Energy Usage Analysis on The Production Process of Canned Crab Meat (*Portunus pelagicus*)

E Hartulistiyoso\(^1\) and M Akmal\(^1\)

\(^1\) Department of Mechanical and Bio-system Engineering, Faculty of Agricultural Engineering and Technology, IPB University, Bogor 16680, Indonesia

E-mail: edyhartulistiyoso@apps.ipb.ac.id

Abstract. The energy usage analysis has been done on the production of canned crab meat (*Portunus pelagicus*). The analysis was based on the walkthrough and detailed energy auditing at a canned crab meat production company located in Indramayu, Indonesia. It aims at obtaining the specific energy consumption used to produce canned crab meat and its saving opportunity. The result showed that the energy specific varied depending on the operated capacity, from 10.04 MJ/kg to 31.73 MJ/kg, with the average of 16.21 MJ/kg. The primary energy consumption were including diesel fuel 9.95 MJ/kg (61.4 %), electricity 5.91 MJ/kg (36.5 %), and human biological energy 0.34 MJ/kg (2.1 %). The largest energy was consumed at pasteurisation process, amounted 10.21 MJ/kg. Energy saving can be gained in amount of 5.38 MJ/kg of crabs if the process is running in full capacity using two pasteurization tanks.

1. Introduction

Small crab (*Portunus pelagicus*) is a crustacean that has high protein content and good tastes, which is potential to be exported in various countries as indicated by the its proximate values (Table 1).

| Commodity       | Protein (%) | Fat (%) | Water (%) | Ash (%) |
|-----------------|-------------|---------|-----------|---------|
| Male crab       | 16.85       | 0.10    | 78.78     | 2.04    |
| Female crab     | 16.17       | 0.35    | 81.27     | 1.82    |

Source: [1] BBPMHP (1995)

However, small crabs can only survive for a few hours after catching. Export it in a fresh state will affect the taste and texture of the meat itself and potentially exposed to pathogenic bacteria that are at risk to the health of the consumer. Crabs are therefore commonly processed as canned crabs to protect from spoilage, changes, moisture content, losses due to oxidation, or changes in taste. Canning is a process of careful food packaging, which means that the closure is very tight, so it is not easily penetrated by air, water, microbes, or other materials. Canned food must be free from any viable micro-organisms [2].

Canning process consumes generally intensive energy, in particular due to the use of heat for the pasteurization. Pasteurization is the process of heating at a certain temperature and time so that all pathogenic bacteria which are harmful to humans will be killed [2, 3, 4]. Pasteurized canned crabs are processed with fresh raw crabs through the following treatments: boiling and meat collection,
filling in cans, weighing, closing cans, pasteurization, cooling, and packaging, then stored [5]. Cooling is needed after pasteurizing cans to prevent over cooking or over processing, because crab meat that is overcooked causes a change in the taste, color, and texture of the meat. The study on the energy usage of canned crabs will therefore beneficial to estimate the potential of energy saving and its related improvement of the production process [6,7]. The study was aimed at calculating the energy requirements to produce per unit of canned and reviewing energy saving opportunities that can be done at a canned crabs production plant in Indramayu, Indonesia.

2. Methods

2.1. Study Approach and Scope

In order to meet the objective of the study, this research uses a walk through energy audit continued to the detailed energy audit stage by assessing the type, amount and source of energy at each stage of the production process. Energy auditing can help small firm in energy efficiency effort [8]. Energy auditing is a form of activity to calculate the amount of energy used at each stage in a system as a whole [9]. The energy audit method consists of two stages, namely the preliminary energy audit and the detailed energy audit. Stages of walk-through audit as preliminary audit were preparation of work completeness, examination of field data and evaluation of collected data. While the detailed audit stage was carried out to measure the machines used in the pasteurization crab canning production process (from preparation of materials to cold storage of products), as well as energy analysis of the production process. Part of the energy conservation effort is to find out the sources of wasteful use of energy, as well as provide analysis and answers about actions that can be taken towards more appropriate energy use without reducing productivity that has been previously achieved [10].

The energy analysis covers the production process for producing canned crab starts from receiving raw materials to the processing of crab meat into canned crab with its supporting facilities. Observation of canned crab production process was carried out sequentially following the on-going process. All activities and processes of canned crab production are considered to be permanent every year and under normal conditions.

