

Optimization of the Process for Production of Enriched Ketchup

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Abstract

Post-harvest losses of fruits and vegetables in Uganda are estimated at 30% which is approximately 4 billion shillings lost annually. This is due to limited knowledge on value addition and preservation technologies being unaffordable. This study sought to add value to fruits and vegetables with a focus on mangoes, tomatoes, and carrots produced locally. The study determined the effect of processing conditions and addition of fruits and vegetables on the physico-chemical and sensory properties of tomato ketchup. Tomatoes were replaced with mangoes in increments of 10% up to 50% while keeping carrot levels constant at 5%. The best sensory properties were observed in the treatment that contained 15% mango. The

Physico-chemical and sensory properties of ketchup were enhanced by the addition of fruits and vegetables up to 20%. The sensory evaluation revealed that ketchup prepared by the addition of fruits and vegetables (local mangoes and carrots) was preferred as compared to the control sample at 0% mango. The color of ketchup was affected by the incorporation of mangoes and carrots and it was acceptable up to at 5% carrot and 15% mango including taste, appearance, flavor, mouthfeel and aroma. The best treatment was then subjected to different processing conditions at different holding times and temperatures of 5, 10 and 15 minutes at temperatures of 70, 75, 80, 85, 90 and 100 degrees Celsius respectively. The best conditions were observed to be between 80°C and 85°C and 10 to 15 minutes holding time. It was also evident that time and temperature had a significant ($p < 0.05$) effect on the Physico-chemical properties of ketchup.

Keywords: Ketchup, Mango, Carrots, Enriched, Tomatoe

1. Introduction

In Uganda, horticulture is one of the fastest-growing branches among the agricultural sectors (Ssemwanga, 2010), contributing 1% to the total world vegetable and fruits production. However, the fruit and vegetable consumption per capita per day in Uganda is still low (Ssonko, 2005) estimated at 200 g/day as compared to 490 g/day as recommended by FAO (2010). The low fruit and vegetable consumption is attributed to the seasonal changes which limit production and supply to only a few months of the year. Furthermore, post-harvest losses are estimated at 15-30 percent according to MAAIF (2016) due to high susceptibility to spoilage caused by the inefficient post-harvest technologies, aggravate the low fruit and vegetable consumption per capita per day in Uganda. Post-harvest losses are both quantitative and qualitative and they result in a measurable decrease in the monetary value of products. Fruit and vegetable production are also currently challenged by limited land, water, and increased weather variability due to climate change (La Pena & Hughes 2007, Moretti, Mattos et al., 2010). These losses do not merely reduce the food available for human consumption but also cause negative externalities to society through costs of waste management, greenhouse gas production, and loss of scarce resources used in their production.

To achieve the Sustainable Development Goal (SDG) of food security and food availability, there needs to be reductions in the post-harvest losses at the farm, retail and consumer levels. There are several examples of promising practices that have been employed to reduce post-harvest losses (Boateng, 2016) which range from training in improved handling and storage hygiene to the use of hermetically sealed bags (Murdock, Margam, Baoua, Balfe, & Shade, 2012) and household metallic silos (Olajide & Oyelade, 2002) and are supported by enhancing the technical capabilities of local blacksmiths in silo construction.

Overcoming the perishability of crops, improving marketing, enhancing nutritional value and adding economic value through processing are the main strategic areas for reducing postharvest losses. There are different processing techniques employed and these can be divided into traditional and improved methods of processing. Examples of the commonly used processing methods include peeling and washing, grating, pressing/fermentation, sieving, frying/drying. An important aspect of processing is that it is often intended to prolong the preservation period of a product under ambient conditions. Besides permitting better preservation, processed products are easier to transport and create new opportunities for the

farmer such as new markets. The different products as a result of the processing may include; sauces, wines, dried fruits and vegetables, juices, squashes, cordials, and fried products among others. The current growth in the middle class coupled with modernization of the Ugandan economy has seen changes in eating habits and food trends which have boosted the fast-food sector (Ayo, Bonabana-Wabbi, & Sserunkuuma, 2012). This is evident in urban centers where fast food outlets have increased tremendously over the years.

A recent study by Sa et al. (2012) reveals that the majority of working-class Ugandans prefer to dine in restaurants to preparing meals at home. Consequently, they spend more on ready to eat meat products and fast foods that include chips, deep-fried chicken, sausages and deep-fried meat including pork. This has boosted consumption of sauces as an accompaniment to the meals. According to UNIDO (2004), sauces are among the products with the highest demand. Currently, the sauce market in Uganda is dominated by mainly products from tomatoes. This has not only seen a lack of diversity and high charges in times of tomato scarcity, but also a limitation in nutritional value that could be attained from other ingredients/ sauces. Furthermore, a venture into other ingredients would create a market for other agricultural products and boost farmers' incomes and the economy at a large. It is against such a background that the basis of this study is to formulate and optimize the process for production of an innovative tomato-mango-carrot ketchup.

2. Material and Methods

In this experiment, mangoes and carrots were added to tomatoes in different proportions and the functional properties including the nutritional, rheological and sensory characteristics of the resulting formulations were examined. The proportions according to Table 1 that gave the best properties were selected for further study.

