Waste Management 32 (2012) 2431–2438

Contents lists available at SciVerse ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Food residue recycling by swine breeders in a developing economy: A case study in Da Nang, Viet Nam

Takaaki Kato [a,*], Dung Thi Xuan Pham [b], Hai Hoang [c], Yonghai Xue [d], Quang Van Tran [c]

[a] Faculty of Environmental Engineering, The University of Kitakyushu, 1-1, Hibikino, Wakamatsu, Kitakyushu, Fukuoka 808-0135, Japan
[b] Graduate School of Environmental Engineering, The University of Kitakyushu, 1-1, Hibikino, Wakamatsu, Kitakyushu, Fukuoka 808-0135, Japan
[c] Faculty of Environment, Da Nang University of Technology, Da Nang University, 54 Nguyen Luong Bang St., Da Nang City, Viet Nam
[d] Tianjin Yuchuan Environmental Technology Co., Ltd., 101, D2, Tianjin University Science Park, 4th Avenue TEDA, Tianjin 300457, PR China

ARTICLE INFO

Article history:
Received 23 November 2011
Accepted 11 July 2012
Available online 9 August 2012

Keywords:
Food residue
Animal feed
Swine breeder
Viet Nam

ABSTRACT

This study provides a detailed description of food residue collection by swine breeders in Da Nang, Viet Nam. In January 2011, the study surveyed 30 swine breeders in two villages with respect to locations, methods, prices, quantities, and prospects for food residue collection. The sampled swine breeders regularly visited 55 locations in central Da Nang to collect raw food residue. They then transferred the food residue to their piggeries, boiled it, and fed it to their swine. A regression analysis revealed that the total amount of food residue collected by a farm depends on the number of swine in the farm and the number of collections made per day. Swine breeders in Da Nang were estimated to collect 26.3 metric tons of organic waste per day, which amounted to 4.1% of domestic waste collected by the local government. Among the sampled swine breeders, 93% answered that they would continue using food residue for the next five years.

1. Introduction

The International Monetary Fund (IMF) estimated that from 2001 to 2010, Viet Nam's real per capita GDP increased by 68% to 1173 US dollars (IMF, 2011). Speedy (2003) conducted a cross-section analysis of different countries and found that the main determinant of per capita meat consumption was per capita GDP. During the course of economic growth, swine breeding has become more popular among farmers in Viet Nam. According to the Food and Agriculture Organization (FAO), the number of domestic swine in the country increased from 21.8 million in 2001 to 27.4 million in 2010 (FAO, 2012). The same FAO statistics shows that domestic supply of pig meat increased by 74.2% between 2001 and 2007 (latest available data). Many believe that swine breeding offers a viable way to relieve the poverty of farmers in Viet Nam. For example, a local newspaper article featured a story of a rural family in the Mekong Delta whose income increased dramatically after the family introduced swine breeding into their farm; the increased income enabled the family to provide a better life for their children (Sunday Viet Nam News, January 2, 2011).

Despite the importance of the role played by swine breeders in food residue recycling in the country, their activities have not been systematically documented. The four central wards in Ha Noi have conducted a preliminary estimation of the amount of food residue collected by swine breeders (Osako et al., 2010). Based upon interviews with 20 restaurants and hotels in 2009 their rough calculation is that swine breeders recycled 6.5% of the 1100 metric tons per day of domestic waste discharged by the establishments. Other studies have focused on informal waste collectors in Viet Nam (Mitchell, 2008), but have not paid much attention to swine breeders. The extent of food residue collection by swine breeders was unclear; for example, we did not know how they collected food residue from households, restaurants, and hotels. We chose Da Nang City in Central Viet Nam as our study site and conducted a detailed survey of food residue recycling by local swine breeders. In 2010, Da Nang City had a population of 926 thousand (Da Nang Statistical Office, 2011). In 2008, the People's Committee of Da Nang publicized a plan to become "The Environmental City" by 2020; to achieve that goal, more appropriate management of solid waste is required there (Da Nang People's Committee, 2008). Integrating informal waste collectors into formal waste management organizations is an important option to consider when attempting to create a sustainable city in developing countries (Baud et al., 2001).

Food residue comprises a large proportion of municipal solid waste (MSW) discharged from large cities in Viet Nam. In 2007, the Kajima Corporation (2007a) randomly sampled waste from garbage trucks that arrived at the Khanh Son landfill in Da Nang City and reported that food residue comprised 43.7% of the wet weight of MSW. According to the Department of Natural Resources

* Corresponding author. Tel.: +81 93 695 3237; fax: +81 93 695 3337.
E-mail addresses: tkato@kitakyu-u.ac.jp (T. Kato), dungpham296@yahoo.co.jp (D.T.X. Pham), hhai@dut.udn.vn (H. Hoang), xueyh@tjycjt.cn (Y. Xue), tvquang@dut.udn.vn (Q.V. Tran).

0956-053X/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.wasman.2012.07.015

and Environment of Da Nang City (Da Nang DONRE, 2009), organic components comprised 56.85% of MSW in Da Nang in 2009. Note that this proportion of waste includes not only food residue but also organic components, such as pruned branches, which are difficult to decompose. The Kajima Corporation applied the aforementioned sampling procedure to Hai Phong City, as well, and the proportion of food residue there was 52.4% (Kajima Corporation, 2007b). In Hanoi City, the World Bank/MoNRE/CIDA (2004) mentioned that easily degradable organic waste comprised 51.9% of MSW.

