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Spreadsheet Modeling Applied to Food Waste Reduction in Food Supply Chains

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Abstract

Food waste is a global issue addressed by the United Nations 2030 Agenda for Sustainable Development to reduce half of the food waste at the retailer and consumer levels. The quantitative approach is required to make correct decisions regarding food waste reduction options in food supply chains. In this study, a spreadsheet modeling method was applied to achieve quantifiable impacts on food waste reduction. A case study of the downstream retail phase of a two-level supply chain of a fresh prepacked food product was used to demonstrate the model application. Information regarding the buying and consuming behaviors of consumers was collected by questionnaires to be used for stochastic analysis of inputs in the spreadsheet model. The results showed that adjusting the packaging size to match a distinct local profile could play a major role in food waste generation with appropriate sizing of retail packages enabling a reduction of up to 127 kgs. per month, or 62%, of food wastage in the supply chain. The tradeoff between the two levels of the supply chain was required to achieve this reduction of food waste. At the consumer level, smaller packaging sizes were preferred to reduce food waste which was more sensitive to the package sizes than the retailer's preference for larger packaging sizes. As well, self-weighing of unpackaged food in quantities required by the customer could reduce food waste by 7 kgs. per month, representing a 10% reduction over the selling-buying method of small pre-packed packages. Overall, good consumer food buying alone could reduce the total food waste by 59% and good consumption practices alone could reduce the total food waste by 66%.

Keywords: Food Waste Reduction, Retail Supply Chain, Spreadsheet Modeling, Selling Method, Consumer Behavior.

1. INTRODUCTION

The Food and Agriculture Organization (FAO) reported that one-third of food was being lost and wasted along the global food supply chain (FAO, 2011). This waste amounted to 1.3 billion tons per year. Food that has been purchased by consumers at the retail level for personal consumption that eventually becomes waste not only has an economic impact on the consumers but also represents significant economic and environmental impacts at every stage of the food supply chain and food life cycle (Nellemann et al., 2009).

Food production and distribution require logistics activities and manpower that consume natural resources such as water and oil. When the food becomes waste, greenhouse gases are produced, and landfill sites for disposal are required with the attendant landfill management cost. Therefore, it is unacceptable if the food is thrown away as waste. The extent of this worldwide issue needs to be addressed by practitioners, researchers, and policymakers not only for these reasons but also from a food security dimension.

The United Nations (2015) has implemented programs on sustainable consumption and production for all countries to achieve a 50% reduction in food waste per capita at both the retail and consumer levels, by 2030. There is an intercorrelation of the two-level supply chain whereby the food waste generation of each of the two stages is interrelated. For example, if the retailer provides only large packaging sizes and introduces sales promotions that attract customers to buy more than they need, there is a greater chance of food waste at the consumer level. Our study investigated these relationships and ensures that food waste is not just pushed from one level to the other level of the supply chain thus avoiding responsibility for food waste.

Our study followed the prevention approaches to food wastage (Papargyropoulou et al., 2014) in proposing some strategic and operational options for the total food waste reduction of the two-level supply chain. Quantitative approaches are applied in our study so that the result could be quantified and the practitioner can see the influence of each option to be able to make the best decisions for their supply chains (de Moraes et al., 2020; Yetkin Özbük and Coşkun, 2020).

This study used a spreadsheet modeling to represent the two-level supply chain of food retailing with consideration of the stochastic consumers' behaviors and the age-based inventory system. The aim was to investigate the impacts of (1) packaging sizes, (2) two selling-buying methods which were small pre-packed packages versus self-weighing of unpackaged food, and (3) good practice of buying and consuming behaviors of the consumers on the total food waste.

In the organization of this paper, Section 1 introduced the background, importance, scope, and objectives of this study. Section 2 identified research gaps and distinctions of this study from the existing work. Section 3 presents the research methods while the results and discussions are in Section 4. Section 5 provides the conclusions that can be drawn from the study and provides future research opportunities.

2. Literature Review

A hierarchy of favorable approaches for food waste solutions has been introduced for all parties (Papargyropoulou et al., 2014). The “prevention”, whose purpose is to prevent or reduce the production of excess food which may become waste, is the most promising approach when compared to other approaches such as “reuse” which is when food that would otherwise be discarded would be provided to people in need, “recycle” is the practice of food waste being used animal feed or being composted, and “recover” is the application of food waste to the production of energy.

Existing research that focused on the preventive methods of food waste reduction of perishables by applying quantitative approaches featured common configurations such as stochastic customer demands, product maximum life, and the inventory of aging products. These studies include Haijema and Minner (2016) who emphasized food waste reduction by comparing the performance of the stock-level dependent inventory replenishment policies of retailers. Other studies that focused on inventory replenishment practices include Janssen et al. (2018a) who investigated the benefit of adjusting replenishment frequency and Janssen et al. (2018b) who considered incorporating retail store closing days into inventory management policy. Another focus has been on dynamic shelf-life management and price discounting for the food that passed its optimal quality (Buisman et al., 2019; Adenso-Díaz et al., 2017).

