THE EFFICIENCY OF DRYING PISANG AWAK BANANAS WITH THE HYBRID METHOD AND THE BREAKEVEN POINT OF ENGINEERING ECONOMICS

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Abstract

This research objectives were to find out the efficiency of making dried bananas with hybrid methods; solar drying and hot air drying and to compare the costs of using the traditional method and hybrid methods using breakeven analysis. Pisang awak bananas are used for drying with a hybrid method; drying in the solar dome and hot-air oven. Pisang awak banana was grown in Suan Phueng district, Ratchaburi, harvested in stage 2, and kept for proper ripeness at stage 6. The experiment used 10 clusters of Pisang awak bananas sliced vertically into 688 pieces. The drying process started in a solar drying dome for 18 and 36 hours at 42°C and went on drying with hot-air ovens at 35°C and 40°C for 18 and 2 hours, respectively. The indicators used to measure the efficiency and quality of dried bananas were the percentage of moisture, color index, firmness, and percentage of shrinkage, including breakeven analysis. The results revealed that the most appropriate way to dry Pisang awak bananas was in the solar dome at 42°C for 18 hours, and a hot-air oven at 35°C for 18 hours. Dried bananas were 19.54%

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of moisture and were under Thai Industrial Standards of dried banana products (less than 21%). The color index results were 42.65, 6.23, and 22.32 of L^*, a, and b^*, respectively that the color of dried banana was golden brown with soft texture; 412 ± 86.14^b g. of firmness. The percentage of shrinkage was relatively low because of drying with low temperatures. Moreover, the breakeven analysis showed the producer could gain a profit after selling 5,832 pieces or 584 jars of 10-piece dried bananas for 7 Baht a piece. The hybrid method helps reduce drying time by 78.57% from 168 hours of the traditional drying method.

Keywords: Pisang awak, Hybrid method, Dried bananas, Breakeven point analysis

Introduction

Banana is one of the economic plants generally grown in tropical areas since it is easy to cultivate and consume. There are many banana varieties worldwide, but the famous varieties are Gros Michel, Pisang awak, Pisang mas, and Saba. According to the major economic plants of Thailand, 15,051 metric tons of fresh bananas with 374 million Baht of values was banana production in 2020 (Centre of Agricultural Information, 2021). Pisang awak is a common name for tropical bananas and is called Kluai Namwa in Thai. It is a famous banana variety in tropical countries, especially in Thailand, Malaysia, Myanmar, and Vietnam (Crichton, 2020). Three significant characteristics of Pisang awak varieties in Thailand are red, white, and yellow banana fruits. Pisang awak is full of nutrition, i.e., carbohydrate, protein, fats, and various types of vitamins. However, banana is climacteric fruit that keeps going on ripening, stages of ripening are different, and so are internal and external changes (Pornchalermpong & Rattanapanon, 2021). Therefore, bananas can be consumed in fresh and processed fruits, and banana processing is food preservation that adds more value to fresh bananas.

There are many kinds of banana processing in Thailand, banana drying is one of the popular processing methods. Pisang awak has been used as raw materials for the drying process for a long time with the traditional Thai method of drying in the sun. This method makes bananas dry with some moisture and can keep dried bananas longer than fresh ones. However, dried banana processing methods have been developed continuously, including adding more flavors, such as honey, and syrup. Since the amount

of sunlight and its intensity are not stable overall of day and the year, dried banana products can easily be contaminated and infected with some diseases from insects, such as flies and fruit fries, which makes them moldy during the processes (Musikachai, 2018). Since there are many methods for banana processing, they are nature sunlight, microwave, hot-air oven, greenhouse solar dryer, and solar domes with various energy sources; solar cells, LPG, electricity, and gasoline (Piwsaoad, 2023; Piwsaoad & Phusampao, 2022; Nabnean et al., 2020; Dongbang & Nuantong, 2020; Musikachai, 2018; Boonchouy, 2017). Therefore, the developed methods to dry bananas are proposed to reduce costs and processing times with more hygiene and food standards domestically and internationally. There are many methods of making dried bananas, for example, sun drying, baking in ovens, hot air drying, and mixed methods. However, each method has its own advantages and disadvantages. The producers mainly aim to make their best-dried banana products with good taste and favors under industrial standards. Thai food industrial standard consists of food hygiene and processes with some specific properties, such as moisture. The moisture standard of dried banana products in Thailand should be at most 21% (Thai Industrial Standards Institute, 1985). Besides, there are many features that concern commercials with the customers and the competitors, such as flavors, colors, hardness, and toughness. As mentioned above, the methods used for dried bananas aim to reduce costs and time and make the products meet the food standards. Since bananas are probably the most important fresh fruit in the world in terms of production and international trade, it is a very delicate fruit that is easily damaged and has a comparatively short marketable life (Thompson et al., 2019). It should be adding more values by processing. So, the researchers proposed to find out the efficiency of making dried bananas with hybrid methods; solar drying and hot air drying and to compare the costs of using the traditional method and hybrid methods by using breakeven analysis.

