JMBFS

Journal of Microbiology, Biotechnology and Food Sciences

International peer-reviewed scientific online journal

Published by Faculty of Biotechnology and Food Sciences

EFFECT OF FOAMING AGENT CONCENTRATION AND FOAM STABILIZER ON THE FOAMING CAPACITY AND PHYSICAL PROPERTIES OF TOMATO POWDER AT DRIED AT DIFFERENT TEMPERATURE

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https://doi.org/10.55251/jmbfs.4741

ARTICLE INFO

Received 4. 5. 2022
Revised 5. 11. 2022
Accepted 22. 11. 2022
Published 1. 2. 2023

Regular article

OPEN ACCESS

ABSTRACT

This study aimed to develop natural colorant tomato powder using foam mat drying method varying egg albumin (3, 5, and 7% w/w) as foaming agent, carboxymethyl cellulose (0.5% and 1%) as foam stabilizer concentrations and dried at three various temperatures (60, 65, and 70 °C). The foaming properties of tomato juice and powder properties of foam mat dried tomato juice powder were analyzed. Foams were prepared using tomato juice, incorporating egg albumin (EA), carboxymethyl cellulose (CMC), and whipped thoroughly at maximum speed for about 5 min. The foam stability and foam expansion were increased from78.4 to 92.1%, and 415.33% to 691.56%while foam density was reduced from 0.2 to 0.139 g/cm3 as air was incorporated into foam. Results showed that 7% egg albumin and 1% carboxymethyl cellulose had good foam expansion, foam stability, and foam density. Among color parameters, redness (a*) increased while lightness (L*) and yellowness (b*) decreased with the increasing temperature. The water solubility index increased from 25.43% to 47.44% with the increasing EA and CMC concentrations and drying temperature. However, the water absorption index decreased with increasing CMC and EA concentrations. The rehydration ratio of tomato powder ranged from 3.22±0.007 and 4.25±0.05 and rose with increasing temperature due to formation of more porous structure. The result showed that 7% EA, 0.5 % CMC concentration, and 70 °C drying temperature of foam produced red colorant tomato powders with good quality characteristics. Obtained powders can be easily converted into juice by reconstitution and used to prepare different value-added products like ketchup, sauce, chutney, etc.

Keywords: Carboxymethyl Cellulose (CMC), Egg Albumin, Foam Expansion, Foam Density, Foam Stability, Water Absorption Index (WAI), Water Solubility Index (WSI)

