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ARTICLE · MAY 2014

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AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 14 No. 3
May 2014
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

THE INFLUENCE OF BLANCHING, ANTI-BROWNING AGENT AND PROCESSING TIME ON SOME PHYSICO-CHEMICAL PROPERTIES AND APPEARANCE OF GREEN PEPPERS (*CAPSICUM SINENSIS*) DURING CANNING

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ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 14 No. 3
May 2014
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
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ABSTRACT

Central Composite Rotatable Design (CCRD) was used to generate twenty combinations of these factors: blanching time, processing time and sodium metabisulphite concentration. The optimized conditions were then adapted for the canning process of green pepper. Blanching time ranged from 0-1 min whereas processing time and sodium metabisulphite concentration ranged from 10-30 min and 0-0.2%, respectively. The canned products were analyzed for physico-chemical qualities using standard analytical methods. Results obtained from various physico-chemical analyses showed variable trends and influences of the linear, quadratic and exponential interactions on the measured quality indices such as pH of the drained liquid, drained weight of the canned product, leached solids and colour of the canned products. The results showed significant ($p \leq 0.05$) quadratic effect of sodium metabisulphite as well as linear effect of blanching time on the drained weight of the canned green pepper. Generally, the pH of the medium decreased (increased acidity) with increasing processing time, which was also positively associated with the extent or amount of leaching. Additionally, all three factors were observed to have affected (to variable extent) the colour of the canned products. Blanching and processing times also affected the degree of browning. There was a strong significant ($p \leq 0.05$) influence of the quadratic factors of blanching time, processing time and sodium metabisulphite concentration on the colour properties (a-values, b-values and L-values) of the canned products. Statistical analysis showed significant ($p \leq 0.05$) linear effects of blanching time and sodium salt concentration as well as the combined effect of both factors on all the colour properties. All the studied parameters had significant regression coefficients ($p \leq 0.05$) suggesting the studied parameters contributed significantly to the observed changes. Colour of the canned products changed from green toward redness with increasing blanching time at all concentrations of sodium metabisulphite. Optimal processing combination of 0 min blanching time, 10 min processing time and sodium metabisulphite concentration of 0.2% produced a highly acceptable canned pepper product with preferred physico-chemical and appearance properties.

Key words: Canning, pepper, blanching, antibrowning agents

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INTRODUCTION

Vegetables enrich our diets with a variety of food nutrients that are necessary for growth, maintenance and replacement of worn out cells and tissues. They also provide nutrients like carotenoids, vitamins C and, K and folic acid. Peppers belong to the group of vegetables from the genus *Capsicum* [1] and plants of this group produce fruits in different colours, including red, yellow and orange. The fruit is frequently consumed in its unripe form, when the fruit is still green, hence, the name green pepper. Green pepper (*Capsicum sinensis*) contains several nutrients and is a good source of vitamin C, thiamine, vitamin B6, beta carotene, and folic acid [2-5]. When comparing the nutrient values of the different peppers, studies have shown that red peppers have significantly higher levels of nutrients than green [2, 6]. However, the unripe form (green pepper) is relatively harder and tougher than when in its unripe state [7]. Consequently, the green pepper can better withstand bruises and other external damages after harvesting when compared to the red form. Also, due to the higher moisture content of the ripe pepper fruits, they are usually tender (softer) and hence, are easily attacked by various spoilage organisms [7, 8].

In spite of the nutritious values of green pepper and other vegetables worldwide as a natural source of various vitamins and minerals, it 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 due to their relatively high moisture content [8]. This makes it possible for microbes to survive as well as their nutrient deposits upon which its own inherent enzymes also feed in a process called 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 of which green pepper is no exception.

These vegetables are not only damaged externally, but also suffer qualitative and quantitative, nutritional, economic and even germinative losses [8]. There is thus need to preserve them after harvest. Among the methods available for the preservation of vegetables are drying, freezing and canning. All of these methods are able to prolong the shelf life of the vegetables with some level of efficiency. Of the various methods available for processing green pepper, canning is the preferred method due to its ability to maintain some relatively higher or adequate levels of moisture, nutrient and colour. Canning also produces a commercially acceptable sterilized product that is resistant to all forms of microbial attacks [9].

Canning is a method of preserving food in which the food contents are processed and sealed in an airtight container with the objective of keeping bacteria away [10]. Also, it is a food processing technique that ensures the expulsion of a considerable amount of oxygen (if not absolute), and other respiratory gases which may be trapped in the intercellular spaces of the vegetable. Interaction of these gases with the processed food can lead to rancidity, oxidative reactions or even serve as respiratory gas for

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some thermophilic microorganisms which might be able to withstand heat treatment [10].

Generally, canning is the most suitable processing technique for the maintenance of the nutritional quality of most vegetables. However, various processing conditions or factors used during canning such as the time-temperature combination for the processing, headspace of the can, pressure at which the food is processed, quality of the seam, blanching, exhausting as well as the choice of the processing medium can affect the quality of the processed foods. These qualities include the nutrient content, total polyphenolic content, moisture and leached solid content, pH and titratable acidity, drained weight, changes in texture and even colour of the processed food. For instance, vitamin C, due to its fragile nature with respect to heat, is easily lost over prolonged heating or thermal processing as a result, a direct effect of the time-temperature combination for processing foods and vegetables decreases their vitamin C content. Similarly, the amount of heat treatment used in canning also has a substantial effect on most naturally occurring pigments in the food [11]. For instance, in fruits and vegetables, chlorophyll is usually converted into pheophytin and anthocyanin, which are subsequently degraded to brown pigments. There is, therefore, the need to optimize the various processing conditions in order to achieve best quality products after the canning process.

Response surface methodology (RSM) is a statistical-mathematical method which uses quantitative data in an experimental design to determine and simultaneously solve multivariate equations to optimize processes and products [12, 13]. Thus, this work was aimed at studying the influence of blanching, processing conditions and anti-browning agent concentration on some physico-chemical properties and appearance during canning of green pepper (*Capsicum sinensis*).

MATERIALS AND METHODS

Materials

Green pepper (*Capsicum sinensis*) used for the canning process was obtained fresh from the University of Ghana Agricultural Research Farms in Accra, Ghana on the same day of harvest and transported to the laboratory for processing.

