Food Research 8 (3) : 163 - 171 (June 2024)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

RESEARCH PAPER

Production of foam-mat dried chili shrimp paste and its properties

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Article history:
Received: 2 May 2022
Received in revised form: 25 July 2022
Accepted: 5 April 2023
Available Online: 21 May 2024

Keywords:
Egg white,
Condiment,
Traditional food,
Preservation

DOI:
https://doi.org/10.26656/fr.2017.8(3).249

Abstract

Chili shrimp paste (CSP) powder was developed by foam mat drying technique using egg albumen (100 g) as a foaming agent and carboxymethylcellulose (CMC) as a stabilizing agent. Suitable CSP (30, 40, 50 and 60 g) and CMC (0.25, 0.50 and 0.75 g) levels for foam mat dried-CSP (FM-CSP) production were selected based on physicochemical and sensorial properties. Physicochemical properties included CSP-foam (foam density, rate of drainage and overrun) and FM-CSP (rendement, moisture content, water activity, pH value, browning index; BI, water solubility index; WSI and hygroscopicity) properties. Sensorial properties included color, smell, appearance, texture, taste and overall likings of reconstituted FM-CSP. An increase in CSP level elevated physicochemical parameters excluding overrun, pH value and WSI. An increase in CMC level improved CSP-foam properties by reducing foam density and rate of drainage and enhancing overrun. Although an increase in CMC level did not affect rendement and pH value, it decreased moisture content, water activity and hygroscopicity. Results showed that 50 g-CSP and 0.75 g-CMC were suitable for FM-CSP production, providing FM-CSP with sensorial liking scores ranging from 6.74-7.63 (moderately like). This study demonstrated the possibility of dried CSP production using the foam mat drying technique with the aid of foaming and stabilizing agents.

1. Introduction

Chili shrimp paste (CSP) is a favorite spicy condiment in many Southeast Asian countries especially in Thailand, Malaysia and Singapore (Nadia Sarina *et al.*, 2010). It is known as "nam pherik kapi" in Thailand, "sambal belacan" in Malaysia and "sambal terasi" in Indonesia. CSP is typically made by pounding raw chili with either toasted- or untoasted-fermented shrimp paste then adding sugar, salt and organic acids. It is traditionally consumed uncooked as a side dish with meals or vegetables (Sobhi *et al.*, 2012). CSP is perishable due to its non-thermal process. Its shelf life is less than three days when kept in a refrigerator (Passmore, 1991). Some research works have been done to prolong the CSP shelf life such as a thermal treatment (Sobhi *et al.*, 2012; Cheok *et al.*, 2017), an irradiation treatment (Cheok *et al.*, 2017) including an addition of a microbial reduction agent (Nadia Sarina *et al.*, 2010).

Drying is a process commonly used for shelf life extension by the lowering of water content, leading to a significant effect on microbial activities and physicochemical modification. In the food industry, various drying methods such as spray drying, freeze drying, drum drying and foam mat drying have been used (Aslan and Ertaş, 2021). Foam mat drying has recently gained interest because it is a simple, economical and efficient technique. In the foam mat drying process, a liquid or semi-liquid raw material is converted into a stable foam and hot air dried resulting in a dried powder (Franco *et al.*, 2016; Lobo *et al.*, 2020). The advantages of this drying method are the lower drying temperature and shorter drying time caused by the foam porosity resulting in a greater surface area exposed to air, permitting a higher drying rate. It is also compatible to apply on components with heat-sensitive, viscous and high sugar-content foods that cannot be dried when using other forms of drying methods (Noordia *et al.*, 2020). Foam mat dried material is almost similar to the fresh sample in color, flavor and taste (Kandasamy *et al.*, 2019).

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eISSN: 2550-2166
Published by Rynnye Lyan Resources

