# PROCESS SELECTION FOR REDUCING GREENHOUSEGAS EMISSIONS IN FISH SAUCE INDUSTRY

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**Abstract**—Theobjective of this research isselectionthe potential production processes for reducing greenhouse gas (GHG) emissions using Analytic Hierarchy Process (AHP). There are several processes of fish sauce industry in Thailand which emit GHG and be quite difficult to improve of all. In this study, ten experts who have experiences in GHG emissions answered questionnaires to select the potential processes for reducing GHG emissions. The result from AHP showed that the packaging and fermentation processes had the highest priority,similarly, carbon footprint measurement.

**Index Terms**—Analytic Hierarchy Process (AHP), Carbon footprint, Greenhouse gas (GHG) emissions, Fish sauce industry.

## I. INTRODUCTION

Global warmingaffectedon the subsistence of humans, creatures, and environments. One of the solutions to solve this problem is the decrease of greenhouse gas (GHG) emissions from the industrial sector.

Fish sauce products in Thailand is significant both domestic sales and exportation [1].Furthermore,the outbound export of fish sauce is expected to increase continuously. Nowadays, there are several manufacturers of fish sauce in Thailand, requiring that each launch strategies to multiply their competitive advantages. Interestingly, they manifest their environmental responsibilities to prevent the trade barrier from other countries as well as to create a good image for their organization.

A production of fish sauce consists of four main processes as a fermentation process, a mixing process, a filtering process, and a packaging process. The production and consumption of raw materials, fuels, water, electricity, and packages in all processes caused of GHG emissions. Finding the approach to reduce GHG emissions into the atmosphere in term of making an adjustment in production processes to be more effective is substantially concerned.Because of the limitation of the budget,the improvement of all processes to reduce GHG emissions are quite difficult. The decision making to select potential production processesis very crucial.The decision considers not only the deliberation of GHG emissions in quantitative data, but also the adaptive potential production processes.

In the present, conventional approach to reduce GHG emissions for planning improvement of production processes is carbon footprint. Carbon footprint compiles the data of GHG emissions from beginning to end of production process. The collecting and analyzing data of this approach are hard and tardy. Therefore, this study is interested in finding approach for decreasing the complexity and the period of the finding the results.

The Analytic Hierarchy process (AHP) is widely used approach in multiple attribute decision making. The AHP can solve the problem by rearrangement into a hierarchical structure. This approach is the appropriate way to rank or select the best choice by reducing the complexity of the problem. Since this approach was invented, the various researchers take AHP applied to decide the most appropriate way to rank or best choice. For example, using AHP to select the best vender [2], AHP can be applicable for selecting the appropriate waste-product landfill[3], and using AHP for rearranging the importance of transferring technology for developing is beneficial for profit maximization [4]. From the previous research, there is no research studied in selectingpotential of fish sauce production processes to reduce GHG emissions.

This study aims to apply AHP to select the potential production process.Moreover, the results from AHP are compared with the results of carbon footprint for verifying the decision.

## II. LITERATURE REVIEWS

### *A. Analytic Hierarchy Process*

The Analytic Hierarchy Process (AHP) was created by Saaty as a method as a tool of Multi Criteria Decision Making (MCDM) [5]. It is an effective method which can easily decide issues of complex problems. It is found in [6] that the AHP can make highly faithful judgment and can analyze the changing conditions of "What if" problems called breadth and depth of analysis. For this reason, AHP has widespread acceptance for analyzing decisions by collecting data and rearranging into hierarchical structure [7], which is advantageous for users focused on specific criteria and subcriteria. Moreover, it is crucial for the final outcomes because the differences of hierarchical structure may lead to differences in final ranking [8].

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ 1/a_1 & 1/a_2 & \cdots & 1 \end{bmatrix}$$

**Fig. 1 Pairwise comparison matrix**

Decision making by AHP starts by first establishing a hierarchical structure to a decision problem [5]. Then, a set of pairwise comparison matrices are constructed (see Fig 1). Each criterion in an upper level is used to compare the criteria in the level immediately below with respect to it and do this for every criterion. For each criterion inthe level below add its weighed values and obtain its overall priority.Continue this process of weighing and adding until the final priorities of thealternatives in the bottom most level are obtained.

