Technical study on fish cooling refrigerator using Liquefied Petroleum Gas (LPG) fuel generator on fishing vessel

Sunardi1*, M Kadhafi1, M Khulwatu1, M ARahman1 and E Sulkhani1

1 Faculty of Fisheries and Marine Science, Universitas Brawijaya, Jalan Veteran, Malang, 65145, Indonesia

*Corresponding author: sunardi@ub.ac.id

Abstract. Fish is an important commodity with high economic value, and is a source of protein with affordable prices and abundant quantities. Proteins from fresh fish are essential nutrients for growth and as constituents of the cells. Yet, fish is one of the most perishable foods due to its composition. Many efforts have been done to maintain the freshness of fish. This research was aimed to improve fish handling in fishing vessel by inventing a refrigerator cooling system with an LPG fuel generator as a power source. The use of LPG was based on the availability of natural gas that is still abundant, environmentally friendly and cheaper than fuel. The calculation of refrigeration heat load was carried out by applying the formula that is available in heat transfer theory. Since the refrigeration heat load obtained was 1,533 Watt for all fish storage of fishing vessel, then the type and capacity of generator was easily determined. Application of LPG-fuel generator for refrigeration use in fishing vessel was economically competitive with 22.75% lower operating costs. Finally, re-arrangement was carried out by adjusting layout of fishing vessel for application of LPG-fuel generators to operate refrigerator.

1. Introduction

Fisheries sector is one of the leading sectors in Indonesia that generate high foreign exchange. Based on export data conducted by the Central Statistics Agency (BPS), Indonesia’s exports of fishery and marine products for the period January-September 2018 have reached USD 3.52 billion or an increase of 11.06% compared to the same period in 2017 [1] and was top 5 exporters in the world [2]. In addition, fish is a commodity with high economic value, and is a source of protein with affordable prices and abundant quantities. Proteins from fresh fish are essential nutrients for growth and as constituents of the body’s cells [3] which are very good for the development and growing of the human body and brain. Fish consumption per year in Indonesia continues to increase every year, FAO [2] mentioned that there was an increase from 43.94 kg/capita in 2016 to 46.49 kg/capita in 2017. Fish is one of the most perishable food source commodities. Due to poor handling, 9-15% of the fish caught were discarded and wasted [4]. This research was one of the efforts to improve fish handling system in fishing vessels using a refrigerator cooling system. Cooling systems on traditional fishing vessels generally use an ice cube as cooling system. The weakness of this system is that large amounts of ice can reduce capacity of cargo hold. In addition, in the last three years, the price of ice cube increases which impacted on the operational costs of fishing vessels. An alternative solution is to use a refrigerator using an LPG fuel generator as a power source. The use of LPG as the fuel for generator was based on the fact that LPG is cheaper than diesel or gasoline. In addition, LPG is more environmentally friendly with abundant resources in Indonesia.
2. Methodology

The general arrangement of small fishing boat was presented in Figure 1. The main size of the boat was as follows: Length (Loa) 16 m, Breadth (B) 3 m and Height (H) 2 m. There were three fish holding storage (each of 500 kg) with ice cooling system. One operation trip was estimated lasted for 8 days with fuel consumption of 600 litres and 116 ice cubes for cooling storage of fish.

![Figure 1. General Arrangement of fishing vessel.](image)

For this technical study, we used LPG as the alternative generator fuel for refrigerator. Therefore, re-arrangement of fishing vessel was conducted to provide space supporting facilities needed (as shown in Figure 2). Re-arrangement was also considered the amount of heat to be removed from the products during storage. Styrofoam insulation with 0.1 m thickness was used with the conductivity of 0.03 Kcal/m²h°C. The insulation heat leak through walls, roof and floor were calculated by Equation 1 [5], where the insulation dimensions were 1.5 m (length), 2.5 m (width) and 2 m (height).

\[ Q = A \cdot c \cdot \Delta T \]  

(1)

Where \( A \) was surface area of storage, \( c \) was conductivity of insulation materials and \( \Delta T \) was the temperature difference between ambient and storage were 35°C and -5°C.

