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REVUE EUROPEENNE D ETUDES EUROPEAN JOURNAL OF MILITARY STUDIES
Social Science Journal

Delphi and AHP Methods in Selection of Non-Thermal Process Technology in Honey Pasteurization Process

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Abstract

Non-thermal process technology (NTPT) is widely used in various semi-liquid or liquid food processing industries because of its superior properties. NTPT processes for the food industry for the preservation or pasteurization process include Pulsed Electric Field (PEF), High-Pressure Treatment (HPP), Cold Plasma (CP), Pulsed Light (PL), and Ultrasonication negative (US). Raw honey is a post-harvest product that requires further processing while guaranteeing the honey's quality, nutrition, and aroma does not change and lasts a long time. This study aimed to rank the inclusion criteria for the appropriate NTPT process in honey pasteurization using the Analytic Hierarchy Process (AHP) by considering performance and reducing production costs. The Delphi method facilitates the stakeholders involved in the honey business. This decision involves selecting various conflicting factors, so it must use AHP. Completing is the relative weighting of evaluation criteria and extending this technique to prioritizing technology selection based on similarity to the ideal solution according to stakeholders. The Delphi and AHP methods can describe the effectiveness in completing NTPT selection that bee farmers and honey businesses can achieve.

Keywords— AHP; Honey; NTPT; Pasteurization; Technology Non-Thermal Selection

Introduction

Food quality should be a major concern during food processing for preservation, which is usually done conventionally (Paul et al., 2019)—a rise in consumer awareness about food safety and demand for food free of microorganisms with high nutritional quality and good taste in the mouth (Putnik et al., 2017). Food exposure to high temperatures is done to reduce food or microbial contamination. However, it also causes unwanted food changes, such as loss of temperature-sensitive nutrients and heat-induced textural changes in food's organoleptic properties (Barbhuiya et al., 2021). Food professionals are directed to seek better alternatives to food processing, such as non-thermal processing. Applying a non-thermal process to honey nectar can change its physicochemical properties such as viscosity, water content, color, total phenolic content, hydroxyl methyl furfural, diastase activity, and antioxidant activity (Ramly et al., 2021). The challenge in nectar honey in tropical climates is the high-water content produced by most Apis Mellifera honey bees. The water content has an impact if honey is stored at room temperature. Honey will experience fermentation even with a hygienic harvest method (Schvezov et al., 2019). The effect of humidity on the storage environment can increase the water content of honey because honey has hygroscopic properties, namely the ability to absorb water into the surrounding environment quickly. Therefore, various preservation methods such as cooling, dehumidification, and pasteurization have been proposed to improve postharvest stability and extend the shelf life of this type of honey.

How to cool (Braghini et al., 2020; Cahyani et al., 2021): Honey is stored in a refrigerator with a temperature of (6 ± 1) °C after harvesting, and the container is tightly closed. This method is the simplest. Dehumidification (Morawski et al., 2022): honey is filled into a container covered with sterile gauze, and silica gel is added to control humidity between 17-19%. The dehumidification temperature was maintained at (33±1) °C. In pasteurization (Sahin et al., 2020), honey with a relative humidity higher than 17.98% is treated at 70°C to remove pathogenic microorganisms and maintain taste and texture. Honey processing through non-thermal treatment aims to inactivate it microbiologically without or with little exposure to direct heat. NTPT treatment resulted in microorganisms experiencing cell wall damage, causing microbial death and reducing the microbial burden (Vorobiev & Lebovka, 2019). The current development of non-thermal technology is the development of electric pulse intensity and pulse width, which are very important in reducing microbes in food exposed to electrical pulse treatments (Niu et al., 2020). Development of NTPT as an answer to food products that are fresher, natural, consumer-friendly, and environmentally friendly in food preservation.

NTPTs such as HPP, PEF, PL, CP, and US are designed to inactivate microorganisms, avoid the thermal decomposition of foodstuffs and maintain the organoleptic and nutritional quality, nutrition of food and fresh products (Chiozzi et al., 2022). HPP is used for both liquid and solid foods. Curing is carried out at cold process temperatures for minimal effect on nutrition, texture, and product quality (Evrendilek, 2018). PEF technology (Arshad et al., 2020): used for preservation by deactivating microbes. The PEF equipment comprises a food processing room, a control system, and a pulse generator. Pulsating electric fields are usually used for liquid or semi-solid foods (Koubaa et al., 2018). PL technology (Zhao et al., 2019), known as pulsed UV light, is adequate for non-thermal surface-active microorganisms, such as food or food contact materials. CP technology (Obileke et al., 2022), applied to improve the physiological properties of proteins and carbohydrates in foods, can be applied to various food processing applications. The low-temperature plasma treatment time is critical for the desired results (Nwabor et al., 2022). US technology (Zhang et al., 2018) is a heat-free technology that uses sound waves at certain frequencies above 20 kHz. The US accelerates the chemical synthesis of organic compounds and increases the reaction yield, resulting in increased heat and mass transfer. Several influences of heat and non-thermal technology on the preservation and quality of food products have been considered (Putnik et al., 2018). Thus, to achieve the implications of NTPT in user communities such as honey farmers, honey distributor businesses, and different commercial for semi-liquid or liquid food processing.

Another problem is selecting NTPT technology to be applied to user communities such as honey farmers or entrepreneurs. Although all NTPT processes can process liquid and semi-liquid food, it is necessary to determine and select a technology that is in accordance with business capabilities. Hong et al. (2017), food processing technology can be classified into conventional, modern, and combination. The production scale also reflects the financial status of the beekeeper or honey business and their preference and attitude toward the choice of preservation technology. In a honey farmer or business environment, choosing NTPT is a critical issue for those who have to choose the most suitable process technology for their business at an affordable price. NTPT selection can be seen as a complex multi-criteria decision problem due to the varying expectations of many users from different functional areas. This is of increasing interest to food processors as it can have significant processing costs once adopted by honey growers or businesses as frontline users of products made from honey nectar. Because this research is the steps for selecting the criteria for the preservation process, the appropriate technology for bee farmers or honey businesses will be selected.

Determining the selection of honey preservation technology requires a strategy considering the product's added value through technological innovation (D'Eusanio et al., 2018). The selection of preservation technology in this study was based on several scientific references in determining the selection criteria for NTPT, including suitability, product quality, food safety, construction costs, and sustainability. The identification of appropriate NTPT technology selection criteria (Ren, 2018) is determined based on the relationship of stakeholders involved in the honey business (i.e., honey farmers, honey supply businesses, the honey industry, and food equipment manufacturers). Determining the weight of subjective assessment criteria through the Delphi method in decision-makers based on stakeholder preferences. This decision aims to decide what type of technology can benefit the honey farmer or business according to the criteria (Dey et al., 2018). The decision on AHP refers to the optimal search of all possible alternatives against several conflicting decision criteria. Priority determination of NTPT selection criteria through the Delphi and AHP methods. Applying the Delphi method to identify the criteria needed to judge NTPT selection based on feedback from expert respondents (Wong et al., 2020). AHP is based on the relative weight gain between the total value and the factors for each alternative based on weight (Li et al., 2018). The ranking of each alternative and the weight of the criteria calculated using AHP is based on the solution by considering the gap between each alternative's lowest and best choices. Therefore, this study aims to develop a multi-criteria decision analysis framework in determining the ranking of NTPT selection for an efficient pasteurization process based on the capacity and cost of manufacturing a honey preservative machine that is beneficial to honey farmers or entrepreneurs.

