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Framework of life cycle assessment on nutmeg syrup processing Trisna1), Muhammad1), Mochamad Ari Saptari2) 1)Industrial Engineering Department, Faculty of Technique, Universitas Malikussaleh Kampus Bukit Indah, Jalan Batam, Blang Pulo, Muara Satu, Lhokseumawe, Aceh, Indonesia 2)Information System Department, Faculty of Technique, Universitas Malikussaleh Kampus Bukit Indah, Jalan Batam, Blang Pulo, Muara Satu, Lhokseumawe, Aceh, Indonesia Email: trisna@unimal. ac.id Abstract.

This study aimed to design the life cycle assessment (LCA) framework on two methods of the nutmeg syrup production process. The difference between those two ways based on how to eliminate tannin in nutmeg flesh, namely: using a salt solvent and albumin. There are three environmental impacts considered in the framework: gas emissions, noise levels, and human energy consumptions.

Nutmeg syrup processing has a long process that each step consists of several activities which require resources, including humans, raw materials, water, energy, machine, and tools. Each work has an impact on the environment in the form of solids, liquids, and gas emissions due to the use of those resources. The environmental impact needs to be measured for the sustainability of the industry.

The stages carried out in this study, including field observations, data collections, establish LCA framework based on ISO 14044 involving defining goal and scope, identifying inventory analysis, assessing environmental impacts, recommendations for reducing environmental impacts. This LCA framework can be used as the basic to carry out LCA on nutmeg production.

A decision-maker can use LCA result to choose the right production process that can

reduce environmental impact to result in an environmentally sustainable industry. Keyword: Life Cycle Assessment, Nutmeg syrup, gas emissions, noise Introduction Nutmeg or Myristica fragrans Houtt in Latin is a tall, high-tree fruit plant native to Indonesia, especially from Banda and Maluku.

Nutmeg plants have the advantage that almost all part of the plant can be utilized, the bark, leaves, mace (red objects that cover the seed coat), nutmeg seed, and nutmeg flesh. Nutmeg is generally used as a spice, essential oils, and medicinal ingredients. Nutmeg flesh can be used as a food and beverage such as syrup, pickled nutmeg, candied nutmeg, marmalade, nutmeg jam, dodol (Indonesia traditional food), and others[1].

Aceh Province, in particular South Aceh Regency, is one of the nutmeg producing centres. Many processed food and beverage products are made from nutmeg, one of which is nutmeg syrup. In general, the nutmeg syrup industry is still a small and medium scale industry whose production process is semi-manual.

Manufacturing of nutmeg syrup impacts the environment, such as solid and liquid waste, gas emissions, noise, and others. The environmental impacts that occur due to the use of resources such as energy, air, raw materials, and machine activities that cause noise. These impacts need to be identified, measured and evaluated as a basis for improving the process and reducing environmental impacts.

Life Cycle Assessment (LCA) is one of the methodologies for assessing the environmental impacts produced by industrial activities. Life cycle assessment (LCA) is an approach to estimate and assess the environmental impacts during the life cycle of a product. It can be climate change, stratospheric ozone depletion, tropospheric ozone (smog) creation, eutrophication, acidification, toxicological stress on human health and ecosystems, the depletion of resources, water use, land use, and noise and others [2].

In other words, LCA is a method used to identify the impact of a product on the environment. The LCA method is widely used by various parties to assess the environmental impact caused by a process during the product cycle, including taking raw materials, production processes, products used by consumers until the product is disposed of or sent to a waste treatment facility.

LCA assesses the environmental burden based on an inventory analysis of the use of resources, energy, water, fuel, and other materials, so it loads can be identified and analyzed using several different alternatives to reduce the environmental impact caused. Environmental impacts measured in previous LCA studies include the potential for

global warming [3], [4], gas emissions [5], [6],[7], energy consumption [3], net energy ratio [8], etc. Some research about the nutmeg syrup industry had been conducted among others carried out by Fatmawati [9] regarding feasibility study [9].

Djubaedah et al. [10] examined the effect of the treatment of nutmeg flesh on the quality of nutmeg syrup. Pratama et al.[11] conducted a study of the nutmeg value chain in Pakpak. Sahelangi [12] tested effect adding albumin toward quality of the syrup. There have been many studies conducted on LCA in both small, medium, and large industries.

But there are no studies to measure the environmental impact due to the activity of the nutmeg syrup production process. That is our motivation to conduct LCA studies in the nutmeg syrup industry. This study aimed to develop the framework of LCA for the nutmeg syrup industry by comparing two methods of the production process.

