PERFORMANCE EVALUATION OF FOAM MAT DRYING FOR FORMULATION OF TOMATO POWDER

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Abstract.
The study aimed to determine the optimal drying conditions and foaming agent concentrations for foam mat dried tomato powder while preserving its biochemical properties. The foaming agent used was glyceryl monostearate(GMS), while the foam stabilizer was maltodextrin with different concentrations. Drying temperatures were varied from 60°C to 70°C, and changes in various physicochemical properties were observed, including TSS, pH, ascorbic acid, titratable acidity, β-Carotene, and DPPH radical scavenging activity. The results indicated that drying time decreased with increasing foaming agent concentrations and higher drying temperatures. Overall, the study suggests that the concentration of foaming agent, foam stabilizer, maltodextrin, and temperature play significant roles in determining the physicochemical properties of the food product being analyzed, such as TSS, pH, ascorbic acid, and titratable acidity content. β-Carotene contents increased with the increase of foaming agent concentrations but decreased with increasing temperatures and foam stabilizer concentration. The study found that the DPPH free radical scavenging activity showed an increase as the foaming agent, foam stabilizer, and temperatures were increased. Overall, the optimal treatment of foaming agent was found to be 5% GMS + 1% maltodextrin at 60°C, based on the maximum retention of physicochemical properties. These findings can have implications for the food industry in developing new ways to preserve the nutritional value of food products during the drying process.

Keywords: Foam mat drying, Tomato, Tomato powder, Foaming agent.

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1. Introduction

Tomato is a popular vegetable crop in India and is commonly processed into various food products to increase its shelf life and availability throughout the year. Drying is the most common method of preservation, which reduces the water activity in food and increases its shelf life by inhibiting microbial growth. Among different drying methods, foam mat drying is a less expensive and less time-consuming technique that retains better product quality compared to other methods. This study aims to determine the effective foaming agent and foam stabilizer concentrations for foam-mat dried tomato powder based on its biochemical properties. The resulting powder from foam-mat drying retains the color, flavor, and taste similar to fresh samples and is rich in biochemical composition compared to non-foam dried powder. Foam mat drying is a process that involves whipping a liquid or semi-solid food product with an edible foaming agent and a foam stabilizer to create a stable foam. The foam is then dried in a tray to remove the moisture, and the resulting dried product is scraped off and ground into a fine powder. Compared to other drying methods such as drum drying, freeze drying, and spray drying, foam mat drying is a more cost-effective and simpler process that preserves the nutritional value and quality of the product. Tomato powder produced by foam-mat drying is a good source of essential nutrients and can be used in a variety of food products such as ketchup, sauce, and chutney. By optimizing the concentration of foaming agent and foam stabilizer, the resulting powder can have improved biochemical properties, making it a more desirable product for consumers. In addition to its cost-effectiveness and ability to preserve the nutritional value of the product, foam mat drying also offers several other benefits. It reduces the weight and volume of the food product, making it easier to transport and handle. It also increases the shelf life of the product by reducing the water activity level, which inhibits the growth of microorganisms. Furthermore, foam mat drying produces a product that is similar in color, flavor, and taste to the original fresh sample, making it an ideal choice for food processing. Overall, foam mat drying is a promising method for producing tomato powder with good biochemical properties, and it has the potential to play a significant role in the food industry in the future.

2. Materials and Methods

2.1. Materials

The experiment was conducted in the department of Food Technology, Techno Main Salt Lake, West Bengal, India at average room temperature of 35°C and relative humidity of about 55%. Fresh, Firm, and Red tomatoes were purchased from the local market in Kolkata, West Bengal, India. Glyceryl monostearate (GMS) collected from laboratory (Techno Main Salt Lake, West Bengal, India) used as a foaming agent and Maltodextrin collected from laboratory (Techno Main Salt Lake, West Bengal, India) was used as a foam stabilizer.

