

Optimization of Blanching Time, Sodium Metabisulphite ($\text{Na}_2\text{S}_2\text{O}_5$) Concentration and Processing Time on Vitamin C Content, Microbial Quality and Sensory Characteristics during Canning of Green Pepper (*Capsicum sinensis*) Using Response Surface Methodology

Emmanuel Ohene Afoakwa¹, Henry Mensah-Brown² and Michael Hinnah³

1. Department of Nutrition & Food Science, University of Ghana, Legon-Accra, Ghana

2. Department of Food Process Engineering, University of Ghana, Legon-Accra, Ghana

3. Department of Food Quality and Safety, Ghent University, 653 Coupure Links, B-9000, Ghent, Belgium

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Abstract: Response surface methodology and central composite rotatable design (CCRD) for $K = 3$ were used to investigate the combined effect of blanching time (0-1 min), processing time (10-30 min) and sodium metabisulphite ($\text{Na}_2\text{S}_2\text{O}_5$) salt concentration (0%-2%) on vitamin C content, hardness (texture), microbial count and color intensity of green pepper (*Capsicum sinensis*) during canning. Blanching, processing time and sodium metabisulphite ($\text{Na}_2\text{S}_2\text{O}_5$) salt concentration all had variable effects on the vitamin C, microbial quality and sensory characteristics of the canned green peppers. Significant ($P < 0.05$) interactions were noted between all the factors with high regression coefficients (78.7%-97.0%). Increasing processing time caused significant decreases in vitamin C and microbial load of the product. However, salt concentration had only marginal and insignificant effect on the vitamin C content of the canned product. Sensory evaluation on the product showed that both the pre-processing conditions and of blanching and salt concentrations, and the processing time had varied effects on the color and hardness of the products. Hardness of the canned products generally decreased with increasing processing time and blanching time, while only minimal and insignificant effects were noted with blanching time. Increasing blanching time caused significant increasing retention of the dark green color of the peppers with only slight but insignificant increases noted with processing time, while increases in salt concentration consistently reduced the dark green color of the products. The optimum pre-processing and processing conditions that yielded products with high preference and consumer-acceptability were: blanching time of 0 min, processing time of 10 min and sodium metabisulphite concentration of 0.2%.

Key words: Response surface methodology, canning, blanching, anti-browning agent, colour, microbial quality, texture, optimization.

1. Introduction

Vegetable consumption is crucial to human growth, maintenance and replacement of worn out cells and tissues as they provide a variety of micronutrients and

macronutrients. The different vegetables that are known and used worldwide include bulb vegetables (garlic, leeks, onions and scallions), fruit vegetables (cucumbers, eggplant, bell peppers and tomatoes), inflorescent vegetables (cauliflower and broccoli), leafy vegetables (cabbage, collards, lettuce and spinach), root vegetables (beets, carrots and burdocks)

Corresponding author: Emmanuel Ohene Afoakwa, associate professor, research field: food processing technology. E-mail: eofoakwa@gmail.com, eafoakwa@ug.edu.gh.

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and stalk vegetables (asparagus and celery) among others [1, 2]. They are plants cultivated both as field crops and garden crops, both in the open and under glass [3] and they supply protein, fibers, minerals like iron and calcium, phyto-nutrients like carotenoids, vitamin C, K and folic acid to our body [2].

Peppers constitute a major part of the human diet since at least 7500 BC and there is archaeological evidence at sites located in Southwestern Ecuador that chili peppers were domesticated more than 6,000 years ago [2] and is one of the first cultivated crops in the Central and South America [4], that is self-pollinating. Green pepper (*Capsicum sinensis*) contains several nutrients. They are a good source of vitamin C, thiamine, vitamin B6, beta carotene and folic acid [5, 6]. Vitamin C, due to its fragile nature with respect to heat, is easily lost over prolonged heating or thermal processing, thus, it is instructive to investigate the direct effect of the time-temperature combination for processing on the vitamin C content of the processed food or vegetable. Similarly, the time-temperature combination as well as the amount of heat treatment used in canning also has a substantial effect on the most naturally occurring pigments in the food [7]. For instance, in fruits and vegetables, chlorophyll is usually converted into pheophytin and anthocyanin and they are subsequently degraded to brown pigments. There is therefore the need to optimize the various processing conditions in order to achieve best quality product after the canning process.

Green peppers have a relatively harder and tougher outer covering of the fruit due to their high pectin content when unripe [8] and this helps them to withstand bruises and other external damages after harvesting. Green pepper, like other vegetables is highly susceptible to various attacks or nutritional damage by microbes and rodents as well as other spoilage factors after it has been harvested, hence, the reason for its short shelf-life and post harvest losses. Vegetables are highly perishable because of their relatively high moisture content [9], which makes it

possible for microbes to survive and inherent enzymes also feed on nutrient deposits in the vegetables through the process of autolysis. Most vegetables, during harvesting, tend to sustain several bruises which serve as gateways for further external microbial attacks leading to various post-harvest losses and green pepper is no exception. The vegetables do not only get damaged externally, but also suffer losses such as qualitative and quantitative, nutritional, economic and even germinative [9]. As a result, there is the need to preserve them after they have been harvested to prolong their shelf lives and to make them available to consumers in a more convenient form all year round. Afoakwa [10] noted that, of the various methods available for processing vegetables, canning is preferable due to its ability to maintain some relatively higher or adequate levels of moisture, nutrient and color whilst commercially sterilizing the processed food from all forms of microbial attacks leading to spoilage or post-harvest losses.

Canning is a method of preserving food in which the food contents are processed and sealed in an airtight container with a simple aim of keeping bacteria away from the food product [11, 12]. Also, it is a processing technique that ensures the expulsion of a considerable amount of oxygen (if not absolute), and other respiratory gasses which may be trapped in the intercellular spaces of the vegetable. The trapped gases may interact with the processed food which can lead to rancidity, oxidative reactions or even serve as respiratory gas for some thermophilic microorganisms which might be able to withstand the heat treatment [12, 13].

