APPLICATION OF ANALYTIC HIERARCHY PROCESS IN DECISION MAKING OF PROCESSED BANANA PRODUCTS FOR COMMUNITY ENTERPRISES

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ABSTRACT

Bananas are one of the most produced and consumed fruit crops in the world. However, producers, especially farmers and small businesses, are currently facing many challenges in the market, particularly competitiveness. This article aims to analyze factors that influence the decision-making process of processing banana products for community enterprises. The selection of the best-processed banana products according to the different criteria uses the Analytic Hierarchy Process (AHP) as a multi-criteria decision-making support tool. A case study of community enterprises that process banana products in Prachinburi Province, Thailand is presented. The criteria and priorities are considered based on the opinions of the community enterprises. There are five main factors: main raw materials, readiness for production, profitability and marketing channels, storage conditions, and environmental and societal impacts. The alternatives were divided into two cases: unripe and ripe bananas. The results show that the main factor with the highest priority in processing banana products is the readiness for production. For overall results, the banana chip is the best choice to produce if the supply is unripe bananas. If the supply is ripe bananas, the dried banana is the best choice to produce. These results provide a guideline for decision-making in banana product processing, which helps determine the best option for complex problems.

Keywords: AHP; agricultural processing; multi-criteria decision-making

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1. Introduction

In the agricultural industry, the effects of intense competition must be accepted (Nybom et al., 2021). Many times, this competition will cause the value or price of agricultural commodities to fall. In addition, the agricultural system is complex (Zhao et al., 2012) and is associated with a variety of factors such as labor, land, economy, regulations, technologies, etc. (Barati et al., 2019). Some factors may be uncontrollable, such as weather conditions, which cause price fluctuation all the time. Therefore, agricultural producers or farmers may need to practice, learn, and develop techniques for creating value-added for their agricultural products to be able to increase their income. In general, value-added means adding value to a raw product by requiring at least one more step of production (Anderson & Hanselka, 2009) or by adding special features or some distinctive features to make it different from the original to meet the needs of more consumers. This includes both food and non-food products.

There are techniques to add value to food agricultural products by processing or preserving the food to increase the value of the item resulting in a higher price (Wang et al., 2022). This keeps agricultural products from being oversupplied in the market. These techniques can also help create new opportunities for employment in the community and reduce the cost of producing products. The processing of the agricultural products results in making most of them are smaller which reduces the cost of transporting goods from the source to the distribution site. In addition, processing the product allows it to be stored for a longer time, which will also generate income for continuing business. Processing agricultural products into new products increases their shelf life and market opportunity and adds value to ordinary products.

Bananas are one of the world's most popular fruits, with high consumption around the world (Jayasinghe et al., 2022). Bananas originate in South East Asia (Nyombi, 2010), and are mainly produced in Asia, Latin America, and Africa (FAO, 2021). In Thailand, bananas are also a popular fruit that can generally be found in both local markets and department stores. Customer demand is high for both fresh bananas and processed banana products. Bananas can be processed into different value-added products to extend their shelf life and expand their market value. Processing is not only a way of preserving bananas, but also a way of increasing profit. There are many different kinds of processed banana products, such as banana chips, banana cake, banana toffee, banana crackers, banana drinks, etc. (Wardhan et al., 2022). The decision to process bananas depends on many factors, including the types and stage of ripeness of the bananas. Over one hundred types of bananas grow in Thailand, such as cavendish bananas, golden bananas, and cultivated bananas. Different types and stages of ripeness of bananas have different texture characteristics, which affect the control of processing operations (Gafuma et al., 2018). Ripe and unripe bananas are suitable for processing different kinds of banana products. A few types of bananas are appropriate for banana chips, and not all types of bananas can be processed into banana cake. Moreover, there are many factors to be considered, such as cost, production process, market, etc. To solve the problem, we need a multi-criteria decision-making tool.

In this study, we propose a decision support framework for the decision-making process of processing banana products for community enterprises. We focus on the cultivated banana, which is the most popular type of banana that grows in Thailand. We analyze the data using the Analytic Hierarchy Process (AHP) method to quantify the qualitative and quantitative data. The main criteria to consider when deciding to process banana products are raw materials, production readiness, profitability and marketing channels, storage, and environment and society. The analysis is divided into two parts based on the type of raw materials; in this case, the types of raw materials are ripe bananas and unripe bananas. The goal is to select the best choice for processing banana products under the criteria. The priority weights of the criteria were obtained through a pairwise comparison, which was based on the preferences of the community enterprises in our case study area, which is Prachinburi Province, Thailand.

The remained of the paper is structured as follows. Section 2 presents the related literature review on supplier selection and solution methods. In Section 3, we present research methodology, which details the conceptual framework of the Analytic Hierarchy Process (AHP) method and the research steps for this study. The results are reported in Section 4, which includes criteria selection, the priority weighting, and alternative evaluation. The sensitivity analysis is also provided in Section 5. Finally, the conclusion and future research are summarized in Section 6.

2. Literature review

The AHP is a popular tool for handling decision-making problems. It has been applied and used to solve many decision-making problems in business and manufacturing, including agricultural production. The agricultural product supply chain consists of three main parts: upstream, midstream, and downstream. Several methods have been applied to help decision-makers make decisions throughout the supply chain system. The upstream agricultural supply chain engages in the initial processing of agricultural commodities, which includes crops, fertilizer, land, preparing raw materials, procurement, supplier selection, machinery, and technology. Akıncı et al. (2013) determined suitable land for agricultural use in Turkey by utilizing the AHP method to determine the weights of the parameters. The experts' opinions were given, and an agricultural land suitability map was generated and divided into five categories according to the land suitability classification of the United Nations Food and Agriculture Organization (FAO). Sekvkli et al. (2008) proposed an AHP weighted fuzzy linear programming model (AHP-FLP) for supplier selection which was applied to solve an industry case. The weights of criteria given by the judgment matrix were considered as the weights of the fuzzy linear programming model. Both methods, the AHP and the AHP-FLP, were compared. The following six main supplier selection criteria were considered: performance, assessment, human resources, quality system assessment, manufacturing, business, and information technology. The results of both methods led to different solutions. Anggani et al. (2017) developed a framework for supplier selection for the daily food supply chain using the AHP method. The framework of supplier selection was based on company requirements, where the main criteria for supplier selection were quality, quantity, delivery, warranty, and pricing. The sensitivity analysis also showed that all the criteria were robust. For more research on supplier and site selection for the upstream supply chain, see Koul and Verma (2012), Khodadadzadeh and Sadjadi (2013), Costa et al. (2016), Teniwut et al. (2019), and Achatbi et al. (2020).

