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A set of sustainability performance indicators for seafood: Direct human consumption products from Peruvian *anchoveta* fisheries and freshwater aquaculture

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ABSTRACT

Different seafood products based on Peruvian *anchoveta* (*Engraulis ringens*) fisheries and freshwater aquaculture of trout (*Oncorhynchus mykiss*), tilapia (*Oreochromis* spp.) and black pacu (*Colossoma macropomum*), contribute at different scales to the socio-economic development, environmental degradation and nutrition of the Peruvian population. Various indicators have been used in the literature to assess the performance of these industries regarding different aspects of sustainability, notably their socio-economic performance. In this study, a novel set of indicators is proposed to evaluate the sustainability performance of these industries in Peru, based on life cycle assessment (LCA) and nutritional profiling, as well as on energy and socio-economic assessment approaches. The emphasis is put on the potential of different products to contribute to improving the nutrition of the Peruvian population in an energy-efficient, environmentally friendly and socio-economically sound way. The set of indicators includes biotic resource use (BRU), cumulative energy demand (CED), energy return on investment (EROI), production costs, gross profit generation, added value, and nutritional profile in terms of vitamins, minerals and essential fatty acids; as well as a number of life cycle impact assessment indicators commonly used in seafood studies, and some recently proposed indicators of resource status (measuring the impacts of fish biomass removal at the species and ecosystem levels). Results suggest that more energy-intensive/highly processed products (cured and canned *anchoveta* products) represent a higher burden, in terms of environmental impact, than less energy-intensive products (salted and frozen *anchoveta* products, semi-intensive aquaculture products). This result is confirmed when comparing all products regarding their industrial-to-nutritional energy ratio. Regarding the other attributes analysed, the scoring shows that salted and frozen *anchoveta* products generate fewer jobs and lower gross profit than canned and cured, while aquaculture products maximise them. Overall, it was concluded that less energy-intensive industries (*anchoveta* freezing and salting) are the least environmentally impacting but also the least economically interesting products, yet delivering higher nutritional value. Aquaculture products maximise gross profit and job creation, with lower energy efficiency and nutritional values. The proposed set of sustainability indicators fulfilled its goal in providing a multi-criteria assessment of *anchoveta* direct human consumption and freshwater aquaculture products. As often the case, there is no ideal product and the best trade-off must be sought when making decision regarding fisheries and seafood policy. No threshold for performance of the different indicators is offered, because the goal of the comparison is to contrast the relative performance among products, not of products against reference values.

1. Introduction

Seafood systems represent an important source of protein and other nutrients, especially to coastal human populations worldwide. A variety of processing methods and products has been

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developed, ranging from fresh fish to energy-intensive canned or cured seafood products. These products exert different pressures on the environment and society, while producing different socio-economic benefits. Sustainability assessment of seafood systems has been addressed by means of certification and eco-labelling mechanisms, life cycle approaches, economic and bio-economic analyses and modelling, indicator systems, etc (e.g. Ayer and Tyedmers, 2009; Kruse et al., 2008; Leadbitter and Ward, 2007; McCausland et al., 2006; Samuel-Fitwi et al., 2012). Given the complexity of the seafood systems, it is necessary to combine approaches and integrate in a consistent way the supply chain, management, environmental, energy, socio-economic and nutritional features of the studied systems in order for sustainability to be comprehensively assessed.

Sustainability indicators can be defined as variables or combinations of variables collected and analysed with a well-defined analytical or policy goal, and for which certain reference values are significant in the context of the analysed system (Rametsteiner et al., 2011; Singh et al., 2009). Indicators are expected to feature certain properties, such as (Pingault and Préault, 2007; Roth, 2002): pertinence, reliability (i.e. scientifically sound), operationality (easy to estimate and update), legitimacy (accepted use, appropriation by stakeholders), interpretability (easy to understand and communicate), genericity (allowing comparison at various spatio-temporal scales), and defined in a finite interval (e.g. 1–5, A–D, etc). Indicators can be organised within an indicator system or dashboard when several of them are required (Halog and Manik, 2011; Shin and Shannon, 2010). For Joerin et al. (2005) and Balestrat et al. (2010), modelling is often necessary to build a system of indicators, for a model allows the indicators to be organised into a coherent whole. A number of knowledge and politically-driven indicator development frameworks have been proposed and adopted by leading international organisations (reviews in Bowen and Riley, 2003; Rametsteiner et al., 2011; Singh et al., 2009).

