Clean label approach for condiment sauces: A case in Thai style sauces

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Abstract Clean label food which contains fewer synthetic chemicals, shorter ingredient lists, and minimally processed ingredients, drives extensive attention from both industries and consumers. Clean label food products have gained popularity in the food market recently. This study employed both scientific and strategic techniques to address the issues regarding approaches for clean label implementation in Thai style condiment sauces. The quality and safety parameters of four popular condiment sauces were evaluated. Results suggested that all four condiment sauce samples can be classified as high acid foods which exhibited low pH value of less than 4.5. The quality and safety parameters of condiment sauces, as indicated by preservative contents and microbiological properties, were found to be complied with the Thai standard. However, many artificial ingredients, especially preservatives, were added in the conventional formulas of condiment sauces. These artificial ingredients must be avoided if implementing clean label approach. Results from strategic techniques (SWOT analysis and focus group interviews) suggested that condiment sauces have the potential to be developed as a clean label product. There are opportunities for manufacturing and marketing of clean label Thai style condiment sauces. However, there are also a number of weakness points that needed to be addressed and preferably eliminated. Strategies for the successful implementation of clean label approach in Thai style condiment sauces included minimizing mycotoxin contamination which naturally occurs and the use of natural ingredients with antimicrobial properties. Methods to prolong the shelf-life of condiment sauces using only clean label additives were identified as the key concerns.

Keywords: chili, clean label food, health food, natural ingredient, safe food

1. Introduction

Over the last few years, food producers have identified the term “clean label” as an important market trend. Nevertheless, there is no official nor clear definition of the term. A “clean label” in the context of food refers to a product that has a simplified and transparent ingredient list, with easily recognizable and commonly understood components to the public (Choi et al., 2024). Clean label food products using natural and fresh ingredients with minimal additives have gained popularity in the food market (Hsu et al., 2023). Demand for clean label food products continues to grow (Maruyama et al., 2021) as concerns over negative health impact of ultra-processed foods (Saulais et al., 2023). International food companies respond to the trend with various innovative clean label food products in strategic marketing (Aschemann-Witzel et al., 2019). With increasing health awareness, consumers pay extra attention to ingredients and tend to prioritize clean label food products in purchasing intentions and decisions (Cao & Miao, 2023).

As clean label concept intends to minimize or remove the artificial ingredients or replace them with natural ingredients that provide targeted functionality (Aschemann-Witzel et al., 2019), various clean label ingredients or alternatives were studied. For instance, flaxseed aqueous slurry and sesame cake were employed, instead of the commonly used structurant, methylcellullose, for the development of gluten-free breads (Papagianni et al., 2024). Proteins and their conjugates with natural bio-emulsifiers have the potential to develop food-grade sustainable emulsions that can replace synthetic surfactants (Chutia & Mahanta, 2023). A clean-label antimicrobial agent, cultured dextrose and vinegar blend, was successfully employed to control the Listeria growth in meat products (Shrestha et al., 2022). Clean label alternatives can be enhanced by incorporating non-thermal processing as a clean label process together with hurdle technology approach to overcome the limitations related to the single technologies (Bigi et al., 2023; Roobab et al., 2021).

Condiment sauces containing spices, herbs, seasonings, flavorings, and colorings are becoming popular because consumers are increasingly open to trying other cuisines and find them convenient to use. There are different varieties of condiment sauces available in the market (García-Casal et al., 2016). They serve not only as cooking components but also as table condiments for dressings and dips. The excessive salt (sodium), allergens, and chemical preservatives in condiment sauces are hindering health-conscious customers from embracing supplementary foods (Śmichowska et al., 2021), therefore...
impeding industry growth. Condiment sauces used for Thai-style grilled and flash-boiled meats are gaining popularity despite health concerns, owing to the widespread presence of these sorts of restaurants across the country. They are commonly known locally as "Moo Kra Ta" and "Sha Bu" eateries. An estimated 300,000 to 500,000 restaurants and food stalls are anticipated to provide these types of dishes in various locations across Thailand, particularly in tourist-dense areas.

In view of the importance of clean label approach as well as the demand for safe condiment sauces, this study investigated the possibility of applying clean label approach to Thai style condiment sauces made from fresh chilies and mixed herbs. Their quality and safety parameters were also examined. The findings could assist the food industry in understanding the effects of clean label alternatives on the quality and safety of the products, and help selecting suitable clean label alternatives over harsh chemical preservatives.

