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Factors influencing adoption of vertical forced-air sulfur dioxide fumigation technology of fresh longan exporters in Thailand

Rasiga Sevilai[1,*], Jaturapatr Varith[2], Paisarn Kanchanawong[1], Jakrapong Pimpimol[3], and Sayam Aroonsrimorakot[4]

[1]Agricultural Interdisciplinary Program, Faculty of Engineering and Agro-industry, Maejo University, Chiang Mai, Thailand
[2]Graduate Programs in Food Engineering, Faculty of Engineering and Agro-industry, Maejo University, Chiang Mai, Thailand
[3]Program in Postharvest Technology, Faculty of Engineering and Agro-industry, Maejo University, Chiang Mai, Thailand
[4]Faculty of Environment and Resource Studies, Mahidol University, Nakhon Pathom, Thailand

Abstract

The research aimed to study the factors influencing an adoption of vertical forced-air SO_2 fumigation technology of longan exporters of Thailand. A questionnaire was applied as a tool of data collection, from 101 representative samples in the northern and eastern regions of Thailand which are two main plantation areas of fresh longan. Statistical analysis was applied by factor analysis from the in-depth interviews with 36 variables. The result indicates that there were 28 factors in 6 components which influenced the exporters' decision in adopting the technology with the sum of variance of 53.958%. These components were worthiness, competitiveness, organization goals, operations, management, and technological hindrance. Our findings are useful for further development of the strategic plan and policy, especially for the fresh longan exporters of Thailand, to enhance an adoption of SO_2 fumigation with vertical forced-air technology for safer operation and better food safety.

Keywords: sulfur dioxide fumigation, fresh longan, vertical forced-air technology, factor analysis
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1. Introduction

Longan is considered an economically important fruit generating income with relatively high value crop to Thailand. Consequently, Thailand becomes the world-top longan producer of which a majority of 90% to be exported as agricultural produces [1]. Longan can be exported as fresh produces or processed as dried and frozen products. China, Viet Nam, Indonesia and Hong Kong are major competitive business partners. Based on the export statistic during 2015-2019, the exported fresh longan and its relative products have been significantly growing.

An economic document reports that longan fruit is mainly produced in the northern and eastern regions of Thailand with production capacities of 1,051,552 tons in 2018 and 1,006,913 tons in 2019. Among these, 50% of the longan production was accounted as fresh longan produces. In 2019, the longan was exported in the amount of 743,024 tons with the export value of 28,904 million baht. This figure is 0.51% higher than that of 2018 export value and tended to increase over the years [2]. Two main crucial postharvest losses affecting fresh-longan exporting value are 1) microbes or fungus spoilage, and 2) pericarp browning of longan. Several techniques are currently studied to solve the problems of postharvest losses in longan such as fungicide dip, wax and chitosan coatings, microbial antagonists, heat treatments, and irradiation [3-5]. At present, sulphur dioxide (SO_2) fumigation is only a commercially accepted method to preserve the fresh longan for export. There are two types of SO_2 fumigation that are available in for commercial use, namely, traditional SO_2 fumigation and vertical forced-air SO_2 fumigation. The traditional SO_2 fumigation has been developed and using for more than 30 years, but it is still the most popular method to preserve the longan for export. In traditional SO_2 fumigation, the powder of sulfur is burnt into SO_2, associated with ventilation fan in fumigation chamber. This technique needs low capital of investment and operation. However, the staff must be skillful in sulfur burning process. The disadvantage is that the risk of sulphur explosion due to lack of enough experience and proficient skill of the operator in combustion process. Also, inexperienced operator may cause an incomplete sulfur burning, re-

*Corresponding author; email: 2009rasi@gmail.com

sulting inconsistent SO_2 concentration in fumigation process, longer period per treatment and overdosed SO_2 concentration of longan products [6]. The second method of SO_2 fumigation is to apply the vertical forced-air technology. This technology has been researched since 2011 [6]. In this technique, the SO_2 is released directly from SO_2 gas cylinder which can deliver the consistent residues of SO_2 for exported fresh longan. As a result, it gives advantages in providing the uniform quality of SO_2 longan, and easy control of SO_2 residue. However, the disadvantage is its high capital investment and operation expenditures in fumigation [3, 4, 6-8]. According to the registered list of longan enterprise from Department of Agriculture in 2016 [9], the ratio of enterprise's usage on vertical forced-air per traditional SO_2 fumigations were 1: 16, thus it is less widely recognized than the traditional SO_2 fumigation.