Canning has been reported to be the most suitable processing technique over other methods for the maintenance of the nutritional quality of most vegetables [10]. However, various processing conditions such as the processing time and temperature, can headspace, pressure at which the food is processed, quality of the seam, blanching, exhausting as well as processing medium can affect the quality of the processed food in terms of its nutrient content, total

polyphenolic content, moisture, leached solid content, pH, drained weight, texture and even color of the processed food [11, 13].

Response surface methodology (RSM) is a collection of mathematical and statistical techniques that are useful for the modeling and analysis of problems in which a response of interest is influenced by several variables and the objective is to optimize the response. The rationale for the use of RSM models is that it determines the optimum operating conditions for the system as well as the region of the factor space in which the operating specifications are satisfied. It also ensures simplicity of calculation of the model parameters and has been used in optimizing the processing conditions of many food processing applications [14-18]. Thus, this study was aimed at optimizing the pre-processing conditions of blanching time and sodium salt concentrations, and processing time on vitamin C content, microbial quality and sensory characteristics during canning of green pepper using response surface methodology.

2. Materials and Methods

2.1 Materials

2.1.1 Raw Materials

The raw material used in the canning process was green pepper (*Capsicum sinensis*). These samples, otherwise called “*kpakpo shito*”, were obtained fresh from the University of Ghana Agricultural Research Institute farm on the same day of harvest. The samples were transported under ambient conditions (25-28 °C) to the laboratory (within 2 h of harvest) for the canning operations.

2.1.2 Experimental Design Using Response Surface Methodology

A Central Composite Rotatable Design (CCRD) was set up using the Minitab[®] software with experimental study variable number $K = 3$, for independent variables including blanching time (X_1), processing time (X_2) and sodium metabisulphite concentration (X_3). The process variables that was used in the CCRD for $K = 3$ was

processed using the software, providing the dependent variable limits and their values as shown below in Tables 1 and 2.

2.1.3 Sample Preparation for the Canning of the Green Pepper

The fresh green peppers were transported in an insulated container under ambient temperature to the processing laboratory where, they were cleaned by washing with cold water and their stalks were removed gently to prevent any bruises. They were further sorted according to size and colour uniformity as well as the presence of deformities.

Table 1 Process variables and their levels used in the CCRD for $K = 3$.

Independent variables	Codes	Variable Levels		
		Low	Middle	High
Blanching time (min)	X_1	0	0.5	1
Processing time (min)	X_2	10	20	30
[Na ₂ S ₂ O ₅] (%)	X_3	0	0.1	0.2

Table 2 Design matrix and variable combinations in experimental runs.

No.	Sample code	Coded variables		
		Blanching time (min)	Processing time (min)	Na ₂ S ₂ O ₅ (%)
1	1	0.5	20	0.1
2	1	0.5	20	0.1
3	2	0	30	0.0
4	3	0.5	10	0.1
5	4	0	10	0.2
6	5	0	20	0.1
7	6	1	10	0.0
8	7	0	10	0.0
9	8	1	10	0.2
10	9	1	30	0.2
11	10	0.5	20	0.0
12	1	0.5	20	0.1
13	11	0.5	30	0.1
14	12	1	20	0.1
15	1	0.5	20	0.1
16	13	0	30	0.2
17	1	0.5	20	0.1
18	1	0.5	20	0.1
19	14	1	30	0.0
20	15	0.5	20	0.2

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The samples were then divided into three portions. Two groups were blanched for 30 s and 1 min, respectively, whereas, the third group was left unblanched (0 min). Blanching was done with steam. Before filling into processing cans, the cans were firstly examined for both internal and external defects such as rusting, destining, staining, pinholes, dents among others. Cans were then washed in running tap water and also sterilized in an open jacketed pan for 30-60 min to reduce initial microbial load.

The cans were filled with both blanched and unblanched pepper to the weight of 54 g ± 2 g. They were then filled with their respective concentrations of Na₂S₂O₅ as generated by the CCRD (0%, 0.1% and 0.2%) up to the required headspace of 5/16 (8 mm). The filled cans were then exhausted in a laboratory steam exhausting chamber for 1 min. This was achieved by passing steam over the lidded cans and then quickly seamed using the electric laboratory hand-sealing machine. The cans were subsequently retorted in a vertical retort at a temperature of 121 °C (250 °F) and 20 Hg inches of pressure, for various process times. After processing, water at about 40 °C was sprinkled on the hot cans in the retort and allowed to cool at about 40 °C. The cans were then removed from the retort, allowed to cool further wiped dry with a napkin and stored at normal room temperature (25 °C) for a week.

2.2 Analytical Methods

2.2.1 Determination of Vitamin C

Vitamin C content in the respective samples was determined using the indophenols method 43.51 [19]. The tests were done in duplicate and the mean vitamin C content in mg/100 g was calculated for each sample combination.

2.2.2 Microbial Analysis

The total plate count method was used for microbial analysis. A dilution of 1:10 was prepared by mixing 1 g of the samples with 9.0 mL of distilled water. The samples were then blended using a stomacher blender

and serial dilutions of 10⁰ and 10⁻¹ were prepared under aseptic conditions. 1 mL of each dilution was then pour-plated in duplicates and incubated at 37 °C for 24 h. The numbers of colonies formed were enumerated using the Scientific Stuart Colony Counter.

2.2.3 Sensory Evaluation

2.2.3.1 Attribute Intensity Test

Attribute intensity test was conducted to test the intensities of the color and hardness (texture) of the canned green pepper samples. Six trained panellists were used for this test and they individually ranked the intensities of the color (from light green to dark green) and the hardness (from soft to hard) of the samples on a 10 cm scale/line. The mean rank value for each sample was obtained by calculation of measurements on the scale/line.

