Pertanika J. Soc. Sci. & Hum. 29 (2): 785 - 797 (2021)

SOCIAL SCIENCES & HUMANITIES

Journal homepage: http://www.pertanika.upm.edu.my/

Technical Efficiency of Commercial Stingless Bee Honey Production in Peninsular Malaysia

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ABSTRACT

The Stingless beekeeping project, a relatively new industry in Malaysia, has a huge economic potential because the production of stingless bee honey is low but the demand for this type of honey is slightly higher. This study was developed to measure the technical efficiency of commercial stingless beekeeping farms in Peninsular Malaysia by using Data Envelopment Analysis (DEA). Ninety-two respondents were selected using clustered random sampling and they were personally interviewed using a structured questionnaire. The results showed that the average technical efficiency was at 75%, with a minimum of 21% and a maximum of 100%. However, 25% of the farms were found to be fully efficient. The output slacks were 24.7, revealing that the bee farms produced honey with a shortfall in outputs. Labour hours indicated the highest input slacks which was 457. Mean slack for farm size indicated that the farms should be reduced by 0.58 acre while for the total number of colonies, the value of slack indicated that beekeepers should reduce it by one colony. Determinants of inefficiency results indicated that bee flowers and agricultural extension were significant. In conclusion, the technical efficiency of commercial stingless bee honey production in Peninsular Malaysia is high, but efficiency and inefficiency factors should be of concern to improve the value of technical efficiency.

Keywords: Farm, inefficiency, slack, stingless bee, technical efficiency

ARTICLE INFO

Article history:
Received: 11 August 2020
Accepted: 03 November 2020
Published: 30 June 2021

DOI: https://doi.org/10.47836/pjssh.29.2.03

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ISSN: 0128-7702
e-ISSN 2231-8534

INTRODUCTION

Honey is a natural food product, produced by honey bees (*Apis* spp.) and stingless bees (*Meliponini spp.*). In Malaysia, the sources of honey production are derived from honey bees (*Apis melifera* and *Apis cerana* spp.), Tualang bees (*Apis dorsata* spp.), and stingless bees (*Meliponini* spp.). In the Malaysian meliponiculture industry, there are five species of stingless bees being commercialized for honey production and pollination which were *Geniotrigona thoracica, Heterotrigona itama, Lepidotrigona terminata, Tetragonula fuscobalteata,* and *Tetragonula leaviceps* (Kelly et al., 2014). The *Trigona sp*. was commonly found in Malaysia (Majid et al., 2019) while *Heterotrigona itama* is the most abundant species found in the southern part of Malaysia (Rasmussen, 2008). Currently, most of the honey production in Malaysia depends on *A. dorsata* and *Meliponini* or stingless bees. Stingless bees tend to dwell in the hollow spaces of tree trunks and can be domesticated easily for intensive farming compared to *A. dorsata*. Honey from stingless bees had been proven to be a superfood, possessing high antioxidant and antibacterial activities, with high nutritional and therapeutic values.

Presently, the stingless bee industry is a growing phenomenon among new entrepreneurs due to its contribution to socio-economic development. The higher selling price of stingless bee honey and high return on investment (ROI) tend to capture the attention of new or young entrepreneurs to be involved in this industry. According to Ismail and Ismail (2018), the expected ROI from the stingless bee project is about 70% of its initial investment. This indicates that the stingless bee industry could become a high-impact agriculture project if it is operated commercially. Currently, as reported by the Department of Agriculture Malaysia (DOA), there are 717 stingless beekeepers in Malaysia, and only 192 reported as commercial stingless beekeepers in Peninsular Malaysia. The aggressive development of the stingless bee industry in Peninsular Malaysia occurred due to the abundance of research regarding the health benefits, socioeconomic benefits, and technological improvements on stingless bee honey because of collaborations between research universities and entrepreneurs.