In 2013, the General Administration of Quality Supervision, Inspection, and Quarantine of the P.R.China have notified the overdosed residues of SO_2 of imported fresh longan from Thailand. Later in 2014, suspension of 10 Thai longan exporters was taken place by P.R. China due to overdosed residues of SO_2 in longan flesh over Chinese's standard. That Chinese's restricted import measure made a significant impact to image and accountability of exported longan produces of Thailand [10]. If residues of SO_2 on imported longan is greater than 50 mg/kg, that lot of import longan will be destroyed or rejected to enter the P.R.China [11]. As the priority and awareness of the problem affected Chinese consumers, the sanitary and phytosanitary of Thai longan must be determined. For instance, sources of longan production and packing house must be approved and credited by Good Agricultural Practices (GAP) and Good Manufacturing Practice (GMP) standards. The exported fresh longan must be randomized and verified for SO_2 residue with laboratory analysis certification attached [10]. If overdosed residues of SO_2 in exported fresh longan of Thailand exists, several measures and random inspection will be reckoned with the consequences. Since the vertical forced-air SO_2 fumigation technology can play important role to maintain the good standard of SO_2 residue in longan flesh, it is important to expand the usage with more technology acceptance from the longan exporters. The strong point of the vertical forced-air SO_2 fumigation technology is its assurance of SO_2 penetration with quality consistency and residues controlled under the limit of P.R. China's standards (less than 50 ppm in longan flesh) [6]. Therefore, it is of our interest to study the factors influencing attitude towards the adoption of vertical force-air SO_2 fumigation for the longan packing enterprises. Thus, the objective of this research was to investigate the factors influencing the decision to adopt the vertical forced-air SO_2 technology of packing house exporters of Thai fresh longan. It is expected that result of this work can identify the crucial factors which will be beneficial to the government sector to further elaborate the strategy to expand the boarder usage of vertical forced-air SO_2 technology with better operator's safety and consumer's food safety than the traditional SO_2 fumigation.

2. Materials and Methods

2.1 Materials

The study was a survey research with purposive sampling. The target framework is the owners and managers of SO_2 fumigation enterprise in the northern and eastern regions of Thailand who registered to Registration Company of Agricultural Product Factory in 2016, with a total of 103 fumigation enterprises [9]. Questionnaire was distributed into the target areas; 128 sets for the northern entrepreneurs and 68 sets for the eastern entrepreneurs, with a total of 196 sets from 98 fumigation enterprises (2 questionnaires per enterprise). The returned questionnaires were 101 sets which were further processed for the statistical data analysis.

2.2 Methods and data analysis

The statistical tool for data collection was questionnaire in this research. The questionnaire was designed into 5 parts. Parts 1-3 involved the personal data of the respondents, general data of the company, production pattern and business goals. Parts 4-5 was designed for the factor analysis regarding the topic of "Influencing Attitude towards the Adoption of Agricultural Innovations: A Case Study on Vertical Forced-air Sulfur Dioxide Fumigation Technology". The open-ended questions related to factors influencing production of exported fresh longan and tool verification content were verified and approved by experts in the technical and management fields of longan fumigation and fruit export. The experiment was tried out with 34 staff of fresh longan exporters in the northern region who were not research sampling group. Analysis was proceeded for reliability and alpha coefficient according to Cronbach Technique. Reliability of tool verification was found at 0.92 level, indicating that all variables were related and usable for the factor analysis.