Experimental Design Using Response Surface Methodology

A Central Composite Rotatable Design (CCRD) was set up using Minitab® 14 (Minitab Inc., Minneapolis, MN, USA) 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 used in the CCRD for K = 3 were analyzed using the software, providing the independent variable limits and their values (Table 1 and Table 2). Twenty sample combinations were generated from the software in an experimental design using the design matrix and variable combinations in experimental runs. The dependent variables studied included the following: pH of the drained liquid, drained weight of the canned product, leached solids and colour of the canned green pepper.

Canning of the Green Pepper (*Capsicum sinensis*)

The fresh green peppers were quickly transported in an insulated container containing ice. Upon arrival at the processing laboratory, the green peppers were then cleaned by washing with cold water as 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.

The sample was then divided into three portions; one portion was blanched for 30 seconds, the second was blanched for 1 min while the third was unblanched (0 min). Blanching was done using steam. Before filling into processing cans, the cans were firstly examined for both internal and external defects such as rusting, destaining, staining, pinholes, dents among others. Cans were then washed in running tap water and also sterilized in an open jacketed pan for 30-60 minutes to reduce initial microbial load if any.

The cans were filled independently with blanched and unblanched pepper to the weight of 54 ± 2g; ten cans were processed per sample. The cans were then filled with their respective concentrations of $Na_2S_2O_5$ as generated by the CCRD (0%, 0.1%, and 0.2%) up to the required headspace of 5/16” (8mm). 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 can sealing machine. The cans were retorted in a vertical retort at a temperature of 121^{o}C (250 ^{o}F) and 50 inches of Hg (pressure), for their respective process times (10, 20, and 30 min). After processing, water at about 40^{o}C was sprinkled on the hot cans in the retort and allowed to cool to about 40^{o}C. The cans were then removed from the retort, allowed to cool further and later wiped dry with a napkin. The cans were stored at 25^{o}C for 7 days prior to analysis.

ajfand SCHOLARLY, PEER REVIEWED
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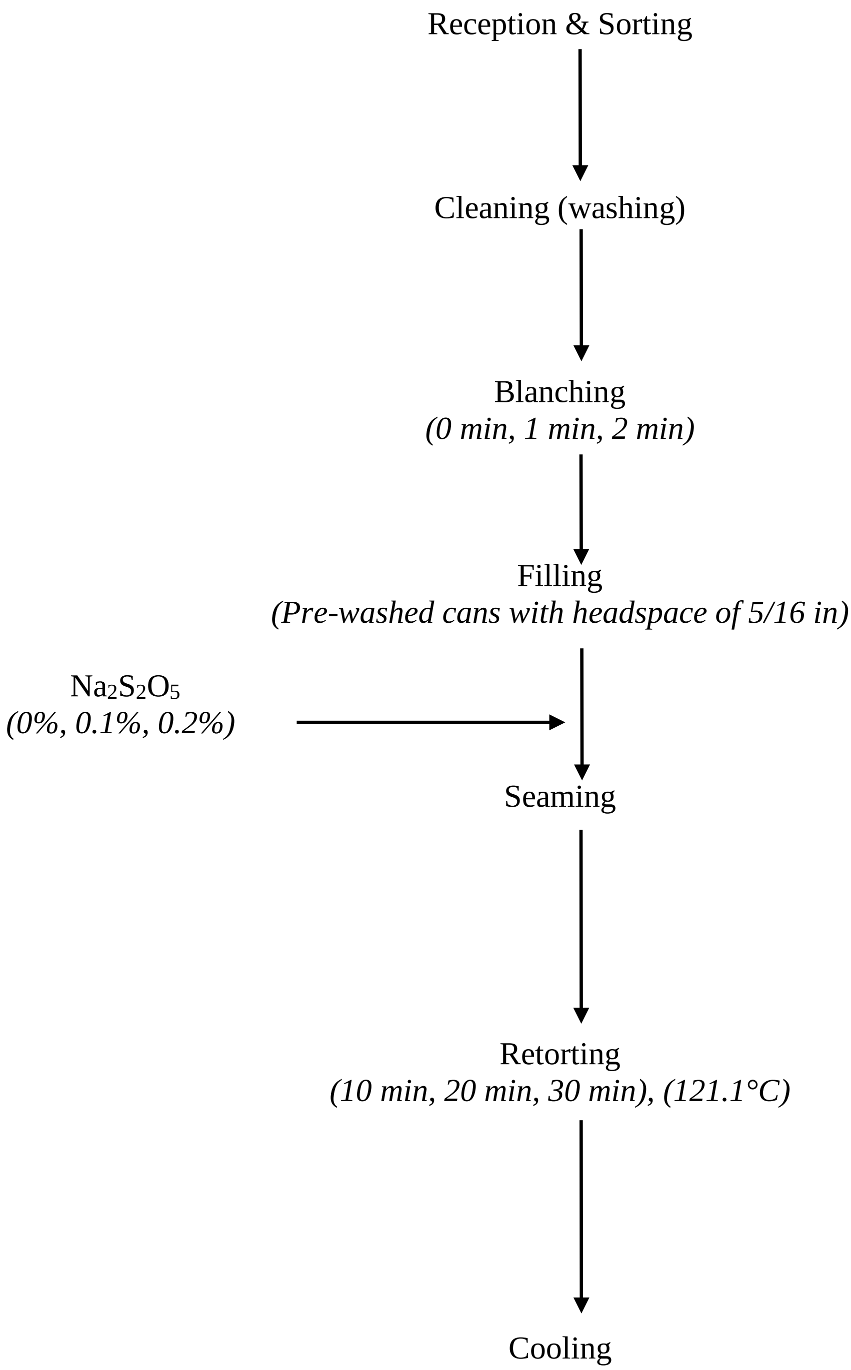

Figure 1: Flow Diagram for the Processing of Green Pepper (*Capsicum sinensis*)

Analytical Methods

pH Measurement
pH was measured exclusively with a glass electrode pH meter. The determination was done on a small amount of syrup poured from the can into a beaker and the pH of the drained liquid was determined using the TOA pH meter (Model HM-3 0S, Tokyo, Japan). This was done in triplicates and the mean pH calculated.

Leached solids
Leached solids were determined using the procedure outlined by Lopez [9] with slight modifications. A 10 ml aliquot of the drained water from samples after canning was dried at 105^{o}C in an air oven for 24 hrs. The weight of the residue was determined after drying. This was done in duplicate and the mean value reported as g/100g dry sample.