Malaysia depends on imported honey from China since the 1990s for domestic consumption (Wah & Baharun, 2008). This indicates that the local honey production is still insufficient to support the domestic demand. Therefore, the stingless bee industry is seen as a future potential to fulfill domestic demand for honey. However, there are a few pertinent issues that need to be solved in order to achieve this potential. Firstly, stingless bee honey tends to be sour-tasting due to its high moisture content which leads to a fermentation process. According to Mustafa et al. (2018), the sour taste of stingless bee honey can be avoided by dehydrating the honey from 35% to 22% moisture content by using a dehydrating machine. Secondly, there is the issue of the capability of producing stingless bee honey in large-scale farms to meet the high domestic demand for honey. Cultured stingless bees facilitate better management activities and better production of honey since the preparation of food sources can be planned through the cultivation of flower species and trees that are suitable to produce honey, propolis, beebread, and other products. Currently, most Malaysian beekeepers only practice meloponiculture without any concern about the efficiency of inputs and outputs used in honey production. Hence, the technical efficiency of commercial stingless beekeepers needs to be improved to ensure that the beekeepers utilize the input wisely. Therefore, the purpose of this study is to assess the performance of commercial stingless beekeepers through a technical efficiency assessment and to identify the factors determining the inefficiency of commercial stingless bee honey productions in Peninsular Malaysia.

Technical efficiency (TE) refers to the maximum achievable level of output for a given level of input within a given range of technology. As noted by Rashidah et al. (2010) and Soh et al. (2016) TE is used to measure how close a firm is to its maximum achievable outputs. It is measured as the ratio of the observed output to its potential output derived from the frontier function. Generally, a firm is considered technically efficient when it produces a higher level of output compared to another rival firm at the same level of inputs (Nurul et al., 2011).

Sabuhi et al. (2012) and Sherzod et al. (2018), stated that technical efficiency can be evaluated through two methods which are parametric and non-parametric methods. The parametric method uses the Stochastic Frontier Analysis (SFA) while the non-parametric method uses the Data Envelopment Analysis (DEA). Our study applied the DEA non-parametric approach for measuring TE and factors affecting TE. The main advantages of DEA are that it considers various factors and does not need parametric assumptions of traditional multivariate approaches. In addition, in terms of estimation of technical efficiency, it does not require prices for the outputs and inputs. On the other hand, there are several critical factors that must be considered in the application of DEA models. The efficiency scores could be very susceptible to changes in the data and are highly dependent on the number and type of input and output factors considered (Talluri, 2000).

The DEA method is based on a model of linear programming. The DEA can be analyzed either with the assumption of Constant Returns to Scale (CRS) or Variable Returns to Scale (VRS). The technical efficiency defined by the DEA method either for CRS or VRS can be calculated based on output or input orientation. Hence, it results in a model that attempts to maximize outputs holding the observed amount of any input constant, or based on input orientation, thus resulting in a model whose objective is to minimize inputs, keeping the observed amount of any output constant (Coelli et al., 2005). The DEA method is one of the regular methods used for measuring efficiency in the agricultural sector (Abatania et al., 2012; Artukoglu et al., 2010; Makri et al., 2015; Sabuhi et al, 2012; Sherzod et al., 2018). Furthermore, TE was also used in determining the efficiency level of agricultural cooperatives (Linh et al., 2017).

METHODS

Study Area and Sampling Methods

The study area was focused on commercial stingless beekeepers in Peninsular Malaysia who are registered with the DOA, Malaysia. In this study, only commercial stingless beekeepers with a minimum of 50 stingless beehives and above were selected as a study sample. The study used primary data sources obtained through face-to-face interviews using a set of questionnaires. The research instruments had been tested and validated through a pilot study and were confirmed by an expert panel before the actual data collection.

According to the DOA Malaysia, there are 192 (2017) commercial stingless beekeepers in Peninsular Malaysia. The Cochran's Formula was used in the determination of sample size for this study. Below is the formula for sample size calculation:

$$n = \frac{p(100-p)z^2}{E^2} \div \frac{1+ p(100-p)z^2}{E^2 * N}$$

n is the required sample size
P is the percentage occurrence of a state or condition
E is the percentage maximum error required
Z is the value corresponding to level of confidence
N is the total sample population

Descriptive Analysis

The descriptive analysis of this study involved socio-demographic factors such as age, gender, level of education, marital status, number of people in the household, types of involvement, and experience. Those socio-demographic factors of commercial stingless beekeepers in Peninsular Malaysia were then summarized into mean, maximum, minimum, and standard deviation as presented in Table 1.

