

Production of instant mixed-vegetables soup using foam mat drying: Impact of various additives on foam properties and physicochemical aspects

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Abstract -Nowadays, many consumers are paying attention to ready-prepared food containing nutritional and functionalities. The objective of this study was to develop an instant mixed-vegetable soup prepared by foam mat drying technique using various additives, e.g., egg white albumin (EA; 10-30%), carboxymethyl cellulose (CMC; 1-3%), and glyceryl monostearate (GMS; 10-30%) was used in combination with maltodextrin (MD; 10-30%) as a drying aid. The results showed that the cooked soup containing 76.99% carbohydrate, 16.98% protein, and 6.03% fat, in which dietary fiber equivalent to 1/3 of total carbohydrate (5.55 g dietary fiber and 17.93 g of carbohydrate). The application of 30% EA in combination with 10% MD showed the highest percentage of foam overrun (34.79 ± 0.30) and the product yield (12.54 ± 0.23), which experienced sensory qualities similar to a freshly cooked soup. The limitation of CMC led to a foam collapsing during drying, while GMS required long periods of drying time resulting in no production yield. The instant powder had a low percentage moisture content (<1%) and water activity (0.38) and could dissolve easily in hot water. The plant-based bioactive compounds such as chlorophyll a, b, and the total phenolic content were retained after processing. The strength of the product was lightweight and could be prepared by a simple technique with mild heat treatment. Moreover, it

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was convenient for individuals looking for time-saving, and reasonable for the elderly market section, specified for chewing difficulties.

Keywords: Food powder, egg white albumin, carboxymethyl cellulose, glyceryl monostearate, maltodextrin

1. Introduction

Marketing of ready-to-eat food concept, i.e., instant product has been developed to accommodate changes in new consumption lifestyles resulting from modern urbanization all over the world (Huq *et al.*, 2018). In addition to convenience reasons, the current food trend alongside the scenario caused by the COVID-19 pandemic has motivated interest in healthy and nutritious diets (Jordan *et al.*, 2021). Among the products sold in the market, the instant soup-based product is more interesting to develop for specific uses since it can fortify micro-nutritional and functional ingredients to reach the body's requirements. These foods can also help support digestion easily, increasing bioavailable ability, improving the immune system, and enhancing the body's recovery from curative care (Thuy *et al.*, 2023; Sinchaipanit *et al.*, 2023).

Vegetable crops are a potential source of energy-yielding nutrients (carbohydrate, protein, and fat) and dietary fiber as well as vitamin, mineral, and plant phytochemicals (Górska-Warsewicz *et al.*, 2021; Opazo-Navarrete *et al.*, 2021). The reliable evidence of the association of vegetable consumption to reduce the risk of noncommunicable diseases (NCDs) assessed by the World Health Organization (WHO) has been published and recommended as a nutritional guideline (World Health Organization (WHO), 2014). Recently, a proof study of the risk reduction of ischemic heart disease, ischemic stroke, hemorrhagic

stroke, and esophageal cancer was confirmed by Stanaway *et al.* (2022). Thus, the utilization of agricultural commodities corresponding with the Sustainable Development Goals (SDGs) not only introduces value-added agricultural products but also generates food and nutrition security as well as food availability and accessibility.

Drying technology is a conventional method for foodstuff preservation and value addition. Typically, a technique used for producing food powder includes a foam mat, drum, spray, and freeze-drying. In comparison among drying techniques, foam mat is a cost-effective method for producing powder, which can be used for large production and is suitable for all types of food materials. Principally, the semi-liquid food is whipped to form a stable foam by adding foaming agent (egg white albumin (EA), whey protein, soy protein, gelatin, and casein) and/or stabilizing agent (carboxymethyl cellulose (CMC), xanthan gum), which created a larger surface area of foam results to rapid drying rate at lower temperature. Moreover, the retention of nutritive value and bioactive compounds, good reconstitution characteristics, and flowability are the key features of foam mat powder (Sangamithra *et al.*, 2014).

A high-quality powder obtained from foam mat drying depends on the proper selection of foaming method, foaming agent, foam stabilizer, time taken for foaming, and drying procedures (technique; hot-air, freeze dried, microwave, etc., time, and temperature)

(Sangamithra *et al.*, 2014). EA is the most widely used protein foaming agent in various products, for example, banana juice (Noordia *et al.*, 2020), mango pulp (Kandasamy *et al.*, 2021), plum pulp (Sifat *et al.*, 2021), and tamarillo pulp (Rohilla & Mahanta, 2022). The good foaming agent should be able to adsorb easily at the air-water interface, reduce interfacial tension, and introduce a viscoelastic film that can be resistant to thermal and mechanical agitation (Sangamithra *et al.*, 2014). The advantage of EA is cheap that is naturally protein derived and easily available. Many intrinsic factors affect foaming properties (size, structure of protein, hydrophobicity, surface potential, and charge), as well as environmental and processing factors (protein concentration, pH, temperature, and other ingredients) (Narsimhan & Xiang, 2018).