2. Materials and Methods

This study is classified as multidisciplinary research, employing both scientific and strategic techniques to address the issues with clean label approach for Thai style condiment sauces. Scientific experiments were conducted to assess the quality and safety parameters of some popular condiment sauces available in the markets. Strategic techniques were applied for qualitative analysis of the importance of Thai style condiment sauces and possibility to promote as potential clean label products.

2.1. Condiment sauce samples

Based on their popularity and commonly used in "Moo Kra Ta" and "Sha Bu" eateries, four commercial condiment sauces were selected for study. These include “Suki Ya Ki (Original)”, “Suki Ya Ki (Cantonese style)”, “Ping Yang (Thai BBQ)”, and “Nam Jim Sea Food”. Their appearances are shown in Figure 1. They were commercial products available in the market throughout Thailand. The samples were purchased from local markets in Phitsanulok province of Thailand in 2023.
2.2. Determination of the quality and safety parameters

According to the Thai standard for condiment sauces set by Ministry of Industry (Thai Community Standard Number 466/2547), quality and safety parameters including pH, preservative (benzoic acid), total plate counts, *Staphylococcus aureus*, *Escherichia coli*, yeast and mold counts were defined as the key quality and safety parameters. The pH meter (Hanna Instruments, Model HI2002) was used for pH measurement. Benzoic acid was determined spectrophotometrically at 272 nm against the standard curve as described earlier (Alfatlawi & Abas, 2012). Total plate counts, coliforms and yeast and mold were determined during storage using the standard Microbiological Methods & Bacteriological Analytical Manual (BAM), released by the US Food and Drug Administration (US-FDA).

2.3. Strategic techniques

Strategic techniques including SWOT (strengths, weaknesses, opportunities, and threats) analysis (Helms & Nixon, 2010) and focus group interview were applied for qualitative study. Ten experts from both academic and industry sectors were selected based on their experiences related to the sauce industry and relevant research. The focus group topics include (1) market position of condiment sauces produced from Thailand, (2) possibility of clean label approach in condiment sauce industry, and (3) strategies to extend shelf-life of the condiment sauce.

3. Results

3.1. Quality and safety parameters

With reference to the four selected condiment sauces, the list of ingredients as declared in their labels are shown in Table 1.

<table>
<thead>
<tr>
<th>Condiment sauces</th>
<th>List of ingredients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suki Ya Ki (Original)</td>
<td>Sugar 25.0%, Pickled chili 9.8%, Iodized salt 3.2%, Vinegar 2.5%, Sesame oil 2.5%,</td>
</tr>
<tr>
<td></td>
<td>White sesame 1.0%, Thickeners (INS1442, INS415), Acidify regulators (INS260, INS514(ii)),</td>
</tr>
<tr>
<td></td>
<td>Natural color (INS160c(i)), Antioxidants (INS304, INS223), Preservative (INS211),</td>
</tr>
<tr>
<td></td>
<td>Monosodium glutamate</td>
</tr>
<tr>
<td>Suki Ya Ki (Cantonese style)</td>
<td>Sugar 18%, Soy sauce, 5%, Garlic 4%, Iodized salt 3%, Chili 2%, White sesame 1%,</td>
</tr>
<tr>
<td></td>
<td>Pickled bean curd 0.4%, Sesame oil 0.3%, Preservative (INS211), Acidify regulators (INS260,</td>
</tr>
<tr>
<td></td>
<td>INS330), Thickeners (INS415, INS1442), Monosodium glutamate</td>
</tr>
<tr>
<td>Ping Yang (Thai BBQ)</td>
<td>Sugar 20.7%, Vinegar 12.1%, Chili sauce 4.7%, Bean paste 3.4%, Red chili 2.5%,</td>
</tr>
<tr>
<td></td>
<td>Garlic 2.4%, Iodized salt 2.0%, White sesame 0.4%, Additives (INS415, INS1422),</td>
</tr>
<tr>
<td></td>
<td>Preservatives (INS202, INS211), Natural color (INS160c(i)), Monosodium glutamate</td>
</tr>
<tr>
<td>Nam Jim Sea Food</td>
<td>Sugar 20.0%, Green chili 13.0%, Garlic 7.0%, Iodized salt 4.0%, Lemon powder 2.0%,</td>
</tr>
<tr>
<td></td>
<td>Fish sauce 0.7%, Coriander 0.7%, Acidify regulator (INS330), Thickeners (INS418,</td>
</tr>
<tr>
<td></td>
<td>INS1442), Preservative (INS211), Artificial color (INS102, INS133), Monosodium</td>
</tr>
<tr>
<td></td>
<td>glutamate</td>
</tr>
</tbody>
</table>

The commercial condiment sauces were tested for their quality and safety parameters including pH, benzoic acid concentration and some microbiological properties. The results are shown in Table 2.

