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Development, Characterization and Process Optimisation of Foam-Mat Dried Tomato-Pepper-Onion Powder (TPOP Powder)

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Abstract: This study aimed to develop and optimize the foam-mat drying process for the production of shelf-stable tomato-pepper-onion powder (TPOP) with optimal quality characteristics using D-optimal design. The research commenced with the formulation of the TPOP mixture and investigated various ratios of the three major ingredients (tomato, pepper and onion) to achieve an optimal blend that offers a harmonious flavor profile and high nutritional value. Subsequently, the foam-mat drying process was explored, involving the use of foaming agents to stabilize air bubbles within the vegetable puree matrix. This process yielded a lightweight, porous and free-flowing powder with improved rehydration properties. A single process parameter namely drying temperature was optimized while keeping the whipping time of 7mins constant. The levels for various input variables were tomato (5 – 76%), pepper (5 – 78%), onion (5 – 80%), egg white (2 - 15%), carboxymethyl cellulose (0.15 - 0.75%) & drying temperature: 50-800C. Some selected physico-chemical, nutritional properties and sensory evaluation were conducted. The optimum condition with the best formulation of the mixture ingredients were found to be 67.26% tomato, 5.0% pepper, 20.0% onion, 7.59% egg white and 0.15% CMC at an optimum drying temperature of 61.940C. Results showed that foam-mat drying produced a powder with desirable physicochemical and nutritional properties. Sensory evaluation showed that the reconstituted powder had good acceptability.

Keywords: Shelf-stable; Formulation; Foam-mat drying; TPOP Powder; Process Optimisation

I. Introduction

As a method for preserving food after harvest, drying is one of the most significant agricultural processing techniques. The oldest and most popular method of food preservation is drying [1]. Agricultural products can be dried to reduce moisture content, weight, and volume as well as to cut costs associated with packaging, storage, and transportation [2]. It has long been known that foaming of liquid and semi-liquid materials is one of the ways to speed up drying. In recent years, foam mat drying has garnered renewed attention in the field of drying technology. This relatively old technique has seen a resurgence due to its improved ability to process difficult-to-dry materials. When employing foam mat drying, the resulting products exhibit the desired properties, such as favorable rehydration and controlled density. Furthermore, this method effectively retains volatiles that might otherwise be lost during the drying process, a significant advantage compared to traditional non-foamed material drying methods [3].

The tomato, also known as *Lycopersicum esculentum*, is a fruit and vegetable that is added to food as a condiment. It is rich in nutrients essential for human growth and health, such as carotene, vitamins B, ascorbic acid (vitamin C), and others. In its natural state after harvest, tomato is highly perishable due to its high moisture content and high rate of metabolic activity; as a result, it is susceptible to significant postharvest losses [4]. In Nigeria, tomatoes are typically grown seasonally, resulting in significant wastage during the growing season and extreme scarcity during the off-seasons due to a lack of suitable storage facilities. Three percent protein and thirty-three percent vitamin C are found in 180 grammes of fresh tomatoes [1]. The Solanaceae family, specifically the *genus Capsicum*, includes both hot and sweet peppers. The general consensus is that red peppers are a good source of vitamins A and C and low in calories, sodium and cholesterol [5]. Red pepper is commonly employed as both a coloring and flavoring agent in various food products, including sauces, soups, pickles, and pizzas. Without proper storage or preservation techniques, fresh pepper, like other fresh fruits and vegetables, deteriorates within a few days of harvest [6]. Due to the perishable nature of pepper, there may be losses in sales, which are exacerbated by marketing, storage, and a lack of processing technologies. Fruits and vegetables like pepper are dried to reduce moisture, which is typically between 5 and 10 percent [7].

Onion (*Allium cepa*) is an Alliaceae-family biennial, herbaceous, winter-seasoned, and cross-pollinated bulb crop. Onion's high moisture content makes it susceptible to microbial and enzymatic spoilage [8]. One of the best ways to keep onions for a long time is to dry them. Fruits and vegetables are in abundance during this time of year, and if they are not preserved in some way, they risk being wasted [9]. According to reports, developing nations waste nearly 40% of our agricultural products because there are inadequate facilities for their proper processing, preservation, and storage. Therefore, the aim of this research is to develop, characterize and optimize the foam-mat drying processing of shelf-stable tomato-pepper-onion powder with optimal quality characteristics that meet the dietary needs of the consumers through the improvement of its nutritional content and sensory appeal.

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II. Materials and Methods

A. Materials

Fresh, ripe and mature tomato, onion, pepper (Scotch bonnet) locally known as *atarodo*, egg and CMC (carboxylmethyl cellulose) were all purchased from Kure Market Minna; the packaging materials were also purchased from the same market.

1. Reagents and Apparatus

Reagents: The following reagents were used during the experiment; Ferric Chloride, Ammonium thiocyanate, Ammonium solution, concentrated H_2SO_4 (Turraco), Sodium hydroxide, Ethanol, petroleum ether, HCL (Brenntag) , N-hexane and distilled water

Apparatus/Equipment: The following apparatus were used during the experiment; Electric Oven (*Esco isotherm*), digital weighing balance (*OHAUS 3001*), electric blender (*400 W jug-style blender)* and flat trays.

2. Sorting

Samples of tomatoes, onions and pepper were selected from the lot based on firmness (free from bruise), colour (ripe) and size uniformity.

B. Experimental Design

The experimental design was established through a combination of the mixture variables with the process variable. The foam-mat drying process is normally influenced by the number of variables, such as drying temperature (^{0}C) and whipping time (min). In this present investigation, the levels of these variables were taken from the literature considering the dietary requirements of all the intended consumers, hence the choice of these boundaries.

