RESEARCH ARTICLE

Hot peppers: vii. Efficacy of chemical preservatives on the quality and stability in red hot peppers (*Capsicum chinensis* L.)

Puran Bridgemohan[1], Majeed Mohammed[2], Ronell S. H Bridgemohan[3], Zareef Mohammed[4]

[1]Biosciences Agriculture and Food Technology, The University of Trinidad and Tobago Waterloo Research Campus, Carapichaima, [2]Department of Food Production, Faculty of Food and Agriculture, University of the West Indies, Trinidad, [3]Georgia College and State University, GA, USA, [4]Department of Information Systems Management , State University of New York (SUNY), Plattsburg, USA

ABSTRACT

The Caribbean is the producer of some of the most pungent red hot peppers (*Capsicum chinensis* L.); however, the quality is affected by pre- and post-processing methods. This reduces several physiochemical quality parameters such as color stability and pungency in particular. A series of experiments were conducted to develop a Caribbean hot pepper visual color standard and the relative pungency of the fresh and processed products. In addition, studies were conducted to assess the effects of preserving agents and various pre-processing methods on color and pungency changes. The study has demonstrated that, from the wide selection of Caribbean hot peppers, there are potential varieties which have met the standards set by the American Spice Trade Association (ASTA) for red color pigmentation and pungency. Carvalho hot which is the second most pungent pepper cultivar (1.07mg capsaicinoids and 16,000,000 Scoville Heat Units) displayed no significant variation in Hue angle (13^0-30^0) and is similar to commercially graded paprika. The ASTA values for that pepper in acetic acid (377 ASTA units) and macerated state are similar to the bright red state (366 ASTA units) in the fresh mature hot fruit. The study found that Carvalho hot peppers can be used for industrial processing as mash, flakes, or powder without loss of color or pungency compared to all the other tested cultivars.

Key words: Capsaicinoids, capsanthin, colorimeter, freeze-dried, pungency

INTRODUCTION

The Caribbean is recognized as the producers of some of the world's most pungent red hot peppers (*Capsicum chinensis* L.). However, food processing enterprises are unable to capitalize on market demands due to variability and consistency in fruit quality in terms of pungency and color.[15,39] The culinary and ethnomedicinal value of red hot pepper increases the demand in the international market whether as fresh or dried, whole or ground powder, or as hot sauces and flavoring agents.[27] Fresh hot pepper fruits are rich in pigments, such as, chlorophylls, anthocyanins, and carotenoids and when dried could be transformed into red chili powder.[40] The carotenoids [Figure 1] give the red–orange color of peppers and may be any of the followings: capsanthin, capsorubin, zeaxanthin, lutein, cryptocapsin, and α- and β-carotene.[23,28]

Hot pepper quality is affected by thermal processing which reduces the physiochemical qualities of the final product particularly color and to a lesser extent pungency.[46] The pigment content increases as the fruit ripens

Address for Correspondence:
Majeed Mohammed, Department of Food Production, Faculty of Food and Agriculture, University of the West Indies, Trinidad. E-mail: mohd2332@hotmail.com

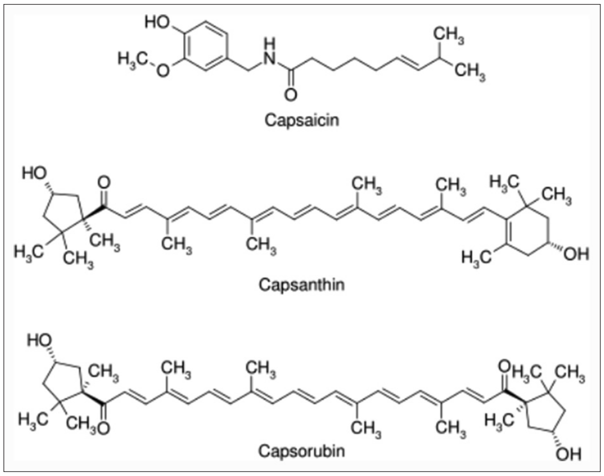

Figure 1: Chemical structure of carotenoids in hot peppers

until postmaturity.[29,30] The mature fresh fruits under ambient conditions can last for 4–5 days with minimal loss of quality, and this can be extended to 14–15 days when refrigerated at non-chilling temperature regimes.[16,29,30,35] Fresh pepper fruits require a safe non-chilling temperature of 7–8°C and high relative humidity (90–95%) immediately after harvest for storage and transportation so that losses due to physiological, biochemical, and microbiological activities are reduced.[12,33,34] Quantitative and qualitative deterioration attributes would result in drastic reductions in flavor, texture, color, and nutritive value.[17,42]

Red hot peppers are traded as whole chilies, powder, or flakes based on color expressed in American Spice Trade Association (ASTA) color value[7,36] Developed by OAMSTA.[4] However, such value-added products also experience similar quality issues with regard to color retention. Processed pepper as hot sauces and pepper mash encounter similar problems in addition to the subsequent loss of pungency due to microbial growth.