2.2. Methods

The process of preparing foam mat tomato powder involves several steps, starting with the washing of fresh tomatoes to remove any unwanted external materials. The tomatoes are then cut and passed through a mixer grinder to obtain tomato pulp, which is then pasteurized at a temperature of 70°C for 3 minutes to ensure microbial safety. Before the formation of foam, the biochemical analysis of fresh tomato juice is performed to identify the relative quantity loss of various nutrients in the tomato juice powder as compared to the fresh juice. This analysis includes the measurement of total soluble solids (TSS), pH, ascorbic acid, titratable acidity, beta carotene, and DPPH. These parameters are essential in determining the nutritional quality and antioxidant potential of the tomato powder. Foaming is achieved by adding a foaming agent and foam stabilizer in different concentrations to the tomato pulp at a whipper. Glyceryl monostearate (GMS) is used as a foaming agent, while maltodextrin is used as a foam stabilizer in varying concentrations. A sample size of 250 mL tomato pulp is taken along with selected concentrations of glyceryl monostearate (3%, 4%, 5% v/v) and maltodextrin (0.5%, 1%). The whipped mixture is then left for 5 minutes at maximum speed to form foam. The concentration of the foaming agent and foam stabilizer plays a crucial role in determining the quality of the foam formed. A higher concentration of foaming agent can lead to the formation of a stable foam with a higher volume, while a higher concentration of foam stabilizer can lead to a more stable foam with improved texture. Overall, the process of preparing foam mat tomato powder involves careful selection of ingredients, optimization of their concentrations, and control of various process parameters to achieve the desired quality of the final product. The resulting tomato powder can be used as a nutritious and convenient ingredient in various food applications. Foaming is a process that involves the incorporation of air into a liquid to produce a foam. In the case of tomato pulp, the incorporation of air results in a lighter and fluffier texture that can be dried more easily. This is because foaming increases the surface area of the liquid, which promotes faster drying. After foaming, the tomato pulp was poured into a tray and placed in a tray dryer for drying. The tray dryer is an equipment commonly used for drying of food products. The drying temperature was varied at 60°C, 65° C, and 70°C. The drying temperature is an important parameter that affects the quality of the dried product. High temperatures can cause over-drying, resulting in the loss of nutrients and flavor. Low temperatures can cause under-drying, resulting in a high moisture content that can lead to microbial growth. Once dried, the tomato pulp was ground to form a powder. Tomato powder has a longer shelf life compared to fresh tomato pulp. Additionally, tomato powder can be easily reconstituted, making it a convenient ingredient for food processing. The reconstitution of the tomato powder was done using the method of Goula and Adamopoulos (2010) with a few alternations. In this method, 4 g of powder was mixed with 100 mL distilled water in a 100 mL glass beaker at room temperature. The mixture was then agitated with a vortex at high speed. Agitation is necessary to ensure uniform reconstitution of the powder. The reconstituted sample was used to determine several quality parameters such as TSS (Total Soluble Solids), pH, titratable acidity, ascorbic acid, beta-carotene, and DPPH radical scavenging assay. These parameters are important indicators of the quality of the tomato powder. TSS indicates the sweetness of the tomato powder, pH indicates its acidity level, titratable acidity indicates the amount of acid present, ascorbic acid and beta-carotene are important nutrients present in tomatoes, and the DPPH radical scavenging assay measures the antioxidant activity of the powder.

2.3. Determination of Biochemical Properties

2.3.1 Total Soluble Solids

TSS estimation was carried out using a Brix scale hand refractometer. A few drops of the reconstituted sample were placed between the prism and the small covering plate of the refractometer. The reading was determined by observing the position of the shadow line that formed between the brightened and dark areas of the refractometer. The TSS value was obtained from the scale at the point where the shadow line intersected it.

2.3.2 Ascorbic Acid

Moazzem et al. (2019) used their own method to determine the ascorbic acid content in reconstituted foam mat dried tomato powder. A 5 mL sample was taken and made up to 50 mL with 3% HPO3, and then filtered. The filtrate was titrated with 2,6 dichlorophenol-indophenol until it turned pink and the colour persisted for 15 s. A standard ascorbic acid solution was also titrated and the dye factor was calculated using the formula: Dye factor = 0.5/titre.

$$Ascorbic\ acid\ per\ 100\ g = \frac{\text{titre} \times \text{dye factor} \times \text{volume made up} \times 100}{\text{aliquiot extract taken for estimation} \times \text{weight of sample}}$$

2.3.3 pH Determination

The acidity or alkalinity of reconstituted foam mat tomato dried tomato was measured using a digital pH meter. The pH meter determines the concentration of hydrogen ions in a water-based solution, which is used to determine the pH value. The pH value indicates whether the solution is acidic or alkaline, and can be used to assess the quality and safety of food products.