INTRODUCTION

Tomato (*Lycopersicon esculantum* M.) is a vital vegetable crop belonging to the Genus Lycopersicon under the Solanaceae family **(Farooq et al., 2020)**. Researchers found that tomatoes have greater bioavailability after processing. Tomatoes are highly nutritious and contain carbohydrates, fiber, essential amino acids, flavoring compounds, proteins, vitamins, organic acids, phosphorous, calcium, dietary fibers, nutrients, β-carotene, glycoalkaloids, and antioxidants, for example, lycopene, phenolics, etc**. (Mehta, 2017).** Tomatoes also provide other beneficial functions, such as anti-thrombotic and anti-inflammatory functions **(Garg et al., 2020)**. Over the past four decades, the world's crop production has increased by around 300 percent because of its potential health benefits **(Silva *et al*., 2017).** About 387653 metric tons of tomato were produced from 69697 acres of land in Bangladesh during 2018-19 **(BBS, 2020).**
As a climacteric fruit, tomato has a brief shelf-life, typically 8-12 days **(Islam *et al*., 2016)**. It is incredibly perishable because of its high moisture content (93-95)%, which poses a significant challenge for handling and transport, causing severe losses **(Hossain et al., 2021)**. In order to be available in the off-season, it must be developed into stable products. A variety of methods are used to conserve tomatoes. Among these, drying is the oldest method **(Radojčin et al., 2021).** Drying is one such technology that decreases the water content, thus achieving a degree of water activity in food that does not promote bacteria and mold growth **(Varhan et al.,** 2019). It also aims to decrease bulk density and minimizes the cost of packaging, transportation, and shipping **(Dehghannyaet al., 2018)**. Different drying methods, namely convective drying, freeze drying, spray drying, vacuum drying, drum drying, and foam mat drying, have been used to process instant beverage powder **(Cheng et al., 2017; Hardy & Jideani, 2017; Radojčin et al., 2021).** Among these, freeze-dried products reduce microbiological reactions and give better quality products, but these are more expensive and time-consuming. While spray drying saves time, it may degrade the quality of the finished product. **(Shen et al., 2021).** The easiest and economical way to dry is by hot air convective drying, but the consistency of the dried product is poor **(Sharma** et al., 2021). Drum drying is used where high heat is required, but this results in an unenviable cooked tang and a significant reduction in the finished product's consistency **(Affandi *et al*., 2017).**
The foam mat drying process is less costly, more convenient, and associated with less product quality deterioration than other drying methods **(Tan & Sulaiman, 2020)**. Foaming liquid and semi-solid substances is a well-known technique to reduce drying time **(Tavares et al., 2020).** It is appropriate for drying viscous products that are generally hard to dry **(Qadri et al., 2020).**
In foam mat drying, liquid and semi-solid materials are spread over a tray to form a durable foam, combined with a stabilizing and foaming substance, varying drying temperatures and also the dried material is scraped and ground to gain powders **(Izadi et al., 2020)**. Foamed materials have higher drying rates than other materials because lower foam density significantly reduces the mass load of foam mat dryers **(Kadam & Balasubramanian, 2011).** In addition, the process results in a product that, relative to non-foamed products, has improved reconstitution and better consistency **(Li et al., 2020).** A variety of factors are accountable for the development of stable foam, such as foaming agent (egg albumin), foam stabilizer (carboxy methylcellulose), whipping time, air incorporation process **(Kadam et al., 2012).**The foam density decreased with increasing ovalbumin concentration, resulting in increasing its expansion and durability. The solubility index decreased as air temperatures, ovalbumin concentrations, and foam thickness increased, while the water absorption index increased **(Dehghannya et al., 2019).**
Previous research has found that tomato powder formed from foam mat drying produces a high-concentration β-carotene, lycopene, ascorbic acid, and antioxidant compound, improving the quality of a variety of foods **(Hossain et al., 2021)**. However, little attention was given to the foaming properties as well as the physical properties of final products. Hence, the present work aims at the determination of the effect of foaming agent (egg albumin) and stabilizer (carboxymethyl cellulose) concentrations and drying air temperatures (60, 65, and 70 °C) on foaming properties of tomato juice, drying properties of foamed tomato juice and powder properties (density, color, water solubility index, water absorption index) of the final products.

MATERIALS AND METHODS

Sample Preparation

Fully mature, natural red-colorant, free of defects or cuts, locally popular Raja hybrid variety tomatoes were collected from the local market in Sylhet (Modina Market), Bangladesh. Tomatoes were carefully washed under running water to remove any dirt and sorted to gain a standard and high-quality product. Then, tomatoes are manually sliced into four pieces with a knife **(Ranganna, 1995).**

Juice preparation

Tomato juice was extracted using a juice maker (Panasonic, MJ-M176P, Malaysia)**,** which separates skin and seeds. The tomato juices were pasteurized at 75 °C for 10-11 min followed by immediate cooling. Then the juice was agitated to ensure no sediment in the juice **(Franco et al., 2016).**

Foam preparation

The foam was prepared by a stand mixture (Miyako, MR-1047, 1200 watt, Japan). 300 mL of juice mixture was taken, and egg albumin with different 3, 5, and 7% concentrations as foaming agent and 0.5% and 1% laboratory-grade carboxymethyl cellulose were added. The juice mixture was whipped thoroughly at maximum speed, about 5 min, and foam was prepared. The prepared foam was used for further analysis and drying**(Chandrasekar et al., 2015).** The entire research design has been presented in Figure 1.