Data analysis was accomplished by descriptive statistics to indicate the general characteristics of workplace for SO_2 fumigation and target of fresh longan business. Factor analysis on influencing attitudes towards the adoption SO_2 fumigation by vertical forced-air technology was applied to analyze the latter part of the data. To consider the suitability of the data for factor analysis, the strength of intercorrelations among the variables using Kaiser-Meyer-Olkin (KMO) was applied. A measure of sampling adequacy of KMO higher than 0.6 was a criterion as the minimum value for a good factor analysis [12]. To determine the numbers of factors or components to be extracted, the eigenvalues that retained the factors greater than 1 and scree plot were used as the references. Finally, the rotation factor was applied using orthogonal (Varimax) method to obtain the group of factors which later were renamed as the factor components, accordingly.

3. Results

3.1 General information of respondents

The general information of respondents (owners or managers of SO_2 fumigation enterprise) was found to be mostly male of 55.4%, with ages between 24-40 years old of 54.5% and 41-63 years old of 39.6%. The education of respondents was mainly below bachelor's degree of 48.5%, and with bachelor's degree of 45.5%. Most of them worked in business of SO_2 fumigation of fresh longan between 1-10 years of 82.2% and 62.4% of which had not yet known the vertical forced-air SO_2 fumigation technology which researched and developed by Maejo University.

Most companies have been running the business for 1-10 years of 73.3%, and for 11-20 years of 22.7%. Most enterprises used the traditional SO_2 fumigation technology of 94.1%. Some enterprises applied both the traditional and vertical forced-air SO_2 fumigations of 4% and minor enterprises of 2% used SO_2 vertical forced-air fumigation solely.

Type of business ownership was as an individual or owner of 60.4%, and as a joint limited company between Thai and foreigner of 30.7%. The findings agreed with report from Office of Agricultural Economics in 2018 whose the business pattern of longan packing house enterprises was mostly by foreign shareholders for export [13]. Most of longan produces was exported by 89.1%. The business modelling was in small size with less than 50 workers by 81.2% and in medium size with less than 200 workers of 69.5%. The production capacity was 10,001 - 50,000 kg/day. Since the longan can be produced off season, 58.4% most of entrepreneurs operated the longan fumigation all year-long both in-season and off-season, while 23.8% of respondents operated the longan fumigation only off-season due to pricing competition, and 17.8% of respondents operated the longan fumigation only in-season.

3.2 Factor analysis of technology adoption

Based on factor analysis, data of Part 4 from questionnaire with 36 variables were analyzed. Derived value of KMO variables on investigation of factors influencing attitudes towards the adoption SO_2 fumigation technology was 0.763, of which the acceptance level lied above the threshold level of 0.50. On the other hand, all variables in the scale were relatively correlated and appropriated for principal factor analysis. According to Bartlett's Test of Sphericity, the finding was found that KMO was equal to 0.763. In conclusion, all variables were correlated at P - Value < 0.0009 as presented in Table 1.

Table 1. The KMO and Bartlett's Test of Sphericity of data obtained from questionnaires.

KMO	**Bartlett's test of sphericity**	
	χ^2	**p-value****
0.763	2,761.136	0.0009

**p-value < 0.05

After considering the KMO value, the principal components approached by the Total Initial Eigenvalues of greater than 1 were further analyzed and rearranged discerningly as shown in Table 2. We found that the first 10 components were accounted for the sum of 77.275% of the variation. The statistical values of the major principal components were tabulated in Table 2.

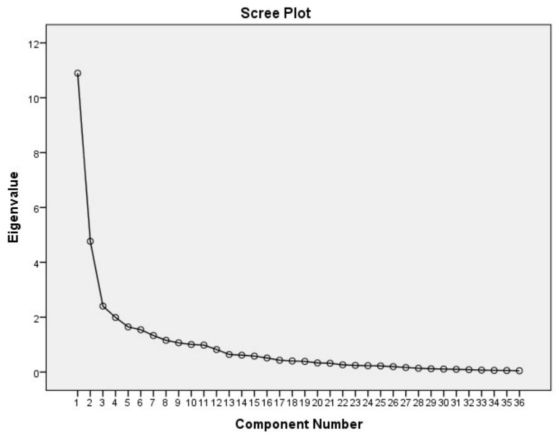

Figure 1: Scree plot Eigenvalue.