2.3.4 Titratable Acidity

To perform the titration, first, take an aliquot of the sample and dilute it with water to a fixed volume. The addition of phenolphthalein indicator to the solution will cause it to change colour, indicating the presence or absence of an acidic or basic substance. Titrate the solution with 0.1 N NaOH until the pink colour of the indicator persists for 30 seconds. Record the volume of NaOH used for the blank titration and the volume used for the sample titration. Use these values along with the weight of the sample taken to calculate the percentage of titratable acidity using the formula:

$$Total\ acid\ (\%) = \frac{\text{Titre} \times \text{Normality of alkali} \times \text{Equivalent weight of acid} \times 100}{\text{Volume of sample taken for estimation} \times \text{weight or volume of sample taken} \times 100}$$

2.3.5 Beta – Carotene Content

The β-Carotene content of reconstituted foam mat dried tomato powder was measured using the method described by Biswas and Chatli (2011). A test tube was used to mix 1 g of reconstituted tomato juice with 5 mL of chilled acetone. The mixture was shaken intermittently for 15 minutes, and then vortexed at high speed for 15 minutes. The resulting mixture was then centrifuged for 10 minutes at 1370 rpm. The supernatant was collected and the same process was repeated with the remaining compounds, using an additional 5 mL of chilled acetone. The resulting supernatant was filtered using a Whatman No. 1 filter paper, and then mixed with 0.025 g of standard β-Carotene that had been dissolved in 5 mL of acetone and kept in the dark for 10 minutes. The resulting mixture was then analysed using a UV-Vis spectrophotometer at a wavelength of 449 nm (Model-1800, Shimadzu).

$$Weight\ of\ \beta - carotene\ in\ sample = \left(\frac{\text{Weight of β-Carotene}}{\text{Absorbance of standard β-Carotene}} \times \text{Absorbance of sample}\right) \times 1000\ mg$$

2.3.6 DPPH Radical Scavenging Activity

The DPPH radical scavenging activity of a reconstituted sample was determined using the method described by Kalantzakis et al. (2006). Firstly, 2.5 grams of tomato powder was dissolved in 10 mL of 70% methanol in a test tube. The mixture was then vortexed at a high speed to ensure proper mixing and then centrifuged at 3500 rpm for 15 minutes using a centrifuge. The resulting mixture was filtered using Whatman No. 1 filter paper, and the filtrate was transferred into a glass bottle and stored in the freezer for further analysis. For the DPPH radical scavenging activity assay, 1 mL of the extracted sample was taken in a test tube and mixed with 4 mL of DPPH solution. The sample was shaken and left to stand for 30 minutes in a dark place. After 30 minutes, the absorbance of the sample was measured at 515 nm using a UV-Vis spectrophotometer. The percentage of DPPH radical scavenging activity can be calculated using the following equation:

% Scavenging activity = [(Absorbance of control – Absorbance of sample) / Absorbance of control] x 100

This assay is used to determine the antioxidant activity of a sample by measuring its ability to scavenge the DPPH free radical. The higher the percentage of scavenging activity, the greater the antioxidant activity of the sample.

3. Results & Discussion

3.1 Total Soluble Solids

Table 1 presents the total soluble solids (TSS) of different samples at varying drying temperatures. The TSS of fresh tomato pulp was found to be 4.5°Brix, while the TSS in reconstituted foam mat dried tomato powder ranged from 3.84±0.04 to 4.10±0.03°Brix. The TSS in dried tomato powder increased with increasing concentrations of foaming agent and foam stabilizer due to inherent components in GMS. Increasing temperature during drying decreased the TSS content in powder due to heat-sensitive components reduction, as observed in foam mat dried tomato and alphonso mango powders. These findings suggest that the foaming agent and stabilizer concentrations, as well as the drying temperature, can significantly affect the TSS content in dried powders.