Drained weight
After determining the fill of the container, the contents of the container was distributed over a mesh of a circular sieve of 8 holes/inch woven wire cloth. Without shifting the pepper, the sieves were inclined to facilitate drainage. About 2 min after the drainage had begun, the green peppers were removed from the sieve and weighed, and the drained weight of the green peppers noted [14]. This was done in triplicates and the mean drained weight was recorded in grams.

Colour determination
The Hunter Lab Colour Difference Meter (Model R-300, Minolta Camera Co. Ltd., Osaka, Japan) was used to determine the colour of the canned products. Using a white porcelain plate, standard parameters of L= 60.51, a= +0.91 and b= -0.88 were obtained. Measurements were done in triplicates and the mean values (L, a, and b) were calculated.

Statistical Analysis
All statistical analysis and graphical presentations were carried out using Minitab® 14 (Minitab Inc., Minneapolis, MN, USA). A Central Composite Rotatable Design (CCRD) regression analysis was done to test the relationship between the response variables (drained weight, moisture content, colour and leached solids) and processing factors (blanching time, processing time and concentration of $Na_2S_2O_5$) using Minitab® version 14. Regression models were fitted to the response variables to obtain the regression equations out of which the response surface plots were generated to explain the trends. Analysis of variance (ANOVA) was done to determine statistical differences. Significance was accepted at a confidence level of 95% ($p \leq 0.05$).

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ISSN 1684 5374

RESULTS

Effects of processing factors on the drained weight of canned green pepper

The regression model obtained for drained weight of the canned green pepper (*Capsicum sinensis*) was; $Z = 62.4541 - 1.0700X_1 - 0.4633X_2 - 0.1300X_3 - 1.0417X_1X_2 - 1.0583X_1X_3 - 0.5250X_2X_3 - 0.6093X_1^2 + 0.1241X_2^2 - 2.0426X_3^2$ with $R^2 = 77.3\%$.
Where X_1 = blanching time; X_2 = processing time; X_3 = sodium metabisulphite concentration.

There was a significant (p=0.001) quadratic effect of sodium metabisulphite on the drained weight of the canned green pepper. The analysis also showed a linear effect of blanching time on drained weight. The model could explain about 77.3% of the variations in drained weight, thus, about 22.7% of the observed variations in drained weight could be due to other factors that were not included in the model.

The response surface plot generated (Figure 2) showed a significant (p=0.001) linear relationship between blanching time and drained weight of the canned green pepper and that drained weight decreased with increasing blanching time (Figure 2). However, the effect of processing time on drained weight was not significant (p=0.634). The analysis also showed significant influences of the combined factors of blanching time and processing time as well as blanching time and the sodium salt (sodium metabisulphite) concentration on drained weight. Drained weight decreased with increasing blanching and processing times with the lowest drained weight being observed at maximum blanching and processing times (1.0 min and 30 min, respectively). Products with lower drained weights can be obtained when these combined factors are maximized.

Also, the combined influence of blanching time and the concentration of the sodium salt yielded a curvilinear plot which also showed a similar trend as observed between blanching and processing time. However, the effect of the sodium salt on drained weight was not linear but quadratic. This trend also showed that products with lower drained weights can only be obtained at higher blanching times and maximum salt concentrations (Figure 2). The canned products showed an increase in drained weight from 0% up to about 0.1% concentration sodium metabisulphite after which drained weight then decreased.

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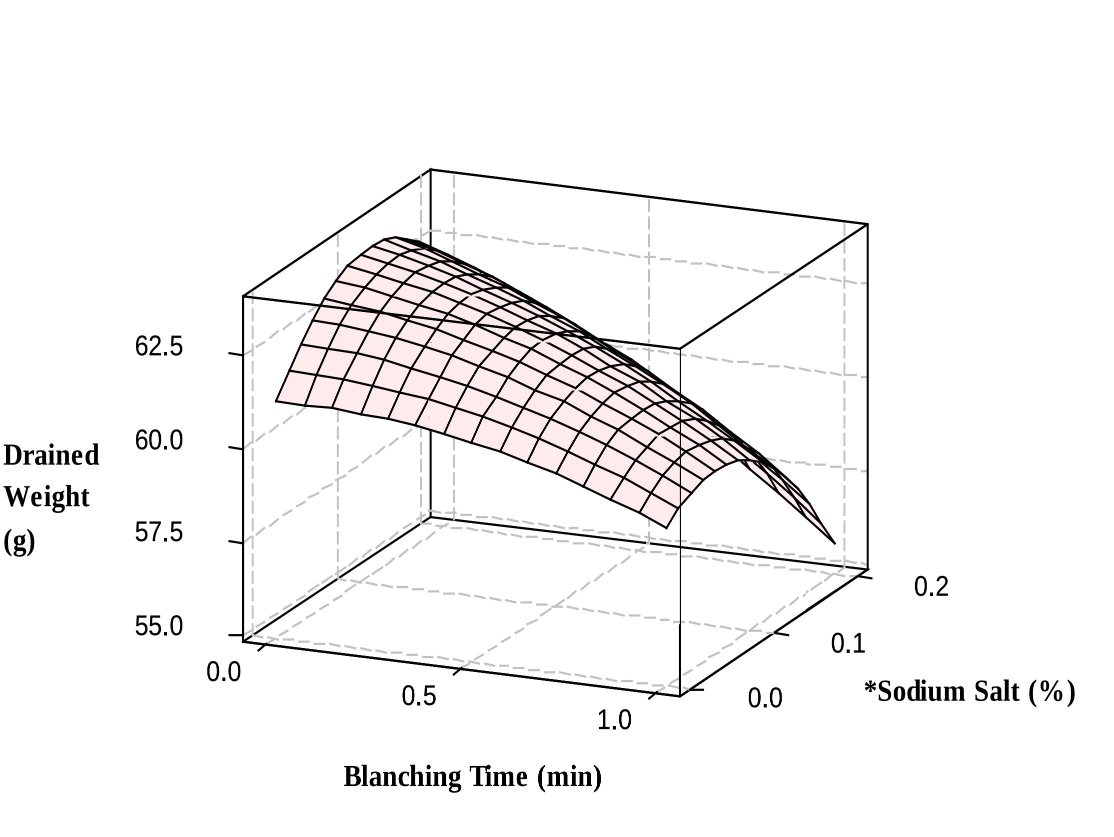

**Sodium Salt = Sodium metabisulfite Concentration*

Figure 2: Response surface plot showing effect of blanching time and sodium salt (%) on drained weight of canned green pepper

Effects of processing factors on the pH of Canned Green Pepper (at 25°C)

The model obtained for pH of the canned green pepper was; $Z = 4.60126 - 0.01767X_1 + 0.09367X_2 - 0.10433X_3 - 0.03792X_1X_2 - 0.17708X_1X_3 + 0.00875X_2X_3 - 0.06574X_1^2 - 0.04574X_2^2 + 0.09426X_3^2$ with $R^2 = 64.4\%$.

