ANTIOXIDANT (FLAVONOID) IN THAI COCOA BEAN

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ABSTRACT

Cocoa is a high-yielding economic crop and well cultivated in the tropical climate of Thailand. *Theobroma cacao* tree, or cocoa, has recently garnered increasing attention and become the subject of research due to its antioxidant properties, which are related to potential anti-cancer effects. In the past few years, identifying and developing active compounds or extracts from the cocoa bean such as polyphenol and flavonoid have become an important area of health and biomedicine-related research. Phytochemicals (Phytonutrients) are biological substances found only in plants. One of them is Polyphenols: Flavonoids. Cocoa is an important source of Polyphenol, which is a healthy antioxidant. It can be seen that cocoa has many beneficial nutrients. Therefore, this research was done with the Department of Food Science, National Pingtung University of Science and Technology, Taiwan and Thai coffee-cocoa company. Cooperated with the Faculty of Innovative Agricultural Management, Panyapiwat Institute of Management, Thailand. The objective of this research was to determine volume of antioxidant (Flavonoid) from Thai cocoa (Chumphon#1 Pa7xNa32) bean. The samples of cocoa bean were analysis by ISO17025 laboratory and using High Performance Liquid Chromatography (HPLC). The result showed that total flavonoid content of cocoa formula B is higher than formula A. For future study can be adds value to farmers who are interested in this business including food and non-food products and for commercial products.

Keywords: Antioxidant, Flavonoid, Phytochemicals, Polyphenol, Thai cocoa bean

Introduction

Cocoa is a high-yielding economic crop and well cultivated in the tropical climate of Thailand. *Theobroma cacao* tree, or cocoa, has recently garnered increasing attention and become the subject of research due to its antioxidant properties, which are related to potential anti-cancer effects. In the past few years, identifying and developing active compounds or extracts from the cocoa bean such as polyphenol and flavonoid have become an important area of health and biomedicine-related research. Phytochemicals (Phytonutrients) are biological substances found only in plants. One of them is Polyphenols: Flavonoids. Cocoa is an important source of Polyphenol, which is a healthy antioxidant. It can be seen that cocoa has many beneficial nutrients. Therefore, this research was done with the Department of Food Science, National Pingtung University of Science and Technology, Taiwan and Thai coffee-cocoa company. Cooperated with the Faculty of Innovative Agricultural Management, Panyapiwat Institute of Management, Thailand. The objective of this research was to determine volume of antioxidant (Flavonoid) from Thai cocoa (Chumphon#1 Pa7xNa32) bean. The samples of cocoa bean were analysis by ISO17025 laboratory and using High Performance Liquid Chromatography (HPLC).

Objectives

1. To determination on volume of antioxidant (Flavonoid) from Thai cocoa bean

Literature Review

A. Overview of Cocoa

Theobroma cacao tree, or cocoa, Peoples from Olmec and Mayan believed that cacao bean had a divine origin and belief it as “food of the gods”. Based on the scientific name of Theobroma, Theo is meaning “food” and Broma is meaning “gods” (Coe SD and Coe MD. 1996; Knight I. 1999; Zainal B. et al., 2014). Cocoa seeds (beans), which was used for drinking called chocolate, a precursor to the modern chocolate. Recently garnered increasing attention and become the subject of research due to its antioxidant properties, which are related to potential anti-cancer effects. In the past few years, identifying and developing active compounds or extracts from the cocoa bean that might have anti-cancer effects have become an important area of health- and biomedicine-related research. Medicinal plants are of great importance to the health of individuals and communities. The medicinal value of these plants lies in some chemical substances that produce a definite physiological action on the human body and these chemical substances are called phytochemicals. These are non-nutritive chemicals that have protective or disease preventive property. The most important of these phytochemicals are alkaloids, flavonoids, tannins and phenolic compounds (Hill, 1952).

Polyphenols are a large groups of natural compounds widely distributed in variety of plants. They are known to have antioxidant properties with potential health benefits (Subhashini R. et al., 2010). Current research has shown that polyphenols contribute to the prevention of cardiovascular diseases, cancers, and osteoporosis and antioxidant character with potential health benefits (Arts & Hollman, 2005; Lambert et al., 2005; Joseph et al., 2005). They are known to have beneficial effects on cardio vascular system. (Keen et al., 2005; Sies et al., 2005; Vita, 2005) and have a role in the prevention of neurodegenerative diseases and diabetes mellitus (Scalbert et al., 2005).

B. Overview of Flavonoid

Flavonoids (Figure 1,2) are an important class of natural products; particularly, they belong to a class of plant secondary metabolites having a polyphenolic structure, widely found in fruits, vegetables and certain beverages. They have miscellaneous favorable biochemical and antioxidant effects associated with various diseases such as cancer, Alzheimer's disease (AD), atherosclerosis, etc (Panche et al., 2016).

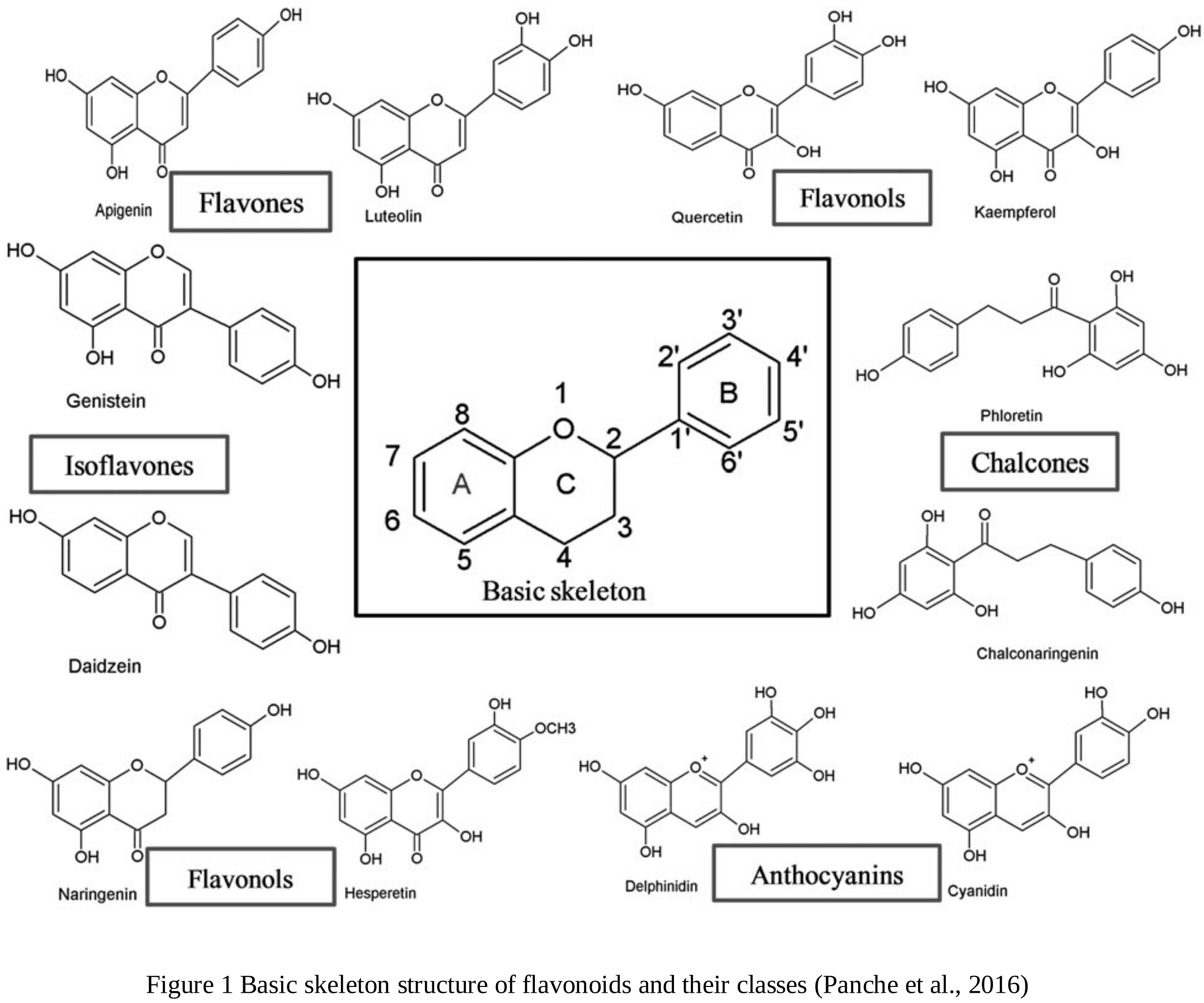

Figure 1 Basic skeleton structure of flavonoids and their classes (Panche et al., 2016)

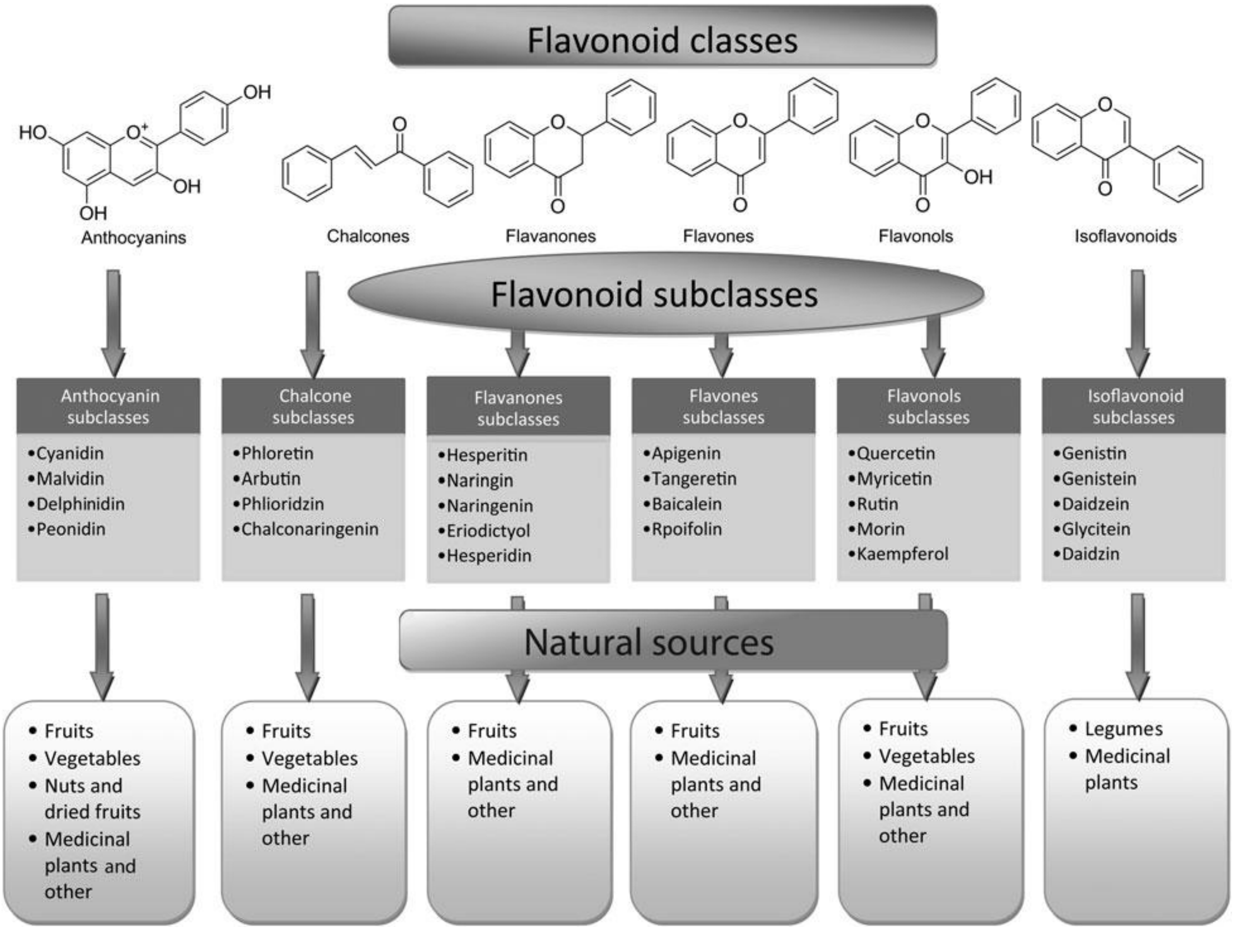

Figure 2 Flavonoid classes, subclasses and natural sources (Panche et al., 2016)

Plants contain a large and heterogeneous group of biologically active compounds, including a subgroup of phytochemicals known as phenolic compounds. Flavonoids are a family of phenolic compounds with strong antioxidant activity present in fruits, vegetables, and other plant foods. More than 5000 structurally unique flavonoids have been identified in plants, and several hundred occur commonly in consumed foods. Flavonoids may be divided into six different major classes (flavonols, flavanones, flavones, isoflavones, flavonols and anthocyanidins) based on differences in molecular backbone structure (Figure 3) **(**Nasiruddin et al., 2014**)**.

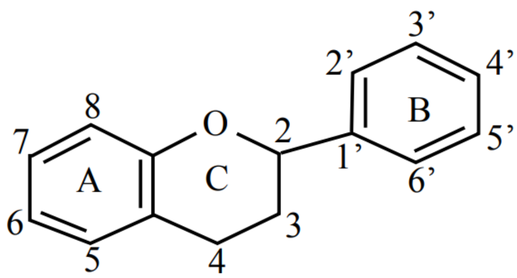

Figure 3 General structure of flavonoids **(**Nasiruddin et al., 2014**)**

Flavonoid content determination Total flavonoid content (TFC) was determined using the aluminium chloride (AlCl3) colorimetric assay. Briefly, 50 µl of the extracts at 1 mg/ml in 80% ethanol was mixed with 50 µl of 2% AlCl3 solution in the well of a 96 wellplate. The plate was incubated for 15 min at room temperature. The absorbance at 435 nm was measured using a microplate reader. Quercetin from 1.56 to 100 µg/ ml served as a standard. Total flavonoid content is expressed as mg quercetin equivalents (QE) per g dry plant material. Samples were analyzed in triplicate (Moragot Chatatikun1 and Anchalee Chiabchalard, 2017).

C. Mechanism of flavonoid action

Animal and invitro studies support the concept that food and beverages rich in flavonoids and other phenolic compounds are associated with decreased risk of age-related disease. The mechanisms through which flavonoids exhibit their beneficial effects include the ability to scavenge a wide range of reactive oxygen, nitrogen and chlorine species such as superoxide, hydroxyl radical, peroxyl radicals, hypochlorous acid and peroxynitrous acid. They also chelate ions, often decreasing the metal ion pro-oxidant activity. The positive effects of flavonoids could be attributed to its antioxidant property. Studies suggest that increased oxidative damage may contribute to the development of all major age-related diseases. Flavonoids exhibit better activity than natural (ascorbic acid and α-tocopherol) and synthetic (trolox, butylated hydroxyanisole and butylated hydroxytoluene) antioxidants, used in the food industry. Modern in vitro spectrophotometric methodologies revealed that many plant extracts and isolated compounds possess antioxidant activity (Nasiruddin et al., 2014**)**.

D. Determination of total flavonoid content

Content of flavonoids in purified extract of cocoa beans (Theobrama cacao) is determined by aluminum chloride colorimetric assay method. 1 mg of purified extract is dissolved in methanol solvent. The volume is added up to 50 ml in a measuring flask. 0.5 ml of sample solution is pipetted and put in a 50 mL measuring flask then added 20 mL of distilled water. 1.5 mL of 5% $NaNO_2$ was left for 5 minutes. After 5 minutes was added 0.15 mL of 10% $AlCl_3$. After 5 minutes it was added 10 mL of 1 M NaOH up to 50 mL in volume with distilled water. Solution absorbance was measured at 510 nm. Standard curve was constructed using various concentrations of catechins. Results are expressed as a percent of catechins and purified extract by using HPLC (Shimadzu shim-pack ODS C18) with an eluent of methanol: water: 40:60. (Andi and Elly, 2014).

Methods

A. Cocoa bean sample preparation

Thai cocoa bean sample (Chumphon#1 Pa7xNa32) from Thai coffee-cocoa company after processing, formula A (cocoa bean from northern region) and B (cocoa bean from southern region).

B. Total flavonoid content analysis by High Performance Liquid Chromatography (HPLC) technique from Agriculture and Aquaculture Product Inspection and Certification, Department of Food Science, National Pingtung University of Science and Technology, Taiwan (http://www.caapic.npust.edu.tw/)

B.1 Extraction of Flavonoids from cocoa bean

About 1 g (accurately weighed to 0.0001 g) of cocoa bean was extracted with 25 mL of 95% ethanol under 200 rpm shaking for 24 hr. After filtration, the filtrate was adjusted to 25 mL with 80% ethanol and stored in an amber bottle. In solid form, 0.1 to 1 g (accurately weighed to 0.0001 g) was first dissolved with 10 mL of 80% ethanol. After centrifugation at 1,000 x g for 10 min, the supernatant was collected and the precipitate was then extracted with 5 mL of 80% ethanol twice. Finally, the supernatant was combined with previous supernatant and adjusted to 25 mL with 80% ethanol. Liquid sample were directly diluted with 80% ethanol to the concentrations appropriate for colorimetric analysis (Chang et al., 2002).

