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A Study on the Feasibility of Producing Concentrated Cricket Protein Powder using Ultrasound-Assisted Extraction

Sirirat Pungchompoo[1,*], Supasit Chooklin[2]

[1] Department of Industrial and Manufacturing Engineering, Faculty of Engineering, Prince of Songkhla University, 90110 Songkhla, Thailand
[2] Department of Food Science and Technology, Faculty of Agro-Industry, Rajamangala University of Technology Srivijaya, 90000 Songkhla, Thailand

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ABSTRACT

This research aims to examine the feasibility of extracting cricket protein and investigates the marketing factors influencing consumer decisions to purchase cricket protein products, utilizing a sample group of 303 respondents. The analysis, employing the Chi-square statistic ($p < 0.05$), identifies product features and distribution channels as the most influential factors affecting the purchasing decision. Nevertheless, the impact of product price on purchasing decisions varies depending on occupational status. Consequently, sales promotion strategies should be tailored according to gender, age, and income. Pearson's product moment correlation coefficient indicates a correlation between personal factors and marketing variables. From a technical perspective, the study suggests that cricket protein should be extracted using the ultrasound technique at a temperature of 35 degrees Celsius, with a solvent ratio of 1 N Sodium Hydroxide at an S/L (Solid to Liquid) ratio of 1:6, and an extraction time of 15 minutes, which yields an optimal extraction rate of 60%. Furthermore, the economic analysis reveals that with a daily production capacity of 100 kilograms, a project duration of 10 years, and an initial investment of 4,317,532 baht, the net present value of the project is 1,777,605 baht, resulting in an internal rate of return (IRR) of 26% — exceeding the minimum required rate of return of 15.05%. The project also boasts a benefit-to-cost ratio of 1.42 and achieves full capital recovery in just 5.08 years. Consequently, it is deduced that this project is a viable investment opportunity.

1. Introduction

Currently, edible insects have the potential to become a new source of protein production. Research has shown that the protein from edible insects is of high quality compared to plant and animal proteins. Furthermore, they provide essential amino acids for humans [1]. In Thailand, efforts have been made to promote cricket farming as an important economic endeavour [2], particularly in the northern and northeastern regions. In 2021, there was a total production of 2,747 tons of crickets, valued at 274 million baht. Additionally, Thailand exported 8,150 kilograms of crickets, valued at 3.45 million baht. Cricket farming is now prevalent in various regions, especially in the North and Northeast, with a particular focus in Surat Thani and Nakhon Si Thammarat provinces [3]. The two

* *Corresponding author*
E-mail address: sirirat.pu@psu.ac.th

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most farmed cricket species are *the Gryllus bimaculatus* and *Acheta domesticus*, with both having protein content ranging from 60-70% (dry weight) and fat content from 10-23% [4]. Various protein extraction methods are used, including heat extraction, acid/base extraction, and enzymatic extraction [5], resulting in three types of protein concentrates: concentrated protein, isolated protein, and hydrolysate protein.

To increase protein quantities and enhance certain functional properties, such as emulsification, foaming, gelling and solubility, traditional protein extraction methods involving water and alkali have been utilized [6]. However, these conventional methods, such as acid/base extraction and heat treatment, typically require extended processing times ranging from 1 to 24 hours depending on temperature and solvent concentration [6,13]. This prolonged exposure can induce protein denaturation, reduce nutritional quality, and alter functional properties such as solubility, emulsification and gelling capacity [5,6]. Moreover, the average protein yield obtained through these methods often ranges between 30–45%, which is relatively low compared to newer technologies such as ultrasound-assisted extraction (UAE) [7-9].

Additionally, traditional methods usually require large volumes of solvents and energy, contributing to environmental concerns [13]. Due to these limitations, an alternative extraction process known as UAE has been developed to improve extraction efficiency and reduce processing time [7]. Other mild extraction methods, such as microfiltration and ultrafiltration, have also been explored in protein extraction processes. These membrane-based techniques allow for selective separation of protein fractions under gentle conditions without the use of high temperatures or harsh chemicals. They help preserve protein functionality, such as solubility and emulsifying ability, and are considered environmentally friendly due to reduced solvent consumption. MF and UF are promising methods for extracting proteins from edible insects. MF is typically applied to remove microbial contaminants and lipids, while UF enables the concentration and purification of proteins based on molecular weight. Marella *et al.,* [23] demonstrated that ultrafiltration in the dairy industry can yield whey protein concentrates with purities exceeding 80%, suggesting its adaptability to alternative protein sources like insects. Ribeiro *et al.,* [24] found that ultrafiltration using a 50 kDa membrane could concentrate proteins from *Tenebrio molitor* to over 80%, improving foaming capacity, brightness, and browning index. Moreover, a systematic review by Kusumah *et al.,* [25] reported protein purities up to 96% using UF, surpassing conventional isoelectric precipitation methods, though with slightly lower yields. Membrane-based separation shows promise as a scalable, non-chemical method for producing high-value insect protein concentrates.