For making comparisons, the scale of relative importance is in the form of question "How is important criterion A related to criterion B?" by measuring the proportion into the 1-9scale (see Table I) to identify the level of relative importance compared with the different criteria [9].

Hierarchical composition is now used to weigh the eigenvectors by the weights of the criteria and the sum is taken over all weighted eigenvector entries corresponding to each criterion to obtain the composite priority of the criteria in a level. These are then used to weigh the eigenvectors corresponding to those in the next lower level and so on, resulting in a composite priority vector for the lowest level of the hierarchy. The AHP can detect inconsistent judgments by the consistency ratio(C.R.) [9]. C.R. is calculated based on the consistency index (C.I.) to test the validity. C.I. which is the deviation of consistency

can be calculated (1)

$$C.I. = \frac{\lambda max - n}{n-1} \quad (1)$$

wheren is the number of conditions.

$$A \cdot W = \lambda_{max} \cdot W \quad (2)$$

whereA is the pairwise comparison matrix, W is the eigenvector, and $\lambda_{max}$is eigenvalue Max.

$$C.R. = \frac{C.I.}{R.I.} \quad (3)$$

Where random index (R.I.) is determined by the size of n.

The suggested value of the C.R. should be less than0.10 in assessing acceptable overall consistency. If C.R. exceedsmore than mentioned,the pairwise comparison needs to be done again or the questionnaire has to be revised [9].

Table I

The Saaty scales in pairwise comparisons

| Intensity of importance | How is important A related to B ? |
|---|---|
| 1 | Equally important |
| 3 | Moderately more important |
| 5 | Strongly more important |
| 7 | Very strongly more important |
| 9 | Extreme important |

The value in between such as 2, 4, 6 and 8 are intermediate values intensity of importance.

*B. The carbon footprint of product*

The carbon footprint is a measurement of carbon dioxide and other greenhouse gas emissions that are released directly and indirectly caused by product life cycle [10].

For calculating carbon footprint, collecting the data for calculating includes all inputs and outputs of production processes related to emissions of GHG.For example, the production and consumption of raw materials, fuels, water, electricity, and packages. It is measured in term of carbon dioxide equivalent ($CO_2$eq) following step as in [11] and calculated by using (4)

$$CO2eq\ Emission = Activity\ data \times Emission\ factor \quad (4)$$

where$CO_2$eq Emission is the emissions of GHG in term of carbon dioxide equivalent, Activity data are quantitative data of productionand consumption resource resulting in emissions,and Emission factor is the average emission rate of a given GHG for a given source, relative to units of production andconsumption resource.

## III. APPLICATION OF THE AHP IN A FISH SAUCE INDUSTRY

*A. Hierarchical structure model*

This section of the study is the overview of the fish sauce industry. Relevant documents and the opinions from experts; the ways to reduce GHG emissions, were summarized into AHP hierarchical structure, as presented in Fig. 2

From Fig. 2, the top level is the objective of the AHP analysis, defined as to "Select the potential production processes for reducing GHG emissions".

The second level is the criteria whichare used to decide.These criteria consist of four major factors as follow:

1) Input material change
   It is the possible input material change for reducing GHG emissions.
2) Technology improvement
   It is the possible adaptation technologies, machine improvement or addition of the instrument to increase
   efficiency and reduce using electricity, heat, and water.
3) Operational management
   It is the possible adaptation procedure to increase efficiency and reduce using electricity, heat and water.
4) Reuse/recycle
   It is the approach to find the methods or technologies to reuse/recycle for reducing waste.