Different techniques based on how to remove tannin from nutmeg flesh. The first method is done by soaking in a salt solution and the second method using albumin. We considered the environmental impact for both methods were gas emission, human energy consumption, and noise. The study began with field observations, data collection, and compiled an LCA framework for the industry.

We use LCA methodology based on ISO 14044 2006 [13], which consisted of determining goals and scope, identifying inventory analysis, measuring environmental impact, and interpretation. Methods The tools and materials used in this study are 1. A stopwatch that is used to measure the time of each worker's activity in making syrup. 2. Body scales used to weigh workers' weight. 3. Sound Level Meter used to measure the noise level of the nutmeg syrup production process.

Figure 1 shows the flowchart of the stages of research, and Figure 2 describes the LCA framework._ Figure 1. Flowchart study LCA of nutmeg syrup _ Figure 2. Life cycle analysis framework (ISO 14044 2006[13]) Results and Discussions Goal and Scopes The purpose of this LCA is to measure gas emissions, human energy consumption, and the noise for the two methods of nutmeg syrup processing. The syrup is a drink containing a thick liquid that has high sugar content.

Fruits or spices added to the syrup to get a natural flavour or to get the benefits of the fruit or spice. Before processing, the tannin content is first removed to eliminate the bitter and bitter taste. Two ways to get rid of tannins are to soak nutmeg with 5% salt for 12 hours, [10] and the addition of 1% albumin to nutmeg juice [14].

The scope of measurement based on the system limitation of LCA gate to gate that is starting from raw materials receiving, production process until finished goods. 3.1.1 Unit functions definition The number of resources required based on the need to make 1 litre of syrup. Some parameters and units used in this LCA study can be seen in Table 1.

Parameters _Units _ _The amount of nutmeg flesh needed to produce 1 liter of syrup _kg _ _The amount of sugar needed to produce 1 liter of syrup _kg _ _The amount of salt needed to produce 1 liter of syrup _kg _ _The amount of albumin needed to produce 1 liter of syrup _kg _ _The amount of water needed to wash nutmeg flesh _Litre _ _The amount of water needed to make nutmeg juice _Litre _ _The amount of electricity power needed to make 1 liter of syrup _Kwh _ _The amount of gas needed to make 1 liter of syrup _Kg _ _The amount of solid waste produced _Kg _ _The amount of byproduct produced _Kg _ _Noise level generated by machine _Db _ _The amount human energy required _calorie _ _Weight of worker _Kg _ _Time for each activity _minute _ _Type of gas emission generated _ _ _Type of waste generated _ _ _Sound level _dB _ _ 3.1.2 Input–output allocation This factor divides the input and output produced in a production process.

The basis for determining the allocation can be mass, energy, and the added value generated by each output. In this study, this allocation can be illustrated as in Figure 1. The detailed production process of making nutmeg syrup can be seen in Figure 2 for tannin removal with salt solvent and Figure 3 with albumin.

_ Figure 1 Input-output allocation _Figure 2 Production process of nutmeg syrup with salt solvent [10] _ Figure 32 Production process of nutmeg syrup with albumin [14] Inventory Analysis Inventory analysis is the process of collecting data needed in an LCA. The data required includes the use of raw materials, fuel, human energy consumption, and waste generated, including solid waste, liquid waste, and gas waste.

One important thing in determining the environmental impact caused is through the flow of the nutmeg syrup production process. The data collected is then recapitulated in the Life Cycle Inventory (LCI) table, as shown in Table 2. Table 2 Resource requirements Type of raw material _Unit _The amount required _ _ _ _Tannin removal with salt solvent _Tannin removal with albumin _ _Nutmeg flesh _Kg _… _… _ _Water _Litre _ _… _ _Sugar _Kg _… _… _ _Salt _Kg _… _… _ _Albumin _Kg _… _… _ _Energy requirements The nutmeg industry is generally of small and medium capacity so that the production process is carried out semi-manually. Some activities use machines, and others use human power.

Energy requirements data in this study consists of energy requirements for machines and energy released by humans to carry out activities. Tables 3 and 4 respectively show

the energy requirements for the production process using salt and albumin. Calculation of human energy using the method in the SNI 7269 2009 about the Assessment of workloads based on the level of calorie needs according to energy expenditures.