Furthermore, for the purpose of advancing research and business development, conducting preliminary investment and market analyses is essential. These analyses ensure the success of entrepreneurs and enable precise production planning. The insect processing industry begins by harvesting and euthanizing insects for further processing. After this, they are typically handled in two primary forms: fresh-frozen or dried. These initial formats are then refined depending on the product application and consumer preference. However, a significant challenge arises from consumer concerns and hesitation when faced with insect-based products that retain the physical appearance of whole insects. To address this, products from the initial processing phase undergo further refinement through a drying process, resulting in insect powder. During this process, specific components, such as proteins or fats, may be extracted from the insects for use in various products. This additional processing step enhances consumer acceptance and willingness to incorporate insects into their diets [8], primarily because it alters the original appearance of insects. When insects are processed into powders or extracts, their recognizable form is eliminated, reducing feelings of disgust or rejection among consumers. Regarding the physical and chemical properties of edible insects, they typically exhibit a high protein content, ranging from 60-70% by dry weight, along with fat content

ranging from 10-23% [4]. Extracting lipid components from insects has been explored through methods such as oil extraction and supercritical fluid extraction (SFE). Although SC-CO_2 technology combined with hexane extraction via the Soxhlet technique has shown promise in laboratory-scale studies, its practical application in the insect protein industry remains limited. In industrial practice, fat removal is more commonly performed using simpler and more cost-effective methods such as thermal centrifugation or solvent-based extraction. Experimental studies using SC-CO_2 typically operate under pressurized conditions ranging from 200 to 400 bar and temperatures between 50°C and 70°C to optimize yield. The experimental design incorporates surface response methodology (RSM) employing the Box-Behnken Design, with key factors including temperature, solvent-to-sample ratio, and time. These experiments result in protein extraction levels of up to approximately 45%, with the most favourable outcomes achieved at 300 bar and 60°C. It's important to note that extraction levels tend to decrease within the pressure range of 159 to 200 bar due to a decline in CO_2 density, even at elevated temperatures [9].

The aforementioned protein extraction methods generally involve heat extraction, acid or alkali extraction, and enzymatic extraction. However, these methods have drawbacks, including long extraction times, low yields, and environmental unfriendliness. Therefore, UAE is an alternative method that can improve the efficiency of extraction. This technique utilizes ultrasonic waves, which are high-frequency sound waves vibrating at approximately 20,000 cycles per second or higher. Nevertheless, it should be noted that achieving high-quality protein or concentrated protein from insects can be due to the high content of lipids (which include fats and oils) [10], along with the presence of chitin—both of which can interfere with protein extraction processes and reduce the final protein yield from insect materials [11].

From a business standpoint, conducting feasibility studies to inform investment decisions or operational strategies serves to reduce risks in management [12]. Some key points in such a comparison could include efficiency, extraction time, solvent consumption and the quality of extracted compounds. UAE is known for its ability to improve extraction efficiency and reduce extraction time compared to conventional methods. The use of ultrasound can lead to higher yields of bioactive compounds and can be considered a more environmentally friendly option due to lower solvent consumption. Moreover, traditional extraction methods pose constraints in terms of time, energy, and solvent usage. UAE overcomes these limitations by efficiently extracting bioactive components in a shorter timeframe, at lower temperatures, and with reduced energy and solvent demands. As a non-thermal extraction technique, UAE excels in preserving the functionality of bioactive compounds [13]. These studies encompass various aspects, including marketing and technical considerations, such as establishing a food factory. A case study, for instance, examines the feasibility of establishing a Halal food factory, which involves five key dimensions: marketing, technical aspects, management, environmental factors, and financial data. This comprehensive analysis helps determine the project's viability and its overall worthiness.

