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Review Article

Proximate Composition of Foam Mat-Dried Tomato Powder as Affected by Process Variables: A Review

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Abstract

This study aimed to optimize the production of high-quality foam mat-dried tomatoes. For this study, Box-Behnken experimental design of response surface methodology (RSM) was used for designing the experiments. The independent variables selected for the foam mat drying were acacia gum (1-3%), temperature (60-80°C) and weight of tomato pulp (170-210 g/m^2). The controls were dried at temperature values of 60, 70 and 80°C. The fresh ripe tomato was washed, desked, cut into smaller pieces, pulped before adding the foaming agent and stabilizer then whipped for 7 min. and dried in a rectangular tray at 60, 70, 80°C, scarped, milled and packaged in air tight container. The dependent variables: moisture, ash, fat, crude fibre, crude protein, carbohydrate ranged from 4.23-5.78, 8.17-10.74, 10.04-12.88, 3.58-5.22, 1.11-2.43, 64.35-70.54%, respectively and the control ranged from 9.05-15.54, 10.43-23.61, 8.67-13.21, 1.18-1.70, 1.45-4.09, 49.34-63.40%, respectively. The condition for the optimized samples was 1%, 170-171 g/m^2, 61-63°C, respectively for the concentration of foam stabilizer, weight of pulp and temperature.

Key words: Face centered composite design, foam mat drying, foam stabilizer, tomato powder, tomato preservation

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a widely researched fruit-vegetable due to its numerous health benefits. Studies have shown that tomatoes are rich in essential nutrients such as vitamin C, potassium and dietary fiber[1,2]. Furthermore, tomatoes are a significant source of antioxidants such as lycopene, which has been associated with reducing the risk of chronic diseases such as heart disease and cancer[3,4]. Tomatoes are the fruit of the Solanum lycopersicum plant, which is native to South America. They are a good source of vitamins A and C, potassium and lycopene, an antioxidant that has been shown to protect against various chronic diseases such as cancer and cardiovascular diseases[5]. Boiling tomato pulp or frying it for 30 min increased the lycopene content from 24.2-32.9%, respectively. However, both the beta-carotene and the Vitamin C content significantly $p<0.05$ decreased as boiling or frying period increased between 2 and 30 min[6]. Tomatoes are widely used in the food industry to add flavor and color to various dishes, including sauces, soups and pizzas. However, tomatoes have a short shelf life due to their high-water content and susceptibility to microbial spoilage. As a result, various processing methods have been developed to extend their shelf life and increase their functionality. One of these methods is foam mat drying. Foam mat drying is a method of producing high-quality powders from liquid foods using foam as a drying medium. This method involves the production of foam from a surfactant solution and then mixing the foam with the liquid food to form a foam mat. The foam mat is then dried using hot air, resulting in a dried powder with improved nutritional and functional properties[7]. Foam mat drying has become increasingly popular due to its ability to produce powders with improved solubility, dispersibility and reconstitution properties. It also helps to preserve the color, flavor and aroma of the food product, making it a suitable processing method for fruits and vegetables, including tomatoes.

Egg albumin is a protein that has been widely used as a foaming agent in the food industry. It is known to improve the stability and texture of foams and is commonly used in the production of meringues, soufflés and other baked goods[8]. In foam-mat drying, egg albumin is often added to tomato puree to create a stable foam that can be dried into a powder[9]. The addition of egg albumin can help to improve the quality of the final product by enhancing its rehydration properties and preventing caking[10]. Acacia gum, also known as gum arabic, is a natural polysaccharide that is commonly used as a stabilizer, thickener and emulsifier in the food industry. It is derived from the sap of the acacia tree and is known for its excellent water-solubility and low viscosity[11]. In foam-mat drying, acacia gum is often used as a stabilizer to improve the foam stability and prevent collapse during the drying process[12]. The addition of acacia gum can also improve the rehydration properties of the final product and prevent caking[13]. Several studies have investigated the use of egg albumin and acacia gum in the foam-mat drying of tomato powder. For example, Li *et al.*[14] used a response surface methodology to optimize the foam-mat drying conditions of tomato powder using egg albumin and acacia gum as foaming and stabilizing agents. The study found that the optimal conditions for foam-mat drying were a drying temperature of 70°C, a foaming time of 5 min, an egg albumin concentration of 0.5% and an acacia gum concentration of 0.2%. The resulting tomato powder had good rehydration properties, high antioxidant activity and a bright red color. In another study, Azlan *et al.*[13] compared the nutrient and anti-nutrient composition of foam-mat dried and freeze-dried tomato powder using egg albumin and acacia gum as foaming and stabilizing agents. The study found that foam-mat drying with egg albumin and acacia gum resulted in a higher retention of nutrients such as vitamin C, lycopene and phenolics, compared to freeze-drying.

Response surface methodology (RSM) is a statistical tool used in the optimization of process parameters. It involves the use of a mathematical model to relate the response of interest (in this case, the proximate composition of dried tomato powder) to the input variables (processing parameters)[15]. RSM has been used in the optimization of various food processing methods, including foam mat drying. Response Surface Methodology has been employed to evaluate the effect of process variables on the qualities of plantain and cassava flours[16,17]. By using RSM, it is possible to determine the optimal processing conditions that result in a high-quality product with desired properties. The input variables that are usually optimized include the foam concentration, drying temperature, drying time and foam flow rate. The proximate composition of dried tomato powder refers to the nutrient content of the powder. This includes the moisture content, ash content, protein content, fat content and carbohydrate content. The proximate composition of dried tomato powder varies depending on the processing conditions used during foam mat drying.

Several studies have reported on the proximate composition of dried tomato powder produced by foam mat drying. For instance, Fernandes *et al.*[18] reported that dried tomato powder produced by foam mat drying had a moisture content of 5.7%, ash content of 5.9%, protein content of 14.7. Also, several models research has been done in optimizing the process condition for foam mat dried tomato powder and among these includes: Gonzaga *et al.*[19] optimized the foam mat drying process of pineapple by using response surface methodology (RSM). They found that the optimized conditions for the highest retention of vitamin C and overall acceptability were a foaming agent concentration of 2.5%, temperature of 60°C and pulp thickness of 6 mm. Also, Priyadarshini *et al.*[20] investigated the drying characteristics and quality attributes of foam mat dried jackfruit leather. They found that the optimized conditions for the highest antioxidant activity and overall acceptability were a foaming agent concentration of 3%, drying temperature of 60°C and pulp thickness of 5 mm and lastly Li *et al.*[14] studied the effect of acacia gum concentration and drying temperature on the quality of foam mat dried beetroot powder. They found that the optimized conditions for the highest retention of betalain pigments and overall quality were a foaming agent concentration of 3%, drying temperature of 60°C and pulp thickness of 2 mm. Due to the scarcity of information on this topic this study aimed to evaluate the individual effects of different concentrations of acacia gum, temperature of drying and weight of pulp on the quality of foam mat dried tomato powder. While the current study focused on foam mat dried tomatoes, previous research on the effect of wet heat on moisture content, such as that conducted by Nzelu and Ishiwu[21] on Bambara groundnut flour, can provide insights into the thermal processing techniques used in our study.

MATERIALS AND METHODS

Sources of raw of material: Fresh ripe tomatoes and egg white powder was purchased from Eke-Awka Market, Anambra State Nigeria. Acacia gum of CAS No. 9004-32-4 (food grade) was bought from Altran Chemical Store Nsukka-Nigeria. Other materials that were used include oven, conical flask of various types, blender (Master chef MC-307B), digital weighing balance (AR3130), stainless steel tray and containers.

Experimental design: The central composite face-centered design (CCFC) was used in this study with the help of Design Expert software version 12. Table 1 shows the process variables and their levels. The experimental matrix that was used in this study, based on central composite face-centered design is shown in Table 2. The experimental space had a total of 20 runs. The data obtained from the study was fitted to the second-order polynomial regression model[19] of the form:

$$Y = b_0+b_1A+b_2B+b_3C+b_{11}A^2+b_{22}B^2+b_{33}C^2+b_{12}AB+b_{13}AC+b_{23}BC+e \quad (1)$$

Table 1: Key depicting independent variables and their levels

Parameters	Levels of the factors -1	0	+1
Foaming agent (%) A	1	2	3
Temperature (°C) B	60	70	80
Weight of pulp (g/m²) C	170	190	210

Table 2: Central Composite face centered (CCFC) design matrix and the independent variables and their actual levels and coded values

Samples	Factor 1-3 A: Acacia gum (%)	B: Temperature (°C)	C: Weight of tomato pulp (g/m²)
1	2 (0)	70 (0)	210 (+1)
2	2 (0)	70 (0)	190 (0)
3	1 (-1)	60 (-1)	170 (-1)
4	1 (-1)	60 (-1)	210 (+1)
5	2 (0)	80 (+1)	190 (0)
6	1 (-1)	80 (+1)	170 (-1)
7	3 (+1)	70 (0)	190 (0)
8	3 (+1)	60 (-1)	170 (-1)
9	2 (0)	70 (0)	170 (-1)
10	2 (0)	60 (-1)	190 (0)
11	2 (0)	70 (0)	190 (0)
12	2 (0)	70 (0)	190 (0)
13	1 (-1)	80 (+1)	210 (+1)
14	2 (0)	70 (0)	190 (0)
15	2 (0)	70 (0)	190 (0)
16	3 (+1)	60 (+1)	210 (+1)
17	1 (-1)	70 (0)	190 (0)
18	3 (+1)	80 (+1)	170 (-1)
19	3 (+1)	80 (+1)	210 (+1)
20	2 (0)	70 (0)	190 (0)
21 (control)	-	60 (-1)	-
22 (control)	-	70 (0)	-
23 (control)	-	80 (+1)	-

Values in bracket are the coded values while the ones not in bracket are the actual values

Where:

Y	=	Response parameters
b_0	=	Intercept
b_1-b_{23}	=	Coefficient estimate of the linear, interaction and square terms
A	=	Concentration of foam stabilizer (%)
B	=	Temperature of drying (°C)
C	=	Weight of tomato pulp (g/m²)
e	=	Estimated Error

Sample preparation: Sample preparation and production of foam mat dried tomato powder was carried out in the food processing laboratory at the department of food science and technology, Nnamdi Azikwe University, Awka, Anambra State, while the analysis was conducted in their food analysis Laboratory. Tomato was washed with running tap water to remove unwanted external material such as dust, clay etc.

Then, were cut with a stainless-steel knife and passed through a Blender (ORPAT model: HHB 100E, Ajanta Limited, Morbi, India) to make tomato Pulp. Eggs weighing between 47.2 and 50.7 g which contains about 26.7-28.5 g of egg albumin was added. The egg albumin extract was homogenized for 2 min and used as foaming agent. Foaming was achieved by adding foaming agent at a constant value of 14 g and foam stabilizer in different concentrations at a whipper. Different quantities of tomato pulp were measured, along with the selected concentrations of foam stabilizer and egg albumin which is constant at 14 g. Then the mixers were whipped using hand blender (ORPAT model: HHB 100E, Ajanta Limited, Morbi, India) at a constant time of 7 min.

The foamed tomato pulp was poured in a tray (stainless steel) and placed in an oven dryer (Model: SFKM9051D, 220-240 V~50-60 Hz 1000W) at different temperature rates for drying the different samples. After drying, the dried tomato pulp was ground and sieved to form powder. The reconstitution of powder was done by the method of Bhandari *et al.*[22], with few alternations. For reconstitution, 2 g of powder was mixed with 50 mL distilled water in a 100 mL glass beaker at room temperature and the mixture was agitated with the vortex at high speed. The reconstituted sample was used to determine the amount of TSS, pH, titratable acidity, ascorbic acid, beta carotene.