B.2 Estimation of total flavonoid content

(I) Aluminum Chloride Colorimetric Method, The aluminum chloride colorimetric method was modified from the procedure reported by Woisky and Salatino 1998. Quercetin was used to make the calibration curve. Ten milligrams of quercetin was dissolved in 80% ethanol and then diluted to 25, 50 and 100 µg/mL. The diluted standard solutions (0.5 mL) were separately mixed with 1.5 mL of 95% ethanol, 0.1 mL of 10% aluminum chloride, 0.1 mL of 1M potassium acetate and 2.8 mL of distilled water. After incubation at room temperature for 30 min, the absorbance of the reaction mixture was measured at 415 nm with a Shimadzu UV-160A spectrophotometer (Kyoto, Japan). The amount of 10% aluminum chloride was substituted by the same amount of distilled water in blank. Similarly, 0.5 mL of ethanol extracts or 15 flavonoid standard solutions (100 ppm) were reacted with aluminum chloride for determination of flavonoid content as described above.

(II) 2,4-Dinitrophenylhydrazine Colorimetric Method The current method was modified from the procedure described by Nagy and Grancai 1996. (±)-Naringenin was used as the reference standard. Twenty milligrams of (±)-naringenin was dissolved in methanol and then diluted to 500, 1000 and 2000 µg/mL. One milliliter of each of the diluted standard solutions was separately reacted with 2 mL of 1% 2,4-dinitrophenylhydrazine reagent and 2 mL of methanol at 50˚C for 50 min. After cooling to room temperature, the reaction mixture was mixed with 5 mL of 1% potassium hydroxide in 70% methanol and incubated at room temperature for 2 min. Then, 1 mL of the mixture was taken, mixed with 5 mL of methanol and centrifuged at 1,000 x g for 10 min to remove the precipitate. The supernatant was collected and adjusted to 25 mL. The absorbance of the supernatant was measured at 495 nm. The ethanol extracts of propolis and 15 flavonoid standard solutions (1000 ppm) were similarly reacted with 2,4-dinitrophenylhydrazine for determination of flavonoid content as described above.

C. Statistical analyses

Statistical analysis was using PASW Statistics 18 software. Difference between two means was evaluated using Student's t-test. Differences were considered significant when the *P*-value was less than 0.05.

Results and Discussion

A. Total flavonoid content analysis

The levels of total flavonoid content were determined using High Performance Liquid Chromatography (HPLC) technique. The results showed that total flavonoid content of formula A was 61.48b mg/100g and formula B was 131.74a mg/100g respectively. That significant when the *P*-value was less than 0.05 follow by Figure 3. Therefore, formula B have total flavonoid content more than two time when compare with formula A because preparing technique from Thai coffee-cocoa company.

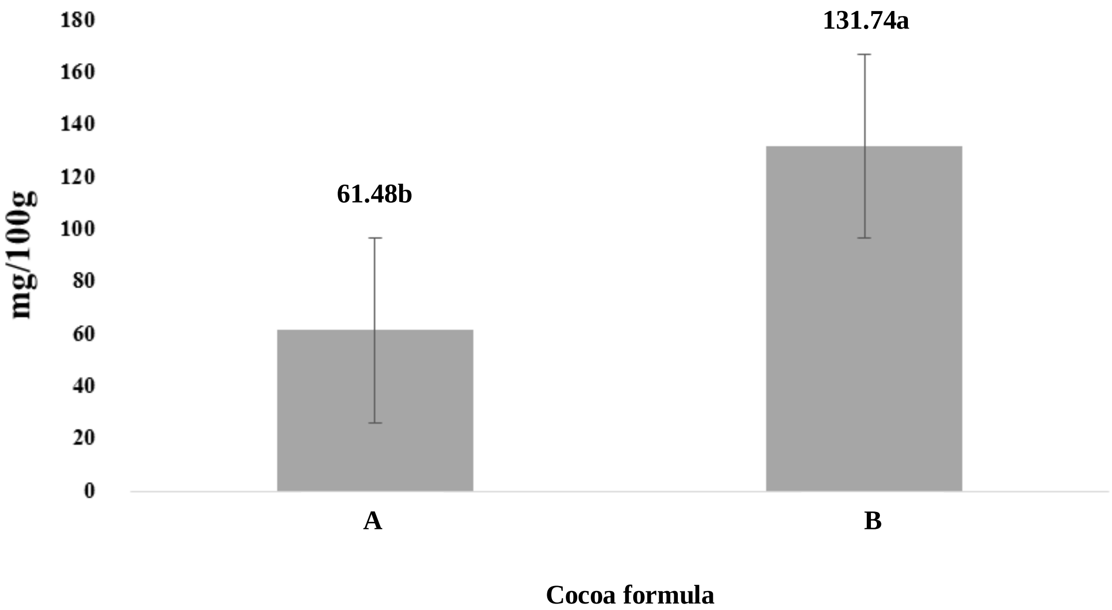

Figure 4 flavonoid content from Thai cocoa bean formula A and B

Moreover, Gu et al., 2013 reported, the levels of total flavonoid content were determined through the colorimetric assay method. The average total flavonoid content ranged from 35.03 mg/10 g to 126.21 mg/10 g. The total flavonoid content was the highest in the Hainan 2011 Foods 2013, 2 191 sample, followed by the samples from Papua New Guinea and Indonesia. Therefore, total flavonoid content depending on cocoa species, area, planning technique, fermentation and food process from cocoa farm to cocoa bean.

For Thai cocoa company and business can be modify and develop technique to increase the phytochemicals, antioxidant, flavonoid. Value added for food and noon-food that use cocoa bean was concern for future research.

Conclusions

The results obtained from this study are essential in understanding on volume of antioxidant (Flavonoid) from Thai cocoa bean. The sample of cocoa bean were analysis by ISO17025 laboratory and using High Performance Liquid Chromatography (HPLC). This research is a first report of total flavonoid from Thai cocoa bean (Chumphon#1Pa7xNa32). The flavonoid content of cocoa formula B (131.74 mg/100g) is higher than formula A (61.48 mg/100g). Further research is needed to determine the effect of the growing conditions, storage time and fermentation on the physico-chemical and flavor quality attributes of industrial raw cocoa material. Moreover, can be added value to farmers who are interested in this business including food and non-food products and for commercial products.

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MEASUREMENT OF PORK LOIN EYE AREA BY USING LOW COST IMAGE PROCESSING SYSTEM

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ABSTRACT

The intent of this study was to develop a method to measure the loin eye area of swine carcass. In the experiments, the RGB color images of loin cuts were acquired by using low cost flatbed scanner. The acquired RGB images were converted to HSI (hue, saturation and intensity) color space. Gray-scale thresholds were employed to detect and count the total number of pixels of loin eye area. The total number of pixels of loin eye area were computed to determine the loin eye area in comparison with three different method, so-called point counting method by using 0.25 and 1.0 cm^2 of grid and planimeter. Pearson correlation and linear regression were used to investigate the accuracy among all methods. Easiness and difficulties perception of users in the performance of each method were recorded. The results indicated that the developed method was shown the highest correlation with traditional planimeter method and it had the high potential applicability to measure the loin eye area of swine carcass in consideration of being easy and fast to operate and economical.

Keywords: loin eye area, plastic grid, point counting, image processing, planimeter.

Introduction

From 2014 to 2018, the growth of swine production in Thailand had significantly increased. The number of pigs increased from 12.82 million in 2014 to 19.88 million in 2018. Moreover, the domestic consumption of pork in Thailand increased from 0.973 million tons in 2014 to 1.45 million tons in 2018 and accounted for 97% of the swine production (Office of Agricultural Economics, 2015; Office of Agricultural Economics, 2019). Lean meat are widely used for different cooking methods of Thai cuisine. In order to receive a better market price, the pork producers are trying to develop the pig breeds that will give the high quality carcasses with a high percentage of lean meat (Srikanchai and Charoensook, 2018). To determine the quality of swine carcass, many methods were applied including the determination of loin eye area which can be estimated by point counting method, circumference method, weighing paper method and planimeter (Satos et al., 2014; Ray, 2004). However, these traditional methods were time consuming and tedious.

Recently, image processing method has been intensively employed to assess the quality of agricultural products including meat quality (Ferreira et.al, 2012; Shiranita et al., 2000; Girolami et al., 2013; Gerrard et al., 1996). As such, the adoption of image processing method, many researches were also done to determine the quality of meat by measuring the area of different parts in pork carcass by using image processing such as loin eye area of pork (Satos et al., 2014) and ham area (Jia et al., 2010). However, these studies were carried out by using various types of device such as a CCD camera and video camera that were required the suitable illumination unit. Nowadays, a flatbed scanner (FBS) has been gradually used to record the image for image processing system according to the advantages in term of cost and applicability (Ferreira et.al, 2012; Junkwon et al., 2014; Kaur et al., 2014). In this sense, the image processing method incorporated with scanning image by the flatbed scanner would represent an easier and cheaper method for measuring the loin eye area of swine carcass.

Objectives

The purpose of this study was to evaluate the potential applicability of image processing method to measure the loin eye area of pig in comparison with analysis based on traditional point counting on plastic grid method and planimeter.

Literature Review

Meat and meat products are an important source of protein in human diet and their quality varies according to intrinsic and extrinsic parameters that can sometimes be affected to the characteristics of meat (Furnols & Guerrero, 2014). A survey about consumer preferences for pork chop in Canada by Ngapo (2017) revealed that the most important choice criteria for the consumers were fat cover and lean color while they were taste, tenderness, juiciness, flavor, scent and marbling in Swaziland (Ndwandwe & Weng, 2017). In addition, a study that was done by Brewer at al. (2001) on marbling effects on quality characteristics of pork loin chops indicated that highly marbled chops appeared lighter color, less lean and less acceptable appearance. In Thailand, the lean meat is preferable meat for the consumers. Therefore, the consumer‘s preferences on pork are different and varies by the countries. For swine production in Thailand, Currently, Large White, Landrace and Duroc are the most popular pig breeds. The majority of pork producers prefer to breed the female hybrids of Large white and Landrace with a male Duroc, in order to explored the heterosis and complementarity of litter size trait from the female, and the fast growth rate and high percentage of lean meat from the male. Such a pattern is the standard pig breeding model utilized in Thailand (Srikanchai and Charoensook, 2018).However, fat thickness and loin eye area are two crucial factors for measuring the quality of pork carcass. Research by Pringle and William (2000) revealed that lean growth by reducing fatness and increasing muscles may have negative impact to consumer acceptability. Therefore, an appropriate breeding program for swine production should emphasis on the preferences of the customers and quality of meat.

Computer vision employing image processing method has been developed rapidly in diverse fields: medical diagnostic, factory automation, remote sensing, forensics, autonomous vehicle and robot guidance and assessing of agricultural products (Tan, 2004; Brosnan and Sun, 2004). In general, image processing method generally consists of the following five steps as shown in Figure 1, which are (1) image acquisition operations to convert images in to digital format; (2) pre-processing operations to improve the original image to obtain the suitable image which has the same dimensions the original one; (3) image segmentation operations to partition a digital image into disjoint and non-overlapping regions; (4) object measurement operations to measure the characteristics of objects such as size, shape, color, texture and (5) classification operations to identify objects by classifying them into different groups (Du and Sun, 2004).

For image acquisition, it is the first step of image processing system where an image is captured in digital form. The development of sensors has been intensively done for image acquisition for decades. Various configurations of sensors have been used to convert images in to digital form such as charge coupled device (CCD) camera, video imaging (VI), flatbed scanner (FBS), hyperspectral imaging (HI), ultrasound magnetic resonance imaging (MRI), computed tomography (CT) and electrical tomography (ET) (Du and Sun, 2004; Elmasry et al., 2012; Feng and Sun, 2012; Cross et al., 1983; Ferreira et.al, 2012; Junkwon et al., 2014; Kaur et al., 2014). CCD camera is frequently utilized by the image processing system. However, the suitable illumination system is a crucial requirement to capture the high quality image. On the contrary, flatbed scanner is also widely used for acquiring the image because it is user friendly and low cost device.

Pre-processing is the step that image is improved its quality by reducing the degradation of image during the image acquisition. Two different types of image preprocessing approaches can be identified for agricultural products: pixel pre-processing and local pre-processing. For pixel-preprocessing, color space transformation is the most common pixel pre-processing method. HSI (hue, saturation and intensity) is an effective tool for color image distinguishing. In general, color images are taken by a digital device and saved in the three-dimensional RGB (red, green and blue) color space. For the efficient color image processing of beef, Li et al. (2001) transformed the image from RGB format into the HSI format. Examination and preliminary analysis of the different image formats indicated that the saturation component gave a monochromatic image and revealed the muscle image texture most clearly. Local pre-processing methods calculate the new value based on the averaging of brightness values in some neighborhood points. In the most basic local pre-processing approach, simple filter is usually used to suppress noise or other small fluctuations in the image.

Image segmentation is generally used to partition an image into its constituent objects which meets the objective of the analysis. Thresholding based method is the most effective method that has been employed for segmentation. To detect the bruise in the magnetic resonance image of apple, a simple thresholding was used to distinguish between bruise and non-bruise pixels (Zion et al., 1995).

After the image segmentation is successfully done, the objects can be described and represented for further processing and analysis by measuring the individual features of each object. In general, a segmented object can be represented in features of its external characteristics or internal characteristics such as size, shape, color and texture.

Then the classification to identify objects is done by classifying them into one of the finite sets of classes, which involves comparing the measured features of a new object with those of a known object or other known criteria and determining whether the new object belongs to a particular category of objects. Statistical, fuzzy logic, and neural network are three main methods of classification in the literature (Du and Sun, 2004).

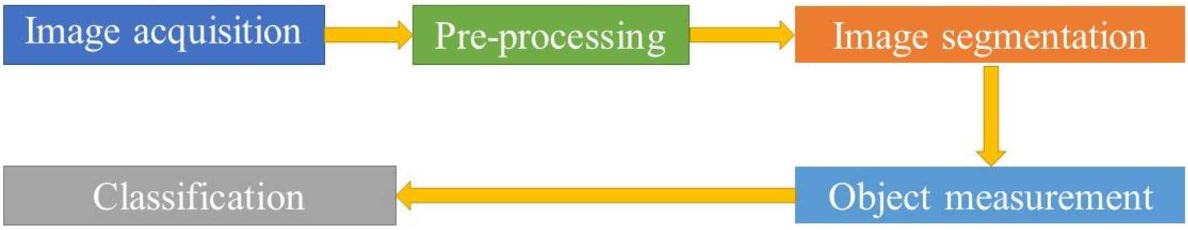


Figure 1 Common image processing system configuration (Du and Sun, 2004)

Research in meat quality started in the early of 80s to analyze the characteristics and qualities of meat (Tan, 2004). Ferreira et.al (2012) developed the method to measure the rib eye area of sheep by using image processing method. Scanned images were measured the dimensions of the rib eye area and calculated to determine their size in comparison with planimeter and grid method. The results revealed that image processing method showed high correlation with other traditional method and could be considered to determine the rib eye area of the sheep carcass. Irie and Kohira (2012) tried to develop the rapid method to measure the beef marbling in loin muscles. A spot method that measured 3 to 5 locations (2.5 to 3.0 cm in diameter) compared to the overall trace method which analyzed the whole muscles. The results indicated that the spot method could be used for measuring the marbling especially for high marbled beef. Cross et al. (1983) used the video image analyzer to predict the composition of rib eye section of beef. Total lean area, rib weight, total fat area and fat thickness were measured. The results showed that video image analyzer may have the considerable potential for yield grading device for commercial or research purpose. Chmiel and Slowinski (2016) developed the method to determine the defects of *logissimus lumborum (LL)* of swine by using image processing. The HSL (hue, saturation and lightness) color apace was selected for classifying the color of the muscles to detect the defects and yielded the accuracy at 81.7%. The results implied that the developed method was able to employ for rapid analysis under industrial condition. Barbin et al. (2012) developed the method to assess the quality of loin eye area of pork by using near-infrared hyperspectral imaging region 900-1700nm. Spectral information was use to predict the color features, drip loss, pH and sensory characteristics by partial least-squares regression (PLS-R) models. The results showed that color reflectance, pH and drip loss of pork meat could be predicted with determination coefficients (R^2) of 0.93, 0.87and 0.83, respectively. Results indicated that this technique is a potential tool for rapid assessment of pork quality. Since many researches were done to determine the quality of meat by image processing method, it may have a potential to apply for measuring the qualities of loin eye area of pig.

Methods

Forty samples of 1 cm thick of loin cuts from swine carcasses in Nakorn Pathom province were used in this study to develop a method to measure the loin eye area by using image processing. To capture the image of the loin cut, the samples were individually put into the transparent plastic bag and scanned by low cost flatbed scanner (Brother, DCP-1610W) as shown in Figure 2. Next, the loin eye area of each image was manually determined (Figure 3) and saved in the three-dimensional RGB (red, green, blue) color space as illustrated in Figure 4. Then, color space transformation was selected in present study to enhance some image features. HSI (hue, saturation and intensity) color space is frequently selected for color space transformation according to the effective color image distinguishment (Du and Sun, 2004). Therefore, hue, saturation and intensity band images of loin area in HSI color space were created based on red, green and blue band images of color images by using image processing software (Halcon 7.0, MvTec Germany) as shown in Figure 5 and 6. With trial and error approach, gray scale values ranging from zero to 128 of saturation band image displayed the most efficient method of detecting loin eye area from background as displayed in Figure 7. Finally, the total number of pixels of loin eye area were counted and were used to estimate the size of loin eye area by calibrating with the total number of pixels of calibration object which had area of one cm^2 as noted in equation (1).

$$\boldsymbol{Loin\ eye\ area\ (LEA)(cm^2) = \frac{total\ number\ of\ pixels\ of\ loin\ eye\ area\ (pixels)}{total\ number\ of\ pixels\ of\ calibration\ object\ (1\ cm^2)}} \quad (1)$$

Furthermore, the samples were drawn on sheets of paper and copied to measure the loin eye area by using three methods. The first and the second method were point counting on plastic grid of 1 and 0.25 cm^2 as described by Santos et al. (2014) as shown in Figure 8. The last method was based on polar planimeter (Koizumi, KP 90N, Japan) as done by Ferreira et.al (2012) as in Figure 9.Then data of loin eye area from each method were submitted to analyze Pearson correlation and linear regression by using SPSS version 24 (SPSS, Inc., Chicago, IL). Easiness and difficulties perceived by the evaluators in the performance of each method were also recorded.