The air exchanges into or from refrigerator were calculated by multiplication of 2.7. The air exchanges were assumed to occur for 24 hours with heat gain of 40 Kcal/m³. At worst case, it was assumed that the surrounding temperature was 35°C and relative humidity (RH) at 60%, as shown in Equation 2 [5].

\[ Q = \frac{Vol_{store} \times Heat_{gain} \times ACH}{24} \]

(2)

The product load heat or heat removed to freeze the products was calculated by multiplying latent heat of fish products and amount of fish products per 24 hour, as shown in Equation 3[5].
\[ Q = m \cdot h_f \]  

(3)

Where \( m \) was weight of product and \( h_f \) was latent heat of product.

![Figure 2. Re-Arrangement of fishing vessel.](image)

Load of refrigerator was calculated by adding up all items of heat transfer respectively. Finally, based on the heat load calculation result, the power needed to operate the refrigerator was estimated.

### 3. Results and discussion

The insulation heat leak, calculated using Equation 1, was 28.14 Kcal/h, while heat load from air exchange (calculated using Equation 2) was 33.75 Kcal/h. The amount fish that can be stored in the refrigerator were 300 kg, so the heat load calculated was 229.17 Kcal/h. By adding up of a heat load, total heat load of refrigerator were 291 Kcal/h. Considering the refrigerator heat load and estimation of electrical load (220 Watt), total heat load of generator for one fish storage compartment was 584 Watt and the total heat load for three storage compartments were 1,751 Watt. The generator was set to meet the electrical power requirements of three fish storage was a generator with a capacity of 2,200 Watt.

LPG fuel consumption of generator were 0.8 kg per hour, thus the requirement for 8 days of fishing vessel operations was 153.6 kg equivalent to 13 tubes of LPG (12 kg each). The total cost needed for 13 tubes of LPG was IDR 1,792,000. If ice cooling was used, the amount of ice cubes needed were 116 blocks at a price of IDR 20,000 per block, so the total cost for ice in one fishing trip was IDR 2,320,000. Thus, the operational costs for using LPG fuel for refrigerator on fishing vessel was 22.75% more efficient than using ice blocks.

Application of LPG-fuel generators for operating refrigerator must be followed by layout adjustments of fishing vessel, without changing much of the existing fishing vessel construction. By considering the adequacy of space, re-arrangement has been carried out as presented in Figure 3.

Technical instructions for vessel re-arrangement (Figure 3), are as follows:

1. Make a bulkhead in the fuel chamber by placing the LPG tube, generator and refrigerator on top of the fuel tank. To prevent fire, the walls of the fuel tank were made from impermeable materials.
2. LPG tube should be placed on the right and left side of the generator set and positioned on the deck of a fishing vessel (fuel tank). The space area of 0.9 meter length and 3 meter width was enough to accommodate 2 sets of generator and 18 tubes of LPG during fishing operations as shown in Figure 4. Dimension of generator set was 450 x 350 x 365 cm^3. LPG tube dimension: radius 28 cm and height 74 cm (SNI standard).
3. Attach additional layer of polyurethane and place a series of spiral pipes connected to the refrigerator.
Figure 3. Detail of re-arrangement.

Figure 4. The placement of generator set and tubes of LPG on fishing vessel (scale to fit).

4. Conclusion
Application of LPG-fuel generator for refrigeration use in fishing vessel was economically competitive with 22.75% lower operating costs. Finally, re-arrangement has been carried out by adjusting the layout of fishing vessel to accommodate LPG-fuel generators to operate refrigerator.

References
[1] Ministry of Maritime and Fisheries Affairs 2018 *Indonesian Fisheries Productivity* (Jakarta: Ministry of Communication and Informatics)
[2] Food and Agriculture Organization of the United Nations-FAO 2019 *GLOBEFISH Highlights: A Quarterly Update on World Seafood Markets* (FAO: January 2019 Issue)
[3] Gokoglu N and Yerlikaya P 2015 *Seafood chilling, refrigeration and freezing: science and technology*. John Wiley and Sons
[4] Food and Agriculture Organization of the United Nations-FAO 2011 *Global food losses and food waste* (Germany: Düsseldorf)
[5] American Society of Heating, Refrigerating and Air-Conditioning Engineers 2010 *Handbook Refrigeration* (Atlanta: Inch-Pound Edition)