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RESEARCH ARTICLE
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Effects of Foaming Agents on the Properties of Foam-mat Dried Spicy Seasoning Powder from Chili Placenta

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ABSTRACT

The objective of this study was to develop a foam-mat spicy seasoning powder from chili placenta, a by-product of processed vegetables and fruits, to identify the appropriate type and amount of foaming agents to obtain a product with good physicochemical properties. Six foaming agents were evaluated: Methocel™, egg albumin, various ratios of Methocel™ and egg albumin, distilled monoglyceride, maltodextrin, and sodium chloride. The most effective formulation consisted of Methocel and egg albumin in a 2:1.5 ratio, supplemented with 1.5% distilled monoglyceride, 15% maltodextrin, and 5% sodium chloride. After drying at 70°C for 3 hours, the obtained product had a solubility of %86.23, a dispersibility of %0.236, a total phenolic content of 1.382mg gallic acid equivalents per gram (eq./g), a DPPH antioxidant activity of 261.18µg Trolox eq./g, and a capsaicin content of 3, 163.67SHU, which was at a moderate spiciness level. The product demonstrated a shelf life of at least two months and met microbiological safety standards, indicating its potential for development as a commercial seasoning derived from agricultural by-products.

Keywords: Capsaicin, Methocel™, Egg albumin, Maltodextrin, Foaming properties.

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INTRODUCTION

Chili pepper (*Capsicums* pp.) is one of the most significant economic crops of Thailand, and its special organoleptic qualities and health advantages have been known for centuries. (Olatunji and Afolayan, 2018; Cervantes-Hernández, 2019). Apart from their practical use in daily cookery, chili peppers can be utilized as raw materials in other industries, including the manufacturing of pharmaceuticals, cosmetics, and animal feed (Chakrabarty et al., 2017). They are known for their hotness, which increases appetite through a neurotransmitter chemical mechanism. Capsicum species are rich in phytochemicals, including capsaicinoids, capsinoids, carotenoids, flavonoids, vitamins, essential oils, and others. These phytochemicals give the plants their special characteristic flavor and smell and are beneficial for health (Loizzo et al., 2015; Aranha et al., 2017). Capsaicinoids consist of two main congeners, namely capsaicin and dihydrocapsaicin. The two main chemicals that are similar to capsinoids are capsiate and dihydrocapsiate (Huang et al., 2014). Capsaicin is an active substance responsible for their hotness and burning sensation. In addition, chili peppers contain other substances known as capsaicinoids with structural similarities to capsaicin derivatives, which give them a spicy flavor. The variety, cultivation area, growing conditions, and maturity all affect the content of capsaicinoids in chili peppers (Luo et al., 2011; Sun et al., 2016; Sun et al., 2023). The Scoville heat unit (SHU), the primary metric used to indicate the capsaicinoid content of chili peppers and regulate the quality of each chili variety sold in the global market, is used to determine the spiciness of chili peppers. The Scoville Scale or Scoville test was first developed in 1912 by Wilbur Scoville. There are five levels of spiciness classified using SHU: non spiciness (0–700 SHU; 0-4.4mg/100 g), mildly spiciness (700–3,000SHU; 4.4-18.8mg/100 g), moderately spiciness (3,000–25,000 SHU; 18.8-156.3mg/100 g), highly spiciness (25,000–70,000 SHU; 156.3-437.5mg/100 g) and very highly spiciness (>80,000 SHU; >500 mg/100 g) (Weiss, 2002; Magied et al., 2014; Ahmad et al., 2020). The SHU levels of chili placenta and seeds are usually higher than those of the pericarp because

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capsaicinoids are found in higher concentrations in the placenta and seeds, while the pericarp contains comparatively lower amounts (Khanema et al., 2024).

The chili pepper placenta is the internal white pith or central tissue of the chili pepper, which connects the seeds to the fruit's pericarp (the fleshy outer part). It is an important part of the chili because it contains a high concentration of capsaicinoids. As a result, the placenta gives chili peppers their hotness, not the pericarp or exocarp (Meckelmann et al., 2013). Besides contributing to the heat, the placenta also contains various bioactive compounds such as vitamins, antioxidants, and other phytochemicals that provide health benefits (Cervantes-Hernández 2019; Tanaka et al., 2021). In the chilled and frozen minimally processed chili industry in Thailand, the red chili fruits are sliced and separated, and the core and seeds, or the placenta, are discarded. The placenta from chilies is regarded as a waste that may be utilized as a valuable raw material in several industries in the future.