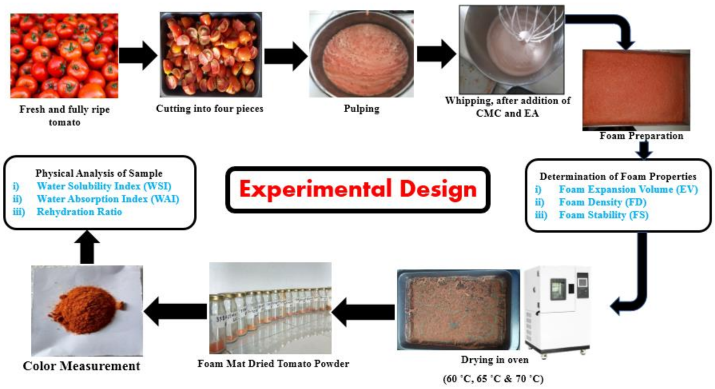

Figure 1 Schematic diagram of the experimental setup

Determination of foam properties

Foam Expansion Volume (EV)

The foam expansion volume denotes how much air is introduced into the juice while foaming and is expressed as a percentage increase in juice volume. The following formula was used to measure the foam expansion**(Aktas & Tontul, 2021):**

$$\text{Foam Expansion (\%)} = \left(\frac{\text{Vf}-\text{Vi}}{\text{Vi}}\right) \tag{1}$$

where,

V_i= Initial volume of tomato juice (cm^3); V_f= Final volume of tomato foam (cm^3)

Foam Density (FD)

The FD was determined as a ratio of mass to volume and was expressed in grams per cubic meter. Immediately after the preparation of foam, 100 mL of foam was measured after being shifted into a 250 mL measurement cylinder. Foam transfer was carried out very cautiously to ensure that the foam structure was not destroyed. Equation 2 was used to measure the foam density**(Izadi et al., 2020):**

$$\text{Foam Density (g/cm}^3\text{)} = \frac{\text{Weight of foam(g)}}{\text{Volume of foam}(cm^3)} \times 100 \tag{2}$$

Foam Stability

The stability of foam was calculated by taking the foamed juice in a transparent graduated measuring cylinder. It was kept for 2 hours at 25-27 °C. The reduction of foam volume was noted after 2 hours. The percentage of foam stability was determined by using Equation 3 **(Tan & Sulaiman, 2020):**

$$\text{Foam Stability (\%)} = \frac{\text{Vf}}{\text{Vi}} \times 100\% \tag{3}$$

Where,

V_i= Initial volume of the foam at time zero; V_f=Final volume of foam after 2 hours

Drying of Foamed Tomato Juice

The foamed tomato juice was formulated using the optimized parameters of foaming. The foam was then spread in a 10-mm-height stainless steel plate and subjected to oven drying at air temperatures of 60, 65, and 70 °C (Oven dryer, GE-83H, Malaysia). When the sample's weight reached at constant levels, drying was stopped. The dried foam was scraped, packaged in glass bottles, and processed for consistency determination at room temperature. Tomato juice took 780, 750, and 710 min to dry at 60, 65, and 70 °C, respectively.

Color Measurement

One of the most visible sensory properties of food items is their color. The colorimeter was used to evaluate the color of dried powder samples (PCE-CSM4, Germany) and was reported in CIELAB color scales **(Guiné & Barroca, 2012).** The lightness index (L*) is a number that ranges from 0 (black) to 100 (white). The parameter a* represents red color when the value is positive (0 to 60), and green color when the value is negative (0 to −60). The b* value represents yellow (0 to 60) and blue ones (0 to −60) **(Moniri et al., 2020).** The total color change (ΔE) estimated the cumulative color difference between dry samples and fresh tomatoes. The following equation 4 was used to measure theΔE**(Dehghannya et al., 2018):**

$$\Delta E = \sqrt{(L_0 * - L *)^2 + (a_0 * - a *)^2 + (b_0 * - b *)^2} \tag{4}$$

Where,L_0 *= lightness,a_0 *= redness and b_0 *= yellowness values of the fresh ripe tomato samples.

The fresh ripe tomato samples were used as the reference, and a higher ΔE indicates a more significant color difference from the reference content. Before analyzing the sample, a white-colored tile was used for calibration. The samples were measured in triplicate, and the mean was reported **(Asokapandian et al., 2016).**

Water Solubility Index (WSI) and Water Absorption Index (WAI)

At 30 °C, 2.5 g of dry powder was poured into 30 mL of water and stirred periodically for 30 minutes. The solution was then centrifuged for 30 minutes at 4000 rpm. After that, the supernatant was moved gently into a Petri dish followed by dried overnight. Equation 5 was used to measure the solubility index based on the percentage of solids in the dry supernatant relative to the weight of the original sample**(Dehghannya et al., 2019).**The volume of wet solid left after centrifugation was used to calculate the water absorption index according to the Equation 6 (Asokapandian *et al*., 2016).