Figure 1 shows the scree plot of Eigenvalue sorted in descending order. To consider component analysis of adoption of SO_2 fumigation technology based on decreased Eigenvalue, the principal components with value greater than 1 were found only 10 components. It means that the variables were to be extracted up to 10 components, accordingly.

Based on the variables of each component, the orthogonal rotation approached by Varimax criterion was applied and found that 36 variables were reordered into 10 principal components following the weighing factors. The variables of each component were regrouped and renamed as followings:

Component 1 was composed of 9 variables: Q6, Q7, Q5, Q3, Q4, Q9, Q8, Q2 and Q32, named as **Worthiness**.

Component 2 was composed of 5 variables: Q28, Q34, Q30, Q33 and Q12, named as **Competitiveness**.

Component 3 was composed of 5 variables: Q36, Q21, Q22, Q29 and Q31, named as **Organization goals**.

Component 4 was composed of 2 variables: Q24

Table 2. Statistical values of major components before and after extracting the factors.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	10.895	30.265	30.265	10.895	30.265	30.265	5.475	15.208	15.208
2	4.768	13.244	43.509	4.768	13.244	43.509	4.317	11.992	27.200
3	2.405	6.680	50.190	2.405	6.680	50.190	3.297	9.157	36.357
4	1.993	5.535	55.724	1.993	5.535	55.724	2.544	7.065	43.423
5	1.648	4.577	60.302	1.648	4.577	60.302	2.424	6.732	50.155
6	1.545	4.291	64.593	1.545	4.291	64.593	2.284	6.344	56.500
7	1.333	3.703	68.296	1.333	3.703	68.296	2.173	6.035	62.534
8	1.158	3.218	71.514	1.158	3.218	71.514	1.945	5.403	67.937
9	1.067	2.964	74.478	1.067	2.964	74.478	1.733	4.813	72.750
10	1.007	2.797	77.275	1.007	2.797	77.275	1.629	4.525	77.275
11	.985	2.735	80.010						
...	...	...	...						
...	...	...	...						
36	0.049	0.135	100.000						

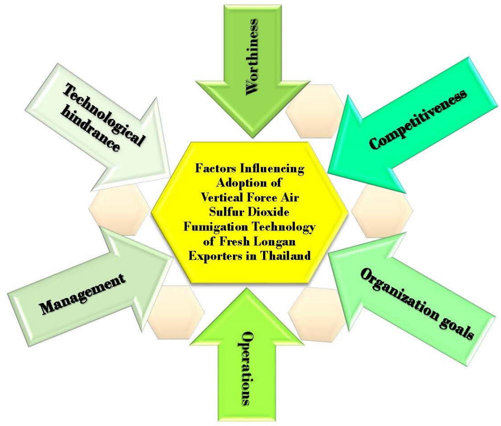

Figure 2: Factors influencing adoption of the vertical forced-air SO_2 technology of Thai longan exporters.

and Q23, named as Production **standards**.

Component 5 was composed of 3 variables: Q14, Q13 and Q27, named as **Operations**.

Component 6 was composed of 3 variables: Q17, Q16 and Q18, named as **Management**.

Component 7 was composed of 2 variables: Q11 and Q10, named as **Potentiality**.

Component 8 was composed of 2 variables: Q26 and Q25, named as **External constraints**.

Component 9 was composed of 2 variables: Q20 and Q19, named as **CEO attitude**.

Component 10 was composed of 3 variables: Q35, Q1 and Q15, named as **Technological hindrance**.

The 10 principal components consisted of detailed questions and weighing factors after rotation as shown in Table 3.

