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Preservation of Tomato Paste Using Chitosan Monosaccharide Complex

Ahmad Ahmad Saleh, Ameh O. Alewo and N.S. Maina
Department of Chemical Engineering, Ahmadu Bello University, Zaria
Corresponding author's email address: ahmadkargi3@gmail.com, +2348032401577, aoameh@abu.edu.ng, +2348053385249, nsmaina@yahoo.com, +2348037015056

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Abstract

This study is using one of the alternatives that are currently being investigated to replace the use of chemical preservatives to inhibit microbial growth and increase the shelf life of tomato paste. The chitosan monosaccharide complex has shown promise as a preservative in inhibiting microbial growth, extending shelf life, and retaining the quality of tomato paste. The preserved tomato paste (sample B) was stored for 70 days and its proximate and nutritional compositions were compared with those of the tomato paste (sample A). The chitosan glucose complex reduced microbial growth in tomato paste by using 0.1% glucose and 2.0% chitosan. The optimum reduction was 0.6666 log cfu/ml and 5.9102 log cfu/ml for bacteria and fungi, respectively, with a paste/complex ratio of 10 g/ml. The proximate analysis of the tomato paste (sample A) and preserved tomato paste (sample B) were 83.69% and 85.88% for moisture content and ash content, 3.31% and 2.18%, crude fat: 1.63% and 1.20%, crude fiber: 3.56% and 3.14%, and carbohydrate: 4.27, 5.0. The mineral and vitamin C contents were as follows: Ca 127 mg/100 g, Mg 37 mg/100 g, Na 113 mg/100 g and Fe 22 mg/100 g for sample A while sample B and 109, 31, 75, and 27 mg/100 g (Ca, Mg, Na and Fe). The vitamin C content of 6.53 mg/100 g for sample A and sample B 15 mg/100 g. The overall acceptability of samples A and B was 8.20 and 6.00 for the sensory qualities.

1.0. Introduction

Tomato (*Lycopersicon esculentum*) ranks as one of the world's leading crops and an essential part of the human diet [1]. Tomatoes have less sugar than other edible fruits. Tomatoes are widely consumed in the fresh state because they provide a balanced and rich nutritional supplement [2], but their flowering nature means they quickly deteriorate when ripe. Tomato fruit can be processed and made available off-season as tomato puree, ketchup, paste, powder, tomato chutney, etc. The red color of the carotenoids in some vegetables and fruits is due to the presence of lycopene, a powerful antioxidant that helps prevent certain types of cancer and heart disease. Tomatoes are considered not only a food but also medicine, a nutraceutical, a flavoring agent, an antidote, and a cleaner for the human system [2]. Tomatoes are lost due to climatic conditions and postharvest microbes [3]. Microbial growth in food leads to several biochemical changes in food, including the biochemical formation of acids, amines, and gases. Microbial food spoilage refers to food deterioration manifested as loss of texture and often a distortion of color and odor. Mycotoxin contamination can cause potential carcinogenic and mutagenic diseases in humans [2]. Due to the high perishability of

tomatoes, edible coatings, and films are used to reinforce natural layers and retain moisture to extend the shelf life (pre and post-harvest) of tomatoes by regulating their metabolic activity which can prevent the loss of control exchange of important gases such as oxygen, carbon dioxide and ethylene that are involved in the respiratory process.

Edible coating elements are split up into three classes: hydrocolloids, lipids, and composites (hydrocolloid and lipid components). Hydrocolloids comprise proteins and polysaccharides such as chitosan, starch, alginate, cellulose derivatives, gelatin, and agar. Lipids include waxes, acylglycerols, and fatty acids [4]. The essential sustainability of biopolymers has shown much attention in recent years due to their potential use in food as preservatives [5]. Among these biodegradable essential polymers is chitosan, which seems to be the future alternative as a preservative [6].

Chitosan is a unique synthetic soluble polysaccharide that exhibits organic and non-toxic properties through the chemical and enzymatic processes of chitin [7]. Chitosan (1–4)-2amino-2-deoxy-β-D-glucan, derived from partial deacetylation of chitin in alkaline media, is the most abundant and most natural cationic polysaccharide with potential food applications after cellulose [6]. Chitosan varies according to the field of application. Some areas such as water treatment, pulp and paper, pharmaceuticals, cosmetics, biotechnology, agriculture, food, membranes, and pharmaceuticals [8]. Chitosan is recognized as useful as an antibacterial agent, emulsifier, thickener, and stabilizer in the food industry [9]. Applications of this polysaccharide are limited by its high molecular weight and poor solubility in aqueous media [8]. The greatest advantage of chitosan is that it can be chemically enriched into various by-products due to the presence of major alcohols and amino groups [10].