Our survey results show that food residue recycling by swine breeders in Da Nang is done in a primitive manner. Food residue is collected in the urban center, transported to piggeries and boiled well, and then served for swine. Many swine breeders add rice bran and/or vegetables when they prepare feed rations. In the past, this kind of primitive treatment of food residue was also seen in developed countries. In his work, Ackerman (1996) summarizes the history of feeding raw food waste to swine in the USA between the mid-18th century and the 1950s. However, now in developed countries, there is a strong concern about the biological/chemical hazards and nutrition imbalance of feeding food residue to animals. Garcia et al. (2005) is cautious about the use of household food residue as feed since their samples taken at Madrid, Spain, contained cadmium (Cd) and lead (Pb). The Swine Health Protection Act of the United States is an example of the regulation of food residue recycling in the swine industry, and it aimed at keeping certain swine diseases out of the country (Taft et al., 2000). In addition, the Taiwanese government has developed regulatory and restrictive measures to decrease the use of food residue when breeding swine in order to prevent diseases and environmental pollution (Tsai, 2008). However, a more sophisticated approach in feeding food residue to livestock has been pursued in developed countries. For example, in 2009, Japan began requiring the certification of quality, safety, and environmental load of feed produced from recycled food residue (Sugiura et al., 2009). A description of modern procedures for producing liquid rations by sterilization with heat and dry rations by dehydration is mentioned in Ogino et al. (2006). Correspondingly, the primitive form of feeding food residue to swine in Da Nang may not last much longer. Nevertheless, the Da Nang case is worth investigating because swine breeders accrue a non-negligible amount of food residue in comparison to the Da Nang Urban Environment Company (Da Nang URENCO), a public company of the Da Nang City Government.

The primary goal of this paper is to illustrate, through a case study, the role of swine breeders in food residue recycling in Da Nang. To the best of our knowledge, this is the first study to measure the amount of food residue collected by swine breeders in Viet Nam. Such a study will provide a more thorough understanding of the current situation of food residue recycling and will assist in the formulating of future policies to mitigate the environmental

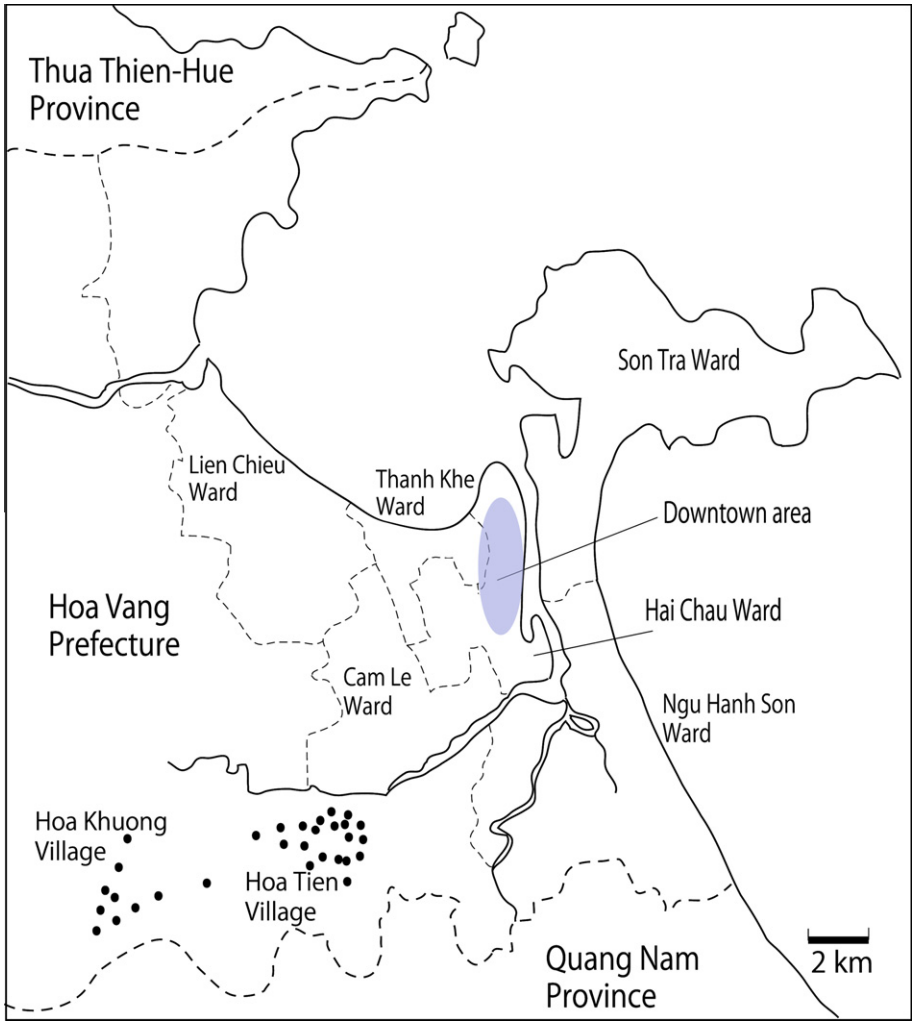

Fig. 1. Location of swine breeders surveyed.

impact of food residue discharge. We conducted the survey to accomplish the following objectives: (a) To describe the detailed procedure of food residue collection by swine breeders, and (b) To estimate the amount of the city's food residue used by swine breeders.

