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# The study of business process and decision support of raw milk blending for a collecting centre in Thailand

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**Abstract**

Milk is a high nutrient food source. Its major composition includes water, fat, protein, sugar, vitamin and minerals. In Thailand, milk consumption has been promoted through school dairy projects. There are dairy farms throughout Thailand, of which most are small-sized farms. This leads to an uneven nutrient composition due to different agricultural practices, feed, and environments. Thus, the factors that affect the nutrient composition in raw milk should be studied. The Royal Thai government should encourage farmers to Good Agricultural Practice (GAP) so that the nutrients in raw milk are compliant with national standards. The collecting centre must inspect the nutrient composition to ensure that it meets specifications before it is delivered to milk plants. In addition, the raw milk price depends on the fat content. The collecting centre collects raw milk from farmers twice a day. The results of a survey show that raw milk collected in the morning and afternoon has different nutrient compositions; raw milk in the morning has less fat than milk in the afternoon. After raw milk is delivered to the collecting centre, it is cooled and kept in a storage tank. Then, it must be delivered to the milk plants on a daily basis. Hence, our objective is to formulate a mathematical model to determine how to blend raw milk collected in the morning and afternoon so that the total cost of raw milk is minimised while the nutrient composition specification is satisfied. Then, the model is solved using a spreadsheet, and a decision support system is proposed so that the quality control supervisor can determine how to blend raw milk daily. Finally, the blending model is compared with manual blending using the actual data for ten days. It shows that the average costs of both methods are the same; however, the percentage of passing on total solid is improved from 50% to 70%. In addition, the decision time is reduced from 15 minutes to one minute.



## Introduction

In Thailand, the dairy industry has been promoted according to the National Economic and Social Development Plan No. 4 (1977–1981) and the National Economic and Social Development Plan current No.11 (2012–2016) (The National Economic and Social Development Board, 2011). The objectives aim to augment Thai people's health and to support cow milk farmers (Food Intelligence Center, 2014). The Royal Thai government established a school milk project in 1992 to boost elementary and primary students' nutrition. In addition, the school milk project has reinforced the domestic milk supply chain, which has low competitiveness (School Milk Programs, 1992). The consumption rate of milk products increased, on average, by 3.4% annually from 2009 to 2013, and the yield of raw milk increased by 7.66% annually (Office of Agricultural Economics, 2013). Cow farms are spread throughout the country, but the central region is the major producer accounting for 70% of milk produced. Most farms are small in size with no more than 20 cows per farm. After milking, farmers (or a third party) must deliver raw milk to the nearest collecting centre within one hour (Thai Agricultural Standard TAS 6401-2005, 2005). After that, raw milk is inspected to ensure that it does not contain undesirable components such as additional water, antibiotics, detergents and disinfectants, pesticides or bacteria.

Milk is a high nutrient food source, and its composition includes water, lactose (milk sugar), fat, protein and minerals. It contains energy-supplying nutrients from fat and carbohydrates, body-building nutrients from proteins and minerals, and adequate amounts of almost all vitamins necessary for the proper functioning of the biochemical processes

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essential for life (Porter, 1975). However, the undesirable components found in milk are additional water, antibiotics, detergents and disinfectants, pesticides and bacteria. In addition, somatic cells in milk indicate that the milk is from an infected cow or mastitis (Wattiaux, n.d.). From a commercial viewpoint, features of milk composition include its content of protein, fat, solids-not-fat (SNF), and total solids, since the amounts of these constituents affect the yield of milk. According to raw milk standards, it must contain no less than the specific amounts of these ingredients, and there must be no signal of infection, adulteration or contamination. This standard is to ensure that raw milk is of good quality and is safe for consumption. Milk collecting centres have an important role in the flow of raw milk from farms to dairy manufacturers (Muhammad *et al.*, 2014; Ongkunaruk, 2014). Specifically, their main role is to inspect raw milk for food safety purposes. Previously, there were problems regarding the inclusion of antibiotics, specific chemicals and adding water to the milk (Demirbas *et al*., 2009).