Based on the study, it has been observed that there is a growing trend in the crispy coconut market, particularly in the Arab countries, where there is a high demand for healthy products like crispy coconuts. Regarding the technical aspect, the Pattani Industrial Estate is found to be suitable for establishing a factory. A layout plan using CORELAP indicates a factory space of 3,024 square meters. The production capacity is estimated at 2,000 coconuts per day, resulting in the production of 10,000 pouches of crispy coconut products daily. These production processes are semi-automated and require labour. In terms of financial analysis, the investment required for the project is 30,000,000 Baht. The net present value (NPV) is calculated to be 29,009,452 Baht, with a return on investment (ROI) of 50.19%, and a payback period of 2 years and 2 months. Comparing this to the minimum required ROI of 27.50%, it demonstrates the project's suitability for investment [14].

Additionally, in behavioural research on market acceptance, it is found that building a positive attitude toward cricket protein is essential. Public relations and information dissemination about the safety and health benefits of consuming cricket protein are crucial [15]. Moreover, having reference groups, such as environmental nutritionists, to promote cricket protein consumption and support its use in various products like cricket protein pasta or other cricket protein-based foods can reduce consumer apprehension and increase acceptance. The market analysis indicates that several factors play a significant role in consumer decision-making when purchasing products and services online in the lower southern region of Thailand. All factors are of high importance, except for marketing promotion, in both products and services. The top three factors in order of importance are product and service variety (4.38), completeness of product and service information (4.07), and product and service reputation (4.02) [16].

Therefore, to overcome traditional extraction methods and meet business purposes, the study investigated the technique of UAE to produce high-protein cricket powder. In addition, Economic feasibility was also examined to support investment decision-making by potential investors.

2. Methodology

The research methodology consists of three main components designed to comprehensively evaluate the feasibility of producing concentrated cricket protein powder. These components include:

i. An analysis of consumer behaviour and market factors influencing the purchase decision of cricket protein products.
ii. A technical evaluation through experimental design using UAE.
iii. An economic feasibility study to determine the financial viability of commercial-scale production. Each part is described in detail below.

2.1 A Behaviour Analysis in Marketing

From the research of Muthén *et al.,* [17] main market factors that influence product purchase decisions have been explained. Under the concept of marketing mix, these include the Product, Price, Place and Promotion factors. Additionally, market trends such as organic products should also be considered. The study will also analyse the relationship between market factors affecting consumer purchasing decisions based on personal factors such as gender, age, occupation, income and education level. Data will be collected using a Likert Scale 5-point questionnaire to express opinion levels and will be validated by experts using the Index of Item Objective Congruence (IOC) and reliability analysis with Cronbach's Alpha on a target sample of 20 people [18]. Subsequently, data will be analysed using descriptive statistics, the Wilcoxon signed-rank test to test differences, and Chi-Square and Pearson correlation to examine the relationship between personal and market factors [19].

2.2 Design of Experiment and Analysis

In this experiment, the primary objective is to evaluate the technical feasibility of extracting protein from cricket powder using UAE. The study employs a systematic design of experiments incorporating three independent variables: temperature (X_1), solvent-to-sample ratio (X_2), and extraction time (X_3). Each factor is tested at three coded levels (−1, 0, +1), as shown in Table 1. The

experimental design and analysis were conducted using the Box-Behnken Design (BBD) within Minitab statistical software [20,21]. A total of 17 experimental runs were performed, with each condition replicated to ensure consistency and accuracy.

The statistical evaluation included tests for normality, independence of samples, and variance homogeneity across groups. The results were used to fit a second-order polynomial regression model and to identify the optimal extraction conditions through RSM.

In addition to technical evaluation, this study also assesses the economic feasibility of producing highly concentrated cricket protein powder for commercial applications. The analysis includes considerations of mass and energy balance, production costs, and financial performance. Financial projections were based on a bank loan with an annual interest rate of 8.05% (sourced from Thailand's Medium and Small Enterprise Development Bank) and accounted for an inflation rate of 7%.

Table 1
Factors and factor levels

Factors	Level		
	-1	0	1
Temperature (X_1)	30	35	40
S/L ratio (X_2)	1:3	1:6	1:9
Time (X_3)	10	15	30