Figure 2 Image of loin cut by using flatbed scanner

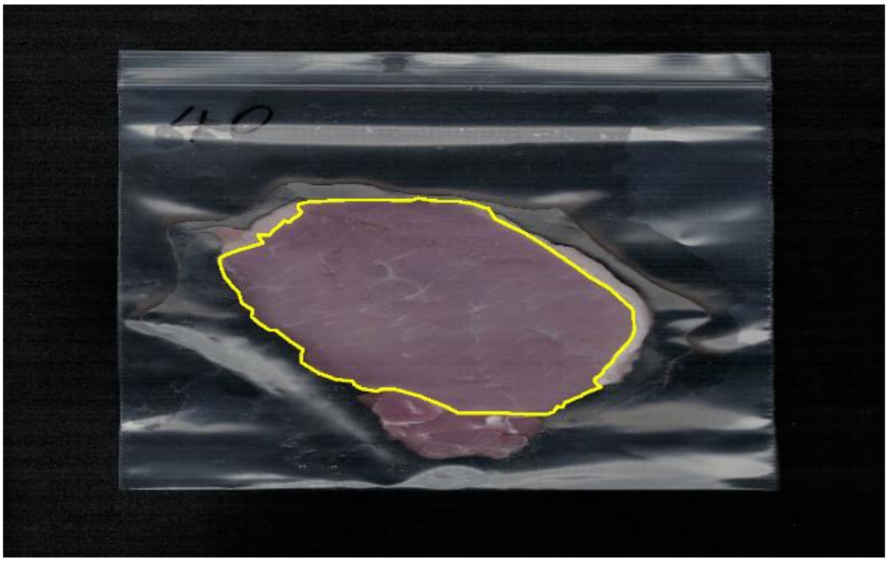


Figure 3 Manually selection of loin eye area

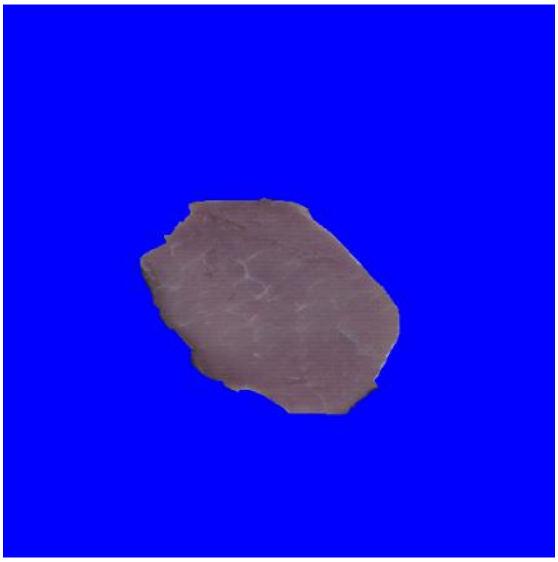


Figure 4 Image of loin eye area

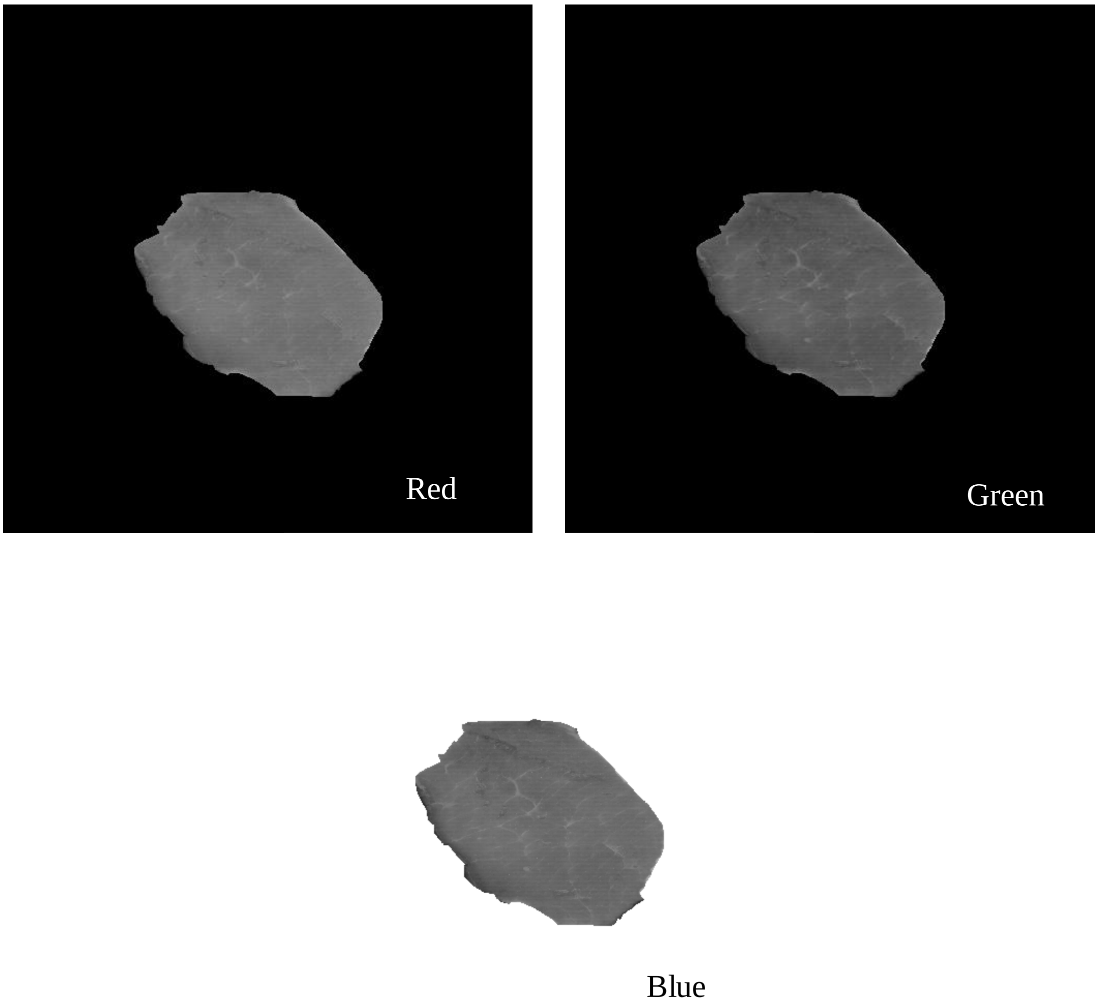


Figure 5 Image in RGB color space

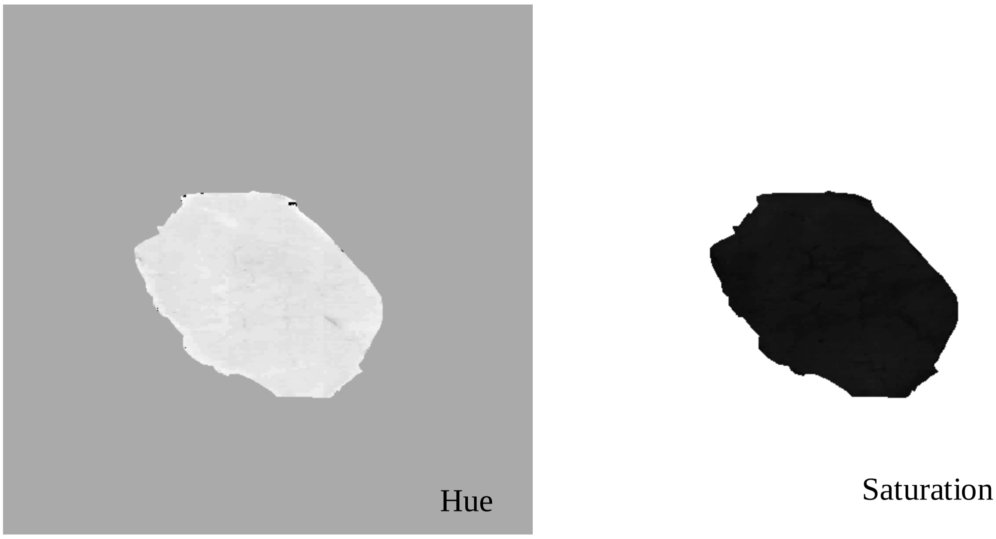


Figure 6 Image in HSI Color space

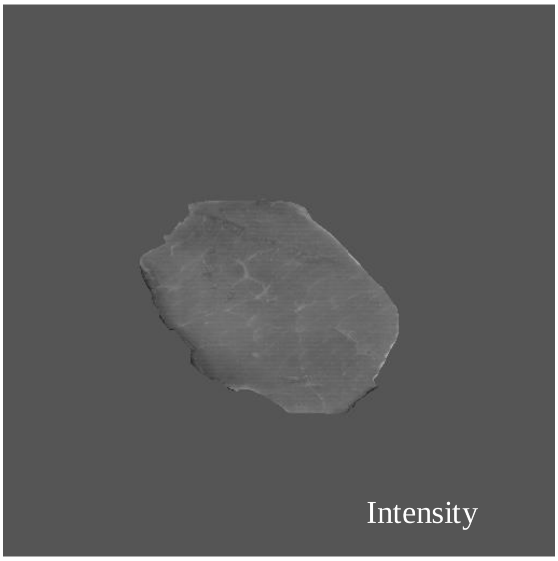


Figure 6 Image in HSI Color space

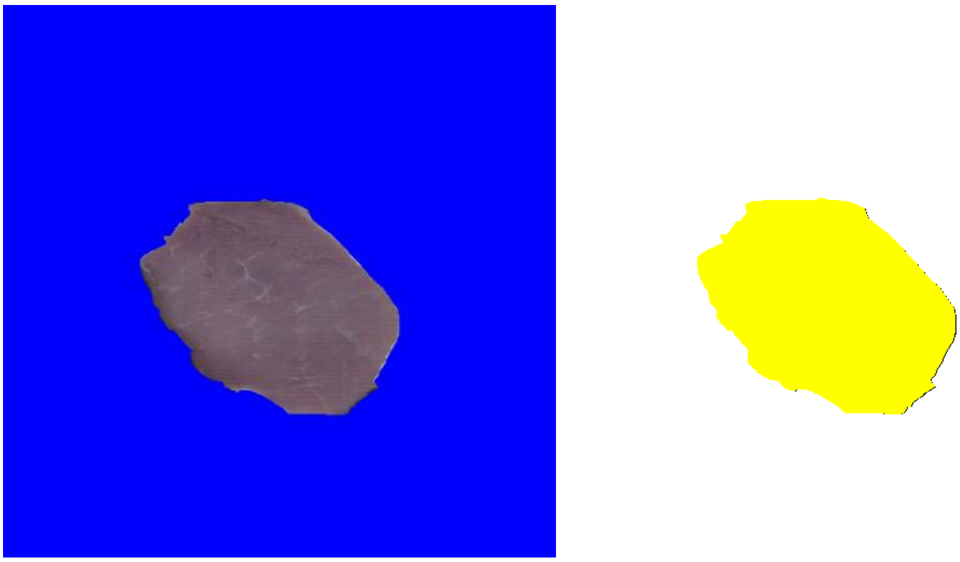
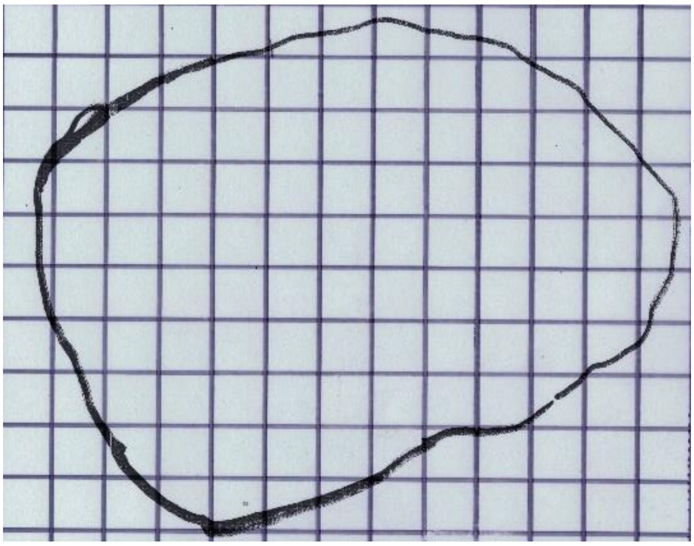
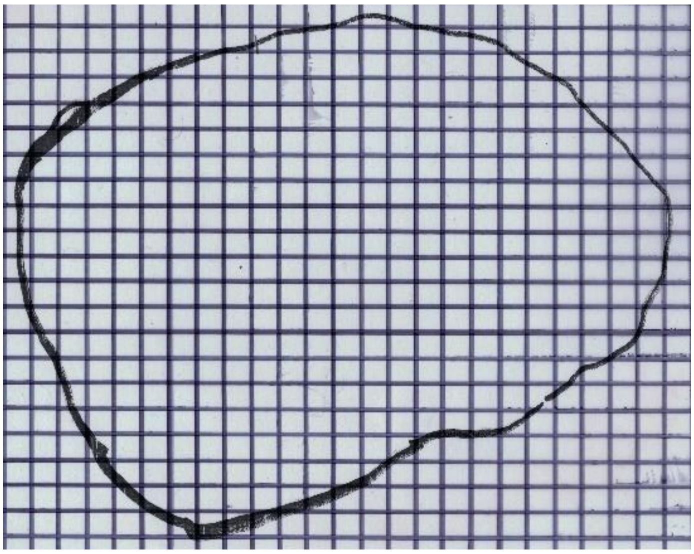


Figure 7 Detection of loin eye area



(a) $1cm^2$ grid
Figure 8 Point counting method



(b) $0.25cm^2$ grid
Figure 8 Point counting method

Figure 9 Measurement of loin eye area by using planimeter

Results and Discussion

The correlation coefficient obtained for loin eye area value determined by each method were displayed in Table 1 and the relationships of loin eye area obtained by image processing method and other methods were illustrated in Figure 10. In this study, the Pearson correlation coefficients were higher than 0.969 in all correlations. This may implied that all methods would have very high accuracy and high potential for measuring the loin eye area.

For image processing method, the highest correlation coefficient was found in correlation between image processing method and planimeter while the lowest correlation coefficient was expressed in correlation between image processing method and point counting method on plastic grid of 1 cm^2. As the correlation between image processing method and point counting method, the correlation results showed that the greater correlation coefficient was obtained in smaller grid. This fact could be confirmed by the linear regression in Figure 10 that the relationship between image processing to other method had the same tendencies as the one of Pearson correlation. In this case, the image processing method underestimated the loin eye area as occurred in comparison with that obtained by other methods.

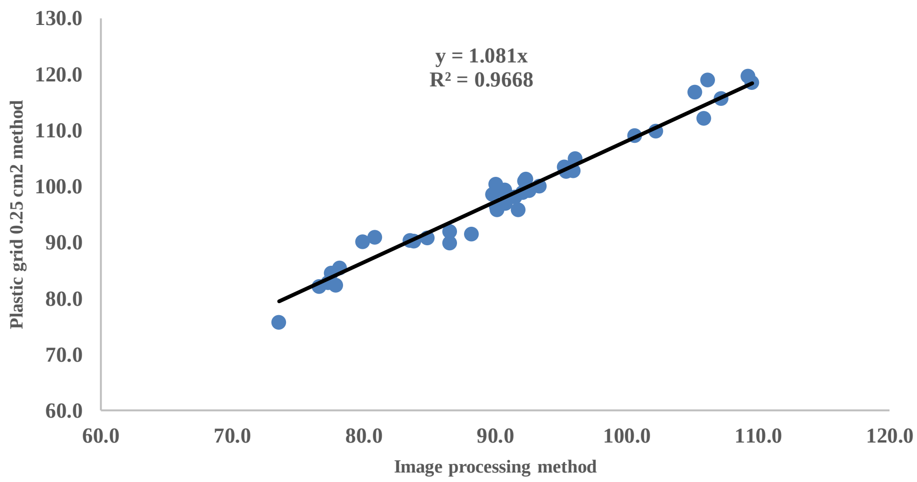
For point counting method, the higher correlation coefficients was obtained by the correlation between point counting method on 0.25 cm^2 of grid and planimeter than that of 1.0 cm^2 of grid. The similar result was described by Santos et al. (2014) that 0.25 cm^2 of grid expressed the superior accuracy than 1.0 cm^2 of grid according to an overestimation of user.

Among the methods tested, the point counting method was the most difficult method in this study especially 0.25 cm^2 of grid. Due to the determination of area fractions in the small squares is extremely difficult and it consumed time for counting than 1.0 cm^2 of grid. For planimeter, it was faster than point counting method but the suitable fixation of the sheet of paper was required to minimize the error during the measurement as described by Ferreira et.al (2012). As image processing method, it was the fastest method for measurement of loin eye area in comparison with other method. However, the need of the expertise to classify the loin eye area from other part in the image during the analysis was needed to obtain the high accuracy.