Determination of moisture content: Moisture content was determined according to the standard methods of Association of Official Analytical Chemists[23]. Stainless steel oven dished were cleaned and dried in the oven at 100°C for 1 hrs to achieve a constant weight. They were cooled in a desiccator and then weighed. Two gram of sample was placed in each dish and dried in the oven at 100°C until constant weight was achieved. The dishes together with the samples were cooled in a desiccator and weighed.

Calculation:

$$\text{Moisture content (\%)} = \frac{w_3 - w_1}{w_2 - w_1} \times \frac{100}{1}$$

Where:

W_1 = Initial weight of the empty crucible
W_2 = Weight of crucible+food before drying
W_3 = Final weight of the crucible+food after drying

Determination of crude protein: Crude protein was determined using kjeldahl method[23]. The test was performed by the Kjeldahl method, 0.5 g of sorghum flour sample was weighted into a 50 mL Kjeldahl flask and 8 mL of concentrated H_2SO_4 was added with 2 g of (copper and potassium sulfate) mixture catalyst. Samples were digested until pure colorless solution was observed. Then, digested samples were distilled by using Kjeldahl distiller and the distilled steam gas (ammonia) was collected with 25 mL of the mixture of 2% boric acid mixed indicator of bromocresol green plus methyl red. The distilled sample was titrated by 0.1 N HCl until the first appearance of the pink color.

$$\text{Total nitrogen (\%)} = \frac{\text{Titre} - \text{(blank)} \times \text{Normality of acid} \times 0.014 \times 100}{\text{Weight of sample}} \times \frac{100}{1} \quad (3)$$

Nitrogen factor = 6.25

$$\text{Crude protein} = \text{Percentage of total N} \times 6.25$$

Determination of fat: The fat content was determined using soxhlet extraction method[23]. A 500 mL capacity round bottom flask will be filled with 300 mL petroleum ether and fixed to the soxhlet extractor. Two grams of the sample was placed in a labeled thimble. The extractor thimble was sealed with cotton wool. Heat was applied to reflux the apparatus for six hours. The thimble was removed with care. The petroleum ether was recovered for reuse. When the flask was free of ether it was removed and dried at 105 °C for 1 hr in an oven. The flask was cooled in a desiccator and weighed.

Calculations:

$$\text{Fat (\%)} = \frac{\text{Weight of fat}}{\text{Weight of sample}} \times \frac{100}{1} \quad (4)$$

Determination of ash content: Ash content was determined according to AOAC[23] procedures. Two grams of sample was placed in silica dish which had been ignited, cooled and weighed. The dish and sample were ignited first gently and at 550°C in a muffle furnace for 3 hrs, until a white or grey ash was obtained. The dish and content were cooled in a desiccator and weighed.

Calculations:

$$\text{Ash content} = \frac{w_3 - w_1}{w_2 - w_1} \times \frac{100}{1}$$

Where:

W_1 = Weight of the empty crucible
W_2 = Weight of crucible+sample before drying
W_3 = Final Weight of crucible+ash

Determination of crude fiber: Crude fiber content was determined using the method of AOAC[23]. Two grams of predefatted samples was transferred into a one-liter 1 beaker and then, a sample was digested in a hot plate for 1 hr with a mixture of an equal volume of 2.5 M H_2SO_2 and 2.5 M NaOH. Then, filtering was performed by moisturizing with a small portion of ethanol. The filtrate was dried in an oven at 100°C until a constant weight was obtained (W_1). Then, the oven-dried samples were again incinerated at 600°C for 3 hrs in a muffle furnace. Then, the incinerated sample cooled at room temperature and reweighed (W_2).

$$\text{Crude fiber}(\%) = \frac{\text{Oven dried sample} - \text{Weight of sample after incineration}}{\text{Weight of sample taken}} \times \frac{100}{1} \quad (6)$$

Determination of carbohydrate content: The Carbohydrate content was determined using the Phenol-Sulfuric Acid method. The Carbohydrate was estimated using the following equation[22].

$$\text{Carbohydrate }(\%) = 100 - \text{protein }(\%) + \text{ash }(\%) + \text{moisture }(\%) + \text{crude fiber }(\%) + \text{fat }(\%) \quad (7)$$

Statistical design and analysis: All Analysis were carried out in triplicate. The data were analyzed using one-way analysis of variance (ANOVA). All statistical analyses were performed using the Statistical Package for Social Science (SPSS) version 23.0 for windows (SPSS Inc., Chicago, IL, USA). The ANOVA was used to determine the statistical significance in the processing variables (Concentration of foam stabilizer, weight of pulp and drying temperature) on the response variables (Proximate properties) of the foam mat dried tomato powder.

Process used to obtain the optimized plot: Design Expert was used to generate the ANOVA, regression, model graphs and numerical optimization was carried out and the limits of the parameters were set based on the desired response variables characteristics. This was followed by the graphical optimization which displayed the optimized plot and proportions for both process variables and response variables. The optimized data were used to produce the foam mat dried tomato powder. The last sample produced was subjected to analyses and the result corroborated with the predicted optimized response variable properties.

Plate 1: Fresh tomato

Plate 2: Foam mat tomato pulp

Plate 3: Foam mat dried tomato powder

RESULTS AND DISCUSSION

Response surface approach was used to evaluate the effect of process variables (Concentration of foam stabilizer, temperature of drying and weight of tomato pulp) on the physicochemical properties of foam mat dried tomato powder.

Table 3: Proximate composition of foam mat-dried tomato powder

Sample	PVC AG	T	WP	Moisture	Ash	Crude Fiber	Protein	Fats and oil	Carbohydrate
1	2	70	210	4.60 ± 0.00^{c}	9.06 ± 0.04^{d}	10.04 ± 0.04^{b}	3.58 ± 0.02^{e}	1.64 ± 0.01^{f}	70.54 ± 0.01^{t}
2	2	70	190	4.36 ± 0.04^{b}	9.44 ± 0.07^{f}	10.23 ± 0.03^{c}	4.03 ± 0.04^{g}	1.84 ± 0.03^{hi}	70.10 ± 0.00^{s}
3	1	60	170	5.50 ± 0.01^{i}	10.56 ± 0.03^{l}	12.81 ± 0.01^{m}	5.18 ± 0.01^{j}	1.60 ± 0.02^{ef}	64.35 ± 0.03^{d}
4	1	60	210	5.44 ± 0.04^{h}	9.07 ± 0.01^{d}	10.53 ± 0.03^{e}	4.03 ± 0.01^{g}	1.76 ± 0.00^{g}	69.17 ± 0.01^{o}
5	2	80	190	4.26 ± 0.01^{a}	8.78 ± 0.06^{c}	12.88 ± 0.04^{n}	4.13 ± 0.01^{hi}	1.22 ± 0.01^{b}	68.73 ± 0.04^{l}
6	1	80	170	4.23 ± 0.02^{a}	9.26 ± 0.04^{e}	10.44 ± 0.01^{d}	3.55 ± 0.04^{e}	1.30 ± 0.01^{c}	71.22 ± 0.03^{u}
7	3	70	190	4.36 ± 0.08^{b}	10.23 ± 0.01^{j}	10.79 ± 0.01^{f}	4.18 ± 0.01^{i}	1.48 ± 0.04^{d}	68.96 ± 0.01^{m}
8	3	60	170	5.30 ± 0.00^{g}	10.66 ± 0.01^{m}	10.25 ± 0.05^{c}	5.91 ± 0.01^{m}	1.12 ± 0.01^{a}	66.76 ± 0.01^{g}
9	2	70	170	4.63 ± 0.02^{c}	9.83 ± 0.04^{i}	10.05 ± 0.01^{b}	5.45 ± 0.01^{k}	1.57 ± 0.01^{e}	68.47 ± 0.03^{k}
10	2	60	190	5.43 ± 0.03^{h}	9.57 ± 0.01^{g}	10.51 ± 0.01^{de}	3.46 ± 0.01^{d}	1.94 ± 0.03^{j}	69.09 ± 0.01^{n}
11	2	70	190	4.78 ± 0.01^{d}	9.50 ± 0.07^{fg}	10.23 ± 0.03^{c}	4.13 ± 0.01^{hi}	1.86 ± 0.01^{i}	69.50 ± 0.01^{r}
12	2	70	190	4.90 ± 0.01^{e}	9.43 ± 0.01^{f}	10.28 ± 0.00^{c}	4.15 ± 0.01^{i}	2.00 ± 0.01^{k}	69.24 ± 0.01^{p}
13	1	80	210	5.78 ± 0.06^{j}	8.17 ± 0.02^{a}	12.17 ± 0.00^{i}	3.78 ± 0.03^{f}	3.28 ± 0.04^{o}	66.82 ± 0.01^{h}
14	2	70	190	4.80 ± 0.01^{d}	9.67 ± 0.03^{h}	10.24 ± 0.06^{c}	4.07 ± 0.06^{gh}	2.25 ± 0.03^{m}	68.97 ± 0.01^{m}
15	2	70	190	4.91 ± 0.01^{e}	9.79 ± 0.01^{i}	10.30 ± 0.07^{c}	4.17 ± 0.01^{i}	1.44 ± 0.01^{d}	69.39 ± 0.01^{q}
16	3	60	210	5.22 ± 0.01^{f}	10.42 ± 0.01^{k}	10.56 ± 0.01^{g}	5.22 ± 0.03^{j}	1.98 ± 0.01^{jk}	66.30 ± 0.01^{f}
17	1	70	190	5.36 ± 0.00^{g}	8.69 ± 0.01^{b}	12.31 ± 0.01^{j}	3.45 ± 0.06^{d}	1.81 ± 0.01^{gh}	68.38 ± 0.01^{j}
18	3	80	170	4.42 ± 0.03^{b}	10.42 ± 0.03^{k}	12.47 ± 0.01^{k}	4.03 ± 0.02^{g}	1.11 ± 0.01^{a}	67.55 ± 0.01^{i}
19	3	80	210	4.96 ± 0.00^{e}	10.74 ± 0.04^{m}	12.48 ± 0.01^{l}	5.57 ± 0.01^{l}	1.82 ± 0.03^{hi}	64.43 ± 0.01^{e}
20	2	70	190	4.95 ± 0.06^{e}	9.49 ± 0.05^{f}	10.29 ± 0.07^{c}	4.08 ± 0.06^{gh}	2.43 ± 0.02^{n}	68.76 ± 0.00^{l}
21 (control1)	-	60	-	15.54 ± 0.02^{l}	16.01 ± 0.02^{o}	13.21 ± 0.01^{o}	1.38 ± 0.03^{b}	1.45 ± 0.04^{d}	53.41 ± 0.01^{b}
22 (control2)	-	70	-	9.08 ± 0.01^{k}	23.65 ± 0.01^{p}	8.67 ± 0.03^{a}	1.18 ± 0.06^{a}	2.08 ± 0.03^{l}	49.34 ± 0.00^{a}
23 (control3)	-	80	-	9.05 ± 0.01^{k}	10.43 ± 0.02^{k}	11.33 ± 0.02^{h}	1.70 ± 0.00^{c}	4.09 ± 0.01^{p}	63.40 ± 0.01^{c}

Values are means of duplicate determinations±Standard Deviation, Values in the same column bearing different superscript differ significantly ($p<0.05$). 21, 22, 23: Control sample, PVC: Process variable combination-Acacia gum (%), Temperature °C, weight of tomato pulp g/m^2

Table 3 shows the Moisture, Ash, Fiber, Protein, Fats and Carbohydrate contents of the foam-mat dried tomato powder. The Ideal regression equation showing the response variables as a function of the independent Variables (Process Variables) is given below:

$$Y = b_0+b_1 A+b_2 B+b_3C+b_{11} A^2+b_{22}B^2 +b_{33}C^2+b_{12}AB+b_{13}AC+b_{23} BC+e \quad (8)$$

Moisture content: The moisture content of oven dried tomato powder ranged from 9.04-15.54% while the moisture content of the foam mat-dried tomato powder ranged from 4.23-5.78% (Table 3). Sample 6 has the lowest moisture content (4.23%) (with foam stabilizer at 1%, weight of tomato pulp at 170 g/m^2 dried at 80°C, respectively) and sample 13 (with foam stabilizer at 2%, weight at 170 g/m^2 dried at 70°C, respectively) has the highest moisture content (5.78 %). Results showed that the process variables helped to further reduce the moisture content of the samples.