Foam characteristics are concluded in terms of foaming ability (foam expansion) and foam stability (Azizpour *et al.*, 2017), there are several factors affecting foam characteristics such as whipping time and whipping temperature, type and amount of foaming agent and foam stabilizing agent used. The addition of foaming and stabilizing agents provides foam stability by reducing the surface tension interfaces and foaming the liquid and semi-liquid (Qadri *et al.*, 2020). Egg white so-called egg albumen is widely used as a foaming agent because it contains globulins which are the most surface-active egg white protein for foaming ability (Lau and Dickinson, 2004). Carboxymethylcellulose (CMC), is a hydrocolloid gum used as foam stabilizing agent. It increases the interfacial viscoelasticity of foam lamellae, subsequently increase the stability of foam (Dickinson, 2015). The applications of egg albumen, CMC and their combination for foam mat drying have been previously studied in various foam mat dried foods such as brown rice porridge (Inchuen and Duangkhamchan, 2021), yogurt (Yüksel, 2021), *Nigella sativa* beverage (Affandi *et al*., 2017) and shrimp puree (Azizpour *et al.*, 2017) especially in foam mat dried fruit such as blueberry pulp (Gao *et al.*, 2022), tomato (Hossain *et al*., 2021), guava pulp (Maciel *et al*., 2020) and sour cherry (Abbasi and Azizpour, 2016). However, no research has been attempted to develop CSP powder using the foam mat drying technique. Therefore, this present study aims to produce foam mat-dried CSP (FM-CSP) and to investigate the effect of different CSP and CMC levels on the CSP foam and FM-CSP properties.

2. Materials and methods

2.1 Preparation of chili shrimp paste

Ingredients used for CSP production included shrimp paste, birds' eye chili, garlic, lime, water and table sugar. Shrimp paste, a semi-solid paste obtained from naturally fermenting krill and salt for about 2 months, was supported by Khun Khoei Co., Ltd. (Thailand). Other fresh ingredients were purchased from a local market (Prachinburi, Thailand). The stems of birds' eye chili were discarded before washing. CSP was prepared by mixing shrimp paste (70 g), birds' eye chili (4 g), peeled garlic cloves (10 g), lime juice (65 g), boiled water (10 g) and sugar (40 g) together using a laboratory blender (Waring blender 7011HS, USA.) at 18,000 rpm (speed setting 2) for 3 mins. Moisture content, water activity and pH value of the obtained CSP were 82.05±0.38%, 0.89±0.02 and 4.50±0.02, respectively. CSP was freshly prepared prior to each set of experiments.

2.2 Foam-mat drying of chili shrimp paste

FM-CSP was prepared by mixing fresh egg albumen (100 g), CSP (30, 40, 50 and 60 g) and CMC (0, 0.25, 0.50 and 0.75 g) using a food mixer (KitchenAid Model K-5, USA) with a wire whisk at 265 rpm (speed setting 10) for 2 mins. The foam 2 mm thickened was spread on a flat aluminium tray (25 cm × 25 cm) and hot air dried following the conditions obtained from the preliminary study at 65°C for 4 hrs. The dried product was scratched, ground using a laboratory blender (Waring blender 7011HS, USA.) at 14,000 rpm (speed setting 1) for 15 secs and vacuum packed in an aluminum foil bag. FM-CSP was reconstituted in warm water (60°C) in the ratio of 1:1 (w/v) prior to the determination of color, pH value and sensorial acceptability.

2.3 Determination of chili shrimp paste foam properties

2.3.1 Foam density

CSP foam was gently poured into a 100-mL graduated cylinder without destroying the foam structure. Foam density (g/mL) was calculated as a mass (g) per volume of foam (mL) using equation 1 (Shaari *et al*., 2018)

$$\text{Foam density} = \frac{\text{mass of foam (g)}}{\text{volume of foam (mL)}} \quad (1)$$

2.3.2 Foam stability

Foam stability was estimated from the rate of drainage. The rate of foam drainage was measured by pouring CSP foam (50 g) into a funnel (80 mm diameter) and was placed on a 50-mL graduated cylinder. The volume of liquid naturally drained from the CSP foam structure during 60 mins was recorded. The rate of drainage (mL/min) was calculated by dividing the volume of drainage (mL) by time (60 mins) using Equation 2 (Azizpour *et al*., 2017). A higher rate of drainage implies a lower foam stability.

$$\text{Rate of drainage} = \frac{\text{Volume of liquid drainage (mL)}}{60\ \text{(min)}} \quad (2)$$

2.3.3 Overrun

Overrun was determined based on the mass (g) of 100 mL of the CSP mixture before a foam whipping (m_1) and the mass (g) of 100 mL of CSP foam (m_2). Overrun (%) was calculated using Equation 3 (Inchuen and Duangkhamchan, 2021).

