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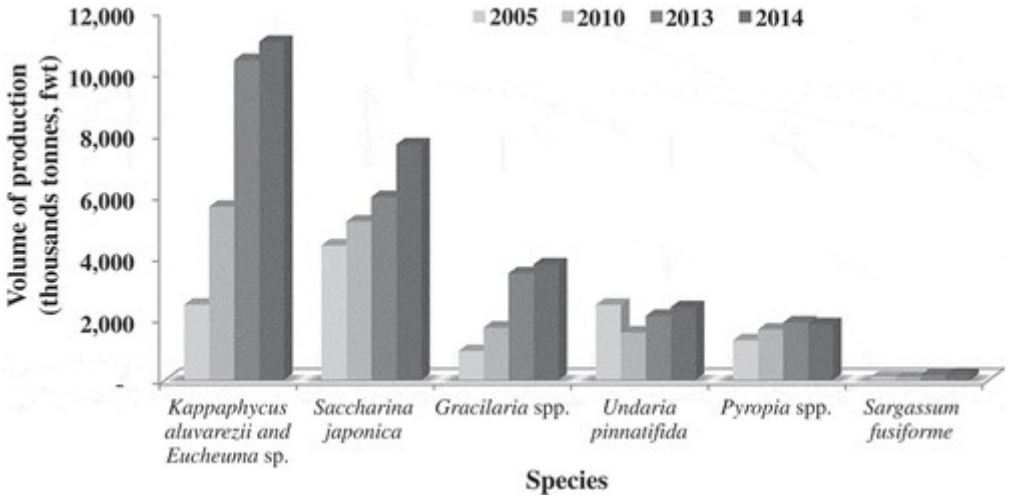
South Africa: Enhancing the production and changing the uses of seaweed to improve food availability and affordability

It is a well-known image, children in central Africa who are starving and slowly dying. Or their skeletal parents that are walking miles for semi clean water. Obviously, they do not have access to sufficient safe food. This is a rather extreme image, but with 7.7 billion people today on earth, it would not be truthful to say that they would be the only ones suffering from malnutrition (World Factbook). Quite the opposite, in fact: global hunger is affecting 815 million people (2016), or 11 per cent of the total world population (World Food Programme). Especially children suffer greatly from malnutrition. There are presently 151 million children under 5 years of age who are stunted and 51 million who are suffering from wasting due to their lack of nutrition (UNICEF). this negative trend is expected to develop even further. With an expected number of 8-10 billion people on the globe, an estimated increase of consumption of 200 kcal/person/day, and an estimated decrease in agricultural trade of developing countries all by 2050, it is safe to say that the world food problem is far from solved (Alexandratos & Bruinsma, 2012).

An insufficient amount of daily calories per person is not the only problem the world faces. 1 billion people have a so-called 'unbalanced diet', what means that they have a protein deficiency (Semba, 2016). Demand for protein is of particular interest, with projections that the world demand for animal-derived protein will double by 2050 (Henchion, Hayes, Mullen, Fenelon, & Tiwari, 2017). Perhaps one of the most promising solutions to this problem is the cultivation and consumption of seaweed. A whole range of seaweed species is already cultivated all over the globe. Seaweeds are either harvested from the wild or cultivated in farms. They are mainly used as a source of hydrocolloids such as agar, carrageen and alginate. Hydrocolloids are amorphous substances that consist of large molecules. Hydrocolloids are polymers of carbohydrates and spread throughout water, forming a gel. Seaweeds used as a source of these hydrocolloids dates back to 1658 (Kılınç, Cirik, Turan, Tekogul, & Koru, 2013).



With a global production of 225.374.506 metric tonnes of seaweed during the period 1980-2009, China is the biggest producer with a share of 62.81% of the total production. On second and third place we have respectively The Philippines and North Korea (Mazarrasa, Olsen, Mayol, Marbà, & Duarte, 2014). It is remarkable that Asia is responsible for almost the entire production of seaweed. This is because South-East Asia was one of the only places where seaweed was already cultivated for nutritional purposes on a big scale for a long time. In South-East Asia, the cultivation of mostly *Kappaphycus* and *Eucheuma* is done under labour intensive conditions. An interesting fact is that most of the work

on the farms is done by women, the so-called 'seaweed women' (Msuya & Hurtado, 2017). But with the rise in awareness of the world food problem, different species of seaweed are cultivated more and more as a food source in the rest of the world (Figure 1).

