A modification of supply chain of green bean in Indonesia on basis of LCA thinking

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ABSTRACT

Climate change is mainly linked to greenhouse gas (GHG) emissions in which the agricultural sector occupies 14% of total emissions. In this paper, the questionnaires were implemented to investigate the effects of green bean quality including eco-burden factor and price on consumer buying decision. Also, on the estimation of eco-burden, LCA methodology was considered, and the carbon footprint of green bean in the supply chain process in Indonesia was expressed. The results showed that the total emissions (CFP) of green bean were between 4.92 and 7.38 kg-CO_2eq/kg green bean by varying farmers, and they became larger than that of Japan case (1.11 kg-CO_2eq/kg green bean). In addition, through our questionnaires on basis of the quality and price of green bean, we confirmed that the factor of quality is more significant for consumer buying decision.

Keywords: LCI, green bean, supply chain, carbon footprint of product, quality change

1. Introduction

Food sustainability is unquestionably a major issue for the years to come (Catherine et al., 2013). Nevertheless, the food industry is one of the world's largest industrial sectors and a large user of energy. Food production, preservation and distribution consume a considerable amount of energy, which contributes to total CO_2 emission. Andersson et al. (1994) stated, there is an increasing awareness that the environmentally conscious consumers of the future will consider ecological and ethical criteria in selecting food products. In addition, Boer (2002) reported, consumers in developed countries demand safe food of high quality that has been produced with minimal adverse impacts on the environment. It is thus essential to evaluate the environmental impact and the utilization of resources in food production and distribution systems for sustainable consumption (Poritosh et al., 2009).

Based on NASA-Goddard Institute for Space Studies (2012), the climate changes are mainly linked to GHG emissions in which the processes of farming, land use change and transport contribute 14%, 18% and 14% of total emissions. Thus, the reduction of GHG emissions for agriculture and food systems would be required (Catherine et al., 2013). For instance, the improvement of food supply chain would be brought by the higher efficiency of energy usage, and that would contribute to the reduction of GHG emissions.

By mapping all ingredients and components contained in the product, it will be able to assess the environmental impact (Alan et al., 2010). The application of supply chain management techniques has proven to dramatically improve efficiencies in a variety of industries (Haarteveit et al., 2004). As a more systematic and integrated strategy, the green supply chain management has emerged as an important new innovation. This fact helps farmers to develop strategies so as to earn profit and market share by lowering their environmental risks and impacts, while raising their ecological efficiencies (Qinghua et al., 2007). For that reason, our purpose is to evaluate carbon footprint of fresh and rejected green bean along its supply chain in Indonesia. Also, we argued the effect of CO_2 emissions are reflected to the product quality.

In previous studies, it was confirmed that eco-labeling was a way to encourage consumers to prefer the products whose characteristics are more environmentally friendly (Ralph et al., 2007). In the consumer research carried out in recent years, it was shown that consumers would be affected by not only the demand change of reliable products, but also by the corporate social responsibility (i.e. environmental consciousness) to some extent (Turan, 2007). Also, in general, since vegetables are perishable, the growth of these agricultural products is affected by the capability and/or availability of supply chain so as to be quickly delivered to consumer with fresh condition (Madeleine and Zhaohui, 2012). Thus, since the quality of product is an important factor, we should consider the quality change during the handling process. As a first step, we focus on the comparatively popular agricultural product, and estimate the carbon footprint of product of it on basis of LCA methodology. We attempt to verify the relationship between the quality including eco-burden element and price for consumer buying decision. Here, the reason why we select the Indonesia area as a case study is as follows: the cold chain is not enough constructing, the economic loss with quality worse due to the proper climatic condition is caused and the residential people has a great concern on eco-friendliness. Moreover, based on our preliminary research, it shows that 75% of citizen in Indonesia often eat green bean within a week which means that it is one of the popular vegetable in Indonesia.