Several previous studies have been carried out on chili drying, with some focusing on drying the whole fruit (Yap et al., 2022; Krzykowski et al., 2024) and others only on the seeds (Sun et al., 2024). The methods employed include hot air drying and freeze-drying (Materska, 2014; Yap et al., 2022). However, there are no previous studies or publications have specifically investigated the drying process of chili placenta. This research focuses on the utilization of chili residues (placenta), which reduces processing waste and promotes efficient use of resources. The use of the foam-mat drying technique is a method that converts liquid into foam before drying. This technique has several advantages, such as reducing drying time, maintaining the quality of bioactive substances, and enabling the final product to have properties suitable for use as a dietary supplement or health food. Using the foam-mat drying process increases the surface area for heat and mass transfer by converting liquids or viscous materials into foam, which accelerates drying. The characteristics of the foam, which has a higher surface area than general liquids, allow for efficient heat transfer and moisture evaporation, resulting in a reduction in drying time and energy consumption compared to spray drying and freeze drying methods (Khatri et al., 2024; Qadri et al., 2020). It also uses lower temperatures than spray drying, so it can reduce the loss of nutrients and flavors (Buljat et al., 2019). The dried product obtained from foam-mat drying is a foam with a high porosity structure, which is water-soluble, suitable for high-viscosity liquids such as concentrated juice or mixed milk products, which may not be suitable for other drying methods (Dehghannya et al., 2018; Franco et al., 2016; Shameena Beegum et al., 2022).

Foam mat-dried food powder is a high-quality product that can be created by selecting the proper forming process, forming agent, forming stabilizer, foaming time, drying method, and temperature (Salahi et al., 2015; Hardy and Jideani, 2017). Foaming agents added to the food are responsible for foaming and keeping the foam from collapsing for a longer period. The most common foaming agents utilized in the foam-mat drying process include Methocel™, egg albumin, glyceryl monostearate, maltodextrin, soy protein isolate, sodium caseinate, methylcellulose, distilled monoglyceride, and sodium chloride (Sangamithra et al., 2015; Chandrasekar et al., 2015; Ng and Sulaiman, 2018). Drying conditions and foam stability impact the quality of the final product, as foam collapse during drying can reduce the moisture evaporation rate and affect the quality of the resulting product. The factors affecting foam-mat drying include the type and quantity of the foaming agent, the concentration of liquid food, the foaming method and time, the thickness of the foam layer before drying, and the foam drying conditions (Franco et al., 2017).

The objective of this study is to develop a high-quality seasoning powder that imparts spiciness to food by utilizing chili placenta derived from chilled and frozen minimally processed waste generated by the industries. This study investigates the effects of various foaming agents, namely Methocel™, egg albumin, distilled monoglyceride, maltodextrin, and sodium chloride in different formulations on the physicochemical properties and overall quality of the foam-mat dried spicy seasoning powder produced from chili placenta.

MATERIALS & METHODS

Preparation of the Placenta of Chili Pepper and Forming Agent

The chili pepper placenta (*Capsicum* spp.), a by-product from the trimming process of a chilled fresh-cut processing plant for chili peppers in Pathum Thani Province, Thailand, was placed in plastic bags weighing 5 kg each, sealed, and packaged in foam boxes covered with ice to maintain a temperature at approximately 7 to 10°C. The chili pepper placenta is shown in Fig. 1. Methocel™, egg albumin, distilled monoglyceride, maltodextrin, and sodium chloride were purchased from Krungthepchemi Co., Ltd. (Bangkok, Thailand).

Fig. 1: The chili pepper placenta, a by-product from the trimming process of a chilled fresh-cut processing.

The Types and Concentrations of Foaming Agents Suitable on the Foam Properties

To develop a stable chili placenta foam, four experiments were conducted to study the effects of various additives on foam properties. The same base procedure was applied in all experiments. The filtrate obtained from 1kg of chili pepper placenta, homogenized with water at a 1:1ratio, was used. A 100g portion of the filtrate was mixed with selected additives and whipped into foam using a stand mixer (KitchenAid, Model K5SS, St. Joseph, MI, USA) equipped with a whisk attachment at the highest speed for 10min. Foam characteristics, including foam density)Bag et al., (2011, foam stability (Ng and Sulaiman, (2018, and foam overrun (Inchuen and Duangkhamchan, 2021) were then evaluated. The experimental design for foaming agent optimization at each step is shown in Table 1. Each experiment used the optimal result from the previous step to build upon the formulation of the foam.

Physical Properties of Foam-mat Dried Chili Placenta Powder

The chili placenta foam obtained from Step 2.2 was placed in a cotton bag that had a metal head with a circular opening that was 5mm in diameter. The chili placenta foam was squeezed onto a stainless-steel tray and dried at 70°C for 3 hours in a hot air oven or until the mixture was completely dry and its final moisture content did not exceed 6%. Following a cool-down, the samples were ground and sieved through a standard 100-mesh sieve using a sieve shaker (Retsch ASTM, Model AS 200, Germany). The ground samples were vacuum-sealed after being placed in plastic bags. The chili placenta powder was measured for water activity (a_w) using a water activity meter (Aqualab model 4TE), andmoisture content was determined following the AOAC methods (AOAC, 2019). The color values using a colorimeter (Hunter Lab model AMT 501, USA). The color values were reported in Commission Internationale de l'Éclairage (CIE) chromaticity coordinates, lightness (L∗), redness (a∗), and yellowness (b∗), solubility, and dispersibility were analyzed according to Koç, et al. (2014). The total phenolic content was analyzed following the method of Ti et al. (2014) and Qi et al. (2019) using the Folin-Ciocalteau method. Gallic acid was used as the standard, and the results were expressed as mg of gallic acid equivalents/100g of the dry sample weight. DPPH free radical scavenging activity was analyzed according to Zhang et al. (2014). and capsaicin content using a chili-heat detector (Capsella, Model CA-300). The analysis was reported in Scoville Heat Units (SHU).