In this study, D-optimal design was used with three major components: tomato (x_1) pepper (x_2), and onion (x_3) and Egg white (x_4) as the foaming agent and carboxyl methyl cellulose CMC (x_5) as the stabilizer. Table I displays the levels for both the mixture and process variables. The amount of each of the component was selected based on the preliminary test ($tomato\ x_1$: 5-76.5%, $pepper\ x_2$: 5-78.5%, $onion\ x_3$: 5-78.2%,$egg\ white\ x_4$: 2-15%, $CMC\ x_5$: 0.15-0.75%. A total experimental run of 51 was done to produce the composite powder. The process variable which is the temperature was set within the range of 50^{o}C to 80^{o}C.

C. Production of Foam-mat Dried Tomato-pepper-onion Powder

The biomaterials (tomato, pepper and onion) were first blanched to prevent enzyme activity that could affect flavour, colour and texture [1]. After slicing and deseeding, the biomaterials were blended to form the paste. The paste was further divided into 51 containers and different concentrations of egg white (5%, 10%, 15%), Carboxyl Methyl Cellulose (CMC) (0.15%, 0.45%, 0.75%), tomato (5-76.5%), pepper (5-78.5%), and onion (5-80%) based on the experimental treatment combinations, were mixed. A 400 W jug-style blender was used to whip the mixtures for 7 minutes while the top was left open to let air into the foam. Throughout the experiment, all weight measurements were made using a digital scale (OHAUS 3001). All samples were laid out in thin layers (3mm) on flat stainless-steel trays (mats) following the foam formation in order to be dried in an oven. The oven was used for all of the drying procedures.

D. Characterization of the Formulated Foam-mat dried tomato-pepper-onion powder

The formulated TPOP powder was evaluated for proximate analysis, sensory evaluation and physicochemical properties.

Table I: Experimental Design for the Formulation Experiment

Run	X_1: Tomato %	X_2: pepper %	X_3: Onion %	X_4: Egg white %	X_5: CMC %	Z_1: Drying temperature ^{0}C
1	36.1	51.5	5.0	7.3	0.2	65.0
2	20.3	56.5	21.0	2.0	0.2	57.8
3	5.0	74.6	5.0	15.0	0.4	50.0
4	25.8	67.0	5.0	2.0	0.2	80.0
5	45.3	28.6	21.5	4.2	0.4	50.0
6	22.6	70.2	5.0	2.0	0.2	50.0
7	74.3	5.0	5.0	15.0	0.7	80.0

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Run	X_1: Tomato %	X_2: pepper %	X_3: Onion %	X_4: Egg white %	X_5: CMC %	Z_1: Drying temperature ^{0}C
8	63.9	6.4	27.5	2.0	0.2	80.0
9	9.4	41.8	40.9	7.2	0.7	65.0
10	5.0	14.6	78.2	2.0	0.2	80.0
11	61.9	18.0	5.0	15.0	0.2	80.0
12	7.2	78.5	11.5	2.0	0.7	65.0
13	62.1	11.5	10.7	15.0	0.7	50.0
14	76.5	5.0	5.0	13.3	0.2	50.0
15	15.9	5.0	76.3	2.0	0.7	50.0
16	15.3	46.4	35.5	2.0	0.7	50.0
17	69.0	16.3	8.1	5.9	0.8	65.0
18	69.7	17.1	10.4	2.1	0.7	80.0
19	7.0	5.0	72.8	15.0	0.2	80.0
20	23.1	5.3	55.9	14.9	0.7	65.0
21	5.7	9.6	70.8	13.2	0.7	50.0
22	52.6	26.6	5.0	15.0	0.8	65.0
23	41.7	42.0	9.7	5.8	0.8	50.0
24	76.3	5.1	16.5	2.0	0.2	50.0
25	5.0	74.3	18.5	2.0	0.2	65.0
26	56.3	5.0	36.5	2.0	0.2	57.5
27	62.7	5.0	23.2	8.3	0.7	50.0
28	29.0	50.3	5.0	15.0	0.7	80.0
29	26.4	13.7	51.3	8.4	0.2	80.0
30	47.6	21.4	28.9	2.0	0.2	65.0
31	54.0	32.9	5.0	7.6	0.6	80.0
32	26.1	15.8	55.6	2.0	0.4	65.0
33	5.0	26.2	53.0	15.0	0.7	80.0
34	37.8	40.3	19.4	2.0	0.5	80.0
35	73.4	11.9	8.4	6.2	0.2	65.0
36	61.9	18.0	5.0	15.0	0.2	80.0
37	5.0	31.4	48.4	15.0	0.2	65.0
38	13.9	6.6	73.8	5.5	0.2	65.0
39	5.0	26.2	53.0	15.0	0.7	80.0
40	27.8	37.8	19.2	15.0	0.2	50.0
41	32.4	5.3	59.4	2.1	0.7	65.0
42	29.0	50.3	5.0	15.0	0.7	80.0
43	24.2	5.0	55.7	15.0	0.2	50.0
44	5.0	74.9	5.0	15.0	0.2	80.0
45	48.8	13.6	22.1	15.0	0.5	72.8
46	13.7	65.4	14.5	5.7	0.8	80.0
47	12.3	5.0	80.0	2.0	0.7	80.0
48	66.7	19.1	11.5	2.0	0.7	50.0

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Run	X_1: Tomato %	X_2: pepper %	X_3: Onion %	X_4: Egg white %	X_5: CMC %	Z_1: Drying temperature ^{0}C
49	42.9	9.5	35.7	11.7	0.2	65.0
59	5.0	74.3	5.0	15.0	0.7	65.0
51	5.0	12.9	80.0	2.0	0.2	50.0

X_1 for tomato, X_2 for pepper, X_3 for onion X_4 for egg white, X_5 for carboxyl methyl cellulose Z_1 for drying temperature

Determination of Moisture Content

Using the oven drying method, the sample's moisture content was identified. The sample was first weighed in a dry crucible at 5g (W_1). After that, the crucible was heated to 100°C for eight hours to achieve a constant weight. After drying, the crucible was placed in a desiccator to cool for 30 minutes. The dried sample's final weight in the crucible was measured as W_2 [10].

