



Exploring the relationship between activity cost and aroma loss of Hom Mali rice during post-harvest stage

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Abstract

Hom Mali rice contains various unique characteristics with one being its aroma. A reduction in the aroma or 2-acetyl-1-pyrroline (2AP) of Hom Mali rice during post-harvesting activities has become a major problem for stakeholders and exporters in the rice supply chain. This paper investigated logistics and processing cost analysis of the rice mills of two agricultural cooperatives, AC1 and AC2, by using the activity-based costing (ABC) method. Moreover, the relationship between the loss of aroma and the cost processing activity has been explored using partial correlation. Findings showed that the total cost of AC1 was 4.986 baht/kg, which was separated into the logistics cost of 58.18 percent and the processing cost of 41.82 percent. The total cost of AC2 was 5.851 baht/kg, consisting of the logistics cost of 77.34 percent and the processing cost of 22.66 percent. For the processing activities, the significant relationship between the activity costs and the loss of aroma, while controlling the levels of 2AP, suggested that aroma retaining must regard decisions on the selections of processing activities including polishing, whitening, bagging, and dehulling activities. In the logistics aspect, the cooperatives should focus on raw material receiving, warehousing, packing, and transportation activities. Decisions on the improvement of logistics and processing activities involved with aroma loss of Hom Mali rice should rely on cost analysis, maintaining the quality of rice, and meeting both domestic and international demand.

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Introduction

Thai jasmine rice or Thai Hom Mali rice is the most popular fragrant rice of Thailand and is considered as a high quality rice in the international market (Office of Agricultural Economics, 2017). Hom Mali rice production is mainly located in northeastern Thailand, accounting for 80 percent of the total production. The total production of Hom Mali rice is about 5 million tons per year, of which about 50 percent is consumed domestically. In 2018, the export volume of Hom

Mali rice was 1.25 million tons, generating more than 1.2 billion US dollars to the country annually. (Information and Communication Technology center, 2019; Thai Rice Exporters Association, 2019). Recently, the increasing number of fragrant rice exporters from India, Pakistan, Vietnam, and Cambodia has led to a highly competitive market over both price and quality. One prominent problem of Thai Hom Mali rice is quality control (i.e. decreased rice aroma, and a problem with mixing Hom Mali rice with other cultivars), causing the loss of competitive advantages and the market share (Changsri et al., 2015).

The rice aroma is one of unique characteristics of Hom Mali rice influencing consumer purchasing decision (Custodio et al., 2017; Giraud, 2013; Hien, Yoshihashi, Sarhadi, & Hirata, 2006; Sarkarung, Somrith, & Chitrakorn, 2000; Suwannaporn & Linneman, 2008). The major compound

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contributing to the aroma is 2-acetyl-1-pyrroline (2AP), which is a volatile substance that can be easily lost along the supply chain, especially in stages where moisture content, temperature, and time are relevant (Buttery, Ling, Julian, & Turnbaugh, 1983; Champagne, 2008; Tananuwig & Lertsiri, 2010; Yoshihashi, Nguyen, & Kabak, 2004). The survey study by Changsri et al. (2015) reported that the ranges of 2AP contents in Hom Mali rice in northeastern Thailand in the crop year of 2012 were 1.64–8.26 ppm at the seed production sources, 1.04–10.69 ppm in the paddy fields, 0.26–3.44 ppm at the rice mills and 0.94–3.89 ppm in the exported rice. Loss of rice aroma may result from various logistics and production management activities such as lack of proper standard control and the milling process being based on the labor force in various activities such as piling, loading, and bagging (Changsri et al., 2015; Widjaja, Craske, & Wootton, 1996). Moisture reduction methods and storage duration also affected the 2AP content (Wongpornchai, Dumri, Jongkaewwattana, & Siri, 2004).