Where X_1 = blanching time; X_2 = processing time; X_3 = sodium metabisulphite concentration.

The statistical analysis indicated significant (p=0.001) linear effects of both processing time and sodium metabisulphite concentration on the pH of the canned green pepper. The interaction between blanching time and sodium metabisulphite concentration also had a significant (p=0.001) influence on pH of the products. However, there was no significant (p=0.873) quadratic effect of any of the factors (blanching time, processing time and sodium metabisulphite concentration) on the pH of the canned products. The model could only explain about 64.4% of the variations in pH, meaning that about 35.6% of the variations could be due to other factors that were not included in the model.

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The response surface plot (Figure 3) showed the linear influence of all the factors on pH of the canned green pepper with the exception of blanching time. It was generally observed that pH increased with processing time at all blanching times and sodium metabisulphite concentrations. This rise in pH was, however, sharper and steeper at low blanching times than at high blanching times (Figure 3). This indicates that the heat treatment (especially processing), facilitated the liberation of more hydrogen ions into the canning medium.

The trend as observed in Figure 3, also clearly showed an inverse relationship between pH and sodium metabisulphite concentration during the canning process with the lowest pH value, observed at a concentration of 0.2% (Figure 3). This suggests that a high concentration of sodium metabisulphite in the canning medium enhanced the liberation of free hydrogen ions from the green pepper into the canning medium, hence, making the medium more acidic. This is required for a good product since, generally, lower pH is desirable in creating unfavourable conditions for microbial activity hence increasing the shelf life of the canned product.

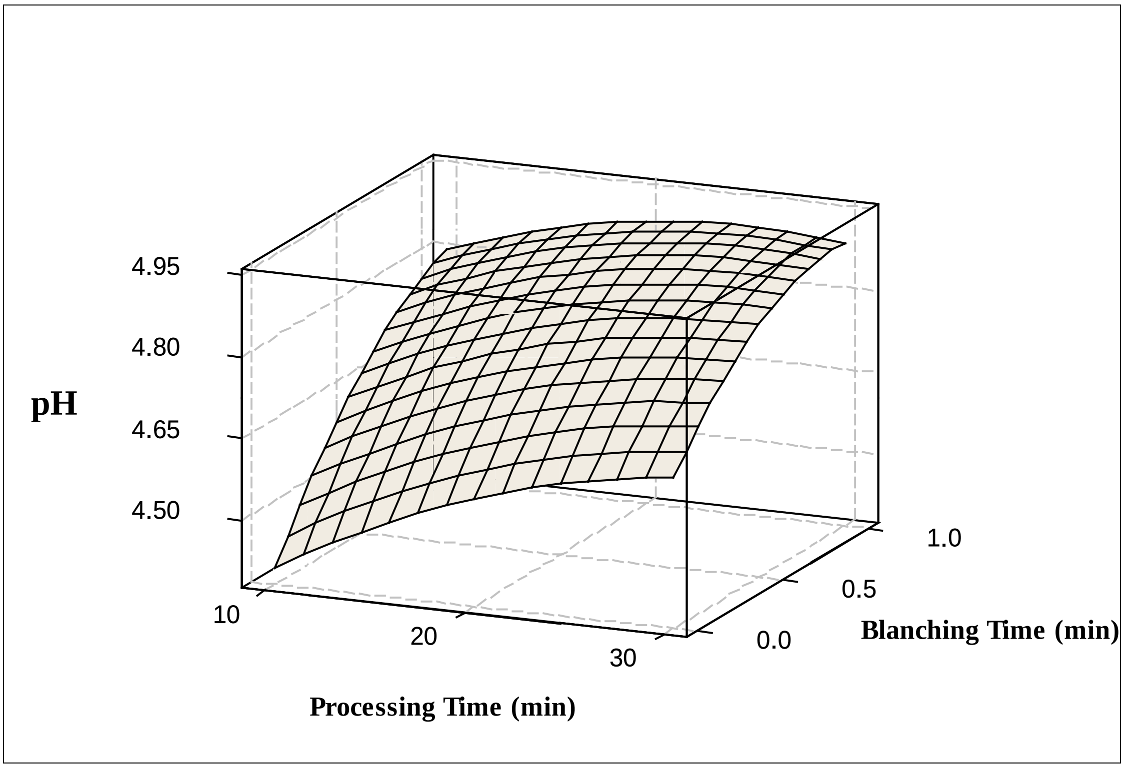

Figure 3: Response surface plot showing effect of processing time and blanching time on pH of canned green pepper

Effects of Processing Conditions on the Colour of Canned Green Pepper

Colour measurement consisting of L, a and b values of the canned green pepper were determined using a Hunter LAB Colour Difference Meter. The +a values denote redness whereas the –a values denote greenness [15]. All samples recorded –a values with each specific –a value indicating different values and/ or degrees of greenness. The L values indicate lightness which ranges between black (L=0) and white (L=100) (Hunter Lab Colour Scale, 2008). Samples had different values and intensities of lightness within the range of L= 0-100. The b-values indicated the extent of yellowness and blueness of the various canned products. Whereas +b values denote yellowness, -b values are indicative of blueness [16]. Within this range, samples showed various degrees of yellowness since all samples had +b values.

Effects of Processing Conditions on the a-values Canned Green Pepper

The model obtained for the a-values of the canned green pepper was; $Z = -4.90274 + 1.19800X_1 - 0.03667X_2 - 1.28700X_3 - 0.00292X_1X_2 + 0.31542X_1X_3 + 0.02959X_2X_3 - 0.43741X_1^2 - 0.42407X_2^2 + 1.20093X_3^2$ with $R^2 = 95.6\%$.

Where X_1 = blanching time; X_2 = processing time; X_3 = sodium metabisulphite concentration.