2. Methodology

We surveyed swain breeders in two villages in the Hoa Vang Prefecture, Da Nang City. The Hoa Vang Prefecture is located west of urbanized area in Da Nang. In 2006, it became the most important center for swine breeding when the Da Nang People's Committee issued a ban on swine breeding in urbanized areas. Among the villages of the Hoa Vang Prefecture, we chose Hoa Tien Village (HT) and Hoa Khuong Village (HK) as our study sites; Fig. 1 shows the locations of these villages. We chose HT because, among Da Nang citizens, it is well known as the major area of swine breeding. HK is farther than HT from the urban center, and we chose it in order to understand the impact distance has on food residue collection. Table 1 shows the demographics of the two villages. The numbers of swine breeding farms and swine listed in the table are estimates provided by an official of the Agriculture Development Office of the Hoa Vang Prefecture. The average numbers of swine per farm are 19.5 for HT and 7.7 for HK.

We chose 20 swine breeding farms that used food residue from HT and 10 from HK. We focused on small to medium farms. The largest swine-breeding farm among our sample had 200 head of swine. Some farms in the area have more swine; however, these large farms were excluded because we knew from previous interviews that these farms did not feed their swine food residue. Given that we did not have a complete list of farms, area sampling would ordinarily be the appropriate standard random sampling methodology. Area sampling is essentially multistage sampling where maps serve as the sampling frame (Crawford, 1997). However, we were not able to use this methodology within our survey. Instead, the Agriculture Development Office of the Hoa Vang Prefecture provided us with a list of swine-breeding farms that would be willing to participate in our survey. Because weighting food residue everyday was a heavy burden on the swine breeders, random sampling from HT and HK was unrealistic as a method of locating farms to be surveyed. Thus, we sampled farms from the aforementioned list so that survey sites evenly represented the areas within the two villages. Table 2 summarizes the demographics of the farms in our sample for each category of farm size, determined by the total number of swine in a farm. On average, the HT farms in our sample began food residue collection earlier than their HK counterparts, since the average number of years of collection is 7.4 years for HT and 4.9 years for HK. The actual number of swine in each farm is found in Table 5.

There were three separate components to our study. First, during the interview process, our survey team visited each swine-breeding farm from January 3 to 4, 2011 and asked the following questions of the person responsible for the farm:

- History of swine breeding and food residue use.
- Food residue sources, collection method, and price of food residue.
- Method of food residue feeding.
- Prospect for food residue use.

Second, our survey team weighed food residue collected by each farm between January 4 (Tuesday) and 12 (Wednesday), 2011. In Da Nang, calm weather usually continues in January and we expected that swine breeders would collect food residue without a disturbance due to harsh weather conditions during our field survey. We planned to observe one week of food residue collection. We added two more days of observation in case of a failure in measurements of food residue at the initial stage of the field survey. We can actually use the nine-days of observations because we completed the field survey without a measurement problem. Swine breeders in Da Nang commonly use 18- or 20-l containers, which were originally used as paint containers, to carry food residue. Our survey team weighed all the containers transported every day to each farm during the survey period. Third, we sampled food residue from three farms on March 23, 2011, and did a content analysis of them. In each farm, we randomly selected one food residue container, mixed its content well, and took a sample of food residue. Then we measured moisture content.

3. Results and discussion

3.1. Food residue collection, transportation, and feeding swine

Table 3 summarizes the location where swine breeders obtain food residue: restaurants, hotels, households, and other urban facilities. The purchase of food residue from brokers is common as well. Fig. 2 shows a map that indicates all the collection points of food residue. These points include where swine breeders collect

Table 1
Demographics of two villages.

Village	Area size (ha)	Population (person)	Number of households	Number of swine breeding farms	Number of swine (head)	Average number of swine per farm (head)
Hoa Tien	1394	14,980	3279	1000	19,500	19.5
Hoa Khuong	5715	10,702	2699	1500	11,600	7.7

Table 2
Demographics of sampled farms.

Village	Farm size[a]	Number of farms	Average number of swine (head)			Average number of years of food residue collection (year)
			Parent stock	Fattening swine	Total	
Hoa Tien	Less than 21	9	2.0	11.2	13.2	5.3
	21–50	7	1.6	26.3	27.9	10.3
	More than 50	4	5.0	91.3	96.3	6.7
Hoa Khuong	21–50	8	2.6	29.1	31.8	5.4
	More than 50	2	0.5	80.0	80.5	3.0

[a] Farm size category is defined by total number of swine.

Table 3
Origin of food residue.

	Hoa Tien	Hoa Khuong	Total
Restaurant	11	2	13
Cafeteria of company/school	6	0	6
Take-out restaurant	2	2	4
Hotel	1	0	1
Factory	1	0	1
Households by street	9	2	11
Broker	11	8	19
Total	41	14	55

food residue directly and where they purchase food residue from brokers. The figure shows a cluster of the collection points in central Da Nang. Our food residue weight survey revealed that 22 swine breeders collected food residue every day, 4 collected for 8 days, 3 for 7 days, and 1 for 6 days, during the 9-day survey period. The collection time of the day varied among swine breeders: 15 collected between 0400 and 1200 h, 14 between 1300 and 1700 h, and 6 between 1800 and 2200 h. Seven swine breeders collected food residue more than once a day.