2.2.3.2 Consumer Acceptability Test

The balanced incomplete block design (BIBD) was used to for the sensory evaluation of 15 different sample combinations, each with seven replicates. The block size of five was used and the occurrence of a pair in the same block was permitted twice. A total number of 21 untrained consumer panellists were used, however, the panellists were instructed on how to rank the five samples in their individual blocks making use of the seven-point hedonic scale. Results were then collated and analyzed for their mean rank values and significant differences ($P \leq 0.05$).

2.3 Statistical Analysis

Minitab[®] software was used for all the statistical analysis and graphical presentations. A CCRD regression analysis was done to test the relationship between the response variables and processing factors (blanching time, processing time and concentration of Na₂S₂O₅) using Minitab[®] 14. Regression models were fitted to the response variables to obtain the regression equations from which the response surface plots were generated to explain the trends. Analysis of variance (ANOVA) was also carried out for the results obtained from the sensory analysis to determine the statistical

differences among the measured attributes. Significance was accepted at a confidence level of 95% ($P \leq 0.05$).

3. Results and Discussion

3.1 Effects of Processing Factors on the Vitamin C (Ascorbic Acid) Content of Canned Green Pepper

The regression model obtained for vitamin C content of the canned green pepper was:

$$Z = 3.426 - 0.752X_1 - 0.752X_2 + 5.452X_3 + 0.940X_1X_2 - 0.940X_1X_3 - 0.940X_2X_3 + 0.418X_1^2 + 0.418X_2^2 + 3.238X_3^2 \text{ with } R^2 = 97.0\%.$$

Statistical analysis showed significant ($P \leq 0.05$) influences of linear factors (blanching time, processing time and sodium metabisulphite concentration as well as their interactions. There was also a quadratic effect of sodium metabisulphite on the vitamin C content of the canned green pepper (Fig. 1). The model explained

97.0% of the variations in the vitamin C content of the canned products, meaning that about 3.0% of the variations could be attributed to other factors other than what was included in the model (Table 3).

The response surface plot (Fig. 2a) revealed an unchanging trend of decreasing vitamin C content with increasing blanching and processing times. However, whereas the fall in vitamin C with respect to blanching was very sharp, that of processing time was quite gentle and appeared almost insignificant. Even though, this observation seemed to be the trend at all sodium metabisulphite concentrations, the extent and magnitude of this influence on the vitamin C varied at each concentration of sodium metabisulphite. It was clearly shown in the subsequent plots (Figs. 2b and 2c) that the decreasing effects of both blanching and processing time on vitamin C was relatively lower, compared to the quadratic effect of sodium metabisulphite

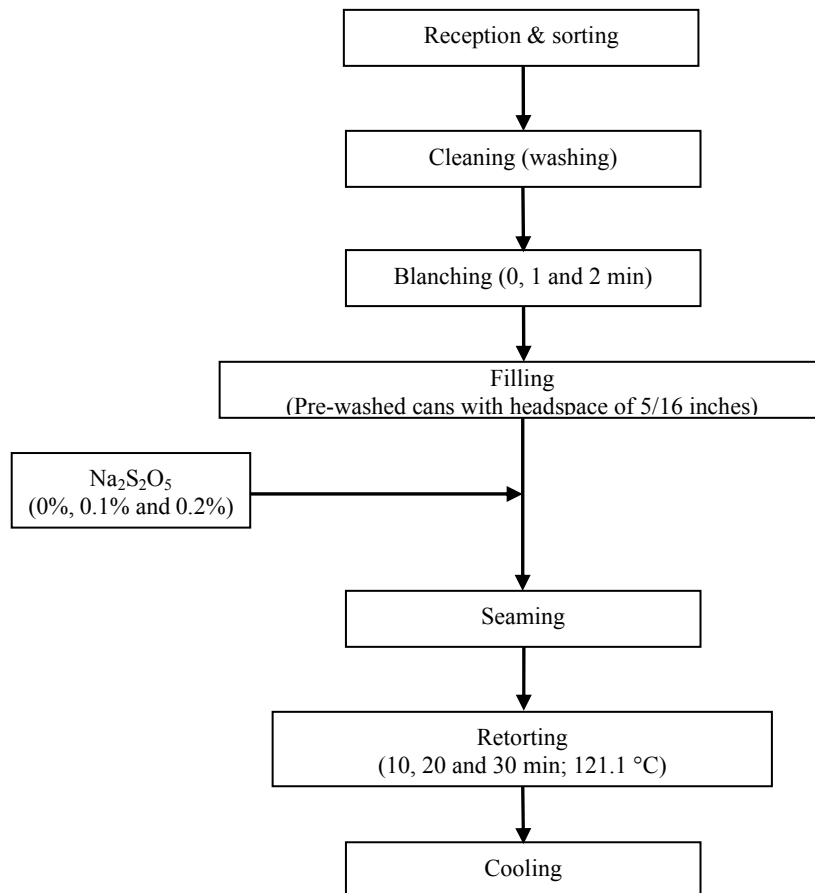


Fig. 1 Flow diagram for the processing of small green pepper (*Capsicum sinensis*).

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Table 3 Regression analysis of the response variables with processing factors.

Terms	Regression coefficient			
	Vitamin C (mg/100 g)	Colour	Hardness	Microbial count (cfu/mL)
Constant	3.4258*	4.10111*	3.63593*	1,6841.3*
X ₁ (Blanching time)	-0.7520*	0.90667*	0.39333	-1,598.0
X ₂ (Processing time)	-0.7520*	0.24000	-0.43833*	-35,981.0*
X ₃ [Na ₂ S ₂ O ₅]	5.4520*	-1.27833*	0.09167	3,008.0
X ₁ X ₂	0.9400*	0.12292	0.01458*	3,525.0
X ₁ X ₃	-0.9400*	0.44792	0.41042	-5,692.5*
X ₂ X ₃	-0.9400*	-0.46042	-0.29375	125.0
X ₁ ²	0.4178	-0.05556	-0.40741	-8,326.7*
X ₂ ²	0.4178	0.41111	0.75093	22,528.3*
X ₃ ²	3.2378*	0.31944	0.30093	13,443.3*
R ² (%)	97.0	79.9	78.7	95.5
Adj. R ² (%)	95.7	72.0	76.5	93.5
Lack-of-fit	2,354.6	231.48	530.80	3,207.94

*Significant at $P < 0.05$.

concentration on vitamin C. This clearly suggested that, irrespective of the destructive effects of both factors (processing and blanching) on vitamin C, some concentration of sodium metabisulphite was necessary to retain some amount of vitamin C in the canned products.