2. Methods

2.1. Basic supply chain of vegetable

Chien-Jung et al. (2013) pointed out that all supply chains cover the processes from the raw material supply to the added value providing, including the sale to customers. In this study, we focused on the Indonesia market. For the supply chain of vegetable in Indonesia, as illustrated in Figure 1, some processes of nursery, planting, growing and harvesting are done by farmers. Until the agricultural products are harvested, some of them are not harvested and are consciously left in the field for new seed production. Once vegetables are harvested, they are transported in use of small trucks from the field to the warehouse managed by farmer union. If the transportation distance to the warehouse is less than 500 meters, they will be carried by man power. Otherwise, the truck is used and the harvested products are sorted and graded. The purpose for sorting and grading the products in the warehouse is to discriminate each product for whether it is suitable for export, modern or traditional market. After they are packed, these products are delivered directly to a distributor, by whom they are sold to consumer or just stored in their warehouse.

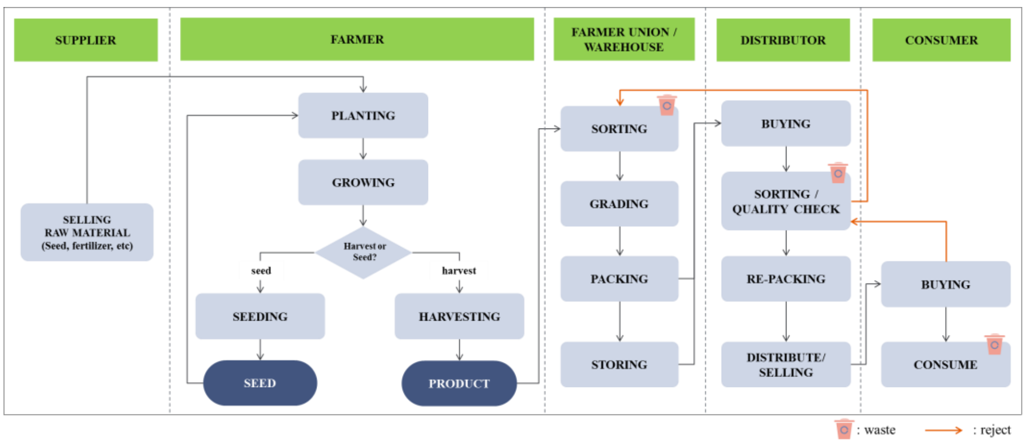

Figure 1. Basic supply chain of vegetable in Indonesia

Next, in a distributor, the agricultural products such as vegetables will be re-sorted on basis of quality requirement. This process is needed because the physical quality of them usually changes due to the influence of transportation process. As a result, all products are determined whether they have commercial value or not. The unfit products mean irregular and/or rotten ones. Those worse products would be caused due to their inappropriate cultivation or physical damages. Thus, both of them would be returned to the farmer, and the irregular product will be re-delivered to another consumer. While, the rotten ones will be no longer possible to be consumed. As Diana (2009) described about the related facts, if growers do not satisfy with the pre-harvest food safety standards, their crops would become waste as significant losses. Also, from the same viewpoint of Lundqvist et al. (2008), they defined that the food waste is the deliberately discarded food. It is no longer possible to eat for human consumption, even if its state would still be eatable. Recently, the requirements of end-consumers have been increasingly requested with regard to the better qualities of food products, assortment and package features, and the presented way of food products at a food store (Jon and Taras, 2009). Simultaneously, the loss percentage of agricultural products of vegetables is approximately 25% to 30% in the following processes of packing, transportation and storage (Dan, 2012). However, this percentage is very small for that of total waste due to its quality loss. Note that the terminology of "loss percentage" does not mean the amount with lost quality but the amount which accidentally fall off in the delivering process.

On the other hand, from the viewpoint of environmental impact, the impact for the lost amount in supply chain becomes smaller than that of the waste disposal, because the total lost amount in supply chain is less than 5% than the percentage of disposal amount including the factors of quality loss. If we describe about the carbon footprint of products and other environmental indexes for agricultural products, we have to discuss about not the material balance in the supply chain but the quality change of target product. Accordingly, in this paper, we focused on the agricultural product of green bean whose quality would be changed in some processes including the delivery process to more extent and whose supplied amount would be affected by its quality loss.