One method to alleviate the degradation in color is fermentation in peppers as in the "Tobasco" sauces.[11] Observed chemical characteristics change during the aging process of pepper mash as the pectic substances are degraded by the hot pepper pectic, enzymes. Degraded by peptic enzymes increasing the salt content of the mash or by aging in oak barrels, based on the pH of the, mash fermentation has been used as a means to create new products and alleviate color degradation.[11]

To monitor the changes or loss of pigments Jung *et al*.,[25] and Hu and Xia[21] used color reflectance of red pepper with a colorimeter. Jasim *et al*.[24] found the colorimeter to be effective to determine a* (reflected light in the red-to-green color spectrum) of the L*a*b* uniform color scale for pepper spray potency. Nunez *et al*.[38] used the colorimeter to measure changes in quality of dried red peppers and found that dipping red peppers in the solution of 2% ethyl oleate + 2% NaOH + 4% K_2CO_3 at 60°C resulted in the best color retention. Color retention and quality were also improved by vacuum packaging chilies at reduced temperature storage.[17] Ethoxyquin is used to prevent color loss due to oxidation of the natural carotenoid pigments.[1] Refrigeration showed minimally extractable and visual color loss on storage stability of paprika-based products during long-term storage.

The major issues in processing of red hot peppers are loss of color and pungency and microbial spoilage.[31] This study was conducted to assess the red color stability and the retention of the pungency of selected Caribbean hot pepper processed products destined for the export trade.

MATERIALS AND METHODS

A series of experiments were conducted in 4 separate studies during the period 2013–2018 at the Waterloo Research Center, University of Trinidad and Tobago. All varieties of hot peppers used in the study were cultivated in pots using soil as the growing medium. The crop was "fertigated" daily (2.0 kg/ha/200 L of water) with the recommended rates of N.P.K. nutrient mix (9:18:36) using a drip irrigation system as described previously by Bridgemohan *et al*.[16] The peppers were harvested in the mature ripe stages, weighed and size sorted, and recorded for each tree. All trials were laid out as randomized block design with a minimum of 20 plants per treatment. The fruits were sanitized with 250 ppm sodium hypochlorite solution and air-dried before any treatment was applied as described previously by Minguez-Mosquera *et al*.[29] and Mohamed and Bridgemohan.[30]

- Study 1: Developing Caribbean hot pepper visual color standards.
- Study 2: Effect of organic solvents on color changes in fresh hot peppers.
- Study 3: Effect of pre-processing methods on color retention in hot pepper products.
- Study 4: Effects of preserving agents and capping on color retention.

Study 1: Developing a Caribbean hot pepper visual color standards

Four varieties of hot peppers which are representative of the wide color spectrum of Caribbean hot peppers were selected to calibrate the color scheme and to set the standards for the quantification of colors for all other pepper fruits. The distinct colors and cultivars are described and correlated to the United States Food and Drug Administration (FDA)[5,9] and the European Union (EU) food grade colors [Table 1].

The variations in capsanthin pigment were measured using the International Commission on Illumination (CIE) Lab color scale.[6] The colors of the fresh and processed pepper were determined using a Chroma Meter according to the Hunter's Lab scale. The equipment used an internal Xenon light source and was calibrated against a white plate. The capsicum extractable color in the fresh hot peppers was determined according to ASTA analytical methods.[4,8]

Study 2: Effects of preserving agents on color changes in fresh hot peppers

The changes in color during preservation in acetic acid and ethanol were observed over an extended period. 100 g of mature fresh fruits of 11 hot pepper varieties which represent some of the world's hottest peppers were sliced and placed in a glass bottle and topped with 100 ml of the solvents. Samples were stored in the laboratory at 20–22°C with normal room lights, for over 1000 days. Color changes were recorded every 6 months during the period and the final color change reported. The study was designed with 11 varieties in 2 solvents over 5 color changing intervals.