The combined effects of both processing time and blanching time with the salt concentration on vitamin C (Figs. 2b and 2c) are similar, in that, in both scenarios, the maximum vitamin C content was only obtained in the canned product at higher (increasing) sodium metabisulphite concentrations with low heat treatment (blanching or processing) times. Fellows [20] attributed the loss in vitamin C with increasing heat treatment (blanching and processing) to vitamin C, a water-soluble vitamin and also sensitive to heat and thus can easily be lost. Rafael [21] also explained that the nutrient losses in the canned products are usually due to factors such as heat treatments, peeling, washing as well as blanching. He further stated that vitamin C losses in canned vegetables also depend on the pH of the environment in which the vegetable is canned, the chemical composition and nature of the food as well as the presence of pro-oxidants and anti-oxidants. This could possibly be the reason why increasing sodium metabisulphite concentration facilitated the retention

of vitamin C in the canned products. In an earlier work, it was observed that the pH of the canned products was lower at higher concentrations of sodium metabisulphite during the canning process [22]. This was probably due to the action of the sodium metabisulphite in enhancing the release of free hydrogen ions from the green pepper into the canning medium during processing, thereby, making it more acidic.

3.2 Effects of Processing Factors on the Microbial Quality of the Canned Green Pepper (*Capsicum Sinensis*)

The model obtained for the microbial quality of the canned green pepper was: $Z = 16,841 - 1,598X_1 - 35,981X_2 + 3,008X_3 + 3,525X_1X_2 - 5,692X_1X_3 + 125X_2X_3 - 8,326X_1^2 + 22,528X_2^2 + 13,443X_3^2$ with $R^2 = 95.5\%$.

There were significant ($P \leq 0.05$) influences of the quadratic factors of blanching time, processing time and sodium metabisulphite concentration on the microbial quality of the canned green pepper. There was also a significant ($P \leq 0.05$) linear effect of processing time and sodium salt concentration on the model (Table 3). The model could explain about 95.5% of the variations in the factors and the measured index

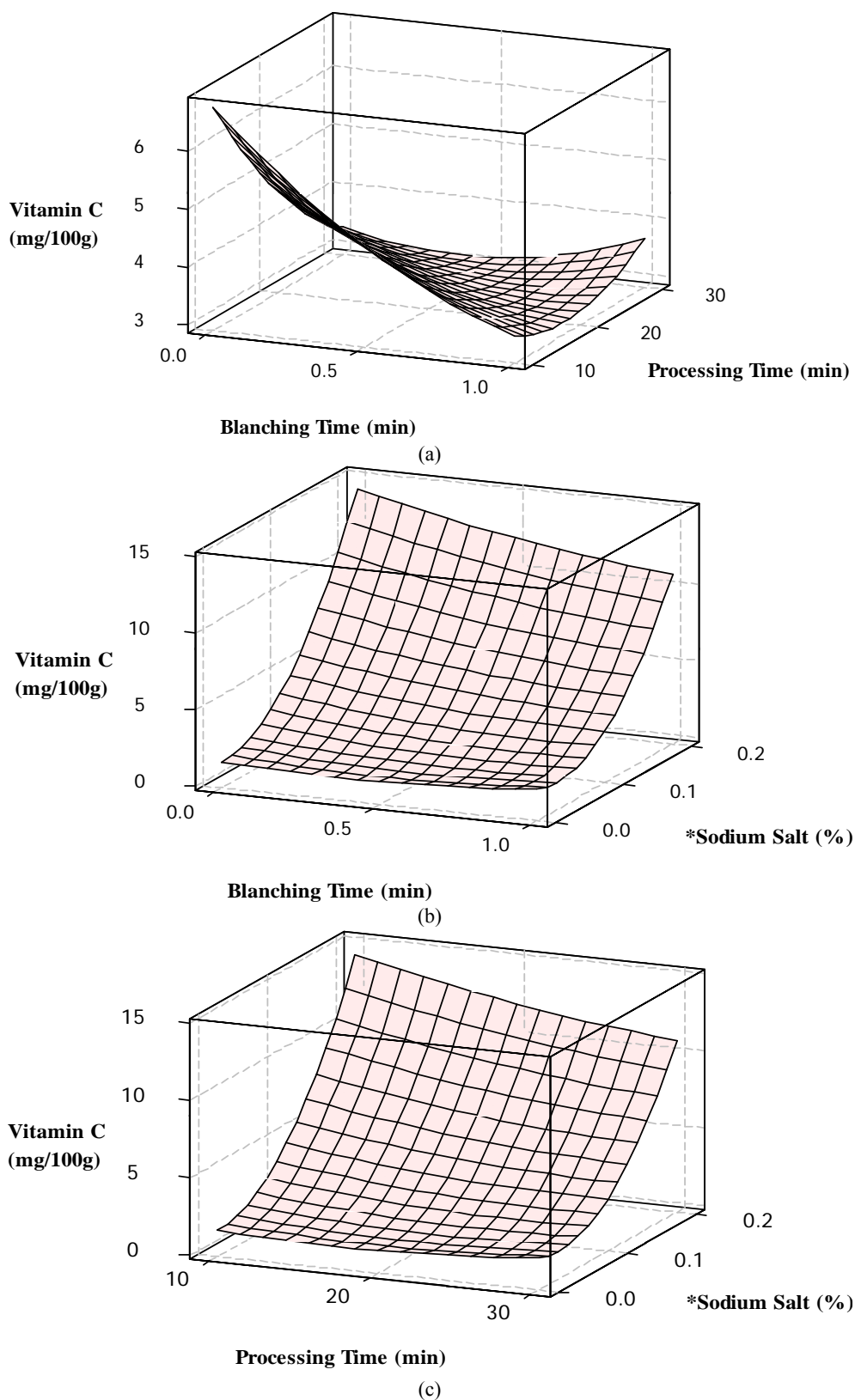


Fig. 2 Response surface plot for the vitamin C content of canned green pepper.