$$\text{Overrun} = \left(\frac{m_1 - m_2}{m_2}\right) \times 100 \quad (3)$$

2.4 Determination of foam-mat chili shrimp paste

2.4.1 Color determination and browning index

Color parameters (*L**, *a** and *b**) of reconstituted FM-CSP were measured with a colorimeter (HunterLab colorFlex 4510, USA.) using illuminant D65 and CIE:2°

https://doi.org/10.26656/fr.2017.8(3).249

standard observer. The colorimeter was calibrated using white and black standard reflective calibration plates. Browning index (BI) was calculated as following equation:

$$BI = \frac{100 \times (x - 0.31)}{0.17} \quad (4)$$

where $$x = \frac{a* + 1.75L*}{5.645L* + a* - 0.3012b*} \quad (5)$$

2.4.2 Water solubility index

Water solubility index (WSI) was conducted following the method of Waseem *et al.* (2021) with some modifications. Approximately 3 g of FM-CSP were added with 30 mL of distilled water. The mixture was stirred and then centrifuged at 3,000 rpm for 15 mins. The supernatant was carefully transferred into a known-weight aluminum can and oven-dried at 105°C till the constant weight. The remained dry solids were an indication of solubility. WSI was expressed as a percentage of the total dry solids in the original weight of the sample. It was calculated following Equation 6.

$$WSI = \frac{\text{weight of dried solid after centrifugation}}{\text{initial weight of dried sample}} \times 100 \quad (6)$$

2.4.3 Hygroscopicity

The hygroscopicity of FM-CSP was determined following the method of Oliveira *et al.* (2014). Approximately 3 g of FM-CSP was put into petri dish and placed in a desiccator filled with NaCl saturated solution (75.29% RH) for 1 week. The percentage of hygroscopicity was calculated using Equation 7.

$$Hygroscopicity = \frac{(\%\,WI + \%\,\text{Free water}) \times 100}{100 + \%\,WI} \quad (7)$$

where $$\%\,WI = \frac{\text{weight of adsorbed water} \times 100}{\text{initial weight of sample}} \quad (8)$$

2.4.4 Moisture content, water activity and pH value

FM-CSP was determined for moisture content and water activity while reconstituted FM-CSP was determined for pH value. Moisture content was determined according to the AOAC method (AOAC, 2000). Water activity was measured using a water activity meter (Novasina Lab Touch, Switzerland) and pH value was measured using a pH-meter (Eutech Instrument, pH 700, Singapore)

2.5 Rendement

Rendement of the FM-drying process was calculated as a percentage by dividing the weight of the final product produced (the weight of FM-CSP obtained after drying) with the weight of the processed material (the initial weight of CSP foam before drying) (Noordia *et al.*, 2020).

2.6 Sensorial evaluation

Reconstituted FM-CSP was sensorial evaluated by 40 untrained panellists. All samples were served with a carrier (peeled cucumber slice), coded in 3-digit numbers and presented in a randomized arrangement. Tests on color, smell, appearance, texture (viscous), taste and overall liking were conducted a 9-point hedonic scale (1.00 to 1.89- extremely dislike; 1.90 to 2.79-very much dislike; 2.80 to 3.69-moderately dislike; 3.70 to 4.59 – slightly dislike; 4.60-5.49 – neither like nor dislike; 5.50 to 6.59 – slightly like; 6.60 to 7.69 – moderately like; 7.70 to 8.79 – very much like and 8.80 to 9.00 – extremely like).

2.7 Statistical analysis

The experimental design followed a Completely Randomized Design (CRD) model with three replications for each treatment. Independent variables included CSP level (30, 40, 50 and 60 g) and CMC level (0.25, 0.50 and 0.75 g). The data obtained in this study were expressed as mean ± standard deviation (SD) and statistically analyzed using analysis of variance (One-way ANOVA) by SPSS statistical program version 16. The differences between the means were determined by the Duncan Multiple Range Test (DMRT) at a level of $p < 0.05$.

3. Results and discussion

3.1 Suitable chili shrimp paste level for foam mat-chili shrimp paste production

3.1.1 Foam properties

Foam properties of CSP were expressed as foam density, and rate of drainage which implied foam stability, and overrun. These foam characteristics play an important role in the foam mat drying process and drastically have an effect on the dried powder quality. A low-density foamed material indicates more air was trapped in the foam allowing faster water removal during the heating process. Foam density is inversely related to overrun which indicates foam formation efficiency (Inchuen and Duangkhamchan, 2021). The rate of drainage is conversely reflected in foam stability. Foam material with a high rate of drainage or high drainage volume is unstable foam because it cannot preserve the open pore structure during the drying process. Good quality foam for foam mat drying is considered as foam with a minimum foam density and rate of drainage (maximum foam stability) and maximum overrun.

