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Life cycle assessment in aquaculture

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Method evaluates impacts of a product, from raw material through production, use and disposal

The food industry is likely to come under greater scrutiny over coming years as world population rises put pressure on food stocks and prices with inevitable strain on the environment. There is also significant pressure on energy resources, in which the production of food using carbon-intensive fuels is linked to accelerating global climate change.

The policies of governments and non-governmental organizations on food are therefore moving to a more holistic approach of environmental impact assessment, of which life cycle assessment (LCA) is a part. LCA is also becoming more important in the world of corporate social responsibility, for consumers increasingly consider sustainability as they make seafood purchases.

Life cycle assessment considers product inputs and impacts from raw materials to disposal. Processing and packaging are involved, as well as transportation for distribution.

Life cycle assessment

Life cycle assessment studies the environmental and other potential impacts of a product throughout its life, starting at raw material and following it through production, use and disposal. LCA can also be used to assess the environmental impacts of a process or service from design to disposal, across the entire life cycle.

The general categories of environmental impacts considered include resources used and ecological consequences. Governed by the ISO 14040 and 14044 standards, LCA requires the gathering and appraisal of data on the inputs and outputs of material, energy and waste flows of a product.

LCA consists of four complementary elements:

- Goal definition and scoping. This includes a full description of the product, process or activity. Why the assessment is required should be established, as well as the boundaries and environmental effects to be identified and reviewed.

- Inventory analysis. Energy, water and materials usage and environmental releases need to be determined.
- Impact assessment. This is examination of potential human impacts, the effects of energy, water and material usage, and the environmental releases identified in the inventory analysis.
- Interpretation. The evaluation of the results from the inventory analysis assessment is tailored to the product, process or service. It must reflect clear understanding of the boundaries and assumptions used to generate the results.

LCA can help identify ways to mitigate environmental impacts and generate cost savings. It can also be used for assessing risks to improve systems, such as in risk management. In addition, LCA can support decision making for companies, such as purchasing, product design, process selection and waste management strategies.

Stages of LCA

The use of energy at different stages during production requires an assessment of the overall impact on the environment. This is not dependent on a single event, but a combination of all the processes. LCA considers inputs from the raw material extractions until disposal. During the transformation, manufacturing and packaging are involved, as well as transportation for distribution.

For the entire life cycle in the production of food, the agricultural inputs are the seeds, fertilizers and water. The produce is then harvested and transported to factories for processing. Energy use is associated with this process, and fossil fuel inputs release greenhouse gases during cultivation, conversion and distribution, hence contributing to the environmental footprint. The results of operating procedures need to be compared to other standards to establish the impacts on the environment.

Aquaculture assessment

In aquaculture, feed is the most significant input, but larvae or fingerlings, fuel and occasional medicinal treatments are also required. These key inputs are being measured more closely than in the past and are even published in annual corporate sustainability reports.

A primary measurement related to the productivity of feed is the feed-conversion ratio (FCR). The FCR measures the volume of feed input against the weight of harvested seafood. Salmon production has rather low FCRs, making it competitive in feed use against other proteins and less affected by high feed prices than pork or beef farming. On the basis of fish protein, current salmon production techniques can achieve FCR values below 1, making the industry a net provider of fish protein to the human diet.

Advances in feed technology continually lower the environmental footprint of salmon farming, both as a user of wild fish in feed and in carbon emissions. Shrimp feed needs high protein content as well as lipids, fiber and other essential nutrients. A wide variety of ingredients, from algae to poultry trimmings, are being investigated as replacements for the traditional fishmeal protein base in shrimp diets.

Most aquaculture exhibits LCA assessments lower than those for other farm-raised protein industries.

Low-impact species

Of worthy mention due to their low impacts on carbon emissions during aquaculture are tilapia, carp, oysters and mussels (Table 1). Tilapia and carp can both be grown in aquaponics with horticulture, living in recirculation systems with very little feed inputs needed, as the plants and fish feed off each others' waste. Seen as a promising sustainable food production method for the future, this approach is also known as integrated multitrophic aquaculture.

Davies, Carbon emission values, Table 1

Product	kg Carbon Dioxide/kg	Standard Deviation	Source
Salmon	3.40	1.1	Ayer and Tyedmers, 2009
Salmon	3.40	1.1	Mungkung and Gheewala, 2007
Salmon	3.40	1.1	Friend of the Sea, Seafish
Shrimp	11.10	3.3	Mungkung, 2005
Shrimp	11.10	3.3	Sun, 2009

Shrimp	11.10	3.3	Friend of the Sea
Tilapia	1.67	0	Troell et al., 2004
Carp in RAS	0.80	0	Friend of the Sea
Mussels	0.01	0	Thane

Table 1. Carbon emission values for common aquaculture species.

FCRs in carp culture are commonly as low as 0.3. Fishmeal ratios are on a downward trend, and from a fish sustainability stance, can be 1 in fish in:fish out ratios. Fishing makes up a major part of the aquaculture fishmeal supply, with wild-capture marine protein added to feed, as well as trimmings from fish processing.

Mollusks such as oysters and mussels are grown with only natural feed inputs from the nutrients in the water in which they are raised. This means their feed inputs are zero, so the species have minimal carbon emissions from their growing and harvesting.

Protein comparisons

Carbon footprint assessments of various farmed seafood compare well to those of other protein sources. In Sweden, Skretting found that beef production "cost" about 14 kg carbon dioxide per kg of edible meat. Pork came in with a rating of about 4.8 kg carbon dioxide/kg. Chicken rated 1.9 kg – just below the 2.0 kg carbon dioxide/kg meat mark for salmon.

Both Denmark and Belgium have studied the impacts of their meat industries, as shown in Table 2. The average carbon dioxide footprint of the top 10 retail seafood species in the United Kingdom is included for comparison. Aquaculture is generally much more efficient than beef and lamb production, and modern salmon farming, rated better than even chicken farming, has the lowest carbon value.

Davies, Carbon emission values for protein sources, Table 2

Country	Product	kg Carbon Dioxide/ kg	Source
Denmark	Beef	22.50	Weidema, 2003
Belgium	Beef	34.00	Nemry et al., 2001
Sweden	Beef	14.00	SIK*
Denmark	Pork	3.98	Weidema
Belgium	Pork	11.00	Nemry
Sweden	Pork	5.00	SIK*
Denmark	Chicken	3.10	Weidema
Belgium	Chicken	7.00	Nemry
Sweden	Chicken	1.80	SIK*
Belgium	Lamb	50.00	Nemry

Table 2. Carbon emission values for protein sources in different countries.

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