Impacts on the aroma of Hom Mali rice along the supply chain can be divided into three stages: pre-harvest, post-harvest, and the end-user stages (Champagne, 2008; Changsri et al., 2015). Rice millers (including agricultural cooperatives and corporate rice millers) are considered as the post-harvest stage that perform three important activities: buying paddy from farmers or acting as collectors, converting paddy into milled rice, and distributing milled rice to consumers. From a supply chain management perspective, most agricultural cooperatives face a few challenges: the cost effectiveness of the milling process, no access to markets, and the lack of collaboration along the supply chain. These challenges can lead to high operation costs and unstable quality of rice. Thus, each agricultural cooperative attempts to reduce costs or improve the quality of rice, especially the level of the rice aroma, to gain competitive advantages. To address these issues, the objectives of this paper were: (1) to study logistics and processing cost structures of a rice mill in each of two case-study agricultural cooperatives by using the activity-based costing (ABC) method; and (2) to address whether there is a statistical significant relationship between the loss of aroma and the activity cost. Based on the results, the approaches for improving the aroma of Hom Mali rice and reducing costs on each activity were recommended.

Literature Review

ABC is one method that is usually used to improve business performance, to identify high cost activities, and to measure logistic management performance (Askary, Yazdifar, & Askary, 2010; Banomyong, Supatn, & Chaisurayakarn, 2008; Baykasoglu & Kaplanoglu, 2008; Kolosowski & Chwastyk, 2009). The ABC approach is more accurate than traditional costing approaches (Cooper & Kaplan, 1988; Roztocki, Porter, Thomas, & Needy, 2004). It can determine precise process costs, which leads to more effective improvement and better decisions (Kaplan & Cooper, 1998; Kolosowski & Chwastyk, 2009). The ABC method is used to investigate logistics cost more than processing costs because logistics activities are well defined,

while processing activities vary according to the type of business and processes (Imsil, Mankeb, & Mekhora, 2011; Roztocki et al., 2004). Logistics activities (including logistics customer services, transportation, and inventory management) link to many operations and management along the supply chain and mainly affect the operation costs (Ballou, 2004). In a cost analysis of the rice supply chain, Delivand, Barz, & Gheewala (2011) compared the logistics cost between large and small businesses of biomass power generation from rice straw and found that the logistics cost had a direct relationship with business scale. A few studies of logistics costs of the rice supply chain in northeastern Thailand (Imsil et al., 2011; Thoucharee & Pitakaso, 2012) indicated that material handling and transportation activities contributed most to logistics costs for all participants in the supply chain, except for the intermediaries who had procurement cost as the highest cost.

Many studies on volatiles from aromatic rice have focused on the effect of genetic factors and environmental factors on the aromatic quality of rice (Gaur et al., 2016; Itani, Tamaki, Hayata, Fushimi, & Hashizume, 2004; Vanavichit et al., 2018; Verma & Srivastav, 2018; Yoshihashi et al., 2004). However, reductions in the rice aroma can occur under various conditions related to post-harvest system such as logistics and processing activities (Champagne, 2008; Changsri et al., 2015; Wongpornchai et al., 2004). In some studies on the effects of post-harvest factors on the aroma quality of Thai aromatic rice, however, the evidence is still limited. According to previous literature related to effects of factors in post-harvest stage on aromatic rice, conditions affecting aroma loss during the operation are moisture content, temperature, and storage time as presented in Table 1. Using high temperature in the drying process or sun drying for a long time, and longer storage can reduce the 2AP concentrations in rice (Borompichaichartkul et al., 2007; Sunthonvit, Szrednicki, & Craske, 2005; Wongpornchai et al., 2004). The aroma loss of paddy rice during storage is about 75 percent of the original level after two months (Tulyathan & Leeharatanaluk, 2007). Milling process, such as whitening and polishing can cause the loss of aroma (Tsugita, Kurata, & Kato, 1980; Yoshihashi, Huang, Surojanametkul, Tungtrakul, & Varanyanond, 2005). Storing rice under vacuum conditions can maintain the rice aroma longer than from packing rice under normal conditions (Khomwong, 2004; Tananuwig & Lertsiri, 2010; Tulyathan, Srisupattarawanich, & Suwanagul, 2008). The aroma loss during transportation is about 5–20 percent of the total 2AP concentration of finished products at the rice mill. In addition, time and handling activities in the drying process can cause the loss of aroma (Borompichaichartkul et al., 2007; Champagne, 2008).