In the current work, the foam properties were significantly affected by the CSP level. An increase in CSP level significantly elevated the foam density and the rate of drainage however it lowered the overrun (Figure

1). The foam with 60 g CSP was 38.9% and 38.6% higher in foam density and rate of drainage, respectively but 50% lower overrun compared to that with 30 g CSP. These findings might be due to the different concentrations of egg albumen, a foaming agent that increases the number of bubbles in the foam. At low concentrations of the foaming agent, high foam density was caused by the restriction of movement of the foaming agent from the aqueous phase towards the air-aqueous interface (Karim and Wai, 1999). CSP foam with higher CSP levels contained a lower concentration of egg albumen (foaming agent), therefore, it could not be whipped to form foam well and easily drained resulting in a higher foam density and a higher rate of drainage but a lower overrun. The overrun was low due to the reduction of surface and interfacial tension (Qadri *et al.*, 2020). A similar trend was observed in microwave-assisted foam mat dried brown rice porridge (Inchuen and Duangkhamchan, 2021) and microwave-assisted foam mat dried yogurt (Yüksel, 2021).

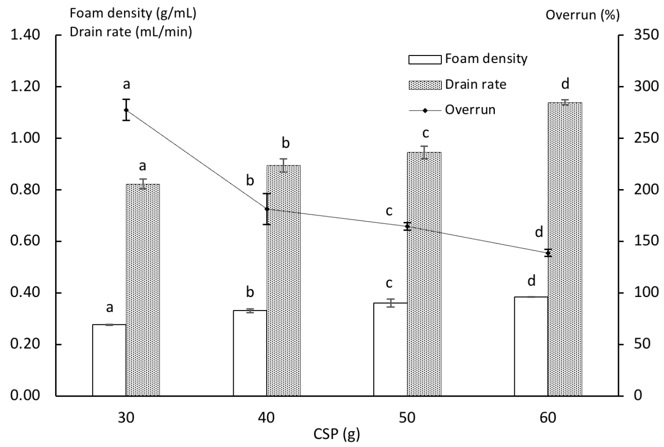

Figure 1. Effect of different CSP levels on CSP-foam properties; foam density (□), drain rate (▩), and overrun (—●—). Bars with different notations are statistically significantly different ($p < 0.05$).

3.1.2 Physicochemical properties of foam mat-chili shrimp paste

Differences in CSP level significantly affected the physiochemical properties of FM-CSP. FM-CSP with higher CSP level provided a higher rendement. It also had higher moisture content and water activity but a lower pH value (Table 1). The rendement of FM-CSP ranged from 16.36% to 21.30%. The moisture content, water activity and pH value were between 4.58-6.84%, 0.21-0.28 and 4.98-5.27, respectively. The moisture content of 8.06-13.38% and water activity of 0.209-0.293 were reported in foam mat-dried Aquafaba (Aslan and Ertaş, 2021). Moreover, less than 0.6-water activity of FM-CSP complies with the regulation of Thai Community Product Standard entitled seasoning shrimp paste powder (Thai Community Product Standard, 2018).

Results showed that an increase in CSP level gave FM-CSP higher rendement, moisture content and water activity (Table 1). This might be due to the difference in the initial moisture content of CSP foam. The CSP foam with 60 g CSP had more amount of boiled water and lime juice than that with 30 g CSP. Therefore, after drying, it exhibited higher rendement (21.30%), moisture content (6.84%), and water activity (0.28) compared to 16.36%, 4.58% and 0.22 of the FM-CSP with 30 g CSP, respectively. This was also in the case of pH value. The FM-CSP with a higher CSP level contained a higher amount of lime juice resulting in a lower pH value. Besides the quantity of lime juice, change in egg albumen concentration also impacted the pH value of FM-CSP due to its alkaline behavior. The FM-CSP with higher CSP level possessed a lower egg albumen concentration, thus it had a lower pH value (more acidic). A rise of pH value from 4.62 to 4.71 when egg albumen increased from 3% to 5% was observed in foam mat dried tomato (Hossain *et al.*, 2021).