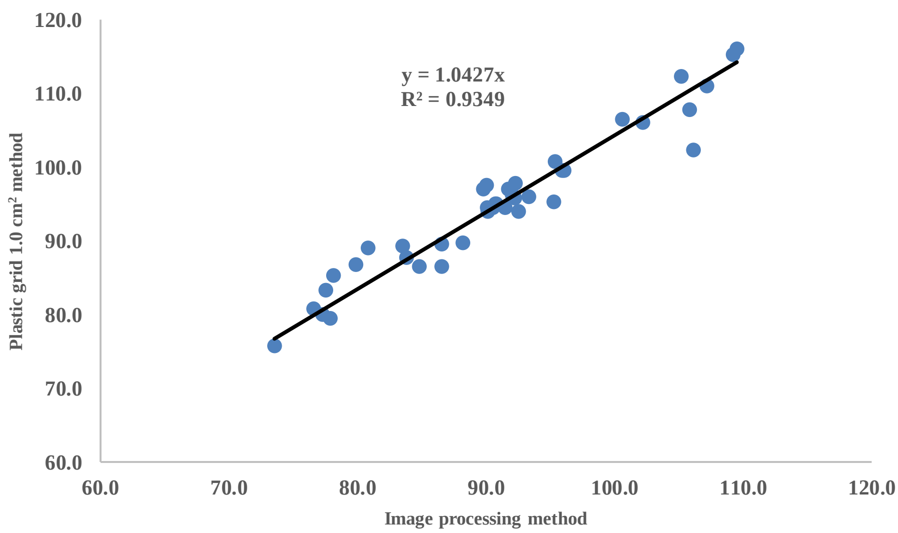
Table 1: Simple correlation between methods

Method	Point counting on plastic grid 0.25 cm^2	Point counting on plastic grid 1.0 cm^2	Planimeter
Image processing	0.984*	0.969*	0.991*
Point counting on plastic grid 0.25 cm^2	1.000	0.970*	0.993*
Point counting on plastic grid 1.0 cm^2		1.000	0.979*
Planimeter			1.000

*Significance P<0.001

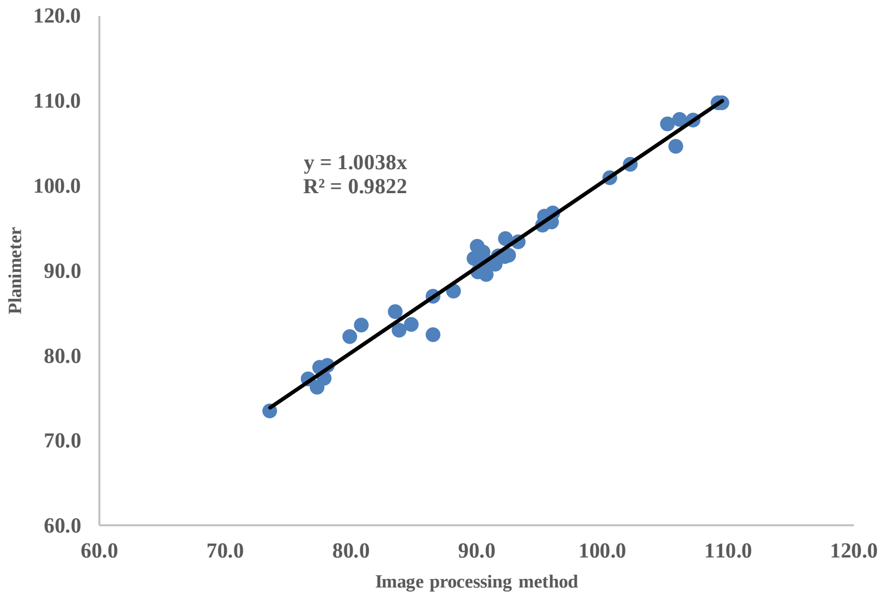


(a) Plastic grid method (0.25 cm^2)



(b) Plastic grid method (1.0 cm^2)

Figure 10 Relationship of loin eye area (cm^2) obtain by image processing method and other methods



(c) Planimeter

Figure 10 Relationship of loin eye area (cm^2) obtain by image processing method and other methods

Conclusions

The developed method to measure the loin eye area of swine carcass by using image processing method acquired image by low cost flatbed scanner may have a high potential applicability and should be recommended to user according to the advantages of greater accuracy, easier operation, lower time consuming and cheaper cost.

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MULTI-OBJECTIVE OPTIMIZATION MODEL FOR WORKFORCE PLANNING OF RICE SEEDS HARVESTING

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ABSTRACT

This paper presented solving a workforce planning problem of farmers who are the members of Ubon Ratchathani Rice Seed Center, Thailand. This center required the farmers to use only workforce for rice seeds harvesting because using combine harvester would reduce the quality of rice seeds. In addition, the farmers used their own experience in workforce planning that could cause the harvest cost very high. Therefore, this research aimed to develop a multi-objective non-linear programming model for workforce planning of rice seeds harvesting then combined the objectives by the weighted sum method. The model was solved with Risk Solver Platform V12.5. Sensitivity analysis was applied and found that the solution depends on the choice of the weight of the decision maker. The result showed the model had more flexible and better solutions compared to the manual planning. It improved the efficiency and reduced the total cost in harvesting rice seeds and workforces gained an income equally as much as possible.

Keywords: Rice Seeds Harvesting, Workforce Planning, Multi-objective Optimization, Non-linear Programming, Weighted Sum Method

Introduction

Rice is an important economic crop in Thailand since it is the first ranking of agricultural products that are exported (Thailand Trading Report, 2019). Rice is cultivated by Thai farmers who must take into account various production factors such as seeds, labors, fertilizers, pesticides, etc. in order to obtain good quality of rice and be able to compete in both domestic and international markets. Nowadays, Thai rice export prices tend to increase (Thai Rice Exporters Association, 2019), which is caused by higher farming costs, climate change, insect pests and plant diseases. When rice had a high export price, causing Thailand to lose its competitors. Therefore, the Royal Thai Government has considered this problem and given the policy to the Rice Department to produce qualified rice seeds and ensure that it is sufficient for the needs of farmers in the country.

The Rice Department is responsible for planning and controlling of 23 rice seed centers, which are distributed in the region of Thailand. In this case study, the researchers studied on the rice seeds production of Ubon Ratchathani Rice Seed Center, which is located in the Northeast of Thailand. In 2018, this rice seed center was the highest target production in the country. The farmers, members of the rice seed center, are assigned to produce photoperiod-sensitive rice such as Khao Dawk Mali 105, RD15 and RD6. As a result, the rice seeds are ready to be harvested at a very similar time. Since harvesting time affects the quality of rice seeds so all farmers need to harvest the rice seeds as soon as possible. In addition, the rice seed center requires farmers to harvest rice seeds by using only workforce because the combine harvester could have a chance of cracking and adulterating with other rice seeds. Hence, the farmers need to grab the workforce for harvesting which can generate a high cost.

The workforce had the capacity of manual harvesting approximately 0.0875-0.2135 tons/man-day (Chinsuwan, et al., 2000). At the time of harvesting, the farmers have hired workforce without considering ability and optimal number of the workforce. This has caused a shortage of workforce. If the planning is not optimized, it causes in job delay and the quantity and quality of the rice seeds then decrease. This study found the problem that the farmers had a high cost of harvesting because the farmers used only their own experiences and they did not have a corporate plan among each other. As a result, some workforces gained high income while some workforces earned less. In addition, some workforce group was probably not able to harvest efficiently, thus the yield of rice seeds was less than the minimum quantity per day. As for the farmers who are the employers, this made a higher cost for them.

Research Objective

Therefore, workforce planning model is necessary in rice seeds harvesting to optimize costs. A multi-objective optimization model with non-linear programming for rice seeds harvesting of the workforce planning problem was developed in this research. The objective function composes of three terms: 1. Minimizing a difference of workforce incomes, 2. Minimizing a total cost and 3. Maximizing a harvesting rate per period. The output of the model could be used in workforce planning for producing an equity of harvesting chances among the workforces and could also increase an efficiency in rice seeds harvesting with remaining the quality on suitable time.

Literature Review

Workforce planning is a combination of individual workers' differences in their ability to learn new skills and perform tasks assigned. Workforce planning was presented by a mixed integer programming (MIP) that allows a number of different staffing decisions in order to minimize workforce related and missed production costs (Wirojanagud, et al., 2007). Several researchers have applied optimization model to determine labor assignments and workforce scheduling. For example, Garaix, et al. (2018) presented an investigation into the application of a MIP for matching workers with their tasks. Fowler, et al. (2008) decided in workforce management assuming individual workers are inherently different by two linear programming (LP) based on a genetic algorithm. Safaei, et al. (2009) studied about workforce scheduling problem which was formulated as a multi-objective model with the aim of simultaneous minimizing the worker cost and maximizing the equipment availability. Abdous, et al. (2018) studied a fatigue criterion for assessing workers fatigue by multi-objective with mixed-integer linear programming model for the assembly line balancing problem and they used ε-constraint approach to address two objectives and present the Pareto front of a solution.

Optimization model have been applied to the agricultural crop harvesting in the early 19th century (Kusumastuti, et al., 2016). Several researchers developed an optimization model to the workforce planning problem, labor allocation problem and harvesting scheduling problem. These problems were similar because the problem used to determine when, where, and how much of the workforce to the harvesting. Ferrer, et al. (2008) used optimization for scheduling wine grape harvest operations. There solved MIP to harvest scheduling, labor allocation decision to account both operational costs and grape quality. There was a similar research such as González-Araya, et al. (2015) used MIP to plan decisions in an apple to minimize the amount of resources for export quality fruit. Limpianchob (2015) applied MIP to harvesting and production planning for the tangerine supply chain that proposed model which was able to save up the operation cost. However, a few of researches involving rice harvest have appeared, for example, He, et al. (2018) applied mathematical model to determine the optimal combine-harvesters' scheduling for fragmental farmland to minimize the wheat harvesting period. Busato and Berruto (2016) applied the data quantification and the simulation model for minimizing manpower in rice harvesting.

Multi-objective optimization model has also been applied widely in various research problems. Multi-objective optimization model can be described as finding the optimal solutions from a set of decision variables to maximize or minimize the objective functions and also satisfy the constraints. Two or more objective functions are considered simultaneously (Collette and Siarry, 2004). Some researches has applied multi-objective optimization model to solve the harvesting problem. Tóth and McDill (2009) studied four multi-objective programming methods to generate spatially explicit forest management alternatives that applied weighted objective function and the Tchebycheff methods provided better overall estimation of the timber. Florentino, et al. (2018) proposed a multiple objective with goal programming model for optimizing the harvest plan of the sugarcane then they developed genetic algorithm (GA) to solve realistically large problems within an appropriate computational time. Sungnul, et al. (2017) studied a multi-objective mathematical model for the optimal time to harvest sugarcane to maximize revenue and minimize gathering cost by the ε -constraints method.

In this work, the weighted sum method was used to solve the Multi-objective optimization model (Deb, 2008). The mathematical formulation of the weighted sum method in general format is given as follows:

$$
\begin{array}{lll}
\text{Maximize/Minimize} & f(x) = \sum_{m=1}^{M} W_m f_m(x), & \\
\text{Subject to} & g_j(\mathbf{x}) \geq 0, & j = 1, 2, \ldots, J \\
 & h_k(\mathbf{x}) = 0, & k = 1, 2, \ldots, K \\
 & x_i^{(L)} \leq x_i \leq x_i^{(U)}, & i = 1, 2, \ldots, n
\end{array}
\tag{1}
$$

Here, x is a vector of n decision variables: $x = (x_1, x_2, \ldots, x_n)^T$. The objective is $f(x) = (f_1(x), f_2(x), \ldots, f_m(x))^T$. W_m $(\in \{0,1\})$ is the weight of the m objective function. The g_j (x) and h_k (x) functions are the constraint functions which have J inequality and K equality constraint functions. The variable boundary is the last set of

$x_i^{(L)} \le x_i \le x_i^{(U)}$, where the decision variable, x_i has a lower bound, $x_i^{(L)}$ and an upper bound, $x_i^{(U)}$.

The normalization scale the objective function into the range from 0.0 to 1.0 (Marler and Arora, 2004). The normalization of objective value is given by:

$$Normalized\left(f_i(x)\right) = \frac{f_i(x) - f_i^{\min}}{f_i^{\max} - f_i^{\min}}, \qquad i = 1, 2, \ldots, b. \tag{2}$$

Here, $f_i^{\max}$ and $f_i^{\min}$ are the maximum and the minimum values of the i^{th} objective function, $f_i(x)$, respectively, in the approximation of Pareto-optimal solutions. b is the number of objective functions. x is a set of the decision variables.

Problem Description and Mathematical Model

In this context, we studied workforce planning problem for rice seeds harvesting. Due to the workforce had different harvesting abilities and the farmers had no corporate harvesting plan. As a result, the harvest was inefficient, delay and high total cost occurred. Therefore, this research aims to optimize workforce planning by considering three different objectives. Diagram of workforce planning for rice seeds harvesting is shown in Figure 1.

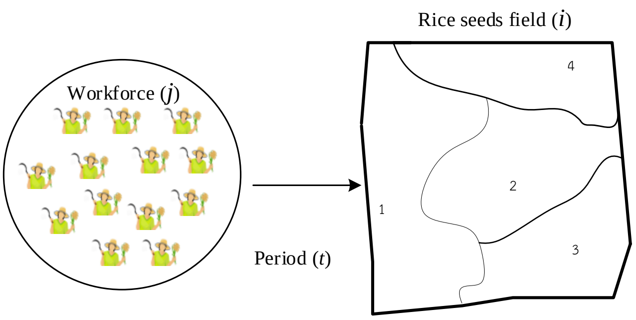

Figure 1 Diagram of workforce planning for rice seeds harvesting.

The related assumption are as follow:

1) Harvesting rice seeds in each field is independent.
2) The occurrence of natural disasters and weather conditions during workforce hours has no effect on harvesting rice seeds such as heavy rains, hot weather and flooding conditions, etc.
3) The workforce cannot switch to harvest in the other fields during the period.
4) The number of workforces is a certain number and they can work continuously without fatigue until the job is finished.

The model was formulated as a multi-objective optimization model with non-linear programming for rice seeds harvesting of the workforce planning. Then the researchers applied the weighted sum method to solve this problem. The model was defined in terms of set of index, parameters, decision variables, the objective function and the constraints that must be satisfied.

Index

i rice seeds field, $i = 1, 2, \ldots, I$
j harvest workforce, $j = 1, 2, \ldots, J$
t harvest period, $t = 1, 2, \ldots, T$

Parameters

C_h workforce cost (baht/ton)
C_p cost when harvesting lower than the minimum requirement (baht/ton)
D_i demand of rice seeds harvested in field i (tons)
I total number of rice seeds fields

J total number of harvest workforce

Q_i amount of rice seeds in field i (tons)

P_j amount of rice seeds that workforce j can harvest per period (tons)

$\overline{P}$ average amount of rice seeds that workforce can harvest (tons/workforce), $\overline{P} = \frac{\sum_{i}^{I} D_i}{J}$

T total number of harvest period

V_{it} minimum requirement to be harvested in field i in period t (tons)

W_{Z1} weight of the objective function in terms of difference of workforce incomes

W_{Z2} weight of the objective function in terms of total cost

W_{Z3} weight of the objective function in terms of harvesting rate per period

Decision Variable

$$X_{ijt} = \begin{cases} 1, \text{ if rice seeds field } i \text{ is harvested by workforce } j \text{ in period } t \\ 0, \text{ otherwise} \end{cases}$$

Objective Function

- Terms of difference of workforce incomes

$$Min\ (Z1) = \left(\frac{C_h \sum_{i=1}^{I} \sum_{t=1}^{T} \left| \sum_{j=1}^{J} P_j X_{ijt} - \overline{P} \right|}{J} \right) \tag{3}$$

- Terms of total cost

$$Min\ (Z2) = C_h \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{t=1}^{T} P_j X_{ijt} + C_p \left(\sum_{i=}^{I} \sum_{j=1}^{J} \sum_{t=1}^{T} \max\left(V_{it} - P_j X_{ijt}, 0\right) \right) \tag{4}$$

- Terms of harvesting rate per period

$$Max\ (Z3) = \frac{\sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{t=1}^{T} P_j X_{ijt}}{T} \tag{5}$$

Since this research used the weight sum method that objective function must have the same aims so this objective is adjusted to minimize. The objective is given as follows:

$$Min\ (Z3) = \frac{1}{\left(\frac{\sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{t=1}^{T} P_j X_{ijt}}{T} \right)} \tag{6}$$

- Multi-objective Function

Due to the objective functions' scale are not equal, each of them must be transformed to be a normalization scale into the range from 0.0 to 1.0 (follow Eq.(2)) before using the weighted sum method. The equation is given as follows:

$$Total\ Min = W_{Z1} \left(\frac{C_h \sum_{i=1}^{I} \sum_{t=1}^{T} \left| \sum_{j=1}^{J} P_j X_{ijt} - \overline{P} \right|}{J} \right) + W_{Z2} \left(C_h \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{t=1}^{T} P_j X_{ijt} + C_p \left(\sum_{i=}^{I} \sum_{j=1}^{J} \sum_{t=1}^{T} \max\left(V_{it} - P_j X_{ijt}, 0\right) \right) \right) + W_{Z3} \frac{1}{\left(\frac{\sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{t=1}^{T} P_j X_{ijt}}{T} \right)} \tag{7}$$

Where, $W_{Z1} + W_{Z2} + W_{Z3} = 1$

Subject to

$$\sum_{j=1}^{J}\sum_{t=1}^{T} P_j X_{ijt} \geq D_i \qquad \forall i \tag{8}$$

$$\sum_{j=1}^{J}\sum_{t=1}^{T} P_j X_{ijt} \leq Q_i \qquad \forall i \tag{9}$$

$$\sum_{i}^{I} X_{ijt} \leq 1 \qquad \forall j,t \tag{10}$$

$$X_{ijt} \geq X_{ij(t+1)} \qquad \forall i, j, t \tag{11}$$

$$X_{ijt} \in \{0,1\} \qquad \forall i, j, t \tag{12}$$

Eq. (3) is the first objective function which is to minimize a difference of income of workforces harvesting rice seeds. It is calculated in terms of Mean Absolute Deviation (MAD). Eq. (4) is the second objective function which is to minimize the total cost that is the sum of workforce cost and the cost when harvesting lower than that of the minimum requirements. Eq. (5) is the third objective function which is a maximizing harvesting rate per period. Eq. (6) is an adjusting eq. (5) to be the minimization function. Eq. (7) expresses that three objective functions is combined with the weighted sum method. Eq. (8) refers to the constraint to ensure that amount of rice seeds harvested by workforces must cover demand of rice seeds in each field. Eq. (9) refers to the constraint that the harvested rice seeds must not exceed the amount of rice seeds that belong in each field. Eq. (10) refers to the constraint of preventing to harvest more than one field in each workforce and in each period. Eq. (11) refers to the constraint that the workforce must harvest in period *t* and then be able to harvest in the next period. Eq. (12) refers to the constraint to ensure that X_{ijt} are binary variable.