That is not without a reason. Seaweeds have high nutritional values, which differs greatly between species. The species *P. dioica* for example has a high protein content of 24.2 % of the dry weight and the species *A. nodosum* has a low protein content of 3.5% of the dry weight (Biancarosa et al., 2017). This means that seaweeds can be selected to fulfil the specific needs of the population. Additionally, seaweeds are also rich in fibre and certain vitamins and minerals. Due to the wide spread in protein content, there is a limited amount of species that are used for nutritional purposes. Two commonly grown genera in Europe and America are *Ulva* and *Gracilaria*. *Ulva* mainly grows in the summer and Gracilaria in the winter, this makes year-round cultivation possible. The species I studied in particular is *Ulva lactuca*. This species is especially interesting because of its high growth rate and its favourable nutritional values (Figure 2 and 3). *U. lactuca* has a high protein content (13.6%), fibre content (28.4%) and is rich in many important minerals, such as calcium (Rasyid, 2017). These properties makes this species particularly suitable as a meat substitute and moreover, it can also play a role in a vegan diet due to its high calcium content.

Nutrients content	Results
Moisture (%)	16.9
Ash (%)	11.2
Protein (%)	13.6
Fat (%)	0.19
Carbohydrate (%)	58.1
Dietary fibre (%)	28.4
Vitamin A (IU/100 g)	< 0.5
Vitamin B1 (mg/kg)	4.87
Vitamin B2 mg/kg	0.86
Sodium (mg/100 g)	364
Calcium (mg/100 g)	1828
Iron (mg/100 g)	14.0
Potassium (mg/100 g)	467
Phosphorus (%)	0.05

Heavy metal	Results (mg/Kg)
Mercury	< 0.005
Arsenic	0.09
Cadmium	0.48
Lead	0.18

Maybe the most important aspect is that the cultivation of seaweed does not require any precious agricultural land. Huge amounts of protein can be acquired from the sea instead of land. This leaves more room for food crops to be cultivated where once livestock was held. This is not only good for the environment, but this will also create more food for the population. This is a wonderful solution in countries where agricultural land is scarce due to urbanisation and increased degradation of the soil. Furthermore, seaweed is a possible outcome for countries where food production is limited because of unfavourable climate conditions. Conditions in seas are far more moderate in comparison to the conditions on land. Even countries that suffer from extreme heat and drought have seas that are suited for sea farming.

One of the many countries that is affected by malnutrition and social tensions is South Africa. South Africa is located in Africa and adjoins Namibia, Botswana, Lesotho, Swaziland, Mozambique and Zimbabwe. The country has 58 million inhabitants, increasing by 0.99% each year, spread out over 1,219,090 sq. km. With a coastline of nearly 2.800 km, the population is mainly concentrated along the southern and south-eastern coast (World Factbook). 66.4% of the total population lives in cities and the urbanisation rate is 1.97%. Some of the natural resources in South Africa include: gold, chromium, antimony, coal, iron ore, manganese, nickel, phosphates and tin. Together with only one active volcano, a natural hazard in the nation are prolonged droughts. However, South Africa is familiar with some environmental issues. The main issues focus on the use of extensive water conservation and control measures due to a lack of important arterial rivers or lakes. Additionally, rivers get polluted by farms because of agricultural runoff and urban discharge. Land degradation is also a relevant issue in South Africa (World Factbook). All of these issues play a factor in the farmer's disability to produce an adequate amount of food to feed the rest of the population and to export the excess.