Literature Review

Delphi Method in a Study

The Delphi method makes it possible to collect and exchange information through electronic communications, such as e-mail and other smart communication tools helping to ensure research validity by obtaining heterogeneity in populations regardless of geographical distance (Kerr & Richards, 2020). The Delphi method is helpful in limited research fields because the survey's instruments and ideas are generated from a knowledgeable pool of participants and are suitable for exploring areas where there is controversy, debate, or ambiguity (Spagnolo et al., 2022). The first step in the Delphi method is to determine whether this research aims to measure the diversity of opinions about a topic or to direct the group toward consensus (Brough, 2019). This is an important difference in terms of the Delphi implementation. Generally, if the study aims to generate consensus, three rounds or more is preferable. Ideally, the same panel should be maintained at all times, and a high response rate is essential to determine the impact of group feedback on panelists (Brough, 2019).

The researcher must also decide how to conceptualize and define 'expertise'. The Delphi method would be at a disadvantage if the panelists involved lack specialist knowledge, qualifications, and a proven track record in the field (Ametepeya, Aigbavboa, & Thwala, 2019), although, of course, expertise comes in many guises and may include those who are 'experts under experience' (Padilla-Rivera et al., 2021). Generally, a diverse panel is considered the best at producing a credible questionnaire, and individuals who may provide a minority or different perspective should be actively recruited to the panel (Ametepeya, Aigbavboa, & Thwala, 2019). In the recruitment process itself, panelists are recruited via email. Recruitment can be expanded through 'snowballing' or asking panelists to extend invitations to other relevant individuals.

The Analytic Hierarchy Process (AHP) as a Decision-Making Method

The AHP is a measurement method using pairwise comparisons and is assessed by experts to obtain a priority scale in decision-making (Kulakowski, 2020). It is a decision-making method with many criteria most widely applied by decision-makers (Sitorus, Cilliers, & Brito-Parada, 2019). Decision-makers and researchers carry out the steps in the hierarchy because it is a simple and precise tool (Sutadian et al., 2017). Thomas L. Saaty first introduced AHP in developing this method to find systematic ways to set priorities on a problem and support complex decision-making (Kulakowski, 2020). The hierarchical structure of AHP steps can measure and synthesize various factors from a complex decision-making process in a hierarchical manner, making it easier to assemble the overall parts derived in a hierarchical form.

Thus, the three main functions of the AHP method are complexity structuring, measurement, and synthesis (Kulakowski, 2020). The first function confirms that to deal with the complexity of the decision-making process, and it is necessary to identify all the factors that influence decisions and arrange them in a hierarchical structure as a group of homogeneous factors (Kulakowski, 2020). Measurement in the form of a ratio scale is obtained by comparing these factors in pairs. The weight of each factor in the hierarchy that is built will be found in a process where each factor is compared with its parent factor. Priorities expressed as weights across the hierarchy will be found by multiplying the priority of one factor at each level by the priority of the factor associated with the first factor, the parent factor. Although AHP has analytics aimed at separating abstract entities into their constituent elements, this method is important due to the ability to measure and synthesize many factors in a hierarchy (Kulakowski, 2020). Many studies conducted by researchers have been published on how to use this method, but this paper aims to assess how the AHP method is applied and how criteria are defined and measured. Decision-making methods always vary from time to time with respect to objectives, situations, and expected results. The evolution of these decision-making methods is a reflection of social, economic, and scientific developments. The development of science presents an important factor in the evolution of decision-making methods, research will continue.

Multi-Criteria Decision Making

The definition of Multi-Criteria Decision Making (MCDM) varies and depends on the criteria set by the decision maker. For this contribution, is the characteristics of multi-criteria decision-making (Yadav, 2021). The multi-criteria nature is a decision-making problem, the preparation of criteria in decision-makers assessing the alternative to be selected. Non-additive criteria are chosen criteria conveyed in different section of measure. The set of criteria can be quantitative or qualitative; in the preparation of criteria, the decision maker wants to maximize outcome criteria and minimize input criteria (e.g., manufacturing cost criteria). The MCDM characteristic is its multi-criteria nature which can be solved based on quantitative criteria of the result to be achieved. Although non-additive and mixed criteria set is not a condition, this characteristic occurs so frequently that it can be defined as a complementary feature of MCDM (Siekelova et al., 2021).

MCDM is a decision-making method that determines the best alternative from other alternatives based on certain criteria (Hanine et al., 2016). A criterion is a measure, rule, or standard used in decision-making (Yager, 2018). MCDM divided in two models, which are Multiple Attribute Decision Making and Multiple Objective Decision Making (Alinezhad & Khalili, 2019), as follows:

1. Multiple Attribute Decision Making (MADM).

MADM solves discrete space problems. Therefore, MADM is typically used to evaluate or select a limited number of alternatives. MADM is used to find the best alternative among several alternatives with specific criteria. MADM determines a weight value for each attribute, which in turn determines the ranking of alternatives to choose from.

2. Multiple Objective Decisions Making (MODM).

MODM is used to solve continuous space problems. MADM used to solve the best alternative from multiple alternatives and MODM is used to design the best alternative.

Expert Choice Solutions - How AHP Works

The AHP method consists of three main steps to making the right decisions (Taherdoost, 2017). First is generates a hierarchy based on complex decision problems. Hierarchical structure is divided into sub-problems containing goals, criteria, sub-criteria and decision options. Top level is the main goal. Primary criteria, sub-criteria, and problem-defining choices arranged in hierarchical structure. Second, pairwise comparisons are made against the alternatives, criteria, and subcategories to identify the importance of each criterion relatively at each level structure. Third, perform consistency check entire ratings developed ensuring that the ratings are acceptable. Determining priority value of all alternatives is sorted by considering selection criteria of the model. The candidate with the top priority score will be ranked at the top and considered the best choice for the objective. The AHP hierarchical structure used in this study is described in Figure 1.

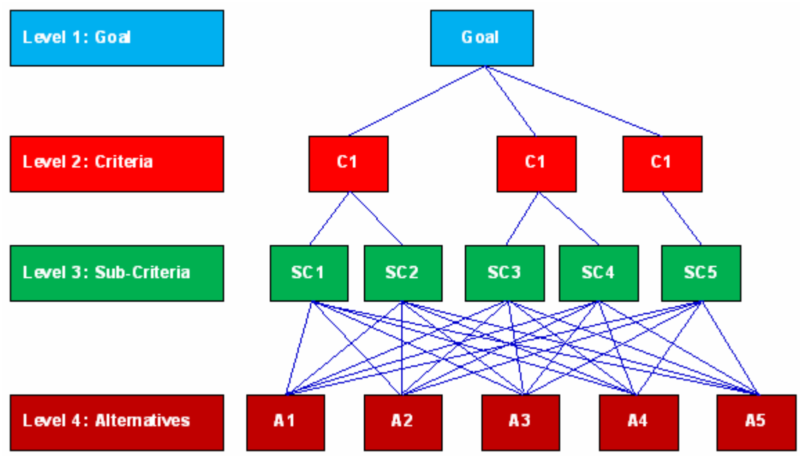

Figure 1. *The AHP hierarchy structure* (Salwa et al., 2019)

~~1.1~~ Level 1 is the goal of the analysis to be achieved. Level 2 is multi-criteria consisting of several factors sought from several sources regarding what will be achieved. The following hierarchy at level 3 can add several sub-criteria and other sub-criteria. Level 4 is a choice. The lines between the levels show the relationship between factors, choices, and goals. Level 2 will have one comparison matrix corresponding to pairwise comparisons between

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The AHP Method in Multi-Criteria Decisions Making

AHP helps make good decisions on a problem. Decision makers need to know and identify: problem, decision needs and objectives, criteria and sub-criteria for evaluating alternatives are implemented, and stakeholders and stakeholder groups (Ho & Ma, 2018). These criteria and sub-criteria can be tangible or intangible. There is no way to measure and rank alternatives when the criteria are intangible. Prioritize criteria to weigh alternative priorities and add up all criteria to get the desired overall ranking of alternatives. AHP consist of six phases (Fei et al., 2019) as follows:

1. Identify the problem and determine the desired solution. The problem to be analyzed is selected from all that are deemed necessary. In defining and choosing a problem, clarifying these assumptions and decision-making perspectives is essential.