The following formula was used to calculate the percentage of moisture.

% Moisture Content = $\frac{W_1-W_2}{W_0}\times 100$ W_o = weight of empty crucible

Determination of the Crude Protein

The method outlined by Musa and Hamza [11] was used to determine the samples' crude protein content. Each Kjeldahl digestion flask was filled with 2g of each sample, 7g of potassium sulphate, 0.35g of mercury (II) oxide, and 12mm of sulfuric acid. In a Kjeldahl digesting unit, the mixtures were digested for 45 minutes at 420°C until they turned clear yellow in colour. The tubes were covered with knobs connected to a water refluxing unit to stop ammonia from being lost through volatilization during digestion. Following digestion, the mixtures were cooled, and each flask received 75 ml of distilled water. After that, 50 ml of the alkaline solution (350 g of NaOH and 60 g of $Na_2S_2O_7$ in 1 litre of water) was added. In a Kjeldahl distilling apparatus, the mixtures were further distilled, and 150 ml of the distillate was collected in a conical flask with 25 ml of a solution of boric acid. The same process was used to create a blank (without the sample). The results of the titration of the distillates against regular hydrochloric acid were recorded. This technique made it possible to determine the amount of crude protein in the samples.

% Crude (CP) $= \frac{(Titre-Blank)\times Normality\times 14.01\times 6.25}{Weigh\ of\ Sample\times 10}$

Determination of Crude Fibre

According to what Musa and Hamza [11] reported, the crude fibre was determined. A label of W_0 was applied after the sample was precisely weighed twice. The valve was then turned to the "off" position, and the material was placed into a porous crucible before being fed into the fibre machine. An additional 150 ml of H_2SO_4 solution and a few drops of acetone were added to the column at that point. Following that, the cooler was opened in order to activate the heating element (power at 900C-1000C). The power was brought to a boil, then turned down to 30°C and left for 30 minutes. In order to make sure that all of the acid from the sample had been eliminated, the valves were then opened to drain the acid, and the column was rinsed three times with distilled water. The aforementioned procedure was carried out once more with 150ml of KOH, and the samples were then dried in the oven for an hour at 150^{0}C. The sample was dried, cooled in a desiccator, and weighed as (W_1). This weighed sample is then placed in the furnace for 3 hours at 600^{0}C to oxidise the organic matter. This was fully ashed, cooled, and reweighed at the end as (W_2), at which point the percentage of crude fibre was calculated.

Crude Fibre (%)$= \frac{w_1-w_2}{w_0}\times 100$

W_0 = Initial weight of sample W_1= weight of mixture before heating W_2 = weight of mixed sample after heating

Determination of Fat/Lipid

The fat content was determined as reported by the Musa and Hamza [11]. The dry extraction method was used for this analysis. Crude fat was identified using the ether extraction technique and the Soxhlet apparatus. The two grammes of moisture-free sample were held in a fat-free thimble before being put inside the extraction tube. The receiving beaker was cleaned, dried, and weighed as W1 before being placed in the apparatus with about 250 ml of petroleum spirit. A tube was then used to allow water to enter the extractor from the tap while it was operating at 600C. To make sure that there was a clean, colourless, fat-free solvent present in the tube above the receiving flask after six hours, eight siphonings were carried out successively. The content of the flask was then subjected to evaporation, leaving only the fat extract in the flask and the flask was weighed as W_2. The percentage crude fat was then calculated as follows:

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Crude fat (%) = $\frac{w_1 - w_0}{w_2 - w_0} \times 100$

Determination of Carbohydrate Content

The carbohydrate content of the sample was obtained by difference, that is, as the difference between the total summations of percentage moisture, fat, fibre, protein, ash and 100. The Carbohydrate was calculate using Equation.

% Carbohydrate = 100 – (% Protein + % Fat + % Crude fibre + % Ash + MC)

Vitamin C

Redox titration with iodine solution was used to determine the amount of vitamin C present. A 250 mL conical flask was filled with a 20 mL aliquot of the sample solution, 150 mL of distilled water, and 1 mL of starch indicator solution. Iodine solution containing 0.005 mol was used to titrate the sample. The first permanent trace of a dark blue-black colour caused by the formation of the starch-iodine complex was found at the titration's endpoint [12]. To calculate the amount of ascorbic acid (vitamin C) present:

Vitamin (ascorbic acid (mg)) = ML × ML × 176.12g/Mol (3.6)

Where:

ML represents the volume of iodine solution used (in mL).

Alternatively ascorbic acid M = (Mass ascorbic acid × mol) / (176.12g of ascorbic acid × 103mL/vol. of iodine solution)

Where:

Mass ascorbic acid is the mass of the sample (in grams).

Mol is the molar ratio of iodine to ascorbic acid (it's typically 1:1 for this titration).