Optimization is important to achieve the best food products for use in food, as it can improve processes and reduce costs. By using modeling methods such as Computational Fluid Dynamics (CFD) modeling and Response Surface Methodology (RSM), the accuracy and reliability of the model can be improved to better predict and optimize the process parameters [11]. Optimization helps to determine the impact of parameters on shelf life prediction and mechanical design, leading to more effective storage strategies [12]. Overall, optimizing the formulation of the best food preservatives allows for better process control, improved product quality and reduced costs [13]. This study aimed to use chitosan monosaccharide complex as a preservative in tomato paste, identify effective microbial reduction methods, optimize best complex, and characterize paste properties.

2.0 Material and Methods

2.1 Sample Treatment

The tomato fruits are crushed in a pestle and mortar to make tomato pastes and dry up using a conventional method of drying technique.

2.2 Preparation of Acetic acid solution

Glacial acetic acid was taken as 1.02ml (98% -1%) and added with distilled water to 100ml, then homogenized.

2.3 Preparation of Chitosan Complexes

1 g (1%) chitosan was inserted into a glass beaker, diluted with 1% acetic acid and 50 ml aquades and distilled for ± 30 minutes (until homogeneous). After homogeneity, 0.5g, 1g, and 1.5g (0.5%, 1%, and 1.5%) of monosaccharide's (glucose, fructose, and galactose) were added, and then the volume was adjusted to 100ml using a volumetric flask. The mixed solution was then sterilized by autoclaving at 121^{O}C for 15 min [14].

Table 1: Preservatives with their respective Microbial Counts

Preservative code(s)	Preservatives (%)	Bacterial counts (cfu/ml)	Fungal counts (cfu/ml)
C0	1% chitosan		
C1	1% chitosan + 0.5% glucose		

C2	1% chitosan + 1% glucose
C3	1% chitosan + 1.5% glucose
C4	1% chitosan + 0.5% galactose
C5	1% chitosan + 1% galactose
C6	1% chitosan + 1.5% galactose
C7	1% chitosan + 0.5% fructose
C8	1% chitosan + 1% fructose
C9	1% chitosan + 1.5% fructose

2.4 Bacterial Load Count of Tomato Samples

Aliquots (1.0 ml) in the test tube containing 9.0 ml of sterile distilled water and a five-fold serial to 10^{-5} dilution factor were prepared, 1.0 ml each of 10^{-3}, and 10^{-4} dilutions were inoculated onto sterile nutrient agar using spread plate technique. Then the plates were inoculated at 37^0C overnight and the established colonies were counted [2].

2.5 Fungal Load Count of Tomato Paste

1cm^3 of the serially-dilute sample 10^{-3} and 10^{-4} was allotted into a conical flask having sterile potato dextrose agar (PDA). The mixture of the contents were sterilized and distributed into sterile Petri dishes. The plates were incubated at room temperature for five days and established colonies were counted [3].

The bacterial and fungal counts were conducted to determine the number of microbial and total counts.

2.6 Response Surface Methodology (RSM)

Design Expert is a recognized statistical method for experimental design and optimization, the process of selecting the best experimental design and estimating the effects of multiple variables interacting independently and simultaneously. Response Surface Methodology (RSM) is used for experimental modeling and analysis of relationships between input and response variables [15]. The input variable consists of four components: Glucose (%), chitosan (%), tomato paste/complex ratio (g/ml) and time (days), response is bacterial and fungal (cfu/ml). Table 2 shows the input variables using optimal design.