2.3 An Economic Feasibility Study

In studying the economic feasibility [22], we initially gather technical data from the production of concentrated cricket powder, both commercially and experimentally, to determine the production process for cricket powder while considering the balance of materials and energy mass. We calculate the investment in year 0, taking into account loans for investment at an interest rate of 8.05% per annum through the Small and Medium Enterprise Development Bank of Thailand, including an inflation rate of 7%. Additionally, we set the conditions for industrial sector taxes, taking into account corporate taxes according to the policies of the Board of Investment (BOI) in promoting medium and small-sized businesses. Under this policy, corporate taxes are exempted for 8 years, and a 20% tax is applied to profits exceeding 3,000,000 Baht in the 9^{th} and 10^{th} years. Furthermore, the production capacity is set at 100 kilograms of freeze-dried crickets per day, considering the production capacity of medium and small-sized business operators. Production occurs 300 days per year over a 10-year project period. The revenue calculation includes the sale of packaged concentrated cricket powder at 1,400 Baht per kilogram and the sale of by-products from the production process at 50 Baht per kilogram. The depreciation cost of straight-line depreciation is calculated for machinery and equipment with a lifespan of 10 years, estimated at 10% of the equipment and machinery investment. Regarding human resources, the factory is staffed with 1 engineer with a monthly salary of 20,000 Baht, 1 administrative staff with a monthly salary of 15,000 Baht, with annual salary increases of 2%, and 2 production line workers with a daily wage of 315 Baht. The return on investment in this research project will be analysed based on the NPV, Internal Rate of Return (IRR), Payback Period and Benefit Cost Ratio (B/C).

3. Results

Alongside the technical evaluation, a market factor analysis was conducted based on data collected from a structured survey of 303 respondents. The sample size was sufficient for statistical analysis, employing both descriptive statistics and Pearson correlation analysis. The questionnaire

demonstrated strong internal consistency, with an Item-Total Correlation (ITC) value exceeding 0.700 and a Cronbach's Alpha coefficient of 0.946. The demographic profile of the respondents revealed that the majority were male (67.98%) and between 18–25 years of age (46.86%). Most participants reported being single (84.16%) and held a bachelor's degree (48.88%), followed by vocational certificates (24.42%), master's degrees (17.16%), and associate degrees (13.20%). A significant portion (50.83%) were students, with most reporting a monthly income of less than 10,000 Baht (65.35%). Respondents were employed in various sectors, including government, self-employment and private companies.

To further understand consumer attitudes toward cricket protein powder, the study examined the influence of four key marketing factors: product, price, distribution channels and promotional activities. The descriptive statistics for each factor are summarized in Table 2.

Table 2
The summarized descriptive data statistics

Factor	Mean	Standard Division
1. Product Factors		
Product Variety	3.789	1.040
Packaging Aesthetics	3.739	0.994
Nutritional Label Information	3.947	1.005
Organic Products	3.867	0.998
Research Certification	3.970	1.027
2. Price Factors		
Fair Price When Compared to The Product Quality	3.993	1.045
Fair Price When Compared to The Product Quantity	3.967	1.013
Fair Price When Compared to The Organic Product	3.950	1.013
3. Distribution Channel Factors		
Reliability of Retailers	3.891	1.015
Health Experts' Consultation	3.904	1.000
Availability in Convenience Stores	3.801	1.030
Availability in shopping malls	3.831	1.030
Online and social media Sales	3.772	1.088
4. Marketing Promotion Factors		
Product Tester Distribution	3.848	1.031
Membership Benefits	3.785	1.064
Advertising in Mainstream Media	3.425	1.052
Online and Social Media Advertising	3.564	1.077
Price discount for Customer Attraction	3.778	1.103
Ease of Access to Communication Channels	3.805	1.041
Product Showcase Booths and Brochures	3.874	1.055

In addition, the relationships between personal demographic variables—such as sex, age, marital status, education level, occupation and income—and the perceived importance of these marketing factors were analysed using chi-square and Pearson correlation methods. The results of the chi-square analysis are presented in Table 3.

Table 3
The relationship between personal information and marketing factors

Marketing factors	Cri-square (*p*-value)					
	Sex	age	Status	Education	Career	Revenue
Product	8.566	30.173	10.510	30.177	28.596	13.575
	(0.073)	(0.059)	(0.321)	(0.017)	(0.911)	(0.329)
Price	16.358	36.150	11.411	41.108	36.552	25.898
	(0.003)	(0.015)	(0.179)	(0.000)	(0.628)	(0.011)
Distribution Channel	8.557	30.715	17.318	32.566	37.281	15.452
	(0.073)	(0.059)	(0.027)	(0.008)	(0.593)	(0.218)
Promotion	9.094	28.003	15.718	37.807	58.210	18.547
	(0.059)	(0.109)	(0.047)	(0.002)	(0.031)	(0.100)

The Pearson correlation coefficients are shown in Table 4.