Methodology

Data Collection

The most well-known Thai Hom Mali rice comes from the Thung Kula Rong Hai region in northeastern Thailand from the five provinces: Roi Et, Surin, Buri Ram, Yasothorn, and Maha Sarakham, one-third being in Roi Et province (Rice

Department, 2017). There are 1,274 agricultural cooperatives in northeastern Thailand, 294 of which are located in these five provinces (Cooperative Promotion Department, 2019). Two agricultural cooperatives, (designated as AC1 and AC2) in Thung Kula Rong Hai region of Roi Et province were selected for this study based on similar production capacity, location, and conditions in order to reduce pre-harvest level effects. Data collection was divided into primary data and secondary data. For the primary data, a questionnaire was developed based on Banomyong et al. (2008) to gather the costs of logistics and processing activities. Data were conducted from in-depth interviews with one manager, three heads of department (procurement, production, distribution), and two staff involved in post-harvest logistics and processing activities at each agricultural cooperative (AC1 and AC2) during November 2015 to February 2016. Hom Mali rice

samples in the rice production process were randomly collected and sent to the laboratory for rice aroma testing (Boonsupthip et al., 2016). Levels of aroma were measured in terms of the amount of the compound 2AP in parts per million (ppm). Secondary data were collected from the recording documents related to production plan and accounting from AC1 and AC2, as well as the review of previous studies of factors affecting the aroma of Hom Mali rice based on logistics and processing costs by using the ABC method.

Data Analysis

The analysis in this study was divided into two parts: the ABC analysis to calculate the logistic and processing costs and partial correlation analysis to investigate the relationship between the aroma and the activity cost.

Table 1 A summary of previous studies focusing on factors affecting rice aroma during the post-harvest stage

Reference	Factors affecting rice aroma	Logistic and processing activities	Main findings on Aroma
Widjaja et al. (1996)	Temperature Time Atmospheric pressure	Storage	Storage condition has impact on the prevention of 2AP.
Lam & Proctor (2003)	Time	Storage	Rice oxidation volatiles increase during storage time.
Khomwong (2004)	Time Types of gas	Packaging	Types of packaging and gas have different impact on the 2AP content.
Wongpornchai et al. (2004)	Temperature Time Moisture content	Drying methods Storage	The amount of 2AP in Thai jasmine rice decreases as the temperature of drying and storage time increased.
Sunthonvit et al. (2005)	Temperature Moisture content	Drying methods	An increase in drying temperature from 100 to 150°C can increase the quantity of 2AP in rice
Yoshihashi et al. (2005)	Temperature	Storage Degree of milling	The higher temperature of storage is, the more decreasing in 2AP concentration.
Borompichaichartkul et al. (2007)	Temperature Time Moisture content	Drying methods Storage	Drying temperature and storage time conditions influenced the amount of 2AP.
Tulyathan & Leecharatanalu (2007)	Time	Storage	The longer storage time has effect on decreasing the amount of 2AP.
Champagne (2008)	Temperature Time Moisture content	Drying methods Storage Drying methods Degree of milling	Postharvest factors have influence on the volatile compound in aromatic rice, which led to loss of aroma.
Kongkiattikajorn (2008)	Temperature Time Moisture content	Storage	Storage duration and temperature has significant effect on preserving 2AP of the aromatic rice.
Tulyathan et al. (2008)	Time Atmospheric pressure	Packaging	The amount of 2AP reduced as storage time increased. Vacuum packaging can stabilize the amount of 2AP concentration.
Goufo, Duan, Wongpornchai, & Tang (2010)	Temperature Time	Storage	Low storage temperature (-4°C) and short storage time (3 months) can maintain 2AP concentration.
Tananuwong & Lertsiri (2010)	Time Temperature	Packaging	Vacuum condition of packaging can maintain the rice aroma longer than regular condition.
Innok, Poommipan, & Thepsilvisut (2016)	Time	Storage	The storage time resulted in reduced amount of 2AP and organic rice has higher level of 2AP than conventional rice.
Wangspa, Vearasilp, & Chanbang (2018)	Temperature Time Moisture content Humidity	Storage	Radio frequency during storage and storage time has affected moisture content and 2AP concentration.

The ABC method (Banomyong et al., 2008; Cooper & Kaplan, 1988), consisted of six steps: defining activity and cost objective, computing total cost for each resource, defining cost drivers and assigning resource costs to each activity by using cost drivers, calculating activity unit costs, conducting total capacity of each activity, and calculating activity cost. Resources were divided into five categories: labor cost, usage area cost, machine and equipment cost, material cost, and transportation cost. These resource costs were allocated to each activity through the cost driver. The cost-based activity was calculated in baht per kilogram (baht/kg) and the percentage of total costs, where the total cost was the sum of the total logistics cost and total processing cost. The gross profit margin of each cooperative was calculated by the difference between revenue and total cost divided by total revenue to compare the ability to generate profit.