2.2. LCA methodology

LCA methodology is required for evaluating the carbon footprint of product in the supply chain process. Almudena et al. (2010) assessed the environmental impacts of products and services in use of LCA, which has been applied to many industrial sectors including food and agriculture. Guido et al. (2000) emphasize that the use of LCA in agricultural sector can cover all environmental impacts and that the result can provide us a significant potential for supporting the environmental improvement and innovation of the proposed agribusiness by Rene (Rene, 2002). This methodology is used to compare the primary energy requirement (Michael, 2005) and to analyze environmental impacts that can occur at all steps of the product chain (Gaudreault et al., 2009) by quantifying and evaluating the consumed resources and/or the emissions at all stages of its life cycle from the extraction of resources, through the production of materials and products parts, and the use of the product including its reuse and/or the recycle of final disposal (Hayo, 2004). In this respect, LCA approach is used to evaluate the impacts from the view point of consumers, which might be able to be reduced significantly on their food purchases (Niels et al., 2000).

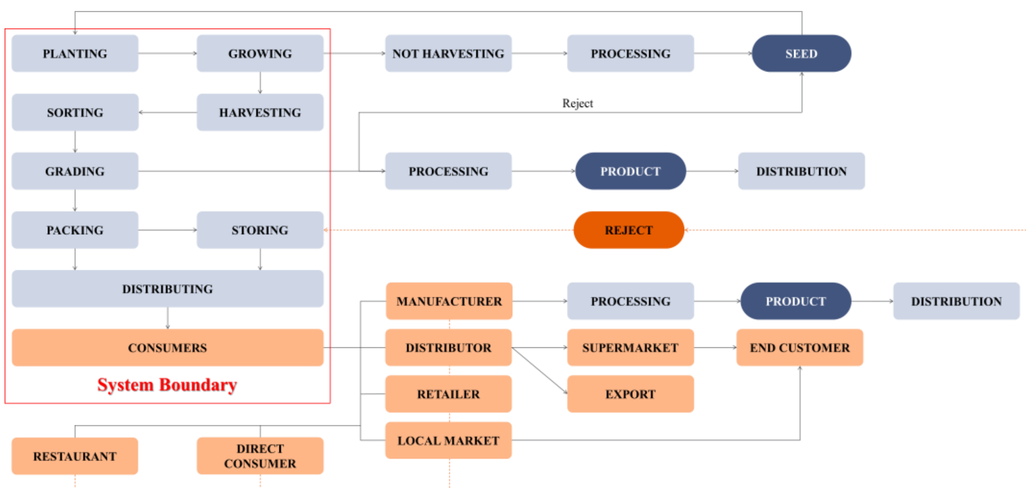

Figure 2. System boundary

In this study, as a first step, we estimated the LCI of green bean which harvested by the three different farmers. Actually, the production capacity would be varied by the cultivation area and/or farmers. Thus, considering these uncertainties, we analyzed the impacts. Also, we prepared the following two cases: (1) the LCI of fresh green bean and (2) that of rejected one. Here, the rejected green bean is defined as an irregular and/or a rotten product which are less commercial value. Note that the rate of rejected amount is from 13 to 20 % against the total harvesting product due to the difference of farmer (see Figure 3). The functional unit of LCI in this study is kg-CO_2eq/kg-green bean. Since the specific CO_2 emission of LCI includes other global warming gasses, that is evaluated as equivalent CO_2 emission. Also, assuming that the total equivalent CO_2 emission of i-th farmer for the final products, that for the fresh ones and that for the rejected ones are $LCI_{total,i}$, $LCI_{fresh,i}$ and $LCI_{rejected,\,i}$, respectively, $LCI_{total,i}$ is,

$$LCI_{total,i} = (1-\alpha)\, LCI_{fresh,i} + \alpha\, LCI_{rejected,\,i} \qquad \text{Eq. 1.}$$

Where, α is the rate of rejected amount.