At present, technological innovations and competitive pressures have encouraged retailers and processors to improve supply chain management for dairy products. Glenn *et al.* (2002) found that the delivery schedule in the Florida milk industry has profound effects on cost structure and profitability. The delivery schedule change from a five-day to a seven-day has reduced the costs associated with inventories and has increased the freshness of the milk. Subbaiah *et al.* (2009) developed the four echelon logistics network distribution for dairy supply chains in India. Other researchers studied the dairy supply chain and a traceability system to enhance capability and to integrate and share information along the supply chain (Magliulo *et al.*, 2013). Glover *et al.* (2014) studied the energy consumption of dairy supply chain stakeholders in UK by implementation of institutional theory with an interview stakeholders from suppliers, farmers, milk processors, retailers, logistics providers and consumers. The findings could be a source of information to policy maker of energy reduction for sustainable supply chain.

Linear Programming (LP) is an efficient tool for solving optimisation problems. Optimisation models express an actual problem in mathematical terms with the goal of solving the problem in the best possible way (Nash and Sofer, 1996). Microsoft Excel spreadsheet has become one of the most popular software packages in the business world. It is convenient for a worker without mathematical programming knowledge to use the Excel interface (Ragsdale, 2004). A spreadsheet is a tool to build problem-solving models. Ghodsypour and Brien (1998) designed a spreadsheet to determine the best supplier by using an integration of the Analytic Hierarchy Process and LP using the Microsoft Excel Solver. Then, Cunha and Mutarelli (2007) proposed a mixed integer programming (MIP) model to minimise the total cost of production and distribution of a newsmagazine in Brazil. Similarly, Ragsdale *et al*. (2008) created an MIP tool for optimising the creation of a golf team pattern to ensure a reasonable level of fairness during the tournament. Spreadsheet was applied for user interfaces with decision support systems, such as in wood panel manufacturers, in which Buehlmann *et al.* (2000) used LP in Excel to determine raw material mix to minimise total cost while respecting all quality related constraints. Then, they developed a decision support system using VBA programming language in Excel, which enables better decision-making in business for users unfamiliar with optimisation and modelling tools. In the brass casting industry, Sakalli and Birgoren (2009) developed and implemented a spreadsheet based decision support tool for blending problems. Furthermore, the user interfaces have been designed to model an LP in Microsoft Excel, which is linked with the Lingo modelling language. In addition, the decision support system implemented in a fishery supply chain can be found in Teniwut and Marimin (2013).

Ongkunaruk (2015) analysed a pasteurised milk supply chain in Thailand using the Integration Definition for Function Modelling. One of the ways to improve a dairy supply chain was to develop a spreadsheet (to support the decision for blending raw milk) so that its composition is aligned with the national standard. Hence, this research aims to solve the raw milk blending problem and proposes a spreadsheet as a decision support system for the staff to increase the efficiency of blending to satisfy the customer requirements and to reduce the cycle time. In addition, cost can be saved t due to higher content of fat after blending. We developed a blending model using linear programming (LP) to minimise the total cost of raw milk while ensuring that the nutrient composition specification was satisfied. Since the LP model has never been implemented in the collecting centre, the model was developed and solved using Microsoft Excel, and the user interface was designed by Visual Basic for Applications (VBA) in Excel as a decision support system for the staff.