2.1 Sample Preparation

All the fruits and vegetables needed for this research were procured from Kalerwe market in the suburbs of Kampala i.e. local mangoes, carrots, and tomatoes. The samples were washed to remove dirt, well-drained and rinsed in distilled water. They were placed in sterilized polythene bags and transported for juice extraction at the Food Technology Nutrition and Business Incubation Center (FTNBIC) at Makerere University Kampala (MUK). Each mango was washed thoroughly in tap water and washed again with treated water (boiled at 100 °C and cooled). The mangoes were peeled to remove the outer covering before being sliced into pieces (5cm long) to remove the seeds. The pieces were then blended using an electric blender (Sayona model: SB 4233). Blending of the mangoes and carrots was done separately at short intervals from time to time to avoid overheating and excessive foaming. The juice was pasteurized at 62°C for 30 minutes (Aurang et al., 1987) and refrigerated at 4°C. The carrot pulp was prepared according to the method of (Lan et al., 2005). The carrots were washed with tap water and peeled using Sodium hydroxide (40 ga/L) at 95°C for 1 min then washed again in tap water. This was followed by blanching in citric acid solution (60 g/l) at 95°C for 5 min then cooling in iced water to inactivate their endogenous enzymes and soften their tissues. In the end, they were sliced and blended with the addition of distilled water 1:1 (v/w) and filtered on a cheesecloth under vacuum to get fresh juice. Mangoes, tomatoes, and carrots were mixed with decreasing amounts of tomatoes and increasing amounts of mangoes keeping the carrot levels constant. Treatment A was the control with 100% tomatoes, 0% mangoes and 0% carrots. The

different treatments were then heated together with spices and held at boiling temperature for 20 minutes and packaged.

Table 1. Different treatment compositions

Treatment	A	B	C	D	E	F
Tomatoes (%)	100	90	80	70	60	50
Mangoes (%)	0	5	15	25	35	45
Carrots (%)	0	5	5	5	5	5

In the order of Tomatoes: Mangoes: Carrots A=100:0:0 B=90:5:5 C=80:15:5 D=70:25:5 E=60:35:5 F=50:45:5.

The treatments in Table 1 above were then each subjected to sensory evaluation and their functional properties measured in the laboratory. The most preferred formulation with the best nutritional properties according to proximate analysis was chosen for further investigations. The best formulation was then subjected to different processing conditions i.e. time and temperature. The nutritional and rheological properties will then be measured and analyzed to determine the best processing conditions for ketchup without compromising the nutritional value.

2.2 Determination of Nutritional Properties

2.2.1 Total Solids

Total solids were determined by measuring 10 ml of the treatments and weighed into a 50 mm diameter flat bottomed petri dish. The treatment will then be evaporated on a boiling water bath until it is solidified and was dried for two and a half hours in an oven at a temperature of 100°C. It will then be cooled in a desiccator and weighed. The difference in weight between the initial and final weight was recorded as total solids (AOAC, 1990). Measurements were taken in triplicates.

2.2.2 Ash Content

The sauce was heated in a water bath to dry most of the moisture content before ashing is determined. The dry ashing method following AOAC (1990) was used for the sauce treatments. Ten milliliters of the treatment were weighed into a crucible and heated with a furnace, at 550°C overnight. The crucible was taken out of the burner and cooled in a desiccator.

$$\text{ASH (\%)} = \frac{\text{weight of ash}}{\text{Weight of sample}} \times 100$$

2.2.3 Total Soluble Solids

The total soluble solids of the treatments were determined with a refractometer instrument at a temperature of 20°C and the refractive index obtained was used to find the degree Brix from a chart and was compared with the degree Brix as described by AOAC. (1990). the results were taken in triplicates.

2.2.4 Titratable Acidity

For titratable acidity, ten milliliters (10 ml) of the sauce formulated was mixed with 100ml distilled water. The mixture will then be titrated against 0.1M NaOH using 1% phenolphthalein as an indicator. The acidity was calculated based on citric acid.

2.2.5 Vitamin C

Vitamin C of the different samples was determined according to the method below;

Balance, capacity 100 to 200 accuracy 3 g-10 g with a set of analytical weights, Tared beakers or weighing pans, Filter paper, fluted, Whatman No. 12, 12.5 cm or the equivalent, Funnel, glass 65 mm, Beakers, 50 ml to 100 ml, Erlenmeyer flasks, 50 ml, Pipette, volumetric, 5 mL, 10 ml and 20 ml, Burette, 10 ml, graduated in 0.05 ml, Burette support and Volumetric flask, 100 ml.

Dissolve 50 mg of sodium 2, 6-dichloroindophenol and 20 mg of sodium bicarbonate in warm water and filter into a 100-mL volumetric flask using a small filter paper. Wash the filter paper until the color is completely removed. Pipette 25 ml juice into a 100-mL volumetric flask immediately after opening the container, and make up to volume with 3 percent metaphosphoric acid after each time swirling or rotating the flask to bring air bubbles to the surface. If necessary, add a drop of capryl alcohol to break the foam. Pipette a 10mL aliquot of filtrate (from 5 ml to 20 ml may be used if desired) into a 50 ml Erlenmeyer flask. Titrate rapidly with the dye solution until a definite pink color is obtained which persists for about 15 s.

In the case of liquid products, results are preferably expressed as milligrams of ascorbic acid per 100 ml the results can be calculated using the following formula:

$$\text{Ascorbic acid (mg per 100 gm or ml)} = \frac{T_a \times D \times 100}{S_a}$$

T_a is number of ml titrated, D is the dye factor which is equal to milligrams of ascorbic acid equivalent of dye and S_a is Number of ml of original treatment titrated.

2.3 Determination of Rheological Properties

The rheological aspects which include viscosity and syneresis were determined according to procedure as stated in the sections below;

2.3.1 Viscosity

Relative Viscosity was determined in an Ostwald viscometer at 25°C with distilled water as a control. It was expressed in centipoises (cPs).