Although these studies provided successful approaches to the prevention and reduction of food waste, an important aspect of the supply chain was missing: that is the interaction between consumer behavior and retail product supply. Food waste at the retail level is reduced and by various means. The possibility of food waste generation moves from the retailer level to the consumer level when the reduced price, promotions such as buy-one-get-one-free, or too large packaging sizes are implemented at the store. Somkun (2017) looked into this issue and combined the two levels via package size decisions with consumer behaviors as inputs for the spreadsheet model. However, the application of Somkun (2017) is limited to highly perishable products that have a single period shelf life. Somkun (2020) proceeded by allowing the shelf life to be any integer value.

Our study is a progressed work after Somkun (2020) but is distinct from the existing work in many ways. First, the consumer data in this study were grouped by occupation. This was done because, as the descriptive statistics from our data collection showed, the factor suggestively contributed to food waste generation. Gender and age which were analysis factors in the previous study were not considered relevant in our study. This alteration from the existing research generated different buying and consuming behaviors and consequently a different result analysis. Our study also investigated other unique points such as the comparison of food waste generation between selling in fixed packaging sizes and the case of the customer personally weighing and packing their purchases according to their personal preferences. Another unique point in the study is that the influence of consumer behavior, particularly purchasing and buying behaviors, on the scale of reduction of food wastage was examined and quantified.

3. Methods

This study presents an application of spreadsheet modeling with a case study of a downstream supply chain that consisted of the retailer and consumer levels. We considered a single retail store as the retailer of interest at that level. The store was located in an urban area in provincial Thailand which was characterized as being a convenience store. This store operated an inventory of around 400 stock-keeping units (SKUs) of prepacked fresh food products such as vegetables, fruits, meats, dairy, and bakery. Most of these perishables had a shelf life of between 3 to 7 days. For the consumer level, there were approximately 290,000 locals living in the area of study which was served by 14 other similar stores.

The specific objective of this study was to analyze the influence of packaging sizes of a single type of product on the total food waste from the two supply chain stages. We also investigated the aspect of selling methods such as selling in prepacked packages and weighing as much as the customer desires. The influence of good practice in purchasing and consuming was also investigated. The content in this section is applicable to any one of those prepacked products.

Three main steps were applied in our research methodology as described in Fig. 1.

3.1 Data Collection and Input Analysis

The first step dealt with collecting the data from the case study. The required information for the retailer such as selling methods for different types of products, the product shelf life, and the store’s inventory replenishment policy was collected by observation and interview. For the consumer level, we surveyed 400 sample consumers to learn their self-estimated percentages of food wastage of three types of perishables such as vegetables (9.7%), bakery (8.0%), and fresh meat (7.1%) as shown in Table 1. In the initial plan, we wished to categorize the customers by their incomes as it was suggested by FAO

(2011) that the wastage percentage highly depended on household incomes. However, information regarding income is sensitive, even in a survey where the participants remain anonymous, and some people preferred not to expose it. Therefore, occupation was used instead as it could roughly represent the revenue. The occupation groups included government officials, businesses, self-employed, students, and others, which showed quite distinct food waste percentages of 10.2%, 9.6%, 8.2%, 6.8%, and 6.6%, respectively.

The questionnaire responses also provided important inputs for the model; multipliers of the purchasing and consuming behaviors. The consumers were asked to rate their usual performance on the five-point Likert scale from highly disagree, disagree, neutral, agree, to highly agree for each question. There were 8 questions to verify the consumer purchasing behavior: (1) perform stock checking routine, (2) use a shopping list, (3) stick to the shopping list, (4) buy a large amount of food each time to avoid frequent shopping, (5) buy reduced-price food, (6) buy food as seen in the advertisement or at friends' suggestions, (7) buy more by sale promotion and discount or collect points, and (8) like to buy new food that was not previously eaten. Six questions for assessing the consumer consuming behavior included (1) only eat food that is still fresh, freshly cooked, and in perfect condition, (2) discard leftover food after every meal, (3) keep leftover food for subsequent meals, (4) discard fruit and vegetable with flaws, (5) understand the distinction between "Expire date" and "Best before", and (6) make leftovers into new appetizing food. These questions were based on frequently mentioned factors for food waste in the literature (FAO, 2011; Mondéjar-Jiménez et al., 2016; Parfitt et al., 2010; Richter, 2017; Secondi et al., 2015; Song et al, 2015).