## Materials and Methods

Our study is to focus on the business process analysis of a case study company, which is a raw milk collecting centre. We selected the company who is a supplier of a dairy milk plant at Kasetsart University. First, we performed in-depth interviews with the managing director and related staff at the case study raw milk collecting centre. Then, a swim lane diagram was drawn to present the sequences, time intervals between activities and relationships of the activities with other functions in a company or with stakeholders such as a supplier or customer. The activities are presented in a square box with a number, and the length of the box indicates the time interval between activities. The box is located in a row, which indicates the responsible functions of a stakeholder of that activity. The arrow identifies the direction of the relationship from one function/stakeholder to another function/stakeholder. Then, a problem was identified with the blending process, and we collected the number and capacity of storage tanks, pricing policies, raw milk specifications, and historical data of actual blending to verify the model. Next, we created a mathematical model formulation in which we proposed an LP model to solve the blending problem and presented it in the Excel spreadsheet. The model was formulated to determine how much to blend from each tank so that the cost was minimised while the nutrient composition specifications were met. Then, we verified the model and solved the problem using Excel. Next, we validated the model with the historical data. In order to implement this model in the milk collection centre or cooperative, the decision support system was developed to aid the staff to determine how much milk to blend. Finally, we constructed a user interface on a spreadsheet by writing a VBA program as a decision support system for the blending problem so that the staff member could simply use the program by inputting the data on the spreadsheet and clicking the “RUN” button. The result is quickly calculated.

## Results and Discussion

### *Business process analysis*

After milking, raw milk is collected in a tank and delivered to the nearest collecting centre within one hour by farmers or collectors. First, upon receiving the shipment, the staff samples the raw milk from each tank and put it in a small tube to begin the quality check (using an alcohol test or the California Mastitis Test (CMT test)). If the test result is positive, it implies that the raw milk is infected, and it will be rejected. Otherwise, raw milk is weighed to record the amount for payment. Next, the raw milk is chilled to 4°C and stored in storage tanks. During storage, the raw milk is fully inspected. Firstly, a total microorganism count is performed with either the methylene blue test (which takes four hours) or the resazurin test (which takes one hour). Secondly, the antibiotic test is performed to ensure that raw milk is from a healthy cow. Thirdly, the nutrient composition test is performed to determine the amount of fat, total solid, solid not fat (SNF), protein and raw milk density to conclude whether there is additional water present (Thai Agricultural Standard TAS 6401-2005, 2005). If the milk passes the inspection, then it is blended, loaded into the truck and delivered to the customers. Otherwise, it is rejected. The staff traces the raw milk back to its owner, and the farmer will be fined.

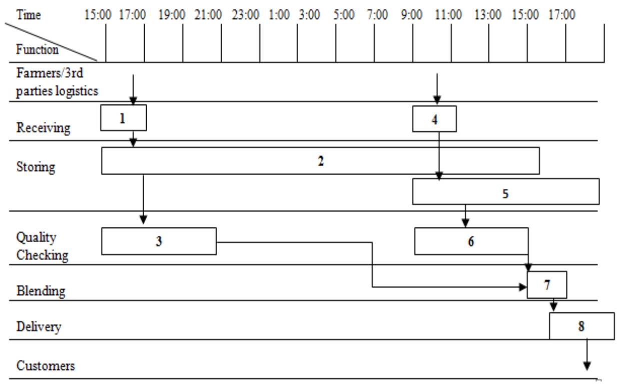

Figure 1. Swim lane diagram of raw milk collecting centre

Then, a swim lane diagram was presented in Figure 1. Farmers, or third parties who collect raw milk from several farms, deliver raw milk to a collecting centre twice a day. Next, activities 1 and 4 represent the receiving process of raw milk in the afternoon and morning, respectively. Each time, the receiving process takes two hours since the centre collects 900 tanks from more than one hundred farms. If raw milk passes the primary test, then it will be weighed and chilled, which is included in the receiving process. Then, activities 2 and 5 represent raw milk kept in the storage tanks in the afternoon and morning, respectively. Raw milk will be kept until it is blended which should not be over 36 hours after receiving. Next, the quality control staff performs the full quality check as mentioned above. Hence, the activities are presented in boxes 3 and 6: these steps take six hours. If the raw milk does not include antibiotics, then the staff will blend raw milk from the storage tank and the truck, since the fat content of raw milk collected in the morning is always less than that collected in the afternoon. The staff used trial and error to blend milk (Activity 7) from yesterday afternoon and today morning tanks so that the nutrient composition, especially the total solid, fat and SNF, was higher than what was required. Finally, the raw milk will be delivered to the customers (Activity 8).