2.2. Energy Use Calculation

Energy used those were related to the process of canned crabs consists of,

1. Biological energy (Human energy, Bi); calculating from the number of workers at each stage of production, the number of work hours, the amount of crab production and the biological heating value of humans. The human energy needs calculate as:

\[
Em = JK \cdot t \cdot Nm
\]

Where:

Em = Human energy consumption (MJ)
JK = Number of workers
\( t \) = working time of people (hours)
Nm = Human heat value (according to SNI 7269: 2009)

2. Electrical energy (El); resulting from the data used include the type of tool, the number of tools, the use time of the tool, the power, the voltage and current installed and measured, the electrical energy, the efficiency and the number of canned crab production. The need for electrical energy calculated as:

\[
P = V \cdot I \cdot \cos \phi \quad \text{(1 phase electricity)}
\]

\[
P = V \cdot I \cdot \sqrt{3} \cdot \cos \phi \quad \text{(3 phase electricity)}
\]

Electrical energy used (Joules) = P \cdot t
Where:
\[ P = \text{Electricity used (Watts)} \]
\[ V = \text{Electric voltage (Volt)} \]
\[ I = \text{Electric Current (Ampere)} \]
\[ \cos \phi = \text{Power factor} \]
\[ t = \text{Time used during the process (seconds)} \]

3. Diesel fuel energy (Di); calculated using data of diesel consumption, diesel heating value, and the number of canned crab production. Diesel fuel energy needs calculated as:
\[ Q_{\text{diesel}} = V \cdot nk \]
Where:
\[ Q_{\text{diesel}} = \text{Diesel fuel energy used (MJ)} \]
\[ V = \text{Volume of diesel fuel used (Liter)} \]
\[ nk = \text{heating value of diesel (MJ/Liter)} \]

4. Specific energy; energy needed to produce a unit of product calculated as
\[ E_s = \frac{\text{energy consumed (MJ)}}{\text{the number of products produced (kg)}} \]

3. Result and Discussion

Figure 1 describes the whole process of the canned crabs, starting from checking raw material, sortation, mixing and filling, weighing, coding, loading, pasteurization, chilling, packing and cooling storage, including ice crushing, with the energy used of its particular step. The energy consumption of its step of the production of 6103 can pieces in an average process time of 6.83 hours is tabulated in Table 2.

Table 2. Energy consumption of each canned crabs production process

| Process           | Energy Use (MJ/kg) | Total (MJ/kg) |
|-------------------|-------------------|---------------|
|                   | Human | Electric | Diesel |           |
| Checking          | 0.0029 | 0.0971   | 0.100  |
| Ice Crushing      | 0.0024 | 0.0209   | 0.023  |
| Sorting           | 0.1120 | 0.8875   | 1.000  |
| Mixing & filling  | 0.0574 | 0.1842   | 0.242  |
| Weighting         | 0.0099 | 0.1840   | 0.194  |
| Seaming           | 0.0165 | 0.2051   | 0.222  |
| Coding            | 0.0082 | 0.0825   | 0.091  |
| Loading           | 0.0086 | 0.069    |        |
| Pasteurization    | 0.0059 | 0.2540 | 9.950  | 10.210   |
| Chilling          | 0.0082 | 0.008    |        |
| Packing           | 0.0248 | 0.025    |        |
| Cooling storage   |        | 2.2782   | 2.278  |
| **Total**         | 0.257  | 4.195    | 9.950  | 14.400   |
In order to determine the energy specific of the canned crabs production, calculation of total energy used was done for various number of canned crabs as shown in table 3. Table 3 shows that energy use for producing 143.464 kg crabs (316 cans) required energy of 31.73 MJ/kg of crab or 14.41 MJ/can, while producing 670.558 kg of crabs (1477 cans) required 10.04 MJ/kg of crabs or 4.56 MJ/can. If the factory works in accordance with its capacity of 1433 cans (670.558 kg) using two tanks, the specific energy consumed will be 5.38 MJ/kg lower in compare with tank of single tank. It was recorded that the average capacity used for the production was only 57.02% (table 4). To optimize the production process it is necessary to process in full capacity. This can be achieving e.g. by processing other commodities besides crab but have the same process treatment as crab (for example canned shells).
Table 3. Energy usage of various number of canned crabs and energy sources