2.3.2 Syneresis

Syneresis of ketchup treatments was determined by centrifuge (3-16 L Sigma, Germany). A measured amount of ketchup was taken in a centrifuge tube and centrifuged at 2200 and 5000g respectively, at 20°C for 10 min (Şahin and Özdemir 2007). The supernatant was discarded, and the remaining part was weighed. The serum separation was measured after each week for one month. The serum separation rate was calculated from (Şahin & Özdemir, 2007).

$$\text{Syneresis (\%)} = \text{Serum weight} / \text{Ketchup weight} \times 100$$

2.4 Sensory Properties

The formulated mango-carrot ketchup was subjected to sensory evaluation using a non-trained panel of 50 people consisting students and staff of the school of Food Technology, Nutrition

and Bioengineering between ages of 20 to 50 years. Six coded samples (A, B, C, D, E and F) were judged by the panelists for; appearance, color, taste, flavor, aroma, mouthfeel and overall acceptability using a 9-point hedonic scale (1= dislike extremely, 2= dislike very much, 3= dislike moderately, 4= dislike slightly 5= neither like or dislike, 6= like slightly, 7= like moderately, 8= like very much, 9= like extremely). Ketchup samples were provided with potato chips to the panelists one week after production. Panelists were requested to rinse their mouth with water before, in between and after testing each ketchup sample

2.5 Data Analysis

Data on nutrient content, sensory analysis and rheological parameters, was obtained and checked for normality. R software was used to perform descriptive statistical analysis including getting the means and standard errors. ANOVA was used at $\alpha=0.05$ to test for differences in parameters for the various mixing ratios, time and temperature values in the data collected. Duncan Multiple Range Test was used to ascertain statistical significance between groups and to determine whether different ratios, times and temperatures or the interactions between the two factors had an effect on the nutritional content and rheological parameters. Nutrient prediction models were done and correlation between factors were carried out in R studio.

The best formulation was established by comparison of nutritional properties, sensory properties and rheological properties of the different formulations. The formulation with the best properties was considered for further analysis in objective two to determine the effect of processing conditions on ketchup.

2.6 Statistical Analysis

The best formulation from objective one based on the nutritional, sensory and rheological properties was selected and considered for further analysis to determine the effect of processing conditions on the quality of ketchup. The temperature time combinations in Table 2 below were determined basing on how the different ingredients i.e tomatoe, carrots, mangoes, behave when subjected to different temperatures (Castro, Teixeira, Salengke, Sastry, & Vicente, 2004; Mrad, Boudhrioua, Kechaou, Courtois, & Bonazzi, 2012; Sánchez, Baranda, & de Marañón, 2014; Saravacos, 1970). Material preparation and measurement of the nutritional and rheological properties for this section will be done as elaborated in section 错误!未找到引用源。 above.

Table 2. The experimental setup

Holding temperature	Holding time		
	5 minutes	10 minutes	15 minutes
70	T1	T2	T3
75	T4	T5	T6
80	T7	T8	T9
85	T10	T11	T12

90	T13	T14	T15
100	T16	T17	T18

T=Treatment.

2.7 Acceptance Analysis

Analysis of all the data obtained was done using the R studio, MATLAB and excel packages.

3. Results and Discussion

3.1 Enhancement of the Functional Properties of Tomato Ketchup by Incorporation of Carrots and Mangoes

On addition of mangoes and carrots to tomato ketchup, there was a drastic increase in the levels of ascorbic acid. The levels of ascorbic acid had their lowest levels in treatment A with 100% tomato and their peak in treatment F in which 50% of the tomatoes were replaced with mangoes and carrots. According to Haugen et al. (2018), it is recommended that a person consumes about 5 to 10 mg of vitamin C daily to prevent the manifestation of scurvy and a higher dose of not less than 120mg daily is recommended in the elderly (Gillberg et al., 2018). For a human being in perfect health a daily intake of 100mg is sufficient to circulate the neutrophils, leukocytes and other body tissues (Naidu, 2003). The average consumption of ketchup per meal is about 100g which translates to about 160mg of ascorbic acid according to Table 3 below. Both starch and soluble sugars followed the same trend having their peak in treatment C and total carotenoids decreased drastically from treatment A and leveled at treatment B, increased slightly at D before decreasing gradually towards. The recommended intake of β -carotenes varies substantially to F. The European Food Safety Authority (EFSA) recommends a daily intake of not more than 15mg while the UK stands at a maximum of 7mg per day (Eggersdorfer & Wyss, 2018).

Total sugars (starch +soluble sugars) were highest in treatment C and lowest in treatment D. Treatment F was generally more acidic with a pH of 3.57 while A was the less acidic with a pH of 3.88. There was no significant difference ($p \leq 0.05$) in the ash content of all treatments. There was also a general increase in fat content from treatment A to F, however, there was a drop at D before a drastic increase at treatment E.

3.2 Nutritional Properties

Table 3. Nutritional and rheological properties after addition of mangoes and carrots

Treatment	T.A	Vit. C (mg/100g)	S.S (glucose/100g)	Starch (glucose/100g)	pH	M.C (%)	A.C (%)	T.C/100g	% Fat content	Viscosity cP
A	1.66	150.4	13.23	6.18	3.88	76.65	2.69	1.21	0.067	84131
B	1.46	162.8	17.83	6.70	3.80	75.87	2.54	0.69	0.097	108612
C	1.73	163.4	20.51	6.96	3.70	71.41	2.44	0.68	0.097	183568
D	1.50	185.5	21.49	7.55	3.76	74.54	2.50	0.74	0.063	191725

E	1.50	178.9	22.14	7.45	3.73	73.46	2.67	0.56	0.124	241994
F	1.51	248.3	26.34	8.35	3.57	73.19	2.47	0.46	0.143	270636

T.C-total carotenoids S.S- Soluble sugars M.C-moisture content A.C-Ash content T.A-titratable acidity.