*Sodium salt = sodium metabisulphite concentration.

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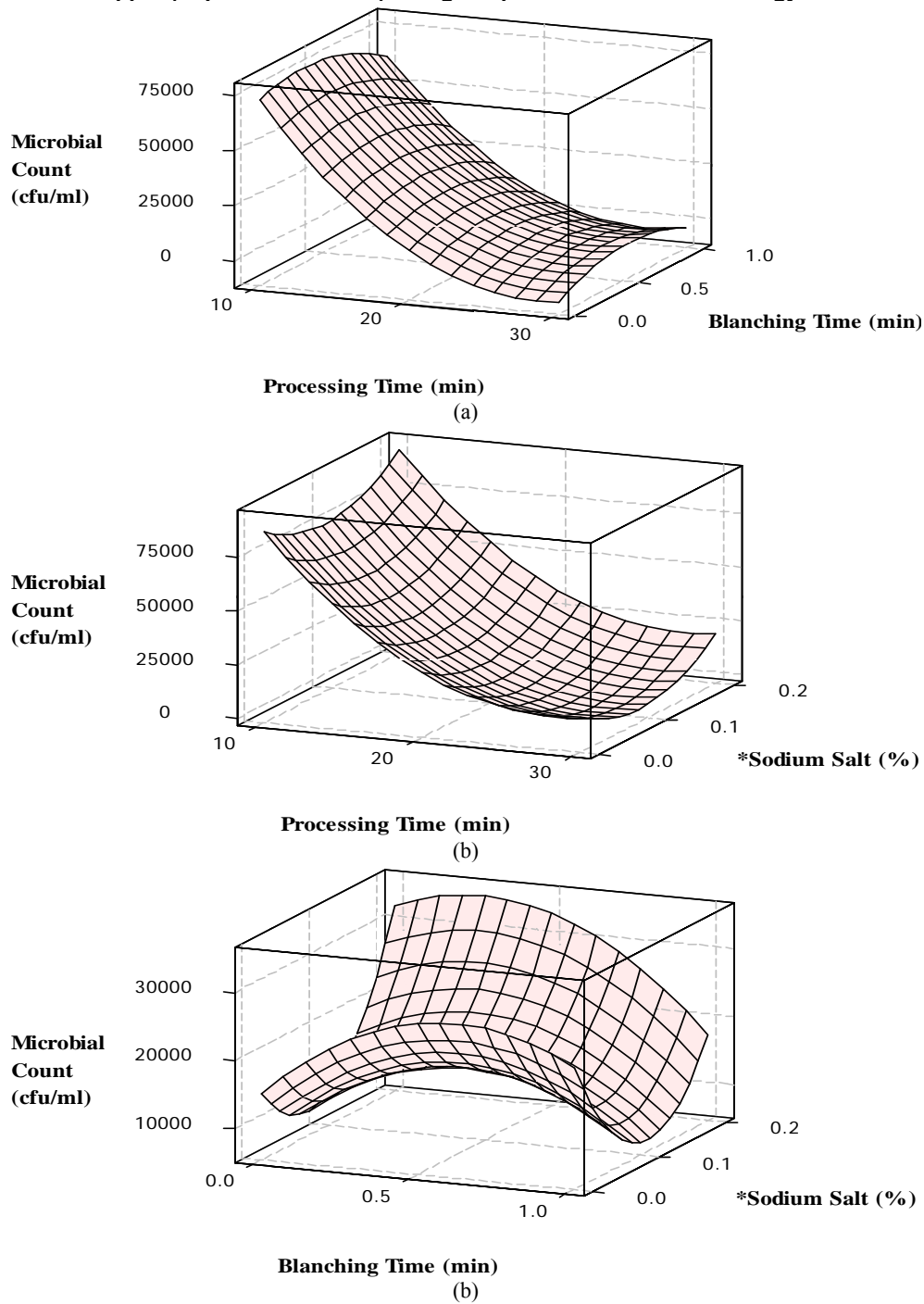


Fig. 3 Response surface plots for the microbial quality (cfu/mL) of canned green pepper.

*Sodium salt = sodium metabisulphite concentration.

(microbial quality). This therefore means that about 4.5% of the variations were due to other factors that were not included in the model.

From the response surface plot (Fig. 3a), microbial load decreased sharply with increasing processing time

at all concentrations of sodium metabisulphite. Blanching time also increased with a slight decrease in the microbial load of the products at all sodium metabisulphite concentrations. However, this was not significant ($P \leq 0.05$). This suggests that the long

processing time was necessary to inactivate most microbial cells and spores from growing in the processed product. From the plot (Fig. 3a), products that were processed for more than 20 min had a drastic fall in microbial load. This, however, became gradual and then increased slightly to the end. The latter increase in microbial load beyond 20 min of processing could be due to post process contamination or during the microbial analysis or due to further growth and multiplication of certain thermophilic microorganisms that must have survived the heat processing. The lowest microbial load, however, was observed at a high processing time with lower blanching time though the effect of blanching alone was statistically insignificant.

Fig. 3b also revealed the combined effect of processing time and sodium metabisulphite concentration on the microbial quality of the canned products with the lowest microbial occurring at the concentration of 0.1% at all blanching times. A similar trend of the effect of sodium metabisulphite on microbial growth was also observed in Fig. 3c. This according to Jay et al. [23] is because the sodium metabisulphite inhibited the growth of spoilage microorganisms by lowering the water activity in the microorganism by an osmotic process which caused the microbial cell to lose water and eventually limit their survival and/or growth. The increase in microbial load or growth at concentrations beyond 0.1% could also be attributed to post-process contamination or survival and growth of thermophilic microorganisms as stated above.