Results and Discussion

A case study of workforce planning to harvest rice seeds of the farmer groups who are members of the Ubon Ratchathani Rice Seed Center in Thailand is presented in this section. The sample problem consists of 20 workforces, 4 fields and 7 periods. The parameters included in this problem such as demand of rice seeds, amount of rice seeds that belong in each field, workforce cost, etc. are shown in Table 1. Also, amount of rice seeds that workforce can harvest per period are shown in Table 2.

Table 1: The parameters of this problem.

Parameter	Field No.			
	1	2	3	4
Demand of rice seeds (tons)	5.00	4.00	6.00	5.00
Amount of rice seeds that belong (tons)	6.25	5.00	7.50	6.25
Minimum requirement of rice seeds (tons/period)	0.125			
Workforce cost (baht/ton)	1,000			
Cost of harvesting lower than minimum requirement (baht/ton)	300			

Table 2: Amount of rice seeds that workforce can harvest per period.

Workforce No.	Amount of rice seeds harvested (tons/period)	Workforce No.	Amount of rice seeds harvested (tons/period)
1	0.105	11	0.194
2	0.102	12	0.214
3	0.214	13	0.194
4	0.172	14	0.154
5	0.125	15	0.214
6	0.194	16	0.154
7	0.135	17	0.214
8	0.194	18	0.214
9	0.189	19	0.154
10	0.143	20	0.154

For the multi-objective optimization model was solved by Risk Solver Platform V12.5 on a PC with an Intel® Core™ i7-3770 CPU @ 3.40GHz Ram 8.00 GB, to find the optimal workforce planning of rice seeds harvesting.

The model considered three objectives: 1. Minimizing difference of workforce incomes, 2. Minimizing total cost and 3. Maximizing harvesting rate per period. All of them were combined by weighted sum method. The model was tested by varying weight W_{Z1}, W_{Z2} *and* W_{Z3}. There were 36 cases in total to analyze. The resulting objective function, difference of workforce income, total cost and harvesting rate period are shown in Table 3.

Table 3: Results of the case study.

No.	Weight			Objective function	Difference of workforce incomes	Total cost (baht)	Harvesting rate (tons/period)
	Z1	Z2	Z3				
1	0.8	0.1	0.1	0.265	122.050	20,507.000	2.930
2	0.1	0.8	0.1	0.747	208.025	20,068.500	2.867
3	0.1	0.1	0.8	0.785	158.575	20,623.500	2.946
4	0.7	0.2	0.1	0.335	125.930	20,362.500	2.909
5	0.7	0.1	0.2	0.340	124.650	20,497.000	2.928
6	0.2	0.7	0.1	0.682	155.400	20,224.000	2.889
7	0.1	0.7	0.2	0.701	173.800	20,104.000	2.872
8	0.1	0.2	0.7	0.802	191.880	21,122.500	3.010
9	0.2	0.1	0.7	0.726	192.075	20,735.500	2.962
10	0.6	0.3	0.1	0.409	126.575	20,616.500	2.938
11	0.6	0.1	0.3	0.413	127.150	20,387.000	2.912
12	0.3	0.6	0.1	0.614	148.675	20,225.500	2.889
13	0.1	0.6	0.3	0.760	213.600	20,248.000	2.893
14	0.1	0.3	0.6	0.781	164.300	20,678.000	2.954
15	0.3	0.1	0.6	0.642	152.500	20,586.000	2.941
16	0.6	0.2	0.2	0.410	125.075	20,483.500	2.926
17	0.2	0.6	0.2	0.689	172.500	20,255.000	2.894
18	0.2	0.2	0.6	0.725	161.100	21,035.000	2.998
19	0.5	0.3	0.2	0.481	136.225	20,316.500	2.904
20	0.5	0.2	0.3	0.483	131.400	20,362.000	2.909
21	0.3	0.5	0.2	0.620	161.025	20,194.500	2.885
22	0.2	0.5	0.3	0.692	168.675	20,245.500	2.892
23	0.3	0.2	0.5	0.636	158.200	20,436.000	2.919
24	0.2	0.3	0.5	0.709	186.525	20,462.000	2.923
25	0.5	0.4	0.1	0.478	135.925	20,350.500	2.907
26	0.5	0.1	0.4	0.492	146.425	20,290.500	2.899
27	0.4	0.5	0.1	0.555	161.750	20,287.000	2.898
28	0.1	0.5	0.4	0.766	182.800	20,110.000	2.873
29	0.1	0.4	0.5	0.775	187.250	20,535.000	2.934
30	0.4	0.1	0.5	0.570	158.525	20,402.500	2.915
31	0.4	0.3	0.3	0.574	158.975	20,833.500	2.976
32	0.3	0.4	0.3	0.655	165.550	20,339.000	2.906
33	0.3	0.3	0.4	0.650	160.600	20,984.000	2.998
34	0.4	0.4	0.2	0.561	151.425	20,569.500	2.931
35	0.4	0.2	0.4	0.571	157.850	20,607.000	2.944
36	0.2	0.4	0.4	0.706	177.575	20,519.500	2.932

Based on the results of the case study, it was clear that if decision makers decided high weight to the interested objective, it provided the better result when compared to the other sets of weights. For example, when the decision makers decided weight in No.1 (0.8, 0.1, 0.1), the solution in terms of difference of workforce incomes showed a better result than No. 2 and No. 3. When they decided weight in No.2 (0.1, 0.8, 0.1), the solution in terms of total cost displayed a better result than No. 1 and No. 3. Another case is that when they decided weight in No.3 (0.1, 0.1, 0.8), the solution in terms of the harvesting rate per period showed a better result than No. 1 and 2. For the sets of weights showing in result No.4 to 36, they were also shown the same pattern of the result.

The solution of this case study aimed to minimize the overall objective function. Therefore, the solution of 0.265 shown in No. 1 seemed to be the optimal workforce planning when considering all objective terms. Table 4 shows the workforce planning based on result No.1 of rice seeds harvesting. The case showed a workforce planning for the farmers who own four fields and planning horizon for harvesting was seven periods. Demands and amount of rice seeds that belong in each field were different. Therefore, it was needed to plan the harvesting workers optimally as they were not able to harvest beyond the amount of rice seeds. The solution showed the number of workforce required in each period and rice seeds amount harvested in each field. It was found that the first period requires 20 workforces because it still had a large amount of rice seeds in the beginning. While the last period of harvest the number of workforce was reduced to 14 people because rice seeds left were already decreased. Such results caused farmers to have a total cost of 20,507 baht. Workforces received similar incomes and the amount of harvested rice seeds was 2.930 tons/period. However, the decision makers can make their own decision to use which workforce planning to fit with their current situation since it provided the different results based on three different objectives with their significant weight.

Table 4: workforce planning of rice seeds harvesting in a case study.

Field	Harvest amount (Tons)	Planning Horizon						
		1	2	3	4	5	6	7
1	5.153	3	9	3	4	4	3	2
2	4.016	2	4	3	3	5	3	4
3	6.249	9	1	8	5	3	6	5
4	5.088	6	4	4	6	5	5	3
		Period Workforce Usage						
		20	18	18	18	17	17	14

Conclusion

This paper presents a multi-objective optimization model with non-linear programming. An optimal solution was able to be used to support decision making for rice seeds harvesting of the workforce planning. A mathematical model was developed with three objective functions: 1. Minimizing the difference of workforce incomes, 2. Minimizing the total cost and 3. Maximizing the harvesting rate per period. These all three objective functions were combined by the weighted sum method. Normalization method was also used to make scales be the same. The multi-objective optimization model was solved with Risk Solver Platform V12.5. Thirty-six sets of objective weights were run and the solutions are found differently depending on the choice of the weight of the decision makers. The mathematical model provides more flexible and better solutions compared to manual planning. The output of the mathematical model was used in workforce planning for equality of harvesting opportunities among the workforces and was be able to increase the efficiency in harvesting rice quality seeds in an appropriate time.

Finally, this research could be improved to address more realistic versions that would include the explicit consideration of the uncertain in the system such as the number of workforces, weather, and the yield of rice seeds, etc.

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PHYSICOCHEMICAL ASSESSMENT OF ROASTED COCOA BEAN SOME PRIVATE COMPANY IN TAIWAN AND THAILAND

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ABSTRACT

Cocoa bean is an economically important seed, which roasted cocoa bean is the sole source of chocolate. According to the International Chocolate Awards (ICA) 2018, Taiwan chocolate was awarded 9 gold, 30 silver, and 29 bronze medals ranking as the top in Asia. Beside, Thailand chocolate was awarded 1 gold, 2 silver, and 2 bronze medals. The objective of the research was to analyze the quality of roasted cocoa bean domestically produced in both Taiwan and Thailand including moisture content, pH, acidity, color, and nutrition facts .The results showed that the moisture contents, red color (a*), yellow color (b*), pH, calories, saturated fatty acid and dietary of roasted cocoa bean of private company in Thailand is higher than Taiwan. On the other hand, the lightness (L*), acetic acid and lactic acid of roasted cocoa bean of private company in Taiwan is higher than Thailand. The roasted cocoa bean from private company in Taiwan and Thailand was summarily graded under the International Cocoa Standards according to the ISO 2451.

Keywords: physicochemical properties, Taiwan roasted cocoa bean, Thailand roasted cocoa bean

Introduction

Cocoa has been known for its good taste and proposed health effects for centuries. In general, most of the world's cocoa is grown in a narrow equatorial belt of 10 degrees either north or south because cocoa trees grow well in humid tropical climates with regular rains and a short dry season. Chocolate originates in cocoa beans, which are fruits of cacao plant. Cocoa beans came to Europe in the 16th century. Since then, the modern chocolate industry has developed and cocoa beans are now processed in different ways. In the past, due to its health effects, it was considered as the drink of Gods. In addition, the scientific name of cocoa trees is *Theobroma cacao* as from the Greek words "theo" means god and "broma" means drink. Significantly, the antioxidants in cocoa are very high and especially the flavonoids in cocoa beans are believed to reduce numbers of free radical in the body, which the free radicals contribute to medical problems, such as cardiovascular disease, cancer, and some anti-aging health benefits (Ensminger *et al*., 1995). In addition, cocoa derived food such as cocoa powder, chocolate, and etc., is consumed all over the world and especially, it is increasingly studied for the poly-phenolic rich food which it is considered as antioxidant and antiradical properties (Sanbongi *et al.*,1998, Wollgast and Anklam, 2000). And the phenolic compounds in cocoa are considered as the bioactive compounds especially, illustrated in antioxidant, antiradical, and anticarcinogenic properties (Ren *et al.*, 2003). Moreover, the catechin as the antioxidant in cocoa beans is four times higher than tea. Cocoa beans also contain tryptophan and anandamide, which lessen anxiety, promote relaxation and trigger the production of endorphins. In addition, cocoa contains less caffeine in comparison to the same consumption amount of either coffee or tea (Rizza *et al*., 2000, Delzenne, 2001). Therefore, cocoa can be considered as a function food due to its nutritional properties. According to the literature, a functional food provides health benefits beyond basic nutrition (Bech-Larsen and Grunert, 2003).

Objective

The objective of the research was to compare the physicochemical properties (moisture, color, pH, acidity, and nutrition facts) between roasted cocoa bean of private company in Taiwan and Thailand.

Literature Reviews

1. Current information of cocoa sector in the world

Cacao tree is native in the Americas and it was so greatly valued by the Aztecs and Mayans. Commercial cacao tree has two main groups, Criollo and Forastero (Cheesman 1944). Criollos were originally planted by the Mayas in Central America (Toxopeus 1985; Motamayor et al. 2002). Criollos are now known to be highly vulnerable to several diseases (Toxopeus 1985; Wood 1985). Forastero is from the upper and lower Amazon basin. It is more disease resistant and vigorous than Criollo (Toxopeus 1985). It is now the most commonly grown cacao in the world (Wood 1985). However, Forasteros are less valuable because their fermented beans are not generally considered to produce a high quality flavor (Wood 1985). In addition, cacao is a plant which it has a lifespan of seventy years and it can produce cocoa pods all year round. Cocoa mass or cocoa powder is made from cocoa beans after the full processing, which there are harvesting, fermenting, drying, splitting and extracting, fermentation, drying, roasting, winnowing, roasting, grinding, conching, tempering, and molding. Especially after grinding process, cocoa beans will become cocoa liquid containing both cocoa mass and cocoa butter. The cocoa liquid will continue processing into the both food and non-food of chocolate industry. According to the World Agroforestry Centre by Cadburys, most of the world's cocoa production locates in a narrow belt between either ten degrees north or south of the equator. In 2018, the International Cocoa Organization (ICCO) stated that, the top world's cocoa consumption countries mainly located in Europe, and respectively in the United States of America, the rest of Asia, the rest of Americas, Brazil, Japan, Africa, China, Australia, and India. And the ranking of World's cocoa consumptions was shown in the following table;

Table 1. Table of World's cocoa consumption and production in 2017/2018

No.	Country/Location	Consumption (in 1,000 Tons)	Production (in 1,000 Tons)
1	Europe	1,852	-
2	United States of America	732	317
3	Rest of Asia	351	368*
4	Rest of Americas	333	-
5	Brazil	189	165
6	Japan	176	-
7	Africa	154	3,518**
8	China	82	-
9	Australia	76	-
10	India	46	-

Source : International Cocoa Organization (ICCO) ,2018
Note : * Indonesia =280 , Rest of Asia = 88 (in 1,000 Tons)
** Ivory Coast = 2,000 , Ghana = 900 , Rest of Africa = 618 (in 1,000 Tons)

From above tables, the world's cocoa consumption in the world is relatively contrasting from the world's cocoa production. The main countries producing cocoa are not the main countries consuming their own products. Besides, most countries consuming cocoa are considered as the developed countries such as European countries and U.S.A., and the most countries producing cocoa are considered as either the developing countries or less developing countries. However, Asia is shown as the least cocoa production countries, and only Indonesia can significantly produce cocoa. As the researcher, I expect that many countries in Asia possibly grow more cocoa trees towards the world demands. Especially Taiwan and Thailand, both countries are ones of the fruitful countries in the world producing many agricultures products into the world food market. And according to the map of cocoa plants around the world, Taiwan and Thailand are ones of the best cocoa growing countries along the equator line.

2. Cacao trees in Taiwan

Over the past decade, tree to bar chocolate was a little-known concept in Taiwan. According to the Council of Agriculture's Soil and Water Conservation Bureau, Taiwan's cocoa cultivation acreage grew from zero to around 300 hectares. Cocoa from Taiwan is five to seven times more expensive than cocoa from other production areas, but it is considered as a high-end product. In September 2018, the International Chocolate Awards (ICA) held its Asia-Pacific competition for the first time in Kaohsiung, Taiwan. Significantly, the judging director of the ICA; Martin Christy, stated the main reason of selecting Taiwan as the host that Taiwan possessed all in one cocoa supply chain from cocoa production, chocolate-making facilities, and a market with purchasing power. In the award competition, more than 700 products from some 100 chocolate companies from 16 countries in the Asia-Pacific region were entered. Taiwan's chocolatiers were awarded as the top rank receiving 9 gold, 30 silver and 29 bronze medals. Besides, Thailand's chocolatiers won 1 gold, 2 silver, and 2 bronze medals. Chocolate, therefore, is one of the best desserts in Taiwan, as it's not only home grown but also home made. Throughout 30 chocolate shops across the island, Pingtung County, where the research was implemented, grow the majority of the island's cacao trees.

Examples of tree to bar chocolate stores in Pingtung County, Taiwan

Fu Wan Chocolate: This chocolate company is one of the best well-known tree to bar chocolate company in Taiwan. From International Chocolate Awards (ICA) 2018, the company won the top brands of tree to bar chocolate among the Asia Pacific region. The company has locally grown cacao trees to craft tree to bar chocolate, but the company also imports Papua New Guinean and Ecuadorian cocoa beans to craft bean to bar chocolates. Significantly, Warren Hsu, the owner, registered for food science classes offered by the local government at National Pingtung University of Science and Technology. From his fascination for tree to bar chocolate, he, therefore, look for ways to incorporate his products into the global chocolate market.

Chuis Chocolate: Chui Mingsong, the owner, has spent more than 14 years dedicating his life to bringing cacao trees as a viable crop to Taiwan. He started with a desire for better quality of Taiwanese coffee, and furthermore, a desire for locally grown cacao trees. He was the first craft chocolate maker in Taiwan, and currently he uses his own cacao to craft tree to bar chocolate. On his property, he offers tree-to-bar chocolate and ice cream, as well as demonstration about how the tree to bar chocolate is made and the history of Taiwanese cocoa.