In the midstream of the supply chain, the raw materials are processed and transformed into the final products that are ready for sale. This part involves production, transportation, and logistics. Hirunyalawan and Ractham (2021) studied the knowledge

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that influenced consumers to perceive a benefit and decide to purchase processed banana products in the Thai market. The data was collected by interviewing farmers who grow bananas and sell processed banana products, as well as consumers who buy and consume processed banana products. The results found that knowledge sharing from farmers to consumers is important; however, knowledge from farmers should be considered and relevant information selected before sharing with consumers. Toloi et al. (2022) identified and analyzed the factors that influence the farmers' decision to produce soybeans using the AHP. The evidence showed that decision-making in soybean production is related to rural production aspects such as climate, financing, cost of inputs, and soil quality rather than marketing and logistics. The decision model was created and tested with 21 farmers and 19 experts linked to soybean production. The findings indicated that farmers and experts agreed that rural aspects were predominant in the decision to plant soybeans. For more research on the production and processing of the midstream supply chain, see Ganguly and Merino (2015), Nyaoga et al. (2016), Tuan and Canh (2022), Siregar et al. (2022), and Kumar and Shilpa (2022).

The downstream aspect of the supply chain includes sales of the products to customers, which can be wholesalers or retailers. Miškolci (2008) addressed the issue of matching agricultural policy with public preferences and willingness to pay for the possible non-production benefits that agriculture may deliver. Given the diversity of economic, social, and environmental services, and the diversity of public needs, the reported study attempts to simplify and evaluate a very complex set of multifunctionality issues and to investigate the policy relevant trade-offs using a combination of the Contingent Valuation (CV) and the Analytical Hierarchy Process (AHP) methods. Din and Yunusova (2016) applied the AHP to an evaluation of criteria for agro-industrial projects. The data was collected from interviews with experts in agricultural regions of Russia. Experts were classified according to their relationship to agro-industrial business, work experience, education, and gender. The agro-industrial projects included financial, social, and risk criteria that were ranked according to their importance, and the experts' attitude toward risk was taken into account. The importance of the criteria and expert features were analyzed and used to improve the presentation of agro-industrial projects. Barati et al. (2019) introduced an integrated method using the Impact Matrix Cross-Reference Multiplication Applied to a Classification (MICMAC) and AHP techniques to deal with understanding the key strategic variables of an agricultural system. MICMAC was used to determine the classifications of variables, and the AHP was applied to weigh these classifications. The results showed that strategic variables had different types of influence and direct, indirect, and potential dependencies did not have the same importance. The results helped supply instructions for the development of the agriculture system. For more research on the consumption and distribution of the downstream supply chain, see Jayant, et al. (2011), Huynh et al. (2021), Barata (2021), Okdalisa et al. (2021), Kumar (2019), and Akman et al. (2022).

In our research, we decided to focus on the midstream supply chain of banana products, where the choices of processed banana products depend on multiple criteria, such as raw material, production skill, production resource, shelf life, profit, etc. The stakeholders in this case are farmers and enterprises in the community. Based on the literature, we applied the AHP method to solve our problem since it is the most popular and suitable for multiple criteria problems incorporating expert opinions.

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3. Research methodology

The AHP method, developed by Saaty (1980), is a powerful tool for solving both qualitative and quantitative multi-criteria decision problems. The complex problem is simplified as a hierarchical structure, which is composed of three main layers, which are the overall goal, decision criteria, and possible alternatives. The AHP method utilizes the following steps:

Step 1: Define the goal of the decision-making problem with the main criteria involved in the decision and the possible alternatives. Then, set up the decision hierarchy in which the first level of the hierarchy represents the goal of the decision, the second level identifies the main criteria, and the last level includes possible alternatives.

Step 2: Collect the data based on the decision-maker preference through a pairwise comparison matrix. A scale of 1–9 is used to make the comparisons, where the values 1, 3, 5, 7, and 9 indicate equal, moderate, strongly, very strongly, and extremely important, respectively as shown in Table 1.

Table 1
Scale of comparison

Numerical value	**Comparative judgments**
9	Extreme importance
7	Very strong importance
5	Strong importance
3	Moderate importance
1	Equal importance
2–4–6–8	For a compromise between the above values

A is a comparison matrix, where the element a_{ij} represents the pairwise comparison rating for attributes i and j as in Equation 1. Note that i, j=1, 2, …, n, where n=number of criteria. If attribute i is equally important to compare to attribute j, then a_{ij} is equal to 1. Note that with the mutual property of the matrix, $a_{ji} = 1/a_{ij}$.

$$A=\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{22} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ 1/a_{12} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \dots & 1 \end{bmatrix} \quad (1)$$

Step 3: Calculate the relative weights of elements on each level in the hierarchy. By normalizing the matrix A, we get $\bar{A}$, where $\bar{a}_{ij}$ is calculated as in Equation 2.

$$\bar{a}_{ij} = \frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}} \quad (2)$$

Then, the criteria weight vector w is built by averaging the row of matrix $\bar{A}$, as in Equation 3. Then, we get the eigenvalue.

$$w_i = \frac{\sum_{i=1}^{n} \bar{a}_{ij}}{n} \quad (3)$$

Step 4: Perform a consistency test. To confirm that the pairwise comparison is consistent, we calculated the consistency ratio (*CR*), where *CI* is the consistency index, *RI* is the random consistency index, and λ_{max} is the maximum eigenvalue, as shown in Equations 4 and 5.

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (4)$$

$$CR = \frac{CI}{RI} \quad (5)$$

A *CR* value of 0.10 or less means the judgments are consistent enough to proceed with the AHP analysis, while a *CR* value of greater than 0.10 means the judgments are inconsistent and should be revised (Saaty, 1990).