$$\text{WSI(\%)} = \frac{\text{Weight of dry solid after centrifugation}}{\text{weight of initial dry sample}} \times 100\% \tag{5}$$

$$\text{WAI} = \frac{\text{Weight of wet solid after centrifugation}}{\text{weight of initial dry sample}} \tag{6}$$

Rehydration Ratio and Quality Evaluation of Tomato Powder

The rehydration ratio is the weight of the rehydrated tomato powder divided by the weight of dehydrated tomato juice powder. The rehydration ratio is modified by **(Kadam & Balasubramanian, 2011)** and determined as follows:

$$\text{Rehydration Ratio} = \frac{A}{B} \tag{7}$$

where, the weight of rehydrated sample is A, and the weight of dehydrated sample is B.

To make rehydrated tomato juice, 2.5 g of foam mat dried tomato powder was dissolved in 11 g of water and stirred for 15 min. A hand refractometer was used to determine the total soluble solids (TSS) of rehydrated tomato juice in °Brix. A digital pH meter was used to determine the acidity or alkalinity of tomato juice **(Tan & Sulaiman, 2020).**

Statistical Analysis

Data were analyzed using well developed statistical program SPSS (SPSS Inc., Chicago, IL, USA), version 25 of Windows. All findings were stated as the mean ± standard deviation (SD) of triplicate measurements. The mean comparison was analyzed using one-way analysis of variance (ANOVA) and Duncan's multiple range test (DMRT). Statistically significant differences were described as those with p-values less than 0.05.

RESULTS AND DISCUSSION

Foam Expansion

Foam expansion can be defined as the air added into the solvent during the foaming process **(Balasubramanian et al., 2012)**. The preliminary volume of tomato juice and the final volume of foam were used to calculate the foam expansion and measured as a percentage **(Sangamithra et al., 2015).** Upon applying various combinations of foaming agent and foam stabilizer, the foam expansion ranged from 415.33% to 691.56%. From Figure 2(a), it was found that for 0.5% CMC and 3% egg albumin the foam expansion was 484.5%, which was 66% greater than 1% CMC and 3% egg albumin. Similarly, it has been seen that at fixed egg albumin concentration, greater foam expansion was observed at 0.5% CMC than 1% CMC.

The foam was expanded with the increasing foaming agent concentration but shrunk with the increasing CMC concentration. This rise in foam volume might be due to the proteins present in egg albumin (EA). Proteins have better foaming capacity and consistency, which results in the formation of a cohesive elastic adsorbed layer due to their hydrophobic nature and confirmative rearrangements **(Asokapandian et al., 2016). Affandi et al. (2017)** studied with egg albumen (2.5-15%), methylcellulose (0.5–1%) and found foam expansion ranged from 45% to 328%. They stated that the foam expansion was expanded with the increasing level of foaming agent concentration. This type of result was found for sapota pulp, where foam expansion value increases from 22.45 to 75% **(Durge et al., 2016).** gain, the foam expansion was increased from 78.2 to 104 %, with an increase in protein concentration from 10 to 30% for mixed vegetables (bitter gourd, cucumber, tomato juice)**(Chandrasekar et al., 2015).**

Foam Stability

The stability of foam represents how much the foam remains stable without the draining of liquid from the foam **(Franco et al., 2016).**If the foam stability is not sufficient, the drying period will be extended, and the finished product's quality will be decreased **(Benković et al., 2019)**. The key aim of foam mat drying is to achieve a stable foam structure. Physical stabilization is necessary to achieve higher drying rates and faster removal of the dried material from the tray **(Franco et al.**, 2015).Because the expanded foam contains a higher concentration of smaller bubbles, a lower density of foam may quickly collapse **(Tan & Sulaiman, 2020).** Foam stability was varied with the various combinations of egg albumin and carboxymethyl cellulose's concentration. Foam stability was the highest 92.1% for 7% egg albumin and 1% CMC, and lowest 78.4% for 3% egg albumin and 0.5% CMC. In all cases, the foam stability of foam prepared by 1% of CMC was about 9% greater than 0.5% CMC concentration. From Figure 2(b), it is clear that the foam stability was increased with the increasing egg albumen concentration. Also, foam stability rises as the amount of foam stabilizer increases, since at low egg albumen concentrations, the interface layer is fragile and can collapse quickly. The CMC concentration also affected the foam stability of the foamed tomato juice. The increased rate was observed for higher CMC concentration as methylcellulose stabilized the foam structure. Similar outcomes were described by **Rajkumar et al., (2007). Gupta (2011)** observed that the maximum stability of 97.87% of foamed grape concentrate was found at 12 % egg albumen, 0.5 % methylcellulose, and 9 min whipping time, where the minimum foam stability 90.24% was found at 0% egg albumen, 0.1 % methyl cellulose concentrations and 9 minutes whipping time. **Chandrasekar et al., (2015)** reported that foam stability increased from 67.7 to 82 % with increased protein concentration for mixed vegetables (bitter gourd, cucumber, tomato juice).