Concentrations	**60°C**	**65°C**	**70°C**
3% GMS + 1% Maltodextrin	4.0 ± 0.02^{ab}	3.95 ± 0.02^{abc}	3.88 ± 0.03^{b}
4% GMS + 1% Maltodextrin	4.06 ± 0.04^{c}	3.98 ± 0.03^{bc}	3.90 ± 0.04^{b}
5% GMS + 1% Maltodextrin	4.10 ± 0.03^{c}	4.0 ± 0.05^{c}	3.93 ± 0.04^{b}
3% GMS + 0.5% Maltodextrin	3.98 ± 0.03^{a}	3.89 ± 0.04^{a}	3.84 ± 0.04^{a}
4% GMS + 0.5% Maltodextrin	4.0 ± 0.05^{bc}	3.92 ± 0.03^{ab}	3.88 ± 0.03^{b}
5% GMS + 0.5% Maltodextrin	4.05 ± 0.03^{bc}	3.94 ± 0.04^{ab}	3.90 ± 0.04^{b}

Table 1. Effect of drying air temperature, foaming agent,foam stabilizer on total soluble solids of tomato powder

Mean ± SD of 3 replicates (n = 3) are presented and significant differences ($p < 0.05$) between values in the same column are denoted by different superscripts.

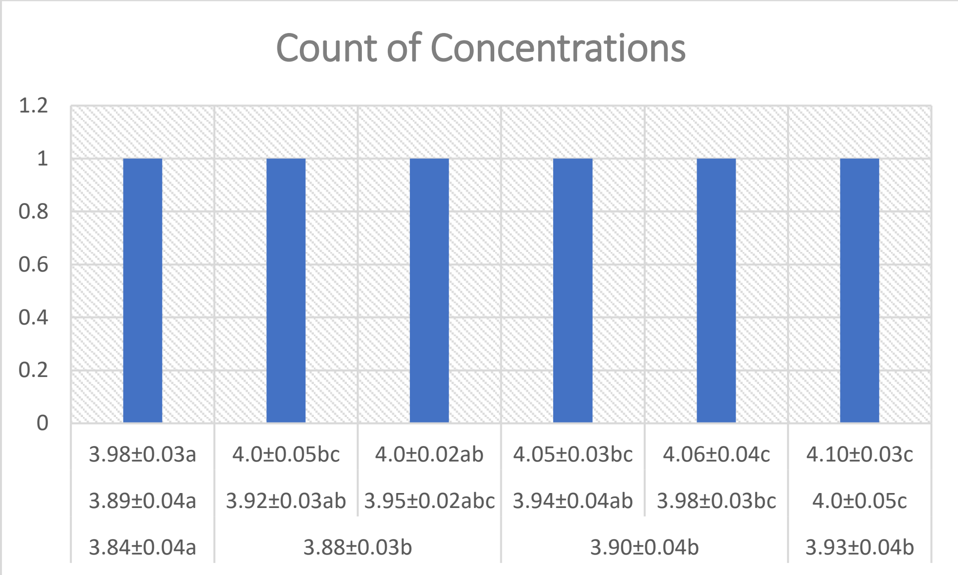

Chart 1. Graphical representation of effect of drying air temperature, foaming agent,foam stabilizer on total soluble solids of tomato powder

3.2 Ascorbic Acid

Ascorbic acid, also known as vitamin C, is a crucial nutrient that plays a vital role in the human body's overall health. However, it is a heat-sensitive, water-soluble vitamin that gets easily degraded during food processing, making it a challenge to determine its presence in processed foods. A recent study revealed that the degradation of ascorbic acid largely depends on the drying temperature used during food processing. The study's findings showed a significant decrease in ascorbic acid content with an increase in temperature. This destruction of heat-sensitive ascorbic acid was observed in various foods, including tomato juice, passion fruit aril, pulses, muskmelon, foam mat dried mango powder, and onion, following heat treatment. Thus, it is crucial to consider the drying temperature in food processing to preserve the ascorbic acid content and ensure that the processed foods are rich in vitamin C, similar to their fresh counterparts. The ascorbic acid content in fresh tomato pulp was significantly higher than in reconstituted foam mat dried tomato powder. The result showed that with the rise of temperature the ascorbic acid content decreased in Table 2.