Microbiological Properties of Foam-mat Dried Spicy Seasoning Powder from Chili Placenta during 2 Months

The samples of foam-mat dried spicy powder made from chili placenta were placed in aluminum foil bags and stored at 27±2°C. The microbiological properties of the samples, including total plate count and yeast and mold counts, were analyzed according to Food and Drug Administration's Bacteriological Analytical Manual; BAM method) (Maturin and Peeler, 2001) at 2-week intervals for 2 months (weeks 0, 2, 4, 6, and 8).

Statistical Analysis

The data obtained in this study were expressed as mean±SD and statistically analyzed using analysis of variance (One-way ANOVA) by the SPSS statistical program version 18. The differences between the means were determined by the Duncan Multiple Range Test (DMRT) at a level of P≤0.05.

RESULTS & DISCUSSION

Methocel™, egg Albumin, and Methocel™+egg Albumin on the Physical Properties of Chili Placenta Foam

The study indicated that the foaming properties of chili placenta foam produced using three foaming agents, namely Methocel™, egg albumin, and Methocel™+egg albumin, in terms of foam density, foam overrun, and foam stability, were significantly different (P≤0.05) (Table 2).

However, stability, which is one of the crucial physical properties of foam, was non-measurable at all levels of Methocel™ and egg albumin, as the results indicate Methocel™ and egg albumin could not produce stable foams. The highest foam density was observed in the foam produced using Methocel™+egg albumin in a 1.5:1.5 ratio, followed by the foams produced using Methocel™+egg albumin in 1.5:3, 2:1.5, and 2:4.5 ratios. There was a significant difference in the foam density of the chili placenta between different types and concentrations of foaming agents. The increase in the foaming agent concentration caused a decrease in the foam. The foam density decreased as a result of the foam volume expanding. According to Ratti and Kudra (2006), foamed materials typically have a foam density of 0.3 to 0.6g/cm^3, which is lower than that of non-foam materials and Ng and Sulaiman (2018) reported that the increase in the types and concentrations of foaming agent caused a decrease in the foam density of beetroot samples. The restriction of the

Table 1: Experimental design for foaming agent optimization

Step	Foaming agent	Concentration Levels and method
2.2.1	Methocel™, egg albumin, Methocel™ + egg albumin	- Methocel™ (1.0, 1.5, 2.0%), Egg albumin (1.5, 3.0, 4.5%) and Methocel™ + egg albumin (1:1.5, 1:3, 1:4.5, 1.5:1.5, 1.5:3, 1.5:4.5, 2:1.5, 2:3, and 2:4.5) - Whip for 10min, at the highest speed. - Analyze: Foam density, Foam overrun, Foam stability - Select optimal foaming agent for next step
2.2.2	Distilled monoglyceride	- Mix optimal foaming agent + distilled monoglyceride 0.5, 1.0, 1.5, 2.0% (w/w) - Whip for 10min (same method) - Analyze: Foam density, Foam overrun, Foam stability - Select optimal distilled monoglyceride level for next step
2.2.3	Maltodextrin	- Mix optimal foaming agent + monoglyceride + maltodextrin 5, 10, 15, 20% (w/w) - Whip for 10min (same method) - Analyze: Foam density, Foam overrun, Foam stability - Select optimal maltodextrin level for next step
2.2.4	Sodium chloride	- Mix optimal foaming agent + previous additives + sodium chloride 1, 3, 5% (w/w) - Whip for 10min (same method) - Analyze: Foam density, Foam overrun, Foam stability - Select optimal sodium chloride level - the all-optimum quantity of foaming agent was chosen to next process in step 2.3

Table 2: Effects of methocel™ and egg albumin on foam density, foam overrun, and foam stability of chili placenta foam