Temperature has significant effect ($p<0.05$) on the moisture content of the foam mat-dried tomato powder: The interaction between the processing factors also had not significant effect except for interaction between the temperature and weight. However, the percentage foam stabilizer and weight of wet tomato pulp had no significant effect on the moisture content. The relative low moisture content in the foam mat-dried tomato powder is an indication of storage stability of the product and shows that the process parameters reduced the moisture content when compared with the controls dried at 60, 70 and 80°C, therefore the low moisture content could produce a more shelf stable product. The tomato powder exhibited low moisture content (5.78-4.23). Low moisture value is desirable in baked or dehydrated products such as cookies because it prolonged shelf-life by discouraging microbial spoilage[24]. The moisture content values observed in the present study are lower than that reported by Adejumo[25] (8.05%) for oven dried tomato powder which was dried at 60°C. Adejumo[25] further reported that the drying method and pretreatments used had significant effect ($p<0.05$) on the moisture content of the foam mat-dried tomato powder.

The mathematical model for the moisture content of the tomato powder is presented in Eq. 2, while Fig. 1-3 shows its contours. Moisture content of tomato powder decreased with an increase in foam stabilizer concentration and drying temperature. Temperature decreased moisture content faster than the foam stabilizer because the coefficient of temperature (0.324) is higher than that of the concentration of the foam stabilizer (0.2050). The interaction of concentration of foam stabilizer and drying temperature (AB)

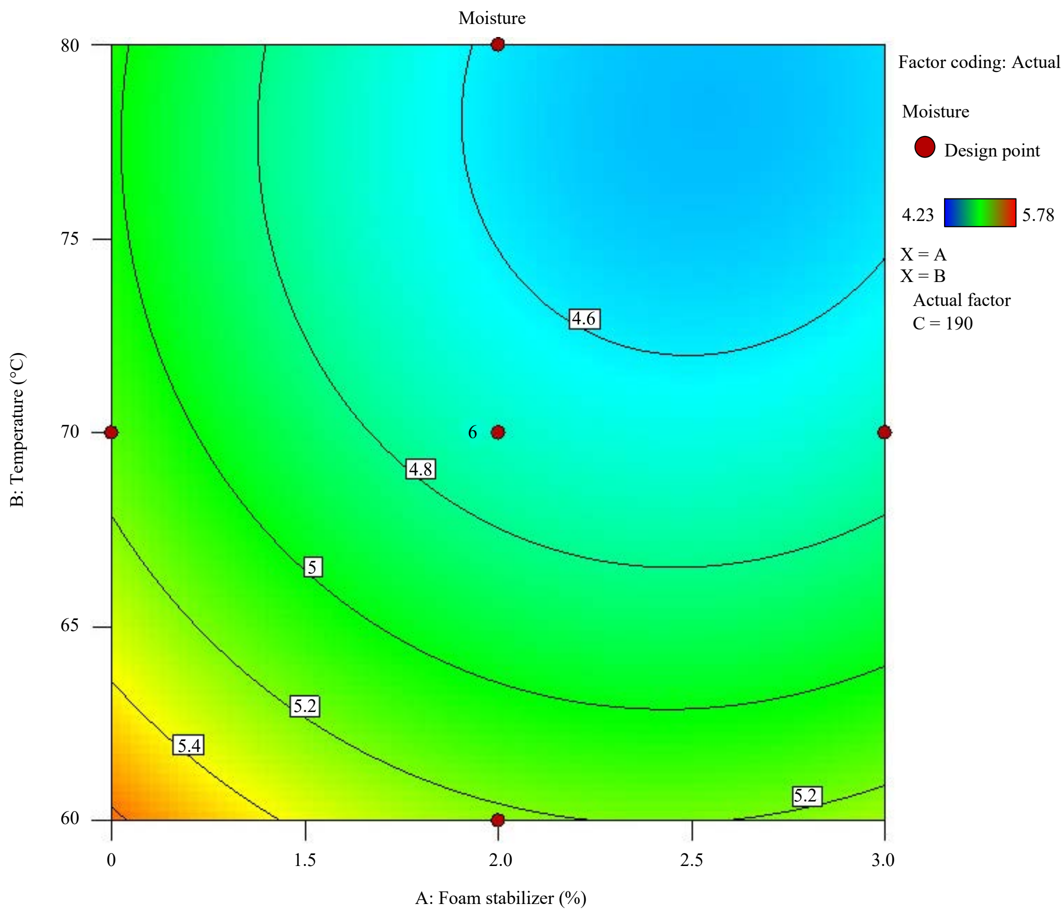

Fig. 1: Contour of interaction effect of temperature and concentration of foam stabilizer on the moisture content of tomato powder

also showed negative coefficient (-0.0263). Contrarily, weight of tomato pulp (C) showed positive coefficient which implies that if the weight of the pulp increased, the moisture content will increase in similar fashion. The interaction of foam stabilizer and weight of tomato pulp (AC) showed negative coefficient, suggesting that it has a decreasing effect on moisture content of the powder. The interaction of the temperature and weight of the pulp (BC) showed positive coefficient (+0.2787). This implies that it caused an increase in the moisture content of the powder. Squares of A and B would increase the moisture content whereas the square of C would decrease the moisture content of the powder.

In Table 4 the value of R^2_{adj} (59.97%) indicates the variance in the moisture content. CV value (5.97%) indicates that the data is relatively close to the mean, with a low level of dispersion.

Figures 1 shows the interaction effect of temperature and concentration of foam stabilizer. As the concentration of foam stabilizer increased from 1.4-2.2% and the drying temperature increased from 63-68°C, the moisture content of the tomato powder decreased from 5.4 -5.2%.

Figure 2 shows that as the temperature increased from 65-75°C and the weight of tomato pulp increased from 174-199 g/m^2, the moisture content of the tomato powder decreased from 4.8-4.2%.

Figure 3 shows that as foam stabilizer increased from 1.3-2.2% and the weight of tomato pulp increased from 171-195 g/m^2, the moisture content of the tomato powder decreased from 5.2-4.8%.

The pearson correlation of the actual and predicted value (0.904) indicates that there is a strong and linear significant relationship between the actual and predicted values of the moisture content with a positive nature. This means that the predicted values are very accurate and reliable and are unlikely to be due to chance. The Pearson correlation coefficient is a measure of the strength of the linear

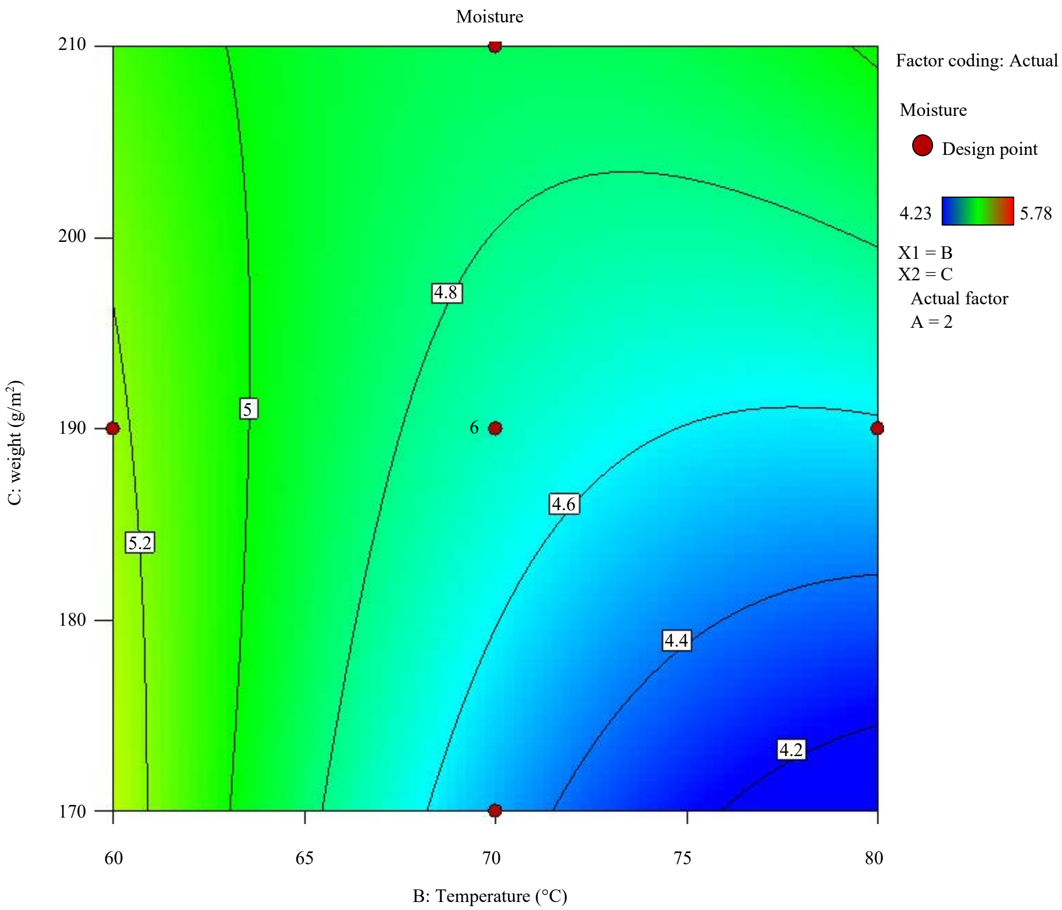

Fig. 2: Contour of interaction effect of weight of tomato pulp and temperature on the moisture content of tomato powder

relationship between two variables. In other words, as the actual values increase or decrease, the predicted values tend to increase or decrease by a similar amount. The significance value at p<0.05 indicates that the observed relationship between the actual and predicted values is highly unlikely to be due to chance.

Ash content: Table 3 shows that the ash content of tomato generally increased in the samples. The Oven dried tomato powder dried at 60, 70, 80°C has the highest ash content of 16.01, 23.15 and 10.43%, respectively. While the ash content of the foam mats dried tomato powder ranged from 8.17-10.74%. Sample 13 (with conc. of foam stabilizer at 1%, weight of tomato pulp at 210 g/m^2 and dried at 80°C) had the lowest ash content (8.17%). While Sample 19 (with concentration of foam stabilizer at 3%, weight of tomato pulp at 210 g/m^2 and dried at 80°C) had the highest ash content. Results showed that the process variables had a significant effect (p<0.05) on the Ash content of the samples when compared with the oven dried samples. Adejumo[25] also found an increase in ash content of dried tomato powder and reported that the ash content of oven-dried tomato samples (dried at 60°C until constant weight was achieved) increased from 1.03% (control) to 2.50% after oven drying. Also, Orhevba *et al.*[26], reported an increase from 10.01-20.5% in ash content of dried tomato powder (using glycerol monostearate). By determining the ash content of the tomato powder, it is insured that it does not contain any toxic minerals. The ash content can also impact the taste, texture and stability of foods so it is vital to know the mineral content for quality control purposes. From Table 4 it can be seen that the foam stability, temperature and weight had significant (p<0.05) effect on the ash content of foam mat dried tomato.