Table 2: The input variables for Chitosan Complex

s/no	FACTORS (units)	Lower	Upper
1	Glucose (%)	0.1	1.5
2	Chitosan (%)	0.5	2
3	Paste/ complex ratio (g/ml)	3.33	10
4	Time (day)	14	70

2.7 Proximate Analysis

2.7.1 Moisture

0.5g of sample material was weighed into a pre-weighed crucible. The crucible containing the sample was dried in an oven for 24 hours, cooled in a desiccator and weighed to a constant weight.

$$\%\, moisture = \frac{W - (W_2 - W_1)}{W} * 100 \quad (1)$$

Where,

W_1 =initial weight of the empty aluminum dish

W_2 =weight of aluminum dish + sample before drying

W =final weight of dish + sample after drying

2.7.2 Ash content

The crucible was dried from the oven in a desiccator at 100 °C for at least 2 h, cooled, and the weight (W1) was recorded. 5g of sample was inserted into the crucible (W2). The sample was then preheated in an oven at 600 °C for 2 h. The crucible was removed from the oven, cooled in a desiccator, and weighed (W3) again [16].

$$\%Ash = \frac{W3 - W1}{W2 - W1} X\ 100\% \quad (2)$$

Where,

W_1 = weight in grams of empty crucible

W_2 = weight in grams of crucible + sample before ashing

W_3 = weight in grams of crucible + ash

2.7.3 Crude Protein Content

A 0.2 g of sample to the digestive tube and 15cm^3 of H_2SO_4 acid was added. The tube was gently swirled until the sample and acid were thoroughly mixed. 5 g of Kjeldahl catalyst mixture was added and heated curiously until the solution became clear. The temperature was raised and the solution was heated to boil for 2 hrs until it became transparent. The solution was cooled and transferred to a 100 cm^3 volumetric flask, made up to volume with distilled water and thoroughly mixed. This completes the digestion process.

For distillation, 10 cm^3 of 2% boric acid was measured into a 100 cm^3 Erlenmeyer flask and added 1-2 drops of mixing indicator. 10cm^3 of aliquots was dissolved into the distillation apparatus. 15cm^3 of 40% NAOH to the mixture was added. Nitrogen was distilled into the flask containing the boric acid/indicator for at least 10-15 minutes. Then, the edges of the refrigerator were washed with distilled water. The distillate was titrated with 0.025 N H_2SO_4 to the pink point and determined the burette reading [16].

$$\%Nitrogen = \frac{\frac{0.014MeN}{100g} X\ titre\ of\ the\ TV\ value\ X\ digest\ volume\ (100ml)\ X\ normality\ of\ acid\ (0.025)}{weight\ of\ sample\ (0.2g) X\ volume\ of\ aliquot\ used\ (10ml)}\ X\ 100\% \quad (3)$$

$$\%Crude\ protein = \%N\ X\ 6.25 \quad (4)$$

2.7.4 Crude Fibre Content

Transfer 2 g of sample (W1) to the filter paper support of a 600 funnel cone, extract three times with 25 cm of ether and apply vacuum until the sample is dry. The extracted sample is quantitatively transferred to a 600 cm^3 beaker by brush while the fibres are broken down. Add 200 cm^3 of 1.25% sulfuric acid solution (H_2SO_4). Place the glass in a preheated digester and boil for exactly 30 minutes. Rotate the glass periodically to prevent solids from adhering to the sides. Remove the beaker and strain the contents through a California Buckner funnel. Rinse in a glass of hot water of 50-75 cm^3 and wash with a funnel. Repeat three times with 50 cm^3 of water and wipe dry. Blow through the funnel to return the residue. Add 200 cm^3 of boiling 1.25% sodium hydroxide (NaOH) solution. Then add it back to the heart and boil for 30 minutes. Remove, filter, and remove the glass as before. Then wash with 25 cm^3 of a boiling 1.25% sulfuric acid solution, followed by 50 cm^3 of water or 25 cm^3 of alcohol respectively. Dry the fiber mat and residue at 130 °C for 2 h. Then cool in a desiccator, weigh (W2) and ignite at 600 °C for about 30 minutes until the weight is consistent. Finally, after cooling in a desiccator, weigh it (W3) [16].

$$\%\ Crude\ fibre = \frac{W2-W3}{W1} X\ 100\% \quad (5)$$

Where,

W_2 = weight in gram of sintered crucible and contents before ashing

W_3 = weight in gram of sintered crucible containing ash.

W_1 = weight in gram of the material used

2.7.5 Crude Fat (Ether Extract)

Ether extract as an estimate of crude lipid was determined using soxhlet extraction method. The solvent was then evaporated by heating on a steam bath. The flask containing the fat extract was dried on a stem bath to a constant weight. The percent fat was determined by using the formula:

$$Fat(\%) = \left(\frac{mf - mi}{m}\right) X\ 100 \quad (6)$$

2.7.6 Carbohydrate Content

Carbohydrate %= 100 – (% C .P + % C. F + %Ash + %Moisture + %E.E).

