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A study of the potential of by-products from pineapple processing in Thailand: Review article

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Abstract---The data, focusing on the supply of pineapple for industrial processing in Thailand during the period from 2011-2020, was acquired. The data indicated that productivity had tended to decrease during the period between 2011-2015 due to phenomena of drought and a reduction in prices, while increasing trends were observed during the years between 2016 -2019. In the year 2020, Thailand was the biggest exporter of canned pineapple in the world, and the export value was approximately 345 million U.S. dollars. During the process, the generated by-products were peels, cores, stems, and crowns at approximately 35.5, 14.7, 4.6, and 4.3%, respectively. Based on the annual production of 1,689,884 tons, the total by-products from pineapple processing would generate 993,402.4 tons, which could be divided into peels, cores, stems, and crowns at 596,713.8, 247,089.9,

773,20.7, and 722,78.0 tons, respectively. Valorization of by-product for health applications such as pharmaceutical, cosmetic, and health food has been reviewed.

Keywords---health applications, pineapple, productivity, by-product valorization, exporting value.

Introduction

Pineapples (*Ananas comosus* (L.) Merr.) have had an important influence on the economic system of Thailand since 1971. Its varieties have been improved to be more suitable for consumption purposes (e.g., fresh cut or processed pineapple). However, processed pineapples have been established and pineapple products have been considered as economic goods for export until the present. At this time, Thailand is the largest exporter of processed products derived from pineapple fruit, particularly canned pineapple, and pineapple juice. In 2011, canned pineapple had a value of around 666 million US dollars, and approximately 641 million tons were exported from Thailand. In 2020, the total value of canned pineapples exported from Thailand was approximately 348 million US dollars and the quantity was 290 million tons. The export markets in 2020 for Thai canned pineapple were the United States, Russia, Germany, Poland, and Japan, respectively (Information Technology and Communication Center, Ministry of Commerce, 2022).

Generally speaking, pineapple fruit can be produced throughout the country although the weather and the environment of certain areas may differ. Based on the geography of Thailand, the production areas have been divided into 4 portions: Northern, Northeastern, Central and Southern portions. The productivity of pineapple from those parts should be reviewed in order to evaluate the production conditions. This number would also be useful in forecasting the number of by-products that are generated from pineapple processing. On average, only 30% of a whole pineapple fruit is processed into finished products, and the leftovers are the by-products. The rate of generation of by-products seems to be the highest during April-June and November-January due to seasonal production. The types of by-products are different depending on the variety of processed products. Those would most likely consist of crowns, peels, cores, and stems from canned pineapple. In addition, pomace, which is a mix of pulp and core, is left over from pineapple juice production. The amount of those parts varies depending on the production technologies. In the past decade, the valorization of those by-products has been interesting, but it relies on the chemical compositions and on the potential amounts of by products that are generated annually (Banerjee, 2018).

However, an investigation that focuses on the supply of pineapple production in Thailand and the potential to utilize the by-products in other industries has not been thoroughly conducted. Therefore, the aim of this review was to present two

features: 1) the supply available for pineapple production and 2) the export values from the past decade in Thailand. In addition, the potential for valorization of pineapple by-products was also explored.

Production Supply of Pineapple Fruit in Thailand

Although the planting area is distributed throughout the country, it has been documented that the demand for producing pineapple has recently reduced. The planting areas have been divided into 4 parts: the Northern, Northeastern, Central, and Southern portions of Thailand. The planting area for pineapple in Thailand was reduced from 659,625 Rai in the year 2011 to 454,100 Rai in the year 2020. The planting areas were also adapted to produce other economic plants, such as palm oil and rubber trees. In addition, the rubber trees growing at that time has reached about 3 years of age and planting pineapple plants, which are flanked by rubber trees, is not possible when the rubber trees are over 3 years old. However, a slight increase in planting areas occurred during the years between 2016-2018, which was activated by an increase in pineapple prices in the year 2016 with an average price of 10.53 baht/kg. (Office of Agricultural Economics, 2022). The area was to cultivate pineapple plants again. It can be noted that the biggest area for planting pineapple trees has been in the Central portion of Thailand (about 304,485 Rai in year 2020) because it accounts for those of Eastern and Western, as well as for Prachuap Khiri Khan Province. The smallest area is the Southern portion of Thailand.

