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Research Article

The Application of Dealing with Kitchen Wastes Recycling Condition Using Factor Analysis in Taiwan

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Abstract For this study, we conducted a questionnaire survey in 2018 on the operating status of four types of resource processing methods and 16 internal/external environmental indicators. The subjects of this survey include personnel related to the environmental protection industry, public agencies, kitchen waste recycling and processing factories, and units and scholars conducting research on kitchen waste recycling and processing that are currently in Taiwan. Multivariate statistic factor analysis was used to explore the characteristics and advantages/disadvantages of the four types of kitchen waste resource processing. The objective is to determine the main factors that affect the four types of kitchen waste processing methods currently used in Taiwan and their mutual relationships.

The factor analysis shows that the main evaluation indicator factors that affect the four types of kitchen waste resource processing methods used in Taiwan are as follows: "kitchen waste processing competitiveness", "kitchen waste processing technology", "kitchen waste processing timeliness" and "kitchen waste quality requirements." Of these, kitchen waste processing competitiveness has the most significant effect. By identifying factors that affect various kitchen waste resource processing methods and then using factor analysis to analyze the results of the questionnaire survey, we can provide a reference for Taiwan kitchen waste operators regarding kitchen waste processing. The results can also serve as a basis for Taiwan's environmental protection agencies to set stricter kitchen waste recycling regulations in the future.

Keywords kitchen wastes, multivariate statistics, factor analysis, survey

1. Introduction

Kitchen wastes contain high concentration of biodegradable organic compounds and therefore are predominant renewable resource in municipal solid wastes [1-2]. Owning to efficient resource recovery and lessened environmental impact, anaerobic digestion compares favorably with alternative treatments, such as incineration, landfill and composting [3-4]. Since 2006, all residents in Taiwan have started a complete recycle of garbage with estimated 4500 tons/day. The current recycling rate in 2018 is about 53% with only 20% of the recovered 400 Tons/day used for raising hogs. The remaining 80% is disposed of by composing, converting to animal feed or anaerobically digesting into methane gas. Feeding the recovered garbage to hogs is popular and easy to implement nowadays because of higher cost of pig feed. However, the possible risks associated with the use of garbage as pig feed, e.g. infectious diseases, is causing a great concern. There have been various opinions expressed by experts in different fields on how to practice resource recovery from garbage.

In 2008 the number of people living in urban areas exceeded the number of people living in rural areas; it is estimated that, in 2050, 70% of the population will live in cities inhabited by more than 10 million people [5]. The accumulation of population around urban zones forces us to manage large amounts of municipal solid waste (MSW). Landfills have been the preferred option in many countries, but the available space for the construction of dumps is limited, and in the middle to long term, other solutions must be proposed. Incineration has been one

of the management strategies considered and used for a long time, but current waste-management policies that establish hierarchies that prioritize reuse and recycling before disposal solutions [6], coupled with issues related to atmospheric contamination, arise serious doubts about the future viability of these processes [7].
Multivariate monitoring methods that consider all available data simultaneously can extract key information about the relationships and combined effects of air pollutants. When failures occur in air quality management systems, univariate monitoring methods are often inadequate to identify causes because the signal-to-noise ratio is very low in each air pollutant measurement. But multivariate monitoring can improve the signal-to-noise ratio through averaging, resulting in a more realistic evaluation of the environmental context. In chemometrics area, multivariate statistical techniques have become one of the most active research areas in modeling and analysis over the last decade. However, to the authors' knowledge, only limited research on the effectiveness of multivariate models for the assessment and management of air pollution has been conducted thus far [8].
Based on the aforementioned reasons, we conducted a survey in 2018 on the operating status of kitchen waste resource processing methods in Taiwan. Experts and scholars in different fields were surveyed using the 16 internal/external evaluation indicators that apply to kitchen waste processing. After the survey results were recovered, multivariate statistics factor analysis was used to explore the differences between the kitchen waste resourcing methods. We then used the analysis results to integrate and plan the best kitchen waste processing method for Taiwan. The result of this study can serve as a reference for Taiwan kitchen waste processing operators when they choose an effective kitchen waste utilization method.