2.8 Determination of Vitamin C (Ascorbic Acid)

The ascorbic acid content of tomato paste was quantified using the method of the Association of Official Chemists [17]. The preserved tomato paste samples were titrated with iodine. Vitamin C was then oxidized to iodine. When there was no more vitamin C to oxidized, there was an excess of iodine. Iodine would then combine with starch to form a blue-violet solution. The amount of vitamin C in mg/g of the paste or per ml of sample was calculated and recorded [18].

2.9 Determination of Minerals

Digest the ash residue with 5 cm^3 of concentrated nitric acid, filter through filter paper into a 100 cm^3 volumetric flask and dilute to the mark with distilled water. Transfer to sample bottle and prepare to analyze. Repeat the procedure for all other samples. An atomic absorption spectrophotometer (AAS) is an instrument used to measure minerals. This device consists of an atomizer (usually a flame), a radiation source (usually a hollow cathode lamp), a radiation scattering device, and an electronic processing unit.

Add 5 cm^3 1N Nitric acid solutions (HNO_3) in the ash contained in the crucible. Dry it by evaporating it on the hot plate at a low heat with ventilation. Place the sample back in the oven and heat it at 400 °C for 10 min to obtain completely white ash. Cool the sample again on an asbestos sheet before adding 10 cm^3 of 1N HCl. The solution is then filtered into a 50 cm^3 volumetric flask. Rinse the crucible and filter paper by adding 10ml of 0.1N HCl, repeat the procedure three times. Bring the volume to 100 cm^3 with distilled water. Minerals such as sodium, potassium, calcium, magnesium and iron are to be determined by flame photometry [16].

2.10 Sensory attributes

Samples of the different tomato paste were coded and subjected to sensory evaluation by using 10 untrained panelists comprised of students in the Department of Chemical engineering. In a comfortable room with enough light and fresh air, the panelists were asked to rate each sample according to its taste/flavor, color, appearance, and overall acceptability. Next, panelists were asked to score evaluation variables using Larmond's (1977), 9-point Hedonic scale. The results obtained from the panelists were converted to scores ranging from: like extremely (9) to dislike extremely (1). Present the samples (B, C) to each panel a control sample (A). Ask panel to rate the size of the difference between each sample and the control by providing a scale for this purpose.

3.0 Results and Discussion

Table 3: Preservatives with their respective microbial counts

Preservative code(s)	Preservatives (%)	Bacterial counts Log (cfu/ml)	Fungal counts Log (cfu/ml)
C0	1% chitosan	5.301029996	5.875061263
C1	1% chitosan + 0.5% glucose	0	5.653212514
C2	1% chitosan + 1% glucose	5.176091259	5.653212514
C3	1% chitosan + 1.5% glucose	5	5.544068044
C4	1% chitosan + 0.5% galactose	5.698970004	6.021189299
C5	1% chitosan + 1% galactose	5.602059991	6.484299839

C6	1% chitosan + 1.5% galactose	6.217483944	6.439332694
C7	1% chitosan + 0.5% fructose	5.875061263	5.812913357
C8	1% chitosan + 1% fructose	6.096910013	6.544068044
C9	1% chitosan + 1.5% fructose	5.875061263	6.511883361
TC	Control	6.544068044	6.736396502

Table 3 displayed the differences between the several preservatives, ranging from C0 (1%) to TC (control). In comparison to the control, the numbers of bacteria and fungi were reduced by the preservatives. However, out of these preservatives, C1 with 1% chitosan + 0.5% glucose exhibits the lowest bacterial decrease, with fungal counts of 5.653212514 (log cfu/ml) and bacterial counts of 0. The fungal decrease in C3 (1% chitosan + 1.5% glucose) is 5.544068044 (log cfu/ml) compared to 6.736396502 (log cfu/ml). This suggests that concentration dependence was observed for the chitosan glucose action. The findings corroborated those of Kanatt (2008), who found that the chitosan glucose complex affects concentration and has superior antimicrobial action against common food spoilers and pathogens that is identical to that of chitosan. The thermal heating (autoclaving) of the chitosan and glucose to form chitosan glucose complex at 121°C for 15mins, indicating the successful interaction, promoted by temperature, between carbonyl group of glucose and amine groups in chitosan chain, through crosslinking and maillard reaction (MR) formation [19], that led to improved antimicrobial, antioxidant and high complexing efficiency of chitosan [20].