Cocosun Cacao Farm: Freddy Lin, the owner, is locally well-known chocolatier for his pure chocolate enzyme drink, which is made with fermented cacao nibs and basically tastes like white wine in chocolate slushy form. He also makes both tree to bar and bean to bar chocolate on his farm. In addition, the company grows cacao trees on the large property and offers the Chocolate DIY classes.

3. Cacao trees in Thailand

For over a century, cocoa trees were brought from Malaysia, but they were rarely grown as a cash crop in Thailand. Within last few years, Thai farmers have been cropping up cocoa trees in both southern and northern Thailand as a potentially large source of income for small-hold farmers. The majority of Thai cacao trees was firstly grown in the Chumphon province in the south of Thailand, and along with growing further in the northern region. Currently, researchers in both areas have studied about growing quality cacao trees in Thailand. Hopefully the cacao farming will be larger scales than before due to the increasing demands of a quality tree to bar chocolate products. Despite the small but growing community of cacao farmers and chocolate makers in Thailand, there are still a few places to learn about cacao farming. By visiting a cocoa farming, either in Bangkok neighboring area; Chantaburi or the southern region; Chumphon or Nakornsrithammarat, or possibly the northern region; Chiang Mai, Nan, each cocoa farming demonstrates the process of making chocolate from tree to bar. In the southern region, farmers grow cacao trees and sell the beans to large chocolate industries (The Chocolate Museum, 2015). Besides the northern region, the climate is usually chillier than the southern, but cocoa trees are still widely grown under this specific condition according to a new breeding of Thai cocoa trees; variety I.M.1 (La-Ongsri, 2015). In addition, cocoa trees are now grown in a variety of locations in Thailand, and more numbers of local farmers are increasingly growing the cocoa trees according to the new breeds cocoa plants which they are suitable grown in different locations in Thailand. Moreover, the demand of cocoa-derived food, such as cocoa power, cocoa butter, chocolate, and etc., totally exceeds the domestically cocoa production. According to the Department of Agriculture of Thailand, approximately 17,000 tons of cocoa beans in 2015 needs to be imported and it cost almost 60 millions US dollars.

The tree to bar and bean to bar chocolate stores in Thailand are gradually increased mainly in Bangkok area and others, for examples; Metha chocolate, Yellow chocolate, Shaba, Aimmika Chocolate, Siamaya Chocolate, Chocolasia, Böhnchen & Co. Chocolate, Sarath N. Chocolatier, Bloom, Paradai Chocolate, and Kad Kokoa. Especially Paradai Chocolate and Kad Kokoa, both tree to bar chocolate stores were awarded from the Asia Pacific Competition of the International Chocolate Awards (ICA) in 2018 at Kaohsiung, Taiwan.

Examples of tree to bar chocolate stores in Bangkok, Thailand

Metha Chocolate: This chocolate company is one of the brand new tree to bar chocolate in Thailand. Methawee Methakajonkul, the owner, has a strong passion to make tree to bar chocolate by local raw material. Together with her Food Science background, she is fascinated in making her own chocolate combing a variety of packaging design with her artistic talent. By the middle of 2021, she will start her new tree to bar chocolate factory in Bangkok. Moreover, this brand new tree to bar chocolate factory will operate under the international food safety standard in both Hazard Analysis Critical Control Point (HACCP) and Good Manufacturing Practice (GMP).

Yellow Chocolate: Bordin Charoenpongchai, the owner, always looks for innovative methods of his tree to bar chocolate production. He has been trying a lot of samples of chocolate through out the Asia. Significantly, he is considered to be one of the first tree to bar chocolate makers in Thailand. Currently, he is willing to connect each sector of tree to bar chocolate production to become an alliance among increasing numbers of chocolate makers in Thailand.

Methods

The samples of roasted cocoa bean

The total of 1,000 grams of roasted cocoa bean were collected from Fu Wan Chocolate, Taiwan and Metha Chocolate and Yellow Chocolate, Thailand. Significantly, both of them were fermented for 7 days, naturally dried for 7-9 days until reaching the final moisture content of 7.5%, and roasted under 125 °C for 15 minutes were shown in the following table;

Table 2. Flow chart of roasted cocoa bean production

Process	Taiwan	Thailand
Harvest	Hybrid variety of cocoa pod from local cocoa farms was harvested in May 2019	Chumpon variety of cocoa pod from local cocoa farms was harvested in April 2019
Split	Manually splitting by local people (under the environmental sanitation control)	Manually splitting by local people
Fermentation	Spontaneous fermentation for 5 – 7 days under 45 – 50 °C (under the professionally control of temperature and time)	Spontaneous fermentation for 5 – 7 days under 45 – 50 °C (no rotation and no temperature control technique)
Drying	Sun drying method for about 7 – 9 days; controlling under the specific condition of temperature and humidity	Sun drying method for about 5 – 7 days due to the weather of Thailand is hotter and more humid than Taiwan
Roasting	Roasting in the temperature of 125 °C under 15 minutes by the standard roaster machine	Roasting in the temperature of 125 -130 °C under 15 - 20 minutes due to Thailand dried cocoa bean contains more moist

The physicochemical property analysis of roasted cocoa bean

The physicochemical properties (moisture content (%), color, pH, acidity, and nutrition facts) of roasted cocoa bean between private company in Taiwan and Thailand were analyzed at the department of Food Science at National Pingtung University of Science and Technology (NPUST). Each experiment was implemented for three times and finally, it was calculated for the average result. The moisture analyzer was used to analyze the moisture content of the roasted cocoa bean. The pH meter was used to measure acidity or alkalinity of a solution of the roasted cocoa bean. The acidity (acetic acid and lactic acid) was determined by titration with sodium hydroxide (0.1 N.) to quantitatively analyze a solution of the roasted cocoa bean for its acidity or base concentration. The color of roasted cocoa beans was determined by the colorimeter (Color Meter NE 4000) followed by CIE L*a*b* measurement. The nutrition fact was used to measure calories, saturated fatty acid, carbohydrate and dietary fiber was determined by A.O.A.C. (2000).

Results and Discussion

The physicochemical property analysis of roasted cocoa bean

The physicochemical properties of the roasted cocoa bean from private company Taiwan and Thailand were shown as the following table;

Table 3. The average of physicochemical property of the roasted cocoa bean from Taiwan and Thailand

Physicochemical properties	Cocoa bean from Taiwan	Cocoa bean from Thailand
pH	4.68	5.03
Acidity (%)		
Acetic acid	1.91	1.32
Lactic acid	2.86	1.97
Nutrition Facts		
Calories (kcal)	535	576
Saturated fatty acid (g.)	25.62	35.74
Carbohydrate (g.)	33.4	28.7
Dietary fiber (g.)	20.15	22
Moisture content (%)	2.2	3.2
Color		

Physicochemical properties	Cocoa bean from Taiwan	Cocoa bean from Thailand
L* (Lightness)	32.54	30.87
a* (Red color)	17.89	21.60
b* (Yellow color)	10.24	14.58

Figure 1 Roasted Cocoa bean from Private company in Taiwan and Thailand

According to the International Cocoa Standards, ISO 2451 defines the terms used and the grade standards used to classify cocoa beans. For the pH measurement of roasted cocoa bean, a high degree of acidity is usually associated with a pH of 5.0 or less in the dried cocoa bean. The roasted cocoa bean from Taiwan and Thailand was 4.68 and 5.03, which their pH measurements were placed under the acceptable standard for the commercial chocolate. Taiwan roasted cocoa bean tasted slightly sourer than Thailand. In parallel with the acidity, the presence of the acetic acid and the lactic acid of Taiwan roasted cocoa bean were higher than Thailand roasted cocoa bean. The nutrition analysis of Thailand roasted cocoa bean contained slightly more calories, saturated fatty acid, and dietary fiber than Taiwan. In contrast, Taiwan roasted cocoa contained more carbohydrate than Thailand. Comparing to other cocoa beans, Taiwan and Thailand had some potentials to be developed for their better quality. After drying and roasting process, Taiwan roasted cocoa bean contained much less moisture than Thailand, and no microbe could grow in this condition of 7% or under. According to the International Cocoa Standards, ISO 2451 defines the terms used and the grade standards used to classify cocoa beans. The grade standards are based on the cut test, which allows certain gross flavour defects to be identified. These standards, as issued by the International Standards Office (ISO), form the basis of the grading regulations of several cocoa producing countries. Manufacturers require cocoa beans to have the moisture content of approximately 7%. If it is above 8%, there is not only a loss of edible material, but also a risk of mould and bacterial growth with potentially serious consequences for food safety, flavour and processing quality. And lastly for the color measurement, the color of roasted cocoa beans was determined by pigment extraction under various conditions followed by CIE L*a*b* measurement. Thailand roasted cocoa beans were darker, more red, and more yellow than Taiwan. However, Taiwan and Thailand roasted cocoa bean had similar color shade to the commercial cocoa bean. The quality of roasted cocoa bean from some private company in Taiwan is considered to be better than Thailand due to the production under the standard control of time and temperature. Especially the good sanitary system, Taiwan chocolate private company operates under the environmental sanitation control. Currently, Taiwan chocolate is gradually reputed among the global chocolate and it was awarded as the top ranked of International Chocolate Awards in 2018. However, Thailand chocolate private company is potentially enhanced the chocolate quality and it can adjust the production regarding to the good practice and the standard control.

Conclusions

The results showed that the moisture contents, red color (a*), yellow color (*b), pH, calories, saturated fatty acid and dietary fiber of roasted cocoa bean of private company in Thailand is higher than Taiwan. On the other hand, the lightness (L*), acetic acid and lactic acid of roasted cocoa bean of private company in Taiwan id higher than Thailand. The roasted cocoa bean from both private company Taiwan and Thailand was graded following the International Cocoa Standards according to the ISO 2451.

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UBER-FOUNDRY: TECHNOLOGY SHARING IN THE CASTINGS INDUSTRY.

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ABSTRACT

Castings production is a highly competitive business hence many foundries are reluctant to collaborate with other foundries or outside organizations such as R&D centres or universities. This is understandable in that any given foundry does not want other casting producers to gain access to its design and production know-how. However, in order for the castings industry as a whole to continue with sustainable development of production technology, and for individual producers to improve their technical capabilities, closer collaboration between suppliers, foundries and the users of cast components is clearly necessary. With respect to fostering improvement and innovation in the Thai casting industry the paper outlines the importance of this sector in manufacturing and considers how technology has been and can continue to be shared via knowledge transfer through partnerships between companies and academia. To make it possible for SME manufacturing companies to gain access to advanced manufacturing techniques and robotics, etc. a tech-shop or shared factory facility approach could be taken. It is therefore suggested that a suitable advanced manufacturing centre for castings technology should be established.

Keywords: sharing economy, castings production, Thai foundries, technology and knowledge sharing.

Introduction.

The "Sharing Economy", often referred to as "Collaborative Consumption", in which digital technology facilitates the sharing of goods, assets or services, continues to experience rapid growth on a worldwide scale. It has been estimated that the global monetary value of the sharing economy was around US$270 billion in 2016 and by the year 2025 it is predicted to reach US$3 trillion, a year on year increase of 30% (Segaran 2017). Enthusiasm and growth is driven by the potential to gain income from under-used assets such as space, accomodation, vehicles, equipment and tools, etc., together with an environmental feel-good factor that sharing means fewer resources might need to be used. As an illustration of spare capacity, one frequently quoted example is the portable electric drill: it is said that there are some 80 million electric drills in the US with each one having an average lifetime usage of 13 minutes (Friedman 2013). If there was greater sharing or hiring of electric drills it might save user costs and use of resources but it would be bad news for drill manufacturers. Hence the sharing economy can be viewed as friend or foe, and its possible disruptive or negative effects on traditional business together with the accompanying issues and problems of quality, risk, trust, regulation, damage to assets, insurance, liability,taxation and other legal aspects have given rise to considearble debate (Schor 2014, Avital et al 2015, Matzler et al 2015, Hamari et al 2016, Kathan et al 2016, Vaskelainen et al 2018).

Most of the research and discussion on the sharing economy has focused on "uberisation" of the accomodation, media, retailing and transportation sectors and on the relationships between digital platform companies, suppliers and consumers. Aside from marketing, procurement, logistics and transport, relatively little attention has been given to the role of the sharing economy approach in technology development, innovation and production in manufacturing industries. Via the Industrial Internet of Things (IIoT) all types of industry can improve their market penetration and sourcing of raw materials, equipment, information, testing facilities and training services, etc. Many companies, including SMEs, are already making valuable use of such resources. With regard to actual production, companies can make effective use of cloud base systems for design, computer aided engineering, setting-up of manufacturing systems, equipment monitoring and maintenance (Wu et al 2014, 2015, Monostori et al 2016, Wang et al 2017) .

In manufacturing industries such as casting, forging and sheet metal fabrication it is thought that *"Sharing Technology"* or *"Collaborative Production"* is needed as the way forward to improve and develop the capability and performance of the SME sector in Thailand, for example, via equipment sharing through wider pilot plant type facilities and via "clubs" which actually carry out joint development projects rather than just talk about co-operation. This paper therefore considers how collaborative efforts may lead to improvements and innovation in castings production with special emphasis on the SME foundries and die-casters in Thailand.

Castings Production – A Key Supporting Industry.

Casting processes allow the near-net shape production of metal components in a wide variety of alloys with a design freedom that cannot easily be matched by most other metal forming methods. Castings can be produced with complicated external and internal design features in sizes that range from a few hundred grams for small die-cast fittings to up to 200-300 tonnes for the very large steel parts used in heavy plant construction. Some examples of the complexity of design, smaller size ranges, and applications are shown in Figure 1 which illustrates Aluminium alloy automotive drive chain parts and a range of Magnesium based cast components. Cast parts, in alloys covering traditional Cast Irons to Superalloys, routinely satisfy service demands in almost all engineering applications including transport, civil engineering, industrial plant and equipment, and electrical/electronic appliances.

Castings production involves a set of relatively complex operations such that efficiency and casting quality are influenced by the interaction of design features and materials & process characteristics. A simplified flow chart for the metal route in light alloy casting is shown in Figure 2. Depending on the casting process under consideration there will also be associated and interacting process route maps for the preparation of die-sets, sand moulds and cores, die and mould coatings, liquid metal treatments, cooling, knock-out, cleaning, machining, etc., and any subsequent heat or surface finishing treatments. In the past, lack of effective controls of variables involved in these process routes in tandem with incomplete technical knowledge and understanding of casting alloys, foundry processes and methods engineering, has meant that the casting route has long been associated with higher numbers of defects compared to other forming processes. However, in recent years, thanks to technological advances in computer aided engineering, computer simulation of liquid metal flow, solidification and cooling, microstructural modelling, materials characterization, use of sensors, etc., together with improved process controls via the implementation of effective quality management systems, the image of castings is much improved and cast components are no longer considered by design engineers to be full of defects and unreliable.

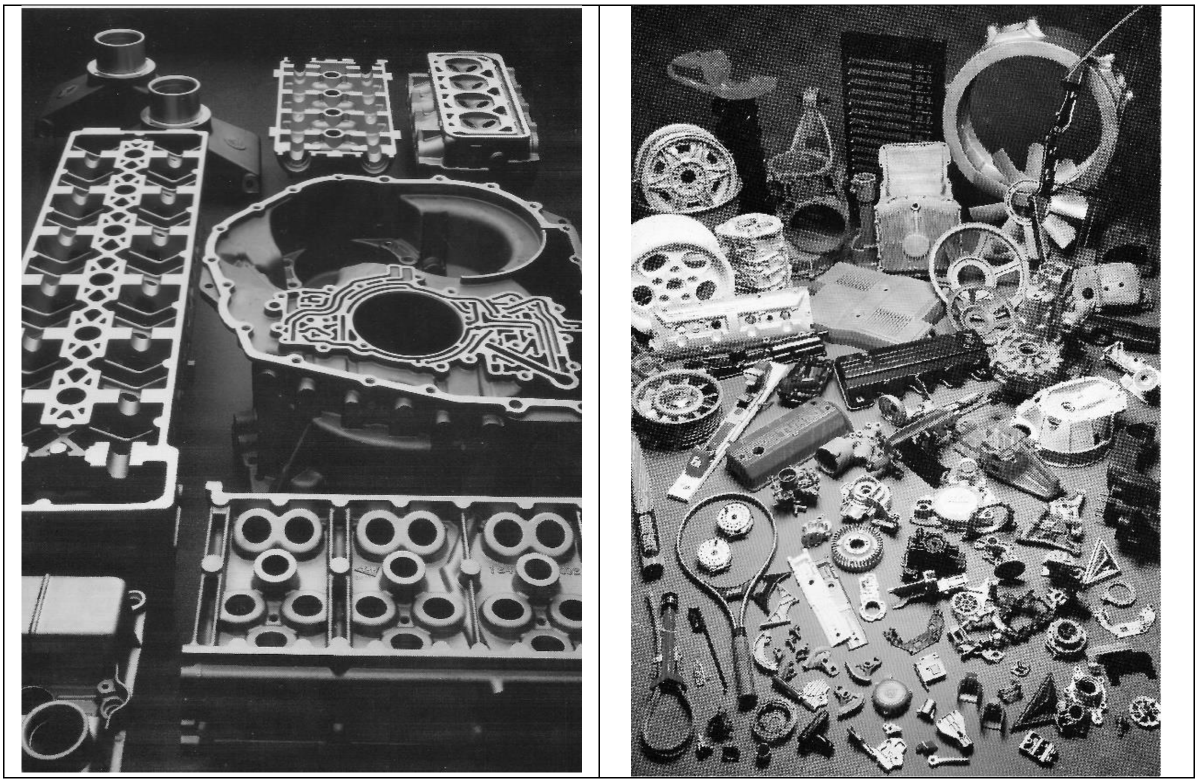

Figure 1 Light alloy cast components: LHS – Al alloy drive train parts (courtesy ETSU).
RHS A variety of Mg alloy castings (courtesy Magnesium Elektron).