Empirical Models

This study employed a two-stage DEA in measuring the technical efficiency of commercial stingless beekeeping in Peninsular Malaysia. In the first stage, the efficiency scores were obtained through the inclusion of input and output variables in the standard DEA model. The input-oriented approach proposed by Bankers et al. (1984), was applied in this study. The detailed formula of the model is as follows:

$$TE_{VRS=\underset{\theta\lambda}{Min}} \ \theta$$

Subject to:

$$Y\lambda - Yi \geq 0,$$

$$\theta Xi - X\lambda \geq 0,$$

$$\lambda \geq 0$$

Y are the output vectors
X are the input vectors
θ represent the scalar which ranges from 0 to 1
λ is an n x 1 vector of constant

The technical efficiency of the commercial stingless bee farms can be defined if the farm obtained efficiency scores of 1. Meanwhile, for the inefficient farms, the efficiency score will be less than 1. The DEA model for this study was performed with three input variables and one output variable. The input variables involved in this study were: 1) the number of colonies, 2) stingless bee farm size, and 3) hours of labor. The single output variable used in this study was total stingless bee honey production (kg). The current annual production of honey for each colony of the stingless beehive is small, about 4 kg. Therefore, the number of colonies is an important variable to increase production. More colonies result in more honey production. Hence, if the beekeepers could not increase the number of colonies through the splitting technique, then it is impossible for them to expand their operation.

This study applied an input-oriented VRS DEA model in order to estimate technical efficiency. This model was applied because input quantities are the main decision variable of farms and it can be controlled by farm owners or managers (Coelli et al., 2005). Based on Huguenin (2012) the CRS model assumes constant returns to scale technology and this model is appropriate when all firms are operating at an optimal scale, but this assumption is quite ambitious and very seldom the case. The second model (VRS) assumes variable returns to scale technology. This is appropriate when farms are not operating at an optimal scale. Usually, the situation happens when farms face imperfect competition, government regulations, and regarding the situation, this model is more appropriated to applied for the study on the technical efficiency of stingless bee farming in Malaysia. Comparison between the two models reveals the source of inefficiency. If there is a difference in two scores for a particular farm, then this indicated that the farm has scale inefficiency and that the scale inefficiency can be calculated from the difference between the VRS TE score and the CRS TE score (Coelli, 1996).

In the second stage of DEA, Tobit Regression was applied to determine the external factor that contributed to the inefficiency of the stingless bee farm. There were 11 external factors identified namely: 1) years of schooling, 2) the number of people in the household, 3) gender, 4) age, 5) experience, 6) involvement in associations, 7) agricultural extension, 8) full-time involvement, and the types of plants for stingless bee food sources such as 9) fruits, 10) flowers, and 11) acacia forest.

RESULTS AND DISCUSSION

Descriptive Statistics of Variables

This study was carried out in each of the states in Peninsular Malaysia and the target groups were beekeepers who have 50 to 300 hives. In total, 92 beekeepers responded, and data were recorded for the analysis. Adeyemo and Kuhlmann (2009) stated that the main socio-economic factors which were assumed to have an influence on the productive efficiency of farmers and hence, included in the model were the age of the farmer, availability of off-farm income, access to credit, access to extension services, education level of the farmers and years of experience in the vegetable production industry. In the present study, the age group of 40 to 49 indicated the highest involvement, with 28.3% followed closely by the 50 to 59 age group, with 26.1% (Table 1). There were very few beekeepers over 70 years old, with only 3 persons, and similarly, the number of beekeepers being 20 to 29 years old was also low, at only 8 persons. The beekeeping industry is involved with many techniques and technologies, and because of that, people of the older generation who are above 60 years old are not interested to get involved. The operation also needs a considerable amount of initial capital to buy the hive and equipment. Because of that, young people who are still not financially stable may find it difficult to get involved in stingless beekeeping projects.

