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RESEARCH ARTICLE

THE WATER FOOTPRINT OF SOY SAUCE

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ABSTRACT

The increasing demand for food has led to the increase in crops' planting/growing activities. This has subsequently resulted in increased competition for water. Increased demand in agriculture, domestic and industry has put pressure on existing water resources system especially when the amount of rainfall received has reduced. In today's industry, water plays an important role in many applications and level especially in the boiling, cooling and cleaning processes. Food processing industry is one of the industries that consume a lot of water. Water is a basic component in the operations and supply chains of many companies. The objective of this study is to quantify the water footprint of soy source in a specific factory in Malaysia. The study illustrates how the water components such as Green, Blue and Grey water are used in the production of soy sauce. The average water footprint for the production of 330 liters of soy sauce is 200 liter. This paper will show the largest component water used which is green water which contributes 86% of water used in the supply chain.

KEYWORDS

Water footprint, Soybean, Industry, Soy sauce.

1. INTRODUCTION

The increased development of the food industry has resulted in insufficient supply of agricultural sources to meet the demand. Soybean is one of the food sources that are imported from producing countries such as Argentina Brazil and America. In Asia, particularly in Malaysia, soybeans are an important crop in the production of foods such as soy sauce and fermented beans (Tempe). Soy sauce is the source of flavor for most foods. This paper shows the water footprint of Soy sauce to analyze its impact on water resources, although the sources of the main ingredients are imported from another country. From the field to end product, the ingredient passes through a number of production stages with different impacts on water resources. This paper will show the impact on the final consumption of the final product, which is soy sauce, of one of the established company in Malaysia by looking at the supply chain and tracing the origin of the product.

Water is an important resource for drinking, sanitary, agriculture, industry, urban development, and other activities. Contamination of several rivers and water storage breakdown has increased the demand for clean water by consumers. Inefficient water management can cause a water crisis. The study of water footprint of soy sauce product will provide useful information to other companies. This study's contribution includes providing knowledge about the processes involved in the production of soy sauce. It also helps readers to know more about the environmental impacts especially on water that are used during the production processes. The study can also be used by the company to set a benchmark for its annual water footprint. Additionally, the company can set a target to reduce the usage of fresh water in the future

The aim of this study is to quantify the freshwater usage in the production of 1 liter of soy sauce from both foreground and background of the production chain. This is relevant to the company's goals of ensuring the production of quality products and the protection of the environment.

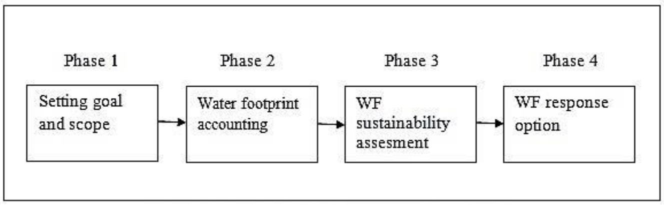

Figure 1: Four phases in water footprint assessment

2. METHODOLOGY

Research methodology is one way to solve problems systematically. This study used Water footprint Assessment framework as a scientific method to analyze the water footprint (Hoekstra and Chapagain, 2011). Figure 1 shows the framework for water footprint assessment. It has four steps or phases. Water footprint study can be undertaken for many different reasons or purposes depending on the need of the individual, company or national government. In this assessment, it has four phases starting with setting goals and scope of the study. Then, it is followed by water footprint accounting where data are collected and accounted for, and after that,

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water footprints are evaluated from an environmental perspective for social and economic sustainability assessment. Lastly, the final step or phase involves response option.