Table 4 summarizes the characteristics of collection with respect to times of collection per day, route distance, and number of collection points. We conducted Kruskal Wallis tests to establish if there was a difference in each of these characteristics across farm sizes in HT. We found a significant difference between farm sizes with respect to times of collection per day at the 5% significance level. The farms within our HT sample collected either once or twice per day. Farms that belonged to the 21–50 head category visited their food residue sources more frequently than their smaller or larger counterparts did. The other two characteristics did not show a statistically significant difference at the 5% level. Due to the limited sample size, we did not statistically test the HK result. HK farms need a longer trip to obtain food residue than HT farms. The shortest and the longest route distance in HT to a collection point are1.0 km and 17.5 km, respectively. In the 1.0 km case, a swine breeder purchased food residue in HT from his neighborhood swine breeder. The shortest and the longest route distance in HK are 24.0 km and 27.5 km, respectively. Swine breeders commonly use motorbikes as a tool of transporting food residue from the urban center to piggeries. A motorbike can carry as many as seven containers, in which the total weight of food residue reaches 130 kg. Among the 30 swine breeders, 23 use solely a motorbike as a means of transportation, two use both a motorbike and a truck, and five use a truck only.

Food residue transactions are similar to those of consumption goods. Swine breeders pay money to either food residue producers or brokers in exchange for food residue. Food residue can be free of charge if there is a strong human tie between a swine breeder and a food residue producer; however, this is not common. Depending

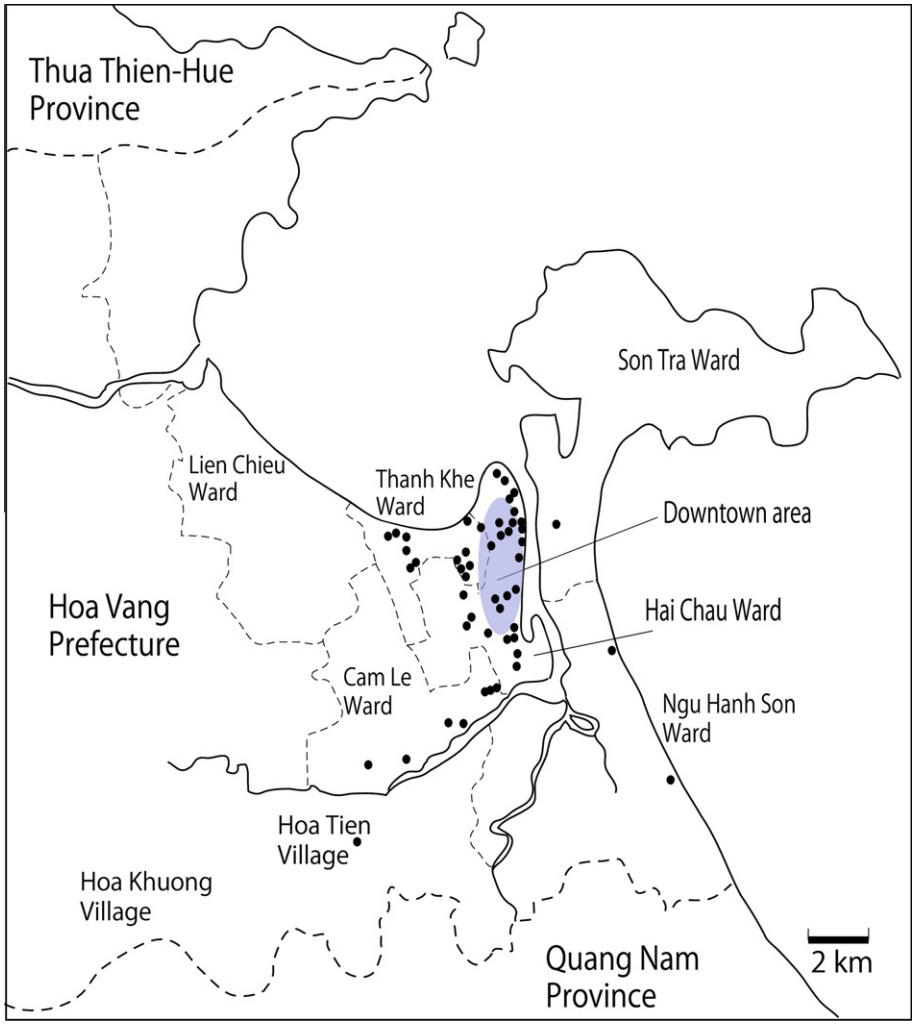

Fig. 2. Food residue collection points.

Table 4
Collection of food residue.

Village	Farm size	Number of farms	Average times of collection per day	Average route distance to collection point (km)	Average number of collection points
Hoa Tien	Less than 21	9	1.0	12.1	1.8
	21–50	7	1.4	14.7	2.0
	More than 50	4	1.0	14.5	2.5
Hoa Khuong	21–50	8	1.3	25.4	1.3
	More than 50	2	2.5	25.6	1.5

on food residue sources, prices are paid either monthly or per container. The price of food residue per kilogram varied between 32 and 556 Viet Nam Dong (VND) across our sample. Both the average and the median prices are 278 VND. This range is equivalent to between 0.2 and 2.7 US cents, with both the average and the median being 1.3 US cents at the October 2011 exchange rate. In HT, 18 out of 20 swine breeders answered that they had relied upon the same food residue sources for the past three years, while 8 out of 10 HK swine breeders had changed their food residue sources during the same period. Thus, the HT swine breeders in our sample seem to have stronger ties with the provider of food residue than their HT counterparts.