Table 1. Formulations and descriptions of raw milk blending spreadsheet

| Cell | Formulations/Descriptions | Explanation |
|---|---|---|
| E11:E13 | Standard fat content and price of raw milk | Input by users |
| C15 | Demand for raw milk (tons) | Input by users |
| C16 | Tank size in a truck (tons) | Input by users |
| C17 | =ROUNDUP(G14/G15,0) | Amount of time to blend |
| B21:B26 | The number of storage tanks | Input by users |
| C21:F26 | Input milk composition contents of storage tanks | Input by users |
| C28:F28 | Requirement of milk composition | Input by users |
| J21:J26 | Available amount of raw milk (tons) | Input by users |
| C27 | SUMPRODUCT(C21:C26,$G$21:$G$26)/$G$28 | % Protein after blending |
| D27 | SUMPRODUCT(D21:D26,$G$21:$G$26)/$G$28 | % Solid not fat after blending |
| E27 | SUMPRODUCT(E21:E26,$G$21:$G$26)/$G$28 | % Total solid after blending |
| F27 | SUMPRODUCT(F21:F26,$G$21:$G$26)/$G$28 | % Fat after blending |
| G21:G26 | Amount to be blended in each tank (tons) | Decision variables |
| G27 | SUM(G21:G26) | Total blended amount (tons) |
| G28 | C15 | Demand for raw milk (tons) |
| H21 | G21/$C$17 | Amount to be blended |
| H22:H27 | Copy from H21 to H22: H27 | in a tank (tons) |
| K21 | IF(F21>0,(F21-$E$11)*$E$13/0.1+$E$12,0) | Price of raw milk by |
| K22:K26 | Copy from K21 to K22:K26 | % Fat (b/kg) |
| K27 | SUMPRODUCT(G21:G26,K21:K26)/G28 | Minimum price (b/kg) |

*Types of raw milk blending*

We assume that the delivery of raw milk is less than the availability of raw milk stored in the tank. In general, there are several sizes of storage tanks. In the collecting centre, there are two cases of blending as follows. First, blend raw milk in medium-sized storage tanks into a large-sized tank. Then, load raw milk from the large tank into the small-sized tanks in the truck. Second, blend raw milk in medium-sized storage tanks into the small-sized tanks in the truck. Hence, we designed a unique spreadsheet to solve both cases simultaneously.

*Mathematical model formulation*

*Indices and Sets*

i A raw milk composition index,

I a set of components in raw milk = {1,2 …K}

j A storage tank index,

J a set of storage tanks = {1,2,…N}

*Parameters*

K The number of components of raw milk

N The number of storage tanks

D Amount of milk to be blended (tons)

$A_j$ Amount of raw milk in tank j (tons)

Ri requirement of proportion of composition I (%)

$X_{ij}$ proportion of composition i in tank j (%)

$C_j$ Cost of raw milk in tank j (THB per kg),

where,

$$C_j = 16.5 + \frac{0.02}{0.1}\left(X_{3j} - 3.3\right) \quad ,\forall\ j \in J$$

*Decision variables*

$Q_j$ Amount of raw milk in tank j to be blended

*Model formulation*

$$\text{Objective Function: } Min \sum_{j=1}^{N} C_j Q_j \qquad (1)$$

The standard raw milk with a fat content of 3.3% is 16.50 baht per kilogram. Every increase in fat content by 0.1% increases the price by 0.02 THB.