Step 5: Evaluate the alternatives by calculating the score of the alternatives based on each criterion. From step 3, we have the priority weights of all criteria (wc_i) and priority weights of all alternatives with respect to each criterion (wa_{ij}). Next, calculate the total score for alternative *j* by summation of all criteria weights as in Equation 6.

$$TotalScore_j = \sum_{i=1}^{n} wc_i wa_{ij} \qquad \text{for all } j \quad (6)$$

Next, rank the rating scores of alternatives based on all criteria to obtain the best alternative. See the details of this calculation and numeric examples in Cheng and Li (2001). For this study, we defined the criteria in two layers, the main criteria and sub-criteria for processed banana production. The alternatives for a processed banana product are two types of banana ripening: unripe bananas and ripe bananas. The steps of building the AHP model for selecting processed banana products are shown in Figure 1.

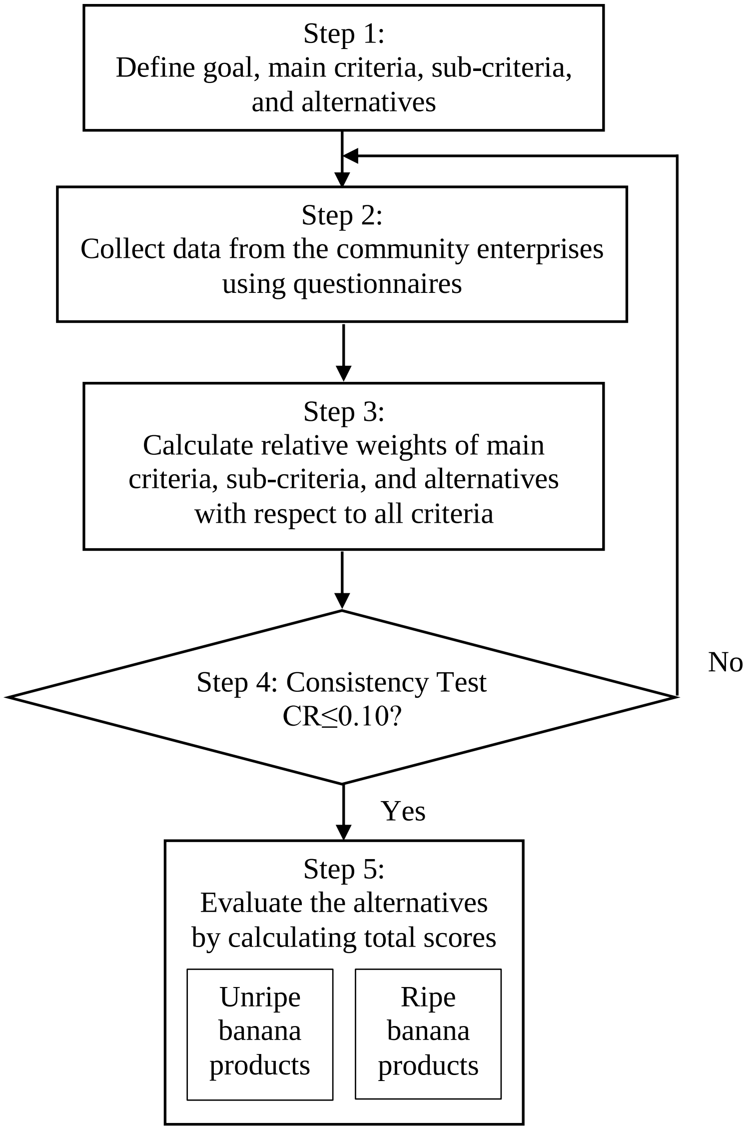

Figure 1 Research steps

4. Results

4.1 Hierarchical structure for processed banana product selection

Both academic and practical points of view were considered when determining the main criteria for processed banana production selection. First, we researched related previous works (Barati, et al. (2019); Marinis and Sali (2020); Tošovi´c-Stevanovi´c, et al. (2020); Toloi, et al. (2022); Kumar and Pant (2023)) and listed all the potential criteria. Next, we presented these criteria to the community enterprises and asked whether they agreed or disagreed with them. The final main criteria agreed upon by the community enterprises considering the processed banana product are the five main criteria: main raw materials, production readiness, profitability and marketing channels, storage, and environment and society. For each criterion, there are sub-criteria that were considered in the selection process. The details of each criterion are shown in Table 2.

Table 2
Criteria and sub-criteria

Criteria		
1. Main raw materials		
	Sub-criteria	1.1 Banana ripening
		1.2 Volume
		1.3 Transportation
2. Production readiness		
	Sub-criteria	2.1 Number of laborers
		2.2 Laborer skills
		2.3 Interest of the business owner
		2.4 Availability of equipment
3. Profitability and marketing channels		
	Sub-criteria	3.1 Profit per unit
		3.2 Cost
		3.3 Customer need
		3.4 Market export trend
4. Storage		
	Sub-criteria	4.1 Store at room temperature
		4.2 Shelf life
		4.3 Space for storage
5. Environment and society		
	Sub-criteria	5.1 Government support
		5.2 Environment
		5.3 Generating income for the community

There are many alternatives for processed banana products that can be separated into two types of ripeness: unripe bananas and ripe bananas. Banana chips, butter-coated bananas, and crispy bananas are made from unripe bananas. While, solar dried bananas, banana candy with coconut, banana toffee, banana crackers, banana juice, banana drinks, and other products are made from ripe bananas. The alternatives of the banana products are shown in Table 3. The hierarchy models for selecting processed banana products in the case of unripe bananas and ripe bananas are shown in Figures 2 and 3, respectively.