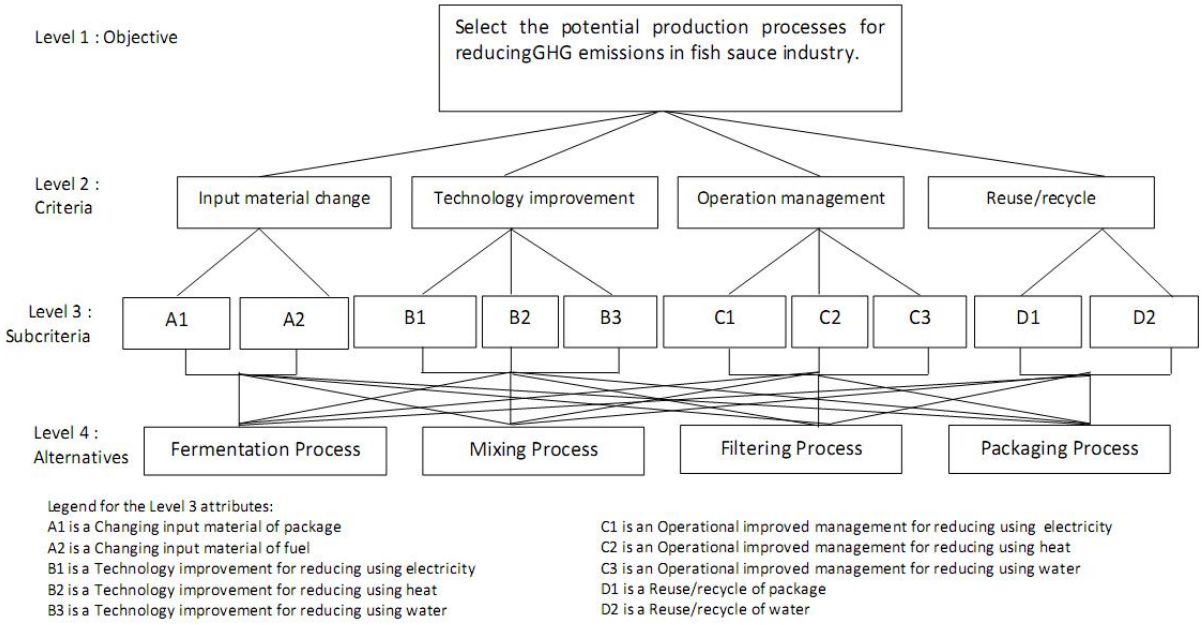



**Fig. 2 AHP hierarchical structure of this study**

In addition, each criterion is further divided into subcriteria at the third level.

The last level comprises the four alternatives or production processes as follow:

1) Fermentation process

Itis the first process of making fish sauce. The fish aremixedwith sea salt and left to ferment for 12 months or longer. This mixtureis coarse filtered through fermented fish mash and transferred to the tank for the next step as a mixing process.

2) Mixing process

The second process is a mixing of fish sauce. The fish sauce is mixed with specific ingredients by mixing machine.

3) Filtering process

The third process isfiltering process.The fish sauce is fine filtered by filter pump and transferred to the packaging process.

4) Packaging process.

It is the last process. Before bottling, the bottles were rinsedby boiled water. The fish sauce is bottled into the glass bottles which were rinsed by boiled water and transferredfor capping and labeling.

*B. Calculating criteria weight*

The ten experts answeredquestionnaire survey in pairwise comparison by weighting the relative importance of the decision based on Saaty scales. This decisionwas a group decision which requires the majority opinions.

The group decision makingdetermined a single representative for the group from aggregate judgments. The Geometric Mean (G.M.) of the group member of judgments can be representative to the decision of many people [5]. It maintains the reciprocal property of the

Judgment matrix [12] by using (5)

$$G.M. = \sqrt[n]{X1X2 \dots Xn} \quad (5)$$

where X1,X2,…,Xnis datafrom questionnaire and n is number of data.

Allof the final input weights for calculating are estimated by using G.M. for the estimation of the C.R. in the judgments and aggregation of weights in criteria as mentioned in topic II.

The priority of all criteria and subcritia were first calculated. The results of all criteria and subcriteriawere prioritized as presented in Fig. 3 and Fig. 4 respectively. From the results, the C.R. in the normalized weights was approximately less than 0.10, suggesting that the judgment could be accepted.