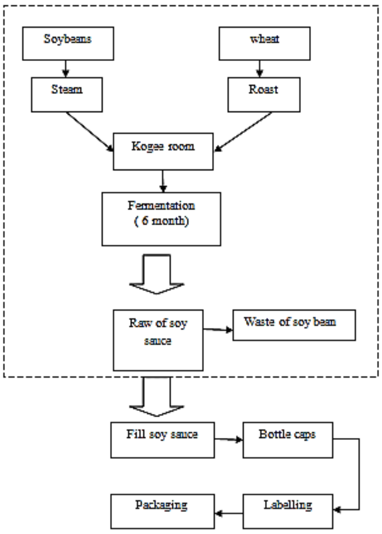

Figure 2: The life cycle of soy sauce production

2.1 Setting goal and scope

The goal of this study is to investigate the water footprint, particularly the blue, green and grey water, of one of the famous additional seasoning in our daily life which is soy sauce. The scope of the study only focuses on one-unit stock of a particular brand located in Kuala Kangsar, Perak in Malaysia. Soy sauce is one of a famous condiment in Asia where it is commonly used as a liquid seasoning for other foods. Today, soy sauce is produced by using two processing methods which are traditional method and chemical method. Traditional method commonly uses fermentation that takes up to six months to complete in order to get the right balance of flavor and aroma. While, chemical method takes only two days to get the flavor and chemical aroma. This process used/applied traditional method and the process involves five parts of production which are component, kogee production, fermentation, pressing and packaging. Figure 2 illustrates the whole process of production (the dotted line represents the system boundary under study). As stated in the scope of the study, all raw material and activities that might contribute in the process are interrogated to calculate the overall water footprint of soy sauce. On this basis, the analysis will estimate the corresponding water requirement of the entire primary crop as well as the soy sauce process. The process consists of input to output as a concept that applies in Life cycle assessment and uses cradle to gate as a variance. Cradle-to-gate is an assessment of a partial product life cycle from resource extraction (cradle) to the factory (gate) (i.e., before it is transported to the consumer).

2.2 Water footprint accounting

In this study, we used product water footprint assessment as the total volume of water that was used directly or indirectly by the product. The water footprint of the product was broken down into green, blue and grey components. In the analysis, we considered the grey water footprint as zero by assuming that the concentration of the pollutant in the effluent equals to its actual concentration in the receiving water body.

2.3 Water footprint sustainability assessment

Sustainability depends on the characteristic of water footprint and local condition where water footprint is located. It can be analyzed from an environmental aspect as well as from social and economic perspective.

2.4 Water footprint response action

In this section, this paper will review the option available to consumer, producers, investors and government to reduce water footprint and give a solution. For this study, the company has taken responsibility to make sure that the water footprint for its product is sustainable.

3. Result and Discussion

3.1 Blue water footprint of fresh water

3.1.1 Sources of fresh water

The company used water from municipal pipe in a form of main water to run its business. On average, the company used 60 m3 (60000 liters) of fresh water per day. This included water used for fermentation, production, others product line and cleaning as shown in Figure 3. According to the management of company x, active production takes place six days per week from Monday to Sunday. Thus, in a month, the active production days for the company will equal to 24 days. It is also important to note that there are also national holidays which are enjoyed by all workers in Malaysia. These holidays are also applicable to “company x”. On this basis, the study has considered the number of working days per year for year 2012 as 250 working days. Hence, based on the usage of 60 m3/day, the total freshwater used for processing of product in 2012 was 15000 m3.

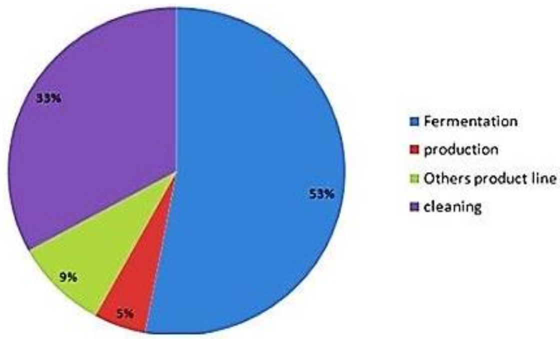

Figure 3: Daily soy sauce water footprint activities

3.1.2 Production line & volume

The company produces a variety of product lines. But, this study only focused on the 3 main product lines with differences in the brand’s appropriate package. During the calculation period, the company only focused on 3 main products of soy sauce packages. However, Table 1 shows that about 10% of total production in 2012 included all the above production lines were wasted due to product development and testing to improve production line in packaging damage and leakages.

Table 1: Production line of Soy Sauce Produced in 2012

PRODUCT	PACKAGES	% SHARE
Product A	29409	26
Product B	28278	25
Product C	44113	39
Waste	11311	10
Total	113,111	100

3.1.3 Estimation of the green water footprint

The study analyzed per country water footprint of the primary crop, soybeans 336 and wheat-15 based on FAO crop code. In this study, the water footprint calculation was based on Hoekstra and Chapagain (Chapagain and Hoekstra, 2004). It indicates the differences in blue, green and grey water footprint in the processing of primary crops. However, we considered grey water footprint as zero by assuming that the concentration of the pollutant in the effluent equals to its actual concentration in the receiving water body. The total crop water requirement and irrigation requirement were calculated based on FAOSTAT models. FAOSTAT models is a decentralized statistical system and statistical activities cover the areas of agriculture, forestry and fisheries, land and water resources and use, climate, environment, population, gender, nutrition, poverty, rural development, education and health as well as many others. However, this study only addressed specific product which was soy sauce. The study had focused on united stated (U.S) and countries where the primary product was imported from, as well as Malaysia where the processing took place (refer Table 2).