Foam Density

In most cases, foam density is used to assess whipping qualities—the greater the amount of air incorporated during whipping, the lesser the foam density. Also, the greater the amount of air in the foam, the greater the whipping ability **(Falade & Olugbuyi, 2010; Sangamithra et al., 2015).** The experimental values for foam density were ranged from 0.14 to 0.2 g/cm^3. From Figure 2(c), it is seen that for 0.5% CMC and 3% egg albumin, the foam density was 0.14 g/cm^3, which is less than 1% CMC and 3% egg albumin. Similarly, it was found that for fixed 5% and 7% egg albumin, foam density was reduced with increasing CMC concentration. The egg albumen concentration and methylcellulose concentration have not significant effect ($p<0.05$) on foam density.
High egg albumen content reduces the foam density as the surface and interfacial tension of the liquid is reduced, which forms an interfacial film **(Tan & Sulaiman, 2020).** Egg albumin and CMC concentration can be shown to have a comparable impact on foam density to the foam expansion volume since the responses are linked to each other **(Affandi et al., 2017). Chandrasekar et al. (20**15) reported that foam density reduced from 0.2 to 0.17 g/cm^3 with an increase in protein concentration from 10 to 30% for mixed vegetables (bitter gourd, cucumber, tomato juice). The foam density ranged from 0.502 to 0.709 g/cm^3 for the treatment of Soy Protein Isolate series (SPI) for muskmelon pulp **(Asokapandian et al., 2016).**