The mathematical model for the ash content of the tomato powder is presented in Eq.10, while Fig. 4-6 shows its contours. The ash content of the tomato powder decreased as the temperature and weight of tomato pulp were increased. The weight of the tomato pulp caused a greater decrease in

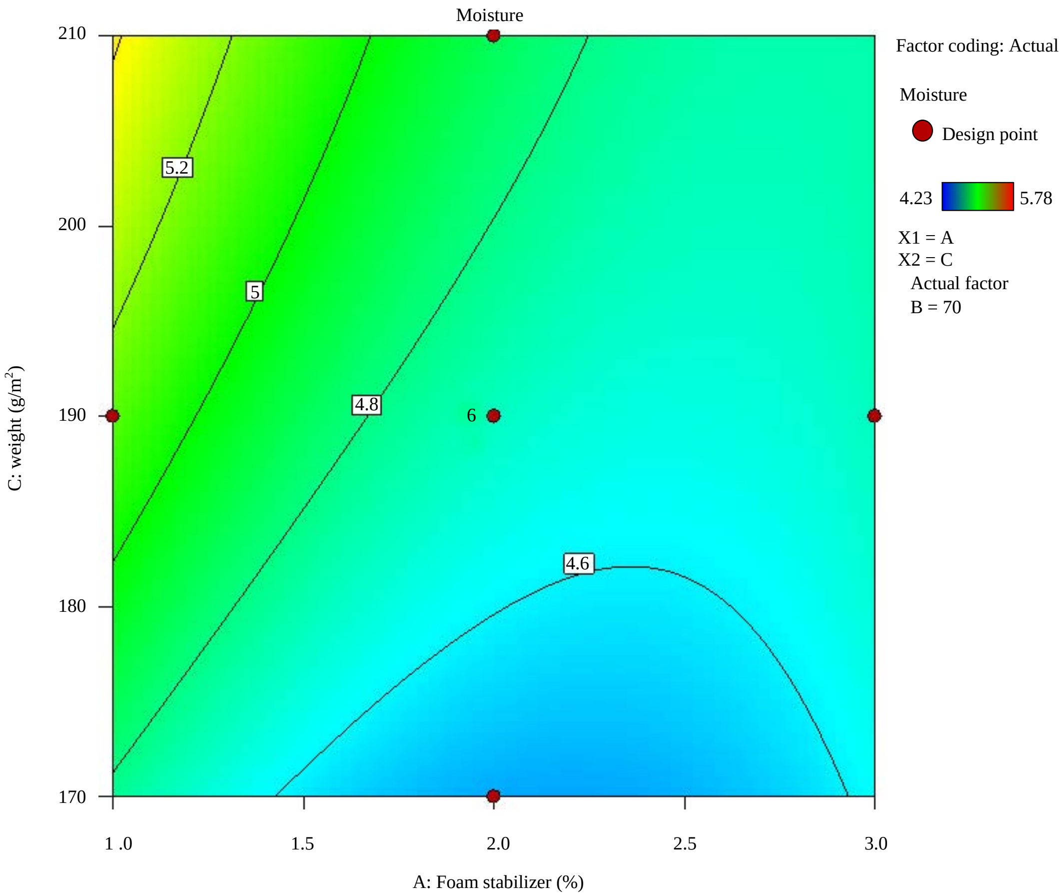

Fig. 3: Contour of interaction effect of weight of tomato pulp and concentration of foam stabilizer on the moisture content of tomato powder

ash content than the temperature because the coefficient of weight of the tomato pulp (0.3300) is higher than that of the temperature of drying (0.2910). The interaction of concentration of foam stabilizer and drying temperature (AB), concentration of foam stabilizer and weight of tomato pulp (AC), drying temperature and weight of tomato pulp (BC) showed a positive coefficient which implies that the different interactions caused an increase in the ash content of the powder. On the other hand, the concentration of foam stabilizer (A) showed positive coefficient, indicating that as the foam stabilizer increases, the ash content will also increase. Squares of A and C would increase the ash content whereas the square of B would decrease the ash content of the powder.

Table 4 shows the coefficients of regression $R2_{adj}$ (8.909) which indicate 89.09% variability in the response. When the value of $R2_{adj}$ (correlation coefficient) close to 1, the correlation is better between the experimental and predicted values. A CV value (2.42%) indicates that the data is relatively close to the mean, with a low level of dispersion. This shows that the data points are relatively consistent and not widely scattered. A low CV value is generally desirable, as it indicates that the data is precise and reliable.

Figure 4 shows that as the concentration of foam stabilizer increased from 1.8-2.3% and the drying temperature increased from 60-70°C, the ash content of the tomato powder decreased from 9.5-9%.

Figure 5 shows that as foam stabilizer increased from 1.63-2.1% and the weight of tomato pulp increased from 177-190 g/m^2, the ash content of the tomato powder decreased from 9.5-9%.

Figure 6 shows that the temperature increased from 74-78°C and the weight of tomato pulp increased from 184-193 g/m^2, the ash content of the tomato powder decreased from 9.8-4 .6.

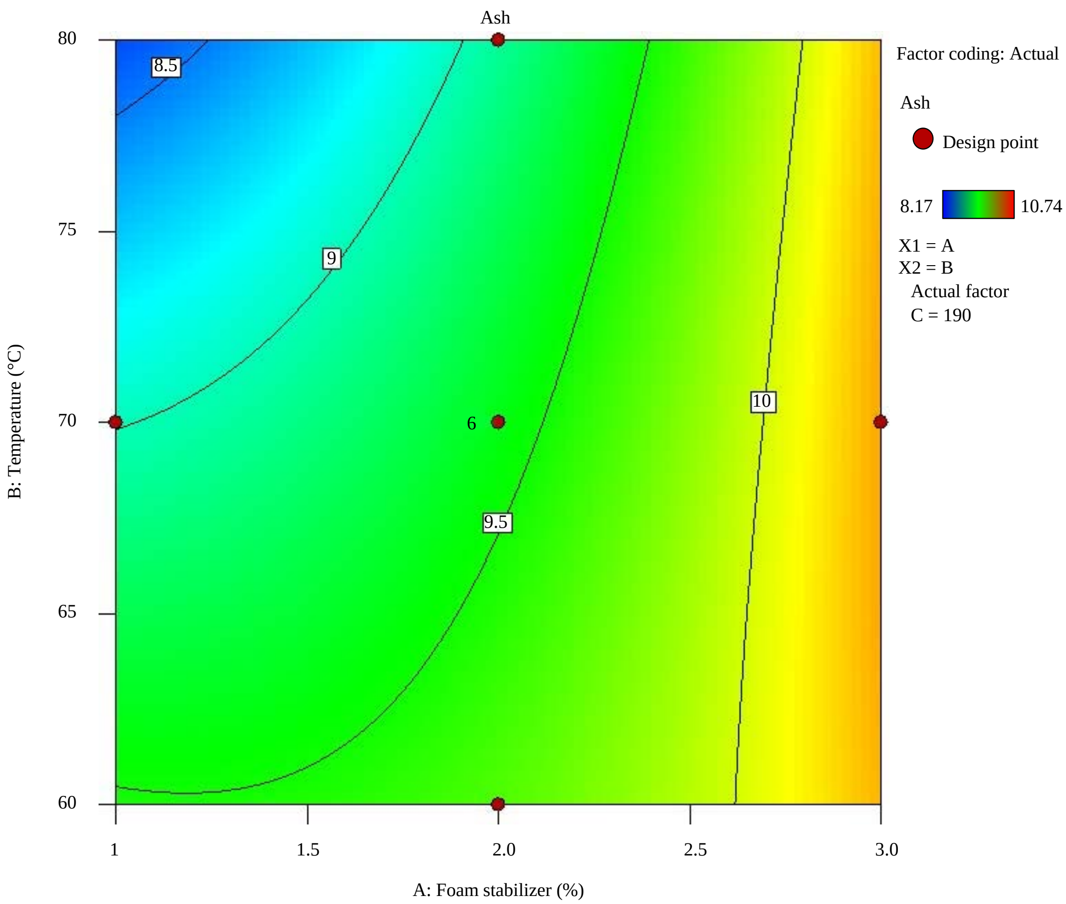

Fig. 4: Contour of interaction effect of temperature and concentration of foam stabilizer on the ash content of tomato powder

Table 4: Summary of Anova and coefficient Estimate of the proximate composition of the foam mat dried powder for the terms that showed significant model

Term	Coefficient	Moisture	Ash	Fat	Fibre	Protein	Carbohydrate
n intercept	b_0	4.7100	9.4200	1.8000	10.4500	4.0000	69.5200
A	b_1	-0.2050	0.6720	-0.2240	-0.1410	0.4920	-0.5940
B	b_2	-0.3240	-0.2910	0.0330	0.5480	-0.2740	0.3080
C	b_3	0.1920	-0.3300	0.3780	0.0060	-0.1940	-0.1090
AB	b_{12}	-0.0263	0.2850	-	0.5713	0.0438	-0.7000
AC	b_{13}	-0.1288	0.3325	-	0.1462	0.2213	-0.5000
BC	b_{23}	0.2787	0.1200	-	0.4263	0.4513	-1.4800
A^2	b_{112}	0.2141	0.2427	-	0.8277	-0.0195	-1.1500
B^2	b_{222}	0.1991	-0.0423	-	0.9727	-0.0395	-0.9100
C^2	b_{332}	-0.0309	0.2427	-	-0.6773	0.6805	-0.3150
R^2 ad		0.5996	0.8909	0.3043	0.5116	0.5073	1.6700
CV (%)		5.9700	2.4200	22.9900	6.6300	12.0300	0.6031

The actual and predicted values of the ash content (0.938) showed that there was a very strong and reliable relationship between the two variables. This means that the predicted values are likely to be highly accurate and can be used with confidence to make predictions about the actual values. In general, correlation value of 0.9 or higher is considered to be a very strong positive correlation. In this case, the high correlation showed that the relationship is statistically significant ($p<0.05$)) and the predicted values are likely to be very reliable. It's important to remember that a high correlation does not guarantee perfect predictions.

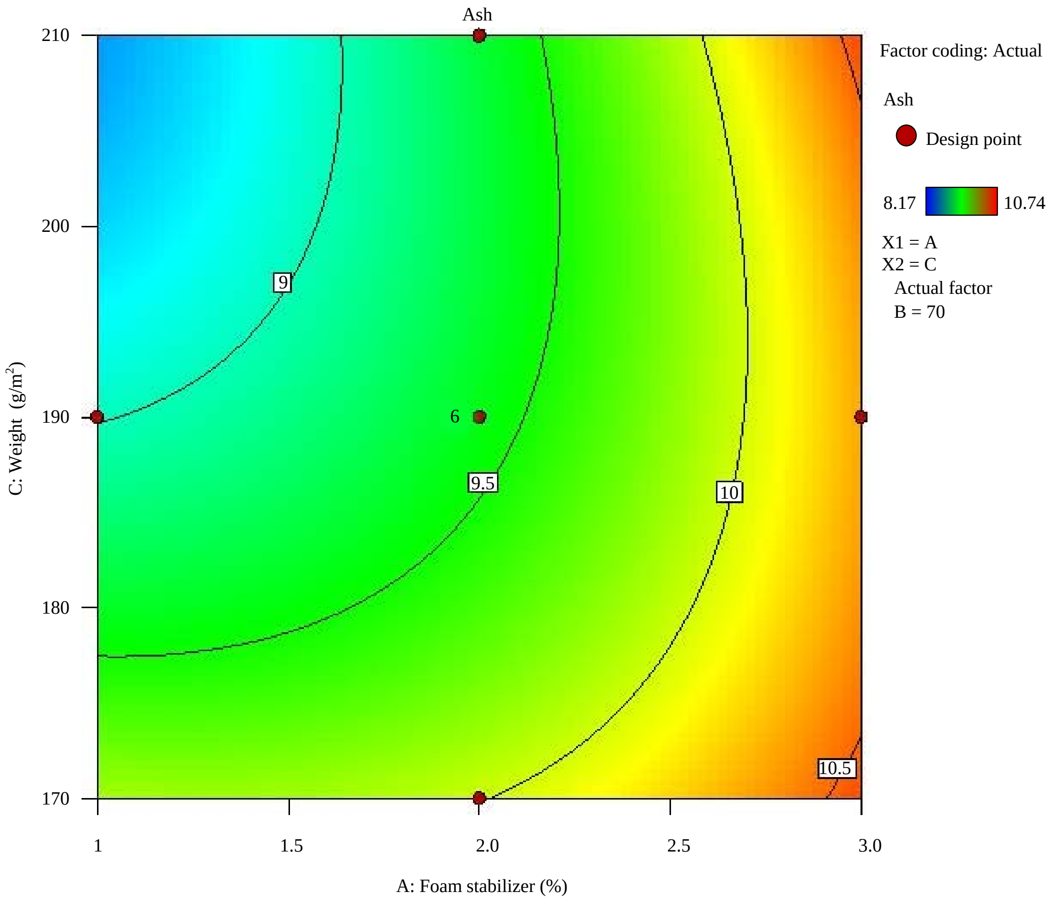

Fig. 5: Contour of interaction effect of weight of tomato pulp and concentration foam stabilizer on the ash content of tomato powder