176.12g is the molar mass of ascorbic acid (in g/mol).

Vol. of iodine solution is the volume of the iodine solution used (in mL).

Titratable Acidity

The titratable acidity was determined as per the method described by Hassein *et al.*,[13].By titrating 10 mL of the foam mat dried pepper onion tomato samples—diluted with 10 mL of distilled water and boiled to evaporate the CO_2—with 0.1 N sodium hydroxide and using phenolphthalein as an indicator—with 0.1 N sodium hydroxide, it was possible to determine the titratable acidity (expressed as citric acid percent). To determine the titration's end point, the pH was measured during titration as tomato colourful fruits up to 8.03. Using the following formula, the titratable acidity was expressed as a percentage of citric acid:

Titratable acidity (%) = $\frac{(V_{NAOH} \times C_{NAOH} \times 0.070 \times 100)}{V_{Sample}}$

Where V_{NAOH} =titratable volume of solution; V_{sample} = titratable volume of sample; C_{NAOH} = Concentration of NaOH solution.

Lycopene Content

Lycopene was measured using a modified version of [14]. Shortly after being homogenised and agitated with 5 ml of petroleum ether and 500 mg of samples, the supernatant was decanted. Supernatants were pooled and the final volume was increased to 10 ml after the procedure was repeated until no colour was obtained. The supernatant's absorption was measured at 505 nm using a UV-visible spectrophotometer. This is how the lycopene content was determined:

LycopeneContent(mg/100g)

$= \frac{3.1206 \times Final\ volume \times Optical\ density \times 100}{Weight\ of\ sample\ taken\ (gm) \times 1000}$

Total Soluble Solid

Using the technique outlined by the Association of Official Analytical Chemists AOAC [12], the TSS was calculated using a digital sugar/Brix refractometer with a resolution of 0.2°Bx (Sper Scientific, China, 300010, 0-32 percent W/ATC). To create a homogeneous mixture, the samples were thoroughly mixed. The samples were dropped onto the refractometer's prism, and a direct reading was obtained by looking at the scale in °Bx. The total amount of soluble solids content is represented by this. The

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refractometer's prism was cleaned with distilled water in between samples and dried before use. Standardization of the refractometer was done using distilled water (0°Bx).

E. Sensory Evaluation

The foam-mat dried tomato-pepper-onion powder samples were analyzed for taste, colour, flavour as well as overall acceptability using a 20 – member semi-trained panel, made up of students at the Federal University of Technology Minna. A 9-point hedonic score system as highlighted by Sengev*et al.*,[15] was used with the following ratings: 9-like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like or dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much and 1 = Dislike extremely.

F. Optimisation of the Foam-mat Dried TPOP Powder

Numeric optimization was employed to search for the best possible values for the variables, guided by specific criteria and constraints. Following the optimization procedure, the outcomes were assessed to identify the most favorable combination of variables that would achieve the highest desired objective as measured by a desirability index. The optimization objectives encompass minimizing moisture content, pepper, and onion quantities, while simultaneously maximizing other nutritional qualities and additional ingredients.

III. Result and Discussion

The results of the proximate composition and physicochemical properties of foam-mat dried tomato-pepper-onion powder are presented in Table II, while the results of the sensory evaluation are presented in Table III.

Table II: Proximate Composition and Physicochemical Properties of the TPOP Powder

Run	MC (%)	Ash Content (%)	Fat (%)	CP (%)	CF (%)	CHO (%)	Vit. C (mg/100g)	TA (mg/L)	TSS (^{0}Brix)	Lycopene mg/100g
1	11.70	6.50	2.13	19.60	2.70	51.07	16.86	0.389	20.0	13.4
2	12.54	4.45	1.87	9.06	3.20	68.88	8.23	0.584	21.8	12.2
3	12.50	2.50	1.06	5.67	3.70	73.07	5.61	0.480	18.7	9.44
4	8.15	2.78	1.63	9.07	0.91	77.46	10.88	0.346	20.3	14.3
5	10.23	5.70	1.20	10.66	3.87	64.34	10.23	0.429	18.6	11.0
6	9.78	2.99	0.90	12.56	3.11	67.81	3.78	0.510	28.1	13.7
7	8.98	3.12	2.80	16.87	1.98	66.30	7.23	0.389	27.2	10.4
8	8.07	5.00	2.24	19.95	2.00	62.74	2.80	0.334	20.7	13.5
9	10.25	6.50	0.57	11.34	2.34	71.00	8.11	0.488	19.3	8.23
10	7.45	2.50	1.08	14.00	1.88	69.00	11.78	0.382	28.1	4.06
11	7.11	2.86	2.89	13.25	1.79	72.10	14.22	0.493	17.4	10.8
12	11.80	3.68	1.80	4.50	2.13	76.09	6.31	0.432	18.3	12.6
13	10.31	3.90	2.70	15.90	3.56	58.63	11.96	0.402	20.5	14.2
14	12.99	2.40	1.30	11.50	3.44	67.03	15.56	0.480	23.4	15.3
15	11.23	2.50	0.71	9.80	3.67	68.09	6.80	0.574	17.6	6.50
16	14.65	4.50	0.45	12.56	3.32	64.52	6.80	0.479	18.5	13.2
17	11.10	3.56	1.23	14.50	2.49	67.15	10.25	0.683	19.9	14.7
18	8.16	2.55	1.11	12.78	1.65	73.75	10.30	0.307	20.8	10.7
19	8.20	2.07	1.78	11.90	1.78	74.27	6.47	0.399	27.6	10.8
20	11.67	4.21	2.10	15.00	2.15	64.87	5.00	0.248	17.3	4.91
21	12.68	2.32	2.04	8.90	3.30	67.76	8.96	0.647	20.6	6.57
22	12.24	3.86	2.80	15.34	2.50	63.23	14.39	0.285	19.4	5.11