This research initially started by reviewing related research and collecting primary data from the dried banana producer in Suan Phueng district, Ratchaburi. Hence, this section is a part of theories, literature reviews, and information on the dried banana products from the producer, as the following:

1. Pisang awak Banana

Pisang awak banana is generally grown in many areas of Thailand, and the major areas are in Phitsanulok, Sukhothai, Nakhonratchasima, Phetchabun, Phetchaburi and Ratchaburi. Pisang awak banana is grown to consume inside the house and for commercials. It can be eaten as fresh fruits and cooked or processed in various types of foods and fruits. The nutrition of the Pisang awak banana is protein, Niacin, vitamin C, carbohydrates, calcium, phosphorus, and content energy (Upawang, 2019). Moreover, water is the main component of Pisang awak banana, which is 70% approximate. Hence, making dried bananas decreases the water inside the fruit. However, its meat is still moist, and banana fruits used as raw materials have to be in the appropriate ripening stage. There are 8 stages of ripening banana as shown in Figure 1.

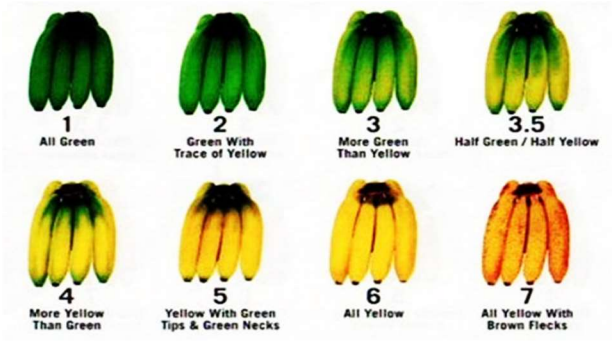

Figure 1 The ripening index

Source: Veroustraete, F. (2016)

The stages of banana ripening are (Veroustraete, 2016)

Stage 1: The external feature is naturally green, hard, and not mature.

Stage 2: The external feature starts changing from green to yellow, but not much.

Stage 3: The external feature becomes more yellow but less than green.

Stage 3.5: The external feature becomes more yellow and more than green.

Stage 4: The external feature becomes more yellow, but the end of the fruit is still green.

Stage 5: The whole fruit is yellow, and it is the maturity.

Stage 6: The external feature is more yellow, and starts with brown dots. It matures fully with scent.

Stage 7: The external feature is yellow, and brown dots spread across the fruit. The internal feature becomes soft with the strong scent and sweeter. It gets rotten within 2-3 days.

Moreover, physical and chemical changes happen not only as explained above but also. The banana taste is sweeter in stages 5, 6, and 7 because the chemical changes occur during the ripening phase.

2. Thai industrial standards of dried banana products

According to the standards of dried banana products under the Thai Industrial Standards Institutes B.E. 2546, it announced that dried banana products had to follow the standards whether the products were processed the whole fruit or in pieces. The standards are as follows:

2.1 General features-shapes and sizes of dried bananas should be the same in each package.

2.2 Colors-good products should have natural colors.

2.3 Scents and tastes-these should be natural tastes, without unwanted smells; musty, rancid, or burning smells, or with a bitter taste.

2.4 Textures-dried banana meat should be soft, flexible, and hard in the package.

2.5 Foreign matters-the products must not have all adulterated things in dried banana products, such as sand, soils, stones, hairs, furs, or animal filth.

2.6 Food additives- the products should not add all kinds of preservatives and must be legally used when adding flavoring agents.

2.7 Water activity-it must not be more than 0.75.

2.8 Microorganism-it consists of the quantity of total variable count, Escherichia coli, Staphylococcus aureus, and yeast and mold.

Therefore, good quality dried banana products must strictly follow this standard.