2. Develop a hierarchy of decisions to be taken. This structure is built "from above with decision objectives, then objectives from a broad perspective, through the middle level (criteria) to the lowest level (in the form of several alternatives)." After the main goals or objectives are determined, to be able to access problems and find solutions through top-bottom (criteria to alternatives) or bottom-top (alternatives to criteria). The decision maker should eliminate alternatives that are considered impractical not fit the criteria that are considered relevant.

3. Build a matrix and calculate set pairwise comparisons. "Each level above is used to compare the level below it for it." One matrix constructed on each criterion at the top level. Verbal scales were used for measuring both quantitative and qualitative criteria, ranging from "same" (number 1) to "really more important than" (number 9). The preferred criterion cell of the matrix has a value and the other has the reverse value. The redundancy of pairwise comparisons helps make more precise analyses and construct solutions to a problem's elements.

4. Calculate the relative weight for each level. (i) add column values to normalize the matrix; (ii) in a normalized matrix, sum the rows to get the relative priority of the criteria; (iii) evaluate the consistency of the matrix, calculate the eigenvalues to compare random consistency according to matrix size; (iv) for each criterion, the previous steps must be taken; (v) calculate the value of each alternative for each criterion included in the matrix, using priority calculations; (vi) adding up the value of each alternative to get the final score. The best alternative is to have the highest score and be the priority.

5.Check and balance decisions. It is result of implementing AHP in line with projections, and if their deficiencies, previous process review is required.

6. Documentation of decisions. Note all reasons that support why and how decision made. These records will help to decide the process for reflecting into the future, enabling decision-making process and sustain improvement.

Non-Thermal Technology in Liquid and Semi Liquid Products

The food industry has been a priority for the world economy for many years, with consumers' changing wants and needs. Consumer needs for food products that are nutritious, fresh, and have a long shelf life encourage producers to find ways to meet these needs. On the other hand, thermal technology that has been used for a long time has high energy consumption to produce heat from burning fossil fuels (Clairand et al., 2020). Using heat in thermal technology can also reduce the freshness and quality of food. This condition possible swamped applying non-thermal technology.

Table 1. *Application of non-thermal technology in food processing*

Process	Description	Critical Factors	Inactivation mechanism	Application	Reference
HPP	Generally, it uses a pressure of 200 - 400 MPa with temperature < 50°C	Independent of food geometry, equipment size, and operator parameters (pressure, temperature, and curing time	Cell membrane permeabilization	Used for packaged food or bulk food ingredients	Marszałek et al., 2019; Roobab et al., 2022
PEF	Electric field intensity 20-80 kV cm^{-1}, with < 1 s processing time	Device parameters (type of wave, electric field intensity, pulse width, frequency) and properties of food (conductivity, pH value, etc.)	Cell membrane disturbance (electrical breakdown and electroporation)	Used for liquid foods, such as fruit juices and milk	Jia et al., 2019; Ranjha et al., 2021
PL	Emits 1-20 pulses per second at an energy density of 0.01-50 J cm^{-2}	Number of pulses, distance from a light source, and product thickness	UV absorption by DNA causes DNA mutations	Used on food surfaces, utensils, and food packaging materials	Ren et al., 2021; Salazar-Zúñiga et al., 2022
CP	Discharge of light barrier between 2 parallel electrodes	Treatment conditions (gas pressure, type, flow, frequency, and plasma excitation strength), and gas composition	Destruction of the lipid bilayer of cell membranes	Used for raw product surfaces, and packaging materials	Jahromi et al., 2020; Goiana et al., 2022
US	Frequencies > 100 kHz at intensities < 1 W cm-2 or frequencies between 18–100 kHz at intensities > 1 W cm^{-2} (usually in the range of 10-1000 W cm^{-2})	The sound energy density (W cm^{-3}) and food properties, such as viscosity and particle size	Due to thinning of cell membranes, local heating, and production of free radicals	Used for food emulsification, sterilization, extraction, and freezing of fresh food ingredients	Nazari et al., 2018; Zhang et al., 2018

Food quality and safety assurance are of utmost focus during food preservation process. Some food technologies are pasteurization, high-temperature pasteurization, steaming and drying, are intended to ensure the microbiological safety and stability of the product.

Conventional methods can remove some ingredients in food, especially heat-sensitive vitamins and polyphenols associated with food quality (Calín-Sánchez et al., 2020). During food processing, higher temperatures and longer times also produce several potentially harmful components to the human body (Gallo et al., 2020; Meijer et al., 2020). The increasing demand for high quality food products with "fresh" characteristics has led to the introduction of the NTPT process into the food processing industry. Characteristics of the NTPT process include low processing temperatures with short treatment times, resulting in little, no change in taste and essential nutrients (Zhang et al., 2019; Barbhuiya et al., 2021). Therefore, NTPT in food processing extensively studied in latest years (Dong et al., 2020). NTPT has the potential to eventually or partially replace established conventional processes.

Non-thermal technology is a food processor that accepts microbial inactivation with or without small direct heat that can extend its life; maintains new nutritional, sensory qualities, and physical (Chacha et al., 2021). Non-thermal technology provides the advantage of costs and processing time reduction, maintaining quality, and increasing the safety of food products (Chen et al., 2022). Some non-thermal technologies used in the food industry are PL, CP, HPP, PEF, and US. The application of non-thermal technology in food processing is shown in Table 1.

Relevance of Pulsed Electric Field Processing in Food

Compatibility, according to the explanation by Morales-de la Peña et al. (2019) and Timmermans et al. (2019) that the processing of liquid and semi-liquid foods through an electric field is an advantageous aspect of non-thermal technology causing an increase in temperature due to ohmic heating, the process temperature is usually quite low at sublethal temperatures. In contrast to the widely used thermal treatment procedures for microbial inactivation, non-thermal methods such as PEF better preserve liquid and semi-liquid foods with sensory, nutritional, and functional properties of foods (Ortega-Rivas, 2009), which corresponds to the increasing consumer demand for fresh foods. Jeantet et al. (2003) explained in their research that the PEF system for liquid sterilization is compatible, which produces rectangular electrical pulses. The equipment can process up to 25 l/h at pulse amplitudes of 5-15kV, 1-815Hz frequencies, and pulse widths of 50, 100, 250, 500, 1000, 2000, or 3000ns. However, a number of experimental studies have proven that a sufficient reduction of microorganisms can be achieved by the application of PEF (Toepfl et al., 2006). PEF is considered the most successful in treating liquid food continuously (Heinz, et al., 2003). However, PEF technology has not yet reached the stage of commercial use at low to medium volume capacities, which warrants further intensive research to complete understanding and minimize deficiencies.

According to Dourado et al. (2019) and Yu et al. (2017), product quality explains that honey processing reduces the water content to safe limits and delays it, thereby increasing shelf life. In addition, after the PEF treatment, the process results can be maintained regarding taste, color, and nutrition to the level (Eshete & Eshete, 2019). Honey humidity is an important parameter in the quality of honey. The amount of water in honey determines the stability of fermentation and granulation (El Sohaimy et al., 2015). Honey that has high water content is easily fermented over time. Therefore, honey must be processed with certain treatments to prevent fermentation by yeast of sugar tolerance (Ramly et al., 2021). In their research, Singh & Singh (2018) explain that treatment in a closed system minimizes the loss of volatile aroma during heating. Honey processed at 60^{o}C has a higher water content (17.98%) compared to 17.06 and 16.40% at a temperature of 70 and 80^{o}C while the processing time does not significantly affect the water content of honey that is packaged in glass jars, plastic jars, and poly pack pockets.