Glyceryl monostearate (GMS) is a saturated monoglyceride obtained from the esterification reaction between stearic acid and glycerol. GMS help improves emulsion stability, enhances protein displacement from oil interfaces, and used as foaming agent in foam mat drying in various products such as cowpea instant soup (Falade & Adedeji, 2021) and powder (Falade *et al.*, 2003), papaya pulp (Kandasamy *et al.*, 2012), mango puree (Sansomchai *et al.*, 2023), and legumes powder (Falade & Adedeji, 2022). The Joint FAO/WHO Expert Committee on Food Additives (JECFA) stipulated the Acceptable Daily Intake (ADI) for GMS is not limited (World Health Organization (WHO), 2021a). The advantage of GMS was reported to prevent needle-like fat crystal shapes that behave as a solid at the oil-in-water interface. A good reconstitution into pastes (Falade & Adedeji, 2021), was a favorable result to challenge this work. However, sparse literature and case

applications were a limitation for further study. Cellulose ether, e.g., carboxymethyl cellulose (CMC), methylcellulose (MC), and hydroxypropyl methylcellulose (HPMC), act as thickeners, stabilizers, film formers, water retention, and foaming agent (Wei *et al.*, 2020), in the host application for foods, cosmetic, pharmaceuticals, etc. The ADI 'not specified' is noted for CMC by Codex Alimentarius, it can be used in food products with no safety concerns (World Health Organization (WHO), 2021b). In foam mat drying, it is typically used as a foam stabilizer when applied in combination with food protein, and/or individually applied in terms of foam forming. For example, the application of CMC (1-3%) and HPMC (1%) to produce foam mat dried fruit leather from seabuckthorn (*Hakea salicifolia*) pulp (Kaushal *et al.*, 2013), purple-fleshed sweet potato powder (Jakkranuhwat & Kunchansombat, 2021), and guava-flesh powder (Thakur *et al.*, 2021). The fact that CMC has many technological roles is an advantage for the application for different purposes. However, instability in acidic conditions (precipitation at pH 3) may be a limitation in some situations (BeMiller, 2019). In addition, maltodextrin is used as a drying aid to make the powder free-flowing and non-sticky, which is usually applied in various food powders in the range of 10-30% (Ekpong *et al.*, 2016; Hajiaghahi & Sharifi, 2022).

According overview mentioned above, foam-mat drying is considered interesting for application in producing instant mixed-vegetable soup, because it requires simple equipment, mild heat, and short drying periods. However, the report on the effect of different kinds of additives was lacking. Therefore, the objective of

this study was to estimate the effect of additives (EA, GMS, CMC, and MD) on the foaming and physicochemical properties of an instant mixed-vegetable soup.

2. Materials and methods

2.1 Raw materials

Agricultural raw materials were chosen for a variety of green leafy vegetables, *e.g.*, bok choy, broccoli, and Chinese cabbage, which contained dietary fiber, vitamins, and minerals. Pumpkin and sweet corn were abundant in carotenoids. A carbohydrate-rich food of potatoes. Shiitake mushrooms contain various amino acids. Garlic, coriander root, and black pepper, and onion were aromatic ingredients with other phytochemicals. They were purchased from a local fresh Market in Yannawa, Bangkok, Thailand, and Siam Makro Pub Co., Ltd. Iodized Refined Salt was purchased from Prung Thip, Saha Pathanapibul Pub Co., Ltd, Thailand.

Plant materials were transferred to the laboratory and then subjected to

the experiment within 3 h. The washing operation with running water was applied for all agricultural raw materials to reduce dirt and other contaminations. After draining, the operation of peeling and cutting into a small piece was prepared before the experiment.

2.2 Preparation of mixed-vegetable soup

The ingredients of mixed-vegetable soup are shown in Table 1. A recommended micronutrient and energy distribution of mixed-vegetable soup was estimated using the INMUCAL-Nutrients Program V.4.0 developed by the Institute of Nutrition, Mahidol University, suggested by Sinchaipanit *et al.* (2023). INMUCAL was appropriated to analyze the nutritional value of Thai food consumption and recipes and provided nutritional information for each subject based on the DRI for Thai. It comprises a reliable nutrient database obtained from the Bureau of Nutrition, Ministry of Public Health, searchable by food code and data input (Jeong *et al.*, 2021).

Table 1. Amount of mixed-vegetable soup ingredients per 100 g.

| Ingredient | Amount (g) |
|-------------------|------------|
| bok choy | 4.65 |
| broccoli | 4.65 |
| radish | 6.21 |
| onion | 6.21 |
| shiitake mushroom | 0.78 |
| potatoes | 2.17 |
| Chinese cabbage | 6.21 |
| Pumpkin | 1.86 |
| sweet corn | 4.65 |

Table 1. Amount of mixed-vegetable soup ingredients per 100 g. (cont.)

| Ingredient | Amount (g) |
|---------------------|------------|
| garlic | 0.22 |
| coriander root | 0.22 |
| ground black pepper | 0.08 |
| salt | 0.05 |
| drinking water | 62.05 |
| Total | 100 |

To prepare soup, the prepared ingredients were cooked in a stainless steel pot using the temperature around 80-90 °C until tendered (approximately 30 min). After seasoning with salt and black pepper, stop cooking and allow the temperature to cool down before blending into a puree using a high-speed electrical blender (DEBRANDT MB311TM, Arnold Electric, Poland) for 5 min at speed level 2. The 250 g of soup purees were packed in plastic bags and kept in the freezer at -18 °C until the experiment (not exceeding two weeks). Therefore, thawing the frozen soup under running water was required before being used in the experiment.