Table 2: Total purchase of primary crop in 2012

Primary crop/ product	Country of origin	Quantity purchased (t/ year)
Soybeans	United Stated (U.S)	50 x 1000=50000
Wheat	Australia	25 x 475=11875

3.2 Soybean

Soybeans (FAO 236 crop code) are referred as the king of legumes because they contain a lot of nutrition. They are also high in minerals particularly calcium, magnesium and vitamin B. They are one of the most essential world crops necessary for protein (Chapagain and Hoekstra, 2007). Soybeans can grow in a variety of soil and different climate condition. Their colors vary from yellow to brown, green and black. But the most common soybeans are yellow. The soybeans used by Company x were imported from and cultivated in the United States (U.S) (refer Table 3). The green water footprint of crop (m3/ton) has been estimated as a green water used (m3/ha) to the crop yield (ton/ha). However, in this study, Crop water Requirement (CRW) was calculated based on the length of growing period (lgp).

Table 3: Cultivation water of footprint of purchase soybean

Crop	Country	Yield (t/ha)	Purchased t/yr, 2012	WF m3/yr 2012	Sources
Soybeans	Florida (State)	2.02	50	119555	USDA
Soybeans	Indiana (State)	3.26	50	74080	USDA
Soybeans	N. Dakota (State)	2.29	50	105460	USDA
Average	U.S	2.5	50	95835	

50000kg soy beans = 50 ton/year.

3.2.1 Soybean water requirement

Soybean is widely grown under warm conditions and relatively resistant to low and very high temperature. Therefore, the growth rates decrease in temperature above 35°C and below 18°C (Chapagin and Hoekstra, 2007). However, crop yield depends on Crop Water used (CWU) and soil. The crop water used has an important impact on the output yield (Chapagin and Hoekstra, 2007). The Crop Water Requirement (CWR) used in this study was taken from the FAOSTAT database on water footprint of a nation by Hoekstra and Chapagain (Chapagin and Hoekstra, 2007). The guideline for calculating the water footprint per hectare by Hoekstra and Chapagain was used (Chapagin and Hoekstra, 2007). The formula for the calculation is effective rainfall (mm/length of growing period) multiply by ten (10) equals water footprint per hectare (Chapagin and Hoekstra, 2007).

3.3 Yield

Company x purchased soybeans through a domestic vendor who imported soybeans from a wholesale company that engaged many farmers in their transaction. It is therefore difficult to know how much soy beans (ton/ha) an individual farmer produces. Because of the difficulties and lack of information regarding the exact farmer from whom the soybeans were purchased, the study had focused on average data yields from three different states (USDA, 2011; Mekonnen and Hoekstra, 2011).

3.4 Wheat

Wheat (FOA crop code 15) is one of the commodities produced by the Australia agriculture industry. It is the most valuable crop in Australia. During the year 1830 to 1840, cultivation of wheat expanded rapidly and the area cultivated for wheat grew from eight hectares in 1838 to 7,592 hectares in 1844 (FAO, 2013). The crop has been integrated as an ingredient in the production of Soy sauce. The crop was organically cultivated in Australia and imported by company x through United Malayan Flour (UMF). Wheat growing areas are determined by soil type, soil fertility, topography and rainfall. Rain should predominantly fall during the winter and spring months. This invariably results in high evapotranspiration of the crop. The crop water requirement for wheat, which was taken from FAOSTAT model, was 309 (FAOSTAT, 2014).

