Carbon footprint of frozen pangasius fillet: a case study

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Abstract. Carbon footprint has become an important issue in the world trade, and can potentially be incorporated into sustainability and ecolabel certification schemes. As the leading seafood producers, Indonesia should start to reduce the carbon footprint of its seafood products, especially those destined for export, to minimize the impact on the environment and to safeguard its product in the world market. The present study aimed to determine the carbon footprint of frozen pangasius fillets produced at PT. KMM, Purwakarta. The carbon footprint was calculated using the Life Cycle Assessment method with a standard emission factor during 3-month observation covering post-harvest, processing, and distribution. Results showed that the total carbon footprint of frozen pangasius fillets was 1.48 kg CO2eq/kg product. The highest emission was in the processing, freezing, and storage, i.e., about 71% (mainly from electricity, ice, and refrigerant), of which refrigerant contributed 41%. The lowest CO2 emission was in the administration office and lighting (1.4%).

Keywords: carbon footprint, LCA, pangasius

1. Introduction

Seafood is one of the most traded food items in the world, and about 35% of global fish production has entered the international market in 2016 (FAO 2018). The products were traded in various forms, either for human or non-human consumption. In Indonesia, fish and fish products provide essential sources for food security and livelihood. Consistently the contribution of fish and fish products is more than 10% to the total food protein intake in the country, which equals more than 50% of total animal protein consumption (Poernomo and Kuswardani 2019). Indonesia ranks number two in the global fish production after China, number one in Southeast Asia (FAO 2018), and lists number three for export in Southeast Asia. Currently, the export value of Indonesian fish and fish products were claimed at about US$4.9 billion, which provides a significant contribution to export earnings.

The emerging issues in environmental quality, fish stock, and climate, confronted with the fast development of fisheries and aquaculture to meet the greater need of seafood for human consumption, have brought concerns in the sustainability of seafood products and supply chains (Ziegler et al 2016). This has made sustainability certification, labels, and guides increasingly gained popularity in the industry and encourage sustainable practices as well as consumer choices (Madin and Macreadie 2015). Many studies have now been oriented towards sustainability assessment of every step of the seafood
supply chain. Efforts have also been concentrated to create and apply cleaner seafood processing technologies (Vidacek and Soro 2018). Indonesian fisheries and aquaculture industries should start to evaluate the existing practices and ensure that the industries give little impacts to the environment; otherwise pressures from the international community global market may affect the competitiveness of Indonesian products in the global market.

One of the sustainability tools frequently used to estimate the impacts of products or services on the environment and greenhouse gas emission is Life Cycle Assessment (LCA). It evaluates the impact in all stages of a product’s or service’s life cycle and measures GHG emissions across all activities in the life-cycle. Depending on the purposes, LCA can cover the whole cycle of the products or services (cradle to grave) or a section of it such as farm or pond to gate (from harvest to a processing plant) and gate to gate (from raw materials entering to leaving the processing plant). Most published LCAs have focused on carbon footprint, although it can be used to assess other environmental impacts. A carbon footprint is the total amount of greenhouse gas emissions caused by products and services expressed in kilograms of carbon dioxide (CO₂) or equivalent emitted (CO₂eq). Some European countries require sustainability certificates for seafood (CBI 2018), and there are now initiatives to include carbon footprint in the sustainability schemes (Madin and Macreadie 2015, Ziegler et al 2016). Although some are in doubt about its benefits and effectiveness (Jonell et al 2013), this certification can potentially be another trade barrier that developing countries like Indonesia should be aware of.