3. Breakeven analysis

Breakeven analysis is a system of determination of a level of activity where total costs equal total selling price. It is also called Cost-Volume-Profit analysis or Cost analysis (Balasubramanian, 2018). It shows the relationship between costs and revenues at a given time and determines the break-even point and profit potential under varying conditions of output and cost (Nikila, 2019). It refers to a level of activity where the

income of the business exactly equals the expenditures. The components of the analysis consist of fixed costs, variable costs, and revenues. It is suitable for creating the project of a new product (Clear, 2021). It can be called the break-even analysis for a single project; the break-even point is the cutting point between total revenue and total costs (Amdee, 2022).

The break-even point formula is shown in Equation 1.

$$BEP\ in\ quantity = \frac{FC}{(P-VC)} \quad (1)$$

where BEP = Break-Even point

FC = Fixed costs

VC = Variable costs per unit

P = Selling price per unit

Materials and Methods

This section is about materials and methods that consist of materials preparation, moisture content, shrinkage, and hybrid method, respectively.

1. Materials preparation and drying methods

Raw materials used in this experimental research were Pisang awak bananas grown in Suan Phueng district, Ratchaburi. Because of its moisture and scent, the variety of Pisang awak banana was Sai Kow. This type of banana is grown all over Thailand. After planting for 9-10 months, the banana blossom will come out, and spend about 3 months for fresh fruits. A bund of bananas has about 12 -15 clusters and a cluster has 15 – 20 banana fruits. After 3 months of blossoming, the banana farmers will cut banana bunds and cut cluster by cluster for sale, but some farmers sell for bunds.

However, in the case of drying banana processes, the researchers kept the fresh cluster for stage 6 as shown in Figure 1. Because it is the stage that is suitable for drying, full of moisture content and its scent. The steps of raw material preparation are as follows:

1.1 Peel the Pisang awak bananas,

1.2 Slice bananas vertically and one banana fruit can be sliced into 4 pieces with 5-6 thick-mm.,

1.3 Separate the slices of the banana piece by piece on the bamboo tray

1.4 Take the banana tray into the solar dome for the first drying with 35-40°C for 18 and 36 hours,

1.5 Take dried banana slices from the solar dome and dry them again in a hot air oven at 35°C and 40°C for 18 and 36 hours, and

1.6 Keep dried bananas at room temperature, and package them in the packages.

All steps are shown in Figure 2.

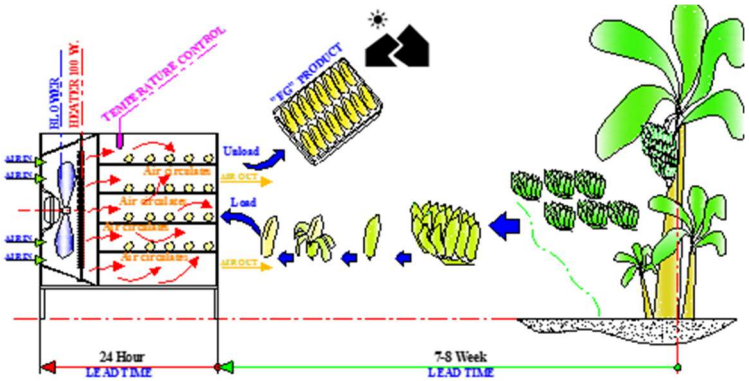

Figure 2 Steps of drying Pisang awak bananas

Source: Tantiwattanodom et al., (2021)

The drying method used as a hybrid method consisted of solar drying in the dome and hot-air drying methods. The solar drying dome which was used in the experiment is cleaner and easier to control the temperatures than the local drying method. Because the solar drying dome is a closed system and its size can be adjusted appropriately to the production area and costs. The solar drying dome is shown in Figure 3.

Figure 3 Solar drying dome

Source: Tantiwattanodom et al., (2021)

The researchers have chosen these 2 methods because it is appropriate for community enterprise and the costs of initial investment of instruments; solar dome and hot-air oven are not too high. Temperature control in the solar drying dome was 42°C on average. Since solar dome and hot-air oven methods are closed systems that keep raw materials from insects and dust. So, dried banana products were less contaminated in the process. Hot-air ovens were controlled at 35°C and 40°C. The costs of instruments, raw materials, and labor are detailed in Table 1.