For gender, the industry is dominated by men at 84.8% or 78 persons and only 14

Table 1
Demographic variables statistics in 2019

Variable	Description	Freq (n)	(%)	Mean	Min	Max	Std Dev
Age (year)	20-29	8	8.7	12.12	6	15	2.78
	30-39	18	19.6				
	40-49	26	28.3				
	50-59	24	26.1				
	60-69	13	14.1				
	70-79	3	3.3				
Gender	Man	78	84.8	0.85	0	1	0.36
	Women	14	15.2				
Marital status	Single	7	7.6	0.95	1	3	0.34
	Married	84	91.3				
	Widow/er	1	1.1				
Level of Education	Primary School	9	9.8	12.12	6	15	2.78
	Secondary School	46	50.0				
	Higher Education	37	40.2				
Household	1 to 3	27	29.3	4.80	1	12	2.27
	4 to 6	46	50.0				
	7 to 9	16	17.4				
	10 and above	3	3.3				
Involvement	Part time	61	66.3	0.34	0	1	0.48
	Full time	31	33.7				
Experience	1 to 3	9	9.8	5.70	1	13	2.14
	4 to 6	58	63.0				
	7 to 9	19	20.7				
	10 and above	6	6.5				
Number of farms			92				

persons or 15.2% are women. Most of the beekeepers in the study are married, with only 7 persons who are still single. Most of the beekeepers (46 persons or 50%) have completed secondary school, followed by higher education with 37 persons or 40.2%. This number showed that most of the beekeepers are educated. This situation may exist due to the issues of capital and technology, where educated and middle-aged farmers are the target group in stingless beekeeping farms. However, the DOA also provides incentives for young farmers who are below 40 years old. Each participant will receive RM30000 in the form of stingless bee colonies. However, only those operating 30 colonies and above will entitle to this incentive. Newcomers will not be entertained.

For the number of people in the household, 50% of beekeepers had four to six members. Meanwhile, 29.3% had one to three members and only 3% of beekeepers had more than 10 members in their household. The largest number of households was 12 members. Family labor is a very important source of labor in the beekeeping industry. Most beekeepers, especially in small-scale beekeeping, do not hire labor to cut the cost of production. More than half of the beekeepers were involved with this activity on a part-time basis and only 33.7% or 31 persons were involved full time. The analysis also showed that all beekeepers had experience in beekeeping. The minimum was a one-year experience, and the maximum was 13 years. More than 91% or 83 persons had more than 3 years of experience, only 9 persons had less than 3 years of experience, and 6 persons had to experience more than 10 years.

Table 2 presents the descriptive statistics of input and output used in this research, where the one output involved was raw honey in kilograms (kg), while the three inputs included farm size in acres, number of hives, and hours of labor. These three inputs are the fundamental components in the production of stingless bee honey and give a significant effect on the total production cost. Technical inefficiency in using major input resources will increase the cost of production and burdening the beekeepers.

Technical Efficiency of Stingless Beekeeping Farms

As presented in Table 3, the results showed a wide efficiency range for VRS which

Table 2
Descriptive statistics of output and input variables in 2019

Variables	Unit Measure	Mean	Minimum	Maximum	Std Deviation
Output					
Honey	Kg	300	45.00	744.00	164.77
Input					
Farm size	Acre	2.61	0.25	15.50	2.98
Colony	Number	97.00	50.00	300.00	54.49
Labor	Hour	1586.21	48.00	8736.00	1579.28