Nevertheless, the casting industry must not be complacent and rest on its laurels since there are still many problems to be tackled and improvements to be made, especially in the SME sector, and particularly in Thailand (Bhandhubanyong et al 2017). However, Thailand is not alone: in a study by the United Nations Industrial Development Organization (UNIDO) on sustainability across the Philippines, Indonesia, Vietnam and

Thailand, the metals industry has been called a *"growth with care"* industry (Evans et al 2014). This study noted that many metal companies across the ASEAN region have inadequate understanding and practices in process control thus producing more scrap, more re-work, and hence using more energy plus other resources than they should, which in turn, leading to more waste. The study also noted that across the region there are many world-class companies using Best Available Technology (BAT) in "green" production practices, and that the knowledge and experiences in these companies could be used by government organizations to help support training & education for the technical development of local industries, especially those in the SME category. Again, this is particularly relevant in Thailand where the SME foundry and die-casting sector might improve their capabilities by learning from the approaches to production & process control in the joint-venture (JV) modern casting plants of the automotive sector (Pearce et al 2017).

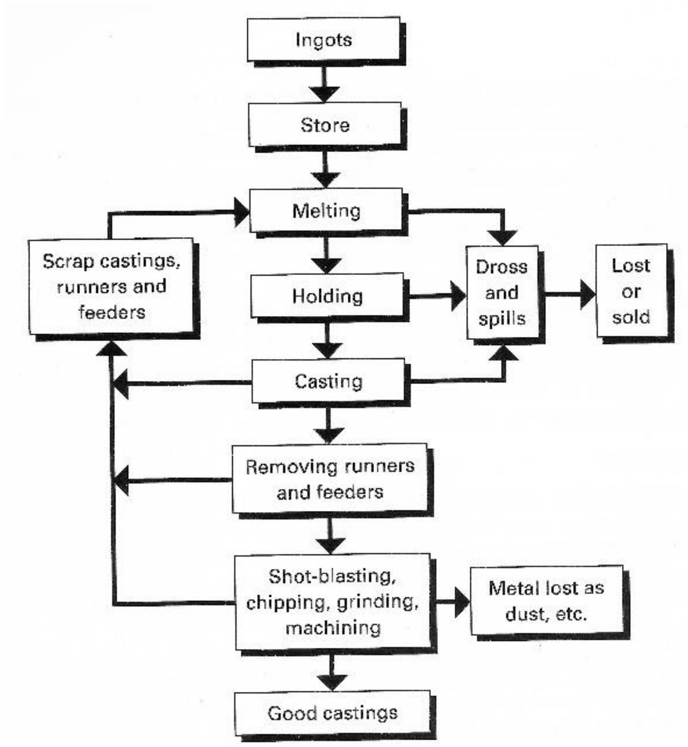

Figure 2 Flow chart for metal in a light alloy foundry (courtesy ETSU).

During the development and continued growth of manufacturing industries in Thailand most technical progress and innovation has arrived through technology transfer from overseas companies, notably Japan, who have established, and have continued to develop, modern JV plants to produce automotive parts, vehicles, and electrical and electronic goods, etc. Among these, several automotive foundries and die-casting plants were recognized some 20 years ago as already demonstrating world-class performance (Mitchell 1997). From factory visits, seminars, and trade shows and via employee movements from the JV to SME plants, casting producers in the Thai SME sector have gained considerable benefit from exposure to the advanced production systems and best practices used in JV plants. This is an example of sharing technology in practices that is beneficial and which could be further expanded.

Some important areas for the continued development of the Thai foundry sector have been discussed in detail elsewhere (Bhandubanyong et al 2017, 2018a, 2018b). It is significant to note that some 70% of the castings produced in Thailand are for automotive applications and that this sector is highly competitive. The vehicle builders continually ask for ever improving performance with regard to shorter lead times, costs reduction, zero defects, minimum variation, and not least for component weight reduction to give improved fuel efficiency. To satisfy the last demand requires the production of cast components not only having thinner sections in designs with increased complexity but also possessing higher mechanical and other properties combined with guaranteed integrity and reliability. This necessitates the increased use of lighter Aluminium or Magnesium based alloys in place of steel forgings or pressed fabrications and instead of Grey and Ductile (FC and FCD) Irons. In some commercial vehicles there will still be a need for advanced cast iron components which, compared to Al or Mg alloys, can offer improved strength to weight ratios and higher temperature properties such as creep resistance. Ferrous founders will therefore need to develop improved capability in the production of Compacted Graphite irons (CGI) and of thin-sectioned Ductile Irons and will also need to consider producing Austempered Ductile Iron (ADI) components. ADI production (Pearce 2018) is a classic example of where collaboration in technological aspects and sharing of information between the foundry and a suitable contract heat treatment provider is an absolute necessity.

On an increasing scale, Al-based castings have replaced welded steel fabrications as chassis and suspension parts and are being incorporated with sheet and extruded Al-wrought alloy forms into vehicle body and closures constructions. For example, cast parts are used as nodes to join extruded sections in construction of the body space-frame. Such light alloy space-form construction requires cast parts capable of high energy absorption, stronger and lower cost extruded hollow sections, reliable low-cost joining techniques and, for when a vehicle is in service, ease of damage repair in the body shop. With the move to replace conventional internal combustion (IC) engines by electric power units the move to lightweight bodies is of even greater significance (Bhandhubanyong et al 2019). In battery electric vehicles (BEVs) weight saving must be achieved to compensate for the weight of the battery pack in order to increase vehicle range or enable the use of smaller, more economic batteries. As BEV production increases at the expense of IC powered vehicles there will be a gradual reduction in the need for cast drive train parts such as engine blocks, cylinder heads, bed plates, oil pans, pistons and manifolds, etc. In their place the casting industry must change their production to be able to supply parts for battery pack supports, electric motor and power electronics housings and for new transmission designs.

The die-casting sector in Thailand has considerable capability and experience in the production of both low- and high-pressure die-cast parts, mainly for motor-cycle applications, auto-wheels and the electrical/electronics industry. However, it is recognized (Bhandhubanyong et al 2019) that for the die-casters to be capable of supplying high strength-high integrity, thin-walled complex parts for future body and chassis applications in both IC and EV powered vehicles, then further technical developments must be made. These include significant progress in die design and in the use of vacuum die-casting technology together with sustained improvements in metal cleanliness, in die filling and in overall process control. In producing components for body frame and BEV battery pack construction the casting producers must collaborate with the extrusion companies since these constructions require the compatible use of cast parts and extruded sections (Scamans 2018). Currently most of the extrusions produced in Thailand are in conventional 6061 and 6063 (Al-Mg-Si) alloys for architectural applications. For future automotive purposes, higher strength extrusions will be needed e.g. in 7xxx (Al-Zn-Mg-Cu) series alloys. To minimize imports cast Al-alloy billet producers must be able to extend their range of available compositions to include newer extrusion alloys together with alloys suitable for subsequent sheet metal production to be formed into structural body parts (e.g. 5754 Al-3Mg alloy) and into outer body panels (e.g. 6451 Al-Mg-Si). To make effective use of these various alloys cast billet suppliers, rolling & extrusion mills, press shops and the auto-assemblers will need to cooperate. Considerable process development work will be necessary in order to optimize compositions, homogenization, forming processes, strengthening heat treatments when required, joining methods and corrosion protection/paint finishing, etc. When a sufficient supply of clipping, off-cuts and scrap is available users and the billet cast house will also need to cooperate in the set-up of recycling systems for composition control and melt/cast billet quality assurance.

As a general comment, to make progress and survive in an increasingly competitive market, casting producers in the Thai SME sector must make improvements in a number of areas, these include the need to:

- reduce scrap and rework and improve quality
- optimize processes to reduce both variation and costs
- improve methods engineering
- become more energy efficient, cleaner and safer

Making such improvements in many of these SME companies continues to be restricted by limited investment and shortage of shop-floor and technician skills. Be that as it may, collaborative solutions to such problems are or should be made available through knowledge and know-how transfer, via better communication and discussion with both material and equipment suppliers and with casting users, and by taking advantage of the advanced materials characterization and computer aided engineering expertise available in Thai universities, R&D centres and other bureau providers

Collaboration Does Work.

SME and indeed the large foundries in Thailand run into many common technical problems such as making cost effective use of charge materials, coping with high return green sand temperatures on mechanized moulding lines, deterioration of cores during storage in high humidity conditions, selection and control of inoculation treatments, and environmental issues, etc. If an effective techno-economic foresight type appraisal of the Thai cast metals sector were to be performed, then such industry-wide problems could be more readily recognized. R&D facilities and funding could then be effectively directed towards their solution leading to improvements for the overall well-being of the industry. Such work naturally requires a high degree of collaboration and trust between the foundries involved who may well be competitors, and between the foundries, the funding agencies or stakeholders and the respective project organizers such as a research centre, institute or trade association. This approach has been successfully used for many years in Europe and the USA, hence there is no reason why it cannot happen in Thailand subject to the preparation of a correct legal framework for each project to cover confidentiality, non-disclosure agreement, intellectual property, access to know-how, etc. An example of a successful project in the UK that was carried out some 50 years ago on behalf of the British SG Iron Producers Association (BSGIPA) by the British Cast Iron Research Association (BCIRA) in collaboration with member foundries involved the development of SG Iron production know-how. SG iron, now more frequently known as Ductile Iron or FCD, was a relatively new industrial material in the 1960s. The aim was to determine the running and feeding characteristics in relation to production of a wide range of casting designs (size, shape, section thickness and complexity, grades, etc. Most of the experimental work was carried out in the actual foundries during normal runs of production. In this way the casting yield, and the integrity, quality. microstructure and mechanical properties of the various castings could be related to real production conditions. The outcome of the work in the form of a comprehensive report incorporating recommended design and methoding guidelines was then made available to BSGIPA member foundries. BCIRA was merged with British Steel Casting Research Association; another casting membership organization merged to form became Castings Technology International (CTI) in 1996. CTI is now part of the Advanced Manufacturing Research Centre (AMRC) at the University of Sheffield. In the USA cooperative work in Ductile Iron is continuing via the Ductile Iron Society with the aim of advancement in the technology, art, science of Ductile Iron production through R & D programs aimed at improving production technology and the promotion of Ductile Iron as an engineering material. Output of information in the form of research reports is provided at no charge to members. These reports are for their exclusive use for a period of two years, after which they are made available for open purchase.

Collaboration is not just needed for R&D projects; it also has proven success in a number of countries for the development of Best Practice or Best Available Technology (BAT) routes for industry, particularly with regard to energy efficiency and environmentally friendly sustainable manufacturing. For example, a collaborative project in the Indian casting industry has resulted in the issue of a Best Practice Guide (BEE 2012) for key foundry processes. In Thailand the National Metals & Materials Technology Centre (MTEC), which is part of the National Science & Technology Development Agency (NSTDA), began collaboration with interested Thai foundries in an initiative to improve technical performance and quality. Through the Manufacturing Design & Technology Centre (MDTC) group in MTEC a "Quality Programme" was set up starting in 2000 to operate alongside the main role of MDTC, which was assisting manufacturing industries including foundries with the introduction of computer aided engineering and simulation. At the outset the main objectives were to improve process technology and control, to assist foundries in scrap reduction and in tackling associated technical problems, to encourage foundries to achieve compliance with ISO/QS 9000 and to implement Total Quality Management (Pearce 2000). With each foundry the order of activities was assessment, training and implementation followed by any necessary project work into production problems and/or process development. The programme focused on technical not commercial aspects and examined performance in terms of quality levels and constraints such as limitations or problems in technical capability with raw materials, plant & equipment, production planning, and process & product development. It also included assessments of the technical and skills levels of the workforce to examine the needs for training and personal development. The theme for tailor made training and consulting was *"helping foundries to help themselves".* Foundries taking part were encouraged to start their own initiatives such as Process Improvement Teams or Quality Circles. With better understanding of the state of their various operations the foundries were then able to decide where improvements were needed and they could then begin internal projects to modify processes on a planned basis rather than make spur of the moment fire-fighting changes in the hope of solving production problems. The Quality Programme was incorporated into MDTC casting technology work which eventually tended to concentrate on Al-base casting developments. MDTC was later merged into the overall R&D programmes at MTEC in line with the NSTDA policy to support target industries such as new generation eco-vehicles, electronics and automation & robotics.

Successful outcomes from MTEC collaboration with Al-alloy ingot producers and high pressure die-casting (HPDC) plants research included the development of affordable, easy to use shop-floor test equipment plus associated computer software to assess melt cleanliness, gas content and fluidity and thermal analysis tests to predict microstructure (Phetcherai et al. 2011, Saohin et al. 2014) and the proving of a ring pull mechanical test procedure on test pieces produced in a specially designed die-set (Lounkosonchai et al. 2012). This test was developed to help HPDC plants to evaluate the quality of molten metal and to show how melt conditions and process settings can affect casting quality. Using mechanical testing of Weibull analysis of test results it can be clearly demonstrated that even if the supply of liquid metal is clean and correctly treated the resultant castings will have inferior, more variable mechanical properties if the shot sleeve conditions result in unfavorable melt flow into the die. Likewise, without correct liquid metal treatment, die castings will be inferior even when computer simulation has been used to set up correct shot sleeve conditions for satisfactory liquid metal flow.

Work during and subsequent to the Quality Programme has shown that to be innovative, research projects do not have to only involve design and development of new products but also to get improvements via the further development of existing processes. In conventional processes with existing alloys industry can still get "new from old" by improving quality, efficiency and environmental aspects and by reducing costs. All interested parties, especially those that control the provision of research funding, should recognize that that optimization of existing processes offers real opportunities for improvements in the Thai SME metal castings sector.

There continues to be a need for greater interaction between industry and academia, not only in Thailand but also worldwide. To encourage knowledge transfer in the UK the TCS-Teaching Company Scheme was established in 1976 as means for graduates to work on industry-based projects under joint industrial and academic supervision and with funding from the UK Science & Engineering Research Council for 2 to 4 years. The main aims were to introduce new technology to improve efficiency and productivity and to develop the next generation of products. In 2003 TCS evolved into the current Knowledge Transfer Partnerships (KTP) programme which is now led by Innovate UK, a Non-Departmental Public Body reporting to the Department for Business, Energy & Industrial Strategy (WECD 2015). KTP is not just for large enterprises, all KTP projects must involve at least one SME company. Recent and current emphasis is on robotic and AI systems with projects co-funded by the companies involved and government. A similar approach could prove beneficial for manufacturing industry in Thailand and especially in castings sector since it is quite difficult for SME cast metal companies to attract well-qualified graduates into what is often perceived as an out-of-date smokestack industry

Making Advanced Manufacturing Possible – Tech-shops for Foundries?

Most SME foundries are not able to invest in advanced manufacturing and materials/product testing equipment such as automated or robotic production lines, additive manufacture units, computer modeling & simulation software and instruments for analysis and characterization such as XRF and SEM, etc. Through NSTDA Science Park laboratories, some Thai universities and at a limited number of commercial testing or CAE/simulation centers, some of these facilities are available on a buying time basis. For the future development of SME foundries, it is essential that bureau services in simulation, modeling, prototyping and additive manufacture become more widely available. For example, in Thailand HPDC production capacity has rapidly expanded but this sector continues to be limited in performance by lack of design capability. Using simulation castings can be "designed and made correctly on the computer" before any tooling, die-sets or patterns etc. are produced. For all casting processes the use of simulation thus offers considerable savings in time and production costs since yield (in the foundry sense) is optimized by avoiding oversized gating and feeding systems, whilst overall yield is improved by reduction in scrap caused by defects such as shrinkage, misruns, dross and inclusions in castings. Simulation can also be used to create a model and predict various outcomes such as the occurrence of certain casting defects, residual stress patterns, microstructure and properties variations in different parts of a casting, effects of thermal treatments, flow of sand in core production, etc.

If not already doing so SME foundries should make use of smartphone communication via image capture or data exchange, for example to issue real time work instructions to shop-floor operators, for process control, and in condition monitoring for information exchange with equipment suppliers. SME foundries may be able to invest in small scale robotic production cells, e,g. for HPDC machines, which can be inter-linked for control and exchange of information, and for fettling of castings. They should also be aware of the application developments of small flexible robots which could enable easier and improved inspection of internal cavity surfaces in complex castings and which could also be used to examine the state of production equipment without any need for disassembly, saving time and costs. All casting producers should take advantage of the increasing encouragement and technical support for robotics in Thailand (Pearce 2019). In addition, they could benefit by using Additive Manufacturing (AM) to produce prototype castings thus shortening pre-production time or for moulds or cores for one-off and short run production. There is already practical experience in the application of 3D sand printing (3DSP) technology in Thailand using binder jetting to produce ready to cast chemically bonded sand moulds or core parts for use with other moulding systems (Valun-araya 2017). Other AM techniques such as Fused Deposition Modelling (FDM) can produce patterns in polymeric material for use in sand moulding with the advantages of time-saving and reduced costs when compared to conventional CNC machined Aluminium patterns. Patterns or core-boxes may not be necessary since, as well as sand models of castings for prototyping, they can be produced directly from CAD data enabling pattern-less casting, reverse engineering, and customizing of cast parts. Worn or damaged parts for plant or equipment can be quickly replaced minimizing any downtime.