After comparing the weights across various levels to obtain of the final priority of the alternatives, the final priority was calculated to select potential production processes as shown in Fig. 5

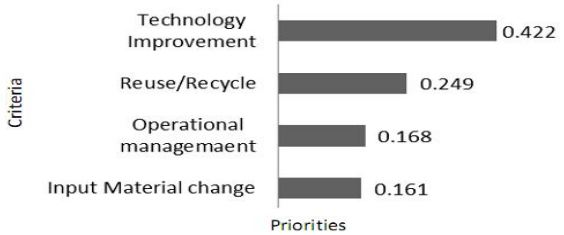



**Fig. 3 The priorities of criteria**

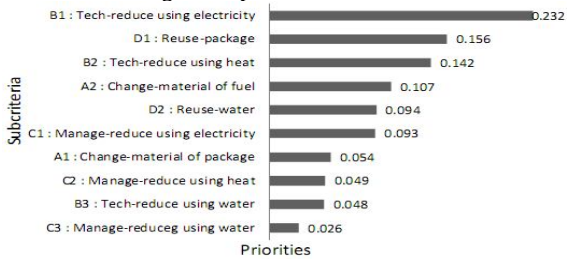



**Fig. 4 The priorities of subcriteria**

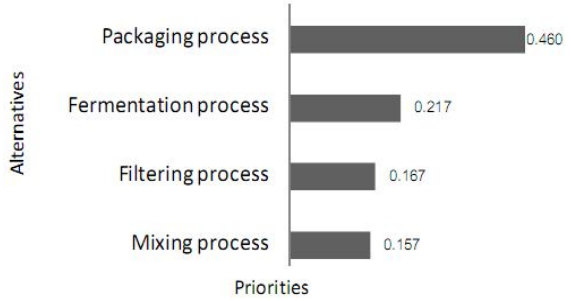



**Fig. 5 The priorities of alternatives**

Table II
The result of carbon footprint in a 250 ml per glass bottle of fish sauce

| Production Process | Total GHG emissions (kgCO2eq) in each fish sauce factory | | | Average GHG emissions (kgCO2eq) in fish sauce factories |
|---|---|---|---|---|
| | Factory no.1 | Factory no.2 | Factory no.3 | |
| Fermentation process | 0.255 | 0.207 | 0.324 | 0.262 |
| Mixing process | 0.031 | 0.033 | 0.032 | 0.032 |
| Filtering process | 0.0001 | 0.00007 | 0.0001 | 0.0003 |
| Packaging process | 1.202 | 1.068 | 1.441 | 1.237 |

## IV. RESULTS AND DISCUSSION

Priorities for selecting the potential production processes to reduce GHG emissions in fish sauce industry, based on the opinions of experts revealed by questionnaire survey in pairwise comparisons.
The highest priorityfor selecting the potential production was technology improvement with 0.422. The second priority was reuse/recycle with 0.249. The third priority was operational management with0.168 and the lowest priority was input material change 0.161. (see Fig. 3)
According to the priorities of subcriteria, Technology improvement for reducing of using electricity was the highest with 0.232because it was easily practicable and important for reducing GHG emissions. Reuse/recycle of package wasthe second priority with 0.156. Technology improvement for reducing of using heatwas the third priority with 0.142. Operational improved management for reducing of using water wasthe lowest priority with 0.026 and other rankingswere shown in Fig. 4.
The final result in Fig. 5 foundthat thepackaging process and the fermentation process werethe two highest priorities. These processes had relation with the priorities in Fig. 3 and Fig. 4.
Furthermore, this study assessed cradle-to-gate carbon footprint in four fish sauce processes of three factories in 2013-2014. The assessment did not include waste water treatment and transportation. The data collection of carbon footprint was verified by facility managers and consultant of carbon footprint assessment from Thailand Greenhouse Gas Management Organization (Public Organization) and the results were shown in Table II. The packaging process and fermentation process were the two highest average GHG emission values because the values were included in raw materials acquisition from suppliers.Similarly, the values were considered only production processes in fish sauce factories, using electricity caused high GHG emission values.Hence, carbon footprintshould focus on improvement planning of these processes for reducing GHG emissions.
This study found that the result of selecting the potential production process for reducing GHG emissions from the AHP was consistent with the result from carbon footprint.