Table 3
Frequency distribution score of TE in the first stage DEA

RANGE	CRS	VRS	SCALE
0.0-099	2	0	0
0.1-0.199	8	0	4
0.2-0.299	20	6	4
0.3-0.399	11	4	12
0.4-0.499	7	2	9
0.5-0.599	11	10	6
0.6-0.699	6	16	13
0.7-0.799	11	13	9
0.8-0.899	7	7	7
0.9-0.999	4	9	23
1	5	25	5
Mean	0.50	0.75	0.67
Minimum Efficiency	0.07	0.21	0.16
Maximum Efficiency	1	1	1
Standard Deviation	0.27	0.23	0.27

was between 0.21 to 1.00, and for CRS the efficiency was wider which was 0.07 to 1.00, this confirmed that beekeepers produce honey with a wide variation in output. Accordingly, we found that 25 out of 92 farms were fully efficient under VRS while only five farms were fully efficient under the CRS analysis. Compared to VRS, CRS indicated a lower score, and this is because the CRS model was assumed to have a tighter enveloping surface where the use of the CRS specification when not all farms are operating at the optimal scale will result in measures of TE which confounded by scale efficiency and thus, only permits a lower efficiency score. Based on Idris et al. (2013), the technical efficiency scores in CRS and VRS were used to verify the trend of farmers' operation, whether it is at an increasing scale or returning to decline. If the score of VRS is higher than CRS, the beekeepers are increasing their scale of production.

The results indicated that mean TE under CRS and VRS obtained from this study were 0.5 and 0.75 respectively. This result indicates that beekeepers in Peninsular Malaysia only utilize up to 50% and 75% of their input or in other words if beekeepers are to reduce input application by 50% and 25% bee farms will still produce the same level of production. Furthermore, the study also calculated the scale efficiency (SE). The mean SE in this study was 0.67 and only 5 farms were fully efficient under SE, suggesting that some of the farms were not optimal in size. This is a major issue in the stingless beekeeping industry where it is difficult to increase the number of colonies without cutting trees.

Table 4
Summary of input output slacks and optimum value

Variable	Mean Slack	Frequency (n)	Percentage (%)
Output	24.70		
Input:			
Farm size	0.58	32	34.78
Total colony	1.00	7	7.61
Labor hours	457.26	36	39.13
Farm without slack		34	36.96
Optimum mean value after slack adjustment			
Farm size	2.03 acre		
Total colony	96 colonies		
Labor hour	1129 hours		

The splitting technology is not yet perfect thus, many beekeepers have failed. The value of SE was also lower than TE (VRS), suggesting that apart from farm size as a cause of inefficiency, poor management also contributed to the inefficiency of bee farms. Therefore, the results suggest that beekeepers can improve their efficiency through size optimization and implement the best management practices.

Table 4 was indicated the summary of input slacks and the optimum input after slacks adjustment. The value of output slacks is 24.7, revealing that the bee farms involved in this study produced a shortfall in output. The input slacks showed the quantity of which input that could be reduced but still produced the same level of output. Based on Table 4, it is obvious that labor hours indicated the highest input slacks which were 457.26 and 36 bee farms involved with this input slack. This value is very high, suggesting that beekeepers should reduce their hours of labor to increase the TE of their bee farm. Mean slack for farm size indicated that farm size should be reduced by 0.58 acre to produce the same output and 32 bee farms were involved (Table 4).

For the total colony, the value of slack indicated that beekeepers should reduce by 1 colony to produce the same level of output and 7 bee farms were involved with this slack. In this study 34 bee farms (36.96%) reported 0.00 input slack, meaning that these farm operations were at the optimum farm size, the number of the colony, and labor hours. Based on the analysis, it can be suggested that the optimum value for farm size was 2.03 acre, the optimum number of colonies was 96, and the total labor hours to produce optimum production were 1129 hours annually.

Determinants of Technical Inefficiency

Several factors were regressed upon the efficiency scores to identify the inefficiency factor and stated in Table 5. The estimated coefficient of the year of schooling was insignificant and carries a negative sign which implied that educated beekeepers were more technically efficient compared to less educated beekeepers. The result for the number of people in the household was also not significant but indicated a positive sign, which means that the increase in the number of people in the household will increase the inefficiency of the farm. Gender and age of beekeepers were also indicated as insignificant in VRS, though the sign was positive which means that if the farm was managed by a male, the technical inefficiency of the farm will be reduced while younger beekeepers were technically more efficient than older beekeepers. Based on the results, the experience variable was noted as insignificant but carries a negative sign which means that increasing beekeepers' experience will decrease the technical inefficiency of bee farming. Table 5 also indicated that agricultural extension was significant at 0.5% but carries a negative sign. Extension service is important for any agriculture activity. Guidance from agricultural officers is important and provides significant effects.