Fat content: The fat content of the samples was generally low. As seen in Table 3 the fat content of the oven dried tomato sample ranged from 1.45-4.09% while the fat content of the foam mats dried tomato powder ranged from 1.11-3.28%. Sample 13 (with concentration of foam stabilizer at 1%, weight of tomato pulp at 210 g/m^2 and dried at 80°C) had the highest fat content (3.28%) while sample 18 (with concentration of foam stabilizer at 3%, weight of tomato pulp at 170 g/m^2 and dried at 80°C) had the lowest fat content (1.1%). Opadotun *et al.*[27] observed a decrease in the fat content of tomato from 1.77% (for the control) to 1.19% after oven drying (dried at 65°C for 72 hrs). Results showed that the process variables had significant effect on the fat content of foam mat dried tomato powder. Higher fat content could cause the powder to spoil during storage due to oxidation. The low-fat contents are beneficial as it ensures longer shelf life for the products[28] because all fat containing foods contain some unsaturated fatty acids and hence potentially susceptible to oxidative rancidity.

The mathematical model for the fat content of the tomato powder is presented in Eq.11, while Fig. 7 shows its contour. The fat content of the tomato pulp increased as the drying temperature and weight of tomato pulp increased. Because the coefficient of weight of the tomato pulp (0.3780) is a bit higher than that of the drying temperature, weight of the tomato pulp caused a greater increase in fat content of the sample than temperature (0.2910). The concentration of foam stabilizer (A) showed a positive coefficient, indicating that the fat content increased as the weight of the pulp increased.

Figures 7 shows the interaction effect of temperature and concentration of foam stabilizer. The concentration of foam stabilizer increased from 1.2-2.7% as the drying temperature increased from 62-72°C, the fat content of the tomato powder decreased from 2-1.6%.

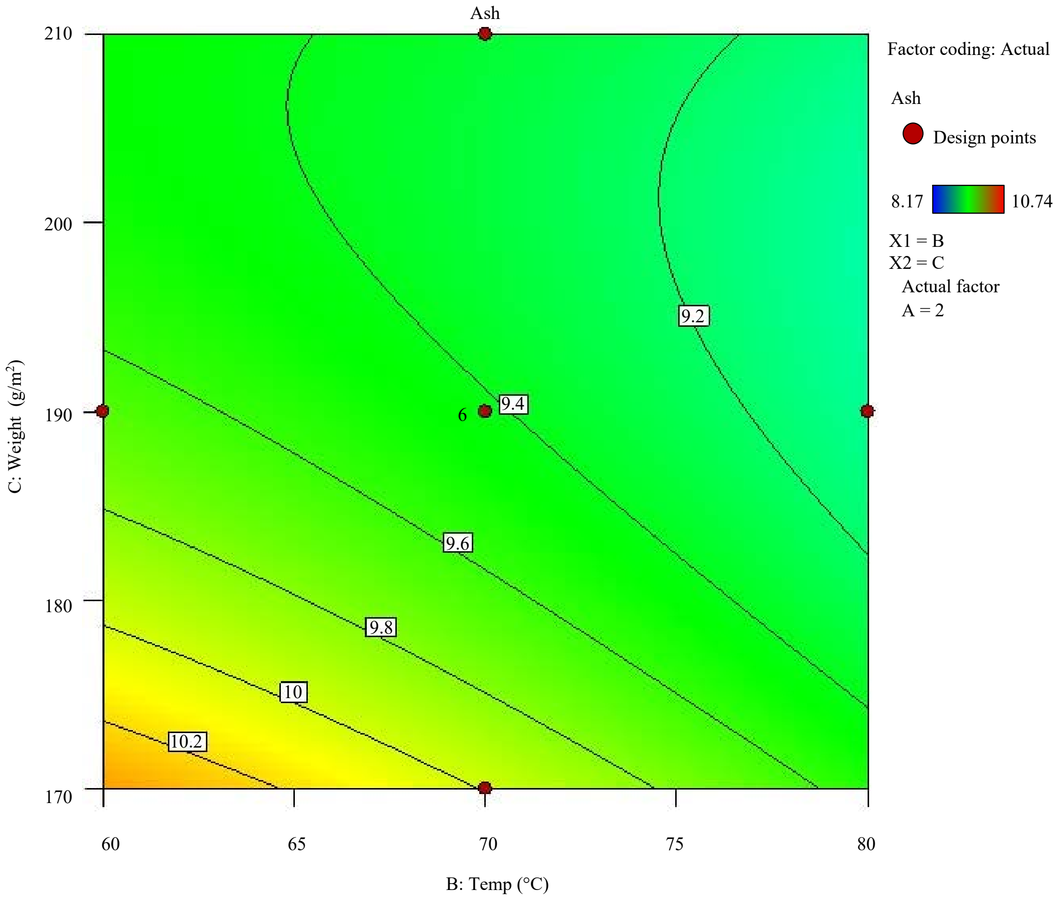

Fig. 6: Contour of interaction effect of weight of tomato pulp and temperature on the ash content of tomato powder

The pearson correlation between an actual and predicted value of the fat content (-0.14) showed that there was a weak, negative relationship between the two variables and that this relationship was not statistically significant. This means that the observed relationship between the variables could be due to chance rather than a true underlying relationship. As one variable is increasing, the other may be decreasing.

Crude fiber: Table 3 shows that the crude fiber content of the oven dried tomato powder ranged from 11.33-13.21% while the crude fiber content of the oven dried tomato powder ranged from 10.04-12.81%. Samples 2 (control dried at 70°C) had the highest content of crude fiber (12.81%) while sample 13 (2% concentration of foam stabilizer, 210 g/m^2 weight of tomato pulp, dried at 70°C) had the lowest content of crude fiber (10.04%). The result showed that the crude fiber of the foam mat dried tomato sample was lower than that of the oven dried tomato sample. This was due to the fact that the tomato powder (controls) and the foam mat dried tomatoes had different fiber contents and the controls had more content of crude fiber. Famurewa and Raji[29] reported a lower crude fiber value after oven drying of tomato (0.16-0.28%). They reported more crude fiber content in the dried tomatoes than that of the control, it therefore implies that there are more indigestible materials in the dried tomato. Dietary fiber is essential for maintaining the integrity and function of the gastrointestinal tract. The presence of fiber in the diet increases the bulk of feces, which has a laxative effect in the gut. Fiber-rich food also promotes proper bowel function and reduces the risk of developing intestinal disorders such as constipation, diverticulitis and colon cancer[30].

The mathematical model for the crude fiber content of the tomato powder is presented in Eq. 5, while Fig. 8-10 shows its contours. As the concentration of the foam stabilizer

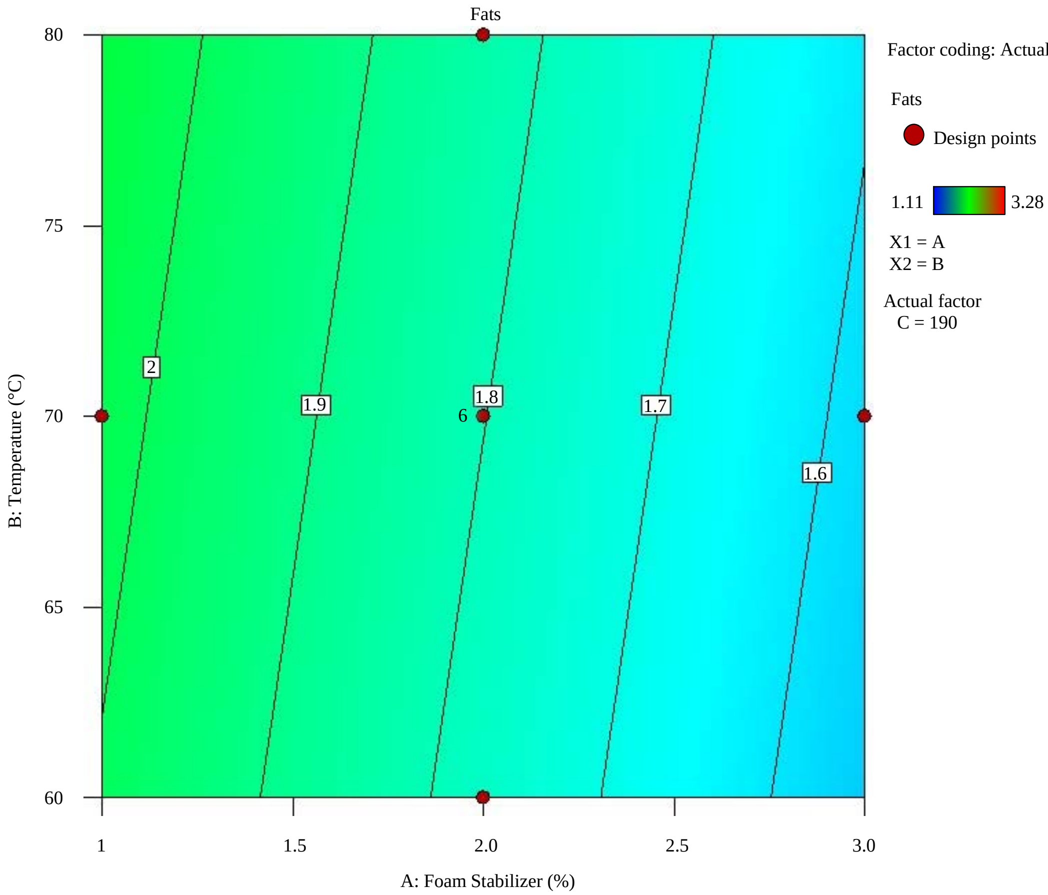

Fig. 7: Contour of interaction effect of temperature and concentration of foam stabilizer on the fat content of tomato powder

increased the crude fiber content of the tomato powder decreased. While increase in the drying temperature and weight of tomato pulp increased the crude fiber content of the tomato powder. Temperature caused greater increase in the crude fiber content than that of the weight of the tomato pulp because the coefficient of temperature (0.5480) was higher than that of the weight of tomato pulp (0.0060). The interaction of concentration of foam stabilizer and drying temperature (AB), concentration of foam stabilizer and weight of tomato pulp, drying temperature and weight of tomato pulp showed a positive coefficient which is an indication of increase in crude fiber content of the tomato powder. Squares of C would decrease the crude fiber content of the powder while squares of A and B would increase the crude fiber content of the powder.

Figure 8 shows that as the concentration of foam stabilizer increased from 1.8-2.8% and the drying temperature increased from 68-79°C, the crude fiber content of the tomato powder decreased from 13-12%.