A large percentage of the Peruvian population, notably in remote Andean areas, suffers malnourishment, including iron and vitamin deficiency (FAO, 2000, 2011; INEI, 2011). Annual per capita edible fish consumption in Peru was estimated to vary between 4.2 and 11.2 kg (up to 22.5 kg in whole fish equivalents, in the period 2005–2011), being much higher in the coastal and Amazonian regions than in the Andean region (INEI, 2012a). These mean values rank Peru, according to FAOSTAT, as the 61st country in fish and seafood consumption worldwide, whereas it is the second fishing country (first, when only catches in national waters are considered). The main types of fish products consumed in Peru are listed in Table 1.

Table 1
Consumption patterns of fish products in Peru (2005–2011).

Product	Consumption[a] (kg person^{-1} y^{-1})				Area of consumption	Main species
	2005	2007	2009	2011		
Fresh fish	11.6	13.8	13.2	11.7	Coastal areas	Jack mackerel, Mahi mahi, jumbo squid
Canned fish	3.1	4.2	4.3	6.1	National level	Jack mackerel, tuna, *anchoveta*
Frozen fish	2.8	2.4	3.5	3.8	Major cities	South Pacific hake, jumbo squid
Cured (salted) fish	1.1	1	1.1	0.9	Provinces	Chub mackerel, jack mackerel, *anchoveta*
Total	18.6	21.4	22.2	22.5		

[a] Figures expressed in whole fish-equivalent volumes (INEI, 2012a,b). National consumption of freshwater aquaculture products is marginal, and mostly limited to the producing communities and regions.

Most fish consumed in Peru is sourced by fisheries other than *anchoveta*, and scarcely by freshwater aquaculture. Seafood, especially that derived from the *anchoveta* supply chains, has been often suggested as a suitable means to improve nutritional intake of vulnerable human communities and consumers at large (De la Puente et al., 2011; Jiménez and Gómez, 2005; Landa, 2014; Paredes, 2012; Rokovich, 2009). Analysing the factors limiting such consumption – e.g. prices, availability, preferences, etc. (Olsen, 2004), – as well as the nutritional-toxicological conflict associated with seafood intake (Sioen et al., 2009, 2008; Ström et al., 2011) and the particular characteristics of the *anchoveta* exploitation (Fréon et al., 2013), exceeds the scope of this study. We rather focus on the sustainability assessment of those *anchoveta* and aquaculture products, to inform on their relative sustainability performance and assist in providing information for future popularisation or policy/management measures involving these products. Our emphasis was put on the different products' potential to contribute in an energy-efficient and socio-economically sound way to improve the nutrition of the population. We propose a novel set of sustainability performance indicators addressing the three conventional pillars of sustainability (environment, society and economics). It is mainly based on life cycle assessment (LCA) and additional nutritional, energy and socio-economic assessment approaches to evaluate *anchoveta* (*Engraulis ringens*) direct human consumption (DHC) and freshwater aquaculture products in Peru. Finally, we use the results of this assessment to suggest directions for further sustainable development of fishfood industries.

2. Methods

Sustainability assessment of the following products and their comparison was carried out: canned, frozen, salted and cured *anchoveta*, as well as cultured rainbow trout, black pacu and red hybrid tilapia. The selection of species is determined by the goals of the ANCHOVETA Supply Chain project (http://anchoveta-sc.wikispaces.com), which include the sustainability assessment of *anchoveta*-based products (including Peruvian fed aquaculture); and the promotion of increased consumption of these products in Peru.

The production system assessed includes infrastructure, heavy equipment, use of water and chemicals, energy use, agricultural inputs to *anchoveta* products (e.g. vegetable oils), fish and the whole aquafeed subsystem (including agricultural inputs), and transportation of key inputs. For both *anchoveta* DHC and aquaculture systems the analysis encompassed cradle to gate and distribution interventions.

2.1. Life cycle assessment

Life cycle assessment (LCA) is an ISO-standardised framework for conducting a detailed account of all resources consumed and emissions associated with a specific product along its whole life cycle (ISO, 2006a). LCA has been widely applied to study the environmental performance of fisheries (Avadí and Fréon, 2013), seafood including aquaculture products (Aubin, 2013; Henriksson et al., 2011; Parker, 2012) and industrialised seafood products (Hospido et al., 2006; Iribarren et al., 2010). LCA consists of a goal and scope definition phase, where the functional unit (FU) and system boundary are defined; a life cycle inventory (LCI) phase, where life cycle data related to the FU is collected; a life cycle impact assessment (LCIA) phase where a set of characterisation factors are used to calculate environmental impacts on a wide number of impact categories; and an interpretation phase, where conclusions are drawn from the LCI and LCIA results (ISO, 2006a,b). The midpoint-based CML methods, baseline 2000 and 2001 (Guinée et al., 2002),