## CONCLUSION

This study applies the AHPto help the decision to select the potential production processes for reducing greenhouse gas emissions in a fish sauce industry. The results showed that the packaging process and the fermentation process were the potential production processes.
The criteria which highly influencedon the decision of selecting the potential process for reducing GHG emissions were technology improvement, reuse/recycle, operational management, and input material change, and the subcriteria were technology improvement for reducing of using electricity, reuse/recycle of package, technology improvement for reducing of using heat, and changing input material of fuel respectively.
For the application to other food industries, selection of potential production processes for reducing GHG emissions had steps as follow:

1) Enumerating the production processes for selecting the potential process which reduce GHG emissions.
2) Weighting the relative importance for pairwise comparison with criteria,subcriteria and production processes in questionnaireby the group decision making.
3) Calculating relative weight of all the components of each level based on AHP approach.
4) Checking the consistency ratio corresponding to the judgments.
5) Ranking the production processes for selecting the potential process which reduce GHG emissions.

Decision to select the potential production processes for reducing GHG emissions should consider not only the amount of GHG emissions in each process, but alsostudying the possibility of modifying the production process such as technology or methods, or knowledge besides including a rate of return on investment.

## REFERENCES


[1] Ministry of Commerce. (2015, March 7). Thailand Trading Report. [Online]. Available: http://www.ops3.moc.go.th/infor/MwnuComTH/stru1_export/export_topn_re/report.asp

[2] K. UmaDevi, C. Elango, and R. Rajesh, "Vender selection using AHP," International Conference on Modeling Optimization and computing, vol. 38, pp. 1946-1949, 2012.

[3] W. Guiqin, Q. Li, L. Guoxue, and C. Lijun, "Landfill site selection using spatial information technologies and AHP: A case study in Beijing," J. Environ. Manage, vol. 90, pp. 2414-2421, April 2009.

[4] S. Lee, W. Kim, Y.M. Kim, and K. J. Oh, "Using AHP to determine intangible priority factors for technology transfer adoption," Expert Systems With Applications, vol. 39, pp.6388-6395, 2012.

[5] T.L. Saaty, "Decision making with the analytic hierarchy process," Int. J. Services Sciences, vol. 1, no. 1, pp. 83-98, 2008.

[6] K. Peniwati, "Criteria for evaluating group decision-making methods," Mathematical and Computer Modelling, vol. 46, pp.935–947, March 2007.

[7] G. Coyle, "The Analytic Hierarchy Process (AHP)," Practical Strategy. Open Access Material. Pearson Education Limited, 2004.

[8] J. Franek and A. Kresta, "Judgment scales and consistency measure in AHP," ECE Trans. Procedia Economics and Finance, vol. 12, pp. 164-173, March 2014.

[9] T.L. Saaty and L.G. Vargas "Models, Methods, Concepts & Applications of the Analytic Hierarchy Process," 2nd ed. Springer New York Heidelberg Dordrecht London, pp.6, 2012.

[10] T. Wiedmann and J. Minx, "A definition of Carbon Footprint," In: C. C. Pertsova, Ecological Economics Research Trends: Chapter 1, pp. 1-11, Nova Science Publishers, Hauppauge NY, USA, 2008.

[11] Thailand Greenhouse Gas Management Organization (Public Organization) and National Metal and Materials technology Center of the National Science and technology Development Office, "Guideline for Organization Carbon Footprint Assessment," C, Bangkok, Thailand, 2011.

[12] J. korpela, A. Lehmusvaara, and J. Nisonen, "Warehouse operator selection by combining AHP and DEA methodologies," Int. J. Production Economics, vol. 108, pp. 135-142, 2007.


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