In the order of Tomatoes: Mangoes: Carrots A=100:0:0 B=90:5:5 C=80:15:5 D=70:25:5 E=60:35:5 F=50:45:5.

There was a gradual increase of ascorbic acid on addition from treatment A to treatment F and this is attributed to the increasing levels of the quantity of mango pulp per treatment from A to F according to

Table 3 (Shah, 2010). There was also a gradual decrease in the levels of total carotenoids from treatment A to F which is attributed to the decreasing levels of tomato pulp from treatment A to F. tomatoes have very high concentrations of carotenoids mainly lycopene (Shi et al., 2004) which is responsible for their red color. The total sugars increased substantially with addition of mangoes from treatment A to treatment C where then gradually to E before increasing rapidly to F as seen in. The increase in sugars is attributed to the increase in levels of mangoes and addition of carrots. Mangoes are characterized with high levels of soluble sugars and very low levels of starch which are responsible for their sweetness (Malundo et al., 2001). According to Table 3 the levels of titratable acidity decreased slightly with addition of mangoes from treatment A to F. this can be attributed to the buffering nature of ripe mangoes due to presence of the citrate cleavage enzyme responsible for ripening. The levels of citrate cleavage enzyme are stimulated by the levels of glucose, fructose and fatty acids (Oleic acid and palmitic) (Mattoo & Modi, 1970). The following models can be used to predict the behavior of the different nutrition parameters with increasing levels of mangoes;

$$\text{Total carotenoids} = 1.10148\text{mangoes} * 0.011657$$

$$R^2 = 0.707$$

$$\text{Viscosity} = 84338 + \text{Mangoes} * 3830.9$$

$$R^2 = 0.969$$

$$\text{Vitamin C} = 141.56 + \text{Mangoes} * 1.5997 \quad R^2 = 0.731$$

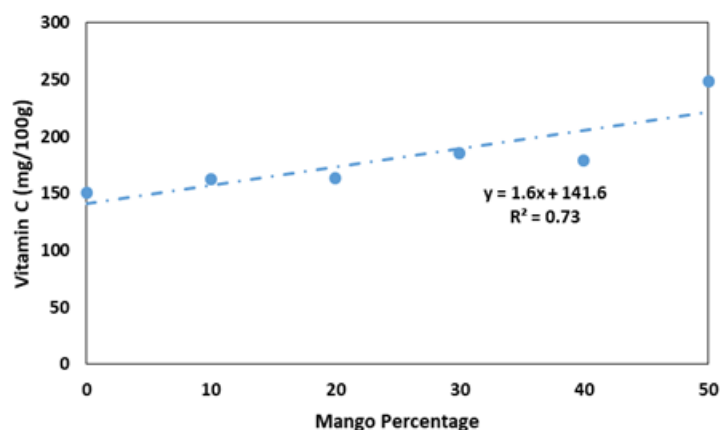


Figure 1. Relationship between vitamin C and percentage of mangoes

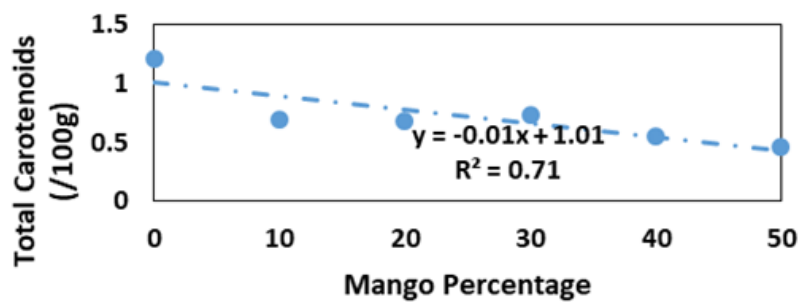


Figure 2. Relationship between total carotenoids and percentage of mangoes

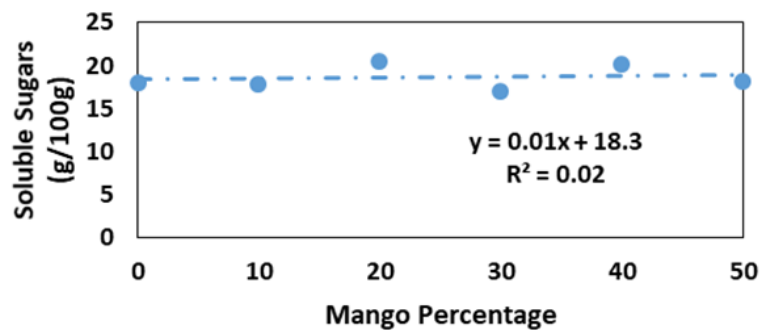


Figure 3. Relationship between soluble sugars and percentage of mangoes

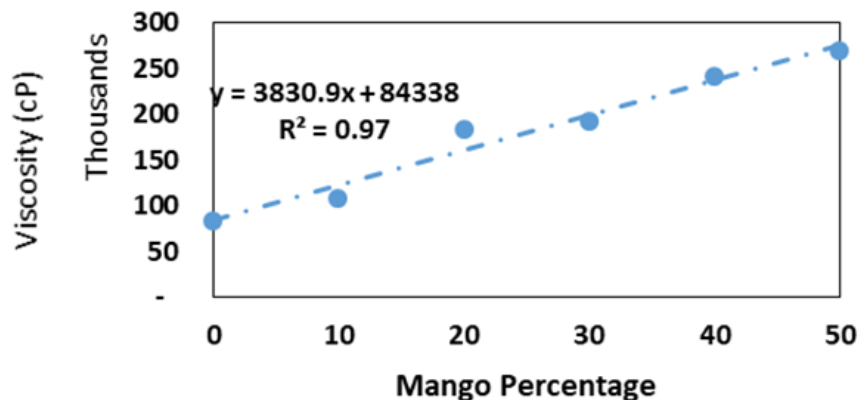


Figure 4. Relationship between viscosity and percentage of mangoes

3.3 Sensory Properties

In this section, results obtained from sensory analysis done using a non-trained panel of 50 participants whose responses were recorded are presented. A total of six samples were provided to each participant and responses on appearance, aroma, color, taste, flavor, mouthfeel and overall acceptability were recorded and analyzed.