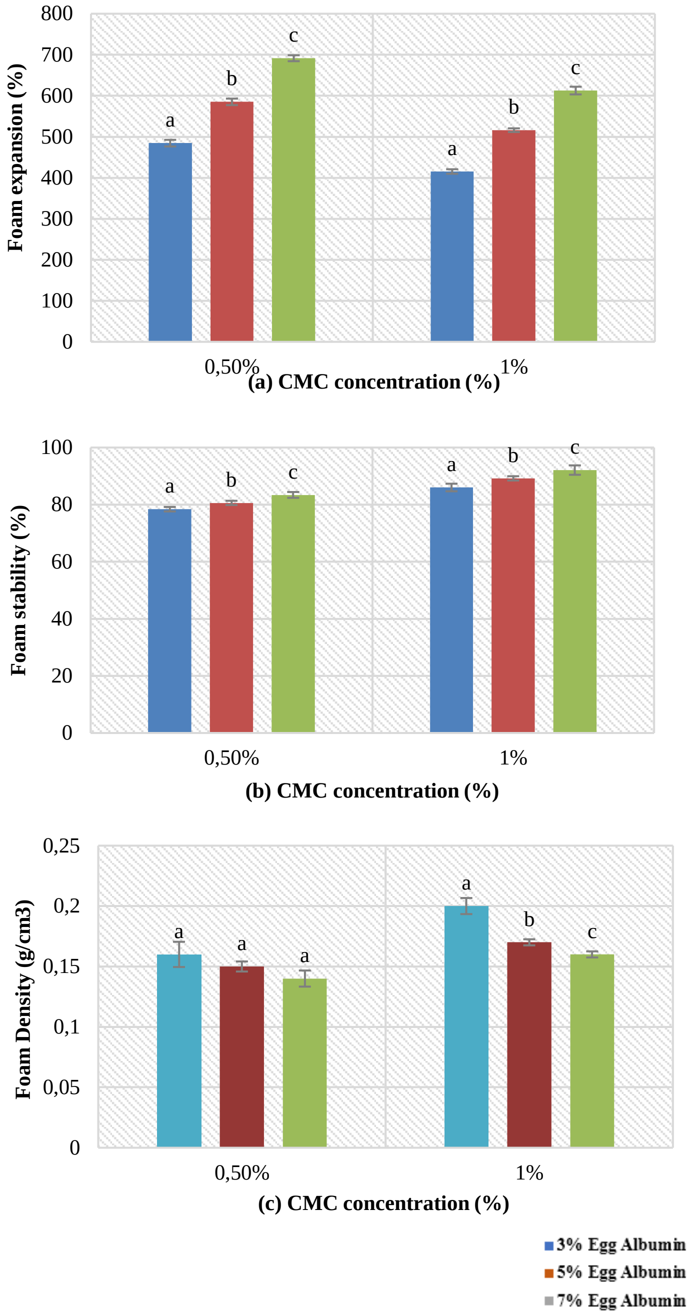

Figure 2 (a) Foam expansion (%), (b) Foam stability (%), and (c) Foam density (g/cm^3) of tomato juice for different foaming agent concentration

Color Measurements

L*, a*, and b* values of the fresh tomato were 40.76,19.27, and 22.23, respectively. In terms of L*, a*, and b* values, Table 2 shows the color values of foam-mat dried tomato powder dried at various temperatures.

L* Value

The L value ranged from 43.82±0.58 to 61.67±0.56, with the L value decreased as the drying temperature increased. It was also reported that a higher concentration of foaming agent had a greater lightness value than lower concentrations of egg albumin **(Asokapandian et al., 2016; Kadam et al., 2010).**As high energy is transmitted to the food content by the high air temperature, the rate of degradation in color became quicker, as shown by the lower L* value at increasing drying temperatures. **Karabulut *et al*. (2007)** stated that the development of brown pigment during drying might be related to a decrease in the L* value. It was found that grape also showed a similar decrease in L* value **(Gupta and Alam, 2014; Asokapandian *et al.*, 2016).** Egg albumen was white in color, and the existence of air in the product caused an increase in L* volume. This was true for muskmelon fruit **(Tan & Sulaiman, 2020).** The introduction of air into muskmelon powders decreased the lightness due to an increase in L* value caused by the foaming process **(Sangamithra et al., 2015).**

a and b* Value*

The a* value represents the degree of redness (0 to 60) or greenness (0 to −60), whereas the b* value represents yellowness (0 to 60) or blueness (0 to −60). The range of a* value is 23.13±0.14 to 28.85±0.09. The values of a* increased with increasing drying temperature, EA, and CMC concentration, which could be attributed to chlorophyll and other pigment degradation and non-enzymatic reactions that turned the samples more reddish. The best result (28.85) was found at 70 °C, 1% CMC, and 7% egg albumin. It was found that 70 °C drying temperature can help to achieve improved color results. A similar result was found by Kadam & Balasubramanian (2011). The b* value was reduced with the increasing drying temperature, EA, and CMC concentration. The b* value ranged from 21.29±0.07 to 26.89±0.13 in dried tomato powder. **(Farooq et al., 2020)** suggested that carotenoid degradation and Maillard reaction take place during drying, which may cause a color change.

The total color difference (ΔE)is a combination of the L*, a*, and b* values, widely used to describe the color variance in foods during processing. The color difference parameter has increased from 8.94±0.14 to 19.15±0.11 due to an improvement in temperature from 60 to 70 °C and foaming properties. The statistical study also revealed that the color values differed significantly depending on the drying temperature.

Table 1 Color of foam mat dried tomato powder at different drying temperature, foaming agent and foam stabilizer concentration