A typical procedure for feeding swine with collected food residue is as follows: Hazardous contaminants, such as plastic bags and chopsticks, are manually removed. Then, food residue is boiled well and fed to the swine. Among the 30 swine breeders, 26 added ingredients during this procedure. Rice bran and corn are the two most common supplements. Among the swine breeders, 21 did not change the amount of food residue collection seasonally. The rest might change their collection amounts over the rainy and dry seasons, although not explicitly stated, since they changed either the kind or amount of supplements between the seasons.

3.2. Measurement of food residue collection by the sampled swine breeders

Table 5 summarizes food residue collection by each farm during the 9-day survey period. Average daily food residue collection per swine head in HT is 7.3 kg, 5.9 kg and 2.7 kg for farm sizes of less than 21, 21–50, and more than 50 head, respectively. An ANOVA test shows that these averaged values are statistically significantly different at the 5% significance level ($F(2,17) = 3.65$, $p = 0.048$). The Kruskal–Wallis test, which is robust to heteroskedasticity, also detected a difference in the collection amounts among the three categories ($p = 0.012$). Thus, on average, larger farms feed less food residue to each swine. The average daily, food residue collection, referencing HK's 21–50 head category, is 5.3 kg per head, and similar to the value of their HT counterparts. HK's larger farms collected 5.3 kg per head, on average; however, as an estimate of the population value, because of its small sample size, this result could be unreliable. The column of "Standard deviation" in Table 5 shows the standard deviation of daily collection amounts across the 9-day survey period per farm.

We conducted a linear regression analysis and sought the factors that decided amounts of food residue collection. The depen-

Table 5
Food residue collection, by each farm, in the 9-day survey period.

Village	Swine farm code[a]	Number of swine (head)			Food residue collection (kg/day)				
		Parent stock	Fattening swine	Total	Average	Max	Min	Standard deviation	Average per head
Hoa Tien	HT12	1	7	8	82.5	91.6	68.9	7.1	10.3
	HT11	3	7	10	89.0	169.4	0.0	62.6	8.9
	HT2	2	9	11	84.3	127.1	0.0	41.8	7.7
	HT13	1	11	12	78.2	112.5	0.0	34.3	6.5
	HT1	2	11	13	61.2	79.5	29.7	15.6	4.7
	HT14	3	12	15	182.8	209.9	165.2	13.7	12.2
	HT4	1	15	16	45.4	69.0	33.8	11.4	2.8
	HT9	2	14	16	129.2	175.4	71.5	26.8	8.1
	HT6	3	15	18	85.1	107.4	48.8	15.3	4.7
	HT8	1	20	21	94.0	212.3	0.0	76.3	4.5
	HT3	2	20	22	165.7	234.8	141.0	27.3	7.5
	HT10	2	20	22	100.1	113.6	89.8	6.9	4.6
	HT7	2	22	24	126.8	158.1	49.5	31.2	5.3
	HT15	0	32	32	163.9	303.5	110.7	60.9	5.1
	HT5	4	30	34	374.7	472.8	213.8	93.5	11.0
	HT19	0	40	40	143.4	224.7	103.2	43.9	3.6
	HT20	2	50	52	158.1	174.5	146.8	9.6	3.0
	HT18	5	60	65	173.9	190.2	110.6	24.6	2.7
	HT17	3	65	68	154.9	192.3	116.5	24.8	2.3
	HT16	10	190	200	577.3	649.8	509.0	49.3	2.9
Hoa Khuong	HK5	2	20	22	49.3	58.9	0.0	18.6	2.2
	HK7	2	20	22	164.0	190.6	122.5	19.6	7.5
	HK8	2	22	24	79.4	114.4	55.2	20.5	3.3
	HK9	1	30	31	174.8	440.4	0.0	141.8	5.6
	HK2	3	30	33	161.4	169.2	150.3	6.3	4.9
	HK4	5	30	35	346.5	418.7	0.0	132.0	9.9
	HK1	2	41	43	254.8	333.0	114.5	78.5	5.9
	HK10	4	40	44	141.9	181.8	115.3	20.9	3.2
	HK6	0	80	80	167.6	252.0	0.0	100.7	2.1
	HK3	1	80	81	690.5	977.0	163.5	299.0	8.5

[a] Smaller swine farms are listed earlier among each village.

dent variable of the analysis is the average daily weight of food residue collection per farm during the survey period (model 1 of Table 6). Model 2 uses a logarithm of the average daily weight of food residue collection as its dependent variable. The Breusch-Pagan test (Wooldridge, 2009) detected heteroskedasticity in model 1 ($X^2(2) = 10.52$, $p = 0.005$) at the 5% significance level, but not in model 2 ($X^2(2) = 0.38$, $p = 0.83$). Thus, model 2 is more appropriate than model 1. Model 2 shows that the amount of food collected is positively correlated with the number of swine in the farm, and the number of food collections per day. These two variables are clearly statistically significant with their p-values being smaller than 0.01. The R-square value of model 2 is 0.59, meaning that the above-mentioned two variables explain about 60% of the variation of the dependent variable. We tried other independent variables in an attempt to achieve better fitness for the model; number of farm workers, year of food residue collection, price of food residue, average distance to the collection point, and availability of a truck. However, none of these variables were accepted as statistically significant at the 5% level. The distance to the collection point is irrelevant to food residue collection; as such, our estimation of total food residue collection will become simple in the next subsection.

3.3. Estimate of food waste collection by swine breeders in Da Nang

We then estimated the total amount of food residue collection by swine breeders in Da Nang City. We used the following information for our estimation (because of the limitation of obtainable information, this is a preliminary attempt):

- Weight of daily food residue collection, per head, for small and medium farms.
- Number of swine-breeding farms.
- Shares of small and medium farms among all farms in the area.
- Among the small and medium farms, the share of farms that use food residue.