There was a strong significant (p=0.001) influence of the quadratic factors of blanching time, processing time and sodium metabisulphite concentration on the a-values of the canned products. The statistical analysis also showed significant (p=0.001) linear effects of blanching time and sodium salt concentration as well as the combined effect of both factors on the model. The model explained about 95.6% of the variations in the a-values of the canned green pepper. This suggests that about 4.4% of the variations in greenness could be due to other factors that were not included in the model.

The response surface plot (Figure 4) showed an inverse relationship between blanching time and greenness of the canned products. It was observed that canned products decreased in colour from green toward redness with a corresponding sharp increase in blanching time at all concentrations of sodium metabisulphite. Greenness also decreased slightly with increasing processing time between 10 and 18 minutes, and then remained almost constant and then increased slightly after 20 minutes of processing at all sodium metabisulphite concentrations, However, this linear effect was not statistically significant (Figure 4). It was clear from the observations made from the response surface plot (Figure 4) that the exposure of the green pepper to heat treatment (blanching) had some degrading effect on the greenness of the canned products irrespective of the concentration of the sodium metabisulphite used. This could be as a result of the high amount of heat that was used in blanching the fresh green pepper as well as the direct exposure of the green pepper samples to the hot steam whilst blanching. Also, the length of blanching could have been a contributing factor to this observation.

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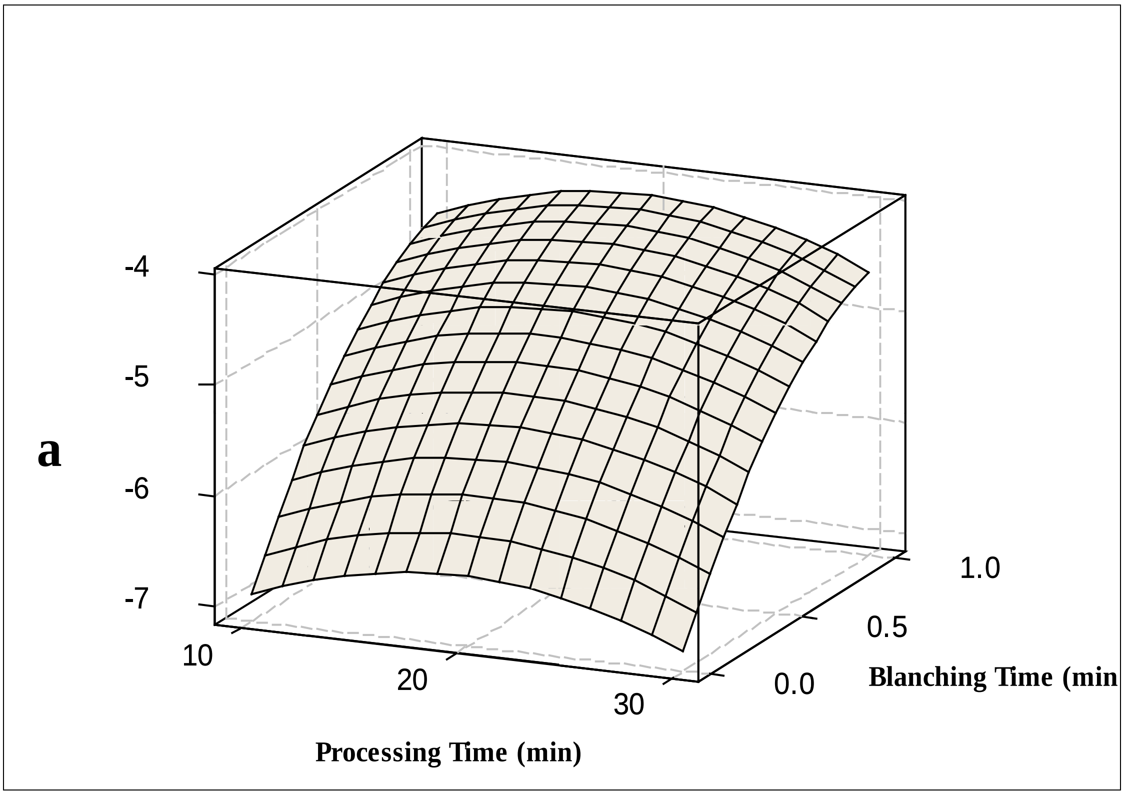

Figure 4: Response surface plot showing effect of processing time and blanching time on the a-values of canned green pepper

Effects of processing factors on the L values (lightness) of canned green pepper

The model obtained for the L values of the canned green pepper was; Z = 39.8190 - $3.4467X_1$ - $0.6313X_2$ + $1.7790X_3$ + $0.4971X_1X_2$ - $0.4929X_1X_3$ + $0.1404X_2X_3$ - $0.2170X_1^2$ + $1.5996X_2^2$ - $1.4287X_3^2$ with $R^2 = 91.1\%$.

Where X_1 = blanching time; X_2 = processing time; X_3 = sodium metabisulphite concentration.

There were significant (p=0.001) influences of all the linear factors (blanching time, processing time and sodium metabisulphite concentration) and quadratic factors of processing time and sodium metabisulphite concentration on the L values of the canned products. The model could explain 91.1% of the variations in the L values of the canned green pepper, meaning that about 8.9% of the variations could be attributed to other factors that were not included in the model. The response surface plot (Figure 5) showed the individual as well as combined effects of the various factors on the degree of lightness of the canned products. It was observed that at all concentrations of sodium metabisulphite, blanching had some influence on the lightness (L-value) of the canned products.