Drying Temperature (°C)	CMC Concentration (%)	Egg Albumin Concentration (%)	L*	a*	b*	Color difference ΔE
60	0.5	3	53.17±0.144^{h}	23.13±0.14^{a}	23.25±0.184^{def}	13.53±0.12^{f}
		5	54.12±0.188^{i}	23.32±0.12^{ab}	23.53±0.47^{fg}	14.34±0.48^{g}
		7	55.20±.0.105^{j}	23.73±0.24^{bc}	24.39±0.12^{hi}	15.26±0.05^{h}
	1	3	58.87±0.105^{l}	24.12±0.08^{cd}	26.18±0.23^{j}	19.15±0.11^{k}
		5	61.23±0.21^{m}	24.31±0.065^{d}	26.10±0.53^{j}	21.47±0.16^{m}
		7	61.67±0.56^{m}	24.88±0.12^{ef}	26.89±0.13^{k}	22.13±0.13^{n}
65	0.5	3	51.35±0.31^{f}	25.32±0.23^{f}	21.98±0.12^{b}	12.18±0.08^{de}
		5	52.20±0.1^{g}	26.32±0.09^{g}	23.35±0.05^{ef}	13.48±0.24^{f}
		7	54.09±0.79^{i}	26.17±0.16^{g}	24.30±0.58^{hi}	15.15±0.05^{h}
	1	3	51.25±0.22^{ef}	24.62±0.23^{de}	24.09±0.31^{gh}	12.08±0.21^{d}
		5	57.29±0.35^{k}	25.21±0.27^{f}	24.27±0.84^{hi}	17.67±0.21^{i}
		7	58.20±0.17^{l}	25.10±0.14^{ef}	24.85±0.73^{i}	18.39±0.06^{j}
70	0.5	3	46.12±0.77^{b}	26.35±0.16^{g}	21.29±0.07^{a}	8.94±0.14^{a}
		5	48.36±0.29^{c}	27.68±0.89^{h}	22.67±0.33^{de}	11.34±0.07^{c}
		7	49.55±0.44^{d}	28.02±0.74^{h}	24.15±0.14^{ghi}	12.55±0.14^{f}
	1	3	43.82±0.58^{a}	28.57±0.11^{i}	22.17±0.18^{bc}	9.79±0.06^{b}
		5	48.81±0.82^{cd}	28.72±0.07^{i}	22.57±0.36^{bc}	12.44±0.20^{ef}
		7	50.51±0.69^{e}	28.85±0.09^{i}	22.70±0.07^{de}	13.67±0.12^{f}

Mean ± standard deviation (n = 3); ^{abcdefghijk}column—means within the different superscript letter indicate significant difference at different drying temperature and foaming concentration ($p < 0.05$)

Water Solubility Index (WSI) and Water Absorption Index (WAI)

The WSI measures the quantity of soluble elements released from the sample**(Dehghannyaet al., 2018).** On the other hand, the water absorption index is the weight of the water absorbed per gram of dry sample. This is directly related to hydration capacity **(Asokapandian et al., 2016).** A suitable powder can be identified by its complete wettability in a short amount of time. It also can sink instead of floating and dissolve without creating a cake **(Jafari et al., 2017).** Drying conditions and foaming properties largely affect powder dissolution (Franco et al., 2015). Table 2 shows that the WSI and WAI ranged from 25.43 ± 0.19% to 47.44 ± 0.34%, and 2.24 ± 0.09 to 5.45 ± 0.19 %, respectively, indicating good rehydration capacity (Table 2).

The WSI increased with the increasing drying temperature, as shown in Table 2. When the temperature increase WSI increase by 7.52% and WAI decrease by 3.21%. The reason behind this is that powder with a higher porosity was produced at a higher temperature. Higher porosity resulted in higher powder surface area, resulting in a higher powder-water surface contact area **(Pua et al., 2010). Asokapandian et al. (2016)** showed a similar result: the average WAI was found to reduce with an increase in drying temperature for muskmelon powder using soy protein. The WSI was decreased, whereas the WAI increased with the increasing stabilizer concentration (Table 2). The WSI was reduced by 14.42 %, and the WAI increased by 1.65 % when the CMC concentration was increased from 0.5 to 1%. When foaming agent concentration increased, it resulted in greater surface area of the foamed juice by incorporating more air. However, an increase in foam stabilizers resulted in reduced surface area. Similar results have been reported by **Thirupathi & Rajkumar (2008).**

When the egg albumin concentration was increased from 3 to 7%, the increase in WSI was 3.40%, and the decrease in WAI was 0.76% at 60 °C. Powders with the high WAI may be used as food additives even at low temperatures because of their high water absorption **(Azizpour et al., 2016).** The solubility index calculated in this study is lower than spray dried, drum-dried, and freeze-dried mango powder **(Caparino et al., 2012).**

Table 2 Physical properties of foam mat dried tomato powder at drying temperature and foaming agent concentration