There are proven benefits in using advanced manufacturing techniques but the key question is how can SME companies in Thailand gain an understanding and some basic experiences of such tools and hence start to use them in producing castings. If funding could made available, possibly through the collaborative efforts of government, the castings industry and equipment/software suppliers, a makerspace tech-shop approach, in which one or more communal production centres are set up, could encourage and accelerate the take-up of new technology in SMEs. The original Techshop was a chain of ten do-it-yourself fabrication shops which began in 2006 in the USA and was operated on a for-profit basis funded by membership fees from do-it-yourself enthusiasts, sculpture artists and entrepreneurs trying to start-up businesses (Su 2017). TechShops were also set up in Japan, France and Dubai and continue to operate successfully. However, the original USA scheme ran into financial problems and was closed abruptly in 2017, but a reborn membership sharing makerspace approach has restarted there with the recent setting up of TechShop2.0 (Evangelista 2019).

Compared to a makerspace workshop the establishment of a tech-shop related to castings production would involve a wider range of more advanced equipment, and hence would require considerably more funding to set up and operate. In the first instance, financial and other support would be needed from government, foundations and other sponsors, and from major equipment suppliers possibly via free loans of manufacturing plant. Castings producers could be given low-cost access during knowledge and know-how transfer and applications demonstration of the various tools and techniques available, and then be charged on as pay as you use basis when they made use of the facilities to solve their production problems or carry out small scale production. The industry would need to consider whether such a centre should operate on a non- or with profit basis. Experiences gained over recent years in the operation of the MTEC Pilot Plant has shown that collaboration can be mutually beneficial in Thailand, in this instance between a research centre and industry in joint R&D projects on HPDC component development, thermal spray applications, metal injection moulding, etc.

Conclusion

It is very difficult for SME foundries to tackle many production and environmental problems by themselves. Through collaboration, common problems that are frequently encountered by many foundries can be tackled on an industry wide basis such as that tried and tested in other countries in Europe, Japan and the USA, etc. For example, towards achieving sustainable development there is a need for the Thai casting industry as a whole, and the industry across ASEAN, to pay much more attention to sand reclamation, applications for spent foundry sand, and the recovery of metal from dross. Too much of this valuable "by-product" (it is not “waste”) goes to uncontrolled landfill leading to future environmental threats from leaching into soils and watercourses. Hence as well as sharing efforts in upgrading of production systems using advanced manufacturing, the castings industry must also address environmental issues. In doing so the industry could then provide clear information and practical advice to SME foundries not only in relation to CAE, robotics and other new technologies but also on how to save energy, how to make better use of spent sand and slag, and especially how to be safer and greener.

By taking part in suitable knowledge partnerships with the university and R&D sector, individual or a small group of foundries could not only make improvements and seek innovation in their operations and products but could also attract new talent in the industry.

In order to improve overall technical capability, collaborative action has long been needed across the SME casting industry in Thailand. It is believed that all SME casting producers, as well as larger JV enterprises could make significant technical gains by contributing to and taking part in a tech-shop type casting centre which would enable companies to experience and make use of advanced manufacturing and characterization equipment, AI, computer modeling and robotics, etc. In view of the need for action a suggested banner for such an initiative could be the ACTIVE (Advanced Casting Technology and Innovative Engineering) Centre.

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UPSTREAM VALUE CHAIN ANALYSIS OF SANGYOD MUANG PHATTHALUNG RICE

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ABSTRACT

This research aims to study and analyze the value chain of Sangyod Muang Phatthalung Rice. The data was collected from two groups: 7 middle men who collect Sangyod Phatthalung rice and farmers who sold the rice to those middle men. The results showed that farmers lack management skills to manage value chain in terms of production. Especially, inadequate seed because the farmers cannot produce high purity seed. Mostly the farmer received the seed from Phatthalung Rice Research Center. Moreover, the farmer lack of agricultural science knowledge for rice cultivation. This resulted in low cultivation yield. Additionally, the farmers had low bargaining power, thus they cannot control the selling price. According to the value chain analysis, the farmers should achieve the knowledge about best practice of cultivation, highly purify seed production, marketing.

Keywords: Sangyod Muang Phattthalung Rice, Value chain, Agribusiness

Introduction

Thai rice is one of the famous product of Thailand. Rice in each area has special character and taste. Several Thai rice has been registered as Geographical Indications products there are Khao jek Chuey Sao Hai, Khao Kum Lanna, Kaowong Kalasin Sticky Rice, Thung Kula Rong-Hai Thai Hom Mali rice, Khao leuang Patew Chumphon, Surin Hom Mali Rice, Sakon Dhavapi Haang Golden Aromatic Rice and Sangyod Muang phatthalung Rice (Rice Department, 2018).

Sangyod Muang Phatthalung Rice is a traditional rice variety which grown in phatthalung more than a hundred years. Previously, this rice was produced to be a gift for elderly people and guest. Moreover, this rice was used in special occasions and making merit (Saeton, 2007).

Variety of Sangyod Muang Phatthalung Rice was develop since 1987 by plant bleeder of Phatthalung Rice Research Center and called Sangyod Phatthalung. Later this rice was registered as Geographical Indication (GI) under the name Sangyod Muang Phatthalung Rice. The character of this rice is small and long with dark red pericarp, soft and rich aromatic (Figure 1). Moreover, it has high nutrition which good for health. It helps to nourish the blood supply and strengthens the body and also preventing Alzheimer's disease. The rice contains high oryzanel and gamma aminbutyvic acid (GABA), which be able to reduce the risk of cancer.

Figure 1 Sangyod Muang Phatthalung Rice (Matichon Online, 2016)

Sangyod Muang Phatthalung Rice is well known as healthy rice. According to the healthy trends, the demand of healthy rice is increasing. Therefore, the potential of market for Sangyod Muang Phatthalung Rice is increasing as well. However, the selling prices of Sangyod Muang Phatthalung Riceis quite low. Thus, the aim of this study was to study and analyze the velue chain in the upstream of Sangyod Muang Phatthalung Rice.

Objectives

The objective of this research are 1) to study the velue chain in the upstream of Sangyod Muang Phatthalung Rice and 2) to analyze the problem of velue chain in the upstream of Sangyod Muang Phatthalung Rice and provide the recommendation to improve the value chain.

Literature Review

Value chain

Value is the amount that buyers are willing to pay for the product or service that provides by firm. Whenever the production cost is less than selling price, the profit will occur. Every value activity employs costs such as raw materials, and other purchased goods and services for "purchased inputs," human resources (direct and indirect labor), and technology to transform raw materials into finished goods. Each value activity also creates information that is needed to establish what is going on in the business. Similarly, value is created by reducing stocks, accounts receivable, and so on, while value is lost via raw material purchases and other liabilities. Most organizations, thus engage in many activities in the process of creating value. These activities can generally be classified into either primary or support activities. These are illustrated in Figure 2, which details the view of Michael Porter. Each of these is divisible into a number of specific activities that vary according to the industry and chosen strategy of the firm. These categories can be described as primary activities as follows:

1) Inbound logistics: Activities associated with receiving, storing, and disseminating rights to the product, such as material handling, warehousing, stock management, and so on.
2) Operations: All of the activities required to transform inputs into outputs and the critical functions which add value, such as machining, packaging, assembly, service, testing, and so on.
3) Outbound logistics: All of the activities required to collect, store, and physically distribute the output. This activity can prove to be extremely important both in generating value and in improving differentiation, as in many industries control over distribution strategies is proving to be a major source of competitive advantage especially as it is realized that up to 50% of the value created in many industry chains occurs close to the ultimate buyer.
4) Marketing and sales: Activities associated with informing potential buyers about the firm's products and services, and inducing them to do so by personal selling, advertising and promotion, and so on.
5) Service: The means of enhancing the physical product features through after-sales service, installation, repair, and so on.

The second part of the value chain is the upper section which contains all the overhead service elements (labeled support activities) required by the firm. In Porter's picture there are four elements, firm infrastructure, human resource management, technology development, and procurement:

1) Procurement. This concerns the acquisition of inputs or resources. Although, technically this is the responsibility of the purchasing department, almost everyone in the firm is responsible for purchasing something. While the cost of procurement itself is relatively low, the impact can be very high.
2) Human resource management. This consists of all activities involved in recruiting, hiring and training, developing, rewarding, and sanctioning the people in the organization.
3) Technology development. This is concerned with the equipment, hardware, software, technical skills, and so on, used by the firm in transforming inputs to outputs. Some such skills can be classified as scientific, while others such as food preparation in a restaurant are "artistic." Such skills are not always recognized. They may also support limited activities of the business, such as accounting, order procurement, and so on, and in this sense may be likened to the value added component of the experience effect.
4) Firm infrastructure. This consists of the many activities, including general management, planning, finance, legal, external affairs, and so on, which support the operational aspect of the value chain.

   This may be self-contained in the case of an undiversified firm or divided between the parent and the firm's constituent business units. Within each category of primary and support activities, Porter identifies three types of activity, which play different roles in achieving competitive advantage: • Direct. These are activities directly involved in creating value for buyers, such as assembly, sales, and advertising. • Indirect. These are activities that facilitate the performance of the direct activities on a continuing basis, such as maintenance, scheduling, and administration. • Quality assurance. These are activities that insure the quality of other activities, such as monitoring, inspecting, testing, and checking.

The value chain is another generic framework that permits a range of applications and analyses. It permits the analyst to divide the firm's activities into broad categories (as above) and increasingly into more specific categories. Thus, operations might be refined into subcomponents and assembly: marketing and sales into market research, product development, sales force, and so on. The usefulness of this is to be able to identify those activities that are the source of the competitive advantage and to be able to locate them within the value chain. For example, if Intel's competitive advantage is product performance and this is derived (at least in large part) from R&D activities, then this can be isolated within the value chain and measured, compared to competitors, and provided with support.

Competitive advantage is often quite subtle in its manifestation and in its sources. Cost advantage might arise from the way in which every single activity in the value chain is linked to the others and managed for efficiency. The story of value chain the low-cost airlines such as EasyJet, Ryanair, and Southwest Airlines is about system management of the costs as well as focus on driving down each cost component. Differentiation may be delivered as a service quality perception driven by the way in which each element of service delivery is managed systematically along with all other elements in order to differentiate the product.

The value chain can be a powerful tool in diagnosing and explaining how the management of competitive advantage takes place within the firm. The interrelationships between the elements of the value chain provide an important explanation of the nature of competitive advantage in large, complex organizations. Such organizations typically are rich in tacit knowledge. This is the kind of knowledge that you call upon to ride a bicycle. We all know how to do this however it is impossible to explain it. Similarly, large corporations are used to making links between complex and far-flung activities, and between related and unrelated technologies. This "glue," binds these companies together and makes it impossible for others to imitate quickly. The "hidden" part of the value chain is these linkages that contain the tacit knowledge. The way this "glue," works determines the level of vertical integration, that is, those elements of the supply chain that can be brought within the value chain and within the firm and those that should remain outside the firm. The guiding principle is that when the costs of internal transactions (making the glue work properly) exceed the costs of buying outside, then the firm should source outside its boundaries (Cooper, 2014).

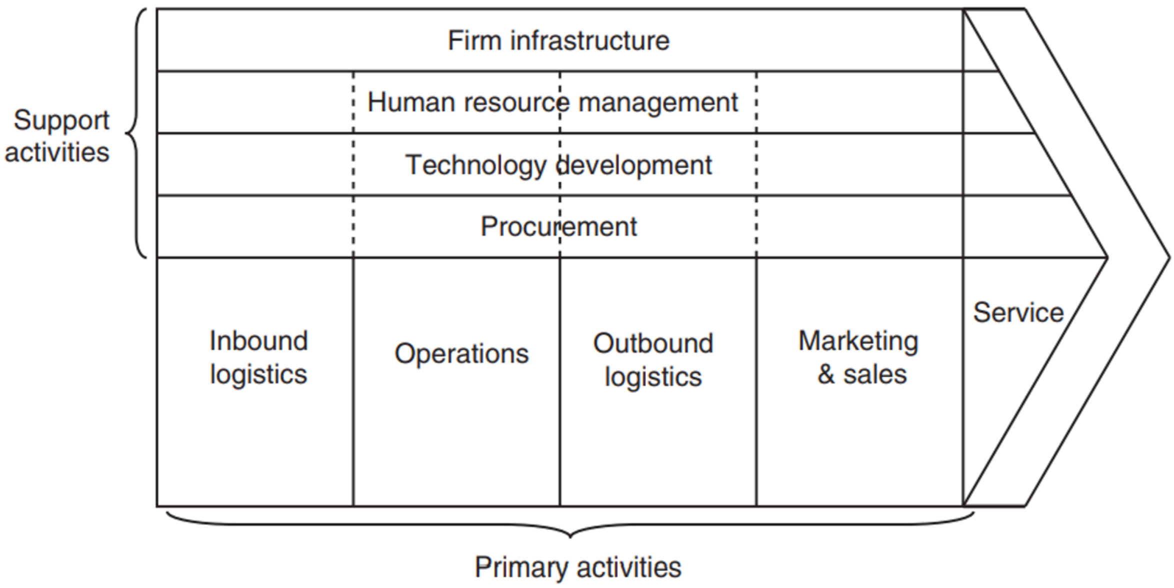

Figure 2 The generic value chain (Porter, 1995)

Methods

Data collection

1) Primary data

The primary data was collected from 7 middle men and farmers.

The middle men were selected by Phatthalung Rice Research Center according to marketing performance. Those middle men are: 1) Phanang Tung organic rice group, 2) Tamnan Sangyod Rice group, 3) Naphakoh group, 4) Roumjai Phatthana group, 5) Kok Sai Phong group, 6) Phang Dan group and 7) Khao Klang group. The data was collected from 7 middle men using questionnaire.

The population of farmers are 83 members of the 7 groups above. The sample size of farmer was determined using formula of Taro Yamane at 95% confidential (Taro Yamane, 1967 cited in Sinjaru, 2007). The selection of sample was done by purposive sampling. Thus the sample size was 69 farmers. The data was collected by interviewing using questionnaire.

2) Secondary Data

The secondary data was collected by collecting information related to this research from several sources such as books, journal and electronic-book.

Results and Discussion

General information about Sangyou Muang Phatthalung Rice business consist of agricultural input business, farmer, middle man, rice mill, whole seller and retailer. However, this research focused on farmer part. The research finding showed that 63.77% of farmers graduated from primary school with approximately 4 family members and 12 years' experience in growing rice. The average production area was 6.17 rai and most of them was the owner of the land (84.06%). Most of the farmers produced seed by themselves (75.36%), however, they cannot produce high purify seed. They cultivated the rice once a year and use rain water as water supply source. Most of them harvested the rice during January to February by combine harvester (85.51%), then sale the rice to middle men.

Most of middle men graduated from University (57.14%) and they all had rice mill. The average member was 12 farmers. The average capital was 115,000 baht and average income was 20,000 baht. The average demand was 36.14 ton per year and the sell both wholesale and retail. The average selling price for wholesale was 58.33 baht and average selling price for retail was 72.86 baht. The ratio of wholesale selling was 20% and retail selling was 80%. The selling channel were shop, online (Facebook) and superstore.

Value chain analysis of Sangyod Muang Phatthalung Rice

Primary activities

1) Primary Activities: Inbound Logistics
Most of farmers received the seed from Phatthalung Rice Research Center. They also produce the seed by themselves, however the purity of seed that they produced quite low. Most of them produced organic fertilizer and also plant bio-protection solution. The farmers did not record the cost of input, therefore they cannot know the exactly cost of production.
2) Primary Activities: Operations
The farmers cultivated rice under organic condition. The mail problem was inadequate water supply. The water supply for cultivation was from rain water. They do not have good irrigation system resulted in low quality and low production yield.
3) Primary Activities: Outbound Logistics
Farmers responded for the logistic cost from farm to the rice mill of middle man. Thus the production cost was high comparing to the selling price.
4) Primary Activities: Marketing and Sales
All farmers sold the rice to the middle man. They cannot control the selling price because lacking of bargaining power. Moreover, the quality of rice was quite low.
5) Primary Activities: Service
Farmer serve the middle man by responding for the logistic cost.

Support activities

6) Support Activities: Firm Infrastructure
The farmers did not had accounting system, thus they cannot know the accurately production cost.
7) Support Activities: Human resources Management
The farmer lack of workforce and most of them quite old. Therefore, the most of production cost were labor cost.
8) Support Activities: Technology Development
The farmer lack of water supply technology resulted in low quality and production yield.
9) Support Activities: procurement
The farmer lack of procurement management, thus the seed was inadequate in some crop.

Discussions

According to the value chain analysis, farmers need help in training to produce seed with highly purification. Then this can solve the problem of lacking seed in some crop. Moreover, they can sell the seed which has higher price than paddy. This seed business model also recommended in the research of Nannipha Prasunluk (2013). Moreover, the result showed that steak holder in rice business work separately (farmer, middle man and seller), hence steak holder should plan and work together. Then they can satisfy the customer which mean that they can increase the selling price. This strategy also recommended in the research of Chathaya Tuangsuwan (2010)

Conclusions

The results of the study on value chain analysis found that the farmers should focus on solving the problems following:

1. Lacking of seed

The main reason of lacking seed is inadequate of purity seed. This is because the farmer cannot produce high purity seed by themselves.

2. Low production yield

Low production yield occurred according to lacking of agricultural science knowledge and inadequate water supply.

3. Low bargaining power

The farmer got low bargaining power since they could not produce high quality rice.

Suggestions

1. Providing seed production training cause to farmer, therefore farmer can produce adequate high purity seed in each production crop

2. Providing production training cause about best practice for rice production to farmer and improve irrigation system.

3. Establishing farmer group, thus farmers can share best production practice to each other and enhance bargaining power. Moreover, providing marketing training cause to farmer. Then farmer scan sale the rice directly to customers.

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