Fig. 3 shows the procedure for estimating the amount of food residue collected by swine breeders residing in the city. First, we used our survey results and determined the weight of food residue collection for two farm size categories: less than 21 head of swine (small farms), and 21–200 head of swine (medium farms). The average collection amount was 7.32 kg and 5.03 kg, for the small and medium categories, respectively. Because our regression anal-

Table 6
Regression analysis of food residue amount.

Explanatory variable	Model 1			Model 2		
	Coefficient	*t*-Value	*P*-value	Coefficient	*t*-value	*P*-value
Total number of swine	2.52	5.73	0.00	0.01	4.66	0.00
Times of collection per day	119.82	3.86	0.00	0.49	3.15	0.00
Constant	−68.65	−1.61	0.12	3.95	18.41	0.00
Sample size	30			30		
R square	0.68			0.59		

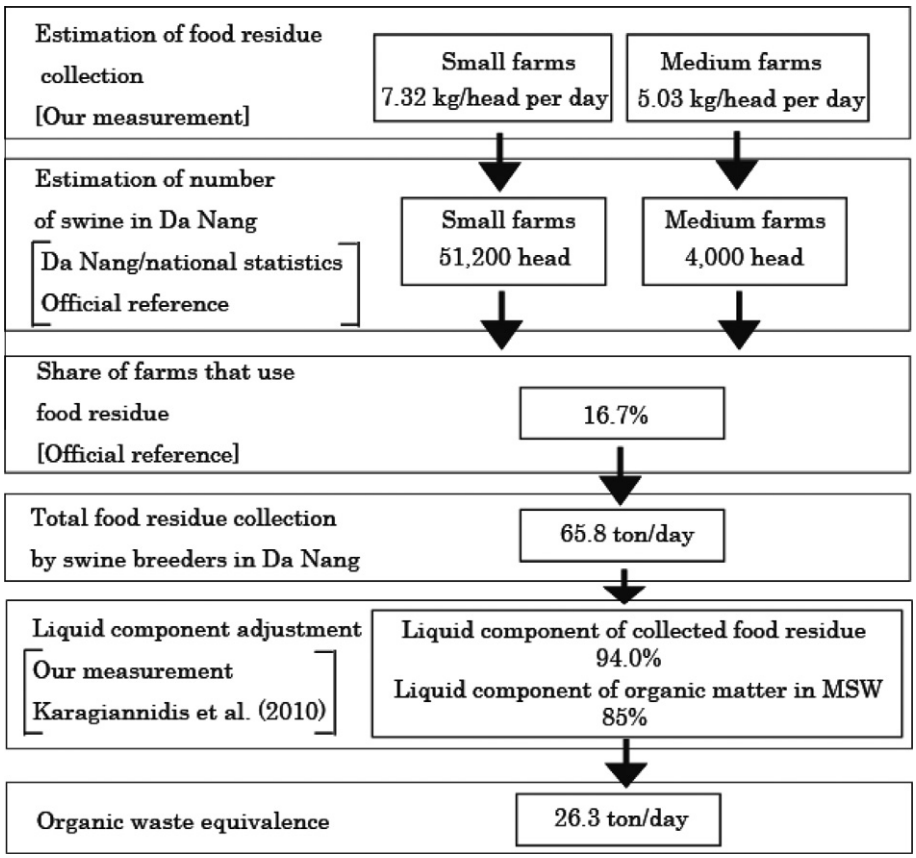

Fig. 3. Estimation of food residue collection in Da Nang.

ysis revealed irrelevance of the amount of food residue collection with the distance of collection points, we assume that the above-mentioned unit values are applicable to all areas in Da Nang City. Second, we learned from the 2011 Da Nang Statistical Year Book that the total number of swine in the city, as of October 1, 2010, was 63,986 (Da Nang Statistical Office; 2011); among them, 83% resided in the Hoa Vang Prefecture. Third, for the share of small farms, we used the national value reported in the literature, since there were no official statistics available for the Da Nang area. Huynh et al. (2007) mentioned that 80% of total swine reside in small farms; thus, our estimate of the number of swine in small farms is 51,200. According to an official reference from the Agricultural Development Office of the Hoa Vang Prefecture, in 2010, there were approximately 8,800 head of swine in large farms, which were unlikely to use food residue for feeding swine. Most large farms in Da Nang City are located in the Hoa Vang Prefecture; therefore, we assumed the number of swine in the large farms in Da Nang was 8,800, and we excluded these from our calculation of food residue collection. We determined that medium farms in Da Nang fed the remaining swine, which was approximately 4000. Fourth, our interview with the Nam Son area leader, in central HT, revealed that 25 of the 150 swine breeding farms within the area used food residue in January 2011. We used this figure as the share of swine that were fed with food residue in Da Nang, since no other information was available then.