It can be seen that the productivity of pineapple in Thailand gradually decreased from the year 2011 to 2015 (Office of Agricultural Economics, 2022), which was concomitant with reductions in the planting areas. Despite reductions in the planting areas, the phenomenon of drought also affected the production of pineapple fruit during the years of 2013-2015 and 2018-2020. From Figure 1, the reduction in rainfall in the planting areas of pineapple was reported to be between 84,208.6 - 100,802.3 mmHg during these periods (Thai Meteorological Department, 2022). The productivity and quality of the pineapple fruit is mainly dependent upon rainfall. The increased pineapple production in the years between 2016-2018 was mainly due to the expansion of the planting areas, which was inspired by higher sales prices during that period.

The changes in pineapple productivity were highly related to the planting area. From Figure 1, productivity started to decrease in its first wave from the years between 2011 to 2015, which was followed by a second wave after 2018. Meanwhile, an increase in productivity was observed between 2015 to 2018 (Office of Agricultural Economics, 2022). Conversely, changes in the price of pineapple tended to be the opposite given that the productivity. For example, in 2015 the price was higher at 10.29 baht/kg, whereas the productivity was lower at 1,825,195 tons.

According to the supply theory, after the farmers had increased their planting areas, the productivity or the quantity of the pineapple usually increased, which resulted in having an oversupply, which further resulted in a price reduction of pineapple at that period. Moreover, the pineapple prices and productivity had a positive relationship with the next crop cycle. Meanwhile, after the price of the pineapple had increased, the farmers became interested in extending their planting areas in the next crop cycle (about two years). Moreover, the opposite phenomenon could be observed during a period of reduced pineapple prices. For example, it was found that in 2015 when the average price was high at 10.29 baht/kg, the productivity of pineapple cultivation increased following a similar trend in 2017 (see Figure 1).

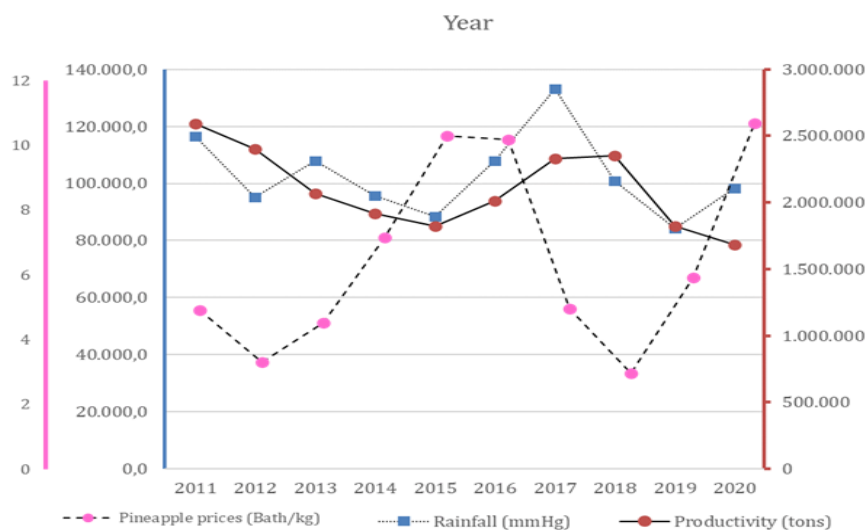


Figure 1. The changes in rainfall, productivity and price of pineapple in Thailand between 2011-2020

Source: The Office of Agricultural Economics (2011-2020)