To maximize Varimax criterion after rotation of components, it was found that there were 3 factors decreasing less than loading data with 4 components e.g., Components 4, 7, 8, and 9. These 4 components showed the least correlation in the matrix in the range of 0-0.5 with only 2 variables. Thus they were considered as the non-significant factors and were to be eliminated from factor analysis. This resulted in the remaining of 6 principal components, which were accounted for the sum of variance of 53.958% with graphically presentation in Figure 2.

When compared to the adoption of innovative technology with other businesses, we found some similarities of the factors affecting the decision of technology adoption. The previous work by Thong and Yap [14] who studied the main factors of adoption of the IT innovation in small businesses showed that management innovativeness, attitude towards new IT technology, business size and competitiveness were the main determinants of IT technology adoption. These influential factors were similar to the determinants found in our study where the adoption of SO_2 fumigation using vertical forced-air technology for fresh longan exporters was partially dominated by the factors involving the management visionary and size of business.

4. Conclusion

In this work, the factor analysis was conducted to analyze the 36 variables that could influence the attitude of longan exporters to adopt the vertical forced-air SO_2 fumigation technology. These variables were

Table 3. The weighing factors of each variable after the Varimax orthogonal rotation.

Variable adoption of SO_2 fumigation technology with experience of exporters in Thailand	**Component**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Q6 Technology design must be easy to use and maintain in operation	.866									
Q7 New technology must efficiently perform to control and reduce pollution i.e. sulfur pungent smell surrounding areas and communities	.817									
Q5 Chosen technology must not too complicated. There must be regularly training session for new staff and knowhow transfer as well as proper manuals for workers	.778									
Q3 Reduction of operating costs/ expenses i.e. sulfur dioxide cost in order to maximize profit	.702									
Q4 There must be unsophisticated and user friendly design in new technology. Easy to operate to reduce product defects and machine malfunction in operation	.693									
Q9 Controllability of contaminants and residues i.e. SO_2 upon fumigating process	.671									
Q8 Reduce maintenance costs. Longevity of equipment and structure by controlling use of sulfur. The corrosive	.631									
Q2 Feasible in investment with shortest payback period from structure and system installation	.578									
Q32 Strict in product quality control and importing rules from import country	.484									
Q28 Trends and future of export fresh longan industry		.827								
Q34 Perception of consumers towards fumigated fresh longan in terms of quality and safety		.825								
Q30 With variety of substitute longan products (dried, canned etc.), which sourcing the same raw material (fresh longan) affects market shares. This would be constraint in opting high investment technology		.772								
Q33 Attitudes and perceptions of business partners or stakeholders (Foreign joint venture, exporters, and importers) towards investment policy affecting the choice of technology		.718								
Q12 Operator must be high alert on dynamics upon product improvement and technology changes in competitive fresh longan export business		.585								
Q36 Issue of uncontrollable consistency of fresh longan yields in season and off-season impacted by climate changes to supply the operation. As a result, poor quality of input fails to comply with import client's orders			.732							
Q21 Policy on increasing market share as well as productivity capability to penetrate new markets			.724							
Q22 Policy on productivity (both quality and quantity optimization) improvement			.689							
Q29 Dependence on Fresh longan export competition in market			.543							
Q31 Government supports in financials, operational extension, export facilities and industrial information to accelerate export fresh longan industry			.376							
Q24 Commitments to improve production standards				.845						
Q23 Aims to improve product quality according to market demands				.821						
Q14 Operator's Human Resource Development plan readiness to cope with adoption in new technology					.846					
Q13 Operator's readiness to recruit qualified personnel (specialist) to cope with new technology					.785					
Q27 High operating costs i.e. chemicals and high wage specialists would reducing competitive advantages in fierce markets					.487					
Q17 Organization structure (in small, medium and large scales) to handle funds for opting in new technology						.733				
Q16 Ultimate goals and objectives in market positioning are varied upon organization structure differences reflects in choosing technology						.721				
Q18 Management styles upon organization structure (likely operators in Thailand are SME scales with limitations in vision in market forecast for long-terms)						.546				
Q11 Potency in efficiently increase productivity upon demands and business needs							.705			
Q10 New technology must have operating capability to maintain consistently product upon market needs i.e. size, color and freshness							.628			
Q26 Fund raising and sourcing difficulties to set up fumigation plant with new technology								.914		
Q25 Since sulfur dioxide being controlled chemical by government regulations. It is difficult to apply in industry								.541		
Q20 Decision in opting new technology depends upon operator management's experiences in competitive fresh longan export business									.864	
Q19 Operator's decision maker and management must keep update on technology improvement information									.663	
Q35 Chosen technology must be controlled in coping with environment impacts on community ecosystem in long-term										.786
Q1 Technology under patent and copyright would be barrier to opt by operator, commercially										.559
Q15 Existing operating staff is difficult to learn and train especially, cheap waged workers										.515