Concentrations	60°C	65°C	70°C
3% GMS + 1% Maltodextrin	$3.00{\pm}0.03^{c}$	$2.84{\pm}0.04^{d}$	$2.63{\pm}0.05^{d}$
4% GMS + 1% Maltodextrin	$2.86{\pm}0.03^{b}$	$2.66{\pm}0.02^{b}$	$2.51{\pm}0.03^{c}$
5% GMS + 1% Maltodextrin	$2.73{\pm}0.03^{a}$	$2.66{\pm}0.02^{b}$	$2.44{\pm}0.03^{b}$
3% GMS + 0.5% Maltodextrin	$2.96{\pm}0.03^{c}$	$2.76{\pm}0.02^{c}$	$2.59{\pm}0.05^{d}$
4% GMS + 0.5% Maltodextrin	$2.81{\pm}0.03^{b}$	$2.65{\pm}0.05^{b}$	$2.59{\pm}0.03^{d}$
5% GMS + 0.5% Maltodextrin	$2.70{\pm}0.03^{a}$	$2.58{\pm}0.03^{a}$	$2.35{\pm}0.02^{a}$

Table 2. Effect of drying air temperatures, foaming agent, foam stabilizer on ascorbic acid (mg/100 mL) of tomato powder

Mean ± SD of 3 replicates (n = 3) are presented and significant differences ($p < 0.05$) between values in the same column are denoted by different superscripts.

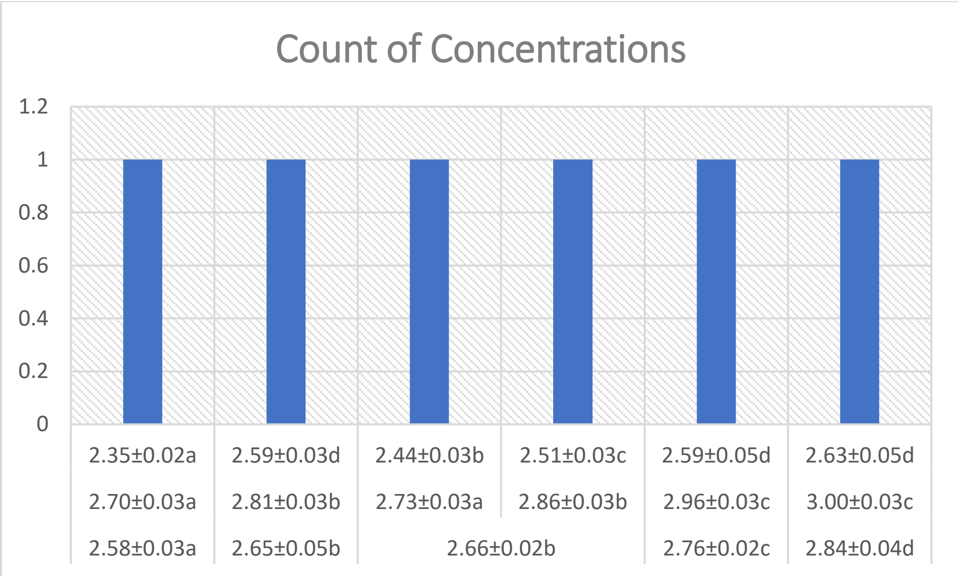

Chart 2. Graphical representation of effect of drying air temperatures, foaming agent, foam stabilizer on ascorbic acid (mg/100 mL) of tomato powder

3.3 pH Determination

The pH level of a product is often affected by the drying temperature, with a lower pH typically being associated with higher drying temperatures. In the case of fresh tomato pulp, the pH was measured at 4.59. However, in the case of reconstituted foam mat dried tomato powder, the pH was found to range from 4.47±0.04 to 4.71±0.04, depending on the concentration of foaming agent and foam stabilizer used. Interestingly, even at very high or very low concentrations of these agents, the pH level remained significant at a 95% confidence level. This is due to the fact that the egg albumin used as the foaming agent has an alkaline behaviour, with a high pH value of around 9 in the alkali range. As a result, when albumin is added to the tomato powder, the pH level rises. Furthermore, it is important to note that an increase in temperature also leads to a rise in molecular vibrations, resulting in a reducing aptitude of forming hydrogen bonds, which leads to an increase in [H+] and a decrease in pH in the reconstituted powder. Overall, the pH level of a product can be influenced by a range of factors, including drying temperature, the use of foaming agents, and temperature during reconstitution.