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Run	MC (%)	Ash Content (%)	Fat (%)	CP (%)	CF (%)	CHO (%)	Vit. C (mg/100g)	TA (mg/L)	TSS (^{0}Brix)	Lyco pene mg/100 g
23	12.34	4.33	2.22	14.60	3.65	62.86	9.56	0.338	18.8	16.4
24	12.30	3.89	0.80	12.00	3.47	67.50	4.68	0.472	29.0	11.1
25	8.90	4.50	2.00	10.12	2.49	71.99	5.11	0.474	19.7	14.6
26	8.30	2.88	3.40	11.47	2.13	66.82	3.53	0.417	25.4	10.6
27	16.2	6.50	1.14	14.00	3.90	58.26	10.00	0.538	17.0	10.4
28	8.00	4.57	2.90	11.72	0.98	71.83	8.09	0.499	18.6	12.6
29	8.90	4.50	1.86	16.18	1.20	67.36	10.66	0.388	19.8	9.08
30	12.78	4.30	0.50	9.87	2.67	69.93	6.87	0.450	19.4	10.3
31	9.46	5.60	0.87	7.74	1.23	75.10	5.00	0.559	20.5	8.82
32	11.50	6.80	0.61	13.80	2.22	63.57	10.43	0.388	17.3	6.72
33	7.67	6.40	2.60	7.80	1.21	74.32	6.22	0.289	18.9	10.4
34	10.15	3.40	0.32	10.60	1.10	74.43	3.56	0.475	23.8	15.6
35	12.19	2.50	2.78	13.80	2.30	65.43	15.64	0.264	19.0	13.1
36	8.67	6.23	2.98	11.00	0.90	70.22	11.45	0.636	25.8	7.78
35	11.34	6.50	1.76	10.06	2.03	66.65	6.00	0.538	17.3	10.2
38	12.71	6.50	0.68	10.00	2.31	67.80	6.68	0.393	18.4	6.43
39	8.40	4.97	1.20	7.56	1.30	76.57	16.86	0.498	20.5	12.4
40	11.40	3.00	2.87	10.50	3.62	64.61	8.23	0.593	21.3	10.3
41	8.30	2.97	0.85	9.60	2.50	75.78	5.61	0.593	19.9	6.60
42	7.26	3.12	2.60	9.79	1.20	76.03	10.88	0.368	17.8	9.36
43	11.56	4.50	2.67	6.70	3.27	68.30	10.23	0.610	19.6	8.56
44	8.47	2.00	0.95	8.23	1.70	78.65	3.78	0.373	27.7	4.87
45	8.15	4.74	2.70	7.60	2.99	73.82	7.23	0.368	18.5	14.3
46	8.70	3.60	0.50	9.30	1.40	76.50	2.80	0.394	20.2	10.5
47	8.33	3.70	0.34	8.56	1.50	77.57	8.11	0.567	23.6	11.2
48	12.10	5.80	1.30	12.10	3.84	62.86	11.78	0.546	19.5	8.38
49	8.40	4.65	2.50	11.60	2.33	70.52	14.22	0.466	17.4	4.28
50	8.00	4.00	1.65	7.40	2.27	76.68	6.31	0.498	18.6	11.3
51	12.20	2.70	0.60	9.08	3.60	68.82	11.96	0.398	15.4	8.76

MC: Moisture content, CP: Crude protein, CF: Crude fibre, CHO: Carbohydrate, TA: Titratable acid, TSS: Total soluble solid

Table III: Mean Score for Sensory Quality of the Foam-mat Dried Tomato-pepper-onion Powder

Run	Taste	Colour	Flavour	Overall Acceptability
1	5.8333	5.7000	6.6333	6.6333
2	7.0667	5.9667	7.5333	7.7333
3	4.0667	6.1000	3.7333	4.5559
4	2.8333	4.6778	5.0000	4.6668
5	5.3360	8.1799	5.0333	5.6777
6	4.9333	6.6000	2.3333	3.5667
7	6.8667	5.5000	5.0000	6.5000

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Run	Taste	Colour	Flavour	Overall Acceptability
8	8.5000	8.0000	8.0333	8.0667
9	5.3333	6.2667	5.8667	5.7000
10	6.5333	5.9000	5.0000	6.0333
11	6.4667	6.4000	5.0000	5.9333
12	5.6667	3.9667	5.0000	4.0333
13	5.8886	5.5000	5.5000	5.4333
14	6.6000	5.1323	6.0000	7.8333
15	7.3333	6.3000	6.5333	5.6750
16	3.9000	6.2333	3.9667	3.7667
17	6.9333	5.5995	6.2555	5.3899
18	6.8000	7.7002	5.0000	6.1000
19	5.4333	3.6667	6.6337	5.9333
20	5.8000	3.7333	5.7000	5.2000
21	3.4667	3.2226	4.5000	4.0000
22	4.5003	5.6420	3.3343	3.6644
23	5.0000	5.3000	5.3242	4.5330
24	7.9533	6.0000	7.4443	7.9044
25	2.0637	5.5543	2.0000	4.5345
26	5.6433	5.9995	4.4234	5.3222
27	4.5350	5.6534	4.3232	5.3332
28	2.3332	5.7434	5.7000	3.0506
29	4.0000	5.3334	7.0333	3.5000
30	5.4233	5.5545	5.0000	4.5435
31	6.3667	5.7333	3.3423	4.5656
32	3.6675	4.5000	3.7574	5.7465
33	2.3544	2.9064	2.9500	2.6432
34	5.4333	5.5350	5.0000	5.5000
35	5.4200	6.4240	4.5352	6.1000
36	5.6333	3.7667	7.1000	6.0000
37	3.0000	5.8320	4.5754	3.0000
38	5.5000	6.4000	4.3343	4.1221
39	2.8443	3.3422	5.0378	2.9949
40	6.3332	5.7295	5.0101	5.5298
41	5.5333	5.4000	4.0000	5.4578
42	5.5000	3.2000	5.5333	4.6433
43	6.6000	5.4333	3.7000	5.5837
44	4.9889	3.9950	4.6600	4.3333
45	6.6000	6.3000	6.6178	5.6333
46	5.6768	5.0000	5.4333	5.0992
47	5.3667	5.0000	4.5556	4.2667
48	3.5000	6.1000	4.0678	4.1333