Although studies on the use of LCA and carbon footprint of fisheries and aquaculture products are available elsewhere (Avadí et al 2018, Abdou et al 2018, Robb et al 2017, Avadí and Fréon 2013, Cao et al 2013), those of Indonesian fisheries and aquaculture industry are very limited. Recent studies on the carbon footprint of Indonesian fisheries were conducted by Fatehah et al (2016) and Supartono (2002). We have also documented three reports for aquaculture, ie. by Alwan (2018), Pelletier and Tyedmers (2010), Prihadi et al (2008), while Sidik and Lovelock (2013) have analyzed only the efflux of CO₂ in Indonesian shrimp ponds, and did not evaluate the carbon footprint of shrimp ponds. For processing, Sofiah et al (2018) have estimated the carbon footprint of seafood produced by a processing plant in Cirebon, West Java, that produced many kinds of frozen seafood. The authors did not separate for each species but took the average from the whole raw material inputs instead, and concluded that the fish products emitted 0.56g CO₂eq/kg and for crab 1.62 CO₂eq/kg.

Indonesia is one of the major pangasius producing countries, with current production of around 470 thousand tons per year, second after Vietnam (Seafood Trade Intelligence Portal), while the share of Indonesia to global pangasius production is 10-20% (FAO 2019). There are 11 pangasius processing plants located in Java and Sumatera supplying the domestic and global markets. The Government of Indonesia and Indonesian Pangasius Association have set the goals to boost the production and export and hence have launched a national pangasius brand: Indonesian Pangasius, a Better Choice. In order to pave the way for better export performance, the Indonesian pangasius industry should be prepared for meeting many rigid requirements set by buyers, and one of the requirements is sustainability certificates. The present paper reports the use of LCA to estimate the carbon footprint of frozen pangasius, of which the results can provide preliminary information on its impact on the environment.

2. Materials and methods

2.1. Materials
The study was conducted at PT KMM, a medium fish fillet processing plant in Purwakarta, West Java. The raw materials were from their own farms (ponds and cages) and fish farmers, while the products are marketed in some cities in Java Island. The locations of farms, processing plant, and destination cities are depicted in figure 1, while the system boundaries are shown in figure 2.
2.2. Methods
The study was conducted for three months in 2019, during which the number of raw materials and products were recorded. The amount of CO\(_2\) emitted from every activity in the system boundaries was estimated by using conversion factors based on electricity, fuel, and refrigerant usage in the several activities from farms, processing plant to market destination. Electricity used for office air conditioning units, office equipment, and lighting were calculated based on the daily average usage time during observation. The conversion factors were taken from literature or from related institutions (table 1). The carbon footprint was expressed as g CO\(_2\)eq/kg edible product.

### Table 1. Estimation of CO\(_2\) emission based on sources

| Sources          | CO\(_2\) (kg) estimation                                                                 | Reference                                                                 |
|------------------|------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|
| Electricity      | CO\(_2\) = Q\(_L\) x EF                                                                | (Ministry of Energy and Mineral Resources of Indonesia 2019)              |
|                  | Q\(_L\) = Electricity consumption (kWh)                                                   |                                                                           |
|                  | EF = Emission factor (0.877 kg CO\(_2\)/kWh)                                         |                                                                           |
| Electricity for ice | CO\(_2\) = \frac{\text{Amount of ice (Kg)}}{250 \text{ kg/h}} \times 30 \text{(Kwh)} \times EF | (Ministry of Energy and Mineral Resources of Indonesia 2019)              |
|                  | EF = Emission factor (0.877 kg CO\(_2\)/kWh)                                         |                                                                           |
| Fuel             | CO\(_2\) = F\(_L\) \times \text{BOE} \times 6.118 \times 10^9 \times 10^{-12} \times EF | (Ministry of Energy and Mineral Resources of Indonesia 2019) and           |
|                  | F\(_L\) = Fuel consumption (KL)                                                          | (NCASI 2005)                                                             |
|                  | BOE = Barrel of equivalent (5. 83/KL for fuel)                                         |                                                                           |
|                  | 6.12 \times 10^9 = Joule equivalent of 1 BOE                                           |                                                                           |
|                  | 10^{-12} = Conversion from J to TJ                                                      |                                                                           |
|                  | EF = Emission factor for gasoline (68,600 kg CO\(_2\)/TJ)                             |                                                                           |
| Refrigerant      | CO\(_2\) = R\(_L\) \times (L/100) \times T \times EF                                  | (EPA 2014) and (Tassou et al 2009)                                       |
|                  | R\(_L\) = Refrigerant used (kg)                                                         |                                                                           |
|                  | L = Leakage (25% for industrial freezer; 10% for refrigerated truck)                   |                                                                           |
|                  | T = Usage time (1 if used for one year)                                                  |                                                                           |
|                  | EF = Emission factor (3,922 kg CO2eq for R404A; 1,430 kg CO2eq for R134A or HFC I34A |                                                                           |
Figure 1. Locations of farms, processing plants, and destination cities of products.