2. Methodology

2.1. Selection of kitchen waste resourcing methods

Currently, four main types of kitchen waste resourcing methods are used in Taiwan: feed for hogs, organic waste anaerobic digestion, converting waste into animal feed, and composting. The analysis in this study is done based on these four main processing methods.

2.2. Content of the questionnaire survey

A questionnaire survey is used as the main basis for this study. The questionnaire was conducted based on the four currently most commonly used kitchen waste processing methods in Taiwan. After the surveys were recovered, the multivariate statistic factor analysis was used to analyze the results. This is expected to integrate and plan the best kitchen waste processing method for Taiwan, and to provide Taiwan kitchen waste operators with a reference when implementing kitchen waste processing. The results can also serve as a basis for Taiwan environmental protection agencies to set stricter kitchen waste recycling regulations in the future. The content of this study's questionnaire survey is mainly divided into the internal and external environmental evaluation indicators. The internal environmental indicators mainly include maturity of the operating technology, supply source stability, the amount of labor, level of the odor problem, processing difficulties, required processing time, nutrient utilization, fat content utilization, product stability, and product quality requirements. The external environmental indicators mainly include market acceptance level, operating and maintenance costs, the size of the area required, environmental quality improvement level, market sales, and policy stability.
For the level of impact, we used the Likert 5-point scale [9] to evaluate the utilization level of the four kitchen waste processing methods. Taking the "required processing time" as an example, Extremely Difficult (1 point), Difficult (2 points), Normal (3 point), Easy (4 points), and Extremely Easy (5 points) are used to measure and evaluate the time required for kitchen waste to be processed with fermentation.

2.3. Clarification of the questionnaire survey and the results

For this study, we conducted a questionnaire survey in 2018 on the operating status of kitchen waste resource processing methods. The subjects of this study include public agencies, general private enterprises that produce kitchen waste, factories and units with composting processing experience, and academic units and scholars that engage in kitchen waste and composting research currently in Taiwan. Factor analysis was conducted on the questionnaire results. A total of 150 questionnaires were mailed out in January 2019, and 121 valid questionnaires were recovered, for a questionnaire recovery rate of 80.7%. The subjects of this questionnaire are described below:

- Personnel engaged in the environmental protection industry: mainly domestic industries that currently engage in environmental protection-related items, along with domestic personnel and operators who have a good understanding of, and care about, environmental problems (75 questionnaires were issued and 60 valid questionnaires were recovered, for a questionnaire recovery rate of 80.0%).
- Academic research agencies and scholars: research agencies and scholars/professors in public and private universities who engage in kitchen waste recycling related research (45 questionnaires were issued and 37 valid questionnaires were recovered, for a questionnaire recovery rate of 82.2%).
- Public agencies and factories and units in Taiwan that engage in kitchen waste recycling (public agencies and kitchen waste-related industries) (30 questionnaires were issued and 24 valid questionnaires were recovered, for a questionnaire recovery rate of 80.0%). This study's questionnaire survey results are shown in Table 1.

Table 1: This study's questionnaire survey results

Questionnaire subject	Questionnaire situation		
	Number of questionnaires issued	Number of valid questionnaires recovered	Questionnaire recovery rate (%)
Personnel engaged in the environmental protection industry	75	60	80.0
Academic agencies and scholars	45	37	82.2
Public agencies and kitchen waste-related industries	30	24	80.0
Total	150	121	80.7