Table 4. Cumulative values of sensory evaluation for the different treatments

	A	B	C	D	E	F
Appearance	385	342	307	299	269	204
Color	390	340	320	284	269	200
Taste	360	334	353	312	317	272
Flavor	350	299	362	307	266	220
Aroma	350	311	371	303	257	233
Mouthfeel	327	276	314	304	283	210
Overall acceptance	362	294	376	292	272	246
	2524	2196	2403	2101	1933	1585

In the order of Tomatoes: Mangoes: Carrots A=100:0:0 B=90:5:5 C=80:15:5 D=70:25:5 E=60:35:5 F=50:45:5

When the six treatments were subjected to sensory evaluation, results showed that treatment C was most accepted by consumers while treatment E had the least mean acceptance. However, from Duncan's multiple range test results, it is evident that there is no significant difference in acceptability between treatment A and C, treatment B and D and there was a slight similarity between E and F. Treatment A had the best appearance and color followed by treatment B and F had the worst. The goodness of appearance is attributed to the ketchup red color that is as a result of lycopene levels (Shi, Kakuda et al. 2004, Intelmann, Jaros et al. 2005) from tomato pulp. The decreasing amount of tomato pulp in the treatments from A to F caused the color deterioration from A to F. Treatment C and A had the best taste and flavor and F the worst. Duncan's multiple range test shows that there is no significant difference in the flavor and taste of treatment C and A however, that of treatment C was slightly higher and this can be attributed to the presence of a significant number of mangoes.

3.4 Functional Properties of Ketchup Under Various Processing Conditions

3.4.1 Viscosity

The values of viscosity were affected by the changes in time and temperature as shown in Table 5 below. The analysis of variance and Duncan's multiple range test showed that there was a significant difference in the viscosities at different holding temperatures with P-value of $2e-16$ ($p \leq 0.05$) since all viscosity values at the different temperatures had different letters from Duncan's multiple range tables. Duncan's multiple range test also shows that there was a significant difference between the viscosities at the different holding times with P-value of $1.14e-09$ ($p \leq 0.05$) with all the viscosity values having a different letter 'a', 'b' and 'c' respectively.

Viscosity of the treatments increased greatly with increasing holding temperature and increased slightly with time. This trend is attributed to the fact that increasing temperature and holding time results in moisture loss from the treatments which increases their

concentration and hence and increase in viscosity(Koocheki, Ghandi, Razavi, Mortazavi, & Vasiljevic, 2009). The increase in viscosity can also be attributed to the decrease in intermolecular distances after cooling because of thermal contraction (Azoubel, Cipriani, El-Aouar, Antonio, & Murr, 2005).

Table 5. Showing the values of viscosity at the different holding times and temperature

Holding Time	5 Mins	10 Mins	15 Mins
Holding Temperature (°C)	Viscosity (cP)	Viscosity (cP)	Viscosity (cP)
100	219333±7696	233333±577	236533±1501
90	188833±1041	191533±416	197167±1387
85	162067±709	150867±6185	168200±1375
80	152700±656	147067±5845	162067±1795
75	87467±208	89333±1193	101967±7157
70	64800±173	69833±850	78867±153

Table 4. Showing the level of significant difference at the different temperatures

Temperature	100	90	85	80	75	70
Viscosity	229733.3	192511.1	160377.8	153944.4	92922.22	71166.67
	a	b	c	d	e	f

Table 5. Showing the level of significant difference at the different times

Time	15	10	5
Viscosity	157466.7a	146994.4b	145866.7c

Means with the same letter in above tables are not significantly different ($p \leq 0.05$).

Viscosity of the treatments increased greatly with increasing holding temperature and increased slightly with time. This trend is attributed to the fact that increasing temperature and holding time results in moisture loss from the treatments which increases their concentration and hence and increase in viscosity (Koocheki, Ghandi et al., 2009). The increase in viscosity can also be attributed to the decrease in intermolecular distances after cooling because of thermal contraction (Azoubel, Cipriani et al., 2005).

The following model can be derived to predict the behavior of viscosity with time and temperature;

$$\text{Viscosity} = 134560.08 + 5240 * \text{Time} + 31014 * \text{Temperature}$$

$$\text{R squared} = 0.9534 \quad \text{Adjusted R squared} = 0.9276$$

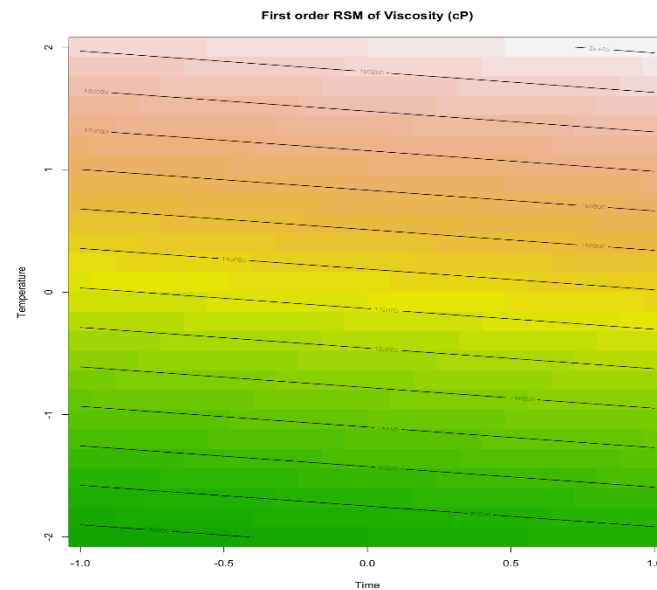


Figure 1. First order response surface for the behavior of viscosity with changes in time and temperature

The color change from the green zone to the light zone shows how increase in temperature and time leads to an increase in viscosity. However, the effect of temperature is more visible showing that viscosity is more affected by processing temperatures rather than processing time.