According to Arshad et al. (2021) and Morales-De La Peña et al. (2019), food safety considers that honey is a raw food product that may contain pathogenic microorganisms, such as bacterial spores (strain clostridium botulinum). However, it has a small effect on honey degradation, causing serious concerns about safe consumption, especially by people who experience immunosuppression or by children and pregnant women. Honey is a definitive food ingredient for baby botulism (European Commission, 2002). As recommended by the World Health Organization (WHO), in the prevention of botulism in infants, it is important not to use honey as a sweetener in infections for babies <12 months (World Health Organization, 2018). Although conventional thermal processing effectively reduces microbes' viscosity and decontamination, the lack of this technique lies in the inefficiency of deactivating bacterial spores such as C. Botulinum (Scepankova et al., 2021).

According to Picart-Palmade et al. (2019) and Gana & Gbabo (2017), installation cost that the actual cost of using the PEF process for installation on food production depends on factors including equipment and installation costs, production capacity, and operating costs (labor and energy). Production rate (process flow: kg or l throughput product per year) is determined by the reactor vessel's cycle time and volumetric efficiency. The greater the use, the more effective the cost of production. According to Barba et al. (2016) in his research explained that the total cost of pasteurization of 1 liter of raw honey with PEF treatment is estimated to be seven times higher than conventional heat pasteurization treatment. Likewise, the implementation of commercial PEF technology by many companies is shown by the high number of PEF machines operating (more than 320 units), showing that costs can be sustainable (Barba et al., 2018). Coutinho et al., 2018; Priyadarshini et al., 2018; and Chacha et al., 2021 explained in their research that the operation cost of commercial-scale PEF units for food processing with a total flow rate of 400-6,000 l/hour (Kempkes 2011). The use of PEF by the juice processing industry that PEF processing costs will be very dependent on the cost of capital and energy consumption (Sampedro et al., 2014). Although some research results are available in the literature, the development of systematic cost analysis studies of this technology's commercial application is still rare.

According to Gana & Gbabo (2017), and Picart-Palmade et al. (2019), in their research, what is meant by sustainability to the environment and economics is a PEF technology approach that is sustainable, environmentally friendly, and food safety. PEF treatment parameters are used in continuous processes such as electric field strength, pulse shape, pulse duration, and pulse frequency (Gulzar & Benjakul, 2019). In addition to the PEF treatment parameters, the treatment medium is an important factor for reversible or irreversible pore formation (Luengo et al., 2015). The main influencing parameters are the conductivity of the pulsed conducting rods, thereby enabling the recovery of a wide variety of foods and by-products while reducing energy costs, solvent consumption, waste reduction, total waste, and shortening processing time (Andreou et al., 2020). Sustainably, the extraction process of valuable compounds must be optimized to minimize environmental impact, increase process efficiency (solvent and energy consumption), and simultaneously obtain high extraction yields without loss of extract function (Panja, 2018).

Research Method

Material

This research is to investigate and evaluate the selection criteria for the honey pasteurization NTPT process and study the influence of these criteria in the priority framework using the Delphi methods and AHP, especially for stakeholders as decision makers (DM) engaged in the honey business. Convergence of the DM's opinion from this method will be easier and use a qualitative collection of technology selection criteria. The proposed method can be used by the development of honey preservation equipment and processed honey in selecting NTPT process criteria more effectively (Al Hazza et al., 2022).

Generating criteria in AHP based on references is used as an evidence-based strategy to obtain different answers to questions and identify problems towards solutions. The definition of criteria and descriptions measured in the AHP method are described in Table 2. The criteria nomenclature search protocol in the preservation process consists of tools to access information (Scholar Google); the words to be researched ("AHP" and "PEF" separately for titles); scope of work (Business, Small and Medium Enterprises); this paper must contain real case studies, not examples; refers to multi-criteria decision making (MCDM); and references published in the last eight years. This paper considers two methodologies on AHP in examining the criteria needed in NTPT for an efficient honey pasteurization process through reference studies from several journals, as summarized in Table 2. Questionnaires and interviews are to analyze the preferences of the expert team. The use of the AHP is one of the MCDM, which analyzes the weight of the NTPT selection.

Table 2. *Identify the initial criteria from the reference journal*

Criteria	Descriptions	Sub Criteria	Sub-Sub-Criteria	Reference
Compatibility	Technological compatibility with the product to be processed	Semi-liquid food	NA	Morales-de la Peña et al., 2019
		Liquid food	NA	Timmermans et al., 2019
Product Quality	Product quality after going through the process of technology	Taste	NA	Dourado et al., 2019
		Color	NA	Yu et al., 2017
		Nutrition	NA	Pallareâ‘s et al., 2020
Food Safety	Food safety after going through process technology	Water content	NA	Arshad et al., 2021
		Spore levels	NA	Morales-de la Peña et al., 2019
Manufacturing Cost	The costs incurred when implementing and operating	Installation	Size	Picart-Palmade et al., 2019
			Control system	Picart-Palmade et al., 2019
			Materials	Gana & Gbabo, 2017
		Operational	Maintenance	Coutinho et al., 2018
			Operation	Priyadarshini et al., 2018 Chacha et al., 2021
Sustainability	Sustainability of applied technology	Environment	Waste reduction	Gana & Gbabo, 2017
			Total waste	Picart-Palmade et al., 2019
		Economics	Energy consumption	Gulzar & Benjakul, 2020
			Productivity	Andreou et al., 2020

AHP uses analytical principles and mathematical models together to perform pairwise comparisons. The AHP hierarchy starts with the top layer being the goal of the problem (i.e. the objective), the next layer being the selected primary factor (i.e. the criterion) or the secondary element (i.e. the sub-criteria), and the last class are possible choices. or a solution to the problem (i.e. an alternative).

The explanation of the NTPT selection criteria in Table 2 that identified is as follows:

1. The criteria for compatibility relate to the suitability of the product processing with NTPT. The compatibility of the product with NTPT is considered. Each food product has its characteristics and characteristics. Likewise, NTPT has its advantages and disadvantages. Food products raised as sub-criteria are semi-liquid or liquid products.
2. The product quality criteria are related to the quality of the product from NTPT. Non-thermal technology can maintain the quality of processed food products. Product quality is maintained, including taste, color, and nutrition. The quality of honey does not change from the original quality in consumer demand.
3. Food safety criteria are related to the safety of food products after being processed using non-thermal technology. NTPT can reduce the content of harmful foods. The original state of food products before processing is contaminated by microorganisms and fungi or spores. NTPT can reduce microorganisms and fungi or spores present. Reducing microorganisms and fungi or spores makes food products safe for consumption.
4. The manufacturing cost criteria are related to the NTPT application. The cost criteria consist of NTPT installation and operation costs. Installation cost includes size, material, and control system from NTPT. Operating costs consist of operational and maintenance costs. Sustainability criteria relate to the sustainability of NTPT in the environmental and economic spheres. Environmental sustainability includes the ability of NTPT to eliminate the causes of toxic substances in products and reduce the amount of processing waste. Economic sustainability includes NTPT's ability to minimize energy consumption and increase productivity.
5. The study began by analyzing problems involving two community groups by interviewing each group and answering many questions posed to stakeholders and a team of experts. They are strategic candidates in the selection review of the NTPT process represented, given the needs, understanding, and ability to interpret all the different questions between the two groups of people. The evaluation procedure in AHP consists of two steps, as shown in Figure 2.

Step 1: Identify NTPT selection criteria and considered most important point to users.

Step 2: Compiling a hierarchy of evaluation criteria, the weighting value of the criteria is calculated by AHP.