2.3 Effect of additives and concentration on the foam characteristics of mixed-vegetable soup

Three types of food additives namely EA (10, 20, and 30% w/v), CMC (1, 2, and 3% w/v), and GMS (10, 20, and 30% w/v) were studied for making a foam of mixed-vegetable soup (250 g) in combination with 10% MD (DE 10-15). The food grade of CMC, GMS, and MD was purchased from the Chemipan Corporation Co., Ltd., Thailand, while EA was obtained from fresh egg white (chicken egg No.1; Charoen Pokphand Foods, Pub Co., Ltd, Thailand), which produced no more than two days.

The procedure for preparation of mixed-vegetables soup powder by foam-mat drying is shown in Figure 1. For EA, egg at room temperature was used, and white was separated from the yolk by hand manually. To prepare a foam, egg white was beaten to a coarse bubble using a food mixer (5KSM150LR, Kitchen Aid, USA) fitted with a stainless steel wire whisk with the speed of level 10. Then, MD was gradually added with continuously whipped until permanent foam was observed, which took approximately 10 min. After that, add a pureed vegetable soup into EA foam and use a rubber spatula to fold it together. The CMC-stabilized foam was prepared according to the method of Kaushal *et al.* (2013) with minor modifications of solution temperature. The CMC solution (1-3%) at 25 °C was added into a pureed-vegetable soup (1:2) and whipped by gradually adding MD until foamy. For GMS, the application in the form of a slurry solution was recommended by Falade *et al.* (2003) and Falade and Adeniyi (2021). The slight modification was performed by dissolving GMS in a warm soup, then allowing the temperature to cool down, followed by continued whipping for approximately 10 min. The speed of the food mixer in this study was set at level 10. The whipping procedure was performed at room temperature for all experiments.

Once the foam was stable, spread it on an aluminum tray with a thickness of approximately 3 cm, and then dry in the hot air oven (RL10-06575, Red LINE Binder, Germany) at 70 °C for 3 h (EA and

CMC treatments) and 5 h (GMS treatment), respectively. The dried foam was ground into a powder using a blender and collected to determine a yield percentage.

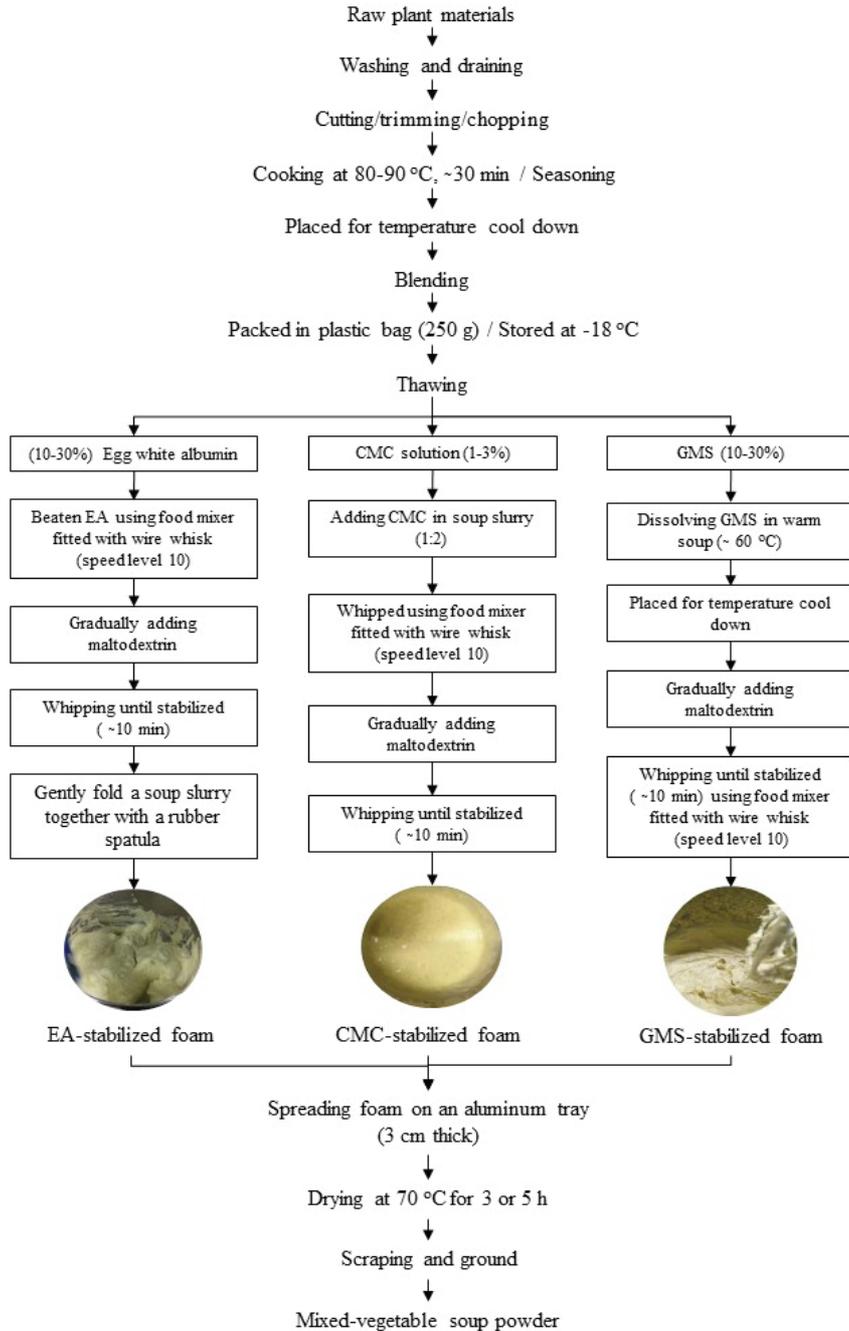


Figure 1. Procedure for preparation of mixed-vegetables soup powder by foam-mat drying with EA (A), CMC (B), and GMS (C).