Foaming Agent	Concentration (%)	Foaming Properties		
		Form density (g/cm³)	Foam overrun (%)	Form stability (%)
	1	0.295±0.09[b]	259.317±5.11[a]	Non-measurable
Methocel™	1.5	0.320±0.01[a]	232.100±4.77[b]	Non-measurable
	2	0.312±0.07[a]	212.833±7.73[c]	Non-measurable
Egg albumin	1.5	0.116±0.02[a]	757.657±8.96[c]	Non-measurable
	3	0.096±0.01[b]	930.383±9.77[b]	Non-measurable
	4.5	0.079±0.02[c]	1,156.277±2.02[a]	Non-measurable
	1:1.5	0.322±0.06[e]	194.890±7.73[b]	52.67±0.01[a]
	1:3	0.313±0.02[e]	196.640±8.21[b]	64.05±0.01[b]
	1:4.5	0.273±0.08[f]	247.515±6.85[a]	69.22±0.01[b]
	1.5:1.5	0.546±0.07[a]	73.165±6.47[ef]	50.81±0.01[a]
Methocel™ + egg albumin	1.5:3	0.498±0.02[b]	84.795±4.25[def]	65.54±0.03[b]
	1.5:4.5	0.457±0.04[c]	103.420±7.50[d]	64.01±0.02[b]
	2:1.5	0.486±0.06[b]	93.020±4.58[de]	84.04±0.04[c]
	2:3	0.372±0.02[d]	146.450±3.50[c]	80.75±0.01[c]
	2:4.5	0.487±0.04[b]	70.540±9.82[f]	85.22±0.01[c]

Values (mean+SD) with different letters in the same column are significantly (P≤0.05) different.

foaming agent's passage from the aqueous phase to the air-aqueous interface was the reason for the high foam density at low foaming agent concentrations. Because foam has a huge surface area for drying air, its low density can help accelerate the process of water removal during drying (Kumar et al., 2023). In terms of foam overrun, the highest foam overrun was observed in the foam produced using Methocel™+egg albumin in a 1:4.5 ratio, followed by the foams produced using Methocel™+egg albumin in 1:1.5 and 1:13 ratios. The foams with the lowest foam overrun were obtained when Methocel™+egg albumin (at concentrations of 1.5:1.5, 1.5:3, and 2:4.5) was used as a foaming agent. The characteristics of foam density, foam stability, and foam overrun are important to the drying process of foam mat and significantly impact the quality of the dried powder. A low-density foamed material indicates the presence of more air contained in the foam, supporting greater removal of water during the heating process. Foam density and foam overrun have an inverse relationship and a measure of foam-generating efficiency (Inchuen and Duangkhamchan, 2021). For foam mat drying, high-quality foam is defined as having a minimum density, a maximum foam overrun, and maximum foam stability or a drainage rate. Foam stability reflects the rate of drainage. Foam material with a high rate of drainage or large drainage volume is unstable because it is unable to maintain the open pore structure throughout the dry process (Eadmusik et al., 2024). Foam stability, Methocel™ and egg albumin (foaming agent) showed non-measurable foam stability, while Methocel™+egg albumin showed higher foam stability and increasing the concentrations of foaming agents can enhance foam stability. There were numerous little air bubbles on the surface of the chili placenta foam when it was beaten. This is because a higher protein concentration in egg albumin causes the film thickness at the interface, which aids in coating and stabilizing the air bubbles. The formation of porous bubbles can increase the surface area exposed to air, which will accelerate the drying process. The creation of form will be influenced by temperature and the amount of lipids, salt, acid, and sugar in the food matrix (Shahidi and Pan, 2022). However, chili placenta foam containing Methocel™+egg albumin was more stable than chili placenta foam with Methocel™ and egg albumin.

The resulting foams must have an optimum foam density, foam overrun and foam stability, considering the foam overrun and foam stability. Therefore, based on the results obtained, among the various foaming agents used for this experiment, Methocel™+egg albumin in a 2:1.5 ratio was chosen as the foaming agent that meets the optimum foam density, foam overrun, and foam stability requirements. This foaming agent was then used to determine the optimum quantity of distilled monoglyceride in the subsequent experiment.

Distilled Monoglyceride on the Physical Properties of Chili Placenta Foam

The study on various levels of distilled monoglyceride (0.5, 1.0, 1.5 and 2.0%) found that using distilled monoglyceride in combination with 2:1.5 Methocel™+egg albumin as foaming agents had an effect on the foam density, foam stability, and foam overrun of chili placenta foam (P≤0.05) (Fig. 2). The foams produced using 0.5, 1, and 2% distilled monoglyceride showed the highest foam density, followed by the foam produced using 1.5% distilled monoglyceride, which showed the lowest foam density. Meanwhile, when 1.5% distilled monoglyceride was used, the foam showed the highest stability, followed by the foam produced using 1 and 2% distilled monoglyceride, while 0.5% demonstrated the lowest foam stability. However, using 1.5% distilled monoglyceride resulted in the highest foam overrun and stability. After drying for 3 hours at 70°C using a hot air oven, the foam showed no collapse compared to the foam with high foam overrun. Therefore, 1.5% distilled monoglyceride was chosen for the determination of the optimum quantity of maltodextrin in the subsequent experiment.