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Table 3
Alternative processed banana products classified by the level of ripeness

Raw material	Processed banana products
Unripe banana (U)	U1. Banana chip U2. Butter-coated banana U3. Crispy banana
Ripe banana (R)	R1. Solar dried banana R2. Banana candy with coconut R3. Banana toffee R4. Banana crackers R5. Banana juice R6. Banana drinks R7. Other products

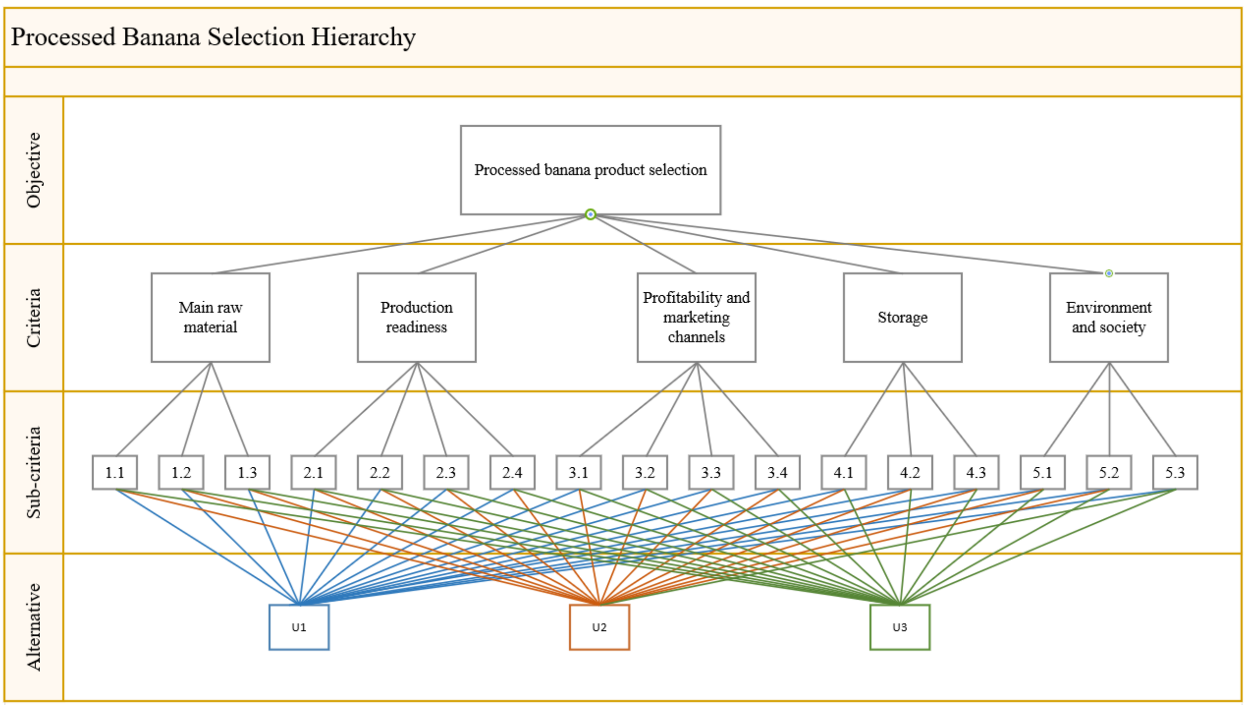

Figure 2 Processed banana selection hierarchy for unripe bananas

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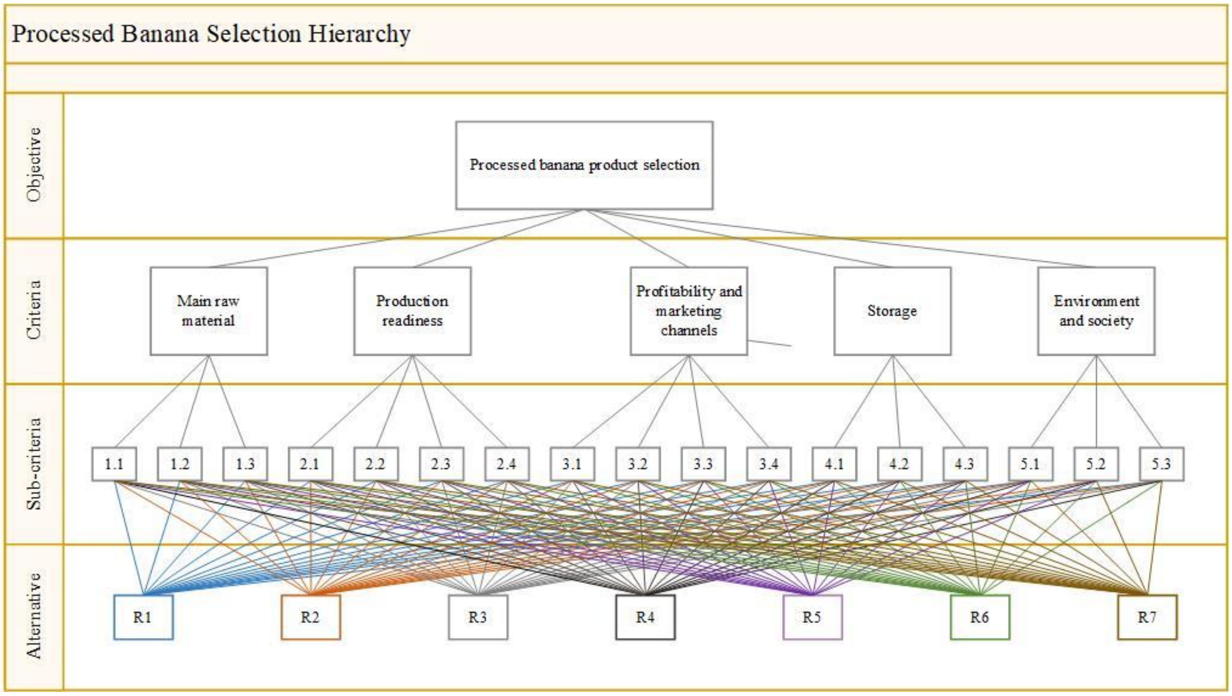

Figure 3 Processed banana selection hierarchy for ripe bananas

4.2 Evaluation and selection of the best alternative

The objective of this study is to analyze the criteria that influence the decision to process banana products in Prachinburi Province. Data were collected from small businesses and community enterprises including a total of eight shops. The questionnaire was divided into two parts based on the principles of the Analytical Hierarchy Process. The first part compared the five main criteria as follows: main raw materials, production readiness, profitability and marketing channels, storage, and environment and society. For each criterion, sub-criteria were considered and compared. The second part analyzed the importance or score of the alternatives of processed banana products that were divided into two cases, unripe bananas and ripe bananas.