Thai pineapple exports and products

Fresh or dried pineapple (HS080430), canned pineapple (HS200820), pineapple juice of a Brix value not exceeding 20 (HS200941) and pineapple juice with Brix level exceeding 20 (HS200949) are mainly Thai pineapple product for export in the global market. Exports of Thai fresh or dried pineapple to global market fluctuated in value and in quantity during 2011 -2020. The fresh or dried pineapple was valued between 1.5 and 10.3 million US dollar. The quantity of Thai fresh or dried pineapple was between 1.5 and 17.4 tonnes. In 2020, the main export markets of Thailand are China, the United States, Myanmar, the United Arab Emirates and Ukraine, respectively. In the world, the fresh or dried pineapple of Costa Rica is mainly exported to many countries in 2020. The Philippines, Netherlands, The United States of America and Belgium are ranked second, third, fourth and fifth, respectively (International Trade Map Centre, 2022).

Thailand is the main exporting country of total canned pineapple in the world. It exported about 345 million US dollar value of canned pineapples in 2020 or about 32 percent of the global canned pineapple exports. Philippines is the second country among exporting country to global. The Philippines export of canned pineapples is approximately 235 million US dollars in value. Indonesia, Kenya, the Netherlands and others are ranked third, fourth, fifth and sixth, respectively. In 2020, Thailand's major export markets are the United States (34.94%), Russia (6.34%), Germany (5.19%), Poland (3.35%) and Japan (3.30%) (Information Technology and Communication Center, Ministry of Commerce, 2022). The amount of canned pineapple exported from Thailand to global is downward during the period from 2011 to 2020. In the value terms, total canned pineapple exports from Thailand to global moved in a lower direction. The canned pineapple exports continuously decreased between 2011 and 2014. The export value of canned pineapple increased from 2015 to 2016. In the following years, there was a decline of the export value to about 337 million US dollars. In 2020, the export value of canned pineapple rose again.

The change in value and in quantity of Thai pineapple juice of a Brix value not exceeding 20 in the world is rather slight. There are two periods of a decrease in the pineapple juice over the last ten years. Exports of the pineapple juice decreased from 2012 to 2015 and from 2017 to 2020. The value of the pineapple juice had decreased by an average of 1.2 million US dollar over the first period and 900 thousand US dollars over the second period. In quantity, the average of the pineapple juice exports in two period was decreasingly 2.2 million tonnes and 950,000 tonnes. Major export markets of Thailand are the Netherlands, South Korea, China, Australia and Vietnam (Information Technology and Communication Center, Ministry of Commerce, 2022). In 2020, Costa Rica is the largest exporter of the pineapple juice with more than 35% of the world export values, followed by the Netherlands, Spain, Belgium and Germany (International Trade Map Centre, 2022).

Export of Pineapple juice with Brix level exceeding 20 are decreasing. The quantity and value of Pineapple juice with Brix level exceeding 20 decreased from approximately 140 million tonnes to 39 million tonnes in quantity and from approximately 222 million US dollars to 63 million US dollars in value. In 2020, Thailand was ranked as the 3rd in the global market with the 15.64% share of the Pineapple juice with brix level exceeding 20. According to Ministry of Commerce, The United States of America is the major export market of Thailand. Pineapple juice with brix level exceeding 20 is also exported to the Netherlands (20.45%), Iran (11.27%), Japan (6.83%), and Spain (4.74%), respectively.

Estimation of by-products from canned pineapple processing

By-product generation

Although there are several varieties of pineapple that are currently planted throughout Thailand, only a few are satisfactory for processing on an industrial scale. In 1967, canned pineapple was established as an export product and still is the main product generated by pineapple factories in Thailand. The most suitable variety to process for export is *Pattavia*, which accounts for about 80% of the total varieties. The main product exported from Thailand has been canned pineapple, which is followed by pineapple juice. Other products, such as frozen pineapple, dried pineapple, and concentrated pineapple juice, may be processed, but the exported amounts are less when compared to the exports of other countries (Rico et al., 2020). Prior to peeling, the processing line for producing canned pineapple starts with the cutting of the crown (if present) and the lower stem. During coring, the pineapple core is removed, and then the flesh (30-65%) is sliced or cut into pieces before it is mixed with syrup in the can (Figure 2). During this process, the crowns, stems, peels, and cores will be generated as by-products in amounts of approximately 2.7 - 5.9, 2.4 - 6.8, 29 - 42, and 9.4 - 20%, respectively. The production line for pineapple juice is slightly shorter since coring and dicing/slicing are not necessary. Afterwards, the pineapple pomace, which remains after pressing the juice is considered to be a by-product from this process instead of the core. The amount will vary due to the pineapples' sizes and the processing technologies employed at each factory.