In this study, the logistic activity of agricultural cooperative was categorized into five primary activities (L1 raw material receiving, L2 warehousing, L3 material handling, L4 packing, and L5 transportation) and four support activities (L6 Maintenance, L7 Purchasing order operation, L8 Customer service and communication, and L9 Planning and management), which was developed based on Banomyong (2004). According to in-depth interview data, Hom Mali rice processing activity was allocated to 11 activities (P1 to P11), including P1 Cleaning rice paddy, P2 Dehulling rice paddy, P3 Paddy separation, P4 Whitening, P5 Separating 1, P6 Polishing 1, P7 Separating 2, P8 Color sorter, P9 Removing bran, P10 Bagging, and P11 Other activities. The conceptual framework of logistics and processing cost-based activities for agricultural cooperatives

were presented in Figure 1. The activities considered were those with the top-six highest logistics cost and processing cost coupled with the effect of aroma loss during operation.

In the second part of the analysis, the partial correlation between the levels of 2AP, the levels of aroma loss, and the costs of processing activities were considered to address the relationship between the loss of aroma and the activity cost. In this study, the level of aroma loss (*Loss*) was a continuous dependent variable defined as the percentage of the difference in the aroma level in the rice sample from the previous stage and that of the next stage. The activity cost (*Cost*) was a continuous independent variable measured in baht/kg. The control variable is the amount of 2AP (*2AP*) measured in ppm. Hom Mali rice samples were randomly collected in four processing activities (P2, P4, P6, and P10) for rice aroma testing. With the limited number of samples, it is difficult to assess the relationship with standard statistic approaches. The study by De Vaus (2013) indicated that the relationship between variables could be influenced by the third variable. In this case, the relationship between two variables (*Loss* and *Cost*) is biased, caused from the third variable (*2AP*). To explore the relationship between *2AP*, *Loss*, and *Cost*, comparison of the zero-order correlation and the partial correlation (the correlation after controlling for the third variable) was addressed. If the relationship between two variables is influenced by the third variable, controlling for the third variable should substantially reduce or increase the correlations between two variables. The output of this analysis will be used for providing the impact on improvement in four processing activities relating to aroma and cost.