Subject To

$$Q_j \le A_j \qquad ,\forall\ j = N \qquad (2)$$

$$\sum_{j=1}^{N} X_{ij} Q_j \ge R_i \qquad ,\forall\ i \in K \qquad (3)$$

$$\sum_{j=1}^{N} Q_j \ge D \qquad (4)$$

$$Q_j \ge 0 \qquad ,\forall\ j \in N \qquad (5)$$

The objective function minimises the cost of raw milk as in Equation (1). Next, Inequality (2) implied that the amount to be blended was no more than the availability in the storage tank. Then, Inequality (3) ensures that the composition of raw milk after blending meets at least the requirement. Inequality (4) implies that the total blended raw milk is no less than the demand for raw milk. Finally, Inequality (5) are the non-negativity constraints.

*A case study problem solving*

In the case study, let $I$ = {Protein, SNF, Total solid, Fat} and $J$ = {Tank B1, Tank B2, Tank B3, Tank A1,

Table 2. Comparison between current and proposed model blending of the actual data

| Date | Cost (Baht) | | Solid not fat (%) | | Total solid (%) | | Fat (%) | |
|---|---|---|---|---|---|---|---|---|
| | Current | Program | Current | Program | Current | Program | Current | Program |
| 1 | 16.58 | 16.55 | 8.70 | 8.72 | 12.38 | 12.30 | 3.68 | 3.57 |
| 2 | 16.57 | 16.59 | 8.46 | 8.48 | 12.11 | 12.23 | 3.65 | 3.75 |
| 3 | 16.55 | 16.59 | 8.38 | 8.36 | 11.28 | 12.00 | 3.56 | 3.73 |
| 4 | 16.54 | 16.54 | 8.30 | 8.30 | 11.85 | 11.85 | 3.52 | 3.52 |
| 5 | 16.56 | 16.55 | 8.43 | 8.43 | 11.93 | 11.96 | 3.62 | 3.53 |
| 6 | 16.57 | 16.57 | 8.38 | 8.39 | 12.01 | 12.06 | 3.63 | 3.67 |
| 7 | 16.57 | 16.54 | 8.47 | 8.49 | 12.13 | 12.00 | 3.66 | 3.51 |
| 8 | 16.55 | 16.56 | 8.48 | 8.50 | 12.04 | 12.11 | 3.56 | 3.61 |
| 9 | 16.56 | 16.56 | 8.48 | 8.48 | 11.86 | 11.88 | 3.59 | 3.60 |
| 10 | 16.54 | 16.55 | 8.42 | 8.44 | 11.93 | 12.00 | 3.51 | 3.56 |
| Average | 16.56 | 16.56 | 8.45 | 8.46 | 11.95 | 12.04 | 3.60 | 3.61 |
| | | % Pass | 10 | 10 | 50 | 70 | 100 | 100 |