The priority weights were calculated based on a pairwise comparison according to AHP principles. Then, the consistency ratio (CR) was calculated. It was found that the CR value was less than 0.1, which means that the survey responses were consistent enough to proceed with the AHP analysis. Table 4 shows the values of the CR, which indicate that all pairwise comparisons are consistent. The priority weights of the main criteria are reported in Table 5, which shows that the main criterion that most influences the selection of privatization is production readiness, with a weight of 0.275. The next criteria are profit and marketing channel, environment and society, main raw material, and storage, with weights of 0.231, 0.167, 0.166, and 0.161, respectively. The priority weights of the sub-criteria are also shown in Table 5. For production readiness, the most important criterion to consider is labor skills with a weight of 0.289, then the number of laborers, availability of equipment, and interest rate with weights of 0.261, 0.231, and 0.220, respectively. The alternatives were also compared based on consideration of each sub-criterion to determine the weight of each alternative, which is also reported in Table 5.

Table 4
Consistency Ratio

Criteria	**Consistency Ratio (CR)**
Main criteria	0.0136
Sub criteria	
- Main raw materials	0.0018
- Production readiness	0.0176
- Profitability and marketing channels	0.0206
- Storage conditions	0.0000
- Environment and society	0.0064

Table 5
Weight of criteria and alternatives

Main criteria (*M*)	**Sub criteria (*S*)**	**Alternatives**									
		Unripe banana (U_i)			**Ripe banana (R_i)**						
		U1	**U2**	**U3**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**
Main raw materials (0.166)	Banana ripening (0.406)	0.590	0.155	0.254	0.156	0.160	0.142	0.119	0.118	0.132	0.173
	Volume (0.300)	0.466	0.220	0.314	0.205	0.190	0.155	0.102	0.121	0.107	0.121
	Transportation of raw material (0.294)	0.362	0.319	0.319	0.156	0.165	0.153	0.124	0.123	0.122	0.156
Production readiness (0.275)	Number of labors (0.261)	0.536	0.170	0.294	0.184	0.167	0.180	0.111	0.119	0.095	0.143
	Labor skill (0.289)	0.524	0.207	0.269	0.191	0.160	0.164	0.128	0.091	0.090	0.175
	Interest rate (0.220)	0.307	0.307	0.387	0.201	0.193	0.149	0.120	0.088	0.096	0.153
	Availability of equipment (0.231)	0.682	0.143	0.175	0.186	0.178	0.146	0.103	0.100	0.107	0.180
Profitability and marketing channels (0.231)	Profit per unit (0.274)	0.506	0.246	0.248	0.180	0.176	0.141	0.106	0.100	0.123	0.174
	Cost (0.195)	0.333	0.333	0.333	0.190	0.146	0.116	0.110	0.133	0.135	0.170
	Customer need (0.306)	0.488	0.229	0.283	0.198	0.198	0.150	0.072	0.100	0.120	0.162
	Market export trend (0.225)	0.556	0.254	0.190	0.192	0.183	0.148	0.109	0.106	0.121	0.141
Storage Conditions (0.161)	Ability to store at room temperature	0.333	0.333	0.333	0.170	0.179	0.144	0.116	0.116	0.123	0.153

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	(0.333)										
	Shelf life (0.333)	0.333	0.333	0.333	0.171	0.155	0.154	0.120	0.109	0.124	0.166
	Space for storage (0.333)	0.374	0.326	0.299	0.164	0.148	0.188	0.113	0.114	0.120	0.153
Environment and society (0.167)	Government support (0.393)	0.425	0.261	0.314	0.177	0.145	0.149	0.117	0.116	0.123	0.172
	Environment (0.367)	0.347	0.307	0.347	0.167	0.168	0.142	0.126	0.128	0.132	0.136
	Generating income for the community (0.240)	0.347	0.307	0.347	0.156	0.155	0.150	0.110	0.126	0.154	0.150

Next, we calculated the total score of each alternative to determine the best alternative. Note that here we have criteria and sub-criteria. We also have two types of alternatives. W is the main criteria weights and S is the sub-criteria weights, where $i = 1,\dots, n$, n = number of main criteria, and $j = 1,\dots, m$, m = number of sub-criteria for each i. Then, U_k is the alternative weights for unripe bananas, where $k = 1, 2, 3$ represents banana chip, butter-coated banana, and crispy banana, respectively, and R_l is the alternative weights for ripe bananas, where $l = 1, 2,\dots, 7$ represents solar dried banana, banana candy with coconut, banana toffee, banana crackers, banana juice, banana drinks, and other products, respectively. Then, we obtained the total score of each alternative as in Equations 7 and 8.

$$Total\ Score\ of\ U_k = \sum_{i=1}^{n}\sum_{j=1}^{m} W_i S_j U_k \quad \forall\ k = 1, 2, 3 \tag{7}$$

$$Total\ Score\ of\ R_l = \sum_{i=1}^{n}\sum_{j=1}^{m} W_i S_j R_l \quad \forall\ l = 1, 2, \dots, 7 \tag{8}$$

From Table 5, we obtained the weights of the main criteria, sub-criteria, and alternatives. Then, we calculated the score of each alternative with respect to the main criteria and sub-criteria, which are detailed in Tables 6 and 7. Next, we calculated the total scores for the alternatives which are shown at the bottom of Tables 6 and 7. The results of the best alternative for processing banana products are the banana chip with a score of 0.425 in the case of unripe bananas. While in the case of ripe bananas, the best alternative is the dried banana with a score of 0.180. The findings can be used as a guideline for decision-making in product processing to enhance the ability of the community and farmers to make decisions that would increase their income in the future.