2.4 Effect of MD concentration on the foam characteristics of mixed-vegetable soup

The optimal type of additives and concentration obtained from subtitle 2.3, chosen by a good foam characteristic and high yield percentage, was used in combination with different MD concentrations of 10, 20, and 30% (w/v). The foaming operation was carried out using a method described in subtitle 2.3., and investigated the characteristics of foam density, foam stability, and overrun percentage. The best treatment obtained in this experiment was used to prepare the final product to determine its physicochemical properties.

2.5 Foam characteristics

2.5.1 Foam density

Foam density was measured according to the method of Ng and Sulaiman (2018) with minor modifications. The foam was poured into a 158 mL measuring cup without any air pocket, then wiped off the overflowing around the mouth of the cup using a rubble spatula. The foam was weighed using a two-digit digital scale calculated using Equation 1 and reported in g/mL.

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

2.5.2 Foam stability

The stability of foam was measured by the foam drainage in terms of volume

reduction as described by Kanha *et al.* (2020) and Susanti *et al.* (2021) with some modifications. For measurement, pour foam on a glass funnel with No.1 filter paper and allow it to be left for drainage at room temperature for 60 min. Foam stability was calculated using Equation 2 and expressed in percentage.

$$\text{Foam stability (\%)} = \frac{\text{volume of foam reduction (mL)}}{\text{volume of initial foam (mL)}} \times 100 \quad (2)$$

2.5.3 Overrun

The percent of foam overrun (the expansion when the foam formed) was determined according to the method of Kanha *et al.* (2020) based on the mass of vegetable puree compared to the mass of foam after the whipping operation, using a two-digit digital scale. Percent overrun was calculated using Equation 3.

$$\text{verrun (\%)} = \frac{\text{mass of sample (g)} - \text{mass foam (g)}}{\text{mass of foam (g)}} \times 100 \quad (3)$$

2.5.4 Yield content

The percent yield of foam-mat powder was stated by the ratio of the dried weight of the product to the weight of the initial sample multiplied by 100 (Equation 4), recommended by Wahyuni *et al.* (2021).

$$\text{Yield (\%)} = \frac{\text{weight of dried powder (g)}}{\text{weight of sample (g)}} \times 100 \quad (4)$$

2.6 Physicochemical properties of an instant mixed-vegetable soup

2.6.1 Moisture content and water activity (a_w)

The moisture content of dried powder was analyzed according to the standard method of AOAC (2000) using the hot air oven at the condition of 105 °C until the weight was stable in the range of 0.001-0.003 g. The a_w value was measured using the water activity meter (Serie 3TE, Aqualab, Switzerland) and calibrated with distilled water to obtain the a_w of 1.00 ± 0.01 before sample testing.

2.6.2 Dissolution time

The time for solubility of foam-mat dried vegetable soup powder was determined according to Ozdikicierler *et al.* (2014) and Abd El-Salam *et al.* (2020) with some modifications. Five grams of powder was dissolved in 25 mL of boiling distilled water in the beaker and stirred continuously using a magnetic stirrer at 250 rpm. The total time (min) required for the reconstitution was noted.

2.6.3 Chlorophylls a and b

Chlorophyll contents in terms of Chlorophyll a (Chl a) and Chlorophyll b (Chl b) derivatives were analyzed using the spectroscopic method according to Anuradha *et al.* (2015) with minor modification. Five grams of foam-mat dried vegetable soup powder was dissolved in 25 mL of acetone, shaken, and filtered through the Whatman No.1 filter paper. After filtration, a sample was used for absorbance measurement at 645 and 663 nm using a spectrophotometer (UV-1700, Shimadzu, Japan). Chl a and

Chl b was calculated using Equation 5 and 6 and reported in the unit of mg/g.

$$\text{Chl a} = \frac{[12.7(\text{OD}_{663}) - 2.69(\text{OD}_{645})] \times V}{1000} \times W \quad (5)$$

$$\text{Chl b} = \frac{[22.9(\text{OD}_{645}) - 4.68(\text{OD}_{663})] \times V}{1000} \times W \quad (6)$$

Where OD was the optical density at respective nm, V was the final volume of chlorophyll extract, and W was the weight of the sample.

2.6.4 Total phenolic content

Total phenolic content was determined by Folin-Ciocalteu colorimetric method described by Zhou *et al.* (2020) with slight modification. One gram of powder was extracted with distilled water at the ratio of 1:10, followed by centrifuging at 4,000 rpm for 10 min. After centrifugation, 0.3 mL of the filtrate was transferred in a test tube mixed with 1.5 mL of Folin-Ciocalteu Reagent (10% v/v) and 3 mL of sodium carbonate (7.5%). The mixture was made up to 10 mL with distilled water and then incubated in a dark environment for 30 min before being measured spectrophotometrically using the absorption wavelength of 765 nm. Total phenolic content was calculated using an equation obtained from the calibration curve of gallic acid and expressed as μg Gallic acid equivalents (GAE)/mL.