According to the Thai standard for condiment sauces (Thai Community Standard Number 466/2547), pH must be equal or less than 4.5, benzoic acid concentration must be less than 1,000 mg/kg sample. For microbiological properties, total plate count, *Staphylococcus aureus*, *Escherichia coli*, and yeast and mold count must be less than 1x104 CFU/g sample, 100 CFU/g sample, 3 MPN/g sample, and 10 CFU/g sample, respectively.

Table 2 shows that all samples demonstrated good safety in comparison to the Thai standard for condiment sauces. A pH level lower than 4.5 is the critical safety parameter for most condiment sauces. With its strong acidity (low pH), it helps to ensure microbial safety. The microbiological properties as indicated by total plate count, *Staphylococcus aureus*, *Escherichia coli*, and yeast and mold count were well below the maximum amount as set by the Thai standard. Total plate count, *Escherichia coli*, and yeast and mold count were found to be less than detection limit, while *Staphylococcus aureus* was not detected in any samples. All the samples in this study had pH values below 4.5. Hence, acidify regulators are used in all samples (Table 1). Various additives were used, but INS260 (acetic acid) being the most popular. Others included INS514(ii) (sodium hydrogen sulfate) and INS330 (citric acid). It should be noted that Ping Yang (Thai BBQ) did not declare any acidity regulator, but it contained high amount of vinegar (a food form of acetic acid) as the main ingredient (12.1%), refers Table 1.

Furthermore, it should be noted that all the selected samples also contain preservatives, as clearly stated on their labels (Table 1). The legal regulations do not mandate the disclosure of preservative concentrations on the labels. However, these quantities were detected in laboratory testing. The presence of preservatives, as indicated by the amount of benzoic acid, was
found to be below 1,000 mg/kg sample, which is in accordance with the Thai requirement. INS211 (sodium benzoate) was the most common preservative used in condiment sauces. The combination of INS211 and INS202 (potassium sorbate) is found in Ping Yang (Thai BBQ) sample.

**Table 2 Quality and safety parameters of condiment sauces.**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Suki Ya Ki (Original)</th>
<th>Suki Ya Ki (Cantonese style)</th>
<th>Ping Yang (Thai BBQ)</th>
<th>Nam Jim Sea Food</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>4.01±0.10a</td>
<td>4.32±0.15a</td>
<td>4.25±0.10a</td>
<td>2.93±0.10b</td>
</tr>
<tr>
<td>Benzoic acid (mg/kg sample)</td>
<td>765.15±3.52a</td>
<td>674.28±1.25b</td>
<td>695.87±2.38b</td>
<td>347.28±2.45c</td>
</tr>
<tr>
<td>Total plate counts (CFU/g sample)</td>
<td>&lt;10</td>
<td>&lt;10</td>
<td>&lt;10</td>
<td>&lt;10</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em> (CFU/g sample)</td>
<td>Not detected</td>
<td>Not detected</td>
<td>Not detected</td>
<td>Not detected</td>
</tr>
<tr>
<td><em>Escherichia coli</em> (MPN/g sample)</td>
<td>&lt;3</td>
<td>&lt;3</td>
<td>&lt;3</td>
<td>&lt;3</td>
</tr>
<tr>
<td>Yeast and mold counts (CFU/g sample)</td>
<td>&lt;10</td>
<td>&lt;10</td>
<td>&lt;10</td>
<td>&lt;10</td>
</tr>
</tbody>
</table>

Note: Values are mean ± standard deviation, except microbiological properties which show minimum detection limits. For pH and benzoic acid, different letters within a row are significantly different (p≤0.05).

