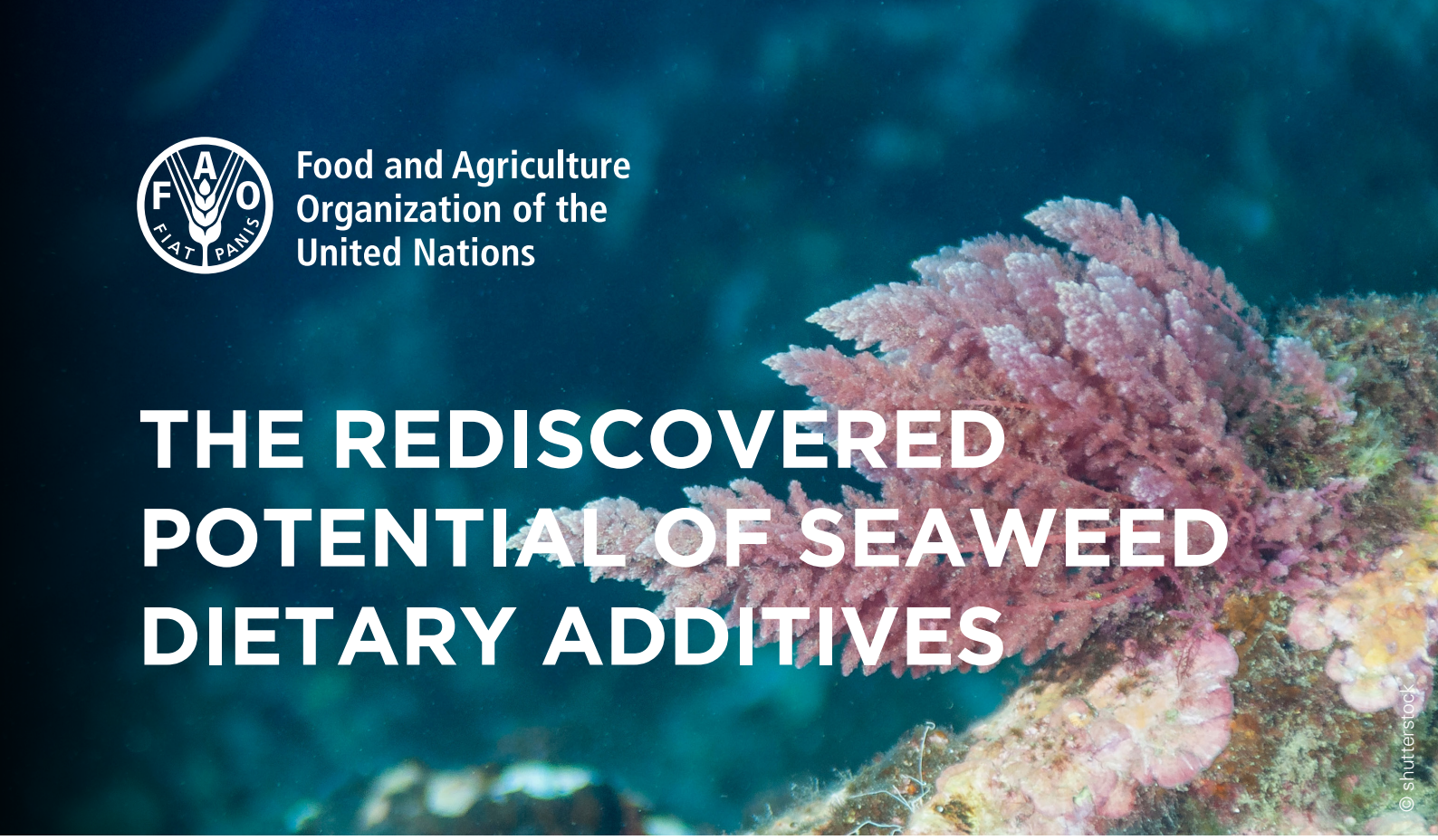
Food and Agriculture Organization of the United Nations

THE REDISCOVERED POTENTIAL OF SEAWEED DIETARY ADDITIVES



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How small seaweed inclusions in the diets of terrestrial and aquatic animals can change the way we produce them and reduce the environmental footprints of food production.