Table 4
A correlation coefficient between personal factors and marketing factors

Marketing factors	Pearson correlation (α = 0.05)					
	Sex	age	Status	Education	Career	Revenue
Product	0.142	0.198**	0.130**	0.251**	-0.166**	0.176**
Price	0.176**	0.175	0.107**	0.238**	-0.165**	0.224**
Distribution Channel	0.152**	0.217**	0.159	0.272**	-0.198**	0.204**
Promotion	0.138**	0.123**	0.133**	0.212	-0.165**	0.157**

Note: ** This difference is statically significant at the 0.05 level

The results of the descriptive analysis in Table 2 indicate that respondents generally placed high importance on all four key marketing factors. Among product-related factors, nutritional label information (mean = 3.947), research certification (3.970), and organic products (3.867) were rated the highest. In terms of price, respondents strongly agreed that fair pricing relative to product quality (3.993) and quantity (3.967) influenced their purchasing decisions. Regarding distribution channels, health expert consultation (3.904) and retailer reliability (3.891) were emphasized, while in the domain of promotional strategies, product tester distribution (3.848) and product showcase booths and brochures (3.874) received the highest scores.

Table 3 shows the chi-square test results examining the relationships between demographic characteristics and each marketing factor. The results reveal statistically significant associations ($p < 0.05$) between several demographic variables and marketing perceptions. Notably, education level had significant relationships with all four marketing factors, while income was significantly associated with price and promotion. In contrast, sex and age showed fewer significant associations.

Further insights are presented in Table 4, which displays the Pearson correlation coefficients between personal demographic variables and marketing factors. The results confirm weak but statistically significant correlations (r < 0.300) for many variables. For example, education was positively correlated with all marketing factors—most strongly with distribution channels (r = 0.272**) and product factors (r = 0.251**). Income also showed positive correlations, especially with price (r = 0.224**) and distribution (r = 0.204**). Conversely, negative correlations were observed between occupation and most marketing factors, suggesting that occupation type may inversely relate to marketing influence in some cases.

The results of the model's statistical analysis using ANOVA and multiple regression are presented in Table 5 and 6, respectively.

Table 5 summarizes the analysis of variance (ANOVA) for the fitted response surface model. The results indicate that the model is statistically significant ($p < 0.001$), with the solvent-to-liquid ratio (X2) emerging as the most influential factor ($p < 0.001$) in both its linear and quadratic terms. Other variables, including temperature (X1), time (X3), and interaction terms, were not statistically significant ($p > 0.05$).

Table 5
An ANOVA analysis table

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	9	250.612	27.846	25.320	0.000
Linear	3	178.207	59.402	54.01	0.000
X_1	1	1.304	1.304	1.190	0.287
X_2	1	175.785	175.785	159.840	0.000
X_3	1	1.118	1.118	1.020	0.323
Square	3	29.268	9.756	8.870	0.000
X_1*X_1	1	1.035	1.035	0.940	0.342
X_2*X_2	1	27.531	27.531	25.03	0.000
X_3*X_3	1	0.749	0.749	0.680	0.417
2-Way Interaction	3	3.934	1.311	1.190	0.334
X_1*X_2	1	0.036	0.036	0.030	0.857
X_1*X_3	1	0.102	0.102	0.090	0.763
X_2*X_3	1	3.796	3.796	3.450	0.076
Error	24	26.395	1.100		
Lack-of-Fit	3	2.508	0.836	0.740	0.543
Pure Error	21	23.886	1.137		
Total	33	277.007			

Table 6 presents the regression coefficients and statistical parameters of the model. The multiple regression in Eq. (1) includes linear terms, quadratic terms, and two-way interactions among the three variables: temperature, S/L ratio, and time. The Variance Inflation Factor (VIF) values were all below 2, confirming that multicollinearity was not a concern. The assumptions for regression analysis were verified: the run test indicated that observations were independent (p = 0.915), and Levene's test showed no violation of variance homogeneity (p = 0.281).

$$Y = 7.8 + 0.99\ temp - 3.85\ S/L - 0.198\ time - 0.0140\ temp*temp + 0.2009\ S/L*S/L + 0.00423\ times*times - 0.0045\ temp*S/L - 0.00213\ temp*times + 0.0216\ S/L*times \quad (1)$$

Table 6
The multiple regression analysis of the factors affecting the yield of cricket protein from the RSM analysis