The scores were rearranged and transformed to represent the purchasing and consuming multipliers using the same process employed in Somkun (2020), where the details are published. The interpretation of a 5-score rating answer to each question can be either of positive or negative meaning. Thus, some rating scores were reversed to usable scores which then have the same direction towards food waste reduction. The usable scores were summed up to the total score. In this way, the total score will be meaningful. Each total score is then transformed by dividing by a neutral total score (half of the full score) to obtain the multiplier value as shown in Table 2. The resultant multiplier values of each occupation group were statistically analyzed to identify the probability distribution function using a well-known test called the Goodness-of-Fit test. All multipliers were found to be normally distributed at a 0.01 significant level. The mean and standard deviation of the normal distribution of the purchasing and consuming behaviors multipliers for each occupation group are presented in Table 1. These parameters were used as the stochastic inputs to the spreadsheet model.

3.2 Spreadsheet Modeling of a Two-Level Supply Chain

The second research step was to construct the spreadsheet model. This model was the key method applied in this study owing to its performance in storing and analyzing large volumes of data and the accessibility of statistical and formula verifying tools that facilitated the model construction and verification.

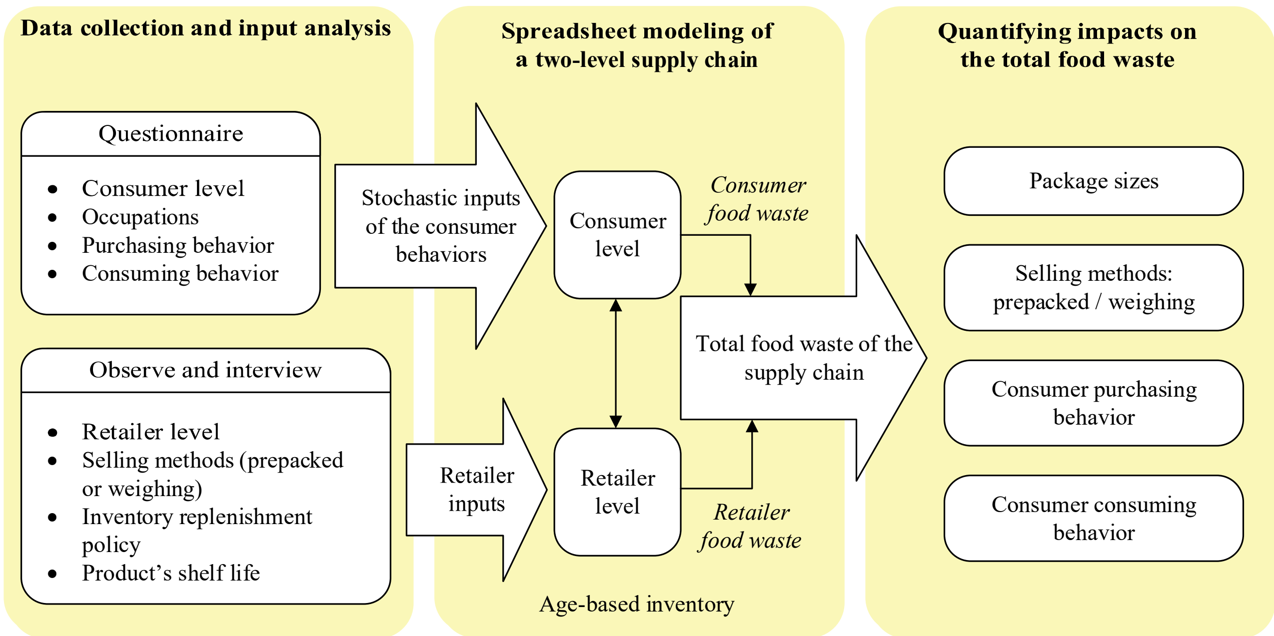


Figure 1 Research methodology

Table 1 Self-estimated percentage of food wastage and behavior multipliers for the model input

Occupations	Number of responses	Self-estimated percentage of food wastage				Behavior multipliers	
		Vegetables	Bakery	Fresh meat	Overall	Purchasing	Consuming
Government official	95	11.5	10.1	9.0	10.2	N(1.066, 0.189)	N(1.153, 0.227)
Business	72	11.6	9.0	8.3	9.6	N(1.043, 0.211)	N(1.220, 0.244)
Self-employed	80	9.7	7.7	7.2	8.2	N(1.034, 0.194)	N(1.276, 0.222)
Students	108	7.8	6.8	5.6	6.8	N(1.164, 0.189)	N(1.130, 0.233)
Others	45	7.7	6.5	5.5	6.6	N(1.052, 0.179)	N(1.224, 0.265)
	Average	9.7	8.0	7.1			

Table 2 Example of score adjustment for a single respondent (Somkun, 2020)