3.4.2 TSS

Analysis of variance showed that there was a slight significant difference between the total soluble solids for the different holding temperatures with P-value of 0.05 ($p \leq 0.05$). This was also confirmed through mean separation using Duncan's multiple range test which indicated TSS values at 80°C and 90°C with the letter "a" which shows no significant difference. There was also no significant difference between the TSS values at 90°C and 85°C, 85°C and 100°C, 70°C and 75°C. However, there was a significant difference between TSS values at 70°C and 80°C since they have different letters 'b' and 'a' respectively.

There was no significant difference between the TSS values at the different holding times with a P-value of 0.766 ($p \leq 0.05$). The Duncan's multiple range test also indicates the same at $p \leq 0.05$ which shows all the TSS values having the same letter 'a' indicating lack of significant difference.

The effect of temperature and time on TSS of ketchup after cooling. It was observed that TSS of ketchup increased with increase in temperature and holding time to a maximum of 31 °Brix due to increasing moisture loss as a result of increasing temperature and holding time then remained relatively constant up to 95°C due to increased inhibition of water loss by the increasing concentration of dietary fiber

Table 6. Values of TSS at the different holding times and temperature

Holding Time	5 Mins	10 Mins	15 Mins
Holding Temperature (°C)	TSS (%)	TSS (%)	TSS (%)
100	30.0±1.2	29.5±2.2	29.7±2.0
90	30.7±1.6	30.8±1.1	30.3±1.4
85	30.3±1.3	29.3±0.3	30.0±1.1
80	30.7±0.8	30.9±0.9	30.3±0.4
75	30.4±1.3	29.6±0.7	28.2±0.1
70	28.1±1.4	29.5±1.0	30.0±0.3

Table 7. Showing the level of significant difference at the different temperatures

Temperature	80	90	85	100	75	70
TSS	30.64a	30.61a	29.84ab	29.74ab	29.38b	29.20b

Means with the same letter are not significantly different ($p \leq 0.05$).

Table 8. Showing the level of significant difference at the different times

Holding time	5	10	15
TSS	30.02a	29.94a	29.74a

Means with the same letter are not significantly different ($p \leq 0.05$).

It was observed that TSS of ketchup increased with increase in temperature and holding time to a maximum of 31 °Brix due to increasing moisture loss as a result of increasing temperature and holding time then remained relatively constant up to 95°C due to increased inhibition of water loss by the increasing concentration of dietary fiber.

The following first order model is derived;

$$\text{TSS} = 29.94 + 0.32667 * \text{Temperature}$$

$$\text{R squared} = 0.3218 \quad \text{Adjusted R squared} = 0.2088$$

However its R squared value is significantly below the recommended value for a good model of at least 0.8 hence it's not a good model.

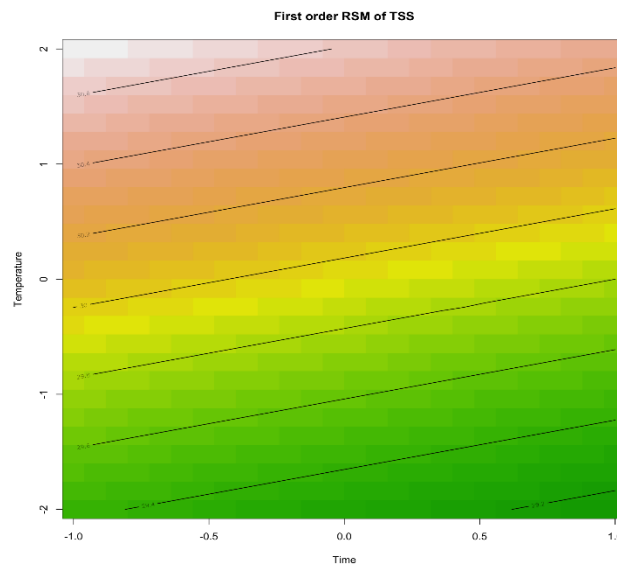


Figure 2. First order response surface for behaviour of TSS with change in temperature and time

The color change from the green zone to the light zone shows how increase in temperature and time leads to an increase in total soluble solids. However, the effect of temperature is stronger and the graphs show that limited exposure to high temperatures leads to an increase in total soluble solids.

3.4.3 Syneresis

From the analysis of variance, there was a highly significant difference between the values of Syneresis at the different holding temperatures with a P-value of $2e-16$ ($p \leq 0.05$). The Duncan's multiple range test also indicated that except for the Syneresis values at 80°C and 75°C with the same letter' which shows no significant difference, all other values of Syneresis are significantly different from each other. Furthermore, there was a slight significant difference between the Syneresis values at the different holding time. Syneresis at 15 minutes was significantly different from that at 5 and 10 minutes which were not significantly different from each other since they have the same letter 'b'.

There was a general increase in syneresis with increasing temperature and holding time ranging between 27% at 70°C and 44% at about 100°C . this can be attributed to the reduction of pectin (Athar, Shah, & Khan, 2000) as a result of reduction in tomato concentration.