Concentrations	60°C	65°C	70°C
3% GMS + 1% Maltodextrin	$4.62±0.02^{ab}$	$4.51±0.02^{a}$	$4.49±0.02^{ab}$
4% GMS + 1% Maltodextrin	$4.65±0.03^{bc}$	$4.59±0.04^{bc}$	$4.53±0.06^{ab}$
5% GMS + 1% Maltodextrin	$4.71±0.04^{d}$	$4.66±0.04^{c}$	$4.61±0.02^{c}$
3% GMS + 0.5% Maltodextrin	$4.57±0.03^{a}$	$4.52±0.04^{a}$	$4.47±0.04^{a}$
4% GMS + 0.5% Maltodextrin	$4.63±0.02^{ab}$	$4.57±0.03^{b}$	$4.51±0.03^{ab}$
5% GMS + 0.5% Maltodextrin	4.68±0.04cd	$4.60±0.03^{bc}$	$4.56±0.03^{bc}$

Table 3. Effect of dried air temperatures, foaming agent, foam stabilizer on pH of tomato powder
Mean ± SD of 3 replicates (n = 3) are presented and significant differences ($p < 0.05$) between values in the same column are denoted by different superscripts.

3.4 Titratable Acidity

The titratable acidity of fresh tomato pulp was 0.346%, while reconstituted foam mat dried tomato powder exhibited a range of 0.37±0.01 to 0.39±0.03% (Table 4). The results indicate that as the concentration of foaming agent and temperature were raised, the titratable acidity of the reconstituted powder decreased. Statistical analysis showed that the highest and lowest concentrations of foaming agent and foam stabilizer were significant ($p < 0.05$) at all temperature ranges. Low acidic GMS was used as a foaming agent, which reduced the acidity of the formed powder. The higher drying temperature raised the molecular vibrations and reduced the formation of hydrogen bonds, leading to an increase in the acidity of tomato powder. However, changes in maltodextrin concentration did not substantially affect the acidity of the foam mat tomato powder. Overall, the results suggest that the use of different concentrations of foaming agents and foam stabilizers, as well as drying temperature, can affect the acidity of reconstituted foam mat dried tomato powder. These findings have important implications for the food industry, particularly in the development of new food products and processing methods.

Concentrations	60°C	65°C	70°C
3% GMS + 1% Maltodextrin	0.37 ± 0.01^{cd}	0.38 ± 0.02^{bc}	0.39 ± 0.04^{b}
4% GMS + 1% Maltodextrin	0.37 ± 0.03^{ab}	0.38 ± 0.03^{ab}	0.38 ± 0.01^{ab}
5% GMS + 1% Maltodextrin	0.37 ± 0.02^{a}	0.37 ± 0.02^{a}	0.38 ± 0.04^{a}
3% GMS + 0.5% Maltodextrin	0.38 ± 0.03^{d}	0.39 ± 0.03^{c}	0.39 ± 0.01^{b}
4% GMS + 0.5% Maltodextrin	0.37 ± 0.02^{bc}	0.38 ± 0.01^{ab}	0.39 ± 0.02^{ab}
5% GMS + 0.5% Maltodextrin	0.37 ± 0.03^{ab}	0.38 ± 0.03^{a}	0.38 ± 0.02^{ab}

Table 4. Effect of drying air temperatures,foaming agent,foam stabilizer on titratable acidity of tomato powder

Mean ± SD of 3 replicates (n = 3) are presented and significant differences ($p < 0.05$) between values in the same column are denoted by different superscripts.