Study 3: Effect of pre-processing methods on color retention in hot pepper products

The 3 physical methods of the preparation of hot peppers used in this study were cutting/slicing, grinding, and chopping which were processed at room temperature, oven heated, or freeze-dried. The two cultivars of hot pepper (Chili and Carvalho hot) from Study 1 were selected as the former already has superior potential as a dry whole or powdered product and possessed the distinct red coloration required by the spice and condiment industries. It was an opportunity to explore the potential of this extremely pungent pepper for processing into flakes or powder. Heat drying was conducted in a convection air oven at 60°C for a minimum of 72 h or until initial constant weights were obtained These were kept whole or later crushed into powder using a high-speed blender (Waring Commercial Heavy Duty Model: NSF- DO 54218). The freeze-dried flakes were undertaken with a Labconco® Freeze Dryer® (FreeZone 2.5 L Model: 117[A65312906]), and color retention was recorded at the fresh state at tri-monthly intervals (100 days) until 1000 days during storage.

Table 1: Pericarp color for various Caribbean fresh hot peppers

Pepper cultivars	Pericarp color
Carvalho hot	Red
Chili and Scotch bonnet	Green
Scotch bonnet	Yellow
Congo	Brown

Table 2: Surface color determination based on Hunter Lab

Code	Value	Color description
L*	100 0	Perfect reflecting diffuse Black
a*	+a* -a*	Red Green
b*	+b* -b*	Yellow Blue

Study 4: Effects of preserving agents and capping on color retention

Freshly harvested hot peppers cv. Carvalho were sanitized with 250 ppm sodium hypochlorite, air dried and blended with a food processor into a mash. Two (2) kg samples of the puree or mash were topped with 1 L of 2 different solutions which included acetic, citric acid, and ethanol. The preservative sodium benzoate (5 g) was added to both acetic and citric acids whereas the control had none.

The effect of a sealant or capping was conducted using 500 ml of vegetable oil and 100 g $NaCl_2$. The materials were placed on top of the mash with a wax paper layer separating in between to ensure no cross-contamination or mixing occurred. This was placed securely to ensure no air spaces in the mash. The experimental design was a completely randomized, with 3 sealant caps (oil, salt, and control) and 5 preserving treatment (acetic acid, citric acid, alcohol, and control with or without sodium benzoate). The jars were placed in a dark cupboard in an air conditioned laboratory and observed weekly. The color retention was conducted 300 days after the bottling process.

Color standards

In all studies, the surface color was determined using Hunter Lab (Hunter Lab – Lab Scan XE, Hunter Associates Laboratory Inc., Reston, VA, www. hunterlab.com), which includes lightness and chroma saturation.[22] Color measurements were based on the three-color coordinates, and the color space is in the form of cube with 3 axes [Table 2 and Plate 1]. The Hue angle (ho) for each

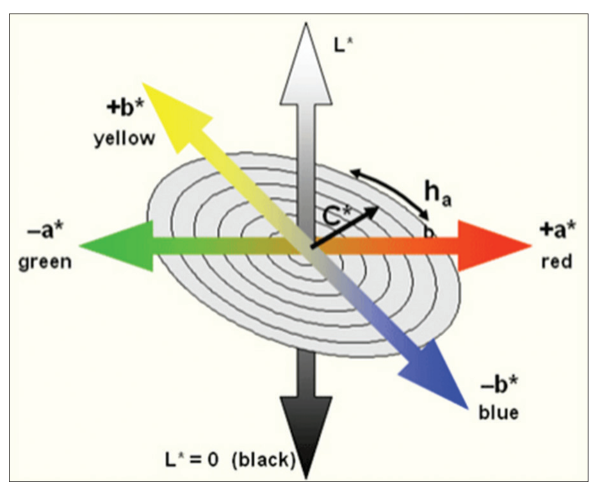

Plate 1: CIELAB color scale

Table 3: Computation formula for capsicum total and oleoresin extractable color expressed as ASTA units and the paprika color index

Color analytical method	Calculation (ASTA 20.1)
Total extractable	$\text{ASTA units} = \dfrac{\text{Absorbance at 460 nm}}{\text{Sample weight (g)}} \times 16.4$
Oleoresin extractable	$\text{ASTA units} = \dfrac{\text{Absorbance at 460 nm}}{\text{Sample weight (g)}} \times 16.4$
Paprika color index	$\text{PACI– paprika colour index} = \dfrac{(1000 \times a^\circ)}{L + h^\circ} \times \left[\ln(\text{ASTA units})\right]$

sample was also calculated as arctan b*/a*.[41,44] All color values represent the average of three measurements. Color change of stored products was monitored during 6–36 months of storage.