The results indicated that the more often officers visited the farm, the less inefficiency occurred. Usually, agricultural officers focus on supporting beekeepers in terms of knowledge, technology transfers, government incentives, and many more to improve honey production. Since stingless beekeeping is relatively new in Malaysia, the adoption rate by existing beekeepers is low (Musa, 2019). As noted in the table, associations also indicated as insignificant and carry a negative sign which means that involvement with associations does not support the technical efficiency of the farm. Sometimes, beekeepers join associations without paying attention to the benefits provided by the associations and many

Table 5
Results of Tobit Regression

Variables	Coefficients	Standard Error	t-Statistics
Constant	0.7781726	0.1884052	4.13
Year of schooling	-0.0089031	0.0094712	-0.94
No. of household	0.0076829	0.0107277	0.72
Gender	0.0316673	0.0627375	0.50
Age	0.0022989	0.0021666	1.06
Experience	-0.0079977	0.0110884	-0.72
Agricultural extension	-0.0098696**	0.0040091	-2.46
Association	-0.0338705	0.0455379	-0.74
Fulltime involvement	0.076641	0.049302	1.55
Fruits	-0.0877575	0.0614719	-1.43
Flower	0.087081*	0.0512718	1.70
Acacia	0 .0853508	0.0719116	1.19
Number of obs		92	
Log likelihood		11.078386	

Note. * and ** indicated values statistically significant at 10%, 5% and 1%

of them also registered just because other people also joined the association. Because of this shortcoming, the beekeepers did not benefit from joining the associations.

The food source is a very important factor in beekeeping activities. This is because the stingless bees will forage for the food sources which are nectar and pollen from the plants around their hive. In addition to wild and existing plants, beekeepers will often grow specific plants around their farm area, especially plants that produce huge amounts of nectar and pollen throughout the year. A simple ornamental plant such as *air mata pengantin* (*Antigonon leptopus*) and *ulam raja* (*Cosmos caudatus)* were commonly planted. In the meantime, beekeepers should also plan for long-term nectar sources by planting acacia and *gelam* (*Mellaleuca cajaputi*) around the borders of their farms. However, based on the results of the analysis, the coefficient for fruits was insignificant and had a negative sign which meant that planting fruit trees was not contributing to the efficiency of the farm. In contrast, planting flowering plants and acacia is more effective because they will contribute to the efficiency of the farm, and planting flowers indicated a significant result at 10%. Most flowering plants produce pollen and nectar, and the shape of the flower itself sometimes supports the stingless bees to have easier access to the nectar and pollen. Beekeepers should wisely choose the right plant species so that their stingless bees will have a sufficient food source. Norasmah et al. (2018) noted that the nectar concentration and food distance influenced both the number of bees exploiting food resources and the overall foraging pattern of *H. Itama,* a major species for commercialization.

CONCLUSIONS

Some important conclusions could be drawn from the findings of this study. By using the DEA method of TE analysis, the results indicated that the TE of large-scale beekeeping in Peninsular Malaysia was high (75%) as this sector is relatively new in Malaysia. The use of inputs should be decreased up to 25% to produce the same level of output. There were a few input slacks that needed to be considered and a reduction in the use of these inputs can be financially beneficial to beekeepers. Two variables that contributed to the technical inefficiency were planted flowers as a source of nectar and pollen and agricultural extension. The right plant species should be determined before they are planted for the short and long terms. This can be assisted by the DOA, who should increase their commitment to give a better service to stingless beekeepers so that the farms will be more efficient and sustainable.

ACKNOWLEDGEMENTS

The authors want to acknowledge the financial support received from the TRGS research grant no. TRGS/1/2016/UPM/01/5/1 provided by the Ministry of Education, Malaysia.

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