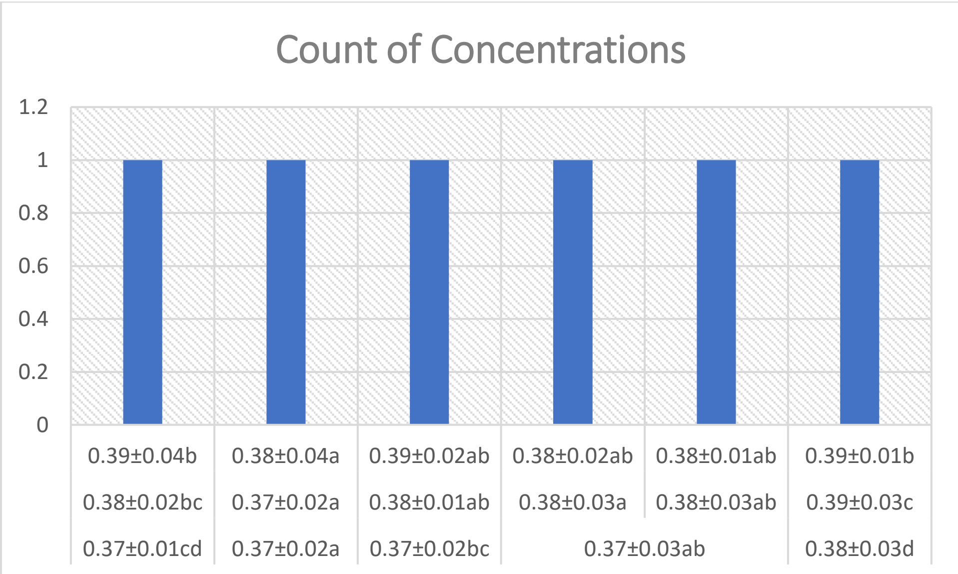

Chart 3. Graphical Representation of Effect of drying air temperatures,foaming agent,foam stabilizer on titratable acidity of tomato powder

3.5 Beta – Carotene Content

The β-Carotene, a crucial provitamin A, is present in fresh tomato pulp at a concentration of 3.13 mg. However, in reconstituted foam mat dried tomato powder, its content ranges from 1.89±0.02 to 2.31±0.02 mg, indicating a significant degradation during processing. The heat sensitivity of β-Carotene is the main cause of its degradation, which is exacerbated by high processing temperatures. The concentration of foaming agent and foam stabilizer used during processing also significantly affects β-Carotene content, with different concentrations producing different results across temperature ranges. Interestingly, increasing protein concentration leads to higher β-Carotene content, indicating a potential approach to mitigate its degradation during processing. These findings are consistent with previous studies that reported the detrimental impact of drying temperature on β-carotene content in cherry tomato and dried Gac aril. Another study found similar results for foam mat dried mango pulp, attributing the increase in β-carotene content to the surface area caused by increasing the foaming agent concentration.

Concentrations	60°C	65°C	70°C
3% GMS + 1% Maltodextrin	2.09±0.03^{b}	1.94±0.03^{b}	1.89±0.03^{a}
4% GMS + 1% Maltodextrin	2.10±0.03^{a}	2.02±0.02^{a}	1.93±0.02^{a}
5% GMS + 1% Maltodextrin	2.27±0.03^{de}	2.14±0.03^{c}	2.10±0.04^{c}
3% GMS + 0.5% Maltodextrin	2.16±0.03^{c}	2.11±0.03^{c}	2.04±0.03^{b}
4% GMS + 0.5% Maltodextrin	2.23±0.03^{d}	2.15±0.02^{c}	2.10±0.04^{c}
5% GMS + 0.5% Maltodextrin	2.31±0.02^{e}	2.26±0.02^{d}	2.19±0.03^{d}

Table 5. Effect of drying air temperatures,foaming agent,foam on β-Carotene content of tomato powder Mean ± SD of 3 replicates (n = 3) are presented and significant differences ($p < 0.05$) between values in the same column are denoted by different superscripts.