Table 1 Costs of instruments, raw materials, and labor

Items	Qty	Prices (Baht)
Solar Dome (4x4x3.5 m^3)	1	25,000
Hot-air ovens	2	9,000
Labor (a day)	1	300
Pisang awak banana (cluster)	1	8
Electricity for processing	1	1.7426*

Remark *Average cost of electricity /unit

The research used 10 banana clusters and sliced them into 688 pieces. They were dried all at once in the solar drying dome for 18 and 36 hours and in hot air for 18 and 24 hours. One hot-air oven can contain 180 pieces of fresh banana. Therefore, all raw materials have to be dried with two ovens 2 times or with 4 ovens at once.

2. Colors

The colors of dried banana products are the indicator that identifies the quality of products as well since consumers will satisfy with the colors of the products. It is the same as the dried banana product's color, which should be golden brown (Athiwittayaporn, 2008). However, colors can be measured by spectrophotometer and identified into L^*, a^*, and b^* which are lightness, redness, and yellowness, respectively. The equation of colors under the Commission Internationale de l'Eclairage (CIE) is shown in Equation 2.

$$\Delta E^*_{ab} = \sqrt{(L^* - L^*_0) + (a^* - a^*_0) + (b^* - b^*_0)} \qquad (2)$$

Where ΔE^*_{ab} = The total color

L^*_0, a^*_0, b^*_0 = Values of light, red and yellow

L, a, b = Values of light, red, and yellow of products

The results of raw materials and dried banana products were sent to the lab and measured the color identification, respectively.

The initial color values of fresh banana fruits were 67.78, 7.33 and 37.79 of $L_0^*, a_0^*\ and\ b_0^*$, respectively.

3. Moisture

The moisture of raw materials and products is the indicator that concerns the firmness of the fruits and the products. It can be measured by using Equation 3.

$$\mathrm{Mc,(w,b,\%)} = \frac{\mathrm{m_i - m_f}}{\mathrm{m_i}} \mathrm{x100} \quad (3)$$

where m_i = the initial mass (kg.)

m_f = the initial mass (kg.)

The moisture of raw materials; fresh Pisang awak bananas and dried banana products were measured, respectively, and follows Thai Industrial Standards that dried banana products must be not more than 21%.

The moisture of raw materials was measured and calculated in average; it was 70.11.

4. Shrinkage

The shrinkage is an indicator measured the final size of the final product. It can be measured after drying and calculated by using Equation 4

$$Shrinkage\ (\%) = \left(\frac{v_i - v}{v_i}\right) x100 \quad (4)$$

where v_i = initial volume

v = after-drying volume

Sizes of fresh bananas as raw materials were 3-4.5 cm. in width and 8.7-9.5 cm. in length.

Results

The results of physical quality after drying Pisang awak bananas with each method and breakeven analysis are shown as the following:

1. Physical quality

After drying raw materials in the solar drying dome for 18 and 36 hours, the results of the physical quality of dried bananas were shown in Table 2.

Table 2 Physical quality of dried bananas after drying in a solar drying dome

Drying Times / Heat Levels	Physical Quality
	42 ^{0}C on average (not more than 50 ^{0}C) Moistures (%)
18 hours	62.76
36 hours	55.21

The results of the physical quality of dried bananas consisting of 18-hour drying and 36-hour drying show that the sizes of bananas were 2.8-4.1 cm. width and 8.0-9.2 cm. length, and 2.7-3.6 cm. width and 7.5-8.6 cm. width, respectively. The levels of moisture during 18-hour and 36-hour drying were 89.76% and 82.21%, respectively. The researchers selected 18-hour dried bananas to be dried in hot-air ovens since 36-hour dried bananas changed in moisture less than expected and spent times twice with 7.5% physically changed. The experiment could save time for 18 hours.

Bananas dried with a solar drying dome for 18 hours were sent to dry with hot-air ovens at 35°C and 40°C for 18 and 24 hours, respectively. The results after drying are shown in Table 3.

Table 3 Physical quality of dried bananas after drying in hot-air ovens

Drying Times/ Heat Levels	Physical Quality			
	35°C		40°C	
	Moistures (%)	Firmness (g)	Moistures (%)	Firmness (g)
18 hours	19.54	412±86.14^b	16.57	523±54.64^b
24 hours	15.77	412±86.14^b	14.43	670±57.09^a

The physical quality results of 35°C of heat level for 18 hours and 24 hours consisted of 19.54 and 15.77% of moisture and 412±86.14^b and 412±86.14^b g. of firmness, respectively, and of 40°C of heat level for 18 hours and 24 hours consisted of 16.57 and 14.43% of moisture and 523±54.64^b and 670±57.09^a g. of firmness, respectively.