In terms of texture and flavor, all samples contained thickeners as texture modifiers. INS415 (xanthan gum), INS4122 (acetylated di-starch adipate), INS418 (gellan gum) and INS422 (glycerol) are found in the selected condiment sauces. It should be noted that all samples also contained monosodium glutamate which is the most common flavor enhancer found in Asian foods.

### 3.2 SWOT matrix and focus group interviews

Focusing on condiment sauce manufacturers’ point of views, SWOT matrix (Table 3) was drawn using the information obtained from experts’ brainstorming. Internal factors (representing strengths and weaknesses) and external factors (representing opportunities and threats) were summarized with regard to the current status of Thai condiment sauce industry and the possibility of applying clean label approach.

In addition, based on the focus group interviews with experts, the information for each key issues related to condiment sauces in Thailand was summarized as in Table 4.

**Table 3 SWOT matrix for the Thai condiment sauce industry and the possibility of applying clean label approach.**

**Strengths**
- Wide selection of fresh and good quality ingredients is available throughout the country.
- Manufacturing facilities with high capacity are readily available.

**Weaknesses**
- Limited shelf life of clean label condiment sauces when compared to conventional formulations with chemical preservatives.
- Clean label products usually possess less desirable sensory qualities.
- Risk of aflatoxin contaminants from dried ingredients especially dried chilies and herbs.
- High cost of natural and alternative clean label ingredients as compared to conventional and chemical food additives.

**Opportunities**
- Increased demand of condiment sauces in domestic market due to the expansion of “Moo Kra Ta” and “Sha Bu” eateries.
- Consumer demand for clean label food products over conventional products with high use of additives.
- Demand for green and sustainable food productions is increasing.
- Various sources of alternative clean label ingredients such as organic acids and natural antioxidants are available to choose from.

**Threats**
- Current market segmentation is limited.

**Table 4 Key messages summarized from the focus group interviews.**

<table>
<thead>
<tr>
<th>Issues</th>
<th>Key important messages from the experts</th>
</tr>
</thead>
</table>

https://www.malque.pub/ojs/index.php/msj
4. Discussion

Consumers looking for differentiated and intriguing flavors to swiftly spice up their favorite cuisine are driving the market position of Thai condiment sauces. Condiment sauces meet this requirement. There are many different varieties of condiment sauces on the market, and they are used not only as cooking components, but also as table sauces for dressings and dips. However, as evidenced in Table 1, the use of artificial preservatives and chemical additives in condiment sauces is limiting the adoption of the supplemental food among health-conscious customers, which may hamper the growth of the market (Jamaluddin et al., 2022).

SWOT analysis matrix showed high possibility in applying clean label approach for condiment sauces. There are many opportunities with fewer threats. Several strengths were identified. However, many weaknesses were also found with particular concerns on mycotoxins, product shelf-life, sensory properties and high cost (refers Table 3).

According to opinions in Table 4, the major concerns of clean label condiment sauces are its less shelf-life and mycotoxin contaminants. To overcome these constrains, ingredients play a major role in controlling the qualities of clean label condiment sauces (Maruyama et al., 2021). Fresh chili obtained from farmers usually has low microbial counts, and the number of bacterial colonies in the products made from fresh chili are usually within safe levels (Makun et al., 2012). However, if the environmental condition is not properly managed during processing, it offers ample opportunity for contamination by microbes at pre-and post-harvest as well as during production, distribution, retailing, or usage (Truckssess & Scott, 2008). Dried chili, the raw material for many condiment sauces, is susceptible to mold formation. Spoilage molds are often a direct consequence of open storage conditions or storage on bare ground or in gunny bags (Pretari et al., 2019). Aflatoxins (AFs) and ochratoxin A (OTA) are mycotoxins commonly found in chili and chili products produced in tropical countries. The contamination levels were significantly higher in dried chilies purchased from open markets, hot and humid conditions, than those obtained from air-conditioned supermarkets (Romagnoli et al., 2007). Samples of red chili sauce, green chili sauce, and garlic red chili sauce samples, collected from central cities of Pakistan were found to be positive with AFs and OTA at high level, 75.4% for AFs and 71.0% for OTA, respectively (Iqbal et al., 2021). In addition, more than 95% of dried chili powder and dried chili pods collected in Thailand was contaminated with fungi (Chuaysrinule et al., 2020). Humidity and moisture levels need to be controlled during storage and transportation of dried chilies to minimize or avoid mycotoxin contaminations (Iha & Truckssess, 2019; Pretari et al., 2019).