Item	Question number	Direction towards food waste reduction	Example rating scores (* to be reversed)	Usable score	Transform by dividing by half of the full score	Multiplier
Buying behavior	1	+	1*	5	which is 20	Buying multiplier
	2	+	3*	3		
	3	+	4*	2		
	4	–	1	1		
	5	–	5	5		
	6	–	3	3		
	7	–	4	4		
	8	–	5	5		
Full Score =	40		Total score =	28	28 ÷ 20 =	1.40
Consuming behavior	1	–	4*	2	which is 15	Consuming multiplier
	2	–	2*	4		
	3	+	3	3		
	4	–	4*	2		
	5	+	3	3		
	6	+	2	2		
Full Score =	30		Total score =	16	16 ÷ 15 =	1.07

The model represented our two-level supply chain with a single retailer and groups of consumers. We used one sheet of spreadsheet software for the consumer level and arranged the components as shown in Fig. 2. Another sheet is for the retailer level as in Fig.3. Each row contained the value of the variables of each day as this model is a periodic model that the same set of events that happens every day.

The overall consumer demand is the total demand from all consumer groups. For each consumer group, the daily requirement per person is multiplied by the buying multiplier, which is a stochastic component, to generate the need per person in weight unit. Then, it is converted to the number of units required based on the packaging size being considered, and the group demand in weight unit is calculated. The consumer is assumed to buy the product with the longest remaining life first.

Next, the retailer checks whether its inventory is enough for the overall consumer demand. If so, the demands of all consumer groups will be satisfied. Otherwise, the demand of each consumer group will be served as much as its percentage of the overall demand. The product with the longest remaining life will be considered first. When the group demand has not satisfied by the product with the longest remaining life, the next longest remaining life is considered subsequently.

The consuming multiplier, another stochastic component, is used to generate the group consumption need. The consumer is assumed to always eat the freshest food first and eat the next freshest food to fulfill the consumption need. The leftover food is kept until its last day.

The product shelf life was counted from the arrival of the product at the retailer until the end of its life either at the retailer if the product was not purchased by the customer or at the household. The life of the product was assumed to reduce constantly every period and was tracked until it was consumed or discarded. This system is called an age-based inventory where the amount of food with different remaining life is tracked.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Consumer level																	
2	Total food waste of the two-level supply chain					142,997	grams/month											
3	Food waste at consumer level				125,672	grams/	month			Consumer group		1	Occupation		Government official		Group size	13
4	Food waste at retailer level				17,325	grams/	month			Buying multiplier pattern		Normal	Mean =	1.066	Stdev. =	0.189		
5	Package size		225	grams						Consuming multiplier pattern		Normal	Mean =	1.153	Stdev. =	0.227		
6	Product life		5	days						Daily requirement		200	grams					
7																		
8	**Day**	**Overall consumer demand**	**Overall 5-day demand**	**Overall 4-day demand**	**Overall 3-day demand**	**Overall 2-day demand**	**Overall 1-day demand**			**Buying multiplier**	**Need per person**	**Number of units required per person**	**Group demand**	**Percentage from overall demand**	**5-day demand**		**5-day bought**	**4-day demand**
9	0																	
10	1	15,975	15,975	-	-	-	-			1.083	217	1	2,925	18.31%	2,925	2,925	2,925	-
11	2	18,675	18,675	2,700	-	-	-			1.167	233	2	5,850	31.33%	5,850	5,175	5,175	675
12	3	19,350	19,350	675	675	-	-			0.923	185	1	2,925	15.12%	2,925	2,925	2,925	-
13	4	14,850	14,850	-	-	-	-			0.777	155	1	2,925	19.70%	2,925	2,925	2,925	-
14	5	18,675	18,675	3,825	-	-	-			1.209	242	2	5,850	31.33%	5,850	4,725	4,725	1,125
15	6	19,575	19,575	-	-	-	-			1.079	216	1	2,925	14.94%	2,925	2,925	2,925	-
16	7	14,850	14,850	-	-	-	-			0.877	175	1	2,925	19.70%	2,925	2,925	2,925	-
17	8	20,025	20,025	5,175	675	-	-			1.201	240	2	5,850	29.21%	5,850	4,500	4,500	1,350
18	9	15,975	15,975	-	-	-	-			0.956	191	1	2,925	18.31%	2,925	2,925	2,925	-
19	10	14,850	14,850	-	-	-	-			0.808	162	1	2,925	19.70%	2,925	2,925	2,925	-
20	11	14,625	14,625	-	-	-	-			0.884	177	1	2,925	20.00%	2,925	2,925	2,925	-
21	12	14,850	14,850	-	-	-	-			0.956	191	1	2,925	19.70%	2,925	2,925	2,925	-
22	13	20,025	20,025	5,175	5,175	3,375	2,250			1.161	232	2	5,850	29.21%	5,850	4,500	4,500	1,350
23	14	13,725	13,725	-	-	-	-			0.895	179	1	2,925	21.31%	2,925	2,925	2,925	-