2.4. Multivariate Statistical Analyses—Factor analysis

For selecting the elements to be included in FA, a minimum of 70% of the samples needs to have measurable levels of the element. In principle, FA actually groups the elements whose concentrations fluctuate together from one sample to another and separates these elements into "factors" [10-11]. Factor analysis is used for source apportionment in environmental data, with the argument that those elements that fluctuate together have some common characteristics. Ideally, each extracted factor represents a source affecting the samples. Factor analysis has been performed using the Statgraphics Plus program package [8]. The initial components were rotated using the varimax method to obtain final eigenvectors with more representatives of individual sources of variation. Although there are no well-defined rules on the number of factors to be retained, usually either factors that are meaningful or factors with eigenvalues larger than 1 are retained. In theory, irrelevant factors have zero eigenvalues and eigenvalues less than 1 indicate that factor contributes less than a single variable. The physical meaning of the factors must be interpreted by observing which elements or variables display high (≥0.25) loading within the factor. Loadings less than 0.25 in absolute value may be dominated by random errors.

3. Results and Discussion

3.1. Selection of a model for analyzing the 16 evaluation indicator factors

Here, we used the varimax rotation method to conduct orthogonal rotation and to explain the characteristics of each factor [12]. The analysis results in Table 2 show four factors with an eigenvalue greater than 1; thus, these four factors were selected. The cumulative explained variance of these four common factors is 72.125%, and the eigenvalues of the four common factors are 7.436, 2.058, 1.153, and 1.017, respectively. Table 3 shows that the KMO value is 0.857, which is greater than 0.5; according to Kaiser, it is suitable for factor analysis. In addition, the Bartlett's sphericity test's approximate Chi-square distribution value (χ^2) is 1013.337 (degree of freedom is120), which reaches a level of significance. This indicates that the population's related matrices have a common factor that is suitable for factor analysis.

Table 2: The cumulative explained variance table for 16 evaluation indicators in the four types of kitchen waste resource processing methods

Components	Initial Eigenvalues	% of total variance	Cumulative variance %
1	7.436	45.209	45.209
2	2.058	13.218	58.427
3	1.153	7.352	65.779
4	1.017	6.346	72.125
5	0.779	4.867	76.993
6	0.704	4.402	81.394
7	0.528	3.297	84.692
8	0.454	2.837	87.528
9	0.407	2.545	90.073
10	0.380	2.376	92.449
11	0.285	1.782	94.231
12	0.260	1.626	95.857
13	0.215	1.341	97.199
14	0.192	1.199	98.398
15	0.148	0.927	99.326
16	0.108	0.674	100.000

Table 3: The KMO and Bartlett's sphericity test for 16 evaluation indicators in the four types of kitchen waste resource processing methods

Kaiser-Meyer-Olkin measure of sampling adequacy		0.857
Bartltett's sphericity test	Chi-square distribution value	1013.337
	Degree of freedom	150
	Significance	0.000

3.2. Determining the factors

As previously described, the number of eigenvalues greater than 1 determines the number of main factors. After orthogonal rotation, the component matrix of these four main factors can be used to select the variables between the factors. Table 4 shows the component matrix after orthogonal rotation. The matrix after rotation can explain each factor's characteristics. The four factors can be used to describe the commonalities and differences between the 16 evaluation indicators.

Table 4: The load matrix for factors of the 16 evaluation indicators in the four kitchen waste resourcing processing methods

Parameters	Factors			
	1	2	3	4
Environmental quality improvement level	0.871	0.172	0.132	0.256
The size of the area required	0.810	-1.084E-02	0.388	5.449E-02
Market sales	0.737	0.489	-0.129	0.174
Policy stability	0.711	0.367	0.125	0.253
Level of the odor problem	0.699	0.131	0.467	0.266
Maturity of the operating technology	0.329	0.783	0.119	0.115
Supply source stability	0.137	0.745	0.301	2.227E-02
Processing difficulties	1.746E-02	0.678	0.476	-0.208

Market acceptance level	.609	0.611	3.437E-02	-1.890E-02
Nutrient utilization	6.978E-02	0.608	0.239	0.568
Fat content utilization	0.394	0.527	0.231	0.286
Required processing time	0.153	0.203	0.774	2.216E-02
The amount of labor	0.256	0.309	0.667	0.183
Product quality requirements	0.400	9.636E-02	7.771E-02	0.751
Product stability	0.412	0.153	0.210	0.613
Operating and maintenance costs	6.332E-02	0.284	0.446	-0.604

3.3. Interpreting the factors

Table 4 shows four main factors that affect the internal/external evaluation indicators in the four types of kitchen waste resourcing processing methods. The following is a complete description of the characteristics of each factor.