3.1 Optimization of the Microbial growths for Green World Chitosan Complex

Table 4: Optimal based design matrix using Response Surface Methodology (RSM)

T	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Response 1**	**Response 2**
Run	A:GLUCOSE %	B:CHITOSAN %	C:PASTE/COMPLEX RATIO g/ml	D:TIME Day	BACTERIAL COUNTS Log (cfu/ml)	FUNGAL COUNTS Log (cfu/ml)
1	0.87	2	7.23195	48.72	5.30103	5.81
2	1.5	1.625	10	28	6.17609	5.88
3	0.8	1.2275	3.33	43.4	5.54407	6.15
4	0.1	1.3925	6.2648	36.68	5.8451	6.05
5	1.5	0.5	10	26.6	7.54033	6.47
6	0.1	1.3925	6.2648	36.68	6.45484	6.08
7	0.8	1.2275	3.33	43.4	6.55023	6.10
8	0.1	0.5	3.33	14	6.89209	6.50
9	1.5	1.4225	5.76455	35	4.69897	6.05
10	0.898	1.0775	7.16525	14	7.23553	6.33
11	0.226	1.58	10	70	7.42488	5.97
12	1.5	2	3.33	14	5.95424	5.79
13	0.282	0.5	4.89745	70	5.74036	6.44
14	1.5	1.6625	10	70	5.17609	6.00
15	0.898	1.0775	7.16525	14	5.8451	6.20
16	0.233	0.5	10	28.56	5.65321	6.50
17	0.114	2	10	14	0	6.00
18	0.87	2	7.23195	48.72	6.84819	5.83
19	1.5	1.58	4.63065	70	0	5.70

20	0.87	2	7.23195	48.72	6.24304	5.90
21	1.304	0.5	9.76655	70	6.26245	6.43
22	0.1	2	3.33	70	5	5.89
23	0.59	1.385	10	36.4	5	6.15
24	1.5	0.5	4.49725	29.68	6.53148	6.49
25	0.1	0.5	9.6665	68.88	7.39794	6.46

The results of the experimental design and response variable for the input factors (glucose concentration, chitosan concentration, tomato paste/complex ratio, and time) are presented in Table 4.

Table 5: ANOVA for the reduced quadratic model for Bacterial counts

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	77.48	9	8.61	18.05	< 0.0001	significant
A-GLUCOSE	2.45	1	2.45	5.14	0.0387	
B-CHITOSAN	5.36	1	5.36	11.23	0.0044	
C-PASTE/COMPLEX RATIO	1.28	1	1.28	2.68	0.1222	
D-TIME	2.51	1	2.51	5.27	0.0365	
AC	14.05	1	14.05	29.45	< 0.0001	
AD	27.06	1	27.06	56.73	< 0.0001	
CD	25.66	1	25.66	53.79	< 0.0001	
A^2	3.95	1	3.95	8.28	0.0115	
D^2	4.70	1	4.70	9.86	0.0067	
Residual	7.16	15	0.4770			
Lack of Fit	4.28	10	0.4281	0.7447	0.6774	not significant
Pure Error	2.87	5	0.5749			
Cor Total	84.64	24				

Table 6: ANOVA for Linear model for Fungal counts

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	1.49	4	0.3728	68.03	< 0.0001	significant
A-GLUCOSE	0.0310	1	0.0310	5.65	0.0275	
B-CHITOSAN	1.34	1	1.34	245.05	< 0.0001	
C-PASTE/COMPLEX RATIO	0.0115	1	0.0115	2.09	0.1637	
D-TIME	0.0285	1	0.0285	5.20	0.0337	
Residual	0.1096	20	0.0055			
Lack of Fit	0.0950	15	0.0063	2.17	0.2013	not significant
Pure Error	0.0146	5	0.0029			
Cor Total	1.60	24				

A quadratic reduced model was used to approximate the response variable for both the bacterial and fungal counts. Results were analyzed using coefficients, p-values, sum of squares, F-distribution,

and 95% confidence level statistical calculations. The model and parameters' significance were established, and the effect of interaction between input variables was also established. The 95% confidence level was used for statistical calculations.
The model F-values for the bacterial and fungal counts are 18.05 and 68.03, respectively, with a corresponding p-value of <0.0001, in both tables. These results show that both models are significant (p-value < 0.05) and that there is only a 0.01% chance that an F-value this large could occur due to noise [21]. A (glucose), B (chitosan), C (paste/complex ratio), D (time), AC, AD, CD, A^2, and D^2 are the model terms of the quadratic model; A, B, and D; are the linear model terms. Using p-values less than 0.05, it is evident that the model terms AC, AD, and CD are significant. This suggests that the combination of glucose with paste/complex ratio, glucose with time, and paste/complex ratio with time has a substantial impact on the bacteria counts.