Table 4 Color Indices

Drying Times / Heat Levels	Color Indices					
	35 ^{0}C			40 ^{0}C		
	L*	a*	b*	L*	a*	b*
18 hours	42.65	6.43	22.32	58.20	5.54	12.85
24 hours	54.37	5.56	22.67	56.32	7.41	22.89

The color results of 35°C of heat levels for 18 hours and 24 hours consisted of 42.65, 6.43, 22.32 and 54.37, 5.56 and 22.67 of L^*, a^*, b^*, respectively, and of 35°C of heat level for 18 hours and 24 hours consisted of 58.20, 5.54, 12.85 and 56.32, 7.41 and 22.89 of L^*, a^*, b^*, respectively.

Table 5 Shrinkage of dried banana

Drying Times / Heat Levels	Physical Quality	
	35°C	40°C
	Shrinkage (%)	Shrinkage (%)
18 hours	16.54	18.66
24 hours	19.02	22.35

The shrinkages of dried bananas at 35°C for 18 and 24 hours were 16.54 and 19.02%, respectively, and with 40°C for 18 and 24 hours were 18.66 and 22.35%, respectively

The best result of this experiment was dried bananas with 18-hour solar drying in the dome and 18-hour hot-air drying in the ovens. Because the color was golden brown with 19.54% of moisture. The left-top figure was in the drying process inside the hot-air oven. The right-top and the below figure were finished fried banana products. The result showed in Figure 4.

Figure 4 Dried Bananas

2. Breakeven analysis

According to the experiment results, breakeven analysis can be calculated from the best solution: dried bananas with 18-hour solar drying in the dome and 18 hours of hot-air drying in the ovens because the color was golden brown with 19.54% of moisture. The total costs are shown in Table 7, and the selling price of a piece was 7 Baht, calculated without the cost of packaging.

Table 6 Total costs of dried bananas

Costs	Item	Total amount
Fixed costs	Solar drying dome	25,00.00
	Hot-air ovens (4,500x2)	9,000.00
	Total fixed costs	34,000.00
Variable costs	Labor (1 unit x ฿300 x 2 days)	600.00
	Raw materials (10x฿8)	80.00
	Electricity (1.7426x36x2)	125.46
	Total variable costs	805.46
Total variable cost a piece (688 pieces)		1.17

In case of the selling price without packaging cost, a piece of dried banana's selling price is 7 Baht. So, the result of the breakeven analysis was calculated from equation (1) as follows:

$$\text{BEP in quantity} = \frac{\text{FC}}{(\text{P} - \text{VC})}$$
$$= \frac{34000}{(7-1.17)}$$
$$= 5{,}832$$

The breakeven is at 5,832 pieces which means the producer has to produce dried bananas for 5,832 pieces, or 584 jars (in case of using a jar for the dried banana package), and the selling price is 70 Bath a jar (for 10 pieces each jar).

Conclusions

Pisang awak bananas were used as raw materials for making dried banana products. Bananas were grown in Suan Phueng district, Ratchaburi. Bananas used were at stage 6 which was suitable for drying in a solar dome for 18 and 36 hours and selected the 18-hour dried bananas to be dry in a hot-air oven for 18 hours and 24 hours with

temperature levels of 35 and 40°C. The results revealed that the most appropriate drying solution was to dry in a solar dome at 42°C on average for 18 hours and to dry in a hot-air oven at 35°C for 18 hours. Dried banana was dried with 19.54% of moisture with golden brown color. The result is under the Thai industrial standard for dried banana products; less than 21% of moisture. However, drying bananas with higher temperature levels made them dry faster but the percentage of shrinkage was higher as well, and dried bananas were distorted and twisted. Besides, dried banana products with high-temperature levels were hard and dry textures. Drying times in this experiment were shorter than the traditional method; sun-drying takes 7 days (168 hours). It saved time by 78.57% approximately.

Moreover, this research showed the results from the breakeven analysis were at 5,832 pieces with 34,000 Baht of total fixed costs and 1.17 Baht of total variable cost a piece of dried banana. I is possible for the farmers or those who are interested in banana processing to invest, by using this research as a guideline and the methods can be used as a prototype for other local producers.