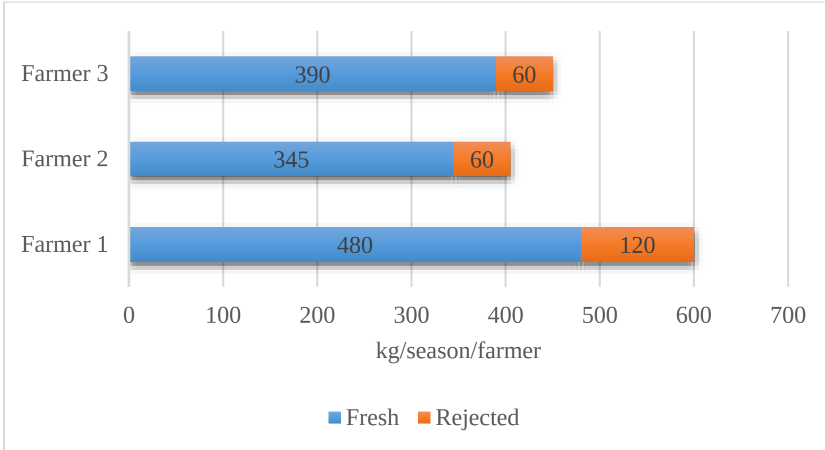

Figure 3. Comparison between fresh green bean and rejected one

Next, as shown in Figure 2, the system boundary of this study encompasses production (planting, growing and harvesting), transportation from field to warehouse, warehouse handling (sorting, grading, packing and storing), and transportation from warehouse to consumers. Based on these conditions, we estimated the LCI of green bean in consideration of the farmer difference and the harvested product difference due to the quality loss.

Here, Table 1 shows material inputs for each case of LCI calculation. For each case, we simulated that in use of LCA calculation software MiLCA (The Japan Environmental Management Association for Industry (JEMAI)). However, the loading ratio of truck long transport was assumed to be 62% of 15 ton truck due to the transportation condition of Japan since there is no data of that in the target area. The estimation of fuel consumption was based on the guideline of fuel consumption of truck (Ministry of Economy, Trade and Industry and Ministry of Land, Infrastructure, Transport and Tourism). Here, the fuel consumption of diesel truck is as follows:

$$LnF=2.71-0.812Ln(R/100)-0.656LnM \qquad \text{Eq. 2}$$

Where, F, R and M are the fuel consumption per t-km [L/tkm], the loading ratio [%] and maximum capacity [kg], respectively. Also, Ln means logarithm natural.

Table 1. Material inputs

Case	Process	Material input	Farmer 1	Farmer 2 Amount	Farmer 3
Fresh and Rejected	Production	Fertilizers	0.041 kg/kg	0.062 kg/kg	0.03 kg/kg
		Pesticide	0.063 kg/kg	0.095 kg/kg	0.1 kg/kg
		Herbicide	0.033 kg/kg	0.05 kg/kg	0.03 kg/kg
		Gasoline	1.54 L/kg	2.31 L/kg	2.1 L/kg
	Transportation from field to warehouse	-	1.5 ton truck	Man power	1.5 ton truck
		-	loading ratio 40%		loading ratio 30%
		-	distance 5 km	distance 0.5 km	distance 4 km
		Diesel	2.17 mL/kg	-	2.93 mL/kg
	Warehouse handling	Electricity	0.018 kWh/kg	0.027 kWh/kg	0.024 kWh/kg
	Transportation from warehouse to distributor	-	15 ton truck	15 ton truck	15 ton truck
		-	loading ratio 62%	loading ratio 62%	loading ratio 62%
		-	distance 32 km	distance 32 km	distance 40 km
		Diesel	0.14 mL/kg	0.14 mL/kg	0.17 mL/kg
Rejected	Transportation from distributor to warehouse	-	15 ton truck	15 ton truck	15 ton truck
		-	loading ratio 62%	loading ratio 62%	loading ratio 62%
		-	distance 32 km	distance 32 km	distance 40 km
		Diesel	0.14 mL/kg	0.14 mL/kg	0.17 mL/kg
	Warehouse handling	Electricity	0.092 kWh/kg	0.183 kWh/kg	0.183 kWh/kg

2.3. Consumer behavior analysis

Next, we argued about the following hypothesis: "Consumer buying decision on green bean would be influenced by variable quality and price". In the quality, the environmental factor is included, too. We perceived the relation between both variables at the time when consumer bought green bean on basis of a multiple regression analysis. This analysis is a statistical technique which can be used to analyze the linear relationship of $Y_1 = X_1 + X_2 + \ldots + X_n$. The objective of multiple regression analysis is to use the independent variables by which the selected single dependent value is predicted (Joseph et al., 2010). The dependent variable in this study is consumer buying decision (Y) and independent variables are quality (X_1) and price (X_2) of green bean. Also, we focused on consumer's behavior analysis so as to discover the importance of quality of green bean when the consumer buys it. For instance, according to the data of Ministry of Agriculture Indonesia, the average consumption weight of green bean in 2009 and 2010 were 832 g/capita and increased to 884 g/capita. Also, FAO reported the average times of eating green bean in Indonesia was 5 days per week with the total consumption of 3 g/capita/day. Thus, from the viewpoint of food LCA concept, on the often eaten food, to analyze the LCI and investigate the number of eating the product are significantly important. Note that the LCI would be affected by the qualities which are the factors of size, color, texture, flavor and nutrition content, and that the inventory result has to be based on the dynamic aspect. This time, we only referred to the LCI of green bean in consideration of the material balance.