Table 9. Values of Syneresis at the different time and temperature

Holding Time	5 Mins	10 Mins	15 Mins
Holding temperature ($^\circ\text{C}$)	Syneresis (%)	Syneresis (%)	Syneresis (%)
100	39.9 ± 2.0	44.2 ± 2.0	43.9 ± 2.2
90	38.3 ± 1.4	41.8 ± 1.7	40.6 ± 1.9

85	36.7±1.1	34.0±1.7	36.8±1.7
80	34.1±0.4	31.3±1.4	34.4±1.2
75	33.5±0.1	30.4±1.3	33.8±0.5
70	28.7±0.3	26.5±1.3	30.0±0.3

Table 10. Showing the level of significant difference at the different temperatures

Temperature	100	90	85	80	75	70
Syneresis	42.67613a	40.26026b	35.84385c	33.27246d	32.54039d	28.40611e

Means with the same letter are not significantly different ($p \leq 0.05$)

Table 11. Showing the level of significant difference at the different times

Holding time	15	5	10
Syneresis	36.59357a	35.20379b	34.70224b

Means with the same letter are not significantly different ($p \leq 0.05$).

There was a general increase in syneresis with increasing temperature and holding time ranging between 27% at 70°C and 44% at about 100°C. This can be attributed to the reduction of pectin (Athar, Shah et al., 2000) as a result of reduction in tomato concentration.

The following first order model can be derived;

$$\text{Syneresis} = 34.06 + 2.69 * \text{Temperature} \quad R \text{ squared} = 0.8473 \quad \text{Adjusted R squared} = 0.8219$$

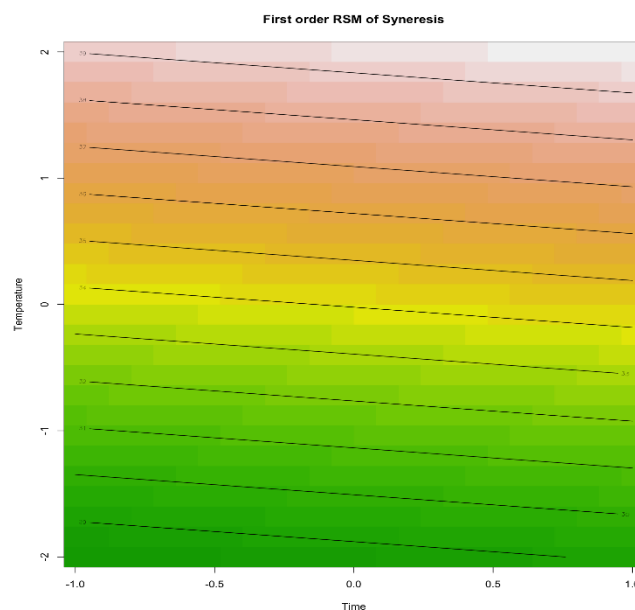


Figure 3. First order response surface for behaviour of syneresis with time and temperature

The color change from the green zone to the light zone shows how increase in temperature and time leads to an increase in syneresis. However, the effect of temperature surpasses the effect of time. Time does not affect the level of syneresis significantly.

3.4.4 Vitamin C

After the analysis of variance, the results showed that the values of ascorbic acid at different temperatures were significantly different from each other with a P-value of $2e-16$ ($p \leq 0.05$). Duncan's multiple range test shows that the ascorbic acid levels at 80°C and 85°C are not significantly different from each other but significantly different from the rest. Analysis of variance also indicates that the ascorbic acid levels at all holding times were significantly different with a P-value of $1.64e-10$ ($p \leq 0.05$). Duncan's multiple range test also indicates the same since all values have different letters in Duncan's table.

The levels off vitamin C decreases with increasing temperature from 75°C to 100°C which is attributed to the volatile nature of ascorbic acid (Kesselmeier & Staudt, 1999; Shin, Liu, Nock, Holliday, & Watkins, 2007).

Table 12. Showing values of Vitamin C at different holding time and temperature

Holding Time		5 Mins	10 Mins	15 Mins
Holding Temperature (°C)	Temperature	Vitamin C (mg/100g)	Vitamin C (mg/100g)	Vitamin C (mg/100g)
100		159.5±4.1	153.2±1.2	150.3±1.5
90		165.3±3.2	161.1±1.8	155.8±4.1
85		169.0±4.8	165.3±1.9	160.1±2.9

80	171.0±2.3	167.1±0.3	163.8±2.4
75	173.7±3.5	170.6±3.3	166.7±2.7
70	178.8±2.4	174.3±4.3	169.9±5.8

Table 13. Showing the level of significant difference at the different temperatures

Holding temperature	70	75	80	85	90	100
Vitamin C	174.31a	170.32b	167.29c	164.8°C	160.74d	154.33e

Means with the same letter are not significantly different ($p \leq 0.05$).

Table 14. Showing the level of significant difference at the different times

Holding time	5	10	15
vitamin C	169.5505a	165.2548b	161.1008c

Means with the same letter are not significantly different ($p \leq 0.05$).

The levels off vitamin C decreases with increasing temperature from 75°C to 100°C which is attributed to the volatile nature of ascorbic acid (Kesselmeier and Staudt 1999, Shin, Liu et al. 2007).