2.7 Statistical analysis

The experimental layout was done in triplicate and reported in mean \pm standard deviation. Data were statistically analyzed using a one-way analysis of variance (ANOVA),

and a comparison of the mean value by Duncan’s multiple range test using SPSS program V. 27 (An IBM Company, Ontario, Canada) at the statistically significant differences at $p < 0.05$.

3. Results and discussion

3.1 Nutrients and energy distributions of mixed vegetable soup

In this study, the mixed-vegetable soup was prepared from various vegetables, which are easily available in the market. The nutritional component and energy distribution of freshly cooked soup before undergoes drying by foam mat method was analyzed by the Thai National Food Composition programed, INMUCAL-Nutrients Program V. 4.0, the results are shown in Table 2. One serving of 500 grams of soup carried approximately 93.43 kcal and distributed the energy by

76.99% carbohydrate, 16.98 % protein, and 6.03% fat. Noticeably, the developed soup was a good source of fiber as FDA defines, since it contains over 10% (5.55 g) compared to its recommendation (28 g per day for adults on a 2,000 kcal diet) (US Food and Drug Administration (USFDA), 2021). Appropriate intake of dietary fiber has been reported to be associated with a reduced risk of cardiovascular diseases, diverticulosis, constipation, irritable colon, cancer, and diabetes (Sinchaipanit *et al.*, 2023). Micronutrients, essential trace elements, and vitamins, of mixed-vegetable soup, delivered 79.37 mg of calcium, 56.89 RAE of vitamin A, 56.89 mg of vitamin C, 1.75 mg of iron, 0.24 mg of riboflavin, and 0.14 mg of thiamin, respectively. There is play a major role in metabolism and the supporting of immune function, e.g., cofactors and coenzymes in metabolism, genetic control, and antioxidants (Gombart *et al.*, 2020).

Table 2. The recommended nutrient and energy distribution of mixed-vegetable soup.

| Nutrients | Amount | Thai DRI (%) for male | Thai DRI (%) for female |
|-----------------------------------|----------------------|-----------------------|-------------------------|
| Macronutrient | | | |
| Carbohydrate (g) | 17.98 | | |
| Fat (g) | 0.63 | | |
| Protein (g) | 3.96 | 6.96 | 7.62 |
| Dietary fiber (g) | 5.55 | | |
| Energy per serving (500 mL), kcal | 93.43 | 4.45* | 5.34* |
| Energy ratio (CHO: Pro: Fat) | 76.99 : 16.98 : 6.03 | | |
| Micronutrient | | | |
| Iron (mg) | 1.75 | 16.83 | 18.62 |
| Vitamin A (REA) | 57.94 | 8.28 | 9.66 |
| Thiamin (B1) (mg) | 0.14 | 11.39 | 12.43 |
| Riboflavin (B2) (mg) | 0.24 | 18.56 | 21.94 |
| Vitamin C (mg) | 56.89 | 63.21 | 75.85 |
| Calcium (mg) | 79.37 | 9.92 | 7.94 |

Note: * % DRI for males and females at aged 35-65 based on the energy requirement of 2,100 and 1,750 kcal/day, respectively.

3.2 Effect of additives and concentration on the foam characteristics of mixed-vegetable soup

3.2.1 Egg white albumin

Foam characteristics of mixed-vegetable soup made by EA (10-30%) are shown in Table 3. The results showed that the application of 30% EA obtained the highest foam overrun percentage (34.79 ± 0.30), followed by 20 and 10% EA, respectively. The highest foam overrun in 30% EA treatment indicated that a large amount of air was entrapped in the bubble of foam structure, developed a noticeable foam expansion, and considerably decreased in foam density (0.50 ± 0.00 g/mL). The reduction of density is attributed to the rapid moisture removal during drying operation as it provided a large surface area for drying air. On the contrary, higher foam density resulted in prolonged drying time, which could lead to lower product quality due to

thermal degradation (Sangamithra *et al.*, 2014).

Foam stability is necessary for foam mat drying since it is considered mechanically or thermally stable for the entire drying process (Sangamithra *et al.*, 2014). In this experiment, the 30% EA treatment had a significant decline in foam stability percentage (79.80 ± 0.17), which might be due to the large amount of thin film bubble generated during whipped, and the adjacent cells coalesce into one larger cell at a later time. The liquid flows between the dispersed cells' bubbles could force them closer together and then loss of stability (Sangamithra *et al.*, 2014). However, the use of 30% EA obtained the highest yield percentage (12.54 ± 0.23) because of the addition of the soluble solids in the formulation. The appearance of mixed-vegetable soup powder made by EA is shown in Figure 2A, which appeared as a fined powder, light green, and had a flow ability.