(a)

	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO
1																		
2																		
3																		
4																		
5																		
6																		
7																	**Total food waste for this group (grams/month) =**	**31,057**
8	**2-day deman d**		**2-day bought**	**1-day demand**		**1-day bought**	**Consuming multiplier**	**Group consumption need**	**5-day consumed**	**4-day consumed**	**3-day consumed**	**2-day consumed**	**1-day consumed**	**4-day stored**	**3-day stored**	**2-day stored**	**1-day stored**	**Food waste**
9																		
10	-	-	-	-	-	-	0.878	2,275	2,275	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	1.001	2,600	2,600	-	-	-	-	650	-	-	-	-
12	-	-	-	-	-	-	1.379	3,575	2,925	650	-	-	-	2,575	1,325	-	-	-
13	-	-	-	-	-	-	0.801	2,080	2,080	-	-	-	-	-	1,925	1,325	-	-
14	-	-	-	-	-	-	1.625	4,225	4,225	-	-	-	-	845	-	1,925	1,325	1,325
15	-	-	-	-	-	-	1.399	3,627	2,925	500	202	-	-	500	1,970	-	1,925	1,925
16	-	-	-	-	-	-	0.934	2,418	2,418	-	-	-	-	-	-	1,768	-	-
17	-	-	-	-	-	-	0.877	2,275	2,275	-	-	-	-	507	-	-	1,768	1,768
18	-	-	-	-	-	-	1.108	2,873	2,873	-	-	-	-	2,225	1,857	-	-	-
19	-	-	-	-	-	-	1.270	3,302	2,925	52	325	-	-	52	2,225	1,857	-	-
20	-	-	-	-	-	-	1.013	2,626	2,626	-	-	-	-	-	-	1,900	1,857	1,857
21	-	-	-	-	-	-	1.570	4,069	2,925	299	-	-	845	299	-	-	1,900	1,055
22	675	450	450	225	225	225	1.088	2,821	2,821	-	-	-	-	-	-	-	-	225
23	-	-	-	-	-	-	1.226	3,185	2,925	260	-	-	-	1,679	-	675	450	450

(b) continue from (a)

Figure 2 Spreadsheet model for the consumer level

When the product that has one period left before the end of its life is not purchased or consumed, it becomes food waste. Therefore, food waste can occur at both the consumer level and the retailer level. Our analysis utilizes food waste at each of the two levels and the total food waste of this supply chain as the key performance measures. We recommend interested readers to read Somkun (2020) for the mathematical expressions of the relationship of this system.

The Order-Up-To inventory replenishment policy, in which the retailer placed an order periodically (daily) to raise the inventory level of the particular product to the target level, was employed in the model. The formula for the Order-Up-To level (S) in the weight unit is described by:

$$S = (1 + L) \times \bar{D} + z \times \sqrt{(1 + L)} \times s_D, \qquad (1)$$

where L is the lead time between the retailer and the distributor, $\bar{D}$ is the average consumer demand and s_D is the standard deviation of the consumer demand.

The lead time was zero from the interview with the store as the store placed an order at the end of its working hour and the product would be received the next morning, effectively immediately in store opening terms. The $\bar{D}$ and s_D were calculated from a set of the generated overall demand that corresponds to the distribution of the multipliers shown in Table 1. The z term is the inverse of standard normal cumulative distribution or $F^{-1}(prob.)$ function. Input for this function is the cycle service level (CSL). The CSL value shows the probability that the retailer will be able to respond to customer demands by on-hand stocks. The CSL value closer to 100% means a higher stock level and thus a higher customer service level.

3.3 Quantifying Impacts on the Total Food Waste

The final step of this research method was to numerically quantify the impacts of three methods to food waste reduction. We assumed the product shelf life to be 5 days. The Cycle Service Level (CSL) was set to 0.98, which means 98% of the orders in a cycle out of all cycles were satisfied by in-stock inventories.

This investigation included (1) setting a suitable package size and (2) providing an appropriate selling method between the prepacked package and weighing as much as the customer desires. For the consumer stance, (3) the influences of good practice in purchasing and consuming were investigated.

For the first objective, the experiment was designed to test the package size between 50 grams to 350 grams with a 25-gram increment as this range covered the current package size of this product of 200 grams. As of the stochastic nature of the model, the data was collected 300 times for each package size and the average value was used for plotting the graph. The result is presented in Section 4.1.

The best packaging size resulting from the first experiment will be used for setting the experiment in the next section. The scenario is that the store provides a station for the customer to self-weight the require quantity of the food product rather than selling the product in prepacked package size. The spreadsheet model for this scenario allows the customers to buy the exact amount of the food product that they want if the inventory is available. The data was collected 300 times. The result is presented in Section 4.2.