Furthermore, because their p-values are smaller than 0.10, the individual model terms A, B, D, A^2 and D^2 also significantly affect the response variable (Bacterial counts). However, given the p>0.05, the individual model term C is not significant. Moreover, the optimization study's validity was assessed using the Lack-of-Fit criterion. Tables 5 and 6 demonstrate that the Lack of Fit is not significant in proportion to the pure error for the bacterial and fungal counts, with F-values of 0.74 and 2.17 indicating that there is a 67.74% and 20.13% probability, respectively, that the large lack of fit F-values could be the result of noise. The non-significant lack of fit suggested that the optimization model counts for bacteria and fungi are good [21].

When all other factors were maintained constant, the computed coefficients provide the expected change in response bacterial/fungal per unit change in factor value. The regression models in terms of coded factors shown in Tables 6 and 7 are expressed in Equation 7a and Equation 7b;

$$Bacterial\ Counts = 6.66 - 0.4119 * A - 0.6443 * B + 0.2997 * C - 0.4590 * D + 1.20 * AC - 1.72 * AD + 1.78 * CD - 0.9626 * A^2 - 1.05 * D^2 \quad (7a)$$

$$Fungal\ Counts = 6.14 - 0.0449 * A - 0.3101 * B + 0.0280 * C - 0.0467 * D \quad (7b)$$

The regression model for fungal counts of equation 7b and bacterial counts of equation 8 can be used to estimate the factors' respective effects at each level (high level and low level). However, in actual terms, response predictions should not be made using equations 7(a & b). Equation 8(a, & b) thus expresses the regression model for bacterial and fungal counts effectiveness in terms of actual factor.

$$Bacterial\ Counts = 9.81972 + 2.80259 * A - 0.8591 * B - 1.12204 * C + 0.0386728 * D + 0.514293 * AC - 0.0875131 * AD + 0.0190592 * CD - 1.96455 * A^2 - 0.00133434 * D^2 \quad (8a)$$

$$Fungal\ Counts = 6.72069 - 0.064151 * A - 0.413512 * B + 0.00839758 * C - 0.00166782 * D \quad (8b)$$

The response bacterial and fungal counts for any given level of each factor in its actual terms, with the levels stated in their original units for individual factors, can be predicted using the regression

model in terms of actual factors as shown in equation 8 (a & b). Nevertheless, it is not appropriate to use equation 8 to ascertain the proportionate impact of the variables on bacterial and fungal counts. This is because the intercepts are not in the middle of the design space and the coefficients were scaled to account for each factor's units.

Regression coefficients R^2 and Adjusted-R^2 were used to assess the validity and fitness of the regression model with experimental response. The regression coefficient, or R^2, is a metric that ranges from 0 to 1 and indicates how well the experimental responses match the fitted model. The closer the R^2 number is to 1, the more accurate the model prediction [21]. The obtained regression coefficients, R^2 and Adjusted-R^2 values of the fitted regression models were 0.9155, 0.8647 and 0.9315, 0.9178 respectively for bacterial and fungal counts. This demonstrates that the regression models accurately capture and describe 91.55% and 93.15% of the experimental data. The difference between the experimental and predicted bacterial and fungal counts is less than 0.2, indicating that the Adjusted R^2 value of 0.8647 and 0.9178 indicates reasonable agreement with the Predicted R^2 value [21]. The reduced quadratic and linear models appear to be a good fit for predicting the response bacterial and fungal counts, based on the high R^2 values found in this study, which also show that it describes the experimental data properly. This is due to the expectation that a model with R^2 values near to 1 would properly describe experimental data [25]. The model's qualities were assessed using an accurate signal-to-noise ratio, with a preference for a ratio greater than 4 [25].

The statistics show that a decrease in fungal counts resulting from an increase in glucose concentration from 0.1 to 1.5% and an increase in chitosan concentration from 0.5 to 2% is necessary to achieve a minimum of 5.79405 (log cfu/ml) at 6.665g/ml of paste/complex ratio and time at 42 days. On the other hand, fungal counts increase in response to a decrease in both glucose and chitosan concentrations.