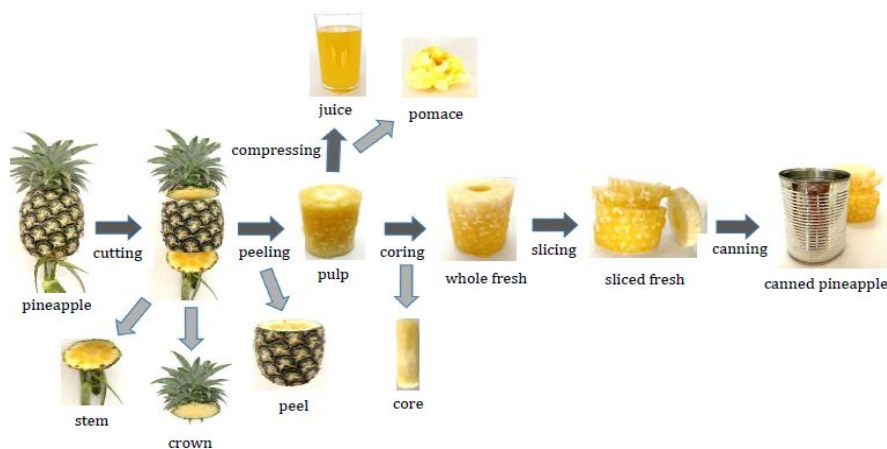


Figure 2. The processing line for manufacturing pineapple juice and canned pineapple

Estimated by-products from pineapple processing in Thailand

Based on the data regarding Thailand's annual production of pineapple for processing into canned pineapple in the year 2020, only 80% of the productivity

was processed. Therefore, based on the productivity, the leftover by-products from each step of production could be estimated at 1,680,884 tons. Thereafter, the leftovers from each part of the fruit were able to be estimated as shown in Table 1. It can be seen that the by-products from the canned pineapple factories had been 596,713.8 and 247,089.9 tons for peels and cores, respectively. These could be processed into dried pineapple cores. However, it may not be worthwhile investing in new production lines since at present, the demand is still limited. Moreover, huge amounts of pineapple peels are still a big burden for processing plants. Although the development of new products, which utilize pineapple peels have been investigated, no commercial endeavors have been launched. At this time, it is still a challenge for the scientists and technologists to develop innovative products, which can be developed using low-cost materials, of which there is a great supply.

The estimated by-products from different regions of Thailand

Based on a similar manner, the by-products from each part of the pineapple processing have been estimated and are shown in Table 1. Moreover, these vary depending upon the production scale. Since the production of pineapple in the Central portion of the country operates at the highest scale, the by-products (peels and cores) were estimated as having the highest amounts. Compared to other areas, the first priority for this area should be promoting the utilization of these by-products.

Table 1: An estimation of the by-products from the canned pineapple industries in Thailand and different regions based on the annual production year of 2020*

Types of By-products	Constituent ranges (%)	Production Regions (tons)				Total (tons)
		Central	North-Eastern	Southern	Northern	
Peels	29.42 (35.5%)	418359.0	49189.2	13358.3	115807.4	596713.9
Cores	9.4-20 (14.7%)	173236.0	20368.5	5531.5	47954.0	247090.0
Stems	2.4-6.8 (4.6%)	54209.9	6373.8	1730.9	15006.0	77320.6
Crowns	2.7-5.9 (4.3%)	50674.5	5958.1	1618.0	14027.4	72278.0
Sums	(100%)	696479.4	81889.6	22238.7	192794.8	993402.5

* The estimation of by-products was based on the average value of the by-products from each part

Valorization of by-products from pineapple industries for health applications

Pineapple by-products is still rich in minerals and vitamins providing a number of health benefits and potential to utilize these materials for value added products is also challenged (Ali et al., 2020). In order to effectively utilize the by-products from

pineapple industries, the chemical composition within those by-products must be discussed. High percentages of water or moisture contents in the by-products have been reported at approximately 76-94% (Rico et al., 2020). It could be possible to spark a great interest in upgrading the by-products to be of higher value upon determining the chemical composition in each part.