Seaweeds are multicellular marine primary producers that include more than 11 000 species (Guiry and Guiry, 2021) spread across three groups, based on their photosynthetic pigments: red (Rhodophyceae), green (Chlorophyceae) and brown (Phaeophyceae). To date, only a handful of seaweed species, mainly brown seaweeds, have been used commercially as animal feed additives. Brown seaweeds dominate world seaweed production, with one species, Japanese kelp (*Laminaria japonica*), contributing to more than one-third of global seaweed production (11.4 million tonnes) (FAO, 2018).

The cellular structure of seaweeds comprises indigestible fibres or complex polysaccharides (carbohydrates). These gel-like products, which tend to constitute the overall composition of most macroalgae, include alginates from brown seaweeds, ulvans from green seaweeds and agar and carrageenan from red seaweeds. Complex seaweed polysaccharides are used as thickening additives or gelling agents in a range of processed foods – such as ice creams – and in cosmetics, pharmaceuticals, nutraceuticals and other industries.

Although seaweeds have been fed to livestock for thousands of years, predominantly during shortages of more easily digested feedstuff, the complex polysaccharides they produce are also why they have been increasingly used as livestock dietary additives since the 1960s (Makkar *et al.*, 2016). Seaweeds are also rich in potassium, sodium, calcium and magnesium and provide key nutrients such as iron, manganese, iodine, copper and selenium. They tend to have high quality proteins, but the total protein content and essential amino acid concentration of seaweeds are considerably lower than traditional proteins used for animal feeds such as soy and cereals. Although seaweeds tend to be low in lipid content (5 percent), this is usually made up of highly unsaturated fatty acids (Morais *et al.*, 2020).

Two key reasons underpin the use of seaweeds as dietary additives: 1) to bolster the immune system of farmed animals and 2) to improve their productivity and quality. Compounds produced by seaweeds, and not just complex polysaccharides, have been shown to have a range of desirable properties – including anti-inflammatory, antiviral, antibacterial and anti-oxidant effects. Seaweed-supplemented animal feeds can have strong immunostimulatory effects and increase growth rates, without impacting on feed conversion ratios.

TECHNIQUE AND APPROACH USED

The techniques used to deliver the seaweed vary, depending on whether the seaweed comes in the form of a powder or an extract and to which type of animal it is being fed. Delivery to animals is normally via feed as it is by far the most cost-effective solution.

Farmed aquatic animals require a feed that is bound in a pellet to prevent loss of nutrients and breakdown of the feed. Complex polysaccharides from seaweeds, such as alginates, have been used as binders during the pellet-making process, to maintain the shape and integrity of the feed pellets (aquafeed binders) or as a vehicle to transport key nutrients (e.g. microencapsulated diets) for farmed fish and crustaceans.

For terrestrial livestock, seaweed has been added as a dried powder to fodder or animal feed – either by sprinkling it on, mixing it in or by blending it in vegetable oils or molasses, which are then added to overcome any unpalatable effects of the seaweed.

The amount of seaweed in animal feeds usually represents a very small percentage of the animals' diet, normally ranging from 0.1 percent to 5 percent. This is because seaweed can have potent beneficial effects at small doses but can have strong detrimental effects on weight gain and feed intake at inclusion levels that are too high.