The following first order model can be deduced respectively;

$$\text{Vitamin C} = 167.62 - 4.15 * \text{Time} - 3.2733 * \text{Temperature}$$

$$\text{R squared} = 0.9893 \text{ and Adjusted R squared} = 0.9875$$

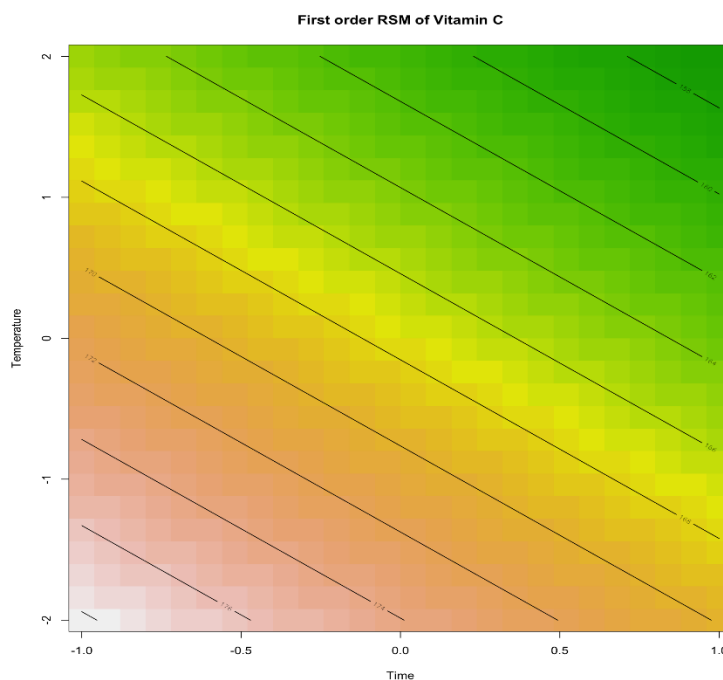


Figure 4. First order response surface for behaviour of vitamin C with time and temperature

The uniform rapid change in color from light pink in the lower left corner to dark green in the upper right corner shows that both time and temperature negatively affect the quantities of vitamin C by equal proportions

3.4.5 Total Carotenoids

The analysis of variance showed that there was a significant impact of temperature on the levels of total carotenoids with a P-value of $1.62e-10$ ($p \leq 0.05$). There was also a slight difference between the different levels of total carotenoids at the different holding temperatures according to Duncan's multiple range test.

There was a reduction in the levels of total carotenoids with increasing temperature. carotenes are volatile in nature and hence greatly affected by temperature increase which explains the decreasing levels as the temperature was being increased (Lee & Chen, 2002).

Table 15. Showing values of total carotenoids at different times and temperatures

Holding Time	5 Mins	10 Mins	15 Mins
Holding Temperature (°C)	Total Carotenoids	Total Carotenoids	Total Carotenoids
100	0.7±0.08	0.7±0.08	0.6±0.12
90	0.8±0.08	0.7±0.08	0.6±0.12
85	0.8±0.01	0.8±0.08	0.7±0.04
80	0.9±0.01	0.8±0.04	0.8±0.07
75	0.9±0.04	0.9±0.02	0.8±0.08

70	1.0±0.01	0.9±0.02	0.9±0.10
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Table 16. Showing the level of significant difference at the different temperature

Holding temperature	70	75	80	85	90	100
Total Carotenoids	0.92a	0.87ab	0.830bc	0.778c	0.711d	0.664d

Means with the same letter are not significantly different ($p \leq 0.05$).

Table 17. Showing the level of significant difference at the different times

Time	5	10	15
Total Carotenoids	0.851a	0.810a	0.727b

Means with the same letter are not significantly different ($p \leq 0.05$).

There was a reduction in the levels of total carotenoids with increasing temperature. Lycopenes are volatile in nature and hence greatly affected by temperature increase which explains the decreasing levels as the temperature was being increased (Lee & Chen, 2002).

The following first order models are deduced respectively;

$$\text{Total carotenoids} = 0.82 - 0.06 * \text{Time} - 0.0567 * \text{Temperature}$$

$$R \text{ squared} = 0.919 \text{ and Adjusted R squared} = 0.9055$$

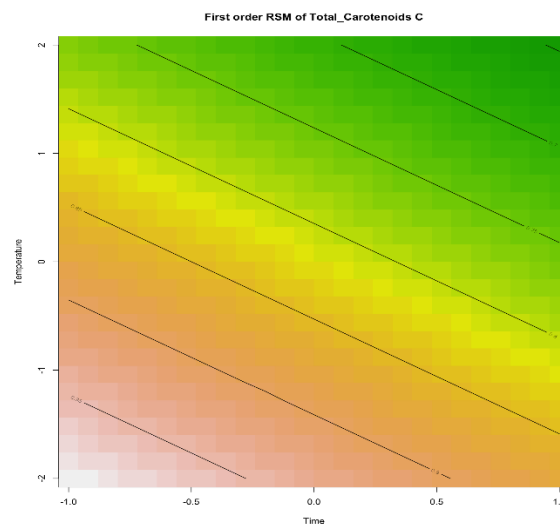


Figure 5. First order response surface for behaviour of total carotenoids with time and temperature

Figure above is a graphical representative of the first and second order response surface models showing how total carotenoids vary with time and temperature. The uniform gentle change in color from light pink in the lower left corner to dark green in the upper right corner shows that both time and temperature negatively affect the quantities of total carotenoids by equal proportions.

4. Conclusions

Addition of mangoes and carrots to the tomato ketchup significantly improved the nutritional properties of the ketchup with the largest increase being observed in soluble sugars and ascorbic acid. The viscosity of the ketchup also increased with addition of mangoes and carrots decreasing flowability. Product processing conditions are essential in determining the quality of ketchup. Processing temperatures above 85°C highly reduce the nutritional quality of ketchup as it significantly reduces the concentrations of vitamin C and total carotenoids. It's safe to process ketchup at temperatures between 80°C and 85°C for about 10 to 15 minutes holding time in order to achieve high nutritional value. Processing conditions have no significant effect on the pH of the ketchup as it's mostly affected by the components of the ketchup and additives.

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