For the last objective, the consumers' buying and consuming behaviors will be investigated to realize how much the consumer can help solve the food waste problem. We assumed that the consumer practiced good buying behavior and therefore agreed to the positive food waste reduction implications of all the questions listed in the questionnaire at the 4th level of the five-point Likert scale where highly disagree is 1, disagree is 2, neutral is 3, agree is 4, and highly agree is 5. This arrangement resulted in a deterministic value of all consumers' buying multipliers while the consuming multiplier still had its stochastic nature. Again, the data was collected 300 times.

The same procedure was applied to the practice of good consuming behavior. Therefore, for this latter case, the consuming multiplier was deterministic while the buying multiplier maintained its stochastic character. The result is presented in Section 4.3.

	A	B	C	D	E	F	G
1	Retailer level						
2							
3	Food waste at retailer level			17,325	grams/	month	
4	Inventory replenishment policy			OUT	OUTL =	100	units
5	Package size		225	grams			
6	Product life		5	days			
7							

8	Day	Incoming delivery	5-day inventory	4-day inventory	3-day inventory	2-day inventory	1-day inventory	Unmet demand	Overall consumer demand	5-day sold	Group 1	Group 2	Group 3	Group 4	Group 5	4-day sold	Group 1	Group 2	Group 3	Group 4
9	0	0																		
10	1	22500	22500	0	0	0	0	0	15975	15975	2925	4500	2475	3375	2700	0	0	0	0	0
11	2	15975	15975	6525	0	0	0	0	18675	15975	5175	2025	2250	5850	675	2700	675	225	225	900
12	3	18675	18675	0	3825	0	0	0	19350	18675	2925	4500	2475	6525	2250	0	0	0	0	0
13	4	19350	19350	0	0	3150	0	0	14850	14850	2925	2250	4950	3375	1350	0	0	0	0	0
14	5	14850	14850	4500	0	0	3150	0	18675	14850	4725	1800	2025	5400	900	3825	1125	450	450	1350
15	6	21825	21825	0	675	0	0	0	19575	19575	2925	2250	4950	6750	2700	0	0	0	0	0
16	7	19575	19575	2250	0	675	0	0	14850	14850	2925	2250	4950	3375	1350	0	0	0	0	0
17	8	14850	14850	4725	2250	0	675	0	20025	14850	4500	1800	2025	5175	1350	4500	1350	450	450	1575
18	9	20700	20700	0	225	1575	0	0	15975	15975	2925	4500	2475	3375	2700	0	0	0	0	0
19	10	15975	15975	4725	0	225	1575	0	14850	14850	2925	2250	4950	3375	1350	0	0	0	0	0
20	11	16425	16425	1125	4725	0	225	0	14625	14625	2925	4500	2475	3375	1350	0	0	0	0	0
21	12	14850	14850	1800	1125	4725	0	0	14850	14850	2925	2250	4950	3375	1350	0	0	0	0	0
22	13	14850	14850	0	1800	1125	4725	0	20025	14850	4500	1800	2025	5175	1350	0	0	0	0	0
23	14	22500	22500	0	0	0	0	0	13725	13725	2925	2250	2475	3375	2700	0	0	0	0	0

(a)

8	Group 1	Group 2	Group 3	Group 4	Group 5	3-day sold	Group 1	Group 2	Group 3	Group 4	Group 5	2-day sold	Group 1	Group 2	Group 3	Group 4	Group 5	1-day sold	Group 1	Group 2	Group 3	Group 4	Group 5	Food waste
9																								
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	675	225	225	900	675	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	675	0	0	0	225	450	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	1125	450	450	1350	450	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3150
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	1350	450	450	1575	675	675	0	0	0	0	675	0	0	0	0	0	0	0	0	0	0	0	0	675
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1575
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	225
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	1800	675	225	225	675	0	1125	450	225	225	225	0	2250	225	0	0	675	1350	2475
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

(b) continue from (a)

Figure 3 Spreadsheet model for the retailer level

4. Results and Discussions

4.1 Influence of Package Sizes on Food Wastage

The results of the first test on the influence of package size of the prepacked food product is depicted in Fig. 4. In general, the smallest size of 50 grams generated the least total food waste. This package size was best for the consumer as it generated the minimum surplus food. This was in opposition to the retailer experience as the smallest size produced the highest food waste at the retail level when compared to other package sizes. This clearly showed the tradeoff situation between this two-level supply chain.