(1) First factor

The first factor mainly comprises the environmental quality improvement level, the size of the area required, market sales, policy stability, and the level of the odor problem. As shown in Table 2, its cumulative variance can reach 45.209%, which is the highest of the four affecting factors. As environmental awareness gradually rises, the environmental quality improvement level is the indicator that the processing operators and nearby residents care about the most at the beginning of recycling/processing kitchen waste during the period when a kitchen waste processing plants is prepared and subsequently operating. At the same time, kitchen waste processing operators must also consider the convenience of the kitchen waste processing location and the size of the plant [13]. Because of processing location limitations, comprehensive consideration must be given to most processing plant locations and sizes. In addition to the aforementioned considerations, the setup of a kitchen waste plant must take into account how to reduce to a minimum the odor produced during the processing process. The market sales of kitchen waste will grow because kitchen waste processing operators believe that vendors will continue to reduce the odor produced by processing kitchen waste. Furthermore, if the government's kitchen waste-related policy and regulations can be sufficiently realized and effectively managed, kitchen waste plants can become more competitive [14].

Thus, the five aforementioned indicators are all related to increasing the competitiveness of kitchen waste plants. Other than taking into account the geographical location and size of a kitchen waste plant to control the cost, operators must also consider the positive effects of kitchen waste processing on improving the environment. Odor during the processing period must be reduced to a minimum. Operators must also cooperate with the government's current kitchen waste policy so that the market sales of kitchen waste products can be effectively increased. This factor has the highest cumulative variance of the four factors, which means that the five indicators in this factor are the most important factors affecting kitchen waste resource processing. Therefore, this first factor can be called the "kitchen waste processing competitiveness factor."

(2) Second factor

The second factor mainly comprises the maturity of the operating technology, supply source stability, processing difficulties, market acceptance level, nutrient utilization, and fat content utilization. Table 2 shows that its cumulative variance can reach 13.218%. During the kitchen waste processing period, operators will generally innovate and improve the operating technology, while gradually having stricter requirements regarding operational convenience. Another item that kitchen waste processing operators care about is supply source stability and whether the quantity of kitchen waste produced by families is sufficient to supply kitchen waste processing needs in a society where the dining culture is moving towards speed and convenience [15]. As technology improves, kitchen waste operators are concerned about whether kitchen waste supply can meet the demand in order for them to maintain superior operating technology [16]. In terms of processing difficulties, there are still many limiting conditions regarding kitchen waste processing that must be overcome. If the operating technology can improve, then the processing personnel can become more familiar with the kitchen waste operating process and the quality of kitchen waste can improve. From the perspective of market acceptance level, requirements for kitchen waste products can vary based on processing methods, control conditions, and product use. Generally, kitchen waste processing operators and the public hope that kitchen waste products can reach a certain level of quality after processing. Conversely, the operating technology must continue to improve to produce better quality kitchen waste products. As for nutrient and fat content utilization, because the sources of kitchen waste are diverse and their quality cannot be completely controlled, the operation must make better utilization of kitchen waste nutrients and fat content. To effectively utilize kitchen waste nutrients and fats, there not only have to be superior operating technology, faster processing time, and products that are recognized on the market, but operators must also consider the control of various operating conditions during the processing period, such as how much moisture and oxygen to add before high-quality kitchen waste products can be produced.

The six aforementioned indicators are all related to the improvement of kitchen waste processing plant technology. Thus, these factors focus on how to effectively improve the products' quality during the kitchen waste processing period. The use of advanced processing methods can make better utilization of kitchen waste nutrients. Thus, this second factor can be called the "kitchen waste processing technology factor."