| Number of Product (cans) | Production (kg) | Energy used (MJ) | Total Energy (MJ) | Energy Specific (MJ/kg) | Specific (MJ/can) |
|-------------------------|-----------------|------------------|-------------------|------------------------|-----------------|
|                         |                 | Human | Diesel | Electric |                 |                 |
| 316                     | 143.464         | 60.03 | 2914.58 | 1577.38 | 4551.99          | 31.73           | 14.41           |
|                         |                 | 1.32% | 64.03% | 34.65%   |                 |                 |
|                         |                 | 118.99 | 3965.74 | 2046.99 | 6131.73          | 20.81           | 9.45            |
| 649                     | 294.646         | 1.94% | 64.68% | 33.38%   |                 |                 |
|                         |                 | 134.10 | 3679.06 | 2185.403 | 5998.57          | 15.92           | 7.23            |
| 830                     | 376.820         | 2.24% | 61.33% | 36.43%   |                 |                 |
|                         |                 | 137.89 | 4443.54 | 2391.35 | 6972.78          | 17.59           | 7.99            |
| 873                     | 396.342         | 1.98% | 63.73% | 34.30%   |                 |                 |
|                         |                 | 143.58 | 4109.08 | 2495.12 | 6747.78          | 15.42           | 7.00            |
| 964                     | 437.656         | 2.13% | 60.90% | 36.98%   |                 |                 |
|                         |                 | 170.96 | 4682.44 | 2917.94 | 7771.35          | 17.22           | 7.82            |
| 994                     | 451.276         | 2.20% | 60.25% | 37.55%   |                 |                 |
|                         |                 | 183.78 | 3774.62 | 2770.79 | 6729.19          | 10.04           | 4.56            |
| 1477\(^{\dagger}\)     | 670.558         | 2.73% | 56.09% | 41.18%   |                 |                 |
|                         | 0.343           | 9.50% | 5.914   | 36.49%   | 44903.38         | 16.21           | 7.36            |
|                         | 2.11%           | 61.40% | 54.95   | 57.02    |                 |                 |

\(^{\dagger}\) using two tanks

Table 4. Production of canned crabs

| Parameter       | Amount        | Average |
|-----------------|---------------|---------|
| Production (kg) | 143.464       | 294.646 |
| Cans (pieces)   | 316           | 649     |
| Capacity (pieces) | 1344       | 1344    |
| Used Capacity (%) | 23.51     | 48.29   |

\(^{a}\) using two pasteurization batch

4. Conclusion
The energy usage analysis has been done in the production process of canned crabs (*Portunus pelagicus*). The energy specific on the production of canned crab meat varied depending on the operated capacity, from 10.04 MJ/kg to 31.73 MJ/kg, with the average of 16.21 MJ/kg. The primary energy consumption consisted of diesel fuel 9.95 MJ/kg (61.4 %), electricity 5.91 MJ/kg (36.5 %), and human (biological) energy 0.34 MJ/kg (2.1 %). The largest energy was consumed at pasteurisation process, amounted 10.21 MJ/kg. Energy saving opportunity in amount of 5.38 MJ/kg of crabs was identified when the process is running in full capacity using two pasteurization tanks.

References
[1] Fishery Product Quality Guidance and Testing Center 1995 *Technical Guidelines for Crab Processing* (in Indonesian language) Jakarta (ID): BBPMHP
[2] Fardiaz S 1992 *Food Microbiology I* (in Indonesian language) Jakarta (ID): Gramedia Pustaka Utama.
[3] Featherstone, S 2015 *Spoilage of canned foods. Canning and Related Processes* Vol. 2: Microbiology, packaging, HACCP and Ingredients 14th Ed. p 27-42

[4] F.V.M.Silva et al 2014 Thermal Process. Encyclopedia of Food microbiology (Second Edition) p 577-595

[5] Featherstone, S (Ed.) 2016 *Canning of fish and seafood. Volume 3: Processing Procedures for Canned Food Products*. Woodhead Publishing Series in Food Science, Technology and Nutrition p 231–265

[6] Sumandiarso IK 2011 *Crab Processing* (in Indonesian language) Jakarta (ID) Counseling Center KP- BPSDMKP

[7] Murniyati AS and Sunarman 2000 *Freezing, Preserving and Fish Refrigeration* (in Indonesian language) Yogyakarta (ID): Kanisius

[8] Kalantzis, F and D. Revoltella 2019 Do energy audits help SMEs to realize energy-efficiency opportunities? *Energy Economics*, V. 83, p 229-239

[9] Abdullah K 1998 *Agriculture Energy and Electricity* (in Indonesian language) Bogor (ID): JICA-DGHE IPB

[10] Kluczek, A. and P. Olszewski 2016 Energy audits in industrial processes. *J. of Cleaner Production*. xxx (2016), p 1-17