Drying Temperature(°C)	CMC Concentration (%)	Egg Albumin Concentration (%)	Water Solubility Index	Water Absorption Index	Rehydration Ratio
60	0.5	3	39.92±0.10^{def}	3.69 ± 0.09^{bc}	3.22±0.007^{a}
		5	40.23±0.11^{def}	3.09 ± 0.075^{abc}	3.34±0.044^{b}
		7	43.32±0.29^{efg}	2.93 ± 0.04^{ab}	3.46±0.039^{c}
	1	3	25.43±0.19^{a}	5.34 ± 0.09^{d}	3.27±0.03^{a}
		5	27.66±0.39^{a}	4.27 ± 0.34^{cd}	3.41±0.032^{c}
		7	31.61±0.35^{ab}	5.45 ± 0.19^{d}	3.51±0.02^{d}
65	0	3	38.89±0.28^{de}	2.66 ± 0.06^{ab}	3.64±0.015^{e}
		5	39.33±0.33^{de}	2.50 ± 0.12^{a}	3.66±0.001^{e}
		7	44.3±0.47^{f}	2.39 ± 0.04^{a}	3.69±0.005^{e}
	1	3	28.30±0.29^{a}	3.85 ± 0.05^{bcd}	3.69±0.015^{e}
		5	34.45±0.34^{bc}	3.80 ± 0.11^{bcd}	3.76±0.026^{f}
		7	37.30±0.14^{cd}	3.83 ± 0.10^{bcd}	3.82±0.02^{g}
70	0.5	3	46.15±0.07^{g}	2.90 ± 0.13^{ab}	4.12±0.03^{j}
		5	47.15±0.39^{g}	2.53 ± 0.08^{a}	4.21±0.035^{k}
		7	47.44±0.34^{j}	2.32 ± 0.055^{a}	4.25±0.05^{k}
	1	3	34.36±0.17^{bc}	2.42± 0.04^{abc}	3.93±0.03^{h}
		5	40.99±0.36^{def}	2.30 ± 0.09^{a}	3.94±0.02^{h}
		7	43.25±0.15^{efg}	2.24 ± 0.09^{a}	4.00±0.015^{i}

Mean ± standard deviation (n = 3); ^{abcdefghijk}column—means superscript letter indicate significant difference at different drying temperature and foaming concentration ($p < 0.05$)

Rehydration Ratio and Quality

The rehydration capacity of dry material is widely used as a quality criterion **(Shaari et al., 2018).** Table **2** exhibits that the rehydration ratio among the samples was statistically significant ($p < 0.05$). The rehydration ratio of foam mat-dried powder ranged from 3.22±0.007 and 4.25±0.05. The rehydration characteristics are positively correlated with the air temperature and drying treatment. It rises significantly as the rehydration temperature rises from 60°C to 70°C also rises with increasing foaming agent and foam stabilizer concentration **(Tan & Sulaiman, 2020).** The rehydration ratio of dried materials dried at higher drying temperatures was greater than that of dried materials dried at lower drying temperatures. The microstructure of the materials may be related to this case. Dried materials at 70 °C have a more porous structure than dried materials at 60 °C, allowing greater water penetration **(Aral & Beşe, 2016).** The pH and TSS value of rehydrated tomato juice were varied from 4.47 ± 0.04 to 4.68±0.04 and 3.84±0.04 to 4.1 ± 0.03 ˚Brix, respectively, as described by **Hossain et al. (2021).**

CONCLUSION

In this study, tomato powder was successfully prepared by foam mat drying method using different foaming agent sand drying temperatures. Results showed that increasing foaming agent concentration accelerates the foam expansion and foam stability and decreases the foam density. The maximum foam expansion (691.56%) and lowest foam density (0.14 g/cm^3) were obtained at 7% egg albumin and 0.5% carboxymethyl cellulose level. However, the maximum foam stability of 92.1 % was obtained at 7% egg albumin and 1% methylcellulose level. An increase in foaming agent concentration accelerates the drying process, increasing the rehydration ratio of the tomato powders. The physical properties correlated positively with the drying temperature and foaming properties. Overall, it can be concluded that the combination of 7% EA and 0.5% CMC at 70 °C drying temperature was the best to develop foam mat dried tomato powder. It can be used as an ingredient in the food industry to develop value-added products.

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