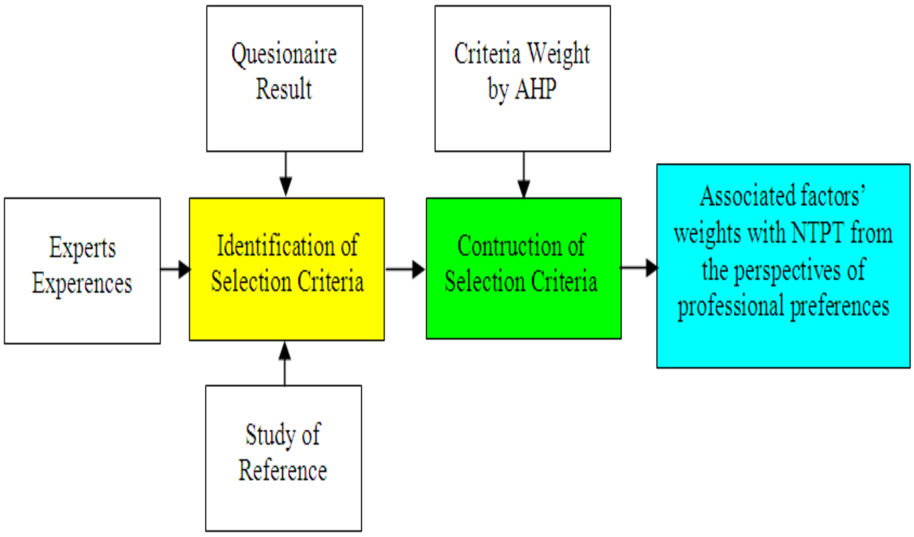

Figure 2. *AHP stages in the selection of NTPT honey pasteurization machine*

The questionnaire is designed to find out the relevance of the criteria, the weight of the criteria, and the selection of alternatives. The first questionnaire for a stakeholder group of three participants as tool users in the honey business consisted of one honey farmer, one honey supply business person, and one honey industry person. The second questionnaire represents a group of six participants: three manufacturing professionals, one technician, and two manufacturers. The expert team group was asked to complete three questionnaires with different objectives. This questionnaire aims to determine the expert team's preferences in determining additional criteria or those needed in the selection of alternative NTPT processes.

Selection Questionnaire

The results of identifying the initial criteria refer to the references in Table 2 for preparing the initial questionnaire. The first questionnaire aims to determine the relevance of the criteria and sub-criteria for NTPT selection. As a team of experts, stakeholders filled out the proposed questionnaires to determine which values were relevant to a value of one and irrelevant to a value of zero.

Select "1" = relevant and Select "0" = irrelevant

Assessment of the initial questionnaire by a team of experts, all criteria have been agreed upon by stakeholders. There was a change in the productivity sub-criteria to increase productivity. The expert team agreed to increase the shelf life. Further literature studies for shelf life are included in the product quality criteria described in Table 3.

Table 3. *Selected criteria, sub-criteria, and sub-sub-criteria based on corrections from the expert team*

Criteria	Sub-Criteria	Sub-Sub-Criteria
Compatibility	Semi-liquid food	NA
	Liquid food	NA
Product Quality	Taste	NA
	Color	NA
	Nutrition	NA
	Shelf life	NA
Food Safety	Number of microorganisms	NA
	Spore levels	NA
Manufacturing Cost	Installation	Size
		Control system
		Materials
	Operational	Maintenance
		Operation
Sustainability	Environment	Waste reduction
		Total waste
	Economics	Energy consumption
		Productivity increase

Steps in solving AHP

In this paper, the analysis of factors in NTPT uses the AHP method. The focus group discussions with both community groups were conducted to synthesize data on the weights of competent factors for the success of NTPT selection. AHP method divided into several steps as follows.

Step 1: Generate matrix table for pairwise comparisons of compared options and factors, as shown in Equation 2, using a scale of 1 to 9 for pairwise comparisons. The selection method uses the fundamental scale (Li et al., 2018), as shown in Table 4.

Table 4. *AHP fundamental scale in questionnaire assessment*

Intensity of Interest	Description
1	Both criterion important
3	One criterion is slightly more important than the other
5	One criterion is more important than other
7	One criterion is more critical than the other
9	One criterion critical compared to other criteria
2,4,6,8	Values between two values of adjacent considerations

$$n(n-1)/2 \quad (1)$$

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ \dots & a_{ji} = 1/a_{ij} & 1 & \dots \\ a_{n1} & \dots & \dots & 1 \end{bmatrix} \quad (2)$$

Where a_{ij} is the ratio of factors i and j

Step 2: Generate normalized matrix by dividing each value in the first step by total of each column in the matrix.

Step 3: Compute the eigenvectors or priority use the coefficient weights and various alternatives (if any), using Equation 3.

Step 4: Compute largest eigenvalue of the eigenvectors obtained in step 3., which is called λ_{max}

$$A \cdot p = \lambda_{max} \cdot p \quad (3)$$

Where p is the local priority vector
Step 5: Calculate Consistency Index (CI), using Equation (4)

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

Step 6: Chose Random Consistency Index (RI) value from table compared to the matrix size (n), using Table 5.

Table 5. *RI values for the AHP method*

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Step 7: Evaluate the Consistency Ratio (CR) of the matrix using equation 5.

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

Step 8: Rank each alternative (if any) according to equation 6 and evaluate, l_{ij} is local score of each option. i compared to j; w_j is the weighted value of the j factor; and g_i is the global score of each alternative i of interest.

$$g_i = \sum_j w_j l_{ij} \quad (6)$$

In the research considering the weight of the criteria considered essential for successful food safety in selecting NTPT, the AHP calculation follows equations 1 to 5, without equation 6 in the analysis.

Results

Open-ended analysis questions and interviews shows the criteria that are considered essential for success in an efficient honey pasteurization process and supported by initial data from a representative expert team revealing criteria that need attention, consisting of cost, product quality, and food safety, become more critical and also the criteria for compatibility, and sustainability. Then the criteria analysis was performed using the AHP method with the primary objective of selecting an efficient pasteurization process machine using non-thermal technology to contribute to process technology selection. AHP with three main steps in determining the decision to choose non-thermal technology based on an efficient pasteurization process. The first step is to form a hierarchy based on complex decision problems. The hierarchical structure is divided into sub-problems containing objectives, criteria, sub-criteria, sub-sub criteria, and decision alternatives.

The top level represents the main objective; the main criteria, sub-criteria, sub-sub criteria, and alternative decisions related to the problem are stated in a hierarchical structure. Then the second step, pairwise comparisons are made for criteria, alternatives, and their sub-subjects to determine the level of relative importance for each criterion in each level structure. Next, third step is conducting consistency check for each developed assessment, ensuring acceptability values. Ranked overall priority value alternatives are considering the selection criteria in hierarchy. The candidate with the biggest priority score is at the top of the ranking and is considered the best selection concerning the study objectives. Discusses the synthesis of criteria regarding the suitability of the selection of NTPT with the AHP, where the results of the identification of criteria are used as the basis for a hierarchical model of criteria for selecting non-thermal technology, as described in Figure 3.

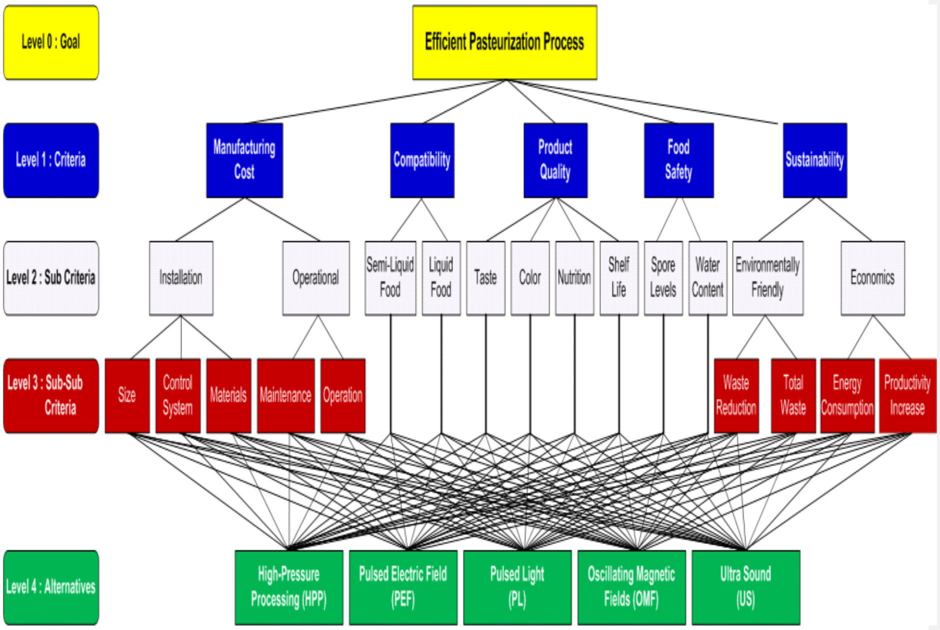

Figure 3. *The hierarchical structure of the selection of non-thermal technology*

Identification of Selection Requirements

In this study, the development of an MCDM framework model to perform technology selection from non-thermal processes. The main criteria for technology selection for applying an efficient honey pasteurization process are cost, product quality, food safety, compatibility, and sustainability. This honey pasteurization process helps maintain food quality and safety during handling and storage time and prevents premature deterioration of honey. The requirements for selecting non-thermal technology are based on the type of viscosity of the honey produced because different types of honey are required to meet different requirements. However, it is noted that Attia et al. (2022) stated that increasing consumer appreciation of bee honey boosted honey production, boosting the economic development of the beekeeping industry.