Fruit color was obtained using a portable tristimulus Minolta Chroma Meter (Model CR-200, Minolta Corp, Ramesy, NJ). The meter was calibrated with a white standard (Minolta calibration plate CR-A43) and fruit chromaticity was measured in "L," "a," "b" coordinates. Color components "L" represents the value (lightness) of colors and is larger for lighter colors. Measurements were taken at three locations chosen at random on the top, middle and blossom end of the fruits.

Total extractable and oleoresin extractable color

The capsicum total extractable color and the oleoresin extractable color in the fresh hot peppers were conducted in accordance with ASTA analytical methods 21.3.[10] Based on absorbance, 460 nm is used for quantifying the color of paprika and oleoresin spices. 100 mg of pepper powder of the four different colors was dissolved with 100 ml of acetone and left to stand for 2 min for the oleoresin extractable and 16 h for the total extractable and incubated at 25°C in the dark. The absorbance for both test samples [Table 3] was determined at 460 nm in UV-Vis dual beam spectrophotometer (Labomed, Inc., USA), and color expressed as ASTA units and Paprika Color Index.[36]

Pungency

The capsaicin and dihydrocapsaicin were analyzed using the U3000 - high-performance liquid chromatography (HPLC) and the ODS-2 Beckmann column (250 mm × 4.6 mm; 5 µm). The solvent was filtered using reverse osmosis water and methanol (HPLC grade - BDH) at 60% methanol/H_2O (0–2 min), 60–99% methanol/H_2O (2–6 min), 99% methanol/H_2O (6–8 min), and 99–60% methanol/H_2O (8–10 min). The standard solutions were prepared from a stock solution of capsaicin and dihydrocapsaicin using six serial dilutions (0.50–0.5 µg/g) which exhibited a linear response for both the compounds. Each solution was injected 3 times and standard solutions were run on the HPLC, and the standard curves were generated by plotting peak area against concentration. The external calibration curves were found at $r^2 = 0.9982$ for capsaicin and $r^2 = 0.9996$ for dihydrocapsaicin, and the values of r^2 were highly significant confirming the good linearity of the method.[14-16]

Freeze drying

The freeze dry flakes were processed using a Labconco Freeze Dryer. The Freeze Dryer parameters were 0.120 mbar vacuum pressure, ambient temperature, and a condenser temperature between − 46 and − 52°C.[26] The pre-freezing sample time was at least 48 h, and freeze-drying time was approximately 3 days for complete dryness. The color retention was recorded at the fresh state and at tri-monthly intervals (100 days) until 1000 days.

Vacuum sealing

Vacuum packing was used to remove air from the package pepper samples (vacuum chamber pouch 5 cm × 30 cm) before sealing and to reduce atmospheric oxygen, thus inhibiting microbial growth and preventing the evaporation of volatile components.[2] The Vacmaster VP210 Chamber machine was operated at PR = 0.0–−0.1 MPa (negative pressure), vacuum time at 23 s, sealing time at 1.8 s, and a cooling time at 3.2 s. The four selected colored peppers after vacuum sealed were stored in the chillier (4°C), freezer (−5°C), and the laboratory counter (25°C) and observed for color change and spoilage up to 60 days after treatment.

Data analysis

All experiments were laid out as completely randomized designs with three replicates as a minimum of 10 treatments per replicate. All data were subjected to generalize linear modeling using Minitab Statistical Software, and where necessary, variables were first subjected to log transformation and then analyzed. For all comparisons, significance was defined at $P \leq 0.05$.

Table 4: Qualitative description of Caribbean hot peppers pericarp according to the FDA and EU color codes

Hot pepper cultivars	Pericarp color	FDA code	EU code
Carvalho hot	Red	FD&C Red No. 40	E160c
Chili/Scotch bonnet (mature)	Green	FD&C No. 3	E140
Scotch bonnet (ripe)	Yellow	FD&C Yellow No. 1, 2, 3,	E107
Congo	Brown	Not determined	E155

RESULTS AND DISCUSSION

Caribbean hot pepper visual color standards

The visual color standards were based on the description of the four selected peppers with the appropriate FDA and EU codes [Table 4]. The qualitative descriptors of the four pepper colors spanned a wide spectrum from mature green, chocolate (brown), and yellow (orange), with shades of dark, light, and bright.[9] Both the FDA and EU color codes were used to align the standards for the quantification of colors for all other peppers in subsequent studies [Plate 1].