The merits of seaweed additives can vary, depending on the life stage of the animal. If growth is the objective, then seaweed is likely to be fed on a daily basis during the whole grow-out period. Similarly, if the goal is to reduce the methane production of ruminants, then they need to be fed *Asparagopsis* spp. daily. To prevent health-related issues associated with a more sensitive life stage – such as weaning for pigs, or sea transfer for Atlantic salmon smolts – then the seaweed additive can be fed for just a small period prior to that time to promote an immune response ahead of such a metabolically challenging time for the animal. Seaweed can be used in finishing diets to improve meat quality, and especially, taste. In that instance, the delivery of the seaweed feed should be during the last weeks prior to despatch to the abattoir or harvest.

Compounds and extracts from seaweeds incorporated into aquatic animal feeds have been found to promote aquatic animal growth and to improve the immune response to disease pathogens.

SCOPE AND SCALE OF APPLICATION

The scope and scale of in-feed seaweed solutions for animal production is immense. In 2018 an estimated 25.9 billion chickens, 1 billion cattle, sheep goats and pigs and 51 million tonnes of aquatic animals were produced.

Seaweed farming currently covers an area of about 9 million hectares, and only a small fraction is dedicated to animal feed supplements. Due to the vast number of seaweed species, novel seaweed additives, with the potential for animal production, are being discovered almost daily. There is now a pressing need to produce seaweeds for these different livestock and aquaculture applications at scale.

A new seaweed application has recently been found for the red seaweed (*Asparagopsis taxiformis*), which may play a major role in ruminant production, in particular cattle, by significantly reducing their methane emissions. Despite the large number of people working in this field, there is still no commercial scale production of this seaweed.

Many seaweed species, like *Asparagopsis taxiformis*, contain compounds and extracts with potential novel uses as aquatic and terrestrial animal feed additives.

ACCESSIBILITY

Although seaweeds grow around the globe, a greater volume and variety need to be grown to cater to demand. Concomitantly, seaweed quality varies greatly, depending on the season and environmental conditions. Seaweeds are extractive and some species are very effective at accumulating toxic elements such as iodine, arsenic and mercury. Thus, careful quality assessment of seaweed biomass must be in place prior to feeding it to animals that are destined for human consumption.

One way to achieve this is to develop a novel seaweed industry focusing on animal feeds to help farmers – both on land and at sea – gain access to premium seaweed feed additives. As for the current industry there is no doubt that Asia, and especially Southeast Asia, could play a significant role in the production of tropical seaweeds, including *Asparagopsis* spp. for animal feeds.

OUTCOME AND BENEFITS

The world currently faces two challenges, which unfortunately are intricately linked: 1) feeding the growing world population and 2) climate change.

Seaweeds produce a range of compounds which can have multiple applications including:

Improving animal productivity by helping to generate faster and more efficiently grown animal protein. For example, when fed to Atlantic salmon (*Salmo salar*), *Asparagopsis taxiformis*, boosted the fish weight gain by 33 percent without having detrimental effects on the fish feed conversion ratio (Thépot *et al.*, 2022).

Increasing disease resistance and thus reducing the need for veterinary drugs for treatments (antibiotic resistance is another major challenge). Some seaweed species can significantly boost fish immunity by up to fourfold, thus improving their resistance to disease-causing pathogens, while also reducing the need for antibiotic treatment (Thépot *et al.*, 2021).

Enhancing meat quality, with better tasting products that are lower in fats.

Producing gut microbiota with reduced methanogens (methane-producing microbes) and thus lowering methane emission from ruminants such as cattle. *Asparagopsis* produces high levels of bromoform ($CHBr_3$), a halogenated compound, which when freeze-dried and mixed at 0.2 percent in cattle diets, reduced methane production in cows by up to 98 percent and simultaneously improved their weight gain by 42 percent (Kinley *et al.*, 2020).

Lastly, growing seaweeds at scale could also have a beneficial environmental impact by absorbing carbon dioxide from the oceans (reducing ocean acidification) and providing a natural ecosystem for small marine life. The challenges of developing a sustainable seaweed industry of the scale needed to meet the demand from animal production on land and at sea are numerous, but the scale of the challenges we face as a species requires much more than the status quo if we are to change the direction in which we are heading.

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