The main criteria for selecting the technology for implementing an efficient honey pasteurization process are cost, product quality, food safety, compatibility, and sustainability. Three criteria were cost, product quality, and food safety. The second thing on a criterion is compatibility and sustainability. Suitability relates to the suitability of the characteristics of honey processed through non-thermal technology, which is of concern. Each characteristic of honey has its characteristics and properties. Non-thermal technology has its advantages and disadvantages. Sustainability relates to the application of non-thermal technology in the environmental and economic spheres. Sustainability for the environment includes the ability of non-thermal technology to reduce waste in honey processing and reduce the amount of waste. The economy's sustainability includes non-thermal technology's ability to minimize energy consumption and increase productivity, as described in Figure 4.

Criteria	Sub Criteria	Description
Manufacturing Cost	Installation	To determine of size, control system, and materials
	Operational	To determine of maintenance, and operation
Product Quality	Taste	To measure to distinguish the flavor of by taking into the mouth
	Color	To measure of the aspect of things that is caused by differing qualities of the light reflected or emitted by them
	Nutrition	To measure of the process by which organisms take in and utilize food material
	Shelf Life	To measure of the length of time a product may be stored without becoming unsuitable for use or consumption
Food Safety	Spore Levels	To measure to can grow into a new organism without uniting with another cell
	Water Content	To measure of the quantity of water contained in a material
Compatibility	Semi-Liquid Food	To measure of having a thick consistency between liquid and solid
	Liquid Food	To measure of a substance in a physical state in which it does not resist change of shape but does resist change of size
Sustainability	Environmentally Friendly	To determine of waste reduction and total waste
	Economics	To determine of energy consumption, and productivity increase

Figure 4. *Selection criteria and sub-criteria were developed to select the most suitable non-thermal technology for the application of the honey pasteurization process*

NTPT Alternative Development

The criteria and eleven sub-criteria for selecting NTPT were obtained from journal references. Complete comparative data of the twelve sub-criteria with five NTPT alternatives were collected from the latest published literature from 2009–2022, as shown in Figure 5.

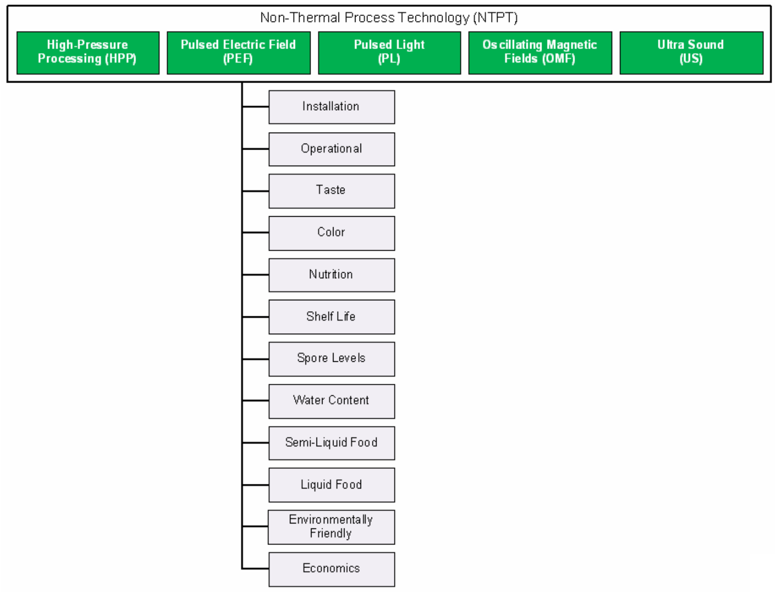

Figure 5. *Twelve sub-criteria for an efficient honey pasteurization process*

Criteria System and Criteria Weight Evaluation

The evaluation on AHP is as follows: (1) evaluation is arranged hierarchically downwards, (2) Each hierarchical node has same assessment technique, and (3) the assessment of sub-sub-criteria nodes as "twigs" from sub-criteria nodes as "branches" and so on to the above hierarchy based on pairwise comparisons. There are five levels evaluation, the study objectives presented at top of the hierarchy, is the main criterion level parent node. The second level contains five nodes as the main criteria, where each criterion is a branch node to a set of sub-criteria branch nodes. The sub-criteria level consists of twelve attributes that are applied to assess different NTPT alternatives. The alternative levels, at lows, represent the twelve alternative NTPTs. Each branch node implies a decision matrix of order n × n, where n is the number of twigs nodes.

Sub Criteria Weighting

Five non-thermal technologies were selected for the honey pasteurization process to understand priorities. The evaluation of the expert team was collected using a direct survey questionnaire identified in the field of honey business. The identified expert team must have at least 5 years of experience in the honey business. Although a single decision maker can use the AHP, combining the assessments obtained from a group of raters for several people would be better, as was done in this study. Pairwise comparisons require a team of experts to make each decision about each n alternative in equation 1. In the ranking mode, it takes no ratings to assess and alternatives to complete the pairwise comparison matrix in assessing the importance of each criterion using a scale, as shown in Table 4.

Main Criteria Weight Evaluation

Main criterion described on second level of the hierarchy; criteria related each others to cost, product quality, food safety, compatibility, and sustainability. The assessment of relative importance of each pair compared against the five main criteria and give equal weight to each criterion. Each paired value comparison is 1.0, indicates equally important of each criteria. Paired matrices for main criteria concerning the objectives and resulting weights of each main criterion describe in Table 5. The main criteria include cost (C), product quality (PC), food safety (FS), compatibility (Co), and sustainability (S) contribute to the equal priority vector. Consistency ratios and priority vectors considered after a pairwise comparison assessment with consistency ratio value (CR = 0.00) less than 0.1, and then the assessment accepted. The CR value is used to decide whether assessment of the expert team can be declared consistent. If the expert team's assessment is inconsistent, a reassessment will occur. The expert team group filled pairwise comparison matrix of main criteria that describe in Table 6.

Table 6. *Pairwise comparison main criteria*

Main Criteria	C	PC	FS	Co	S
C	**1.00**	0.5	3.00	5.00	4.00
PC	2.00	**1.00**	2.00	3.00	5.00
FS	0.33	0.50	**1.00**	2.00	0.50
Co	0.20	0.33	0.50	**1.00**	2.00
S	0.25	0.20	2.00	0.5	**1.00**

It is necessary to consider the assessment in assessing the criteria involving a group of expert teams. The geometric mean calculation in equation 6 is for each assessment, as shown in Table 7.