Maltodextrin on the Physical Properties of Chili Placenta Foam

The study on various levels of maltodextrin (5, 10, 15, and 20%) in combination with 2:1.5 Methocel™+egg albumin and 1.5% distilled monoglyceride showed that all four levels of maltodextrin influenced the foam density, foam stability, and foam overrun (P≤0.05) (Fig. 3). The foam produced using 20% maltodextrin showed the highest foam density and stability, but the density was not different using 15%. When considering the highest foam density and

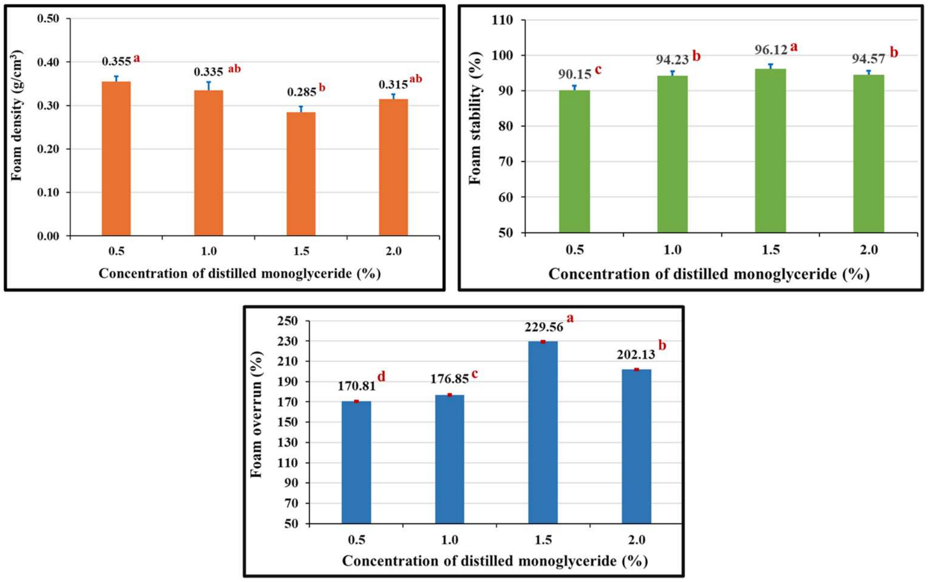

Fig. 2: Effects of distilled monoglyceride on foam density, foam overrun, and foam stability of chili placenta foam. Bar sharing different letters are significantly (P≤0.05).

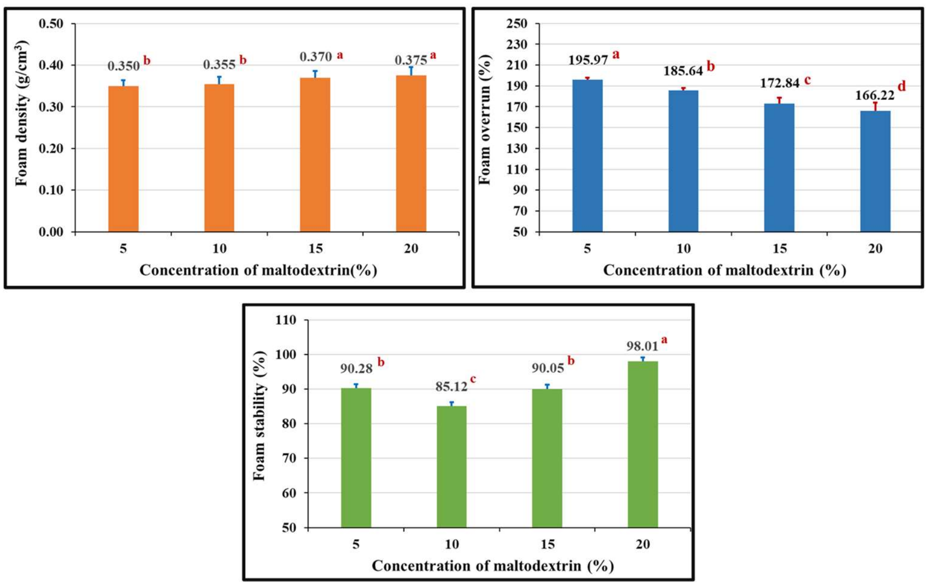

Fig. 3: Effects of maltodextrin on foam density, foam overrun and form stability of chili placenta foam. Bar sharing different letters are significantly (P≤0.05).

foam stability, although the lowest foam overrun, the foam obtained was dense and stable. Therefore, the amount of maltodextrin of 15 % was chosen for the determination of the optimum quantity of sodium chloride in the subsequent experiment.