to be grouped into 10 components and there were 4 components to be eliminated due to non-significant weighing factor for their correlations. The 6 remaining components were then used for Varimax orthogonal rotation analysis. The major factors influencing attitude towards the adoption of vertical forced-air SO_2 fumigation technology for fresh longan exporters in Thailand were found to be 6 components involving worthiness, competitiveness, organization goals, operations, management, and technological hindrance. Since the vertical forced-air SO_2 fumigation technology seems to be a long-term solution in reducing high sulfur residues into a safety consumption limit while maintaining the product quality and appearances, it is important to expand the adoption of the technology for wider usage by longan exporters. Thus these factors are useful to further develop the strategic plan and policy for enhancement of vertical forced-air SO_2 fumigation technology applicable to the fresh longan exporters of Thailand.

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References

[1] Office of Agricultural Economics, Situation and trend of agricultural commodities in 2020, http://www.oae.go.th/assets/portals/1/files/trend2563-Final-Download.pdf.

[2] Regional Commerial Affairs Division, Longan commodities the 3rd week of September 2019 (16 - 20 September 2019), http://kbp.ops.moc.go.th/ewt_dl_link.php?nid=2343.

[3] J. Phimphimol, Postharvest management of commercial fresh longan 2012, Chiang Mai, Thailand: Chiang Mai Documentary Design, 174.

[4] Y. Jiang, et al., Review: Postharvest biology and handling of longan fruit (Dimocarpus longan Lour.), Postharvest Biology and Technology 26 (2002) 241-252.

[5] L. Hetong, et al., Technologies of post-harvest handling and storage for longan fruits, in 2011 International Conference on New Technology of Agricultural Engineering (ICAE 2011), pp. 758-763.

[6] J. Varith, S. Jaturonglumlert, C. Nitatwichit, P. Supapunt, T. Awirothananon, R. Kongtanajaruanun, P. Intanoo, P. Klinkajorn, Policy proposals to push the Vertical Force-air fumigation technology to perform commercial and enhance the export of fresh longan fruits vol. 1, Chiang Mai, Thailand: Wanida printing.

[7] National Bureau of Agricultural Commodity and Food Standards, Code of practice for sulphur dioxide fumigation of fresh fruits, Government gazette, Announcement and general editions, 2015.

[8] J. Pimpimol, et al., Improved Sulfur Dioxide Fumigation of Fresh Longan Using a Vertical Forced-Air Technique, Acta horticulturae 880 (2010) 415-422.

[9] Department of Agriculture, List of the firms to be recognized, 2016.

[10] Department of Trade Negotiations. Barriers to export longan fruit to China, http://www.thaifta.com/thaifta/portals/0/logan_cnsep57.pdf

[11] The Office Agricultural Affairs, P.R.C. Thailand fruit market situation in China in 2018 and trends, https://www.opsmoac.go.th/guangzhou-news-files-412991791854

[12] A. L. Asnawi, A. M. Gravell, G. B. Wills, Factor analysis: Investigating important aspects for agile adoption in Malaysia, in 2012 Agile India.

[13] Office of Agricultural Economics, Annual report in 2018.

[14] J. Y. L. Thong, C. S. Yap, CEO characteristics, organizational characteristics and information technology adoption in small businesses, Omega 23(4) (1995) 429-442.