Table 7. *Geometric mean comparison of main criteria*

Main Criteria	C vs. PC	C vs. FS	C vs. Co	C vs. S	PC vs. FS	PC vs. Co	PC vs. S	FS vs. Co	FS vs. S	Co vs. S
Expert 1	1.00	3.00	2.00	5.00	1.00	3.00	5.00	2.00	2.00	0.50
Expert 2	0.50	3.00	5.00	4.00	2.00	3.00	5.00	2.00	2.00	2.00
Expert 3	2.00	4.00	5.00	5.00	3.00	2.00	4.00	2.00	4.00	2.00
Geometric mean	1.00	3.30	3.68	4.64	1.82	2.62	4.64	2.00	2.52	1.26

The geometric mean values are arranged in a pairwise comparison matrix, and the sum of each row is calculated to determine the total value. The total value of each row is used to normalize the comparison value. The pairwise comparison matrix geometric mean for main criteria can be shown in Table 8.

Table 8. *Matrix pairwise comparison geometric mean main criteria*

Main Criteria	C	PC	FS	Co	S
C	1.00	1.00	3.30	3.68	4.64
PC	1.00	1.00	1.82	2.62	4.64
FS	0.30	0.55	1.00	2.00	2.52
Co	0.27	0.38	0.50	1.00	1.26
S	0.22	0.22	0.40	0.79	1.00
Amount:	**2.79**	**3.15**	**7.00**	**10.10**	**14.06**

Data normalization is done by dividing the comparison value by the total value of the criteria row, as described in equation 3. Then, each criterion row is added to ensure the data is normalized. If the normalized data is added, the result is 1, as in Table 9.

Table 9. *Main criteria normalization matrix*

Main Criteria	C	PC	FS	Co	S
C	0.36	0.32	0.47	0.36	0.33
PC	0.36	0.32	0.26	0.36	0.33
FS	0.11	0.17	0.14	0.20	0.18
Co	0.10	0.12	0.07	0.10	0.09
S	0.08	0.07	0.06	0.08	0.07

After the data is normalized, the priority vector is calculated for each criteria column. The priority vector is average value of each criterion column by dividing the total value of each criterion column by the number of criteria column values shown in Table 10.

Table 10. *Priority vector main criteria*

Main Criteria	C	PC	FS	Co	S	Amount	Priority Vector
C	0.36	0.32	0.47	0.36	0.33	1.84	0.37
PC	0.36	0.32	0.26	0.26	0.33	1.52	0.30
FS	0.11	0.17	0.14	0.20	0.18	0.80	0.16
Co	0.10	0.12	0.07	0.10	0.09	0.48	0.10
S	0.08	0.07	0.06	0.08	0.07	0.35	0.07
Amount:	1.00	1.00	1.00	1.00	1.00	5.00	1.00

The priority vector calculated for each criteria column is average values of each criteria column by dividing the total value of each criteria column by the number of values of the criteria column for the cost criteria, as shown in Table 11.

Table 11. *Priority vector criteria cost*

Main Criteria	C	PC	Amount	Priority Vector
C	0.74	0.74	1.48	0.74
PC	0.26	0.26	0.52	0.26

Determination of the CR value of the criteria cost by calculating the maximum lambda based on equation 3 explained the matrix calculation as follows:

$$\overset{A}{\begin{bmatrix}1.00 & 2.88\\0.35 & 1.00\end{bmatrix}} x \overset{x}{\begin{bmatrix}0.74\\0.26\end{bmatrix}} = \overset{Ax}{\begin{bmatrix}1.485\\0.515\end{bmatrix}} \rightarrow \overset{Ax}{\begin{bmatrix}1.485\\0.515\end{bmatrix}} = \lambda_{\max}\begin{bmatrix}0.74\\0.26\end{bmatrix} \rightarrow \lambda_{\max} = average\left\{\frac{1.485}{0.740}, \frac{0.515}{0.260}\right\} \rightarrow \lambda_{\max} = 2$$

Calculating the CI in equation 4, the CI calculation is explained as follows:

$$CI = \frac{(\lambda_{\max} - n)}{(n-1)} = \frac{(2-2)}{(2-1)} = 0.00$$

Calculating the CR in equation 5, where the number of criteria in the calculation is n = 2, then the divisor of the calculation of the CR value is 0.00, and the CR calculation is explained as follows:

$$CR = \frac{CI}{0.00} = \frac{0.00}{0.00} = 0.00$$

The CR value of the cost criteria assessment is 0.00 or 0%; if the CR value is less than or equal to 10%, then the matrix is declared consistent. The sub-criteria assessment matrix of the cost criteria is stated to be consistent. The CI value is 0, and the CR result is 0; the matrix is declared consistent. Priority vector and CR were calculated from the sub-criteria, as shown in Table 12.

Table 12. *Value of priority vector and consistency ratio for sub-criteria cost*

Main Criteria	Sub-Criteria	Priority Vector	Total
Manufacturing Cost	Installation	0.30	1.00
	Operational	0.70	
Product Quality	Taste	0.18	1.00
	Color	0.14	
	Nutrition	0.28	
	Shelf life	0.40	
Food Safety	Number of microorganisms	0.35	1.00
	Spore levels	0.65	
Compatibility	Semi-liquid food	0.74	1.00
	Liquid food	0.26	
Sustainability	Environment	0.47	1.00

The structure of AHP is based on an efficient pasteurization process formulated from several journal references. Broader criteria in the choosing process will allow us to more comprehensively evaluate the selection of NTPT alternatives, and better-informed decisions can be made stronger. A series of stages of completion in each hierarchy can be summarized in Table 13.

Table 13. *AHP results for the selection criteria for the NTPT honey pasteurization process*

Main Criteria		Sub-Criteria		Sub-Sub-Criteria	
Manufacturing Cost	0.10	Installation	0.30	Size	0.30
				Control system	0.52
				Materials	0.18
		Operational	0.70	Maintenance	0.28
				Operation	0.72
Product Quality	0.30	Taste	0.18	NA	
		Color	0.14	NA	
		Nutrition	0.28	NA	
		Shelf life	0.40	NA	
Food Safety	0.16	Number of microorganisms	0.35	NA	
		Spore levels	0.65	NA	
Compatibility	0.37	Semi-liquid food	0.74	NA	
		Liquid food	0.26	NA	
Sustainability	0.07	Environment	0.47	Waste reduction	0.65
				Total waste	0.35
		Economics	0.53	Energy consumption	0.61
				Productivity increase	0.39

The results of the study in the selection of NTPT on the honey pasteurization process showed that six participants from two different community groups placed the highest importance on the criteria of "compatibility" of technology for processing semi-liquid or liquid foods using the PEF process, followed by "product quality" and "product safety," as described in Figure 6.

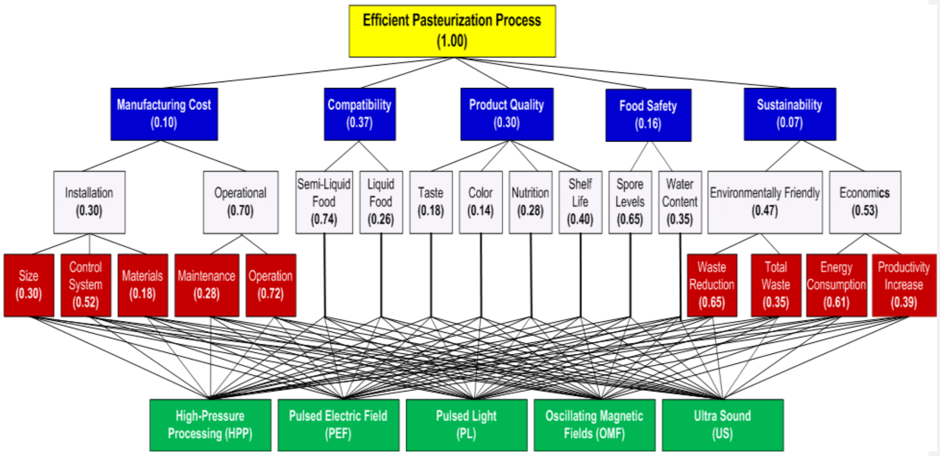

Figure 6. *Hierarchy of criteria that have a priority vector in NTPT selection*

So, the key in selecting NTPT was that the expert team prioritized the "compatibility" of the technology for food processing, which was related to the "cost" of making honey pasteurization process equipment, product quality, food safety, and sustainability. In the main criteria, the cost of the "installation" sub-criteria in the "control system" sub-criteria and the "operational" sub-criteria in the "operations" sub-criteria are the characteristics that most influence the perception of the expert team in determining the honey pasteurization process. Therefore, the successful suitability of the technology for food processing needs to pay attention to these criteria.