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	7.326	0.438	16.730	0.000	
X_1	-0.301	0.276	-1.090	0.287	1.110
X_2	-3.494	0.276	-12.640	0.00	1.110
X_3	0.264	0.262	1.010	0.323	1.130
X_1*X_1	-0.351	0.361	-0.970	0.342	1.010
X_2*X_2	1.808	0.361	5.00	0.00	1.010
X_3*X_3	0.423	0.513	0.830	0.417	1.140
X_1*X_2	-0.068	0.371	-0.180	0.857	1.000
X_1*X_3	-0.106	0.35	-0.300	0.763	1.110
$X2*X_3$	0.649	0.35	1.860	0.076	1.110

According to the regression model, a decrease in the S/L ratio led to an increase in protein yield. The optimal conditions determined through response optimization were 35°C extraction temperature, 1:3 S/L ratio, and 10-minute extraction time. Under these conditions, the freeze-dried protein extract yielded a protein content of 69.57%, and the final adjusted yield was calculated to be 59.55%.

In the final analysis, the economic feasibility study, based on the previously mentioned technical data, resulted in the development of the following production process: Initially, 100 kilograms of frozen crickets are thawed at room temperature. Subsequently, they undergo 6 hours of drying in an 80-degree Celsius hot air oven to reach a moisture content of under 10%. This yields 25 kilograms of cricket material before further processing. Following this, the crickets are finely ground for 30 seconds using a sieve-type grinding machine. The cricket protein powder is then extracted using an ultrasonic machine to ensure purity, following the conditions established in previous experiments. After extraction, the material is introduced into a separating machine for 30 seconds and subsequently subjected to freeze-drying. Upon completing the entire process, a high-concentration cricket protein powder with a protein content of up to 60% is obtained. Any remaining byproducts or residues from the separating machine are sold as raw materials for cricket fertilizer or oil extraction. From a financial standpoint, the estimated investment totals 4,317,321 Baht. This encompasses investments in equipment and machinery in the factory (1,655,093 Baht), land, construction, and equipment costs (2,154,000 Baht), and working capital (508,228 Baht). To secure 50% of the investment, funding will be pursued at an 8.05% annual interest rate, with annual depreciation costs of 145,196 Baht. The analysis of the total annual production cost reveals the following financial metrics:

i. Net Present Value (NPV): 1,777,604 Baht
ii. Internal Rate of Return (IRR): 26%
iii. Benefit-Cost Ratio (B/C): 1.42
iv. Payback period: 5.08 years.

4. Discussion

This study provides comprehensive insights into consumer attitudes, technical optimization and economic viability related to the production of concentrated cricket protein powder. From a marketing perspective, respondents emphasized the importance of product quality, nutritional labelling, organic certification and research credibility—especially among those with higher education and income levels. These factors significantly influenced purchasing decisions, as shown in the statistical correlations, highlighting the need for targeted marketing strategies. Technically, UAE was found to be highly effective, with the solvent-to-liquid ratio being the most influential factor in protein yield. Optimal extraction conditions (35°C, S/L ratio of 1:3, 10 minutes) resulted in a protein content of 69.57% and an adjusted yield of 59.55%. Economically, the production process was feasible, requiring an investment of approximately 4.31 million Baht, and producing favourable financial outcomes including an NPV of 1.78 million Baht, IRR of 26%, and a payback period of just over five years. These findings confirm that the integration of consumer preferences, advanced extraction techniques, and cost-effective operations can support the development of high-value, sustainable insect protein products with strong market and investment potential.

5. Conclusions

This research examined the feasibility of producing concentrated cricket protein powder using UAE, alongside an assessment of market factors influencing consumer purchase decisions and future applications of cricket protein in food products. From a market perspective, all four marketing factors—product, price, distribution and promotion—significantly influenced purchasing behaviour. Education level was found to correlate with all marketing factors, albeit weakly, while income should be considered when designing promotional strategies. Distribution strategies should also reflect educational background and socio-economic status.

Technically, the use of UAE produced high-purity protein under mild conditions with reduced energy and time consumption; however, extraction yield remained below 60%. This suggests that further refinement of the process is needed to minimize protein loss. Economically, with an investment of 4,317,532 Baht over a 10-year horizon, the project demonstrated strong viability: a Net Present Value (NPV) of 1,777,605 Baht, an Internal Rate of Return (IRR) of 26%, a Benefit-Cost Ratio (B/C) of 1.42, and a payback period of 5.08 years—well above the acceptable investment threshold of 15.05%.

In conclusion, the production of concentrated cricket protein powder using UAE is both technically and economically feasible. The results support its commercial potential and provide a foundation for further development of insect protein applications in pasta, bakery items and dietary supplements. Future research will focus on product innovation and commercial partnerships with Thai entrepreneurs in the functional food sector.

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