Sodium Chloride, Maltodextrin, Distilled Monoglyceride on the Physical Properties of Chili Placenta Foam

The study on different amounts of sodium chloride (1, 3, and 5%) mixed with 2:1.5 Methocel^{TM}+egg albumin, 1.5% distilled monoglyceride, and 15% maltodextrin found that all three levels of sodium chloride influenced the foam density and foam overrun (P≤0.05) but did not affect the foam stability (P>0.05) (Fig. 4). The foam produced using 5% sodium chloride showed the highest foam overrun and stability. However, the foam had low density. Therefore, a combination of 5% sodium chloride, 2:1.5 Methocel^{TM}+egg albumin, 1.5% distilled monoglyceride, and 15% maltodextrin was suitable for producing foam-mat dried spicy powder made from chili placenta.

The experimental results indicated that a combination of two or more foaming agents provided better results compared to a single foaming agent due to the synergistic effect of the two foaming agents. Methocel™ is a gum that has excellent binding properties, which improve emulsion stability. It also exhibits excellent gelling properties and can function as a surfactant, giving food a film-like consistency. Additionally, after drying, Methocel™ provides structural support to the foam, preventing the bubbles from collapsing. The dried foam has a porous structure, enabling faster permeation and dissolution. MethocelTM is therefore an ideal foam stabilizer for the foam-mat drying of foods. Meanwhile, when egg albumin is used as one of the foaming agents, it reduces the surface tension due to migration of foaming agents from the liquid phase to the continuous liquid-air interface, thus increasing the foaming ability and decreasing the foam density. Due to the strong relationship between solubility and foaming, foams with high egg albumin show better water solubility (Razi et al., 2023). A study by Ng and Sulaiman (2018) found that the

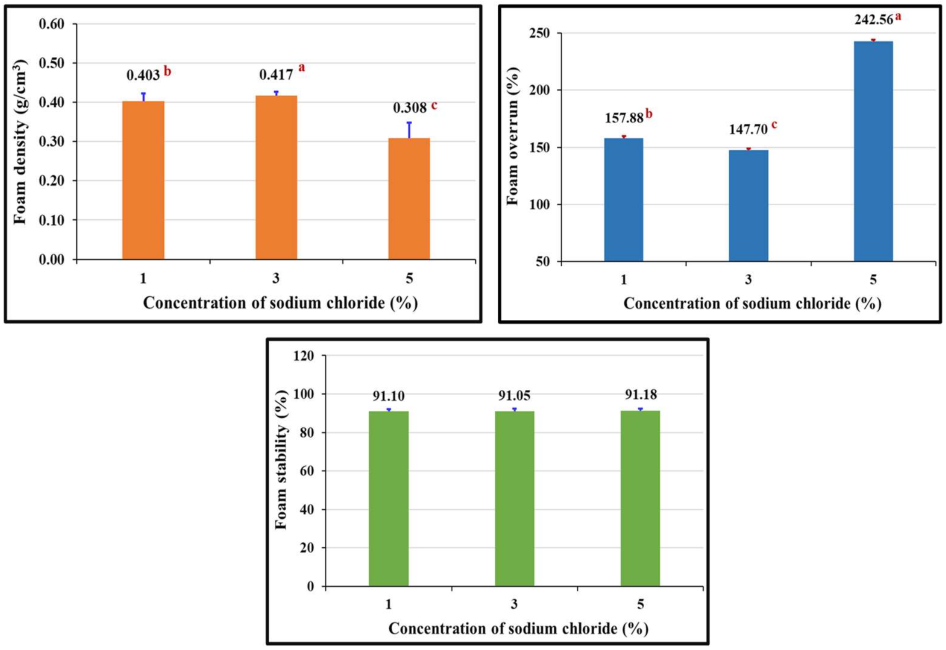

Fig. 4: Effects of sodium chloride on foam density, foam overrun, and foam stability of chili placenta foam. Bar sharing different letters are significantly (P≤0.05).

beetroot powder produced using 10g of egg albumin/100 g of beetroot exhibited a lower recovery rate compared to the beetroot powder produced using 5g of egg albumin/100g of beetroot. However, due to the tiny particle size and low density of the final product after foam-mat drying, it floats on the liquid surface; each foaming agent must therefore be utilized in the right amount. Because the particles are very small and have no spaces between them, there is little to no water permeation among them. This condition contributes to uneven wetting and agglomeration of particles. The particles lose their dispersion qualities and dissolve slowly because their outer surface is wet while their inner core is not. Ezekiel et al. (2024) reported that glyceryl monostearate and egg albumin made the foam density of cowpea paste lower. Additionally, the foam with the most air mixed in and the lowest density was created using a mix of 3% sodium chloride and other foaming agents. However, it became less stable over time. This decline may be due to the reaction between sodium chloride and protein, since it produces a denser gel by increasing binding between gel and water molecules, decreasing the attraction between protein molecules, and deviating the pH value from the protein's isoelectric point (pI). According to Lee and Duggan (2022), the sample's foam overrun increased as its salt level increased. This increase is due to the fact that the protein charges may interact with the salt's positive and negative charges. This process facilitates adsorption at the air-water interface and stabilizes the foam by lowering the electrostatic repulsion in the protein molecules' adsorption and non-adsorption regions.