Table 3. Characteristic of the foam of mixed-vegetable soup produced by EA in various concentrations

| Concentrations (%) | Foam Characteristics | | | |
|--------------------|----------------------|--------------------|--------------------|--------------------|
| | Foam density (g/mL) | Foam stability (%) | Overrun (%) | Yield (%) |
| 10 | 0.89 ± 0.01^a | 86.00 ± 0.00^a | 27.30 ± 0.62^c | 8.63 ± 0.20^c |
| 20 | 0.82 ± 0.00^b | 82.00 ± 0.00^b | 30.00 ± 0.89^b | 9.73 ± 0.16^b |
| 30 | 0.50 ± 0.00^c | 79.80 ± 0.17^c | 34.79 ± 0.30^a | 12.54 ± 0.23^a |

Note: Data presented in mean \pm standard deviation (SD).

: Data in the same column with different letters indicated statistically significant differences ($P \leq 0.05$) between treatments ($n=3$).

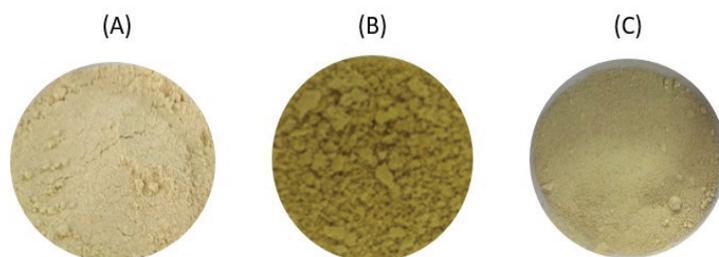


Figure 2. An appearance of foam-mated powder of mixed-vegetable soup prepared by using EA (A), CMC (B), and GMS (C).

However, the yield in treatment 30% EA was less than expected (12.54 ± 0.23). This noteworthy result may be possible, in which similar results reported in previous studies by Yudhistira *et al.* (2020) in a foam mat drying of inulin extract from sweet potatoes. They reported that the increasing EA concentration (2 - 10%) observed a yield reduction from 22.533 to 20.323% and 7.303 to 6.668% in blanched and unblanched samples, respectively. The increasing concentration of foaming agent will expand the surface area and give a porous structure due to the high amount of air trapped so that water can evaporate easily and increase drying speed. Moreover, the composition of mixed-vegetable slurries containing 62% water resulted in weight loss after drying. To solve this point, the effect of drying temperature should be investigated further, since it causes a yield reduction as noted in sweet potatoes inulin powder conducted by Yudhistira *et al.* (2023). With the increasing drying temperature and concentration of the foaming agent, the yield and moisture content are getting lower. As the temperature raised from 40, 60 to 80 °C, the yield of 2% and 10% EA treatment was reduced from 6.93 to 5.29 and 4.40%, and 6.22 to 4.84 and 4.22%, respectively.

3.2.2 Carboxymethyl cellulose

The experimental results of foam characteristics of mixed-vegetable soup produced by CMC (1-3%) are shown in Table 4. The application of CMC obtained the highest foam overrun (59.36 ± 0.32) at the concentration of 2%, while the percent overrun decreased as the CMC concentration increased to 3% (40.03 ± 0.37). Foam stability of three levels of CMC concentration was not significantly different ($p > 0.05$) between treatments during the one-hour examination, with Table 4 being 98.00-98.67%. However, CMC-stabilized foam failed to exhibit sufficient stability during drying, despite its good initial appearance. The sample was dried and adhered to the tray after drying for three hours, which was observed as a sheet. Therefore, it is considered that no yield was obtained from CMC-stabilized foam. Even though a sheet could peel and scrap from the tray, some moisture remains leading to the powder's agglomeration after fine grinding (Figure 2B).

The sheet-like characteristic of the foam mat of mixed-vegetable soup was similar to the report by Kaushal *et al.* (2013), in which the foam mat dried Seabuckthorn berry leather was made using CMC (0.5-3%). They found that the whipping fruit pulp without adding CMC

did not yield any foam, while the increase in CMC levels showed a noticeable rise in foam volume. Applying 2% CMC showed

stable foam and turned into the leather with 12.9% moisture content after drying.

Table 4. Characteristic of the foam of mixed-vegetable soup produced by CMC in various concentrations.

| Concentrations (%) | Foam Characteristics | | | |
|--------------------|--------------------------|---------------------------|---------------------------|--------------------------|
| | Foam density (g/mL) | Foam stability (%) | Overrun (%) | Yield (%) |
| 1 | 1.03 ± 0.01 ^a | 98.67 ± 0.78 ^a | 55.64 ± 0.31 ^b | 0.00 ± 0.00 ^a |
| 2 | 1.00 ± 0.01 ^b | 98.67 ± 0.78 ^a | 59.36 ± 0.32 ^a | 0.00 ± 0.00 ^a |
| 3 | 1.02 ± 0.01 ^a | 98.00 ± 1.00 ^a | 40.03 ± 0.37 ^c | 0.00 ± 0.00 ^a |

Note: Data presented in mean ± standard deviation (SD).

: Data in the same column with different letters indicated statistically significant differences ($P \leq 0.05$) between treatments ($n=3$).