Figure 2. System boundaries for carbon footprint calculation.

Exceptions and limitations of CO₂ analyses in this study were:

1. The refrigerant used for office air conditioning units was not included in the calculation.
2. CO₂ emissions for ice was calculated from the electricity consumed to produce ice that was used during transportation and process. The ice was assumed to be produced by an ice-making machine having a capacity of 6 tons/day that produced 250 kg block ice per hour.

3. CO₂ emissions by humans (labors involved in the production) were not considered in the calculation.

4. For waste treatment, only pumps used in liquid wastewater tanks were included in the calculation. CO₂ emitted by liquid waste while in the tank and by solid waste was not taken into account.

5. The fuel used for raw material transportation and product delivery to wholesalers in other cities was calculated based on the total distance traveled on a standard pick-up truck or refrigerated truck. The distances were estimated by Google Maps, while mileage per one volume unit of fuel was taken from the vehicle manual. No attempts were made to follow the distribution of the products to retailers.

3. Results and discussion

During a three-month observation, 66 batches of fresh pangasius were transported from farms to the processing plant. The weight of the batches ranged from 1,230 to 6,168 kg, totaling to 177.3 tonnes which yielded approximately 383 to 2,195 kgs or 56.3 tonnes frozen fillets in total.

The raw materials were supplied from farms of which the farthest were from Tulungagung, East Java, about 860 km away from the processing plant and 12 hours by road. All fish were transported in ice, in which the ratio of fish to ice was 3 to 1.

Freezing was done using air blast freezers at -30°C to -40°C for 8-12 hours. After glazing, one kg of frozen fillets (four to five pieces) were contained in a plastic pouch (LDPE/low-density polyethylene). The secondary packaging was a master carton containing ten plastic pouches. The products were then kept in cold storage with temperatures ranging from -18°C to -25°C. The average storage time before distribution was seven days. Refrigerated trucks were used for product deliveries to wholesalers of which the farthest was in Surabaya, East Java, about 700 km from the plant.

| Table 2. CO₂ emission in each segment. |
|---------------------------------------|
| Segment                              | Sources of CO₂ | Emission (g CO₂eq/kg frozen fillet) |
| Raw material transportation           | Fuel, ice      | 170.5                                   |
| Processing                            | Electricity, ice| 667.8                                   |
| Cold storage                          | Electricity    | 64.6                                    |
| Product delivery                      | Fuel, refrigerant| 74.8                                   |
| Water and wastewater pumping          | Electricity    | 149.2                                   |
| Office                                | Electricity    | 20.4                                    |
| Freezing and cold storage             | Refrigerant    | 281.1                                   |
| Total emission                        |                | 1428.4                                  |
The CO\textsubscript{2} emissions in this study based on each segment are as shown in table 2, while those based on sources are depicted in figure 3. All figures have been converted into g CO\textsubscript{2}eq/kg frozen fillet. As indicated, electricity in the processing was the highest contributor of CO\textsubscript{2} emission, which accounted as high as 0.7 kg CO\textsubscript{2}eq/kg frozen fillet or 70% from gate to gate emission (table 3), while the lowest was from office equipment and lighting, ie. 20.4 g CO\textsubscript{2}eq/kg frozen fillet. It was observed that air blast freezers used the most of electricity in the processing area (320.9 g CO\textsubscript{2}eq/kg frozen fillet), and thus can be considered the hot spot of the production of frozen pangasius fillet.