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Run	Taste	Colour	Flavour	Overall Acceptability
49	7.1333	6.6000	5.6000	6.5033
50	5.9000	5.8667	6.0000	7.0000
51	6.3333	6.7777	5.6333	5.7667

Table IV: Summary of ANOVA for the Quality Indices of TPOP Powder

Quality Indices	Sum of Square	Mean Square	F-value	p< 0.05
Moisture Content	345.11	345.11	211.59	0.0001
Protein	305.72	25.48	4.26	0.0003
Ash	37.75	1.30	2.77	0.0093
Fibre	37.01	12.34	125.03	0.0001
Fat	9.34	0.6670	4.75	0.0001
Carbohydrate	813.15	135.53	7.37	0.0001
Vitamin C	591.07	29.55	10.59	0.0001
TSS	165.05	15.00	3.64	0.0013
TA	8.37	0.3640	9.19	0.0001
Lycopene	364.38	40.49	10.22	0.0001

TA: Titratable acid, TSS: Total soluble solid

G. Quality Indices of TPOP Powder

The quality indices of foam-mat dried tomato-pepper-onion powder showed a significant difference ($p<0.05$) as shown in Table IV above. The flow and other mechanical properties of a powdered food are significantly influenced by the moisture content of the powder. However, a lot depends on the technique, scope, and atmospheric humidity during drying [16]. The moisture content of the foam-mat dried tomato-pepper-onion powder exhibited a significant range, spanning from 7.11% to 16.2%. The lowest moisture content was observed in sample (7) of the experimental design shown in Table 1, which consisted of 61.9% tomato, 18.0% pepper, 5.0% onion, 15% egg white, 0.7% CMC, and was dried at a temperature of 80°C. Similarly, the highest moisture content was recorded in sample (27) with mixture components of 62.7% tomato, 5.0% pepper, 23.2% onion, 8.3% egg white, 0.7%5 CMC and 50^0C drying temperature. The range of this moisture content contradicts the previous study Joseph *et al.*,[17] that reported the dehydrated tomato and pepper has a moisture content range of 7.85 - 9.20% as presented in Table I. The low moisture content other than sample or run (27) could be attributed to the addition of onion and pepper in the foam-mat dried powder [18].The protein content ranged between 4.50 – 19.95%. The highest crude protein was recorded in a sample containing a mixture of 63.90% tomato, 6.40% pepper, 27.50% onion, 2.0% egg white and 0.2% CMC with a drying a temperature of 80.0^0C. Lowest crude protein was found in a sample containing a mixture of 7.2% tomato, 78.5% pepper, 11.50% onion, 2.0% egg white and 0.70% CMC with a drying temperature of 65.0^0C. The ash content of the foam-mat dried powder samples ranged between 2.0% and 6.50%. The minimum ash content was observed in a sample consisting of 5.0% tomato, 74.9% pepper, 5.0% onion, 15.0% egg white, and 0.20% CMC, dried at a temperature of 80°C. On the other hand, the maximum ash content was found in a sample comprising 5.0% tomato, 31.4% pepper, 48.4% onion, 15.0% egg white, and 0.2% CMC, dried at a temperature of 65°C. The higher proportion of pepper and the lower proportion of onion might contribute to the lower ash content. Different ingredients have varying mineral compositions, and the particular combination of ingredients in this sample could result in a lower overall ash content. Onions are known to contain minerals such as sulfur, potassium, and calcium, which could increase the ash content of the dried powder [19]. The crude fibre of the foam-mat dried tomato-pepper-onion powder varied significantly between 0.90 – 3.90, with lowest amount of the fibre found in 61.90% tomato, 18.0% pepper, 5.0% onion, 15.0% egg white and 0.20% CMC with 80^0C drying temperature. On the other hand, the mixture of 62.70% tomato, 5.0% pepper, 23.2% onion, 8.0% egg white and 0.70% CMC with a drying temperature of 50^0C produced the highest fibre in the powder. The fat content ranged between 0.32 – 3.40%, with minimum fat in sample (34) containing 56.3% tomato, 5.0% pepper, 36.5% onion, 2.0% egg white, 0.20% CMC with a drying temperature of 57.5^0C, while maximum fat was found in sample (26) with mixture components of 37.8% tomato, 40.3% pepper, 19.4% onion, 2.0% egg white and 0.5% CMC with a drying temperature of 80.0^0C. The deviation of this ranges from the previous research for hydrated pepper and tomato of 1.70%-2.00%, as reported by Joseph et *al.*, [17] could be attributed to different composite mixture of the powder. The carbohydrate content ranged between 51.07 – 78.65% with the highest amount recorded in a mixture of 5.0%