Physicochemical Properties of Foam-mat Dried Spicy Seasoning Powder

The physicochemical properties of the spicy seasoning powder product produced using a combination of 2:1.5 Methocel™+egg albumin, 1.5% distilled monoglyceride, 15% maltodextrin, and 5% sodium chloride (Table 3), the resulting foam-mat dried spicy powder was a white-yellow crystalline flake with a slight reddish hue (Fig. 5). They had a moisture content of 2.986%, a water activity of 0.244, a capsaicin content of 3163.670 SHU, classified as a hot spicy powder (3,000-25,000 SHU), a solubility of 86.233%, a dispersibility of 0.236%, a total phenolic content of 1.382 mg gallic acid eq./g, and a DPPH free radical scavenging activity of 261.175µg Trolox/g.

Table 3: Physicochemical properties of foam-mat dried spicy seasoning powder

Physicochemical Properties		Quantity
Color measurements	Lightness (L*)	64.633±0.90
	Redness (a*)	15.450±5.54
	Yellowness (b*)	38.837±0.80
Water activity (a_w)		0.244±0.01
Moisture content (%)		2.986±0.88
Solubility (%)		86.233±0.86
Dispersibility (%)		0.236±0.01
Total phenolic content (mg gallic acid eq./g)		1.382±0.08
DPPH free radical scavenging activity (µg Trolox/g)		261.175±1.03
Capsaicin content (SHU)		3,163.67±5.45

Note: Mean±SD (n=3).

Fig. 5: The foam-mat dried spicy seasoning powder from chili placenta using a combination of 2:1.5 Methocel™ and egg albumin, 1.5% distilled monoglyceride, 15% maltodextrin, and 5% sodium chloride, and drying it at 70°C for 3 hours; **(A):** Foam-mat dried spicy seasoning powder (before fine grinding); **(B)**: Foam-mat dried spicy seasoning powder (after fine grinding).

The resulting foam-mat dried spicy powder was a white-yellow crystalline flake with a slight reddish hue derived from the red chili placenta paste. The foam-mat dried food powder should have a solid-like glassy state, or the resulting powder should be hard and brittle like glass. Because of the restricted mobility of components, the physical, chemical, and microbiological properties of dried foods in a glassy state are usually extremely stable. In order to maintain the glassy state during prolonged storage, powder products should be kept at a temperature below their glass transition temperature (Tg). The glass transition temperature (Tg) of dried food depends on its composition, moisture content, or water activity (Joardder et al., 2024). With a moisture content of 2.986% and a water activity (a_w) of 0.244, the spicy powder in this study is classified as a low moisture food powder that can be kept in its glassy state. The low moisture content of spicy powder may be due to the use of a combination of maltodextrin and other foaming agents. Maltodextrin has a low monosaccharide content, which facilitates moisture absorption and reduces agglomeration (Xiao et al., 2022). In addition, maltodextrin increases the solubility and density of the product. It also acts as a bulking agent, resulting in an increase in solid content and viscosity. The particles become bigger and heavier after drying, which raises the density (Nadali et al., 2022), as density and solubility are strongly associated. During the dissolution of maltodextrin in water, wetting and gradual dispersion of the powder occur without agglomeration. The drying time of foam is therefore improved by using maltodextrin as a foaming agent. The resulting powder product in this study had a low moisture content. The particles of the powder product showed excellent solubility due to their rapid absorption of water. However, the total solubility is affected by chemical composition, size, shape, particle density, and physical state, such as temperature, dispersion of powder product in water, and adhesion of the food powder. Agglomeration of food powder reduces its solubility (Juarez-Enriquez et al., 202.(2

In addition to moisture content, water activity also affects food stability. The water activity (a_w) of dried food below 0.60 water activity will not have microbial proliferation (Rifna et al., 2022). In this study, the spicy power from chili placenta had a water activity (a_w) of 0.244. And moisture content 2.986%. could help to enhance its shelf life. Agglomeration, stickiness, caking, and crystallization changes that can occur in amorphous food, potentially caused by the system's water activity at the glass transition temperature. Water activity in food powder production should be kept relatively low in comparison to traditional dried fruits and vegetables to ensure product stability during storage (Alp and Bulantekin, 2021) and water activity is a significant indicator of the deterioration of food products. The chemical reaction rate is slower, and the microbial stability is relatively high when the water activity is less than 0.6 and the humidity is less than 10%. Thus, the deterioration occurring under this condition is the result of chemical reactions rather than microbial reactions (Aganovic et al., 2021). The capsaicin content is 3163.670 SHU; this chili placenta-based spiciness is classified using Scoville heat units (SHU) as a spicy seasoning powder with a moderate spiciness (3,000–25,000 SHU). In three species (C. *annuum*, C. *baccatum*, C. *chinense*), C. *chinense* had the maximum amount of 1411.6mg/100g. C. *annuum* had a pungency level of 809.0mg/100g, while C. *baccatum* was the least pungent of the three species, with a value of 711.7mg/100g. based on the value equivalent to ca. 250,000 Scoville heat units (SHU) (Meckelmann et al., 2013).