Workload assessment is carried out by measuring workers' weight, observing workforce activities, and calculating calorie requirements based on energy expenditure according to the calculation table in SNI 7269 2009. Workload total can be seen in equation 1 and 2 [15]. ???? ??????????????= (???? 1 ?? ?? 1)+ (???? 2 ?? ?? 2 +….+

(???? ?? ?? ?? ??) ?? 1 + ?? 2 +…+?? ?? ?? 60 ????????/h?????? (1) Total WL = ???? ??????????????+???? (2) Where, BKn = Workload activity n (minute) Tn = Activity time n (minute) BM = basal metabolism BM for male = weight (kg) x 1 kcal per hour BM for female = weight (kg) x 0.9 kcal per hour Calculation of energy from fuels is done by converting the amount of fuel need to power in kilocalorie units.

LCI of energy requirement for two type production process can be seen in Table 3. Table 3Energy requirement for two type of production process Activity _Using salt solvent _Using albumin _ _ _Human energy (kcal) _Electricity (kwh) _LPG (kg) _Human energy (kcal) _Electricity (kwh) _LPG (kg) _ _Cleaning and peeling nutmeg _a _- _- _j _- _- _ _Soaking nutmeg flesh into salt solvent _b _- _- _- _- _- _ _Chopping nutmeg _c _- _- _k _- _- _ _Crushing nutmeg _- _d _- _- _l _- _ _Filtering nutmeg juice _e _- _- _m _- _- _ _Adding sugar into nutmeg juice _f _- _- _n _- _- _ _Adding albumin _- _- _- _- _o _- _ _Cooking nutmeg syrup _- _- _h _- _- _p _ _Packing syrup _i _- _- _- _q _- _ _ 3.3

Life Cycle Impact Assessment This stage identifies and evaluates the amount of potential environmental impacts (gas emissions, waste) that occur throughout the LCI. The impacts can also be in the form of ecological health, public health, resource depletion, and social welfare. Field observation showed that the nutmeg syrup production process brings about two types of waste.

Those are solid waste from nutmeg pulp and liquid waste from the washing process. Gas emissions generated from the use of electricity and gas fuel. Gas emissions Gas emissions produced from the use of electrical energy in the destruction of nutmeg and the use of LPG liquid petroleum gas fuels. LPG fuels produce gas emissions in the form of carbon monoxide (CO), carbon dioxide (CO2), hydrocarbons (HC), and nitrogen oxides (NOx) [16], [17].

The electricity usage produced CO2, SO4, and NO4 emissions. Calculation of emissions for both burning fossil fuels and electricity usage can be calculated as follows: Electricity gas emissions: CO2 emission = EC x 0.84 kg CO2/kWh (3) NO2 emission = EC x 4.17 g

NO2/kWh (4) SO2emission = QL x 8.1

g SO2/kWh (5) Where, QL=electricity consumption (kwh) Gas emissions for fossil fuel usage: CO2 emission = QF x NK x 74100 kg CO2/TJ (6) CH4 emission = QF x NK x 10 kg CH4/TJ (7) N2O emission = QF x NK x 0.6 kg N2O/TJ (8) Where, QF = Fuel consumption (L) NK = Net calorie value (TJ/L) 3.4 Interpretation At this stage, it identifies issues affecting the nutmeg syrup industry's environment based on LCI and LCIA.

Activities that produce emissions are part of the crushing of nutmeg and cooking syrup. Based on the results of gas emissions measurements for both operations, process improvements can be made to reduce emissions. It can be conducted by replacing gas energy with alternative fuels giving a large impact on lower gas emissions.

The use of manually operated equipment can lead to the use of human energy, which can cause muscle fatigue when used in excess. If the noise level is found to exceed the WHO regulation of 80 dB, it can be carried out using sound dampening. Conclusion The LCA framework is established as a basis for measuring the environmental impact of the nutmeg syrup industry by two production process methods, videlicet removing tannins with salt and albumin. This study uses a system boundary, namely gate to gate.

This LCA compares the environmental impact of issuing gas emissions, human energy consumption, and sound levels for the two process methods. The production process that has a lower environmental impact is the best in terms of the environment. The results of this LCA can be used to make decisions to improve the process so that it can reduce the environmental impact.

Future work can measure the impact on the nutmeg syrup industry using this framework based on actual data. Other environmental aspects, such as social, economic, work accident, work completion, and others, can be included in the framework. Acknowledgements We thank to Ministry of Research, Technology and Higher Education of Indonesia who support this study by Fundamental Research Grant with agreement contract no. 180/SP2H/LT/DRPM/2019. We also thank for valuable comment and suggestions from reviewers that their suggestions improve our paper quality.

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