(3) Third factor

The third factor comprises the required processing time and the amount of labor. Table 2 shows that its cumulative variance can reach 7.352%. The required kitchen waste processing time can vary based on the kitchen waste material characteristics and whether the materials need to be fermented. Generally, the longer the processing time, the more control and operation parameters need to be considered. Thus, if kitchen waste processing personnel can use a familiar operating technology, they can shorten the kitchen waste processing time and increase the yield of kitchen waste products. As for the amount of labor, machines are gradually replacing human labor. If the operation time required for kitchen waste can be shortened, then operators can effectively decrease the daily load and save more on operating costs [17].

The two aforementioned indicators mainly focus on how to effectively shorten the operation time and whether human labor can be effectively reduced during the operation time, which can save on processing costs. Therefore, the third factor can be called "kitchen waste processing timeliness factor."

(4) Fourth factor

The fourth factor primarily comprises product quality requirements, product stability, and operating and maintenance costs. Table 2 shows that its cumulative variance can reach 6.346%. The main objective of kitchen waste processing is to continuously pursue improvement in kitchen waste product quality with superior operating technology. Furthermore, different kitchen waste processing methods are conducted under different operating conditions. Therefore, the quality of kitchen waste products required by processing operators also differs. For example, if the kitchen waste processing method is feed for hogs, then the kitchen waste operators can directly recycle the kitchen waste and use it as a product without any processing procedures. In this situation, the requirement for kitchen waste quality is not high. Regarding product stability, when kitchen waste undergoes physical, chemical, or biological treatment, the time required will differ, and the quality stability of kitchen waste products will also differ. Generally, kitchen waste operators will further pursue product stability and obtain higher profit via continuous improvements in kitchen waste quality [13]. Table 4 shows that operating and maintenance costs' factor load, product quality requirements, and product stability are a negative value (-0.604), which indicates that as kitchen waste vendors continue to pursue improvements in kitchen waste product quality and stability, the cost for improving kitchen waste product quality and stability will increase in correspondence, and may affect the profit earnings. In other words, if kitchen waste processing operators spend funding on machine equipment, handling human labor load, and improving the quality of kitchen waste products, the cost of the required operation and machine maintenance/repair will also increase.

Thus, the aforementioned three indicators mainly take into account how to improve the quality and stability of kitchen waste products. Conversely, the cost of operations and maintenance/repair will also rise. Only in this way can operators meet consumers' and the public's needs. Therefore, the third factor can be called the "kitchen waste quality requirement factors."

4. Conclusion

For this study, we conducted a questionnaire survey on the four most commonly selected kitchen waste processing methods in Taiwan. Multivariate statistic factor analysis was then used to analyze the survey results to compile and plan the best kitchen waste processing method for Taiwan. The results can provide a reference for a more effective use of kitchen waste and process improvement in Taiwan's counties and cities. The subjects of the questionnaire are personnel engaged in the environmental protection industry, academic research agencies and scholars, public agencies, and domestic factories and units that engage in kitchen waste recycling. A total of 150 questionnaires were mailed out in January 2019 and 121 valid questionnaires were recovered, for a valid questionnaire recovery rate of 80.7%. Based on the aforementioned questionnaire results, factor analysis was conducted on the 16 internal/external indicators related to current domestic kitchen waste resource processing methods. The results show that the internal/external factors that affect domestic recreation area kitchen waste resourcing methods can be divided into the "kitchen waste processing competitiveness factor", the "kitchen waste processing technology factor", the "kitchen waste processing timeliness factor" and the "kitchen waste quality requirement factor."

For this study, we conducted a comprehensive questionnaire survey on the four types of kitchen waste resource processing methods currently used in domestic recreational areas. The main objective is to use the results of the questionnaire survey to determine the main factors that affect the four types of kitchen waste processing methods currently used in Taiwan and their mutual relationships. The results of this study can be used as a reference when determining the most effective use of kitchen waste by domestic industries in the future.

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