In addition, it showed a total phenolic content of 1.382mg gallic acid eq./g and a DPPH free radical scavenging activity of 261.175µg Trolox eq./g. The antioxidants found in this seasoning powder provide users with additional benefits beyond its spiciness and burning sensation. A study by Meckelmann et al. (2013) found that C. *chinense* had the most total polyphenols at 3.69g gallic acid eq./100g and a Trolox equivalent antioxidant capacity (TEAC) value of 9.2mmol Trolox/100g, while three species (C. *annuum*, C. *baccatum*, C. *chinense*) had total polyphenols of 1.5 and 2.0g gallic acid eq./100g and 3.0 and 5.0mmol Trolox/100 g for TEAC value. According to Hervert-Hernández et al. (2010), dried hot pepper (C. *annuum*) contained total phenolic content of 0.97−1.4g gallic acid eq./100g and 1.9−3.6mmol Trolox/100g.

Microbiological Properties of Foam-mat Dried Spicy Seasoning Powder from Chili Placenta during 2 Months of Storage

The microbiological properties of the foam-mat dried spicy seasoning powder from chili placenta over 2 months of storage showed that the total plate count in the spicy seasoning powder did not exceed $1x10^4$ CFU/g, while its yeast and mold count were not detectable.

After being stored for two months, the microbiological tests on the foam-mat dried spicy seasoning powder revealed that the total plate count and yeast and mold counts were in agreement with the Thai Agricultural Standard requirements for ground chilies (TAS 3004-2560), Thailand (TAS, 2017). According to this standard, the acceptable aerobic plate count for chili powder samples made from drying and grinding chili peppers is $5x10^5$ CFU/g, the unacceptable aerobic plate count is $5x10^6$ CFU/g, the acceptable yeast and mold count is $1x10^2$ CFU/g and the unacceptable yeast and mold count is $1x10^3$ CFU/g. In addition, the Thai Community Product Standards for chili powder (ICS 492/2547) (ICS, 2004) stipulate that the total microbial count of chili powder must not exceed $4x10^5$ CFU/g, the *Clostridium perfringens* count must not be detected in 0.01g of sample, the most probable number of coliform organisms (MPN) must be less than 3 CFU/g, and the fungi count must not exceed 100 CFU/g. Therefore, it can be concluded that the foam-mat dried spicy powder product made from chili placenta has a microbiological quality that satisfies regulatory standards and is safe for customers. However, the product from this study has a bitter taste with a spicy flavor, hence, it is necessary to add additional seasoning to make the taste more palatable. Additionally, the product's spiciness is inconsistent, which necessitates controlling the production process by adjusting the ratio of water to chili core and limiting the selection to only 1-2 types of the most effective foaming agents. The results of this research show that the spicy seasoning powder developed from this study has the potential to be scaled up as a commercial product. The chili placenta, as a zero-cost raw material, is abundantly available as an agricultural waste from current food production processes and falls under the category of upcycling or upcycled food. In addition, the product can be used in the food industry where natural spicy ingredients are required, such as in the processing of chili sauce, snacks, and healthy food seasonings (fat-burning). It can also be used with various types of light-colored foods without altering their color, but further studies are required to determine its viability.

Conclusion

The study on the type and concentration of foaming agents suitable for producing foam-mat dried spicy powder showed that a combination of 2:1.5 Methocel™ +egg albumin, 1.5% of distilled monoglyceride, 15% of maltodextrin, and 5% of sodium chloride was suitable for producing spicy powder made from chili placenta. After drying for 3 hours at 70°C, the spicy seasoning powder product has a moisture content of 2.986% and water activity (a_w) of 0.244. The product had a solubility of 86.23%, a dispersibility of 0.236%, a total phenolic content of 1.382 mg gallic acid eq./g, a DPPH free radical scavenging activity of 261.175µg Trolox eq./g, and a capsaicin content of 3,163.67 SHU. Therefore, this chili placenta-based spiciness is classified using Scoville heat units as a spicy seasoning powder with a moderate spiciness (3,000-25,000 SHU). After 2 months of storage, the total plate count was less than $1x10^4$ CFU/g, and yeast or mold was not found. Therefore, this foam-mat dried spicy seasoning powder product made from chili placenta has a microbial quality that satisfies regulatory standards and is safe for customers.

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Author's Contribution: Unchalin Singkhum: Conceptualization of study, conducted the study, compilation of data, supervision of research work, wrote the original draft, collected and analyzed data, reviewed and edited the manuscript. Nawaporn Lapsongphon: performed the statistical analysis and co-supervision of research work and guidance.

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