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tomato, 74.9% pepper, 5.0% onion, 15.0% egg white, 0.20% CMC at a drying temperature of 80.0^{0}C. On the other hand, the lowest amount was found in a sample containing 5.0% tomato, 74.9% pepper, 5.0% onion, 15.0% egg white and 0.20% CMC at a drying temperature of 80.0^{0}C. Vitamin C content (ascorbic acid) of tomato is important because of its antioxidative characteristics. Ascorbic acid is one of the most thermolabile components of food products, fact also confirmed in the drying of vegetables[20]. The results of this study showed that ascorbic acid degradation was largely influenced by drying temperature The vitamin C of the foam-mat dried powder varied significantly from 2.80 to 16.86 mg/100g with the highest amount found in a mixture containing 78.50% tomato, 5.0% pepper, 5.0% onion, 13.3% egg white, 0.20% CMC and a drying temperature of 50^{0}C. the lowest amount of vitamin C was recorded in a mixture containing 5.7% tomato, 9.6% pepper, 70.8% pepper, 13.2% egg white, 0.7% CMC and a drying temperature of 50^{0}C. Similar result was reported byOgori*et al.*,[18]. The variation in the vitamin C content agrees with the studies that dehydration process can affect the physiochemical properties of tomato or vegetable powder [21].The total soluble solids content ranged between 17.38 – 28.16 ^{0}Brix and the highest amount was found in a sample containing a mixture of 22.6 % tomato, 70.2% pepper, 5.0% onion, 2% egg white, 0.2 of CMC at a drying temperature of 50^{0}C. On the other hand, the highest TSS was recorded in powder mixture of 23.1% tomato, 5.30% pepper, 55.9% onion, 14.9% egg white, 0.7% CMC at 65^{0}C drying temperature. The TSS of the previous studies fell within the range of 3.84 – 4.10 ^{0}Brix as reported by [22]. Similar types of results were noticed by other researchers for foam mat dried tomato powder [3], and alphonso mango powder [23]. TA is a measure of the total acid content in a sample, expressed as a concentration of acid (usually citric, malic, or tartaric acid) in milligrams per liter (mg/L). It provides an indication of the acidity or sourness of a food product [3].The values of titratable acid for the foam-mat dried tomato-pepper-onion powder ranged between 0.248 – 0.683 mg/L. The highest TA value was found in a sample consisting of 69.0% tomato, 16.3% pepper, 8.1% onion, 5.9% egg white, 0.8 of CMC at a drying temperature of 65^{0}C. On the other hand, the lowest TA was recorded in powder mixture comprising 23.1% tomato, 5.3% pepper, 55.9% onion, 14.9% egg white, 0.7% CMC at 65^{0}C drying temperature. The variations in TA values within the current study can be attributed to the different compositions of the mixtures and the drying conditions applied. The proportions of tomato, pepper, onion, egg white, and CMC in each sample can influence the overall acidity of the dried powder. The lycopene content of the powder varied significantly from 4.06 to 16.430 mg/100g. The highest lycopene content was found in a sample containing a mixture of 5.0% tomato, 14.6% pepper, 78.2% onion, 2% egg white, 0.2 of CMC at a drying temperature of 80^{0}C. While the highest lycopene content was recorded in powder mixture of 41.7% tomato, 42.0% pepper, 9.7 % onion, 5.8% egg white, 0.8% CMC at 50^{0}C drying temperature. This result agrees with the one obtained by [18]. The high rate of lycopene content is attributed to the addition of onion and pepper in the mixture. According toCollins *et al.*, [24], tomato and tomato products are good sources of carotenoids in particular lycopene, vitamin C.

H. Sensory Evaluation

The result of the sensory evaluation shown in Table III provides valuable insights into the attributes that drive the acceptability of TPOP powder.Sample 8 comprising 63.9% tomato, 6.4% pepper, 27.5% onion, 2.0% egg white, 0.2% CMC dried at 80^{0}C stands out as the most preferred one across all attributes, as it received the highest scores for taste, color, flavor, and overall acceptability. On the other hand, sample 25 comprising 5.0% tomato, 74.3% pepper, 18.5% onion, 2.0% egg white and 0.2% CMC dried at 65^{0}C was consistently among the least preferred, receiving low scores for taste, flavor, and overall acceptability. The poor rating of sample 25 could be attributed to its composition, due to its higher pungency.

Table V: Optimal Solutions

Number	Tomato	pepper	Onion	Egg White	CMC	DT	Desirability Index	Decision
1	**67.256**	**5.000**	**20.000**	**7.594**	**0.150**	**61.939**	**0.5972**	**Selected**
2	67.243	5.000	20.000	7.607	0.150	61.833	0.5972	
3	67.377	5.000	20.000	7.473	0.150	61.559	0.5971	
4	67.272	5.000	19.991	7.587	0.150	61.232	0.5970	
5	66.568	5.757	20.017	7.508	0.150	60.703	0.5955	
6	65.473	6.298	20.000	8.079	0.150	60.863	0.5945	
7	65.253	5.000	20.004	9.593	0.150	62.858	0.5927	
8	63.212	8.707	20.206	7.725	0.150	59.701	0.5859	

Table V shows the values of the components and processing parameter used for each of the 13 experimental runs chosen by Design

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Expert, along with the desirability index and decision. The desirability index is a number between 0 and 1 that indicates how well the experimental conditions meet the desired target values for each of the response variables. The decision column shows which formulation was selected based on the desirability index. From Table V, the selected formulation (run 1) has the highest desirability index of 0.5972, which was achieved by using 67.256% tomato, 5% pepper, 20% onion, 7.594% egg white, 0.15% CMC, and a drying temperature of 61.939°C. Figure 1 shows the response surface plot for the optimization of the foam-mat dried powder. While figure 2 – 6 shows the surface response plot for the proximate composition of the TPOP powder. This formulation was chosen because it was the closest to the desired target values for the response variables, which were not explicitly given in the table.