The microbial load of the canned products ranged from a low count of 3.23×10^3 cfu/mL at 30 min processing time to a peak microbial count of 9.32×10^4 cfu/mL at a processing time of 10 min. This indicates that increasing processing time is needed to drastically reduce the microbial load of the canned products especially, thermophiles. Jay et al. [23] also added that a total microbial count of 10^7 cfu/mL in canned products is high, undesirable and indicative of food spoilage. Comparing this value to the range of

microbial counts obtained in the study, it can be said that the canned green pepper were still microbiologically safe for usage.

*3.3 Sensory Analysis—Effects of Processing Factors on Some Sensory Properties of the Canned Green Pepper (*Capsicum sinensis*)*

3.3.1 Colour Intensity of the Canned Green Pepper

The model obtained for the color intensity of the canned green pepper by sensory analysis was; $Z = 4.101 + 0.907 X_1 + 0.240 X_2 - 1.278 X_3 + 0.123 X_1X_2 + 0.4482 X_1X_3 - 0.460 X_2X_3 - 0.056 X_1^2 + 0.411 X_2^2 + 0.31944 X_3^2$ with $R^2 = 79.9\%$.

There were significant ($P \leq 0.05$) influences of the linear factors of blanching time and sodium metabisulphite concentration on the color intensity of the canned green pepper as judged by six trained panellists (Table 3). The model only could explain 79.9% of the variations in the color intensity of the canned product. This therefore means that about 20.1% of the variations were due to other factors that were not included in the model. In this analysis, six trained panellists were made to grade each of the samples on a 10 cm scale from light green to dark green.

The observed trends from the response surface plots were not different from the ones associated with the instrumental measurements (a , L and b values) noted elsewhere [22]. As already observed, increasing blanching time was known to have darkened the color of the canned products (Fig. 4). The effect of sodium metabisulphite concentration on the color intensity is shown in Fig. 4. It was realized that increasing concentrations of sodium metabisulphite at lower blanching times helped in keeping the color of the products from darkening. This could mainly be due to the anti-browning effect of the sodium salt on the products during processing.

The results from the attribute intensity test conducted for the color intensity by trained panellists (Table 4) revealed different degrees of greenness based on the rating. However, most samples were not

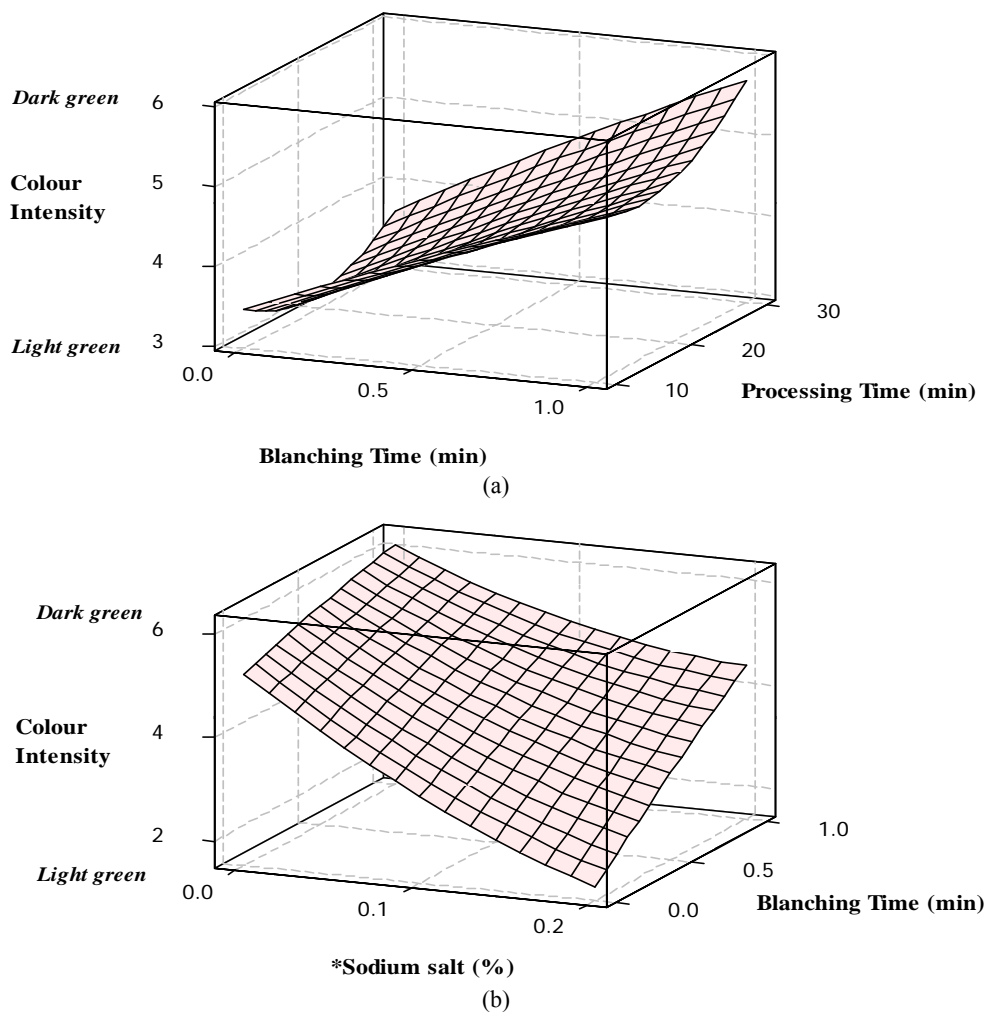


Fig. 4 Response surface plots for the color intensity of canned green pepper.