3.3.3 Glycerol monostearate

Foam characteristics of mixed-vegetable soup made by GMS (10-30%) are shown in Table 5. The increase of GMS concentration (30%) experienced the highest percentage of foam overrun (62.67 ± 0.58), contributed to excellent foam stability (100.00 ± 0.00), and a reduction in foam density (0.64 ± 0.00 g/mL). The results were in agreement with Falade *et al.* (2003), that the final cowpea-foam density decreased with increased GMS concentration from 2.5 (~1 g/mL) to 15% (~0.35-0.55 g/mL). In this study, the application of 10% GMS acquired a 12.17% yield percentage, while other treatments did not produce any yield because it required more than 6 h for dehydration with moisture remaining. Kandasamy *et al.* (2014) described the

drying behavior of foam mat papaya pulp using 3% GMS which depended on drying temperature and foam thickness. At the temperature of 70 °C, the drying time required to bring the final moisture content to 4.5% for the papaya-pulp foam with 2, 4, 6, 8, and 10 mm thickness were 1, 3, 4, 5, and 6 h, respectively.

The appearance of 10% GMS-stabilized powder was a creamy green as shown in Figure 2C, as the general color of GMS (creamy white) which was imparted and retained in a dried powder, similar to the report in the instant cowpea soup by Falade & Adeniyi (2021). However, the rehydration soup was off-flavor, even though the color was turned similar to a fresh soup (data not shown).

Table 5. Characteristic of the foam of mixed-vegetable soup produced by GMS in various concentrations.

| Concentrations (%) | Foam Characteristics | | | |
|--------------------|--------------------------|----------------------------|---------------------------|---------------------------|
| | Foam density (g/mL) | Foam stability (%) | Overrun (%) | Yield (%) |
| 10 | 0.89 ± 0.00 ^a | 98.33 ± 0.58 ^c | 46.22 ± 0.54 ^c | 12.27 ± 0.33 ^a |
| 20 | 0.85 ± 0.01 ^b | 99.10 ± 0.10 ^b | 54.76 ± 0.37 ^b | 0.00 ± 0.00 ^b |
| 30 | 0.64 ± 0.00 ^c | 100.00 ± 0.00 ^a | 62.67 ± 0.58 ^a | 0.00 ± 0.00 ^b |

Note: Data presented in mean ± standard deviation (SD).

: Data in the same column with different letters indicated statistically significant differences ($P \leq 0.05$) between treatments ($n=3$).

According to the results in subtitle 3.2.1-3.2.3, the 30% EA was suitable for producing a mixed-vegetable soup powder compared to other additives, investigated by the high yield obtained (12.54 ± 0.23). In contrast, CMC and GMS did not produce a yield. Moreover, the good foam overrun (34.79 ± 0.30) and foam stability (79.80 ± 0.17) help prolong the periods of foam collapse and reduce the drying time. Thus, the 30% EA was chosen for used as a foaming agent in the next experiment.

3.3 Effect of maltodextrin concentration on the foam characteristics of mixed-vegetable soup

The MD is generally used as a drying aid and improves the stability of food powder. In this study, the 30% EA was selected to apply as a foaming agent to prepare the mixed-vegetable soup powder, since the considerably high yield percentage and foam overrun, which was the crucial factor that substantially affected foam product qualities. The effect of MD concentrations on the foam characteristics of mixed-vegetable soup is shown in Table 6. The results showed that the rising of MD levels (10-30%) did not significantly affect

($p > 0.05$) foam overrun and foam stability. However, the experimental trend showed that foam overrun slightly increased to peak at 20% treatment (37.53 ± 0.58) and declined at 30% treatment (30.40 ± 8.72), while the foam stability decreased. The high MD level exhibited the rise of foam density and resulted in the lot yield, since the functional property as a bulking agent of MD. The lower dextrose equivalent (DE) value of MD indicated a lower level of hydrolysis, resulting in higher molecular mass of the MD component (Nurhadi *et al.*, 2016), which might be a reason for the higher density of foam noted in 30% treatment.

These results were in concurrence with Hajiaghahi & Sharifi (2022), the instant fruit-beverage powder prepared by 3%EA powder in combination with 0-30% MD showed a reduction of foam expansion and higher foam density as MD concentration increased. Application of 20% MD in instant fruit-beverage powder contributed to the best treatment for maintaining foam stability, good flow ability, and lowest rehydration time. In this study, 10% MD was the optimum concentration for preparing mixed-vegetable soup powder since its good foam overrun and foam stability (Table 6),

even though a low yield (12.96 ± 0.67) was noted. Importantly, the 20 and 30% treatment has a liquid texture after rehydration compared to the 10% treatment (data not shown), which was contrasted to the fresh soup. The Good Manufacturing Practices (GMP) for food additives stipulated that

the quantities must be limited to the lowest possible level necessary to achieve the desired effect (Codex Alimentarius Commission, 2021). In this case, the 10% MD was adequate to accomplish a technology function without adverse results and cost efficiency reason.

Table 6. Characteristic of the foam of mixed-vegetable soup produced by 30% EA in combination with various MD concentrations.

| Concentrations (%) | Foam Characteristics | | | |
|--------------------|----------------------|------------------------|-----------------------|--------------------|
| | Foam density (g/mL) | Foam stability (%) | Overrun (%) | Yield (%) |
| 10 | 0.51 ± 0.06^c | 78.17 ± 9.78^{ns} | 30.78 ± 3.08^{ns} | 12.96 ± 0.67^b |
| 20 | 0.59 ± 0.00^b | 77.37 ± 11.06^{ns} | 37.53 ± 0.58^{ns} | 18.22 ± 0.79^a |
| 30 | 0.71 ± 0.01^a | 64.07 ± 18.16^{ns} | 30.40 ± 8.72^{ns} | 20.59 ± 3.55^a |

Note: Data presented in mean \pm standard deviation (SD).