Not only environmental issues are one of the major problems in the country. Social tension and injustice are also taking its toll on citizens. South Africa has been a democracy since 1994. Since then, issues such as poverty, unemployment and social injustice have all been viewed as a key priority by the government. By comparison, 10.2 million people (nearly 20.2% of the population) lived below the breadline of R321.00 per month in 2011 (Van der Westhuizen, Marichen, Swart, & Ignatius, 2015). Poverty and unemployment, two linked factors, play a major role in malnutrition in South Africa. City dwellers are depended on food produced by farmers. This means that unemployed and thereby poverty-stricken people cannot buy an adequate amount of food to provide in their daily need. The great division in social position between the white and prosperous and the black and poor populations have led to an increase in poverty and thereby hunger in South Africa. This contradiction was sharpened during the first decade of democracy by the relative economic growth of these populations. Even though the ethnic group black African makes up for 80.2% of the total population, relative to 8.4% white people, 60-65% of the country's wealth is controlled by 10% of the total population, With around 80% of that population being white (World Factbook; Piketty, 2014).

Provincial wise, the rate of hunger in South Africa is highest in the Eastern Cape and Limpopo Provinces, each having a proportion of more than 30 percent of the total amount of citizens that is malnourished (Megbowon & Mushunje, 2018). 79.4% of the total land area is used as agricultural land, whereof 9.9% is arable land, 0.3% is for permanent crops and 69.2% is permanent pasture (World Factbook). The large amount of agricultural land that is used for extensive grazing of lifestock, which includes cattle, sheep, goats and game, increased massively in the last 20 years due to the increased demand in meat. The wealthy part of South Africa is mainly responsible for this increase of demand. Consequently, the increase in permanent pasture has led to a decrease in arable land. With only 12% of the country suitable for the production of rain-fed crops, this decrease is actually not a bad development, because the production of crops is minimal due to the soil-climate conditions in South Africa, namely a relatively dry climate with only 3% fertile land. Due to a lack of these agricultural products, food prices have risen. When bearing in mind that animal derived products are cost wise unattainable for poor households, these households have to spend more money on these essential and basic products. Money many of them do not have, which means that they can not provide enough food for their daily need.

This malnutrition and in particular a deficiency in protein is a major problem among the poor part of the population. The question is, how can we provide these people with enough affordable food and protein to live an active, healthy lifestyle? Seaweed is a promising solution. By increasing the production and enhancing the cultivation of seaweed many problems would be fixed. Increasing and enhancing the production would provide the people with affordable, nutritious food. The cultivation of seaweed does not rely on water availability on land and soil fertility. Even in periods of drought, which is regularly the case in South Africa, seaweed can be cultivated. Additionally, Seaweed cultivation is way more efficient than the meat production when comparing water costs, land usage and amount of feed needed.

Currently, most of the seaweed that is cultivated in South Africa constitutes as an important feed source for abalone (Haliotis midae L.). Seaweed is also utilised as a tool for biofuel production (Amosu, Robertson-Andersson, Maneveldt, Anderson, & Bolton, 2013). From the start of commercial seaweed exploitation in South Africa in the 1950's, only six wild seaweed genera (Ecklonia, Laminaria, Gracilaria, Gelidium, Gigartina and Porphyra) have been harvested. Over 6,000 t per annum of kelp *Ecklonia maxima* are now harvested for the production of abalone feed (Robertson-Andersson et al., 2017). Because of the rapid development of the abalone industry, some kelp beds have reached maximum sustainable limits. South Africa's wild seaweed resources are well protected under the Marine Living Resources Act of 1998 (Anderson et al., 1989, 2003; GPR, 2005; Anderson et al., 2006). Therefor, seaweed cultivation rates have gone up in the last decades. Twelve seaweed species are currently being cultivated, either in offshore or closed bodies of water: Ulva sp., Porphyra sp., E. maxima, Laminaria pallida, Gracilaria gracilis, Gracilariopsis longissima (S. G. Gmelin) M. Steentoft, L. M. Irvine & W. F. Farnham, G. abbottiorum, G. pteridifolium, G. pristoides, G. capense

(S.G. Gmelin) P. C. Silva, and Plocamium corallorhiza (Turner) Harvey (ESS, 2003; Troell et al., 2006; Robertson-Andersson, 2007). By far, the species that is cultivated the most is *Ulva* spp. (Amosu et al., 2013).