*Sodium salt = sodium metabisulphite concentration.

statistically different ($P \leq 0.05$) in terms of greenness from other sample even though their mean intensities were different. Sample 13 ($X_1 = 0$ min, $X_2 = 30$ min, $X_3 = 0.2\%$) according to the observed trend had the lightest green color whereas that of sample 14 ($X_1 = 1$ min, $X_2 = 30$ min, $X_3 = 0\%$) was judged to be the darkest in color following its processing. Reasons for this trend are not different from the ones already stated. However, prominent of these were the effects of blanching and sodium salt concentration on the overall color. It was observed, that blanching had a darkening effect on the color, whereas, the sodium salt had an anti-browning effect on the color of the canned products.

3.3.2 Intensity of the Hardness (Texture) of the Canned Green Pepper

The model obtained for hardness of the canned green pepper by sensory analysis was: $Z = 3.636 + 0.393 X_1 - 0.438 X_2 + 0.0917 X_3 + 0.0146 X_1X_2 + 0.410 X_1X_3 - 0.29 X_2X_3 - 0.407 X_1^2 + 0.75 X_2^2 + 0.30 X_3^2$ with $R^2 = 78.7\%$.

There was significant ($P \leq 0.05$) influence of the linear factor of processing time as well as its interaction with sodium metabisulphite concentration on the hardness of the canned green pepper (Table 3). The model could only explain 78.7% of the variations in the hardness of the canned product, meaning that as high as 21.3% of the variations in the observed hardness could

Table 4 Effect of processing factors on the attribute intensities of color and texture (hardness) of canned green pepper.

Sample codes	Attribute intensity (mean intensity)	
	Colour	Hardness
1	4.05 ^{abcd}	3.05 ^a
2	6.67 ^{ef}	3.62 ^{ab}
3	5.18 ^{cdef}	4.85 ^{ab}
4	3.02 ^{abc}	4.42 ^{ab}
5	2.98 ^{abc}	2.42 ^a
6	5.65 ^{def}	3.65 ^{ab}
7	4.12 ^{abcde}	4.53 ^{ab}
8	4.45 ^{bcddef}	6.25 ^b
9	5.65 ^{def}	4.22 ^{ab}
10	6.68 ^{ef}	4.93 ^{ab}
11	3.87 ^{abcd}	4.22 ^{ab}
12	5.13 ^{cdef}	4.33 ^{ab}
13	1.83 ^a	3.40 ^{ab}
14	6.80 ^f	3.87 ^{ab}
15	2.18 ^{ab}	3.23 ^a

7-point hedonic scale; 7-dislike extremely, 1-like extremely samples with the same letter as superscript have no statistical significance between them at $P \leq 0.05$.

be attributed to other external factors that were not included in the model (Table 3).

From the response surface plots (Figs. 5a and 5b), it was revealed that processing time had a significant linear effect on the hardness or softness of the canned products. The trend showed that as processing time increased, there was a corresponding decrease in hardness toward softness of the canned green pepper (Fig. 5a). The decrease in hardness resulting from increased processing time could simply be due to the gradual disintegration of the cell membrane, the cell wall and other protective substances that contribute to the hardness of the green pepper. The application of heat breaks down cellular components of the green pepper thus making it possible for the free movement of moisture and some ions across these barriers into the canned products. The effect of blanching on the hardness of the products as time increased (Fig. 5a); however, this effect was insignificant. The influence

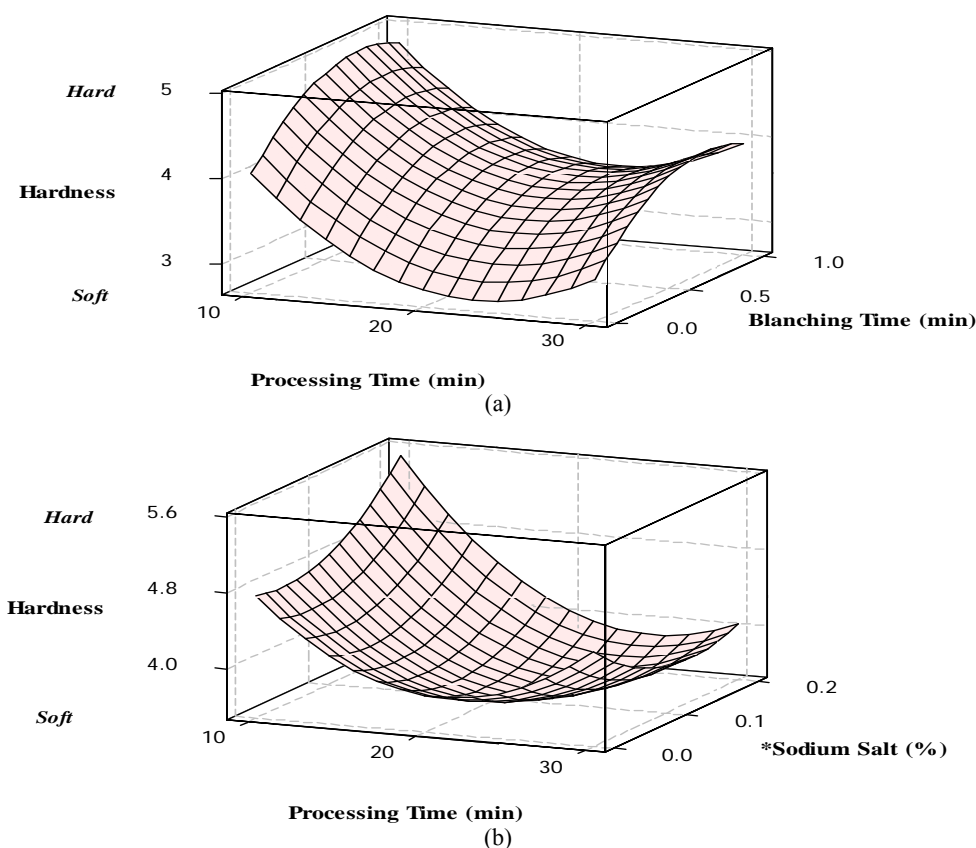


Fig. 5 Response surface plots for the hardness of the canned green pepper.