: Data in the same column with different letters indicated statistically significant differences ($P \leq 0.05$) between treatments ($n=3$).

Naturally, EA is a globular protein and has a foam function, in which a soluble polypeptide rapidly adsorbs at the interface and forms a stabilizing film around bubbles, promoting foam overrun (Table 6) and foam stability (Table 6). The crucial functionality of MD is improving food powder stabilities by increasing a glass transition temperature (T_g), reducing caking, and stickiness, and improving flowability. Sonthipermpon *et al.* (2006) reported that the T_g value of the banana flake prepared with MD increased with increasing MD percentage, and decreased with increasing a_w value (from 0.216 to 0.749). Considering the parameter measured of a_w value in this study was 0.38 (Table 7) and physical flowability observed in Figure 2A. were sufficient to demonstrate material stability. However, the long-term stabilities should be further investigated in depth.

3.4 Physicochemical properties of an instant mixed-vegetable soup

The instant mixed-vegetable soup powder prepared by foam mat drying technique, using 30% EA in combination with 10% MD as a foaming agent, was taken for study in the physicochemical properties of the final product. The experimental results shown in Table 7, in which an instant powder considerably low in moisture content (0.01 ± 0.00) and a_w value (0.38 ± 0.16), restricted microbial growth naturally by $a_w < 0.60$ (Tapia *et al.*, 2007). Furthermore, non-hygroscopic properties of MD with lower DE value (Nurhadi *et al.*, 2016) help maintain the free-flowing characteristic, improving a dissolving capability (Hajiaghahi & Sharifi, 2022), and retard a deterioration of powder qualities. The instant mixed-vegetable soup powder

required 4.10 min to dissolve in hot water (100 °C) under the control of stirring conditions (250 rpm). The moisture content of the product was quite low, which might be due to a foam structure having more air trapped inside facilitating water evaporation during the drying process (70 °C, 3 h). Similar results were reported in egg white powder (1-3%) (Rao & Labuza, 2012) and vegetable powder (0.28-5.04%) (Bas-Bellver *et al.*, 2020), in which depends on raw material, pretreatment applied, drying method, and storage condition.

Chl a and b content of the instant mixed-vegetable soup powder were 0.03 ± 0.001 and 0.02 ± 0.002 mg/g, correlated to a green pigment that was visually observed by eye in a dried- and rehydrated powder. The instant mixed-vegetable soup was prepared from nine kinds of vegetables (bok choy, broccoli, radish, onion, shiitake mushroom, potatoes, Chinese cabbage, pumpkin, and

sweet corn) and three kinds of spice and herb (garlic, coriander root, and black pepper), which was a source of an active phenolic compound expressed as 142.42 ± 5.25 µg GAL/mL. Herein, chlorophyll and carotenoid has been considered as a bioactive compound to become a key to retard the onset of diseases related to oxidative stress since it has antioxidant activity (Pérez-Gálvez *et al.*, 2020), which was naturally occurred in green and orange-yellow of raw materials. Likewise, a phenolic compound is well known for its antioxidant role by reacting with a variety of free radicals (Zeb, 2020). Some ingredients contained substantially active ingredients such as allicin in garlic (Rahman, 2007), piperine in black pepper (Capasso *et al.*, 2002), and essential oils (linalool, λ -terpinene, α -pinene, camphor, limonene, geranyl acetate, and p-cymene) in coriander (Đurović & Blagojević, 2022).

Table 7. Physicochemical properties of an instant mixed-vegetable soup.

| Physicochemical Properties | Mean \pm SD |
|------------------------------------|-------------------|
| Moisture content (%) | 0.01 ± 0.00 |
| Water activity (a_w) | 0.38 ± 0.16 |
| Dissolving capability (min) | 4.10 ± 0.09 |
| Chlorophyll a content (mg/g) | 0.03 ± 0.001 |
| Chlorophyll b content (mg/g) | 0.02 ± 0.002 |
| Total phenolic content (µg GAE/mL) | 142.42 ± 5.25 |

Note: Data presented in mean \pm standard deviation (SD), N=3.

4. Conclusion

The effect of additives on the foaming properties of mixed-vegetable soup was different. EA (30%) in combination with 10% MD was the best to achieve the objective since it provided good foaming

characteristics in terms of overrun and yield percentage. The finished product contained Chl a, Chl b, and total phenolic content. CMC and GMS were not appropriate for preparing a foam of mixed-vegetable soup. A foam made from CMC loses stability during drying and gets stuck to the tray,

while GMS requires a long time of evaporation and loss of the natural taste of soup after rehydration. Further study should be focused on the temperature levels in the yield percentage, and the application of CMC in case of enhancing EA foam stability, including the storage stabilities and shelf-life of the product. The developed instant soup product provided energy (76.99% carbohydrate, 16.98% protein, and 6.03% fat) and micronutrients, as well as being abundant in dietary fiber. The advantage of product was designed for convenience with nutritional benefits, and it is reasonable for elderly people with a loss in chewing and swallowing ability such as vegetables, fruit, and meat. The requirement of functionalities information was the limitation of this product which should be investigated in further study.

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