposes. China and Indonesia, roughly produce 10 million of tonnes of fresh seaweed each and mainly cultivate species of only a few genera for either food or industrial purposes. On the other hand, in the non-Asian countries surprisingly most of the seaweeds are collected from the wild. However in recent years, several successful full scale seaweed farms were established in Europe, and their number starts to increase.

Opportunities

Notwithstanding the huge challenges *"seagriculture"* faces, also opportunities exist. Seaweeds could potentially outcompete traditional arable crops with respect to productivity, and have shown to contain high value food and feed components. Furthermore, seaweeds contain health promoting properties for plants, animals and humans [1-5], which is nowadays more and more acknowledged by the respective industries. Besides the seaweed's specific components, there are many factors favouring large scale off-shore seaweed cultivation. Sufficient space is available. The surface area of our planet earth consists for ~ 70% out of water, whereas only a fraction of that is used for commercial exploitation compared to traditional agriculture. Nutrients are plentiful available, and in case not, mechanically up-welling of nutrients from well down-below the sea's surface area has been suggested [3]. Also, seaweeds do not need fresh water for cultivation contrary to arable crops. Furthermore, once implemented at large scale, precious land could be saved from over-exploitation.

Hurdles to be taken

Even though seaweed cultivation at large scale looks promising still many hurdles have to be overcome. They range from plant specific characteristics, to plaques and diseases [6], to hard-ware construction and logistics to finally economics [7].

Productivity and food and feed properties

Productivity may vary between from year to year, within seasons, and even between closely related "eco-types" within a species. E.g. in a series of land-based experiments at Wageningen University, productivity of a *Ulva* species varied by factor of over more than 4 over a 7 week period [~50-250 kg DW/ha/day; 8]. Also a large variation in productivity between strains of Ulva were observed. This warrants special attention to cultivation technique/harvest schemes, species choice, strain selection and preservation of top quality strains.

Variations in protein concentrations

Protein concentrations may vary substantially between species and within a growing season. For instance, when grown in a land-based system *Ulva* ssp showed a variation of a factor 3 in protein concentration over the period August-November, with a maximum of around 20% DW (unpublished results WUR). Contrary to the protein concentration, amino acid profiles analysed for *Ulva* spp remained for fairly constant over the growing season and where comparable to those of e.g. soy, suggesting a good feed and food quality. When grown approx. 10 km out of shore in the North Sea, the brown seaweed *Saccharina latissima* showed crude protein (N-concentration * 6.25) concentrations up to 30% when harvested in the beginning of May, whereas the concentration dropped by 50% when harvested in June in the same year (results Stichting Noordzeeboerderij/WUR). Similar fluctuations have been observed and described in literature for polysaccharides and many other compounds [5].

All these fluctuations warrant a proper control of the quantity and quality during a growing season. Only then an economically viable seaweed industry is to be expected. When cultivated on off-shore, new on-farm and on-line sensor techniques need to be developed to analyse chemical composition on-line (as is done successfully for commercial terrestrial crops), in order to determine optimal harvest period and so maximum economic output.

Seaweed extracts as alleviators of abiotic stress in arable farming

Seaweed extracts, when applied to arable crops, may exhibit specific positive effects both on productivity and quality per se, as on stress tolerance. Recent reviews of experimental results clearly demonstrated increased tolerance of crops to e.g. salt, drought and cold when seaweed extracts were applied in proper formulations [1,2]. Even though promising, a full appreciation on the use seaweed extracts can only be obtained once the underlying mechanisms in the target plants are known. Insight in the mode of action may lead to a further optimisation of the seaweed extracts and in optimal harvest period(s) (see above). This also holds for an array of compounds that may have beneficial properties for human health.

Methane (CH_4) emissions by ruminants

Ruminant enteric methane emission is one of the major contributors to greenhouse gas emissions from agriculture [9]. Besides environmental effects, methane production by ruminants also results in a considerable loss of up to 5% of the total energy consumption, and therefore comes at a considerable economic cost for dairy farmers. The last decade, many in vitro experiments in which low inclusion rates of seaweed biomass with commercial feed were applied, have been performed [e.g. 9]. Results indicated that some seaweeds contributed to decreased CH4 emissions rates in ruminants at optimal inclusion rates. However, large scale in vivo experiments are still lacking and therefore unanimous conclusions with respect to additional effects on productivity and quality of animal products are still premature.

High quality stock material

The supply of sufficient stock material for a sustainable and economically seaweed cultivation industry is of high importance. Traditional arable farming now relies on a continuous supply and reliable production of seeds and continuous improvement of strains via breeding. For seaweed cultivation being successful it is of outmost importance that worldwide bio-banks are created to preserve the original genetic constitution of the species used in seaweed farming, and to supply a large scale industry with sufficient stock-material. At present, only limited information is available on preservation techniques (e.g. cryogenic) of either thalli and/or spores, and how to establish high quantities of stock-material after preservation.

Seaweed cultivation as alternative for arable cropping?

Examples above clearly demonstrate the potential of seaweeds, and hurdles to be taken. However, a full appreciation can only be obtained when seaweeds can be produced in such a way that a high productivity and quality can be guaranteed at acceptable economic costs, and without severe effects on existing ecosystems.

Future prospects and questions to be addressed:

- Robust cultivation systems
- Robust harvest techniques
- State of the art imaging techniques to control quality and quantity on-farm
- Explore and exploit genetic differences within species
- Develop robust preservation techniques for providing sufficient stock-material of high quality

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