*Sodium salt = sodium metabisulphite concentration.

Table 5 Consumer acceptability of canned green pepper.

Sample code	Attributes			
	Colour	Hardness	Overall acceptability	Overall ranking on 7 point hedonic scale
1	3.29 ^{bcd}	3.71 ^{abcd}	3.43 ^{bcd}	4
2	4.29 ^{def}	4.29 ^{cd}	3.57 ^{cdef}	4
3	3.43 ^{cd}	3.29 ^{abcd}	3.0 ^{bcde}	3
4	1.71 ^a	2.43 ^a	1.43 ^a	2
5	3.14 ^{bcd}	3.43 ^{abcd}	4.14 ^{efg}	4
6	5.71 ^g	3.43 ^{abcd}	4.0 ^{efg}	4
7	3.71 ^{cde}	3.86 ^{abcd}	3.86 ^{defg}	4
8	3.43 ^{cd}	2.71 ^{ab}	3.0 ^{bcde}	3
9	4.43 ^{defg}	4.29 ^{cd}	5.14 ^g	5
10	5.0 ^{efg}	4.14 ^{bcd}	4.57 ^{fg}	5
11	2.86 ^{abc}	2.71 ^{ab}	2.57 ^{abcd}	3
12	3.57 ^{cd}	3.14 ^{abcd}	2.86 ^{bcde}	3
13	2.0 ^{ab}	2.71 ^{ab}	2.0 ^{ab}	2
14	5.14 ^{fg}	4.43 ^d	4.43 ^{fg}	5
15	2.57 ^{abc}	2.86 ^{abc}	2.43 ^{abc}	3

7-point hedonic scale; 7- dislike extremely; 1-like extremely samples with the same letter as superscript have no statistical significance between them at ($P \leq 0.05$).

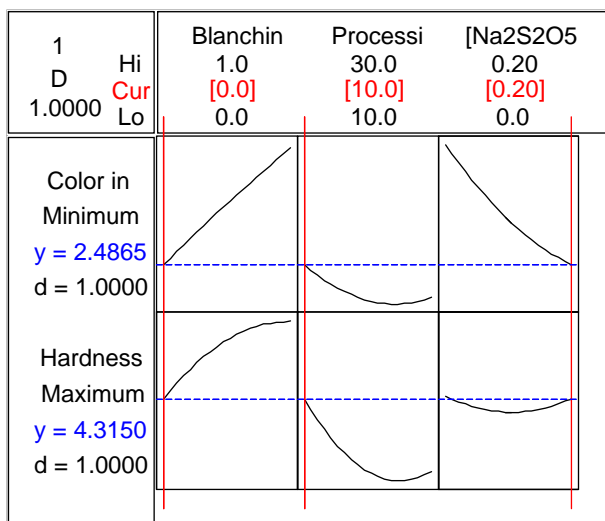


Fig. 6 Response optimization curves for canned green pepper.

of the salt concentration on hardness was also shown in the plot (Fig. 5b), where, hardness decreased slightly toward a concentration of 0.1% and then increased gradually (almost constant) beyond 0.1% to the end.

Form the attribute intensity test conducted for hardness (Table 5), it was realized that most products had been mashed as a result of the prolonged heat treatment of those products.

3.4 Consumer Acceptability of the Canned Green Pepper

All samples were evaluated by a 21-member sensory panel according to the balanced incomplete block design (BIBD). The results from Table 5 revealed that most consumers preferred the color, hardness and overall appearance of sample 4 ($X_1 = 0$ min, $X_2 = 10$ min, $X_3 = 0.2\%$) to any other sample. This was closely followed by sample 13 ($X_1 = 0$ min, $X_2 = 30$ min, $X_3 = 0.2\%$) in terms of the individual attributes. However, their overall ranking placed them on the same level on the 7 point hedonic scale as being liked very much. Comparing the two, it can be said that even though both samples ranked equally, sample 4 recorded the least significant ($P \leq 0.05$) mean rank values (highly preferred) in all three quality attributes (color, hardness and overall acceptability), hence, the most preferred by consumers.

3.5 Optimization of the Processing Factors (Conditions) of the Green Pepper during Canning

Optimization of the processing conditions was done using the color intensity and hardness (texture) of the

canned green pepper. A minimum goal with a target of 3.0 for color intensity and a maximum goal with a target of 4.0 for hardness on a 1-10 scale were used for the optimization. The optimum pre-processing and processing conditions that yielded products with high preference and consumer-acceptability were: blanching time of 0 min, processing time of 10 min and sodium metabisulphite concentration of 0.2% (Fig. 6).

4. Conclusions

All the processing factors—blanching time, sodium metabisulphate concentration and processing time had significant influences on vitamin C content, microbial quality and the sensory characteristics of canned green pepper. Increasing blanching time consistently decreased the vitamin C content of the canned products. Also, its combined effect with processing time and salt concentration also yielded similar effects. Processing time also had significant effects on the vitamin C and microbial quality of the canned products as well as its interactions with the other processing factors. Increasing processing time caused significant decreases in vitamin C and microbial load of the product. However, salt concentration had only marginal and insignificant effect on the vitamin C content of the canned product. Sensory evaluation on the product showed that both the pre-processing conditions and of blanching and salt concentrations, and the processing time had varied effects on the color and hardness of the products. Hardness of the canned products generally decreased with increasing processing time and blanching time, while only minimal and insignificant effects were noted with blanching time. Increasing blanching time caused significant increasing retention of the dark green color of the peppers with only slight but insignificant increases noted with processing time, while increases in salt concentration consistently reduced the dark green color of the products. The optimum pre-processing and processing conditions that yielded products with high preference and

consumer-acceptability were: blanching time of 0 min, processing time of 10 min and sodium metabisulphite concentration of 0.2%.

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