Figure 9 shows that foam stabilizer increased from 1-1.2% and the weight of tomato pulp increased from 203-210 g/m^2, the crude content of the tomato powder decreased from 11-10.5%.

Figure 10 shows that the temperature increased from 60-71°C and the weight of tomato pulp increased from 200-207 g/m^2, the crude fiber of the tomato powder increased from 10-10.5%.

Crude protein: Table 3 shows that crude protein majorly increased after foam mat drying. The protein content of the oven dried tomato ranged from 1.18-1.70% while the protein

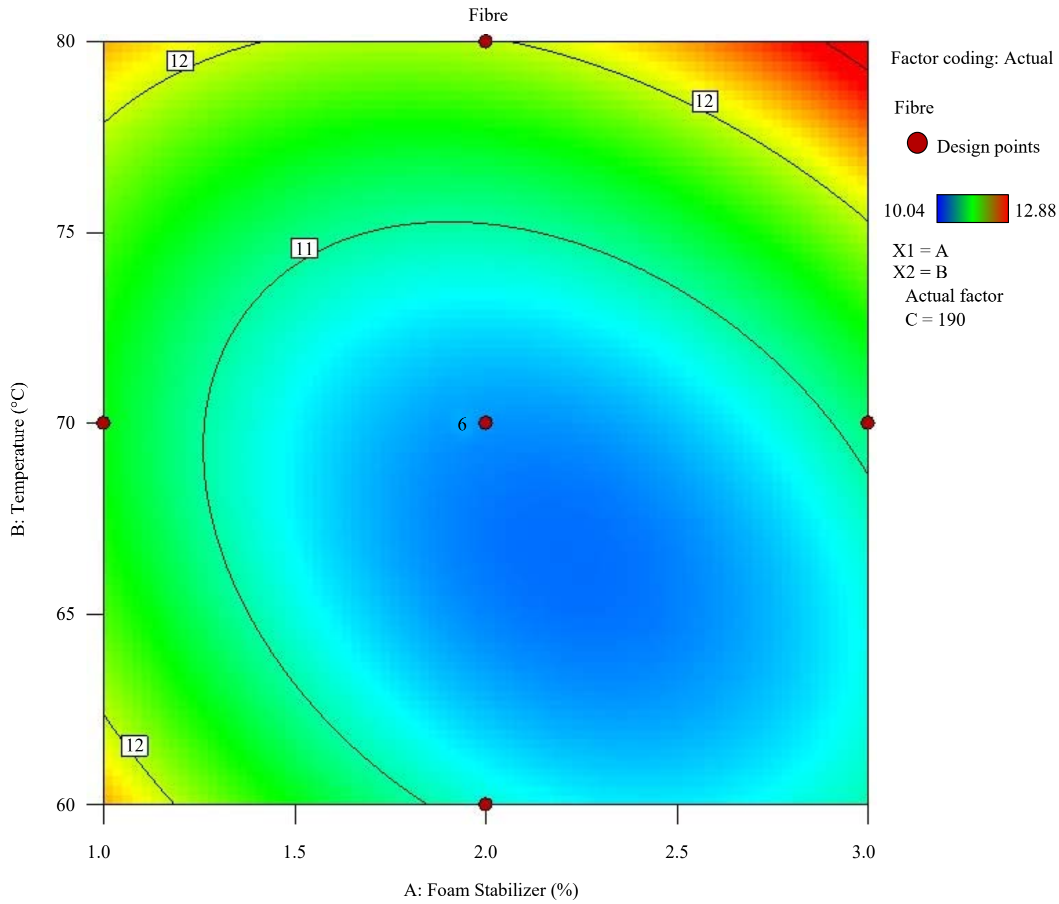

Fig. 8: Contour of interaction effect of temperature and concentration of foam stabilizer on the crude fiber content of tomato powder

content of the foam mat dried tomato powder ranged from 3.45-5.91%. Sample 8 (with foam stabilizer at 3%, weight of pulp at 170 g/m^2 and dried at 60°C) had the highest protein content (5.91%), while sample 22 (Control dried at 70°C) had the lowest protein content (1.18%). Orhevba *et al.*[26], reported that crude protein values for oven-dried tomato (dried at 65°C until constant weight was achieved) reduced from 2.8-0.35% after oven drying. In another study, Gonzaga *et al.*[19] optimized the foam mat drying process of tomatoes using response surface methodology (RSM). They found that the optimal conditions for the highest protein retention were found at a foaming agent concentration of 2.5%, temperature of 60°C and pulp thickness of 6 mm. The protein content of the optimized foam mat dried tomato powder was 13.2%. Table 3 showed that the process variables have a contributing factor in increasing the protein content of the sample when compared with the control. Protein content of a food product can be increased by using foaming agents such as egg white, which have effect on the overall nutritional value. Using acacia gum as a binder in the foam mat dried tomato powder also affects the protein content. Acacia gum is known for its ability to increase the viscosity of a liquid and it could potentially affect the protein content by binding the protein to the matrix of the gum. However, its effect on the protein content would be low compared to the egg white[31].

The mathematical model for the crude protein content of the tomato powder is presented in Eq. 6, while Fig. 11-13 shows its contours. As the temperature and weight of tomato pulp increased the crude protein content of the tomato powder decreased. While increasing the concentration of foam stabilizer increased the crude protein content of the tomato powder. Temperature caused greater decrease in the

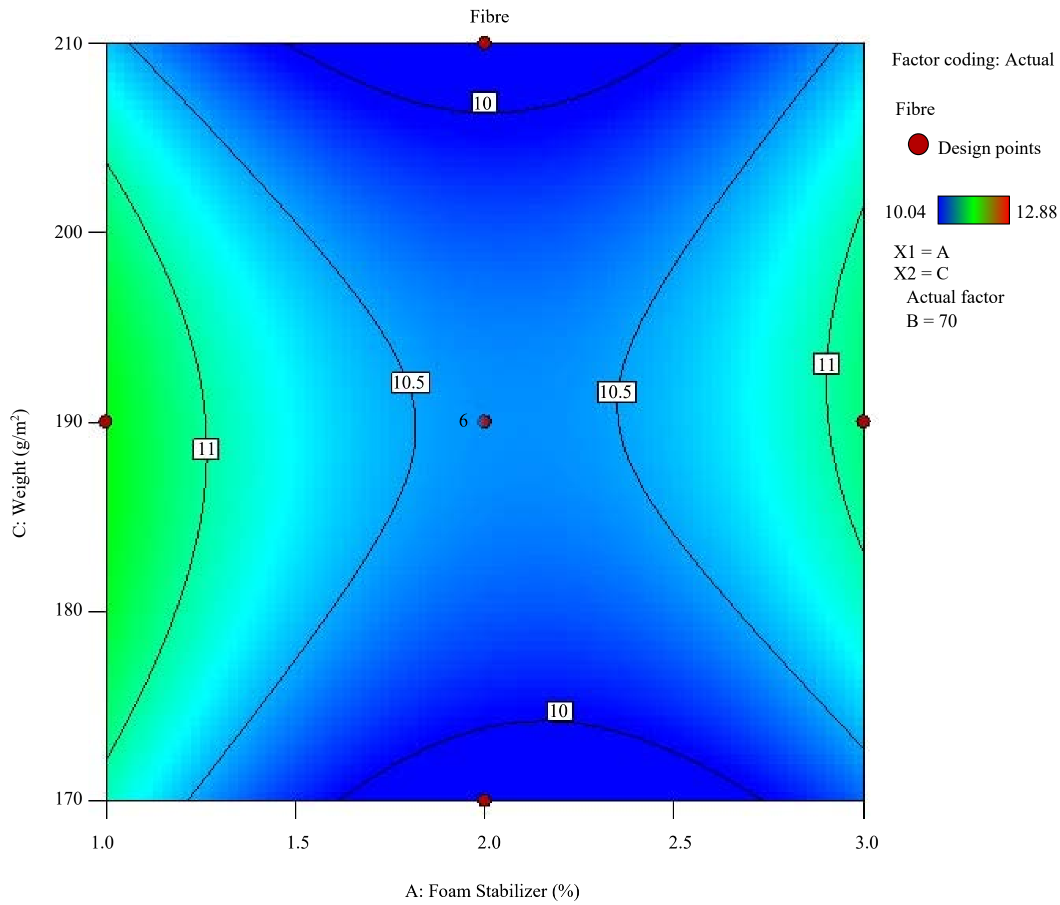

Fig. 9: Contour of interaction effect of concentration of foam stabilizer and weight of tomato pulp on the crude fiber content of tomato powder

crude protein content than that of the weight of the tomato pulp because the coefficient of temperature (0.2740) was higher than that of the weight of tomato pulp (0.1940). The interaction of concentration of foam stabilizer and drying temperature (AB), concentration of foam stabilizer and weight of tomato pulp, drying temperature and weight of tomato pulp showed a positive coefficient which was an indication of increase in crude protein content of the tomato powder caused by the interactions. The crude protein content of the powder would decrease with squares of A and B while it would increase with squares of C.

Figure 11 shows that as the concentration of foam stabilizer increased from 1.4-2.6% and the drying temperature increased from 68 – 80 °C, the crude protein content of the tomato powder produced decreased from 4.5-4%.

Figure 12 shows that as the foam stabilizer increased from 1.3-2% and the weight of tomato pulp increased from 177-171 g/m^2, the crude protein content of the tomato powder produced decreased from 4.5-4%.

Figure 13 shows that as the temperature increased from 68-75°C and the weight of tomato pulp increased from 176-183 g/m^2, the crude protein content of the tomato powder produced increased from 4.5-5%.

Carbohydrate: Table 3 shows that foam mat drying process increased the carbohydrate content of the samples from 64.35-70.54%. Sample 1 (with foam stabilizer at 2%, weight of pulp at 210 g/m^2 and dried at 70°C) had the highest carbohydrate content (70.54%) while control (at 70°C) had the lowest carbohydrate content (49.34%). Table 4 shows that the process variables had a contributing factor in increasing the carbohydrate content of the sample when compared to the control. Opadotun *et al.*[27] also observed an increase in carbohydrate content of dried tomato powder compared with the fresh sample; they reported that the carbohydrate content increased from 8.75% (control) to 27.27% for the oven dried