The known seaweed diversity of South Africa was around 900 species in 2012, making the region one of the most biodiverse places in the world regarding seaweed (Payne et al., 1989; Bolton, 1999; Bolton et al., 2003; Maneveldt et al., 2008). This means that a vast amount of species thrive well in South African waters, one of them being *Ulva* species. My research also confirms that *Ulva lactuca* thrives well in African waters. Not only does a high amount of light contribute to a high growth rate, chlorophyll concentration, and photosynthesis efficiency, a relatively high water temperature also improves these things. Mainly because *Ulva lactuca* thrives in the summer period. In South Africa, the summer period extends from mid-october to mid-february and is characterised by hot, sunny weather. These conditions make it optimal for *Ulva lactuca* to grow.

With recent growth of the abalone industry, the cultivation of *Ulva* spp. has grown rapidly (Amosu et al., 2013). Because of its unique gustatory properties, special nutritional value and the safety standards that abalones need to comply with, these abalones are in high demand and of high monetary value (Øiseth *et al*., 2013; Latuihamallo & Apituley, 2015). By changing the use of seaweed, in particular *Ulva* spp., as a raw material of abalone feed into the use of seaweed for human consumption, much protein rich seaweed becomes available for poor households. Compared to the pricey abalones, seaweed is a lot more cost and nutrient efficient, because of the conversion of seaweed feed into abalone biomass. Production rates of seaweed are already high and even currently growing, so a lot more food would become instantly available if that switch took place.

One condition however, is that the population of South Africa needs to be prepared to eat seaweed. Currently, the amount of seaweed consumption is fairly low in South Africa, being the most along the coastline. This is mainly because of the limited supply in seaweed for consumption. There is no doubt that poor and malnourished household will choose to consume seaweed if it becomes available in local markets. The consumption of *Ulva* by those malnourished households helps in supplementing their lack of energy and a large variety of minerals, vitamins and phytonutrients. When seaweed, and in particular *Ulva*, becomes available on the markets, South Africa should promote the consumption of that seaweed among their people.

As mentioned above, rivers in South Africa are getting polluted by farms because of agricultural runoff and urban discharge. Seaweed can also help solve this environmental problem, and not only *Ulva* spp. Seaweeds are highly efficient in absorbing nutrients and heavy metals and thus serve as a biofilter (Cahill, Hurd, & Lokman, 2010). By placing seaweeds in highly polluted rivers, the water in the rivers will ultimately be more suited for irrigation of crops. This way, production of crops will be higher and food prices of these products will lower, becoming more affordable for poor households. Additionally, seaweeds can also be used as a fertilizer because of its high mineral content. This will prevent land degradation, also a relevant issue in South Africa.

By creating new seaweed farms where *Ulva* is cultivated, new job opportunities will arise. Jobs on the farm itself, the building of the farm and harvesting of seaweed, and jobs regarding *Ulva* as biofilter. This will lower the high unemployment rate among the population of South Africa. With additional jobs, the mean income of the population will rise. More money becomes available for food. Consequently, the amount of malnourished citizens will decrease over time.

By changing the use of seaweed, in particular *Ulva* spp., as a raw material of abalone feed into the use of seaweed for human consumption, much protein rich seaweed becomes available for the poor households. When the seaweed becomes available, the government should promote its consumption. Additionally, by placing seaweeds in highly polluted rivers, the water in the rivers will ultimately be more suited for irrigation of crops. This will increase crop production and ultimately food availability. Lastly, new sources of income will arise with the creation of additional seaweed farms, leading to a higher purchasing power among the population. In conclusion, an enhanced cultivation and a more

efficient use of seaweed ultimately leads to less malnourishment in South Africa. When the issue of malnourishment is tackled, South Africa would have more time to focus on the social division and injustice among different types of the population. This is only an example that is focussed on South Africa, but I believe that the production and consumption of seaweed can be applied in many different places and be a step closer to ending world hunger.

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