Farmers and community enterprise entrepreneurs in Suan Phueng district can use this hybrid method to apply their production, and it can help to enhance production efficiency and reduce costs. This production method enables to use of various raw materials, such as pineapples, lemons, guava, etc. Eventually, farmers and community enterprises in other areas nearby also are able to learn how to use solar drying and hot air for drying fruits and use the accounting pattern for cost evaluation. The Learning Center for Community Enterprise in Suan Phueng district is going to establish with the local administrative organizations in the future. However, the solar dome used in the experiment must be adjusted and improved because of its irregular airflow inside. Meanwhile, the hot-air oven can be changed energy source from electricity to solar cells in the future. So, it improves the cost saving of its production.

The researchers plan to do further study of banana processing with this hybrid method by using the mathematical model in dried banana production.

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Reference

Amdee N. Engineering economy. 3rd ed. Ratchaburi: Mubanchombueng Rajabhat University; 2022.

Athiwittayaporn S. The Study of optimum drying time of dried banana using the combination methods of air drying and vacuum microwave drying. Faculty of Agricultural Industry. Bangkok: Kasetsart University; 2008.

Balasubramanian S. Process engineering economics. Department of chemical engineering, SRM University. 2018 Available at: http://balasubramanian.yolasite.com/resources/Introduction%20 Economics %20Lecture%202%201e%20.pdf Accessed December 13, 2022.

Boonchouy, N. The Study Cost and Returns of Planing Cultivated Banana in Tha Yang District, Phetchaburi Province. Veridian E-Journal, Silpakorn University 2017;10(1):1884-1894.

Centre for Agricultural Information. Annual Report of 2020.Bangkok: The Ministry of Agriculture and Cooperatives; 2021.

Clear C. Break-Even Analysis – Definition, Formula & Examples. 2021. Available at: https://cleartax. in/s/break-even-analysis; Accessed December 13, 2022.

Crichton R. Pisang Awak. 2020. Available at: https://www.promusa/Pisang+Awak#Local_names; Accessed December 13, 2022.

Dongbang W, Nuantong W. Investigation of mathematical modeling for banana slices drying using hot air technique. Naresuan University Journal: Science and Technology 2020;(28)3:79-87.

Musikachai T. Drying Strategy of Kluai Leb Mu Nang and Kluai Khai with Energy Heat Source: LPG. Faculty of Engineering, Songkhla: Prince of Songkhla University; 2018.

Nabnean S, Nimnuan P, Sanorchit O. Solar drying of banana using household solar dryer. Journal of Knowledge Exchange 2020; 19-31.

Nikhila C. Essay on break even analysis, Engineering economics. Business Management Ideas. 2019. Available at: https://www.businessmanagementideas.com/essays/essay-on-break-even-analysis-engineering-economics/6908. Accessed December 13, 2022.

Piwsaoad J, Phusampao C. Greenhouse solar dryer for drying life andrographis paniculata herb. Sciences and Environment Journal 2022;23(2):324-333.

Piwsaoad J. Greenhouse Solal Dryer with LPG Gas Burner for Drying Bananas. Life Sciences and Environment Journal 2023;24(1):53-73.

Pornchalermpong P, Rattanapanon N. Climacteric fruits. Food network solution. (2021). Available at: https://shorturl.asia/hZKNi. Accessed December 13, 2022.

Tantiwattanodom C, Amdee N, Tonglim T, Sonsiri A. Optimum drying times of dried bananas with hybrid methods. Silpakorn International Conference on Total Art and Science 2021 (SICTAS 2021) 2021: 253-257.

Thai Industrial Standards Institute. Standards of drying banana products. Bangkok: MIK Press; 1985.

Thai Industrial Standards Institute. Standards of drying banana products. Bangkok: MIK Press; 2003.

Thompson AK, Supapvanich S, Sirison J. Banana Ripening. Science and Technology. SpringerBriefs in Food, Health, and Nutrition; 2019.

Upawang N. Nutrition of pisang awak banana and its usefulness. Region Health Office 6, Chonburi Province; 2019.

Veroustraete F. Can ethylene, a simple gaseous hydrocarbon, be considered as a plant hormone or as an ozone antagonist? ReserchGate, Redstar-CV&M Open Access Science Publishing; 2016: 4-11.