Based on the aforementioned information, the total amount of food residue collection by swine breeders in Da Nang is 65.8 metric tons per day. The food residue collected by the swine breeders is rich in liquid components, such as noodle soup. We then estimated the weight of food residue, in a form comparable to the official statistics of MSW collection by the local government through adjusting the moisture content. Our measurement of the moisture content is based upon three samples taken from farm codes HT16, HT17, and HK1; the results were 93.9%, 93.7%, and 94.3%, respectively. These values are similar to each other, so we used their average; the moisture content of the food residue, collected by the swine breeders in Da Nang, reflected a 94.0% average. In Ha Noi, the moisture content of organic matter in MSW was 80–90% (Karagiannidis et al. 2010). Here, we assumed the moisture content of organic matter in MSW was 85%. We can then estimate that swine breeders collect an equivalent of 26.3 metric tons of organic waste every day. This amount is as much as 4.1% of the daily waste collection by Da Nang URENCO, which is 650 metric tons in 2010 (Pham, 2012). Da Nang URENCO dumps organic waste into the Khanh Son landfill, while swine breeders utilize food residue for pig-meat production.

We artificially changed some of the parameters in our estimation and observed how much our estimates varied. In particular, we created lower and upper estimates by systematically modifying four parameters that were major sources of uncertainty (see Table 7). The relative amount of organic waste collected by swine breeders against the domestic waste collected by the Da Nang URENCO is 1.1% (6.9 metric tons per day) and 11.1% (72.4 metric tons per day) for the lower and the upper estimates, respectively. We believe that the lower estimate is unlikely to be correct because swine breeders outside Da Nang City collect food residue from central Da Nang as well. In particular, there are many swine breeders in the Quan Nam Province, which is located on the south of Da Nang City.

The rough estimation of food residue collection by swine breeders in 2009, from four central Ha Noi wards amounted to 6.5% of the total collected domestic waste (Osako et al., 2010). However, the Ha Noi estimation did not adjust for the liquid component of waste. If we adjust for this liquid component then the Ha Noi value decrease to 2.6%, which is not that different to our Da Nang estimate.

Table 7
Parameters for lower and upper estimates.

Parameter	Lower estimate	Upper estimate
Food residue collection (kg/head per day)	6.48 (small farms)[a] 4.58 (medium farms)[a]	8.16 (small farms)[b] 5.48 (medium farms)[b]
Number of swine (head)	44,790 (small farms)[c] 10,396 (medium farms)[c]	55,186 (small farms)[d] 0 (medium farms)[d]
Share of farms that use food residue	6.7%[e]	26.7%[f]
Liquid component of organic waste in MSW	80%[g]	90%[h]

[a] Lower boundary of the 95% confidence interval of average collection amount.
[b] Upper boundary of the 95% confidence interval of average collection amount.
[c] Share of swine held in small farms set to be 70%.
[d] Share of swine held in small farms set to be 86%.
[e] Ten-point reduction from original value.
[f] Ten-point increase from original value.
[g] Lower boundary in Karagiannidis et al. (2010).
[h] Upper boundary in Karagiannidis et al. (2010).

3.4. Prospects of food residue recycling

Among the sampled swine breeders, 28 answered that they would continue using food residue for the next five years; among the remaining two breeders, one did not have a specific vision for future food residue use and the other would stop collecting food residue if his health began to deteriorate. Among the 28 swine breeders who would continue to use food residue, 8 answered food residue would be necessary to reduce breeding costs, and 10 planned to expand their farms and collect more food residue. Three swine breeders noted "higher nutritional value" of food residue, and one swine breeder stated that the use of food residue is environmentally friendly.

4. Conclusions

This study has provided a detailed description of food residue collection by swine breeders in Da Nang, Viet Nam. We estimated that swine breeders collected 26.3 metric tons of organic waste per day during our survey period. This is 4.1% of the domestic waste collected by the local government every day. There are uncertainties in the parameters used for the estimation because of a lack of plausible official statistics. Using a very conservative choice of parameters, the organic waste collection by swine breeders amounted to 6.9 metric tons per day. It is notable that swine breeders recycled this waste and so contributed to the reduction of domestic wastes dumped in the landfill of the city. The transaction of food residue is similar to consumption goods. In exchange for food residue, swine breeders pay some money for producers or brokers of food residue. The total amount of a farm's food residue collection depends on the number of swine on the farm and the number of daily collection times. We did not find a statistically significant correlation between the amount of food residue collection and the distance to food residue collection points. The unit price of food residue does not affect the collection amount, either.

As a pioneering study of informal food residue collection in Viet Nam, there are limitations to the results of our study. Our analysis is based upon a relatively small sample of 30 swine-breeding farms. The sample seems to contain a disproportionate number of medium farms when compared to the actual population. We do not know precisely the magnitude of seasonal variation of food residue collection, although 70% of the swine breeders in our sample stated that there were no seasonal change in the amounts they collected. A topic of future research would certainly be to conduct a

larger time series survey of informal food residue recycling in Da Nang and other Vietnamese cities.

The appropriate design for MSW management in Da Nang City will depend on whether swine breeders continue to use food residue in the future. Although 93% of the farms in our sample answered that they will continue to use food residue for the next five years, a rapidly growing society makes this an uncertain variable. Swine breeders may abandon the current primitive form of food residue recycling if the market demands higher-quality pork or if citizens become unwilling to separate food residue in exchange for a small fee. The existing informal collection system seems prone to expected societal changes during the course of economic development; however, we must note the elements of the existing system that are important for protecting the environment, and that they would be difficult to recover once they deteriorate. The official MSW management of Da Nang City should incorporate these elements; for example, the extensive network of food residue collection participants, which includes food residue producers, brokers, and collectors, may be useful in effectively separating reusable food residue, within a formal framework of MSW management. Current activities of swine breeders' food residue collection work in conjunction with many households, restaurants, and hotels, which cooperate as sources of separated food residue. This supportive attitude among citizens could be a strong driving force for the introduction of a formal food residue recycling program; however, the local government would need to act rapidly before there is a possibility that this communal supportiveness would fade over time.