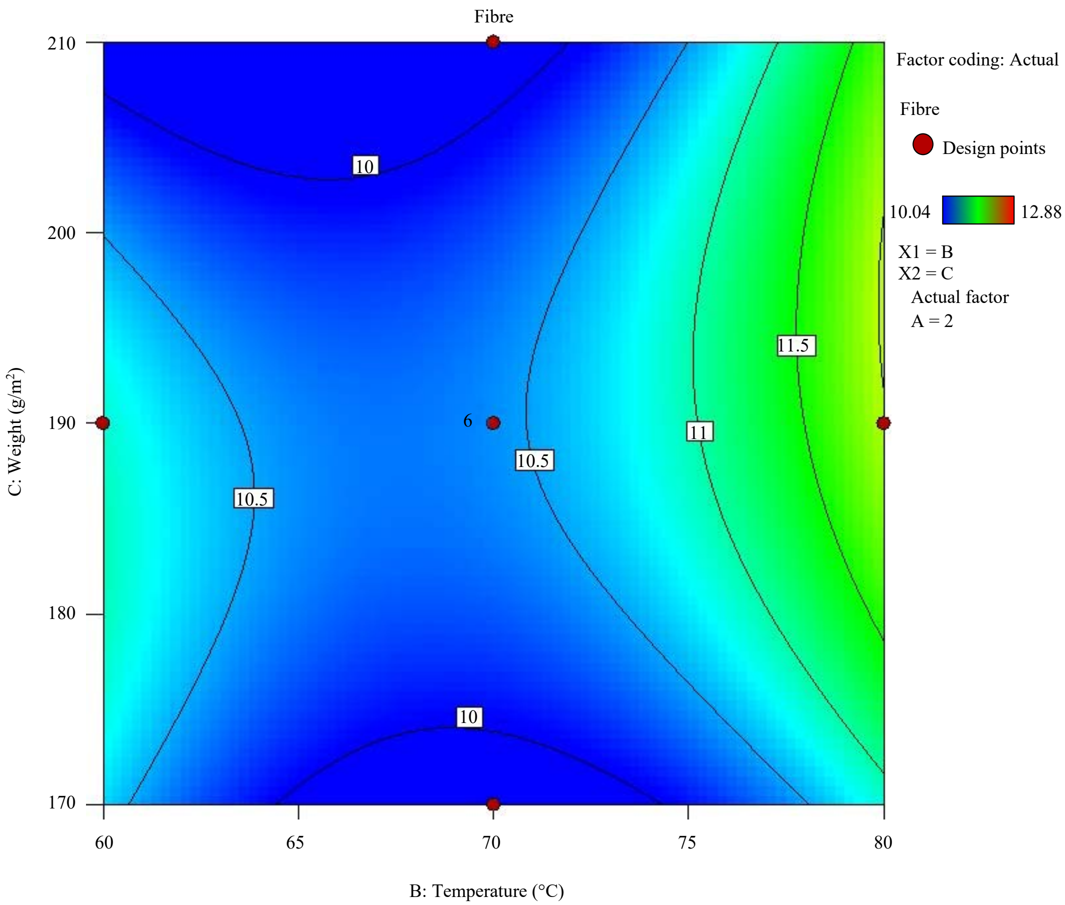

Fig. 10: Contour of interaction effect of temperature and weight of tomato pulp on the crude fiber content of tomato powder

sample (dried at 65°C for 72 hrs). Famurewa and Raji[29] however, reported a decrease in the carbohydrate value from 41.15% (control) to 36.03% for oven-dried tomato (dried at 40°C until constant weight was achieved) compared with the fresh sample. The weight of the pulp and the interaction of independent variables between the foam stabilizer and temperature have significant effect on the carbohydrate content of the foam mat dried tomato powder.

The mathematical model for the carbohydrate content of the tomato powder is presented in Eq. 7, while Fig. 14-16 show its contours. The carbohydrate content of the tomato powder decreased by increasing the foam stabilizer's concentration and weight of the tomato pulp. Concentration of the foam stabilizer caused greater decrease in carbohydrate content than that of the weight of tomato pulp because the coefficient of the foam stabilizer (-0.5940) was higher than that of the weight of tomato pulp (-0.1090). The interaction of concentration of foam stabilizer and drying temperature (AB) also showed negative coefficient (-0.7000) suggesting that it caused a decrease in carbohydrate content of the tomato powder. Contrarily, temperature (B) showed positive coefficient which implies that if the temperature increased, the carbohydrate content will increase in similar fashion. The interaction of foam stabilizer and weight of tomato pulp (AC) showed negative coefficient, suggesting that it has a decreasing effect on carbohydrate content of the powder. The interaction of the temperature and weight of the pulp (BC) also showed a negative coefficient (-0.48). This implies that it caused a decrease in carbohydrate content of the powder. Squares of A, B and C would decrease the carbohydrate content of the tomato powder.

Figure 14 shows that as the concentration of foam stabilizer increased from 1.9-2.8% and the drying temperature increased from 70-77°C, the carbohydrate content of the tomato powder produced decreased from 69-67%.

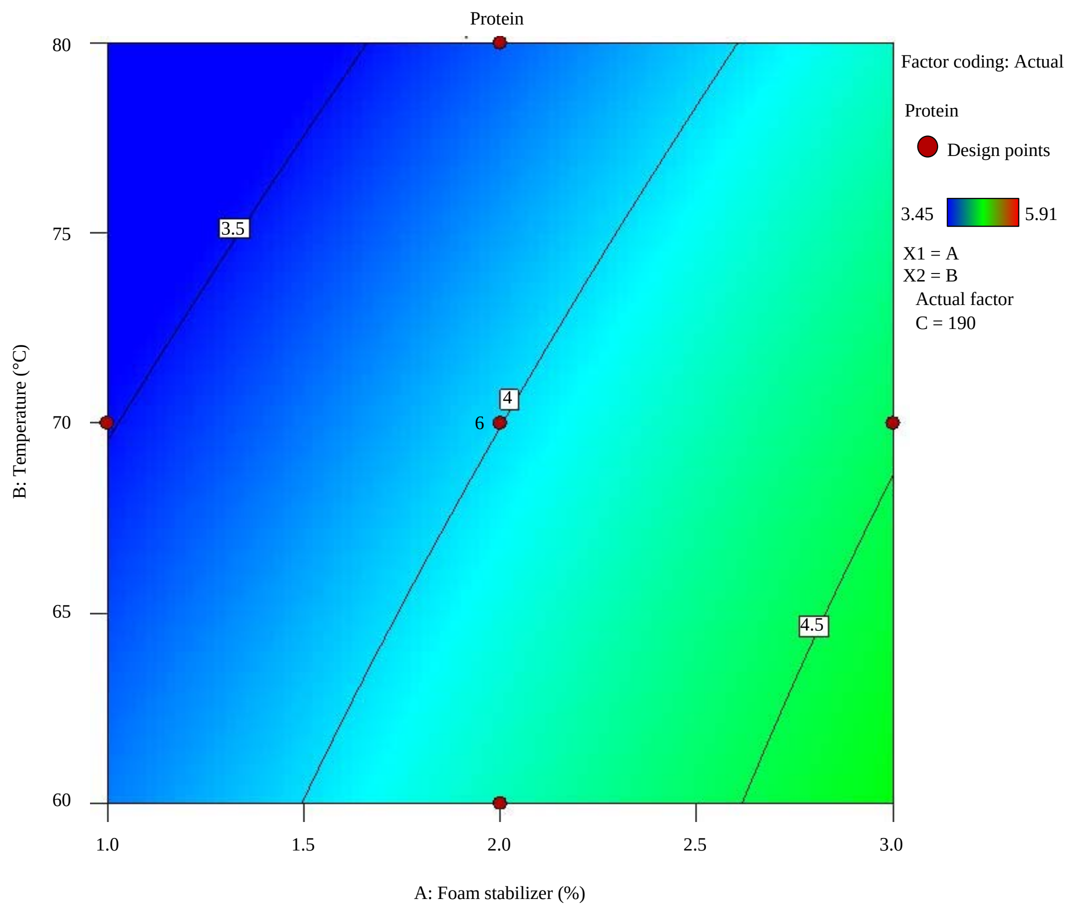

Fig. 11: Contour of interaction effect of temperature and concentration of foam stabilizer on the crude protein content of tomato powder

Table 5: Numeric Optimization solution for the proximate composition of foam mat dried tomato powder.

Variables	Selected values	Desirability
Conc. of foam stabilizer	1.000	0.703
Temperature (°C)	61.308	
Weight of pulp	170.000	
Moisture	5.427	
Ash	10.468	
Fibre	12.004	
Protein	5.220	
Fats	1.619	
Carbohydrate	65.407	

Figure 15 shows that foam stabilizer increased from 1.42-2.5% and the weight of tomato pulp increased from 191-210 g/m^2, the carbohydrate content of the tomato powder produced decreased from 69-68%.

Figure 16 shows that the temperature increased from 61-68°C and the weight of tomato pulp increased from 173-201 g/m^2, the carbohydrate content of the tomato powder produced decreased from 69-67%.

Numeric optimization for the proximate composition: Table 5 shows the Numeric Optimization solution of the proximate composition of foam mat dried tomato powder. The main criteria for optimization of process parameters selected for the proximate composition were minimum foam stabilizer, minimum temperature and weight of tomato pulp which is in range. This generated the solution with desirability of 70.3% (Table 5). The red color showed the

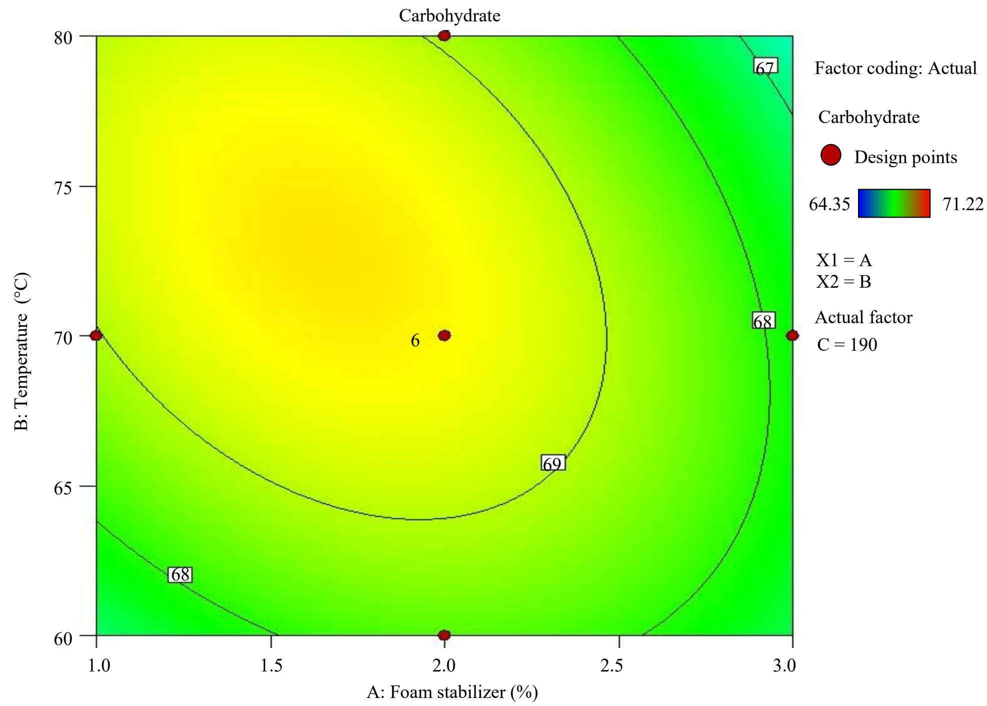

Fig. 12: Contour of interaction effect of concentration of foam stabilizer and weight of tomato pulp on the crude protein content of tomato powder

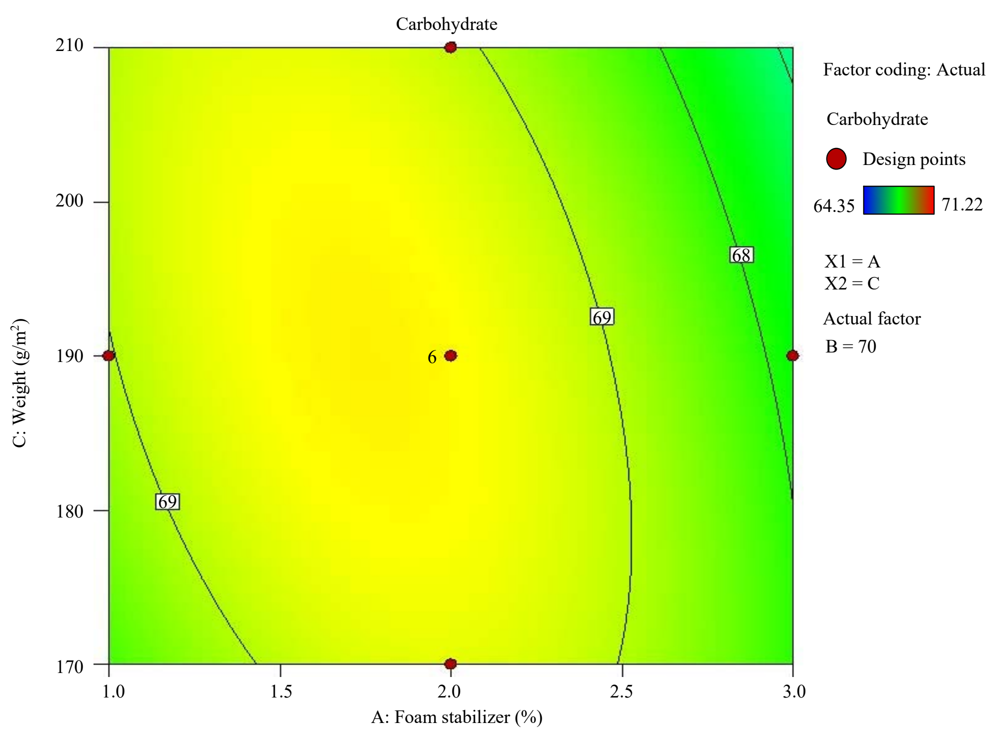

Fig. 13: Contour of interaction effect of temperature and weight of tomato pulp on the crude protein content of tomato powder