In this study, the questionnaires were executed for a month between Jan 1 and 27, 2014 through the online system, and we collected 174 valid respondents. The investigated areas were Jakarta, Surabaya and Bandung in Indonesia. The questionnaire consists of the following 3 sections: (1) the respondent demographics profile, (2) the consumers' awareness on the environment and their health conditions, and (3) the measurement on important factors for consumers.

3. Results

3.1. Carbon footprint of product (CFP)

We used two sources to evaluate the carbon footprint of fresh or rejected green bean in consideration of material balance in the supply chain. These data were collected by the field investigation including the interview with farmers, and the other was based on the reference papers. As we mentioned above, we evaluated the specific CO_2 emissions of fresh green bean and rejected product. The initial green bean is categorized as follows: size of 8-12 cm, weight of 3-5 g, color of green, firm texture and unbruised bean. Here, both of fresh and rejected green beans are assumed to be transported to the distributor warehouse. Then, the rejected one is returned to the farmer.

Using the software of MiLCA in which approximately 3,000 inventories of materials, energy use and transportation were bundled (Haruhiro et al., 2013), we estimated the specific CO_2 emission on basis of Eq. 1. In each case, we obtained the CFP between 4.92 and 7.38 kg-CO_2eq/kg green bean. The influences of rejected green bean were from 0.94 to 1.15 kg-CO_2eq/kg green bean (see Figure 4). Compared to the CFP in the Japan case, there seems to be enough potential to reduce them of Indonesia to more extent. That is, according to Ajinomoto Group Environmental Report 2006, that of same product was 1.11 kg-CO_2eq/kg green bean, and that was equivalent to about 6 times against the CFP in this study.

Table 2. CFP of green bean supply chain in Indonesia (kg-CO_2eq/kg green bean)

	Total Global Warming	Production	Transportation	Warehouse handling
Farmer 1	4.92	4.88	0.02	0.02
Farmer 2	7.38	7.33	0.01	0.04
Farmer 3	6.86	6.80	0.02	0.04

According to Figure 4, the CO_2 emission of rejected product became larger in comparison to the fresh, since that has longer processes in the supply chain process. As illustrated in Figure 2, the rejected product is returned to the warehouse, and then, that is re-delivered to another consumer. That is, the added process requires more fossil fuel for the transportation and electricity in storage of product. The largest CO_2 emission in the production process was emitted in comparison to other ones in the green bean supply chain. This reason is due to the machineries utilization which is fueled by much gasoline.

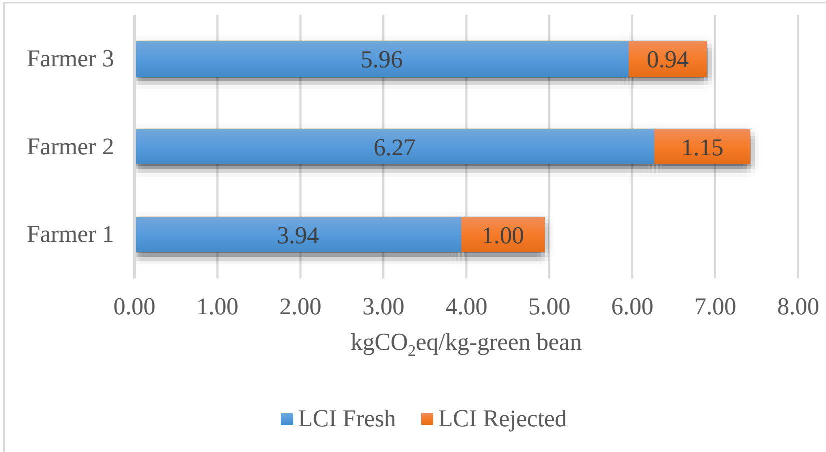

Figure 4. Comparison of emissions produced by fresh and rejected green bean

3.2. Consumer's behavior

This paper also has aim to analyze the relationship between quality and price at the time of purchase. As the result on basis of questionnaire, from first section of questionnaire a respondents profile was obtained. Table 3 shows the demographics profile of the respondents.