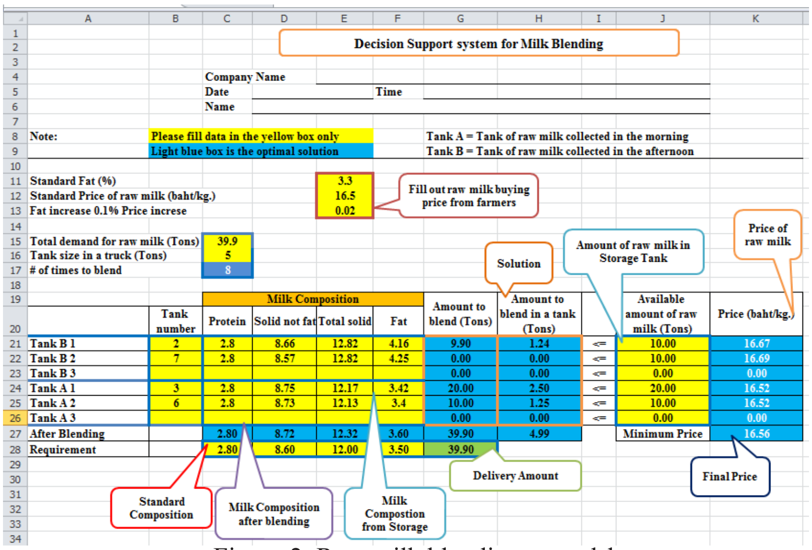


Figure 2. Raw milk blending spreadsheet

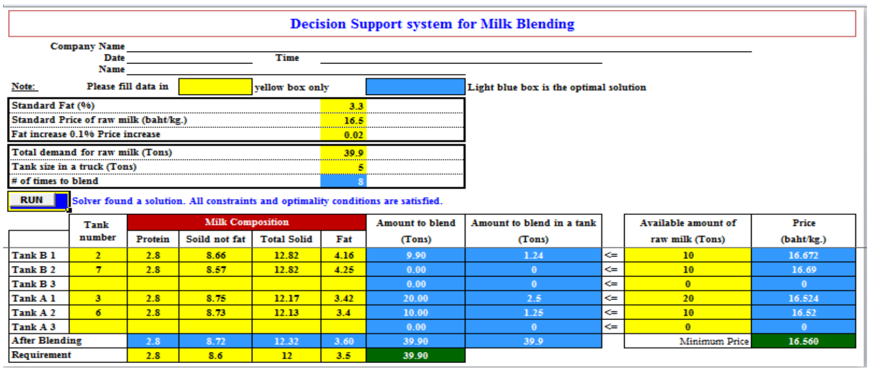


Figure 3. The Decision Support System for Raw Milk Blending

Tank A2, Tank A3}, where raw milk collected in the afternoon is kept in Tank B while raw milk collected in the morning is kept in Tank A. Then, the model and an actual input data are presented as a spreadsheet in Figure 2, and the description of each cell is specified in Table 1. After verifying the model, the problem is solved using the Solver of Microsoft Excel. Then, the decision support system is designed and coded in VBA to interface the model in Microsoft Excel as shown in Figure 3. Hence, the quality control supervisor is able to simply click the “RUN” button to determine how to blend raw milk daily. This would save workers’ time while satisfying the customers’ requirements. Finally, we validate the program by collecting 10 days data and compare the results between program and actual blending. First, the decision time of DSS is shorter than that of current from 15 minutes to one minute. Second, the average costs of both methods are the same, but the percentage of passing on total solid of DSS is improved from 50% to 70%. However, the percentages of passing on solid no fat and fat of both methods are the same as shown in Table 2. This implies that the optimal blending still could not pass the specification. Hence, the collecting centre should discuss this with the farmers and government whether we could enhance the quality of milk or adjust the specification to match the actual production in Thailand.

## Conclusion

The collecting centre must inspect the nutrient composition of raw milk to ensure that it meets specification guidelines before delivery to milk plants. Raw milk collected in the morning and afternoon has different nutrient compositions. Thus, the quality control supervisor has to decide how much milk to blend from different tanks and how much time this will take. Currently, there is no tool to aid in decision-making, and sometimes, after blending, raw milk does not meet specification guidelines. Hence, the linear program for raw milk blending was proposed to determine how to blend raw milk collected in the morning and afternoon so that the total cost of raw milk was minimised while the nutrient composition specification was satisfied. The model is presented and solved in Excel. However, without an understanding of the LP model, a worker could not use it. Thus, the decision support system in Excel is constructed to assist the user to decide on the most efficient raw milk blending tactic. In the future, other raw milk collecting centres and cooperatives that collect raw milk could use this decision support system to aid their staff in completing the most efficient raw milk blending. In addition, the study of factors that affect the nutrient composition in raw milk should be conveyed so that the right strategies are implemented to enhance the compliance probability with national standards. Then, we will provide this program to some collecting centres for their usage and follow the progress. Since different collecting centres may have different pricing scheme and requirement. Then, the program must be customised for the individual collecting centre.

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## References

Buehlmann, U., Ragsdale, C.T. and Gfeller, B. 2000. A spreadsheet-based decision support system for wood panel manufacturing. Decision Support Systems 29: 207-227.