Table 1. Effect of different CSP levels and CMC levels on FM-CSP properties; water activity (aw), moisture content (mc.), pH value, browning index (BI), water solubility index (WSI), hygroscopicity and rendement.

Factors	a_w	mc. (%)	pH	BI	WSI (%)	Hygroscopicity (%)	Rendement (%)
CSP level (g)							
30	$0.22±0.04^a$	$4.58±0.18^a$	$5.27±0.04^a$	$9.19±0.63^b$	$26.04±1.01^{ab}$	$28.58±0.24^a$	$16.36±0.32^c$
40	$0.21±0.11^a$	$5.07±0.37^b$	$5.26±0.03^a$	$8.57±0.29^a$	$27.10±0.61^a$	$29.24±0.30^b$	$18.17±0.71^b$
50	$0.24±0.002^a$	$5.82±0.30^c$	$5.20±0.01^b$	$9.58±0.15^b$	$25.80±0.46^b$	$32.39±0.30^c$	$20.97±0.69^a$
60	$0.28±0.003^b$	$6.84±0.13^d$	$4.98±0.02^c$	$10.36±0.21^c$	$25.05±0.55^b$	$33.47±0.09^d$	$21.30±0.27^a$
CMC level (g)							
0.25	$0.31±0.04^b$	$5.60±0.73^c$	$5.19±0.01^{ns}$	$27.65±1.33^a$	$26.46±0.44^c$	$30.66±0.07^a$	$20.56±0.58^{ns}$
0.5	$0.27±0.01^b$	$5.41±0.23^b$	5.20±0.01	$32.17±0.73^b$	$28.19±0.46^b$	$31.63±0.26^c$	20.16±0.74
0.75	$0.22±0.01^a$	$5.31±0.17^a$	5.18±0.12	$32.86±0.74^b$	$29.54±0.56^a$	$31.21±0.12^b$	20.36±0.50

Values are presented as mean±SD. Values with different superscripts within the same column are statistically significantly different ($p<0.05$).

^{ns}No statistically significant difference ($p \geq 0.05$).

https://doi.org/10.26656/fr.2017.8(3).249

BI, WSI and hygroscopicity of FM-CSP were 8.57-10.36, 25.05-27.10% and 28.58-33.47%, respectively (Table 1). Differences in CSP level significantly affected BI, WSI and hygroscopicity of the obtained FM-CSP. An increment in the CSP level increased BI and hygroscopicity but lowered WSI. This increased BI might be due to the fact that CSP consists of about 20% sugar which can cause a non-enzymatic browning reaction during hot air drying (Korbel *et al*., 2013).

Hygroscopicity is the ability of a food powder to absorb water from an environment with a relative humidity higher than the equilibrium moisture content (Franco *et al.*, 2016). It is also known that sugars such as sucrose, glucose and fructose are the main responsible for water absorption due to the ability of hydroxyl groups to form hydrogen bonds with water molecules (Jaya and Das, 2004). Therefore, the FM-CSP with a higher CSP level had higher BI and hygroscopicity compared to that with a lower CSP level. Besides sugar concentration, it is also reported that the presence of egg albumen influenced the hygroscopicity of dried powder. Maciel *et al*. (2020) reported that guava pulp powder with egg albumen had less hygroscopicity than that without, however, Franco *et al*. (2016) and Shaari *et al*. (2018) reported that the albumen caused a higher hygroscopicity in dried yacon juice powder and pineapple fruit powder, respectively. In the present study, the FM-CSP with higher CSP levels which possessed a lower egg albumen concentration was more hygroscopic than that with lower CSP levels.

Solubility is a major index of the powder's ability to continue homogeneously mixed with water. The lowering WSI in FM-CSP with high CSP levels is caused by a lower concentration of egg albumen acting as a foaming agent (Table 1). Foaming agent creates air bubbles during whipping CSP resulting in a porous and more stable structure of CSP foam during the drying process. The air bubbles cause an increase in the porosity of the powder and its solubility (Abbasi and Azizpour, 2016). Therefore, FM-CSP with a high CSP level containing a lower foaming agent (egg albumen) concentration tend to have a lower WSI. Similar results were observed in foam mat dried yoghurt powder (Yüksel, 2021) and foam mat pineapple fruit powder (Shaari *et al.*, 2018).