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Table 6
Scores of all alternatives for unripe bananas

Sub criteria	Alternatives		
	U1	U2	U3
1.1 Banana ripening	0.040	0.010	0.017
1.2 Volume	0.023	0.011	0.016
1.3 Transportation	0.018	0.016	0.016
2.1 Number of labors	0.038	0.012	0.021
2.2 Labor skill	0.042	0.016	0.021
2.3 Interest of the business owner	0.019	0.019	0.023
2.4 Availability of equipment	0.043	0.009	0.011
3.1 Profit per unit	0.032	0.016	0.016
3.2 Cost	0.015	0.015	0.015
3.3 Customer need	0.034	0.016	0.020
3.4 Market export trend	0.029	0.013	0.010
4.1 Store at room temperature	0.018	0.018	0.018
4.2 Shelf life	0.018	0.018	0.018
4.3 Space for storage	0.020	0.017	0.016
5.1 Government support	0.028	0.017	0.021
5.2 Environment	0.021	0.019	0.021
5.3 Generating income for the community	0.014	0.012	0.014
Total Score	**0.452**	0.255	0.293

Table 7
Scores of all alternatives for ripe bananas

Sub criteria	Alternatives						
	R1	R2	R3	R4	R5	R6	R7
1.1 Banana ripening	0.011	0.011	0.010	0.008	0.008	0.009	0.012
1.2 Volume	0.010	0.009	0.008	0.005	0.006	0.005	0.006
1.3 Transportation	0.008	0.008	0.007	0.006	0.006	0.006	0.008
2.1 Number of labors	0.013	0.012	0.013	0.008	0.009	0.007	0.010
2.2 Labor skills	0.015	0.013	0.013	0.010	0.007	0.007	0.014
2.3 Interest of the business owner	0.012	0.012	0.009	0.007	0.005	0.006	0.009
2.4 Availability of equipment	0.012	0.011	0.009	0.007	0.006	0.007	0.011
3.1 Profit per unit	0.011	0.011	0.009	0.007	0.006	0.008	0.011
3.2 Cost	0.009	0.007	0.005	0.005	0.006	0.006	0.008
3.3 Customer need	0.014	0.014	0.011	0.005	0.007	0.008	0.011
3.4 Market export trend	0.010	0.010	0.008	0.006	0.006	0.006	0.007
4.1 Store at room temperature	0.009	0.010	0.008	0.006	0.006	0.007	0.008
4.2 Shelf life	0.009	0.008	0.008	0.006	0.006	0.007	0.009
4.3 Space for storage	0.009	0.008	0.010	0.006	0.006	0.006	0.008
5.1 Government support	0.012	0.010	0.010	0.008	0.008	0.008	0.011
5.2 Environment	0.010	0.010	0.009	0.008	0.008	0.008	0.008

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5.3 Generating income for the community	0.006	0.006	0.006	0.004	0.005	0.006	0.006
Total Score	**0.180**	0.169	0.152	0.112	0.111	0.117	0.159

5. Sensitivity analysis

The sensitivity analysis was performed by changing the weights of the main criteria. We set up the dynamic sensitivity at ±10% upward change or downward change to see the impact of these changes on the best alternative. The experiments were conducted by varying the weight of one criterion at a time while keeping the rest of the criteria weights fixed. Therefore, ten total experiments were conducted. The scores of each experiment are represented as an upward or downward line in the graphs. All five main criteria weights have been experimented with and the results are shown in Figures 4-8. In Figure 4, we increased the priority weight of the main raw material by 10% and reanalyzed the final score of each alternative. The red line (upward) represents the final scores of all alternatives. By decreasing the priority weight of the main raw material, we get the results as represented in the yellow line (downward). Note that the middle line is the result of the original weights (normal). The graphs show that concerning the main raw material, production readiness, profitability and marketing channels, storage, and environment and society, the best alternative for unripe bananas and ripe bananas remain the same, which are banana chips and dried banana. Therefore, these results show that the AHP method is robust, in that it is not sensitive to changes in weight.