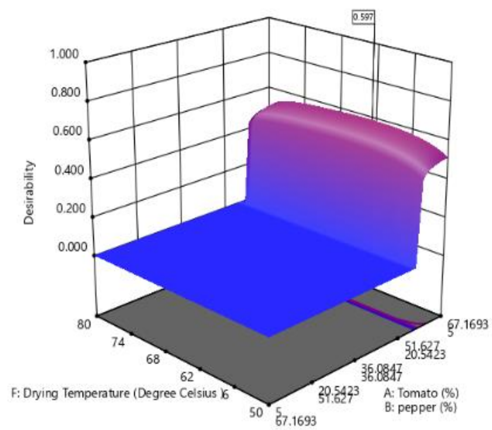


Fig. 1: Response surface plot for optimisedfoam-mat dried tomato-pepper onion Powder

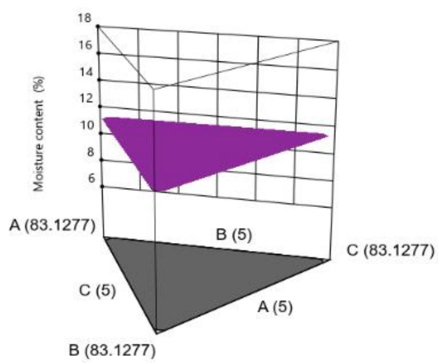


Fig. 2: Response surface plot of moisture content

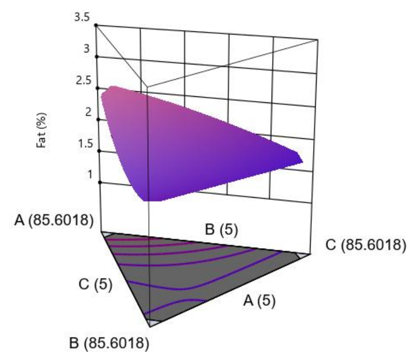


Fig. 4: Response surface plot of fat

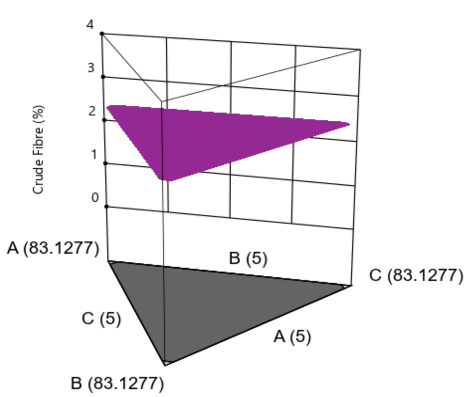
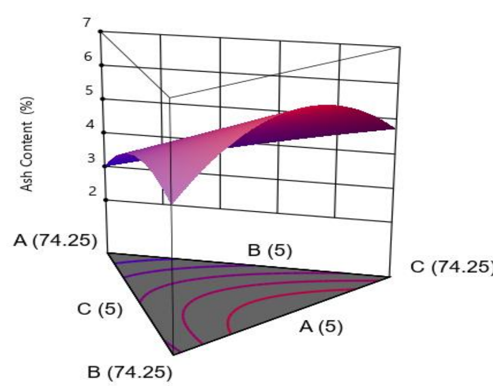


Fig. 3: Response surface plot of crude fibre



5: Response surface plot of ash content

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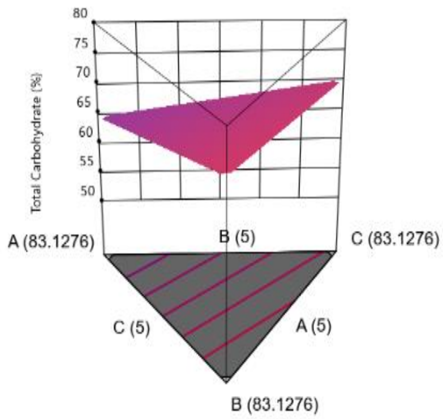

Fig.6: Response surface plot of carbohydrate

IV. Conclusion

The results of this study showed that the TPOP powder was successfully developed using the foam-mat drying method. Analyzing a few chosen physicochemical characteristics of the TPOP powder as part of its characterization yielded useful information about how the powder behaved in various food systems. The powder's moisture content, ash content, crude fibre, protein content, fat, carbohydrate, lycopene content, TSS, TA and vitamin C were determined, providing crucial information for its application in various food products.

The result obtained from process optimisation of its powder indicate that this technique is highly effective for preserving.

the nutritional content and sensory attributes of these vegetables. The optimal proportion of the ingredient in the foam-mat dried tomato-pepper-onion powder, based on the quality indices and sensory characteristics were found to be 67.3% tomato, 5.0 pepper, 20% onion, 7.59% egg white, 0.150% CMC and 61.93ºC drying temperature. The powder can be used to flavour and bolster the nutritional value of a variety of products, including soups, sauces, seasonings, and ready-to-eat meals. Other vegetable and fruit powders can be dried using the foam-mat technique, increasing its applicability in the food processing sector.

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