3.1.3 Sensorial properties of foam mat-chili shrimp paste

The sensorial liking score of FM-CSP ranged from 5.73 (slightly like) to 7.38 (moderately like) (Figure 2). A difference in CSP level did not affect appearance and texture liking scores. An increase in CSP level improved sensorial liking scores in color, smell, taste and overall liking of the obtained FM-CSP. In general, liking scores of the FM-CSP with 50 g and 60 g CSP levels were not significantly different ($p > 0.05$) and the scores ranged from 6.56 (slightly like) to 7.38 (moderately like). Usually, CSP is expected to have a dark brown color, salty and sour taste. The highest color liking score of the FM-CSP with 60 g CSP (7.38) was in accordance with its highest BI (10.36) (Table 1). The FM-CSP with 50 g CSP having pH 5.2 (Table 1) had the highest taste and overall liking scores of 6.72 and 6.88, respectively. Nadia Sarina *et al*. (2010) reported the overall acceptability of CSP with pH 5.0 was 6.12. According to taste and overall liking scores, it could be concluded that the FM-CSP with 60 g CSP (pH 4.98) was too sour while that with 30 g and 40 g CSP (pH 5.26 and 5.27, respectively) were not sour enough to meet the panelist's expectation. Considering the physicochemical properties, the FM-CSP with 50 g and 60 g CSP levels had similar rendement (20.97% and 21.30%) and WSI (25.80% and 25.05%), respectively (Table 1). However, the FM-CSP with 50 g CSP had lower BI and hygroscopicity, 9.58 compared to 10.36 and 32.39% compared to 33.47%, respectively. Combining both the physicochemical and sensorial properties of FM-CSP, the CSP level of 50 g was thus considered as a suitable CSP level and be used for further experiments.

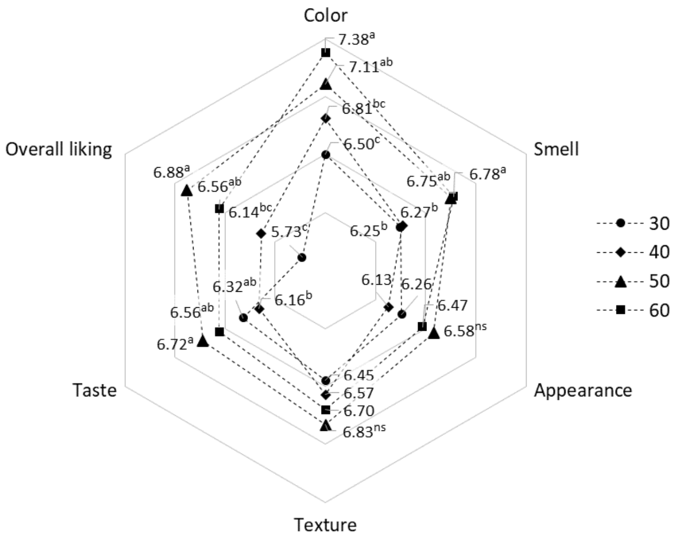

Figure 2. Sensorial liking score of reconstituted FM-CSP with different CSP levels (●, 30 g; ♦, 40 g; ▲, 50 g and ■, 60 g). Values with different superscripts within the same attribute are statistically significantly different ($p < 0.05$). [ns]No statistically significant difference ($p \geq 0.05$).

3.2 Suitable CMC level for foam mat-chili shrimp paste

3.2.1 Foam properties

An increase in CMC level significantly improved CSP foam properties by decreasing foam density, rate of drainage and by increasing overrun percentage (Figure 3). The decreased rate of drainage in higher CMC levels

https://doi.org/10.26656/fr.2017.8(3).249

implied that CSP foam was more stable resulting in less quantity of liquid dripping out from the foam structure. The CSP foam with 0.75 g CMC had lower foam density and drainage rate by 7.16% and 41.55%, respectively, and its overrun increased by 11.70% compared to that with 0.25 g CMC (Figure 3). As previously mentioned, the rate of drainage is negatively related to foam stability which reflects the water holding capacity of foam and one efficient way to determine the rate at which the liquid drains from it (Kampf *et al.*, 2003). An increase in overrun was due to the fact that CMC is a foam stabilizing agent, an agent that helps air bubbles stabilized in the foam structure. A similar effect of CMC on foam properties was also reported in other foam mat-dried products. Abbasi and Azizpour (2016) indicated a decreasing trend in foam density and drainage volume with an increase of CMC concentration in foam mat dried sour cherry. Azizpour *et al.* (2017) also reported that an increase in methylcellulose concentration decreased the rate of drainage in foam mat dried shrimp puree although its foam density increased. In addition, increased foam stability and overrun with increasing CMC levels were also reported in foam mat-dried seabuckthorn (Kaushal *et al.*, 2013) and in foam mat-dried blueberry pulp (Gao *et al.*, 2022).