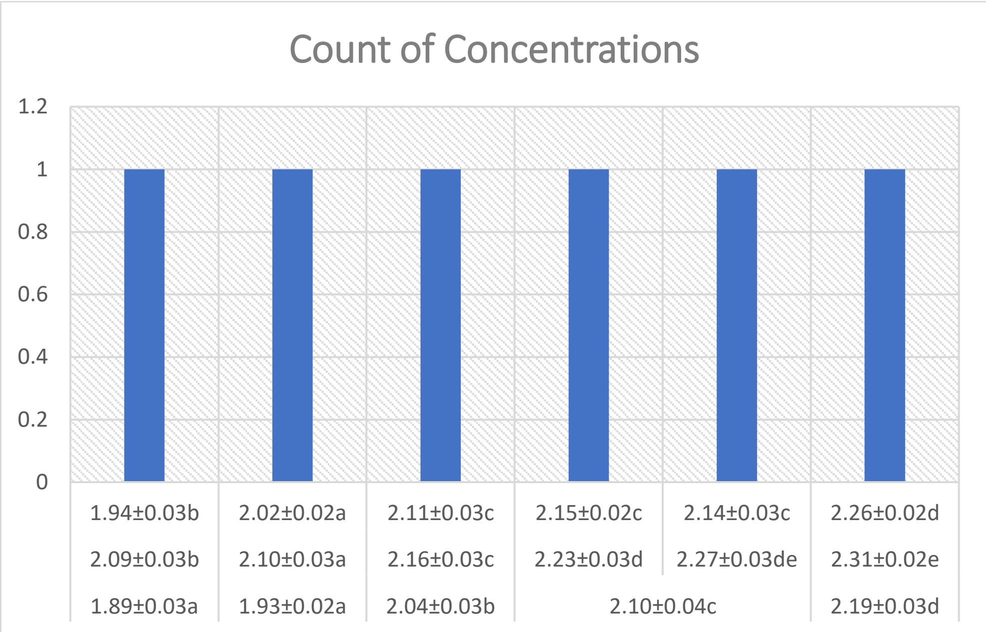

Chart 4. Graphical representation of effect of drying air temperatures,foaming agent,foam on β-Carotene content of tomato powder

3.6 DPPH Radical Scavenging Activity

The antioxidant activity of fresh tomato pulp was found to be 84.136%, while reconstituted foam mat dried tomato powder showed a range of 51.6±2.63 to 71.42±2.46% antioxidant activity. The use of foaming agents and stabilizers significantly increased the antioxidant activity of the reconstituted samples, depending on the processing conditions and product composition. These compounds can undergo various chemical pathways and form different compounds, leading to non-enzymatic browning reactions.

Additionally, the formation of compounds with varying antioxidant activity at different stages of Maillard reactions can be influenced by different temperatures. The findings of this study are consistent with those of previous research conducted by Giovanelli and Lavelli (2002), Turkmen et al. (2006), and Auisakchaiyoung and Rojanakorn (2015). These results demonstrate the potential of using foaming agents and stabilizers to increase the antioxidant activity of reconstituted tomato powder, which could have potential applications in the food industry.

Concentrations	60°C	65°C	70°C
3% GMS + 1% Maltodextrin	57.42±1.75[bc]	62.54±2.82[bc]	63.47±3.42[bc]
4% GMS + 1% Maltodextrin	62.07±2.74[cd]	63.88±3.19[bc]	68.67±2.67[cd]
5% GMS + 1% Maltodextrin	64.09±3.31[c]	67.59±2.26[c]	71.42±2.46[d]
3% GMS + 0.5% Maltodextrin	51.60±2.63[a]	52.22±3.81[a]	56.07±2.9[a]
4% GMS + 0.5% Maltodextrin	56.48±0.03[b]	60.46±4.32[b]	58.71±2.37[ab]
5% GMS + 0.5% Maltodextrin	2.10±2.30[cd]	66.09±1.94[bc]	67.19±3.56[cd]

Table 6. Effect of drying air temperatures, foaming agent, foam stabilizer on DPPH free radical scavenging activity of tomato powder

Mean ± SD of 3 replicates (n = 3) are presented and significant differences ($p < 0.05$) between values in the same column are denoted by different superscripts.

4. Conclusion

This study found that using 5% GMS and 1% maltodextrin as a foaming agent and foam stabilizer, respectively, at a temperature of 60°C resulted in the best quality tomato powder. The use of this combination could provide a viable alternative to traditional tomato preservation methods. However, further research is needed to assess the long-term nutritional properties of the powder.

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