Cunha, C.B. and Mutarelli, F. 2007. A spreadsheet-based optimization model for the integrated problem of producing and distributing a major weekly newsmagazine. European Journal of Operational Research 176: 925-940.

Ghodsypour, S.H. and O'Brien, C. 1998. A decision support system for supplier selection using an integrated analytic hierarchy process and linear programing. International Journal of Production Economics 56-57: 199-212.

Demirbas, N., Tosun, D., Cukur, F. and Golge, E. 2009. Practices in milk collection centres for quality milk production: a case from the aegean region of Turkey. New Medit N(3): 21-27.

Food Intelligence Center. 2014. The Situation of Production Dairy in Thailand. Retrieved from *http://fic.nfi.or.thfooduploadpdf6_1746.pdf.*

Glenn, S.J., Kilmer, R.L. and Stevens, T.J. 2002. Supply Chain Management and Production Agriculture: A Florida Dairy Case. Choices *(www.choicesmagazine.org/2002-4/2002-4-09.pdf)*, Florida, Winter 2001-2002, p. 24-25.

Glover, J.L., Champion, D., Daniels, K.J and Dainty, A.J.D. 2014. An institutional theory perspective on sustainable practices across the dairy supply chain. International Journal of Production Economics 152: 102-111.

Magliulo L., Genovese L., Peretti V. and Murru N. 2013. Application of ontologies to Traceability in the dairy supply chain. Agricultural Sciences 4(5B): 41-45.

Muhammad, Z., Akhter, S.N. and Ullah, M.K. 2014. Dairy supply chain management and critical investigations on dairy informal channel partners in Pakistan. Journal of Business and Management 16(3): 81-87.

Nash, S. G. and Soffer, A. 1996. Linear and Nonlinear Programming. McGraw-Hill, Singapore.

Office of Agricultural Economics. 2013. Milk cow. Journal of the Situation and Trends of Major Agricultural 2014: 151-157.

Ongkunaruk, P. 2015. Business process analysis and improvement for a raw milk collection centre in Thailand. Agriculture and Agricultural Science Procedia 3: 35 – 39.

Porter J.W.G. 1975. Milk and Dairy Foods. Oxford University Press, London.

Ragsdale, C.T. 2004. Spreadsheet Modelling and Decision Analysis (4th ed.). South-Western Publishing, Ohio.

Ragsdale, C.T., Scheibe, K.P. and Trick, M.A. 2008. Fashioning fair foursomes for the fairway (using a spreadsheet-based DSS as the driver). Decision Support System 45: 997-1006.

Sakalli, U.S., Birgoren, B. 2009. A spreadsheet-based decision support tool for blending problems in brass casting industry. Computer and Industrial Engineering 56: 724-735.

School Milk Programs. 1992. History of School Milk Programs School. Retrieved from *http://www.schoolmilkthai.com/home.php.*

Subbaiah, K. V., Member, IEAENG, Rao, K.N. and Nookesh Babu, K. 2009. Supply chain management in a dairy industry-a case study. Proceedings of the World Congress on Engineering I, London, UK, WCE.

Teniwut, Y. K. and Marimin. 2013. Decision support system for increasing sustainable productivity on fishery agroindustry supply chain. ICACSIS 2013, 297-302.

Thai agricultural standard TAS 6401-2005. 2005. Good manufacturing practices for milk collection center. National Bureau of Agricultural Commodity and Food Standards.

Wattiaux, M.A. (n.d.). Milk composition and nutritional value, dairy essentials-lactation and milking. Babcock Institute for International Dairy Research and Development, University of Wisconsin-Madison p. 73-76.

The National Economic and Social Development Board. 2011. The eleventh national economic and social development plan (2012-2016). *(http://eng.nesdb.go.th/Portals/0/news/plan/eng/THE%20ELEVENTH%20NATIONAL%20ECONOMIC%20AND%20SOCIAL%20DEVELOPMENT%20PLAN(2012-2016).pdf)*