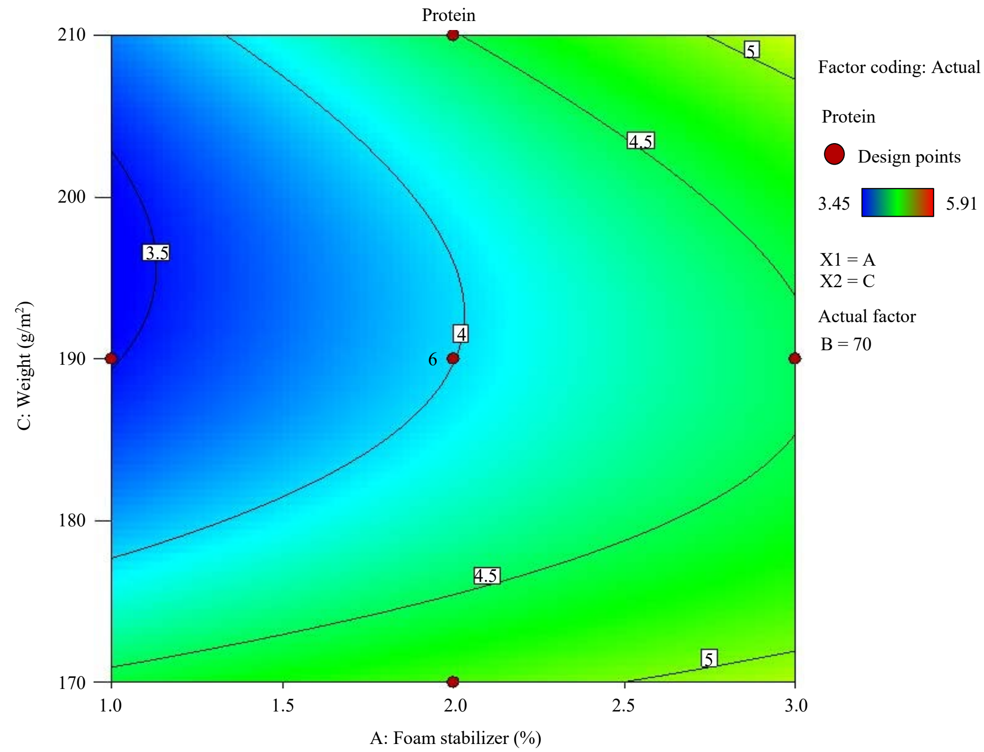

Fig. 14: Contour of interaction effect of temperature and concentration of foam stabilizer on the carbohydrate content of tomato powder

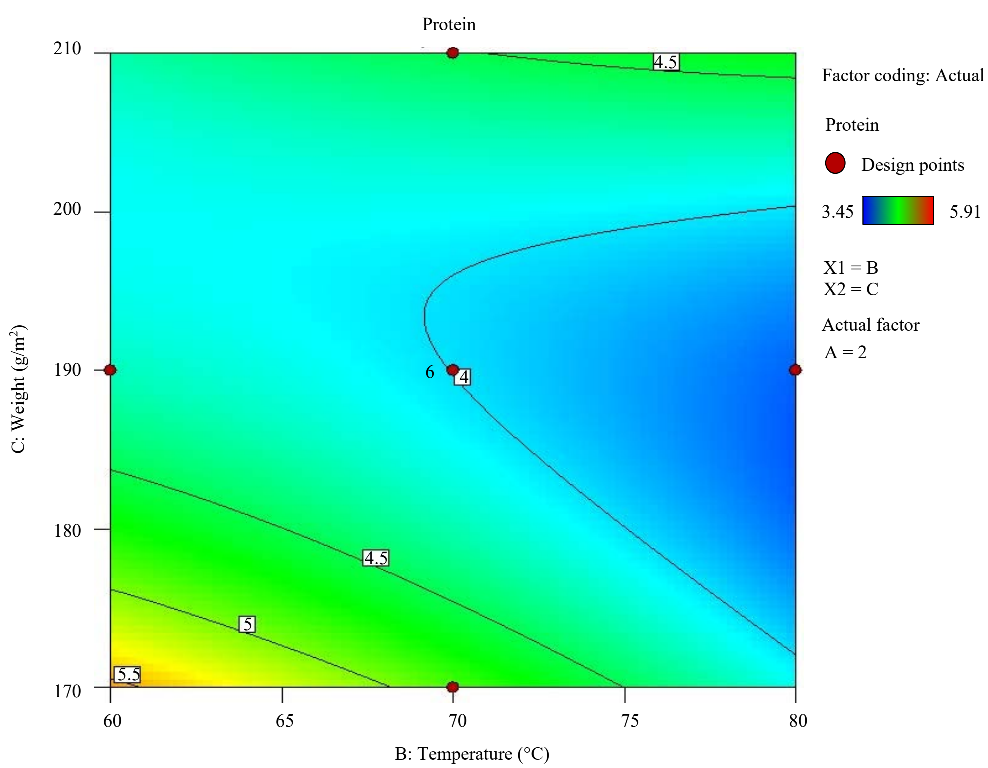

Fig. 15: Contour of interaction effect of weight of tomato pulp and concentration of foam stabilizer on the carbohydrate content of tomato powder

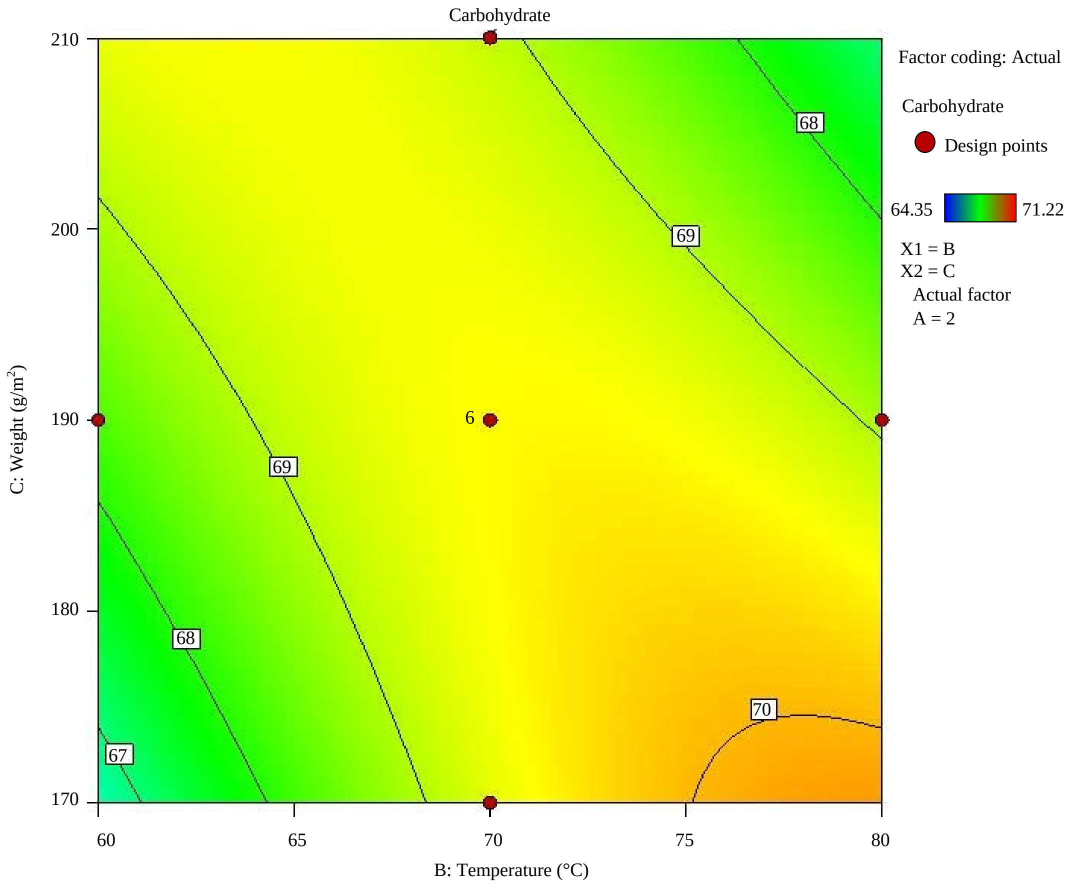

Fig. 16: Contour of interaction effect of temperature and weight of tomato pulp on the carbohydrate content of tomato powder

highest value of the yield and response. The scale range for desirability values was from 0-1, where a value of 0 indicates a fully unwanted response, while a value of 1 indicates a fully desirable response[32]. In this study, the proximate parameters had a desirability of 0.703 or 70%, where the value was closer to the value of 1, which means higher value for the optimization accuracy. The percentage desirability was high and acceptable. However, desirability of 100% is the most ideal if it could be obtained. It shows that if the selected critical values (1.0% foam stabilizer, temperature at 61°C, weight of pulp at 170 g/m^2) are employed, the production of foam mat dried tomato powder would exhibit proximate composition of 5.43, 10.46, 12.00, 5.22, 1.62, 65.40 for moisture, ash, crude fiber, crude protein, fat and carbohydrate respectively, with the desirability of 0.703 (70%).

CONCLUSION

Foam mat drying is an effective method for preserving the nutritional value of tomatoes. The proximate composition analysis revealed significant variations ($p<0.05$) among the samples. The study identified that temperature, foam stabilizer and weight of the pulp significantly influenced some parameters in the proximate composition. The samples had low moisture content, moderate ash and fiber content and low contents of fats and oils. The foam-mat-dried tomato powder had higher protein content compared with oven-dried tomato powder. Additionally, the study found that moisture content was inversely related to temperature and gum arabic. These findings provide valuable information for the development of tomato-based food products with high nutritional value. Based on the optimization results, the study recommends using 1% foaming stabilizer, 171 g/m^2 weight of tomato pulp and a drying temperature of 63°C to achieve an optimal foam mat drying process with a desirability of 70%. Overall, this study highlights the potential of foam mat drying as a promising method for preserving the nutritional value of tomatoes and improving the quality of tomato-based food products. Further investigations could be conducted to optimize the foam mat drying process for different varieties of tomato, as the optimal drying conditions may vary depending on the cultivar used. Th potential of foam mat drying to produce powdered products from other types of fruits and vegetables could be explored. The foam mat drying technique has been successfully applied to a range of liquid foods, including fruits, vegetables and dairy products and could be used to produce high-quality powders from a range of raw materials. Finally, the use of foam mat dried tomato powder in the development of new food products could be investigated. The unique properties of foam mat dried tomato powder, such as its high protein content and improved rehydration properties, make it a potentially valuable ingredient for use in a range of food products, such as soups, sauces and snacks. Further research could explore the potential of this ingredient in product development, as well as its potential to enhance the nutritional value of existing products.

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