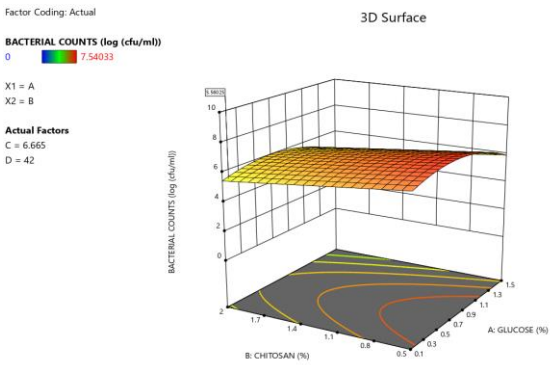

Figure 1: 3D Surface plot for the effect of glucose concentration and chitosan concentration for bacterial counts

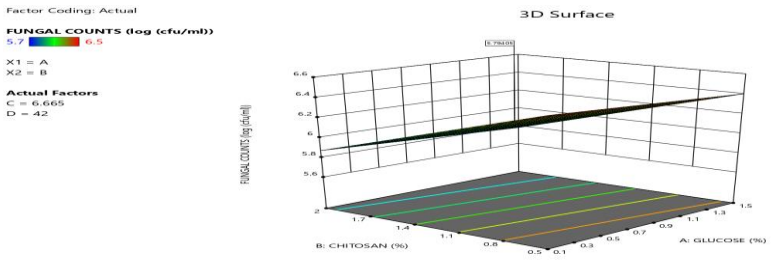

Figure 2: 3D Surface plot for the effect of glucose concentration and chitosan concentration for fungal counts

3.2 Proximate Analysis of Tomato and Preserved Paste

Table 7: Proximate Analysis of Tomato paste

Compositions	Moisture content %	Ash content %	Crude Fat %	Crude fibre %	Crude protein %	Carbohydrate %
Sample A	83.69	3.31	1.63	3.56	3.55	4.27
Sample B	85.88	2.18	1.20	2.59	3.14	5.01

The sample B, contained tomato paste with chitosan glucose complex (CGC) stored for 70 days as compared to sample A, tomato paste without chitosan glucose complex at 0 day and the proximate and nutritional compositions were also compared with those of the tomato paste (sample A).

Proximate analysis of tomato paste and preserved tomato paste was conducted at the National Animal Production Research Institute (NAPRI), Zaria. Table 5 displays the tomato paste. Sample A had lower moisture content (83.69%), indicating a preference for tomato paste with lower moisture levels, which enhanced the flavor and prolonged the shelf life. The moisture level of sample B (85.88%) was slightly higher than that of sample A, potentially impacting the quality, flavor, and texture of the tomato paste. The higher moisture content of sample B could be attributed to the quantity of paste to the complex or preservatives used. In contrast to Joel & Uzochukwu (2020), who claimed that tomato paste had moisture levels ranging from 89.27 to 91.11%, the moisture content in all the two samples was lower, ranging from 83.69 to 85.88%. According to Offor (2015), high moisture content is a sign of low total solid content and low food stability index.

However, the ash contents were comparatively higher than Joel & Uzochukwu (2020) range of 0.82-1.06%. According to Ndife, 2020, ash content indicates a food's mineral level; as a result, the chosen tomato paste samples may have low mineral concentrations. Compared to the control and sample B, had a lower ash content, which may indicate a lower mineral concentration.

Sample A had higher crude fat, crude fibre, and crude protein content (1.63%, 3.56%, and 3.55%, respectively) than sample B, indicating ingredient composition. The low protein levels of the samples (3.14% to 3.55%) may have been caused by heating-induced denaturation, as well as the amount of preservatives applied. However, the total expression of the refractive index is affected by the protein content rather than the commercial quantity of the tomato paste [25]. The crude fat ranged from 1.20-1.63% which is relatively higher than that reported by Ndife 2020, who reported that crude fats were in the range of 0.81-1.09%. The percentage of carbohydrates (4.27–5.01%) was less than that reported by Onyeaghala et al. (2016). According to Lu et al. (2014), low carbohydrate content indicates a low starch content and minimal sugar level, which in turn indicates minimal or no adulteration.