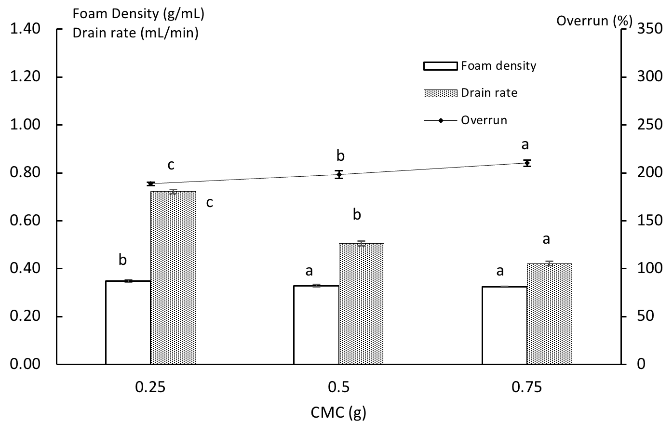

Figure 3. Effect of different CMC levels on CSP-foam properties; foam density (□), drain rate (▩), and overrun (—●—). Bars with different notations are statistically significantly different ($p < 0.05$).

3.2.2 Physicochemical properties of foam mat-chili shrimp paste

The rendement (20.16-20.56%) and pH value (5.18-5.20) of the obtained FM-CSP were not affected by different CMC levels. Hossain *et al.* (2021) found no significant change in the pH value of foam mat dried tomato with increasing CMC concentration. However, water activity and moisture content of FM-CSP decreased with an increase in CMC level. The lowest water activity and moisture content, 0.22 and 5.31%, respectively, were observed in the FM-CSP with 0.75 g CMC which contains the highest CMC concentration in foam structure. As CMC is known as a foam stabilizing agent, air bubbles in FM-CSP with 0.75 g CMC were thus more stable and well retained their structure in the CSP foam, resulting in the lowest rate of drainage and the highest overrun (Figure 3) and allowing water easily expelled from CSP foam during the drying process. This circumstance led to the lowest water activity and moisture content in the FM-CSP with 0.75 g CMC which was 29% and 5.18% lower than that with 0.25 g CMC.

Differences in CMC level did affect the BI and WSI of the FM-CSP. When the CMC level increased from 0.25 g to 0.75 g, BI raised 18.84% from 27.65 to 32.86 and WSI raised 11.64% from 26.46% to 29.54%, respectively (Table 1). A similar trend was observed in foam mat-dried blueberry pulp (Gao *et al.*, 2022). The increase in BI with increasing CMC level might be due to the fact that CMC, a type of polysaccharide gum, enhances foam stability and facilitates water removal from the sample during drying which contributes to the excess surface temperature of the sample in the final stage of drying resulting brown color. A starch gelatinization that occurred during drying also caused a darker color in foam mat-dried blueberry pulp (Gao *et al.*, 2022).

The higher WSI in FM-CSP with higher CMC level may be caused by the ability of CMC to enhance the foam stability by reducing bubble burst and consequently improving the porosity and WSI of foam mat dried product (Gao *et al.*, 2022). Although the hygroscopicity of FM-CSP seemed to be increased by an increase in CMC level (Table 1), no statistically significant correlation was found between CMC level and the hygroscopicity ($p = 0.137$) (data not shown).