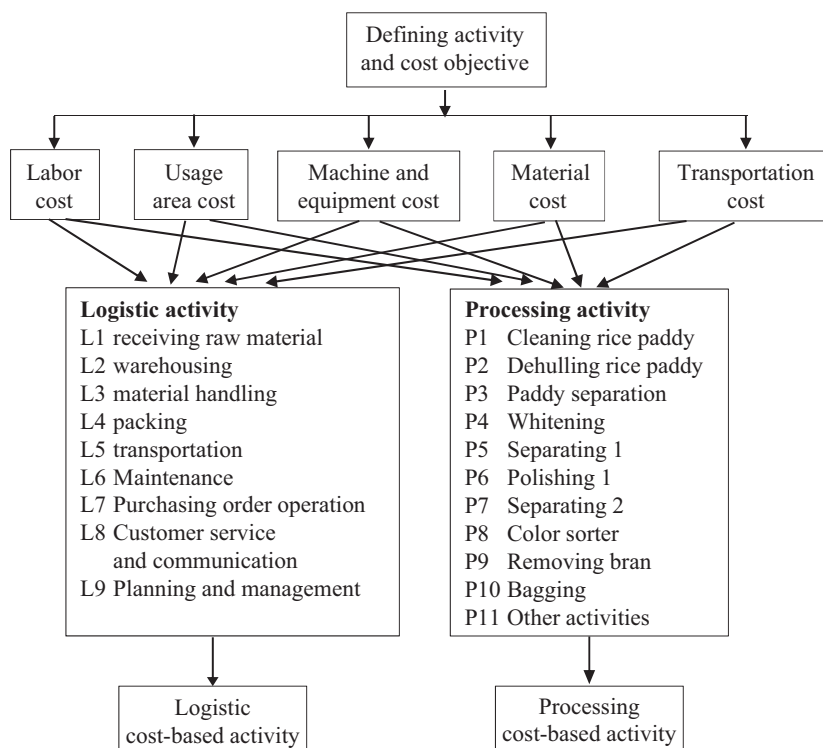


Figure 1 Conceptual framework of logistics and processing cost-based activities

For the improvement of logistic activities relating to aroma, the suggestions were based on the factors affecting the aroma in previous literature due to lack of data on the levels of aroma in logistic activities. In this study, the logistics factors influencing the aroma of Hom Mali rice were temperature, time, and moisture content (Champagne, 2008). Finally, recommendations were provided on loss reduction of rice aroma related to logistic and processing activities. Evaluating the impacts of the improvement in selected activities considered two decision aspects (cost and aroma), where the impact levels consisted of positive (+), neutral (n), and negative (-).

Results and Discussion

Table 2 presents the characteristics of two cooperatives and conditions of Hom Mali rice samples via milling process. The rice milling process of AC1 and AC2 has a production capacity of 90 and 80 tons/day, respectively.

Logistics and Processing Cost Activities

The logistic activity of the agricultural cooperatives started at purchasing paddy from farmer members followed by moving paddy to warehouse, preparing for the production process, milling, packing, and then transporting the packed milled rice to the customer. The logistics costs were allocated to nine activities (L1 to L9) for AC1 and AC2 as shown in Table 3. The findings showed that the difference in logistics cost between AC2 and AC1 was 1.624 baht/kg, where the logistics cost of AC1 was 2.901 baht/kg while the logistics cost of AC2 was 4.525 baht/kg. This difference was due to AC2 having cooling storage of paddy rice, which required more activities in managing inventory level, controlling temperature, and checking quality of rice paddy than did the regular storage of paddy rice.

Overall, the activities with the top-six highest logistics costs for both AC1 and AC2 were similar but were ordered differently. For AC1, the planning and management activity (L9) had the highest logistics cost at 25.49 percent of the total logistics cost followed by those of the packing activity (L4) at 19.69 percent, the raw material receiving activity (L1) at 13.66 percent, the material handling activity (L3) at 12.95 percent, and the transportation activity (L5) at 10.01 percent. For AC2, the warehousing activity (L2) had the highest logistics cost of 34.24 percent and the transportation activity (L5) had the second-highest logistics cost of 18.53 percent, while that of the planning and management activity (L9) ranked third (13.38%), which differed from AC1 because AC1 had four additional receiving raw material centers.

From Table 4, the processing costs were allocated to 11 activities (P1 to P11) for both cooperatives. In general, both AC1 and AC2 had 10 similar processing activities, with one different processing activity (P11) in which AC1 had a grading activity, while AC2 had 2 polishing activities. The results revealed that the processing cost of AC1 was 2.085 baht/kg while the processing cost of AC2 was 1.326 baht/kg. The difference in processing cost between AC1 and AC2 was 0.759 baht/kg because AC2 had a higher cost for bagging, separating, and sorting than did AC1.

Both cooperatives had similar activities with top-six highest logistics costs. For AC1, the highest logistics cost was of the whitening activity (P4) at 18.49 percent of the total processing cost. The costs of cleaning (P1) and polishing 1 (P6) activities were about the same at 12.74 percent and 12.69 percent, respectively. Other activities with a cost higher than 10 percent were dehulling activity (P2) at 11.97 percent and bagging activity (P10) at 11.46 percent. For AC2, the polishing 1 activity (P6) had the highest processing cost at 23.02%, followed by the whitening activity (P4) at 18.49 percent, the cleaning activity (P1) at 10.24 percent, and the first separation activity (P5) at 9.05 percent.

Table 2 Characteristics of the agricultural cooperatives

Cooperative	Production capacity (tons/day)	Storage capacity (tons)	Before milling process		After milling process	
			Moisture content (%)	Temperature (°C)	Moisture content (%)	Temperature (°C)
AC1	90	3,500	14.46	31	14.02	29
AC2	80	8,000	15.82	30	14.67	29