Pharmaceutical and cosmetic applications

When pineapples are conveyed onto the production line, the stems of the pineapples might be present. It has been reported that bromelain can be extracted from the stems and the peels (Campos et al., 2019). In addition, a high recovery yield (80-90%) with the simple method of precipitation has also been demonstrated. Furthermore, it has been documented that the stems can be utilized as a part of starch-based pharmaceutical excipients (Rahma et al., 2019). The bromelain from pineapple exhibits high potential for application in therapeutics as well (Banerjee et al., 2018).

Extractions of Vitamins A, C & E have been successfully performed (Freitas et al. 2015). In addition, phenolic compounds from pineapple peels can either be extracted by conventional extraction methods or by cold percolation extraction methods using different organic solvents e.g., methanol, n-hexane, or mixed solvents (Li et al., 2014). From pineapple peels, oil and fatty acids can be isolated in the form of hydrosol with different yields from 71-81% (Mohamad et al., 2019). Utilization of active compounds from this part could be possible. Extraction of bioactive phenolic compounds e.g. gallic acid, hydroxybenzoic acid, chlorogenic acid, epicatechin, coumaric acid and caffeic acid from pineapple waste were reported (Leonardo et al., 2018). Utilization of pineapple waste as a potential source of biochemicals has been reviewed extensively (Sarangi et al., 2022).

Health food applications

The crown of pineapple was used to extract bromelain using reverse micelle extraction (RME) and a 60% recovery activity was observed (Chaurasiya and Umesh Hebbar, 2013). However, extraction by grinding solely with water could recover 172,964 - 322,734 activity units/100 g of by-products (Ketnawa et al., 2012). Bromelain, which is a protease enzyme, can be recovered, with a recovered activity that was observed to be in the range of 75-78%, depending upon the isolation methods (De Lencastre Novaes et al., 2013; Ketnawa et al., 2012, Banerjee et al., 2018).

Pineapple peels have been considered as a source of dietary fiber, in which cellulose and hemicellulose were found, but lignin was not. Lignocellulose from pineapple peel could be used as a Pickering emulsion stabilizer (Chen et al. 2021). The extraction of the pectin fraction to produce natural plasticizer in biopolymer

films food active packaging for health foods has been documented (Rodsamran and Sothornvit, 2019).

The cores of pineapples have dietary fiber (DF), and purified pineapple core powder has a 99.8% total DF content (Prakongpan et al. 2002). A 5% substitution of the fiber from pineapple cores could be possible without affecting the sensorial attributes of traditional food product according to Chinese cuisine, mantou (Shiau et al. 2015). Pineapple fiber has been commercialized, and it could be applied to produce low fat beef sausages at 1% without appearing to have any severe defects (Henning et al. 2016).

Pineapple pomace, a leftover from juice production, could be a part of a 'fat replacer' in patties and could assist in the creation of healthier beef burgers, which could achieve a reduction in cholesterol (Selani et al. 2016). Microbial biotechnology has been introduced to convert pineapple waste in to healthy food particular antioxidant, probiotic, and organic acids, as reviewed by (Awasthi et al., 2022).

Conclusion

With an annual production of over 2 million tons, Thailand is currently the largest exporter of pineapple products in the world. With regard to processing, approximately 66% of the fruits were processed into several products, while those remaining were regarded as waste. The by-products normally included peels, cores, stems, and crowns. In the production year of 2020, the waste of those by-products was estimated at 596713.8, 247089.9, 77320.7 and 72278.0 tons, respectively. The further utilization of these by-products could be designed to comply with their chemical compositions.

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