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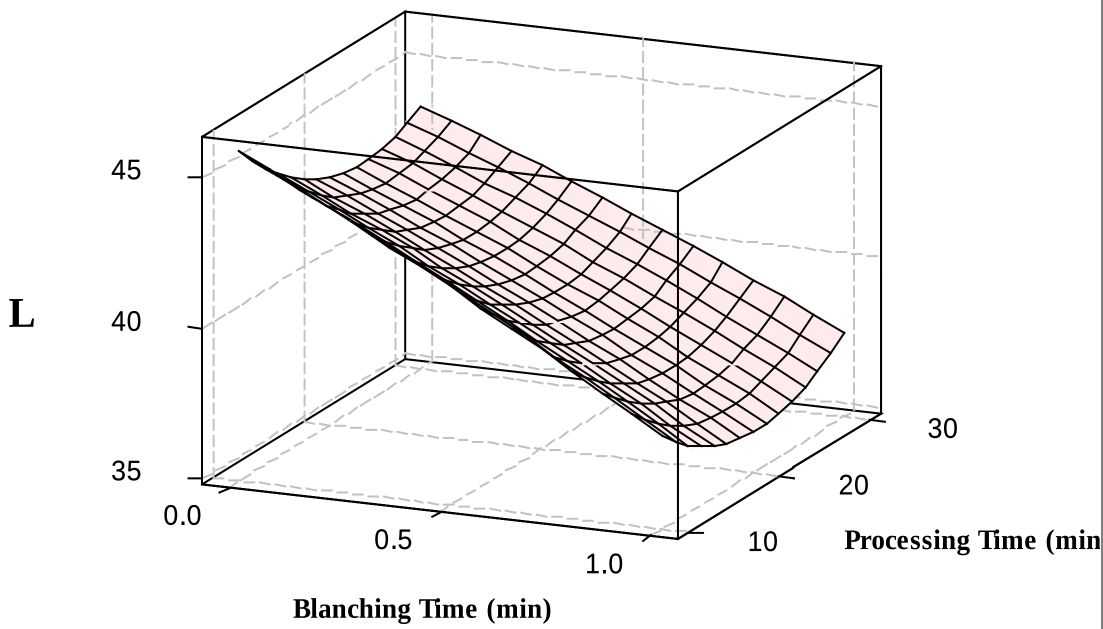

Figure 5: Response surface plot showing effect of blanching time and processing time on the L-values of canned green pepper

Effects of Processing Factors on the b values (yellowness) of Canned Green Pepper

The model obtained for the b values of the canned green pepper was; $Z = 22.9720 - 3.9453X_1 - 0.0107X_2 + 1.0440X_3 + 0.1037X_1X_2 + 0.1296X_1X_3 - 0.0196X_2X_3 + 0.3067X_1^2 + 1.2933X_2^2 - 3.0100X_3^2$ with $R^2 = 83.0\%$.

There was a significant (p=0.001) influence of the quadratic factors of processing time and sodium metabisulphite concentration on the b model for the canned products. The statistical analysis also showed strong and significant (p=0.001) linear effects of blanching time and sodium metabisulphite concentration on the model (Figure 6).

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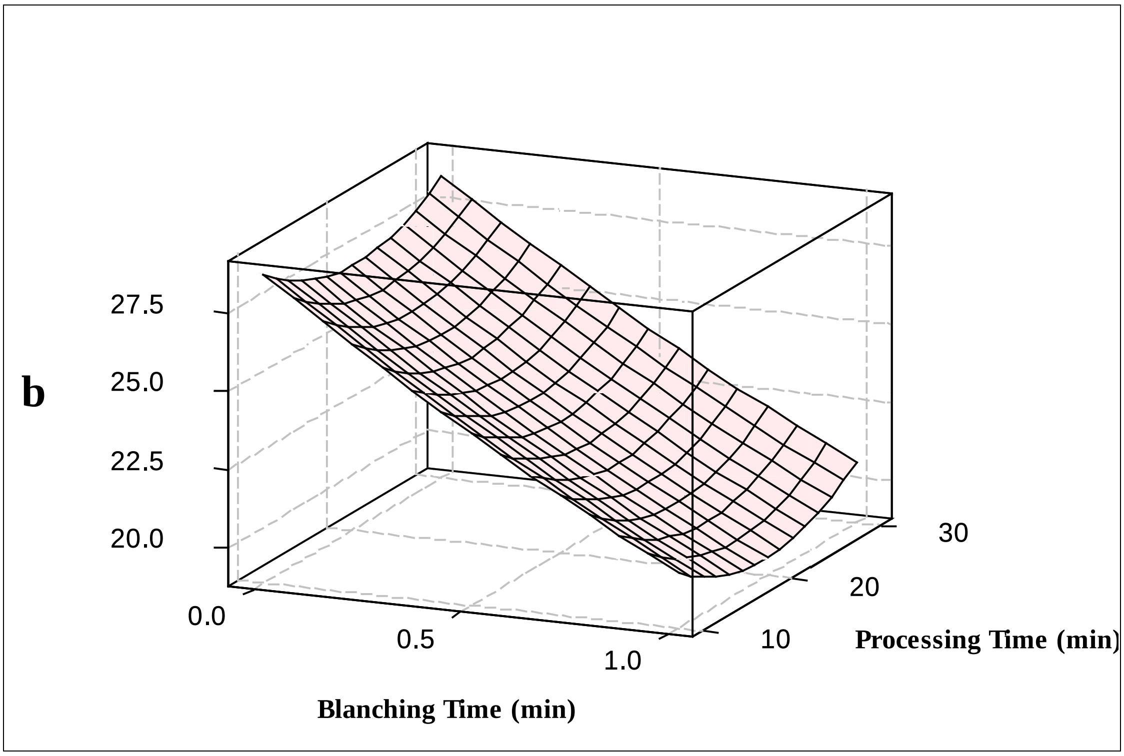

Figure 6: Response surface plot showing effect of blanching time and processing time on the b-values of canned green pepper

The model explained 83.0% of the variations in the b values of the canned green pepper meaning that 17.0% of the variations could be due to other factors which were not included in the model. The trends revealed by the response surface plots (Figure 6) were not different from that already observed.

Effects of Processing Factors on the Leached Solids of Canned Green Pepper

The leached solid content of the canned green pepper is simply an estimate of the loss of tissue mass to the medium during processing. The model obtained for this index of the canned green pepper (*Capsicum sinensis*) was: $Z = 1.34276 - 0.02590X_1 + 0.06155X_2 + 0.05855X_3 - 0.00119X_1X_2 + 0.02356X_1X_3 + 0.06831X_2X_3 - 0.05344X_1^2 - 0.10969X_2^2 + 0.07181X_3^2$ with $R^2 = 65.9\%$.

Where X_1 = blanching time; X_2 = processing time; X_3 = sodium metabisulphite concentration.

From the statistical analysis, there were significant (p=0.001) quadratic and linear effects of the factors of processing time and sodium metabisulphite concentration on the leached solids in the canned products. The model also showed a significant influence of the combined factors of both processing time and the salt concentration on leached solids. The model could only explain 65.9% of the variations in the leached solids, thus indicating a percentage of about 34.1% variations as due to other factors that were not included in the model.