Table 3 Logistic cost structure identified by activities for AC1 and AC2

Logistic activity	AC1		AC2	
	Cost (baht/kg)	Cost (%)	Cost (baht/kg)	Cost (%)
L1. Raw material receiving	0.396	13.66	0.599	13.25
L2. Warehousing	0.221	7.61	1.549	34.24
L3. Material handling	0.376	12.95	0.416	9.20
L4. Packing	0.571	19.69	0.436	9.64
L5. Transportation	0.290	10.01	0.838	18.53
L6. Maintenance	0.186	6.41	0.023	0.51
L7. Purchasing order operation	0.059	2.04	0.025	0.56
L8. Customer service and communication	0.062	2.15	0.031	0.69
L9. Planning and management	0.739	25.49	0.606	13.38
Total	2.901	100	4.525	100

Table 4 Processing cost structure identified by activities for AC1 and AC2

Processing activity	AC1		AC2	
	Cost (baht/kg)	Cost (%)	Cost (baht/kg)	Cost (%)
P1. Cleaning rice paddy	0.266	12.74	0.136	10.24
P2. Dehulling rice paddy	0.250	11.97	0.112	8.42
P3. Paddy separation	0.131	6.27	0.058	4.38
P4. Whitening	0.386	18.49	0.233	17.57
P5. Separating 1 (by size)	0.120	5.77	0.120	9.05
P6. Polishing 1	0.265	12.69	0.305	23.02
P7. Separating 2 (by size)	0.156	7.47	0.063	4.78
P8. Color sorter	0.137	6.59	0.049	3.70
P9. Removing bran	0.057	2.71	0.087	6.58
P10. Bagging	0.239	11.46	0.057	4.32
P11. Other activities	0.080	3.84	0.105	7.94
		(Grading)		(Polishing 2)
Total	2.085	100	1.326	100

In summary, the total cost of AC1 was 4.986 baht/kg, of which the logistics cost was 58.18 percent and the processing cost was 41.82 percent, while the total cost of AC2 was 5.851 baht/kg, of which the logistics cost was 77.34 percent and the processing cost was 22.66 percent as shown in Table 5. The difference in the total cost between AC1 and AC2 was 0.865 baht/kg. The higher total cost of AC2 mainly resulted from warehousing activity, especially cooling storage. If the selling price was about 35 baht/kg, the total cost would be 14.25 percent of the selling price for AC1 and 16.72 percent of the selling price for AC2. Logistics and processing management approaches of AC1 and AC2 could differently affect the cost, profit, and aroma loss during post-harvesting activities. The gross profit margin of AC1 was greater than AC2, indicating that AC1 had a better financial performance than AC2.

Improvement of Logistics and Processing Activities Affecting the Aroma of Hom Mali Rice

Table 6 presented the zero-order and partial correlation between the levels of 2AP (2AP), the levels of aroma loss (Loss), and the costs (Cost) of processing activities. Findings

showed that the zero-order correlations of three pairs were not statistically significant. The correlation of three pairs were statistically significant and remained higher after controlling for the third variable. The negative partial correlation between Loss and 2AP (-0.778), while controlling the activity costs, which was statistically significant, giving that the loss of aroma decreases as the amount of 2AP increases. This suggested that the activity costs have influence in controlling for the relationship between Loss and 2AP. Indirect effects of the activity costs with the levels of 2AP ($2AP \times Cost$) or the levels of aroma loss ($Loss \times Cost$) are larger than direct effects. The relationship ($2AP \times Cost$) changed when controlling the levels of aroma loss in the analysis, providing the positive relationship between the levels of 2AP and the activity costs. This study focuses on the relationship between the activity costs and the levels of aroma loss, which was calculated in the relative value. The positive relationship between Loss and Cost (0.733), giving that the higher the amount of activity cost, the larger the loss of aroma, while controlling the levels of 2AP. Therefore, the significant relationship between the activity costs and the loss of aroma need to be considered in making decision on improvement in processing activity.

Table 5 Comparison between AC1 and AC2 on cost activities and profits

Variable	Cost (baht/kg)		Difference (AC1-AC2)
	AC1	AC2	
Logistic cost	2.901	4.535	-1.624
Processing cost	2.085	1.326	0.759
Total cost	4.986	5.851	-0.865
Selling price	35	35	
Gross profit margin	0.644	0.542	

Table 6 Zero-order and partial correlations between the levels of 2AP, the levels of aroma loss, and the activity costs

Relationship	Zero-order correlation	Controlling for:	Partial Correlation
$Loss \times 2AP$	-0.463	Cost	-0.778**
$Loss \times Cost$	0.493	2AP	0.733*
$2AP \times Cost$	0.553	Loss	0.806**

Note: *** $p < .01$, ** $p < .05$, * $p < .10$.