Acknowledgment

This work was supported by JSPS KAKENHI 22404003, provided by the Japanese government.

References

Ackerman, F., 1996. Why Do We Recycle? Markets, Values, and Public Policy. Island Press, Washington, DC, USA.

Baud, I., Grafakos, S., Hordijk, M., Post, J., 2001. Quality of life and alliances in solid waste management. Cities 18 (1), 3–12.

Crawford, I.M., 1997. Marketing Research and Information Systems. Food and Agriculture Organization (FAO), Rome, Italy.

Da Nang Department of Natural Resources and Environment (Da Nang DONRE), 2009. The Results of Waste Component Analysis, August 2009. Da Nang DONRE, Da Nang, Viet Nam.

Da Nang People's Committee, 2008. The Plan for Developing Danang: The Environmental City. Danang People's Committee, No. 41/2008/QD-UBND, Da Nang, Viet Nam, p. 50.

Da Nang Statistical Office, 2011. Da Nang Statistical Year Book, Da Nang Statistical Office, Da Nang, Viet Nam.

FAO, 2012. FAOSTAT, FAO, <http://www.fao.org/corp/statistics/en/> (cited 22.05.12).

Garcia, A.J., Esteban, M.B., Marquez, M.C., Ramos, P., 2005. Biodegradable municipal solid waste: characterization and potential use as animal feedstuffs. Waste Manage. 25 (8), 780–787.

Huynh, T.T.T., Aarnink, A.J.A., Drucker, A., Verstegen, M.W.A., 2007. Pig production in Cambodia, Laos, Philippines, and Vietnam: a review. Asian J. Agric. Dev. 4 (1), 69–90.

IMF (International Monetary Fund), 2011. World Economic Outlook Database September 2011, IMF, <http://www.imf.org/external/pubs/ft/weo/2011/02/weodata/index.aspx> (cited 30.10.11).

Kajima Corporation, 2007a. Project Design Document Form for Organic Waste Composting Project at Da Nang City, Viet Nam. United Nations Framework Convention on Climate Change (UNFCCC). <http://gec.jp/gec/jp/Activities/cdm-fs/2007/2007Kajima_jVietnam_PDD1.pdf> (cited 30.10.11).

Kajima Corporation, 2007b. Project Design Document Form for Organic Waste Composting Project at Hai Phong City, Viet Nam. UNFCCC. <http://gec.jp/gec/jp/Activities/cdm-fs/2007/2007Kajima_jVietnam_PDD3.pdf> (cited 30.10.11).

Karagiannidis, A., Theodoseli, M., Malamakis, A., Bilitewski, B., Reichenbach, J., Nguyen, T., Galang, A., Parayno, P., 2010. Decentralized aerobic composting of urban solid wastes: Some lessons learned from Asian-EU cooperative research. Glob. NEST J. 12 (4), 343–351.

Mitchell, C.L., 2008. Altered landscapes, altered livelihoods: the shifting experience of informal waste collecting during Hanoi's urban transition. Geoforum 39 (6), 2019–2029.

Ogino, A., Hirooka, H., Ikeguchi, A., Tanaka, Y., Waki, M., Yokoyama, H., Kawashima, T., 2006. Environmental impact evaluation of feeds prepared from food residues using life cycle assessment. J. Environ. Qual. 36 (4), 1061–1068.

Osako, M., Kawai, K., Fukuoka, M., Matsui, Y., Hirata, O., Harada, H., 2010. Tounan-Asia niokeru Haikibutsu Database no Kouchiku oyobi Haikibutsusyori-system no Hyouka (Construction of solid waste database and evaluation of solid waste management in South-East Asia). Report Submitted to the Ministry of the Environment, Japan, K2118 (in Japanese).

Pham, M.T., 2012. Solid waste management in Da Nang City. In: Proceedings of the Japan-Vietnam Joint Symposium on Sustainable Urban Environmental Systems. The University of Kitakyushu, Kitakyushu, Japan, pp. 11–12 (CD-ROM).

Speedy, A.W., 2003. Global production and consumption of animal source foods. J. Nutr. 133 (11), 4048S–4053S.

Sugiura, K., Yamatani, S., Watahara, M., Onodera, T., 2009. Ecofeed, animal feed produced from recycled food waste. Vet. Ital. 45 (3), 397–404.

Sunday Viet Nam News, 2011. From Penury to Prosperity: It's a Pigtale. Sunday Viet Nam News, January 2, 2011, p. 8.

Taft, A.C., Zirkle, E.W., Altizio, B.A., 2000. The history and enforcement of the swine health protection act. In: Westendorf, M.L. (Ed.), Food Waste to Animal Feed. Iowa State University Press, Ames, IA, USA, pp. 51–67.

Tsai, W.T., 2008. Management considerations and environmental benefit analysis for turning food garbage into agricultural resources. Bioresour. Tech. 99 (13), 5309–5316.

Wooldridge, J.M., 2009. Introductory Econometrics: A Modern Approach. South-Western, Mason, OH, USA, pp. 271–274.

World Bank, The Ministry of Environment and Natural Resources (MoNRE), Canadian International Development Agency (CIDA), 2004. Vietnam Environment Monitor 2004: Solid Waste, World Bank, p.16. <http://siteresources.worldbank.org/INTVIETNAM/Data%20and%20Reference/20533187/VEMeng.pdf> (cited 30.10.11).