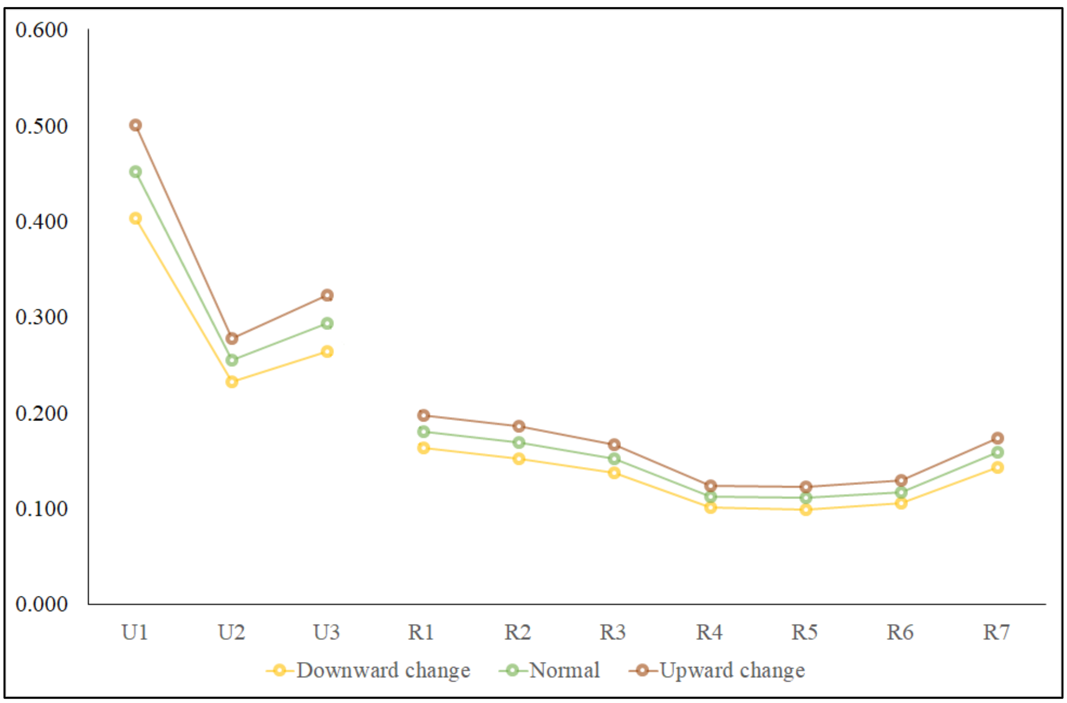

Figure 4 Sensitivity analysis with respect to main raw material

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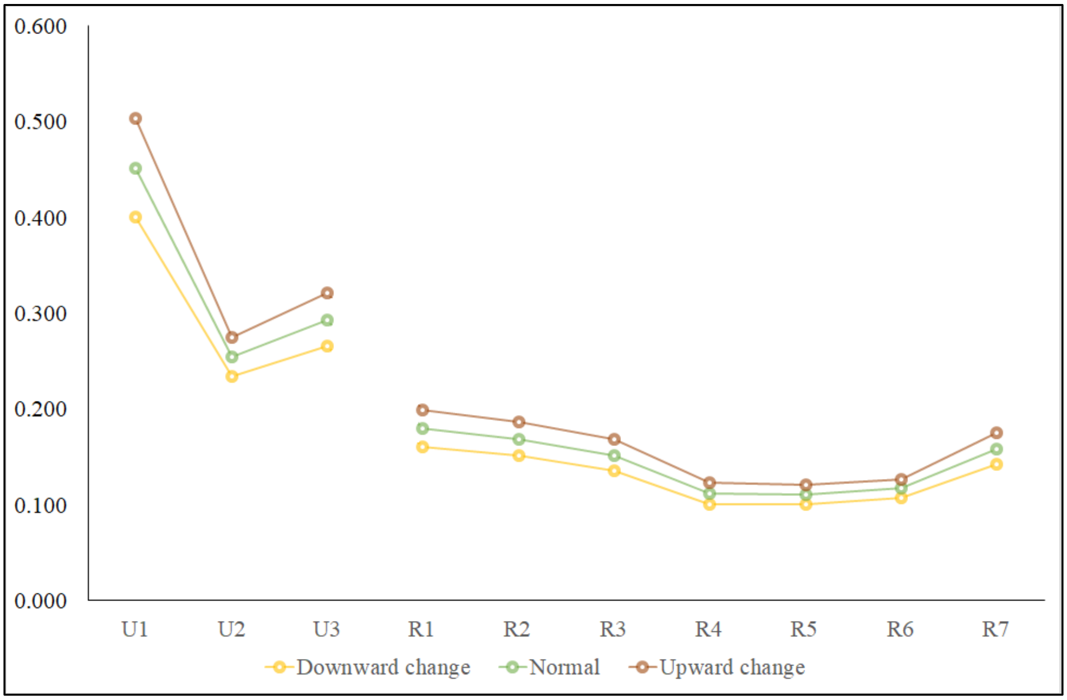

Figure 5 Sensitivity analysis with respect to production readiness

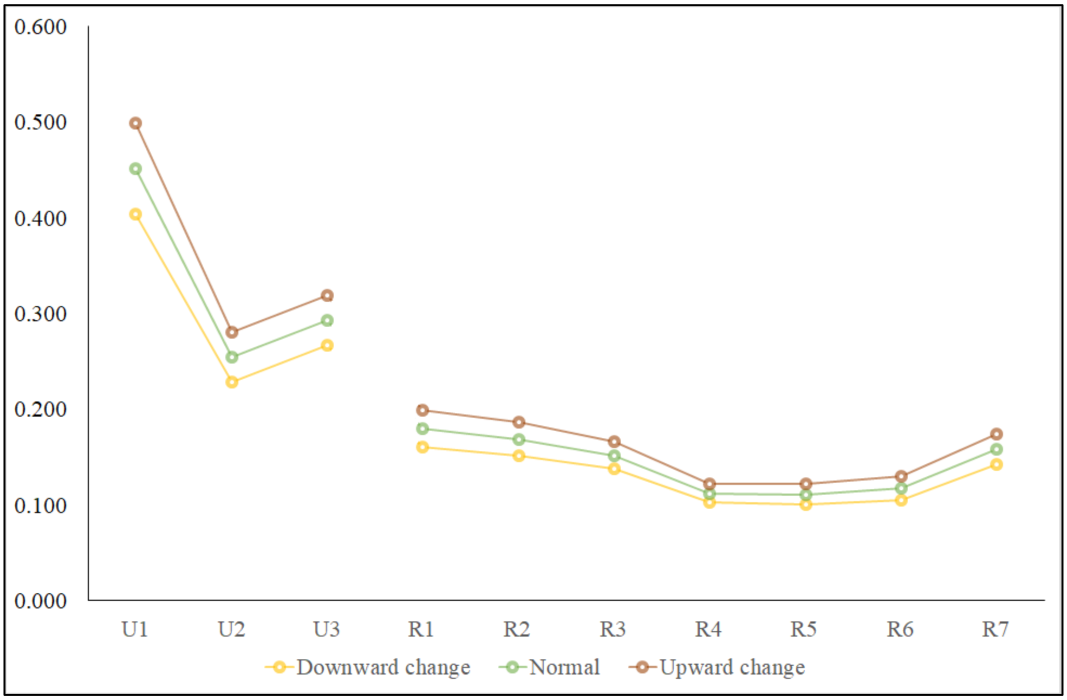

Figure 6 Sensitivity analysis with respect to profitability and marketing channels