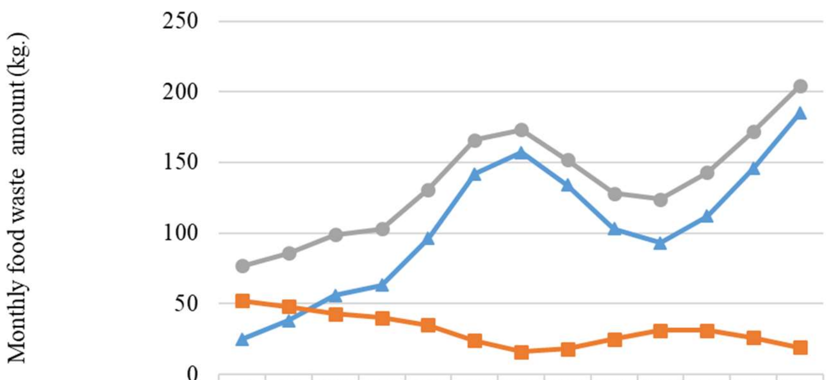
The 200-gram package size, which was the size provided at the store, generated the lowest store level's food waste of 16 kgs. per month but the amount of food waste was relatively high at 157 kgs. per month for the consumer level. It was noticeable that the retailer received less impact from the package sizes where the range between the best and the worst cases was 36 kgs per month of food wastage. The range was 160 kgs per month for the consumer level which showed that the consumer level was much more sensitive to the package size setting. For the supply chain view, the range was 127 kgs per month. This emphasized the importance of the size determination for a distinct community profile.

The relationship between the amount of food waste between the two levels was nonlinear. Although the smallest package size performed the best practice for that two-level supply chain, a smaller package size did not always generate a lower amount of food waste. From Fig. 4, for the package size between 225 to 275 grams, a larger package size produced less food waste. This result showed the benefit of the model in predicting the quantified impact of package size adjusting. The management could then decide the most appropriate package size that helped balance the food waste generation and costs of the implementation.

Another aspect widely debated is that the smaller packing sizes could lead to more packaging waste. Williams and Wikström (2011) suggested that, for some types of food, the total environmental impact could still reduce when trying to reduce food waste increases packing waste. Organic or degradable packaging could also be another option to solve this issue. Other options seen in most open markets are simply arranging food products in a pile or placing the food on a plate just to show the amount of a sale unit. The customers can take the food product directly to their bags. In this way, no packaging is required but the protection provided by a package is lost.

4.2 Influence of the Selling-Buying Method on Food Wastage

Following the result from Section 4.1, the smallest package size introduced the lowest amount of total food waste. The result showed that the weighing scenario could reduce the total food waste of this supply chain from 77 kg. per month to 70 kg. per month as presented in Fig.5. This 7 kg. per month accounted for a 10% reduction when compared to selling-buying by small prepacked packages of 50 grams. The consumers gained more benefit from the weighing scenario as their food wastage could drop 16 kgs. per month from 25 kgs to 9 kgs., which was a 64% reduction. This was unsurprising because the customers bought food in only the amount that they need. Thus, much less surplus food was bought and lessened the chance of food waste generation. The factor for the consumer food waste leaned towards their consuming behavior in this case. However, by implementing the weighing scenario, the retailer could generate 15% more food wastage, which increased from 52 to 61 kgs. per month.



	50	75	100	125	150	175	200	225	250	275	300	325	350
Consumer level	25	38	56	63	96	142	157	134	103	93	112	146	185
Retailer level	52	48	43	40	35	24	16	18	25	31	31	26	19
Total	77	86	99	103	131	166	173	152	128	124	143	172	204

Figure 4 The amount of food waste at the two-level supply chain for different prepacked package sizes

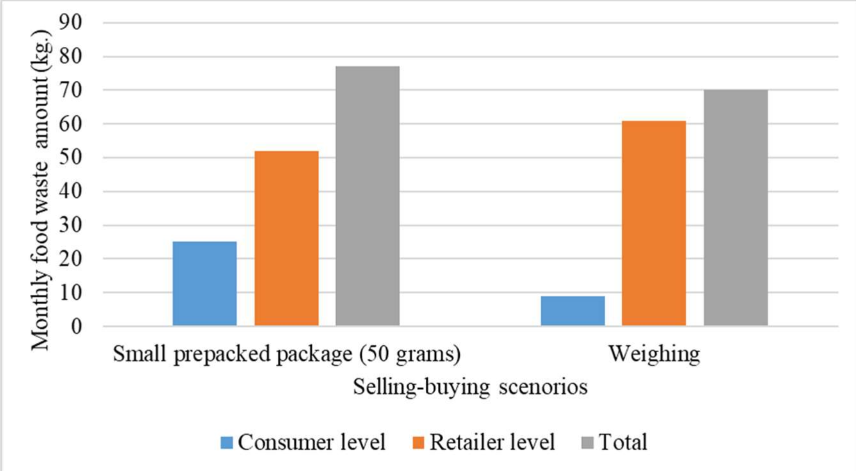


Figure 5 Comparing food waste generation between selling in prepacked package and weighing

This increase in food waste could be higher in real operations. As the retailer generally provides food such as fresh meat, fruits, or vegetables on an open platter for the customers to scoop, pick or select by themselves, the food might be spoiled, bruised, or contaminated as it does not have packaging for protection and eventually more food will be discarded. This deterioration in quality is especially true for food that requires temperature control.