Since both AC1 and AC2 had common logistic and processing activities, the improvement of selected activities could be recommended for both agricultural cooperatives and indeed for others in general. The improvement of processing activities (P2, P4, P6, and P10) on aroma and cost is shown in Table 7. Through the process from rice paddy to milled rice in the bag, the total loss percentage of aroma (%Loss) for AC1 (15.07%) was lower than that for AC2 (49%). The highest %Loss of aroma was in the polishing activity (P6) followed by the bagging activity (P10), the dehulling activity (P2), and the whitening activity (P4). These four selected activities were related to temperature, time, and moisture content; thus, these activities have a direct influence on the aroma of Hom Mali rice (Champagne, 2008; Changsri et al., 2015).

As discussed above, there is a positive relationship between the cost and the loss of aroma. The whitening activity (P4) and the polishing activity (P6) carried the top-two highest costs, thus, these two activities must be considered. The lower the number of polishing and whitening rounds, the better the quality of the rice (+) and cost reduction (+) are (Champagne, 2008; Yoshihashi et al., 2005). The types of packages and packing condition, such as using a vacuum packing technique, help decrease the loss of rice aroma (+), but increase the packing cost (-) (Tananuwig and Lertsiri, 2010; Tulyathan et al., 2008). Running the process during the night would lower the energy cost (+) and the loss of aroma (+) compared to running the process during the daytime (Changsri et al., 2015; Wongpornchai et al., 2004).

The impacts of improvement of selected logistic activities are presented in Table 8. The improvement of the planning and management activity (L9) and the material handling activity (L3) were not captured because these activities were managed within each organization and required more complicated recommendations. Therefore, only the four selected logistics activities (L1, L2, L4, and L5) were considered, accounting for more than half of the total logistics cost.

The raw material receiving activity (L1) consisted of receiving and sampling, inspection, weighing, unloading from farmers' trucks, piling up in warehouse, and drying before filling paddy into big bags and moving them to another warehouse. Setting a standard for receiving raw material and drying paddy resulted in both cost (+) and aroma (+) impacts (Wongpornchai et al., 2004; Sunthonvit et al., 2005). In the sun-drying process, using human labor force had a lower impact on the loss of aroma than using trucks (Boonsupthip et al., 2016), but the labor cost increased. For the warehousing activity (L2), most activities, such as managing the inventory level and checking the quality of rice, had impacts on the temperature, storage time, and moisture content of Hom Mali rice. Storing paddy rice for a long time caused a high inventory holding cost, as well as losses in rice aroma and weight (Tulyathan & Lecharatanaluk, 2007; Wongpornchai et al., 2004). Cooling storage can be another option for agricultural cooperatives, but the investment and maintenance costs are very high. Thus, it was necessary to consider the trade-off among levels of stock for production, holding cost, and the quality of rice.

Table 7 Impacts of improvement of selected processing activities on aroma and cost

	Improvement of processing activity				AC1				AC2				Impact		Supporting studies
					Cost (baht/kg)	2AP (ppm)	SD	%Loss	Cost (baht/kg)	2AP (ppm)	SD	%Loss	Aroma	Cost	
Rice paddy															
P2. Dehulling					0.250	5.86	0.22	2.98	0.112	2.96	0.11	1.33	+	+	Wongpornchai et al. (2004) Kongkiattikajorn (2008)
- Run the process during the night														n	
- Control the temperature of dehulling													+	-	
- Provide a resting tank															
P4. Whitening					0.386	5.81	0.22	0.85	0.233	2.93	0.19	1.01	+	+	Yoshihashi et al. (2005) Champagne (2008)
- Run the process during the night															
- Reduce the number of whitening stages													+	+	
P6. Polishing 1 and 2					0.265	5.37	0.20	7.57	0.305	1.58	0.08	46.07	+	+	Yoshihashi et al. (2005) Champagne (2008)
- Run the process during the night													+	+	
- Reduce the number of polishing rounds (depending on orders)													+	+	
P10. Bagging					0.239	5.13	0.19	4.47	0.057	1.53	0.09	3.16			Tulyathan et al. (2008) Tananuwig & Lertsiri (2010)
- Vacuum packaging													+	-	

Note that: positive impact (+), no impact (n), and negative impact (-).