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The response surface plots generated revealed that all processing factors had significant (p=0.001) effects on the leached solid content of the canned food samples with the exception of blanching. The trend in the plot (Figure 7) clearly shows decreasing drained weight with increasing blanching time. However, the extent of this effect on drained weight was statistically proven to be insignificant (at p=0.256) as it decreased at various stages with increasing sodium metabisulphite concentration as clearly shown (Figure 7). It is, therefore, evident that blanching as a pre-processing technique during thermal processing of such vegetables had no influence on the integrity of the cell walls of the products thereby not influencing the loss of tissue mass (leaching) during further heat treatments.

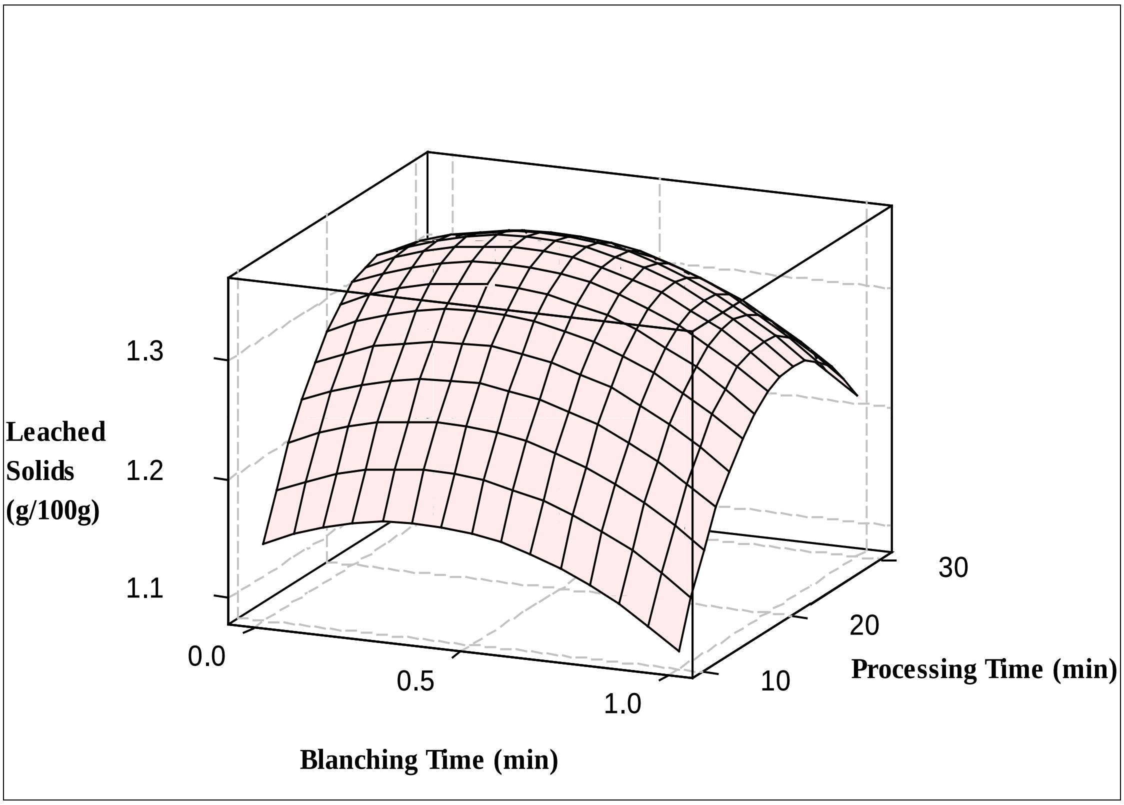

Figure 7: Response surface plot showing effect of blanching time and processing time on the leached solids of canned green pepper

DISCUSSION

Effects of Processing Factors on the Drained Weight of Canned Green Pepper

Unblanched products as well as products blanched for less than 0.5 min had relatively higher drained weights at all sodium metabisulphite concentrations as compared to products blanched for 0.5 min and beyond. This also occurred at lower processing times (Figure 2). Generally, it was observed that the presence of the sodium salt in the medium enhanced the loss of moisture/water from the canned green pepper, thereby increasing the overall drained weight. The initial uptake of water by the products that were canned at fairly low or no sodium salt concentration suggests that the medium had a lower sodium salt concentration than the green pepper. This is probably because water might have left the canning medium by the process of osmosis into the green pepper through their cell membranes until an isotonic condition was reached at about 0.1% salt concentration. As the salt concentration increased further (hypertonic), the process was reversed which resulted in further plasmolysis of the green pepper cells, thereby drastically reducing its moisture content, hence, reduced drained weight. As the amount of heat increased during the blanching process, the living cell membranes of the green pepper were destroyed, hence allowing much water to be lost from the green pepper. The products that were processed in about 0.1% salt (sodium metabisulphite) were able to retain a greater amount of water during storage.

Effects of processing factors on the pH of canned green pepper (at 25°C)

The pH ranged between a peak value of 5.03 at 0% sodium metabisulphite concentration and 4.02 at 0.2% concentration. The combined effect of blanching time and sodium metabisulphite concentration as observed from the plots (Figure 3) also showed that higher blanching time with lower concentrations of sodium metabisulphite and vice versa resulted in an increase in pH of the product. This explains the different patterns of blanching time as observed in the response surface plots (Figure 3) at all processing times but varying concentrations of the sodium metabisulphite. A summary of this trend is observed in Figure 3, where pH was high at either low blanching time with a high concentration of sodium metabisulphite or high blanching time with a low salt (sodium metabisulphite) concentration. The lowest pH was, however, obtained at high blanching and salt concentrations. Fraser [17] has explained that the pH 4.6 is generally considered as the minimum level required to inhibit the growth of pathogens and their toxins. Fraser [17] also reported that the action of spoilage microorganisms (such as acidophilic bacteria) present in the canned product can increase the pH through fermentation, hence compromising the safety of the product.

Effects of Processing Conditions on the Colour of Canned Green Pepper

The change in colour (greenness) was mainly due to browning reactions, such as Maillard browning or caramelization, which are often facilitated by the application of heat. These reactions play a huge role in degrading colour and other nutritive components of the canned product among which is the reduction of protein quality [18] and degradation of chlorophyll (green pigmentation in the cell wall) of the product.

Comparing the effects of blanching and sodium metabisulphite concentration on greenness of the products (Figure 4), it was observed that the effect of blanching on the greenness of the products was not sudden but rather gradual. On the other hand, the sodium metabisulphite had an anti-browning effect on the canned products by maintaining their green colour when applied between concentrations of 0 and 0.1%. Beyond this concentration, however, it was observed to have bleached the colour slightly. The same trend was also observed between processing times and sodium metabisulphite concentrations at all blanching times. The combined effects of blanching time and the salt concentration also revealed that greenness could only be maintained when products are canned in a high salt concentration medium with decreasing (or no) blanching at all processing times.