![Figure 3. CO\textsubscript{2} emissions by source.](image)

**Table 3.** The carbon footprint of seafood products.

| Products                                      | Carbon Footprint (kg CO\textsubscript{2}eq/kg product) | References            |
|-----------------------------------------------|--------------------------------------------------------|-----------------------|
| Frozen cod fillet                             | 2.5                                                    | (Ziegler et al 2016)  |
| Frozen salmon fillet                          | 2.4                                                    | (Ziegler et al 2016)  |
| Canned fish                                   | 1.1                                                    | (Asakereh et al 2010) |
| Canned tuna                                   | 1.4                                                    | (Hamerschlag and Venkat 2011) |
| Canned sardines                               | 7.6                                                    | (Almeida et al 2015)  |
| Frozen salmon                                 | 1.7                                                    | (Hamerschlag and Venkat 2011) |
| Mahi-mahi, snapper, and wahoo (frozen fillet) | 0.6 g/kg                                               | (Sofiah et al 2018)   |
| Frozen pangasius fillet (Vietnam)             | 0.9\textsuperscript{b}                                 | (Rasenberg et al 2013) |
| Frozen pangasius fillet (Indonesia)           | 0.7\textsuperscript{b}-1.0\textsuperscript{c}         | This study            |

\textsuperscript{a} Too low needs more information  
\textsuperscript{b} Only from electricity  
\textsuperscript{c} From gate to gate, including refrigerant

During observation it was recorded that 56.3 tonnes frozen pangasius fillets were produced from 177.3 tonnes raw materials, making approximately 32% yield. The capacity of the plant is 6 tonnes of raw
material per day, for 28 days per month, 11 months per year. If the ideal production is taken at 80%, then the annual yield will be 502.7 tonnes frozen fillets, equals 502.7 tonnes CO₂eq if the gate to gate analysis was used as a base. The Indonesian annual pangasius production is 470 thousand tonnes, and if all the products were converted into frozen fillets through a similar process of PT KMM, then the carbon emissions of Indonesian pangasius frozen fillets were 470 thousand tonnes CO₂eq per year.

According to Tinambunan (2015) in Miharja et al. (2018), one hectare of open green space can absorb 58.3 tonnes CO₂ per year and using this figure, the CO₂ emission from PT KMM can be absorbed by 8.6 hectares open green space. The total area of open green space in Purwakarta was not available, but at least this result can be considered as an input to the local government when planning to provide such space for the public.

The frozen pangasius fillet in this study was marketed only in Java island; thus, no data is available for export. However, Rasenberg et al. (2013) have made exercise to export frozen pangasius fillet from Vietnam and Indonesia to Rotterdam, the Netherland. The products were transported by ship, and the distance from Vietnam and Indonesia to Rotterdam was 16,444 and 15,748 km respectively. The results showed that the GWP of both products, when reached Rotterdam, was 0.18 and 0.17 kg CO₂eq/kg and if combined with the result of the present study the total GWP were 0.92 and 0.72 kg CO₂eq/kg fillets.

Considering these figures, it can be said that Indonesian pangasius is cleaner in processing than Vietnamese pangasius is. However, this premature conclusion should be backed up by other CO₂ emission data along the supply chain, such as those during farming, which can be different between the two products. Moreover, the contribution of seafood processing (and packaging) in CO₂ emission is usually considered small, as low as 10% (SEAFISH 2014). This also warrants that studies in the CO₂ emission of pangasius culture and also at the consumption segment are necessary to provide the entire carbon footprint of frozen pangasius fillet (cradle to grave).

4. Conclusion

This study has attempted to estimate the carbon footprint of frozen pangasius fillets produced by a medium-size processing plant in Purwakarta, West Java. The carbon footprint was 1.48 kg CO₂eq/kg product, of which the highest was from electricity, and the lowest was from office equipment and lighting. When compared to a similar product from Vietnam, the carbon footprint in this study was lower. Further studies are needed to measure the carbon footprint of pangasius fillet starting from farming to consumption so that the level of carbon footprint can be described from cradle to grave.

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