Table 4: Cultivation water footprint of purchase wheat

Crop	Country	Yield (t/ha)	Purchased t/yr, 2012	WF m3/yr 2012	Sources
Wheat	Canada	2.67	12	15236.4	(FAOstat, 2012; IFADATA 2012)
Wheat	United states	2.89	12	9841.2	(FAOstat, 2012; IFADATA 2012)
Wheat	Australia	1.36	12	27265.2	(FAOstat, 2012; IFADATA 2012)

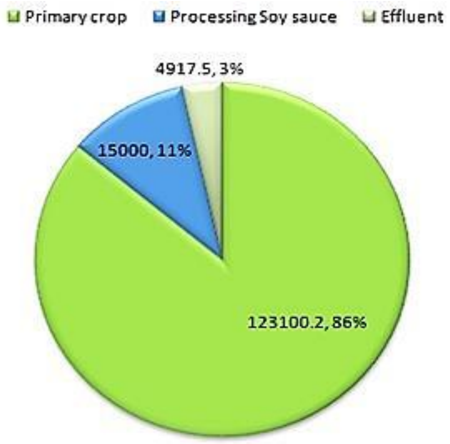

Figure 4: Component of water footprint

3.5 Yield

In Australia most wheat is planted during April and May as the seed requires colder weather to germinate wheat yield (refer Table 4). Relatively, this has resulted in higher yield of wheat cultivation per hectare. This study demonstrated the importance of understanding the amount of water that content in the product that related to consumer goods and services and show how entities cooperate or organization of the company can assess their water footprint in an easier way. This result clearly shows the process of producing soy sauce by company x. It also illustrated the system boundaries for the product. From this system boundary, researchers can estimate water consumption and pollution in all steps of the production chain. The component of the water footprint of soy sauce (Figure 4) was divided into three parts: green as the primary crop, blue as processing of soy sauce and grey as effluent from the factory. The result indicates clearly that a significant amount of water was used in the production of goods. However, about 86% of the water used to produce the soy sauce was derived from supply chain and not from the company's operation. From this data, we can assume that the main crop used in the soy sauce which is soy beans significantly contributed to water used so we can avoid it from buying from other reseller that used minimum water requirement in their crop. Figure 5 shows the green water component used in the cultivation of the product. It is important to understand that the calculation was done by using the crop water requirement value in respective countries. Between the two main ingredients of soy sauce, soybeans significantly contributed 77% of the overall water footprint of the primary crop.

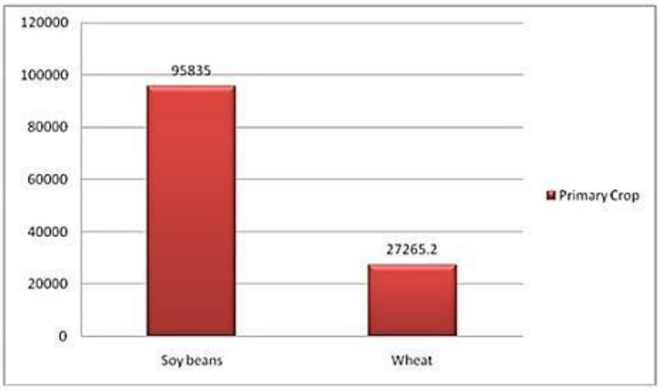

Figure 5: Water footprint (m3) of purchased primary crop

3.6 Calculation of the average water footprint

Table 5 shows the distribution of all soy sauce along the production lines. The calculation was done to produce a volume of water per production lines of 330 ml volume of soy sauce. Production line was calculated with 3 products which were product A, B and C. Product C contributed 39% of the water footprint for year 2012. The focus of the study was to quantify the water used to produce a volume of company x's soy sauce production. The average water footprint for 330 ml of soy sauce was 200 litter.

Table 5: Detail calculation of water footprint for Company x product

Product lines	No of packages per year	Share of soy sauce (%)	WF of Soy Sauce	WF per volume bottle (m3)	Share per packages
Product A	29409	26	35906	0.33	33
Product B	28278	25	34525	0.33	33
Product C	44113	39	53859	0.33	33
Waste	11311	10	13810	0.01	1
Total	113,111	100	138100	1	1

$\frac{1\ meter\ cubic}{5\ unit}$ = 0.2 m3= 200 litter

4. Conclusion

In conclusion, water footprint of soy sauce will be focusing on three component of water which is green as the primary crop, blue as processing of soy sauce and grey as effluent from the factory. Green water component used in the cultivation of the product involved two types of crop which is soybeans and wheat which soybeans contribute more than 77% higher from wheat. In this paper, there are 3 types of soy sauce 330ml volume in this company and this soy sauce collectively contributed 200ml of water footprint.

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