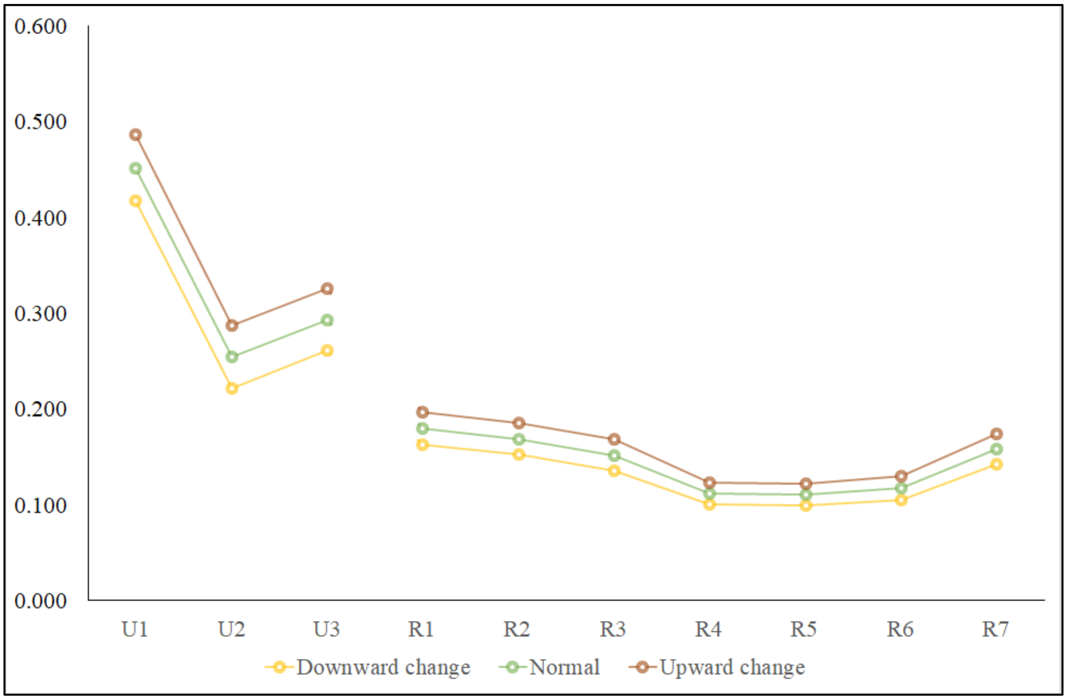

Figure 7 Sensitivity analysis with respect to storage

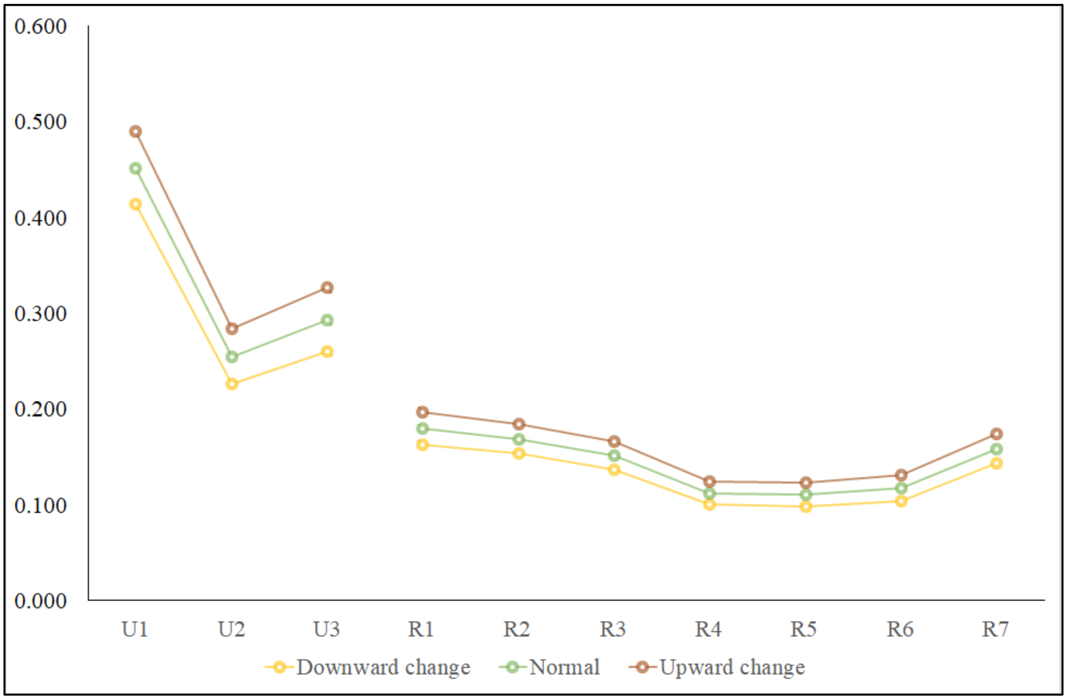

Figure 8 Sensitivity analysis with respect to environment and society

6. Conclusion and future research

In this study, we proposed a decision support system for the processing of products from cultivated bananas and used it as a guide for decision-making. The case study area is Prachinburi Province, Thailand. We collected data on criteria related to the decision to process products from small businesses and community enterprises in Prachinburi Province, Thailand. Data analysis was performed using the Analytic Hierarchy Process (AHP). The results of the analysis of the decision-making criteria revealed that there are five factors influencing the decision to process products, arranged in order of importance as follows: production readiness (0.275), profit and marketing channel (0.231), environment and society (0.167), main raw material (0.166), and storage (0.161). The two cases of unripe and ripe bananas were considered in determining the choice of processed products from bananas. The results of the analysis on the appropriate alternatives were as follows. In the case of unripe bananas, suitable alternatives for processing include banana chips, crispy bananas, and buttered bananas. In the case of ripe bananas, suitable alternatives for processing include dried bananas, banana candy with coconut, and banana toffees. A sensitivity analysis of weight change was also performed, and the results of this analysis can be used as a guideline for decision-making in product processing for communities and farmers.

The AHP is a powerful tool for solving the problem of processing banana products. It can handle decision-making problems that involve many factors, both qualitative and quantitative. Decision makers can participate, share their opinions, and find the best alternative. Our sensitivity analysis showed that the AHP is also robust; the results were not sensitive to changes in the input data. However, we found that the data collection steps were complex and could be confusing when users compared criterion by criterion. To help respondents, we intend to develop a user interface, such as a mobile application, to simplify this step. The application will link to the AHP model, and all respondents will be able to select the individual results or the overall results. Moreover, we would also like to consider more criteria based on external factors such as government policies or industrial supports, which can affect decision-making. In this study, we analyzed the problems of ripe and unripe bananas separately. The users have to first choose the type of their raw material and then obtain the result based on the chosen type of their raw material. For future research, we intend to analyze the case where the users have both types of raw materials, which can be solved by a combined method such as AHP with Linear Programming (LP).

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