In terms of processing, intensive heat treatment and/or low pH and water activity conditions are normally applied to sauces to ensure microbial stability (André et al., 2017). The lowered pH conditions together with reduced water activity in pasteurized sauces can prevent the growth of most pathogenic or spoilage microorganisms. However, surviving spores of acid-tolerant spore-forming spoilage bacteria potentially germinate, outgrow and cause spoilage (Sun et al., 2021). It is impossible to prevent the contamination of sauces with bacterial spores due to the ubiquitous presence in raw materials and environments (Lv et al., 2021). Therefore, inhibiting the growth of spores is vital to enhance the microbial stability of mildly heated sauces (Sun et al., 2021). Non-thermal preservation factors, such as decreased water activity, acidification, refrigeration and addition of natural antimicrobial agents combined with mild pasteurization have been used as alternatives to the traditional intensively heat-treated products (Xu et al., 2021). Acetic and citric acids are frequently utilized in Thai sauces (Table

<table>
<thead>
<tr>
<th>Market position of condiment sauces produced from Thailand.</th>
<th>• The rising trend of consumer’s willingness to experiment and try different cuisines from across the borders has boosted the market of condiment sauces. • The market for clean label condiment sauces is promising.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possibility of clean label approach in condiment sauce industry.</td>
<td>• There is high possibility for clean label condiment sauces from Thailand due to internal strengths and external opportunities as defined in the SWOT matrix. • The major concerns of clean label condiment sauces are its less shelf-life and mycotoxin contaminants. • The sensory quality of condiment sauces can be enhanced by using natural and organic ingredients. • Non-centrifugal sugars with low glycomic response and high antioxidants can be used to replace refined white sugars.</td>
</tr>
<tr>
<td>Strategies to extend the shelf-life of the condiment sauce.</td>
<td>• The use of organic acids or natural ingredients such as lime juice as acidify regulators are recommended. • Natural soluble ingredients such as jaggery can be used to reduce water activity and extend the shelf-life. • Hurdle technology is recommended for the industrial production of clean label condiment sauces.</td>
</tr>
</tbody>
</table>
5. Unrefined food e.g. derived condiment primarily activity polysaccharid (Wendy purpose shorter pronounce research of and refers Food and Agricultural Organization (FAO) and World Health Organization (WHO) create guidelines for the safe use of food preservatives. The permissible level of benzoic acid in food products is <1 g/kg, which is in line with Thai standard. The Commission Regulation (EU) No 1130/2011 provides a Union List which updates Annex III of Regulation (EC) No 1333/2008. It refers to the permitted levels of food additives such as colorants, enzymes and carriers. The EU regulations on benzoic acid and benzoates are detailed in Annex II of Regulation (EC) No 1333/2008. The maximum permitted levels range from 0.15 to 5 g/kg (mg/mL) depending on the food product. The allowable limit varies in different parts of the world and also relies on the type of products.

Commercial Thai condiment sauces investigated in this study were thermally processed using pasteurization technique. They also employed the combination of acidify regulators and preservatives to prevent spoilage and maintain the required shelf-life. All the samples were classified as high acid foods (pH<4.6) as evidence in Table 2. Therefore, there is no need to undergo severe heat treatment, which can degrade the bioactive compounds, influencing the nutritional and sensory qualities of the condiment sauces.

As conventional condiment sauces used a high amount of food additives as well as artificial preservatives as discussed above, these artificial additives should be replaced by natural ingredients for when applying clean label approach. Previous research suggested that consumers perceive some additives and ingredients as more harmful if their names are difficult to pronounce or unfamiliar (Asioli et al., 2017). Consumers interested in clean label food are looking for familiar ingredients, shorter ingredient lists, and ingredients that are minimally processed (Maruyama et al., 2021).

Attempts have been made to utilize natural ingredients and processing aids in the making of chili products for the purpose of preservation. For instance, betel leaves extract showed antibacterial activity against aerobic microbial and fungal in the homemade chili paste, inhibiting the growth of spoilage microorganisms and prolonging the shelf life of the product (Wendy Voon et al., 2014). Essential oils of black cumin, clove, and ginger showed inhibitory effects against the specific spoilage organisms of ready-to-eat chili shrimp paste with the highest inhibition by ginger (Chan et al., 2021).