Table 8 Impacts of improvement of selected logistics activities on aroma and cost

Improvement in logistics activity	Cost (baht/kg)		Impact		Supporting studies
	AC1	AC2	Aroma	Cost	
L1. Receiving raw material	0.396	13.25			Wongpornchai et al. (2004) Sunthonvit et al. (2005)
- Increasing the standard			+	-	
- Drying method i.e. sun-drying process			+	-	
L2. Warehousing	0.221	1.549			Wongpornchai et al. (2004) Kongkiattikajorn (2008) Tulyathan and Lecharatanalul (2007)
- Proper inventory management			+	-	
- Cooling storage			+	-	
L4. Packing	0.571	0.436			Parthanadee & Lilavanichakul (2016)
- Reusing the storage packaging			n	+	
L5. Transportation	0.290	0.838			
- Managing load utilization and transportation schedule			n	+	
- Delivery during the night			+	n	
- Temperature-controlled vehicles			+	-	

Note: positive impact (+), no impact (n), and negative impact (-).

The packing activity (L4) was mostly related to preparing machines, packing and sealing, and quality control checking. The impact of the packing activity on the loss of rice aroma is difficult to specify because of the variety of types of packaging and machines. Reusing the storage packaging could reduce the cost (+), as well as maintaining the packing machines and training the staff could reduce the loss from damage and defects. The transportation activity (L5) involved the costs of vehicle usage, such as fuel cost, driver salaries, and hiring costs of outsourced transport providers. In general, the agricultural cooperative had two types of transportation: outsourced and owned trucks. The selection of the transportation method depended on various factors including load utilization, hiring rates of outsourced transport, delivery time, and transportation scheduling. To improve the cost, the cooperatives should manage to maximize the load and to optimize scheduling and consolidating orders to reduce line hauls. Regarding the rice aroma, the changes in the transportation system, (i.e. open or closed system, and temperature maintenance during transportation) could improve the aroma loss reduction (+) by delivering during the night or using insulated or temperature-controlled vehicles, but have higher costs (-). The case study of the loss of Hom Mali aroma during transportation, for long distance (over 1,000 km with 27-29 hours of transportation), indicated that rice under the closed insulated transportation system (with 2AP loss of 3.34%) has lower losses of 2AP than that under the open system (with 2AP loss of 18.07%) (Parthanadee & Lilavanichakul, 2016).

Conclusion and Recommendation

The cost structure of the rice mills of both agricultural cooperatives was categorized by the logistics and processing activities using the ABC method. The relationship between the loss of aroma and the activity cost for processing stage was explored using zero-order and partial correlation. Not only were the improvements defined in activities with high logistics and processing costs, but the degree of aroma loss during

post-harvest operations was also considered. The results revealed that the total cost per unit of AC1 and AC2 was 4.986 baht/kg and 5.851 baht/kg, respectively. Both AC1 and AC2 had similar logistics activities but slightly different processing activities.

For the partial correlation analysis, the relationship between the activity costs and the loss of aroma, while controlling for the levels of 2AP, is statistically significant. The two prominent processing activities were polishing and whitening following by bagging, and dehulling. Whitening and polishing costs accounted for one-third of total processing cost, so reducing the number of polishing and whitening rounds had a positive impact on loss of aroma and cost. Moreover, the types of package and packing condition could maintain the rice aroma, as well as reduce the cost and damage.

The relevant logistic activities that the cooperatives should focus on were raw material receiving activity, warehousing activity, packing activity, and transportation activity. Some logistics activities (i.e. cooling storage and delivery time) were related directly to the rice aroma loss, while other activities (i.e. managing load utilization and reusing storage packaging) had more impact on the cost than the aroma loss. Moreover, the cooperatives could reduce the logistics cost by increasing collaboration in the supply chain among stakeholders. Improvements in cost and aroma loss reduction could provide a competitive advantage and an opportunity to enter new markets. However, the decision on the characteristics of the rice, and hence the relevant processing activities, must depend on customer requirements and markets. Thus, the cooperatives should make decisions on the improvement of cost and aroma loss reduction based on considering the costs and benefits, as well as the goal of its cooperative.

Conflict of Interest

There is no conflict of interest.

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