The rater placed the highest importance on the PEF process as an effective process for compressing microorganism quantity and spore levels in the matrix of semi-liquid or liquid diets according to the sub-criteria posed to the rater. PEF is a non-thermal technology process in the food industry that has been proven to retain food taste, color, and nutrition better than conventional thermal treatments. This innovative processing technique has also proven exceed to traditional processing techniques regarding the processing time requirement. Therefore, it can reduce processing time and production costs and increase productivity. In the PEF process, employed an electric field across the sample through the PEF electrode for microseconds; this technique differs from ohmic heating primarily in the frequencies and processing times used. Microbial decontamination is successful using this technique (Tony et al., 2017; Syed et al., 2017; Delso et al., 2021). Researchers explore the feasibility of PEF to remove toxins and pesticides from food.

Discussion

The priority scale of the criteria comparison is used as the basis for determining the weight of the criteria in selecting non-thermal technology alternatives. The higher criterion weight rating, the greater effect of the criterion on the alternative selection. On the other hand, the smaller the criterion weight rating, the smaller effect of the criteria on alternative selection. Determination of weight is obtained from the results of distributing questionnaires to DM. The result is that the weight values at each level are the main criteria as level 1, sub-criteria as level 2, and sub-sub-criteria as level 3. However, the weight values are still at their respective levels; it is necessary to generalize the weight values so that they can be used in selecting non-thermal technologies. Equalizing the value of the criteria weight is done by changing the weight of each level to the global criteria weight (Rezaei et al., 2021). As a result, the criteria for semi-liquid food have the most extensive global criteria weight. The semi-liquid food criterion significantly contributes to the choice of non-thermal technology. Material criteria have the most negligible global criteria weight among other criteria. Material criteria make the most negligible contribution to the selection of NTPT. Although the material cost for non-thermal technology is expensive, this technology is compatible with semi-liquid food products. The recapitulation results of Ci* calculations for each alternative explain that PEF Technology has a Ci* value closest to 1 of 0.733. The Ci* results of all alternatives are shown in Figure 7.

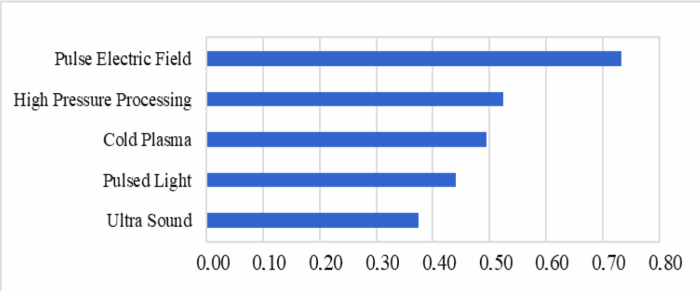

Figure 7. *Recapitulation of Ci* calculations for the selection of each alternative*

Figure 7 explains the relative proximity (Ci*) that the PEF is ranked highest compared to the proposed HPP technology, CP, PL, and the lowest rating, is US. Therefore, PEF was selected as the non-thermal technology devoted to the honey pasteurizer. PEF has a high-performance value or is a positive ideal solution on several criteria, are semi-liquid food, liquid food, taste, nutrition, number of microorganisms, control systems, materials, treatment, reduction of pesticides, amount of waste, and increased productivity (Setiawan et al., 2022). Morales-de la Peña et al. (2019) explained that PEF is recommended in semi-liquid food processing. PEF provides inactivation of Listeria innocua, Escherichia coli, Enterobacteriaceae, Pseudomonas fluorescent, and Staphylococcus aureus. Salinas-Roca et al. (2017), in their research applying PEF to mango juice, found that PEF reduced L. innocua microorganisms by 5 logs. Physical qualities such as taste, color, and smell can be maintained fresh.

The choice of PEF technology in the NTPT process was based on an AHP study to support the food industry for small and medium enterprises. The need for PEF technology is supported by increasing consumer interest, mainly in processed honey, high nutritional value food, food produced and demand for fresh produce in an environmentally friendly, economical manner with due regard to the sustainability of production. Scientific studies on application and principle of PEF technology widely published, fact that PEF has been applied to the food industry long time ago, modifications to this technology application are new and need to consider. There are no specific laws regarding foods processed with PEF in Indonesia. The use of food processing techniques is managed by the Regulation of the Food and Drug Supervisory Agency number 7 of 2021 concerning the registration of processed food and number 20 of 2021 concerning processed food labels; however, implementing the NTPT process in food production does not mean that the food becomes "new".

Other NTPT processes such as HPP, PL, CP, and US can be considered alternatives for food processing. However, one has to look at the complexity of manufacturing, installation, and operating costs because, such PL, CP, and US, further research is needed to explain their use on an industrial scale for small and medium enterprises. Although HPP has developed its application in the food processing industry, the installation requires more attention, and the cost could be higher for small and medium-scale industries. In this study, multi-criteria decision-making (MCDM) was used to develop the framework and priority indicators for the capacity and cost of making honey preservation machines with the aim of an efficient pasteurization process. The Delphi-AHP approach is used to solve problems like this. In this approach, AHP is used to determine attribute weights. The main contribution of this research is to develop a theoretical framework for indicators of the capacity and cost of making honey preservation machines to help honey bee farmers or business enterprises. Based on these priorities, honey bee farmers or honey business enterprises can allocate production capacity plans for post-harvest honey bees.

Policies in developing countries restructured to provide sustainable food needs require better evaluation with multiple criteria. Considering various structures and sustainability factors from a set of criteria, AHP suits this purpose. The AHP method in food processing and subsequent multi-criteria evaluation uses several BPOM regulations. The next suggestion is for the future, where current AHP methods do not consider criteria dependencies. While in practical cases, such as deciding on sustainable and eco-friendly food processing, there are several interdependencies between the criteria and sub-criteria. Considering these dependencies will influence the evaluation outcome and impact cost-effective decision-making. Considering reliability, future research on food technology selection suggests using Fuzzy Cognitive Mapping (FCM) as an excellent decision-support tool (Jahangoshai et al., 2018). FCM is a graphical representation of artificial intelligence (AI) and combines fuzzy logic to model the behavior of complex systems. FCM has been widely employed in decision-making in various domains in recent years.

Limited parties were involved as stakeholders and expert teams in filling out the NTPT selection questionnaire as respondents representing the honey bee business on the south side of the island of Central Java. However, future work is carried out by considering beekeepers and honey bee businesses located on Java's island as the largest bee honey producer in Indonesia.

Conclusion

A systematic procedure at each step of the AHP helps two groups of people efficiently select the best NTPT to produce an efficient application of the pasteurization process. Five main selection criteria, nine sub-criteria in the decision-making process, and twelve sub-criteria for selecting most suitable NTPT from the five alternatives considered. Analysis through open-ended questions and interviews with a team of experts showed the "compatibility" criteria that were perceived to be important in the successful selection of NTPT for the honey pasteurization process. Supported by initial data from a team of experts for the main criteria other than the "manufacturing cost" criteria in the manufacture of pasteurizing machines, the concerns include product quality and product safety. Dominance with a relatively high weight value of the compatibility criteria related to semi-liquid or liquid foods indicates that the use of PEF technology is known to affect the characteristics of NTPT. Less essential and unimportant impacts are found in the "production costs" criteria, such as selecting sub-criteria for materials, maintenance, and size.

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