Natural antimicrobials which derive from plants, animal sources, microorganisms, algae or mushrooms can be used as natural preservatives (Pisochi et al., 2018). Plant-derived natural antimicrobials are the most widely studied recently (Opanede et al., 2017). The antimicrobial features of plant-derived products is generally accompanied by confirmed antioxidant capacity (imparted by phenolic acid derivatives such as caffeic acid, flavonoids and flavone glycosides, coumarins, terpenoids, lignans, polysaccharides), that completes the pharmacological benefits of such extracts (Eddardaki et al., 2024; Kokoska et al., 2019; Vuong, 2021). Edible and herbal plants/spices such as oregano, cinnamon, clove, citral, garlic, coriander, parsley, rosemary, lemongrass, sage and vanillan, have been employed alone or combined with other preservation techniques (Gutierrez et al., 2008; Proestos et al., 2008). Ginger, red pepper, black pepper, cumin, chili powder and curry powder also exerted antimicrobial activity (Holley & Patel, 2005). Condiment sauces contain a variety of herbs and spices which could contribute to the antimicrobial capacity.

Thickener is another ingredient necessary for condiment sauces to modify the texture. Hydrocolloids are commonly used in food processing to create and modify texture and are irreplaceable in food formulation and texture design. They are primarily starch, non-starch polysaccharides, and gelatin. Gums are non-starch polysaccharides and widely used in Thai condiment sauces; xanthan gum and gellan gum as the examples (refers Table 1). Most gums used in the food industry are derived from plants or microbial sources. Depending upon the source, they are classified as plant exudate gum, seed gum, microbial gum, and marine gums. Xanthan and gellan gums are commercially produced via bacteria fermentation (Giavasis et al., 2000; Miranda et al., 2020) which may post concerns to some consumers. Exudate gums e.g. gum arabic and seed gums e.g. guar gum which are obtained naturally from plants (Thombre et al., 2016) may be more appropriate to use as clean label ingredients.

In addition, there is an on-going trend to reformulate condiment sauces with low levels of salt and sugar to ensure they are healthier without sacrificing any flavors. The increase in the usage of natural and nongenetically modified organism ingredients is driving the global market growth, inclining towards a healthier lifestyle. Various technological (salt replacement, food reformulation, size and structural modifications, alternative processing, and crossmodal odor interaction) and behavioral strategies (memory process, gradual salt reduction, and swap) were applied as salt reduction strategies (Nurmilah et al., 2022). Unrefined sugars or non-centrifugal sugars contain minerals, bioactive compounds, flavonoids and phenolic acids, which have therapeutic potentials (Zidan & Azlan, 2022), could be used to replace refined white sugar in clean label condiment sauces.

It should be noted that the application clean label approach in condiment sauces by reformulating using clean label ingredients could interfere with product sensory attributes. Research and development are required to reformulate new clean label products that compensate for the health and taste of the products.

5. Conclusions
The concept of clean label food is relatively new, without any legal definition. However, it holds significant importance and relevance in the market and industrial sectors. The feasibility of using a clean label approach to Thai style condiment sauces was examined as a case study. Four commercially available condiment sauces underwent quality and safety testing and were confirmed to be in compliance with the Thai requirement. Nevertheless, these products consist of numerous problematic components, including synthetic chemicals and preservatives. The presence of mycotoxins in the raw ingredients used in the sauces may also possess potential health risk. Regardless of their concerned ingredients, condiment sauces have the potential to be developed as a clean label product. Mycotoxin contamination and shelf-life of the clean label condiment sauces are the key important aspects that needed to be addressed. Effective post-harvest management of raw materials can reduce the prevalence of mycotoxins. Choosing natural ingredients that have antimicrobial properties can assist in extending the shelf-life. Notably that any clean label product that is developed requires thorough research and development in order to guarantee its quality, safety, and sensory satisfaction.

Acknowledgment

The authors would like to thank Pibulsongkram Rajabhat University (Thailand) and Suan Dusit University (Thailand) for providing necessary resources.

Ethical considerations

This study was authorized by the Pibulsongkram Rajabhat University’s Ethics Committee (Approval number: PSRU-EC 2023/027).

Conflict of Interest

The authors declare no conflicts of interest.

Funding

This research did not receive any financial support.

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