The weighing and prepacked selling scheme could also be provided simultaneously by appropriate types of products at various store settings for customers with different levels of convenience preference. Although this adjustment in selling methods could cost more for the retailer, the pressure from the sustainable development goals (United Nations, 2015) that are currently applied would request all players to act.

4.3 Influence of the Consumer Behavior on Food Wastage

The comparison between the current buying and consuming behaviors of the consumer and these two scenarios showed a significant reduction in the total supply chain food waste as depicted in Fig. 6.

The reduction of 59% of the total food waste from 173 kgs. per month down to 71 could be achieved by the practice of good buying behavior. Considering the consumer level, the reduction was very large where the food waste was reduced to less than 1 kg. per month. The retailer however produced 54% more food waste due to the low customer demand resulting from the better buying behavior.

For the scenario that the consumer practiced good consuming behavior, the reduction of the total food waste was 114 kgs per month or 66%. This food waste reduction happened only at the consumer level. The retailer level's food waste was maintained at the same value (16 kgs.).

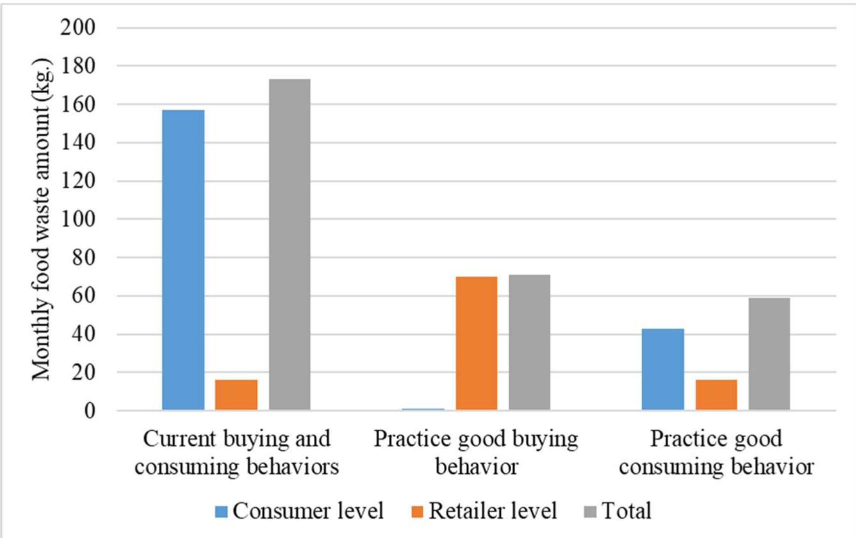


Figure 6 Influence of the consumer's behaviors on the amount of food waste

The result emphasized the importance of consumer involvement to achieve food waste reduction. Good practice of buying behaviors (such as constantly checking food stock at home, using a shopping list and buying as listed, and ignoring sale promotions and advertisements) could adjust the demand volume and the amount of food brought into a household to the appropriate level and resulted in lower household food wastage. Furthermore, good practice of consuming behaviors (such as keeping and re-cook leftovers, being more flexible about the appearance and freshness of food, and understanding date labels) could reduce food discarding.

5. Conclusion

This study proposed spreadsheet modeling for decision-making regarding food waste reduction. The model represented a downstream supply chain of a prepacked food product that had a single retail store at the retail level and 5 groups of consumers at the consumer level. The stochastic input data of the buying and consuming behaviors of the consumers were analyzed from a case study of an urban community.

The results suggest that package sizes highly influenced the reduction of the supply chain's total food waste. The consumer level was more sensitive to the package size than the retailer level. The model is a useful tool for the management to decide on a proper package size that helps reduce food wastage for a dissimilar population profile of each area.

Furthermore, the result indicates that allowing the customers to personally weigh the amount of food according to their needs could reduce the total food waste under the assumption that no food was spoiled by the customer selection process.

The consumers' buying and general consuming behaviors also played a major role in food waste reduction. The result showed that the total food waste of the supply chain could be reduced when the consumers applied good buying and consuming behaviors such as routine checking food stock at home, using a shopping list, keeping leftovers for next consumption, and understanding the best-before date labels, for example.

The limitations of this study could be further considered in new research studies. This study is limited to a two-level supply chain to focus on a downstream supply chain. However, the scope could be extended to other supply chain players in the various scenarios in which the product is being packaged, such as the distribution center or the factory, to complete the downstream chain.

A future study could also investigate the selling-buying method of weighing and packing the amount that the customer desires in a more realistic setting. The assumption that no food was spoiled during the customer selection process should be exempted to understand the real benefit of this selling-buying approach.

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