Table 3. Respondents' demographics profile

Category		Frequency	Percentage
City	Jakarta	92	52.87
	Surabaya	33	18.97
	Bandung	49	28.16
Gender	Male	78	44.83
	Female	96	55.17
Marital	Single	69	39.66
	Married	105	60.34
Education	Secondary	12	6.90
	Diploma	9	5.17
	Bachelor	105	60.34
	Postgraduate	48	27.59
Monthly income	Below USD 85	10	5.75
	USD 85 – USD 339	52	29.89
	USD 340 – USD 595	35	20.11
	USD 596 – USD 850	27	15.52
	Over USD 850	50	28.74

Also, we asked the respondents about their consciousness on environment and their health. More than half of respondents (66.67%) always dispose their garbage in the appropriate place, the 29.89% of them often do that, and the rest of them (3.45%) seldom do that in the appropriate place. That is, they have seems to have highly environmental awareness.

Table 4. Consumer's behavior

Questions	Never		Seldom		Often		Always	
	Total	%	Total	%	Total	%	Total	%
How often do you throw away your garbage in the appropriate place?	0	0.00	6	3.45	52	29.89	116	66.67
How often do you pay attention on your food consumption?	1	0.57	32	18.39	97	55.75	44	25.29
How often do you consume organic vegetables or fruits?	7	4.02	98	56.32	59	33.91	10	5.75
How many times do you shop for vegetables in one week?	17	9.77	47	27.01	73	41.95	37	21.26
How often do you consume vegetables in one week?	0	0.00	31	17.82	91	52.30	52	29.89

Next, in order to discover consumer's behavior in consuming vegetable, we asked the respondents about the importance of their food consumption. The majority people have an attention to the products (55.75%), the 25.29% always worry about the qualities. Although there are respondents who seldom do it (18.39%) or have no attention to it (0.57%), most consumers concern with their health conditions which reflected by their behavior in consuming of vegetables. On the other hand, on their consumptions status of both organic vegetable and fruit, almost respondents hesitate to consume them (56.32%). That is, it is shown that the organic products are unpopular for Indonesian.

On the behavior of purchases of vegetables, the 41.95% of respondents go shopping of them by a few times for a week. However, there are also respondents who seldom do it (27.01%) or do not go shopping (9.77%).

Finally, according to the personal habit of vegetables eating, the 52.30% of respondents often eat them per a week, or the 17.82% seldom do it. However, there is no people who do not eat them. That is, this results indicate that they are likely to eat vegetables for their health condition.

Using the questionnaire results, we analyzed them due to Likert-scale (i.e. 1=strongly disagree, 5=strongly agree) for estimating the statistical perception.

A multiple regression analysis was used to analyze the data. A validity test was conducted to evaluate the questionnaire. A questionnaire can be stated as valid if its questions were able to reveal something that will be measured by it. Using the correlation coefficient of Pearson, the results are clearly valid, because R-value is larger than sample correlation coefficient r table (0.148) and P-value is smaller than 0.05. Also, the t-values of quality (X_1) and price (X_2) are 8.15 and 2.10, respectively (See Table 5).

$$Y = 6.28 + 0.39 X_1 + 0.26 X_2 \quad \text{Eq. 3}$$

Based on this equation, the regression coefficient of quality was 0.39. This means that the quality would have a positive effect on consumer buying decision. For instance, if the quality of green bean is good, the consumers' awareness for buying that would increase. On the other hand, the variable of price was 0.26. That is, the consumers have awareness of the price to some extent, but, they have stronger interest in the condition of green bean at their purchases.