Effects of processing factors on the L values (lightness) of canned green pepper
It was evident that as blanching time increased, the products become darker (decreased lightness) a similar effect or trend of influence of processing time on the degree of lightness as was observed for the a-values above. The dark colouration of the canned products could be due to the degradation of chlorophyll from the green pepper samples as well as the formation of certain intermediary compounds during the browning reactions (such as Maillard browning or caramelization reaction). From Figure 5, it was observed that at all processing times, lightness increased directly with sodium metabisulphite concentration but inversely with blanching time until it reached a lightness of about L=43.7 at a concentration of 0.1%. A similar trend was also observed in Figure 5, between processing time and sodium metabisulphite concentration.

Effects of processing factors on the b values (yellowness) of canned green pepper
Figure 6 showed that blanching time increased with decreasing yellowness in the colour of the canned products and that this was mainly due to the degrading effect of the heat treatment on the colour pigments of the green pepper. All products, however, showed a certain degree of yellowness without any blue colouration. Yellowness also increased with a corresponding increase in sodium metabisulphite concentration and decreasing blanching time until a concentration of about 0.1% beyond which yellowness gradually fell.

Effects of processing factors on the leached solids of canned green pepper
Increasing the concentration of the sodium metabisulphite in the medium was known to facilitate leaching of the food mass into the medium. This, according to Prescott *et al*. [19], is as a result of an initial occurrence of plasmolysis. These authors explained that there is usually an initial loss of fluid from the cytoplasm of the vegetables cells due to the creation of a hypertonic environment (as a result of the sodium metabisulphite). Plasmolysis, according to Prescott *et al*. [19] leads to the shrinkage of the plasma membrane which can contribute to the gradual tissue disintegration as observed during the processing.

At all blanching times, it was also observed that leaching increased gradually with processing time and attained a maximum at about 20 min of processing time (Figure 7). However, this occurred at lower sodium metabisulphite concentrations. At higher concentrations of sodium metabisulphite, processing time increased gently with leached solids. This trend could also be attributed to the initial occurrence of plasmolysis in the canned products leading to leaching of its tissue mass into the processing medium as explained by Prescott *et al*. [19]. From the surface plots (Figure 7), it was observed that the combined effects of processing time and sodium metabisulphite concentration required to yield the lowest leached solid content normally occurred at a very low processing time and low salt concentrations.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 14 No. 3 May 2014
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

CONCLUSIONS

Central Composite Rotatable Design (CCRD) and Response Surface Methodology (RSM) can be effectively employed to evaluate the effect of blanching time, processing time and sodium metabisulphite salt concentration and their interactions for the determination of optimal processing conditions for canning green pepper (*Capsicun sinensis*). All the processing factors: blanching time, processing time and salt (sodium metabisulphite) concentration had significant effects on at least one quality index. Increasing blanching time resulted in an undesirable change in colour (L, a, and b values) of the canned products. Apart from this, its combined effect with processing time and salt concentration yielded similar effects on the same indices. Processing time as well as its interactions with the other processing factors had significant effects on pH, colour, and leached solids content of the canned products. It increased directly with pH and also facilitated leaching of the tissue mass of the products. The influence of the sodium salt was also significant in its effects on quality indices such as pH, colour (L, a, and b), and leached solids. The pH decreased with increasing salt concentration and increasing leached solids; salt concentration also played a key role in maintaining the colour of the canned product.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 14 No. 3
May 2014
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 1: Process variables and their levels used in the Central Composite Rotatable Design 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
$[Na_2S_2O_5]$ (%)	X_3	0	0.1	0.2

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Table 2: Design matrix and variable combinations in experimental runs

No.	Sample Code	Coded variables Blanching Time (min)	Processing Time (min)	$[Na_2S_2O_5]$ (%)
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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Table 3: Regression analysis of the response variables with processing factors

Terms	Regression Coefficient						
	Drained Weight/g	**pH at 25ºC**	**Moisture Content (%)**	**a-value**	**L-value**	**b-value**	**Leached solids (g/100g)**
Constant	62.4541*	4.60126*	92.4595*	-4.90274*	39.8190*	22.9720*	1.34276*
X_1 (Blanching Time)	-1.0700*	-0.01767	0.1091	1.19800*	-3.4467*	-3.9453*	-0.02590
X_2 (Processing Time)	-0.4633	0.09367*	0.3781	-0.03667	-0.6313*	-0.0107	0.06155*
X_3 [$Na_2S_2O_5$]	-0.1300	-0.10433*	-0.2317	-1.28700*	1.7790*	1.0440*	0.05855*
X_1X_2	-1.0417*	-0.03792	0.2634	-0.00292	0.4971*	0.1037	-0.00119
X_1X_3	-1.0583*	-0.17708*	-0.1031	0.31542*	-0.4929*	0.1296	0.02356
X_2X_3	-0.5250	0.00875	0.5216*	0.02959	0.1404	-0.0196	0.06831*
X_1^2	-0.6093	-0.06574	-0.0581	-0.43741*	-0.2170	0.3067	-0.05344
X_2^2	0.1241	-0.04574	-0.8517	-0.42407*	1.5996*	1.2933*	-0.10969*
X_3^2	-2.0426*	0.09426	1.1468*	1.20093*	-1.4287*	-3.0100*	0.07181*
Adj. R^2	0.664	0.501	0.602	0.944	0.888	0.786	0.506

* Significant at $p<0.05$

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 14 No. 3 May 2014 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Table 4: Regression analysis of colour and hardness variables with processing factors

Terms	Regression Coefficients	
	Colour	Hardness
Constant	4.10111*	3.63593*
X_1 (Blanching Time)	0.90667*	0.39333
X_2 (Processing Time)	0.24000	-0.43833*
X_3 [$Na_2S_2O_5$]	-1.27833*	0.09167
X_1X_2	0.12292	0.01458*
X_1X_3	0.44792	0.41042
X_2X_3	-0.46042	-0.29375
X_1^2	-0.05556	-0.40741
X_2^2	0.41111	0.75093
X_3^2	0.31944	0.30093
Adj. R^2	0.022	0.0

*Significant at $p \leq 0.05$

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