3.2.3 Sensorial properties of foam mat-chili shrimp paste

The FM-CSP sensorial liking scores in color, smell, appearance and overall liking were not affected by a difference in CMC level. They were in the range of 6.46 (slightly like) to 7.68 (moderately like) (Figure 4). However, an increase in CMC level provided FM-CSP with higher texture and taste liking scores. No significant difference was observed in texture and taste liking scores between the FM-CSP with 0.25 g CMC and that with 0.50g CMC. Their scores ranged from 6.23 (slightly like) to 6.34 (slightly like). The FM-CSP with 0.75 g CMC received the highest liking scores in texture and taste which were 6.89 (moderately like) and 7.14 (moderately like), respectively. It also had the highest WSI (29.54%) (Table 1) and the lowest drain rate (0.422 mL/min) (Figure 3). High WSI implied that the FM-CSP can well dissolve with water, resulting in a smooth texture after reconstitution. Moreover, the low drain rate reflected that a great amount of CSP was retained in the foam structure during drying which may consequently affect the taste of reconstituted FM-CSP. Combining both the physicochemical and sensorial properties of FM-CSP, the suitable CMC level was 0.75 g.

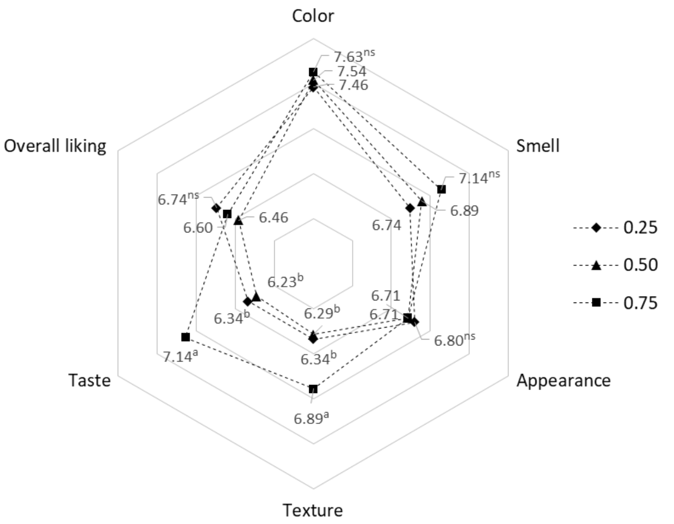

Figure 4. Sensorial liking score of reconstituted FM-CSP with different CMC levels (♦, 0.25 g; ▲, 0.50 g and ■, 0.75 g). Values with different superscripts within the same attribute are statistically significantly different ($p < 0.05$). nsNo statistically significant difference ($p \geq 0.05$).

Overall, the suitable formation was the FM-CSP with 50 g CSP and 0.75 CMC due to its best physicochemical and sensorial properties. The drying curve of the final FM-CSP was then plotted (Figure 5). The results found that foam mat drying techniques with and without CMC can drastically reduce the drying time compared to conventional drying methods. To obtain CSP with less than 8% moisture content following the notification of the Ministry of Public Health, Thailand (2000), the drying time of FM-CSP with and without CMC was 133.83 mins and 95.2 mins, respectively compared to more than 240 mins of conventional drying CSP.

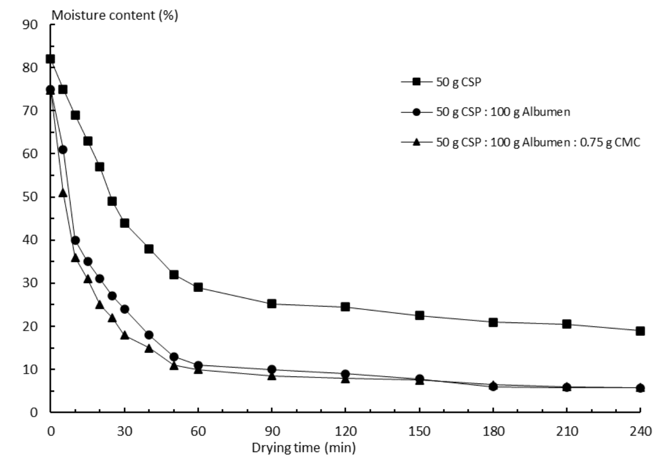

Figure 5. Drying curves of 50 g CSP.

4. Conclusion

Results showed that the most suitable formula for FM-CSP production included 50 g CSP, 100 g egg albumen and 0.75 g CMC. Changes in CSP and CMC levels strongly affected the physicochemical properties of FM-CSP except that CMC level had no effect on rendement, pH value and hygroscopicity. Overall liking scores of the final FM-CSP ranged in moderately like. Compared to the conventional drying method, drying time was drastically reduced in FM-CSP. This work provided guidance for dried CSP production using foam mat drying technique which could be applied using other drying techniques.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgments

The authors appreciate the Takahashi Foundation for the financial support.

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