3.3 Mineral Compositions of Tomato and Preserved Paste

Table 8: Mineral Compositions of Tomato Paste

Sample	Calcium Ca (mg/100g)	Magnesium Mg (mg/100g)	Sodium Na (mg/100g)	Iron Fe (mg/100g)
Sample A	127.00	37.00	113.00	22.00
Sample B	109.00	31.00	75.00	27.00

N:B; sample A; Control, sample B; CGC

Table 8 shows the mineral content in the tomato paste. Sample A had a calcium content of 127.00 mg/100 g, and sample B with 107.00 mg/100 g. Sample A had the highest calcium content among

the three samples. This could be attributed to the freshness of the tomato sample, Sample B increased to 109.00mg/100g because it was stored for about 70 days.

The magnesium content in all samples ranges from 31.00-37.00 mg/100 g. Sample B showed a decrease in magnesium content, which may have been caused by the storage duration of the sample.

All of the samples have sodium contents ranging from 113.00 mg/100 g to 75.00 mg/100 g. The mineral composition of nearly every element in the preserved tomato paste decreased slightly. The only substance whose content increases between samples A and B is iron (22.00 mg/100 g to 27.00 mg/100 g).

The mineral compositions of fresh and canned tomato pastes have been reported by Abdullahi *et al.* (2016). The tomato paste samples included sodium Na (21.52-127.25 mg/kg), magnesium Mg (66.50-132.72 mg/kg), potassium K (61.90-89.09 mg/kg), calcium Ca (1.60-2.78 mg/kg), and iron Fe (10.89-34.45 mg/kg).

3.4 Vitamin C composition

Table 9: Vitamin C content of tomato paste

Paste	Vitamin C (mg/100g)
Sample A	6.53
Sample B	15.29

NB: sample A: control, sample B: CGC

Tomato paste was graded according to the amount of vitamin C it contained. Tomatoes, like other food items, contain vitamin C. This vitamin functions as an antioxidant, halting the oxidation of certain fatty acid components, and is essential for healthy bodily metabolism [24].

Compared to (control) sample A (6.53 mg/100 g), sample B had a higher vitamin C content (15 mg/100 g). However, compared to Ndife, 2020, who reported vitamin C contents ranging from 19.39 to 23.58 (mg/100g) in various tomato paste brands, all the two samples had a lower vitamin C content.

Sample A showed a more noticeable decrease in the vitamin C content, which could have been influenced by the tomato variety used. The other sample higher vitamin C content chitosan glucose complex that was used as a preservative may have contributed to the higher vitamin C content in the other samples. Sample B which had been stored for the longest time, had the highest vitamin C content of all samples. These variations may also have been caused by temperature variations in the storage environment.

On the other hand, research by Of et al. (2014) showed that as temperature rises, ascorbic acid levels usually decrease significantly. The ascorbic acid content in heat-treated tomato paste tends to decrease when chemical preservatives are added, as noted by Nwanekezi & Onyeali (2005). This result is consistent with the State (2018) finding that fresh tomato paste had the lowest vitamin C content compared to commercially produce and locally processed tomato paste. In addition, Mohamed et al. (2021) reported that the storage of tomatoes and their products increased the amount of vitamin C in the bioactive compounds.

3.5 Sensory Quality for Tomato and Preserved Paste

Table 10: Sensory Qualities of Fresh Tomato Paste, Preserved Tomato Pastes (mean± SD)

Samples	Colour	Taste	Appearance	Overall acceptability
Sample A	8.70 ± 0.67	8.30 ± 0.67	8.30 ± 0.67	8.20 ± 0.63
Sample B	7.00 ± 0.81	6.00 ± 0.81	6.20 ± 1.22	6.00 ± 0.81

9*- point Hedonic scale

The sensory evaluation fell between 7.00 and 8.70. Sample B displayed a low color, whereas Sample A had a high color. The results of the taste tests varied from 6.00-8.30. The range of overall acceptability results was 6.00-8.20. Sample A (control) had a higher acceptability than sample B, which had a low overall acceptability.

4.0. Conclusion

The growth of microorganisms in tomato paste was found to be inhibited by chitosan glucose complex, while the vitamin C, mineral components, color, and taste were all preserved. Furthermore, the scope of this study can be expanded by identifying the bacteria through morphological and biochemical tests and fungal presence in tomato paste before and after using the preservatives on the tomato paste and toxicology analysis should be performed on the preserved tomato paste to determine whether it is edible.

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