Table 5. Results of multiple regression analysis

Model Summary[b]

Case	Model	R	R square	Adjusted R square	Std. Error of the estimate
Green bean	1	0.61	0.37	0.36	2.17

a Predictors: (Constant), Quality, Price b Dependent Variable: Consumer decision

ANOVA[b]

Case	Model		Sum of squares	df	Mean square	F	Sig.
Green bean	1	Regression	477.16	2	238.58	50.55	0.000 (a)
		Residual	807.14	171	4.72		
		Total	1,284.30	173			

a Predictors: (Constant), Quality, Price b Dependent Variable: Consumer decision

Coefficients[a]

Case	Model		Unstandardized coefficients		Standardized coefficients	t
			B	Std. Error	Beta	
Green bean	1	(Constant)	6.28	0.93		6.76
		Quality	0.39	0.05		8.15
		Price	0.26	0.12		2.10

a Dependent Variable: Consumer decision

Coefficient of Correlations[a]

Case	Model			Quality	Price	Consumer' decision
Green bean	1	Correlations	Quality	14.16		
			Price	2.23	2.16	
			Consumer decision	6.10	1.43	7.38

4. Discussion

Based on our results, it was shown that the total emission of fresh green bean was smaller than that of the rejected. This implies the following matters: if the farmer who cultivates green bean does not pay attention to the handling of product, the rejected amount, that is, the waste amount would be increased. Likewise, in Indonesia where the annual consumption of green bean is large, the CO_2 emission for the target product might be attributed to the large amount of emission. Also, as we referred to the section of 3.1, the specific CO_2 emission of green bean was about 6 times larger than that of product of Japan. We have to think what kind of good countermeasure for reducing that we can propose. For instance, the Photovoltaic (PV) technology would be able to be promoted in the agricultural product. In the previous study by Eidelweijs et al. (2012), it was shown that the promotion of PV system on paprika distribution process in Indonesia can decrease CO_2 emission by 1.947 g-CO_2/paprika, that is, the 11.9% of cultivation process, the 30% of packaging, and the 30% of cold storage in comparison to the conventional case, respectively. As the same as the study by Fukumoto et al. (2011), the advanced paprika cultivation system in consideration of the energy supply of low carbon emission fuel such as a bio-fuel was proposed. Based on the biomass gasification process of Blue-Tower (BT) technology, they showed that the promotion of new technology can reduce the CO_2 emission on LCA concept. The BT co-generation (BT-CGS) was able to decrease by 104.6 gCO_2/paprika, that is, the CO_2 abatement was 82.0% in comparison to the conventional system.

According to Douadia and Pierre (2009), the shopping choices can contribute to the global warming protection. All over the world, the use of eco-labelling as a market-driven environmental policy tool is increasing. A number of articles have dealt with eliciting consumer's preferences and willingness to pay (WTP) for eco-friendly food products. Also, in the previous study about consumers' awareness in Jakarta, Indonesia, we understood that the consumers have a high awareness on global warming issues. Simultaneously, we knew that CO_2 emission factor is the most important factor and that their decision on purchase of paprika is affected by the communication index of eco-label. In other words, there would be somewhat potential market for paprika with eco-label in Indonesia. In that case, the WTP of consumers was corresponding to the 15% or more against the average existing price of paprika (Eidelweijs et al., 2012).

Furthermore, it was shown that the carbon footprint of product (CFP) for agriculture products of vegetable is unique, since the quality is attributed to many of the changes which would be produced in its life cycle. That is, the quality is an important factor of vegetable because it will change inevitably by passage of time. From the point of view of consumer, the good commercial product is defined as an attractive physical appearance and/or its good taste. In this study, the main reason why green bean was rejected is due to the lack of consumer satisfaction on quality. That is, that was the following causes: the size of green bean was too large or small, the color was bruised, and the green bean itself was rotten. If we can reduce the rotten amount, there would be an improvement on the total emission to some extent. In our future plan, we will investigate the effects of cold chain, the buying decision for the eco-friendly vegetable and the promotion of low emission agricultural product system.

5. Conclusion

Due to the quality change of green bean, the total CO_2 emission of product would be different. For this difference, the consumers' behaviors would be changed, and the worse environmental effect would be brought. Hence, in the future work, we will propose a dynamic LCA based on quality change on vegetable.

As described by Annie et al. (2010), a dynamic LCA is proposed to improve the accuracy of LCA by addressing the inconsistency of temporal assessment. For instance, the utilities by which consumers' behaviors would be influenced need to obtain the basic data through the experimental measurement and/or the process investigation. Also, the multi-indexes might be necessary for clarifying the product status, since there are many physical parameters of size, weight, color, edible portion, and nutrients such as sugar, acidity, vitamin and protein content. Based on this study, at the next stage, we will analyze the dynamic life cycle inventory data set of green bean.

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