The fresh hot pepper standards using the whole red fruits showed that the "L" value range displayed the wide spectrum of reflective diffusim. Thus, cv. Congo with "L" value of 29.43 depicted a brown pericarp, Freshly harvested hot peppers cv. Carvalho hot attained a value of 42.77. However, significant ($P \leq 0.05$) differences existed for cv. Scotch Bonnet with mature green fruits showing "L" values of 51.29 and ripe yellow fruits with 62.91 [Tables 5 and 6]. That is, the low brown value was closer to the black, and the higher yellow value was closer to the whiter spectrum. The highest a* value (38.46) demonstrated the most redness Freshly harvested hot peppers cv. Carvalho. Similarly, the negative a* (−18.11) clearly described the green coloration (Chili and green Scotch bonnet), but the positive b* (56.23) confirmed the degree of the yellow pericarp coloration for ripe cv. Scotch bonnet [Table 6].

The Hue angle determined the color purity. The cv. Carvalho Hot had a hue angle of 34.4^0 with a red color intensity of 1644.9. Meanwhile, the ripe cv. Scotch bonnet had hue angle of 71^0 making it a close to deep yellow, while the cv. Chili with Hue angle of 120^0 as almost to pure green [Table 6]. Commercial paprika has a Hue angle of $0–45^0$ and is usually described as red to orange.[1]

The total extractable color based on the absorbance (460 nm) ranged from 665.8 (green) to 1382.92 (brown) ASTA units [Table 7]. It showed that the carotenoid pigments for red coloration were higher than of commercial paprika (2151 ASTA units).[36] The color index for paprika (PACI) which is based on the CIELAB coordinates L*, a*and b* and h showed that surface color is not well correlated with extractable color but can be used to distinguish between sample groups of different ASTA units. The regression analysis (C5 = 221 + 0.0118 C4) was not significant and the Pearson correlation = 0.144, and *P* value = 0.85.

Table 5: Color standard for mature-green Scotch Bonnet fruits

Standards	Value
PACI	366 units
Hue angle	34.40°
ASTA	2100–2400 units
Color intensity	1645
FDA code	FD&C red No 40
EU code	E160 c
Chroma 50	Reddish brown and bright

ASTA: American Spice Trade Association, PACI: Color index for paprika

Although paprika has a dominant shade of cooler red, the quality indicator is the degree of yellowness (1653.12 ASTA units) in the red pepper [Table 7]. The typical ASTA color value for paprika is 2000 ASTA units and the IC color is 80,000 IC units.[20] In this study, the color red in cv. Carvalho hot was in excess of the ASTA standards. The color code standards developed for Caribbean red hot peppers are summarized hereunder.

Study 2: Effect of preserving agents in color changes in fresh hot peppers

The color changes of 11 cultivars some of the world's hottest peppers stored in solutions of acetic acid and ethanol over an extending period of 6–36 months were evaluated [Table 8]. Both cvs. Trinidad Scorpion and Bhut Jolokia retained their reflecting diffuser capacity (L*) in both acetic acid and ethanol for red color, while the color in Scotch bonnet and Congo deteriorated in both solutions compared to their fresh state. The cvs. Habanero and 7-Pot peppers reflecting diffuser capacity were reduced when placed in ethanol as opposed to acetic acid.

All the peppers were bleached of their red pigmentation (a*) in both acetic acid and ethanol after 100 days and their value from the standard (a* = 38.4) compared to acetic acid (0.77) and ethanol (14.61).The red color of Carvalho hot (10.77) and 7-Pot (12.08) was reduced by 60% compared to the fresh samples and those treated with acetic acid. Ethanol had a

Table 6: CIEB standard for whole fresh Caribbean hot peppers

Pericarp color	L*	a*	b*	Color intensity[1]	Hue angle[2]
Red	42.77	38.46	26.42	1644.9	34.4
Green	51.29	−18.11	32.54	−928.8	120.2
Yellow	62.91	18.57	56.23	1168.2	71.7
Brown	29.43	9.15	2.25	269.2	13.8

[1]Color intensity: L x a*. [2]Hue angle: ($\tan^{-1}$ b*/a*)

Table 7: The absorbance of four colored hot peppers at 460 nm in UV–vis dual beam spectrophotometer (Labomed, Inc., USA) and total and oleoresin extractable color (ASTA units)

Pepper color	Oleoresin extractable color		Total extractable color		
	Absorbance (460 nm)	ASTA units	Absorbance (460 nm)	ASTA units	PACI 1
Yellow	0.07	11.80	1.008	1653.12	933.71
Green	0.02	4.75	0.406	665.84	-413.9
Red	0.50	82.49	7.042	11548.88	366.90
Brown	0.60	98.72	8.428	13821.92	324.72

ASTA: American Spice Trade Association, PACI: Color index for paprika

Table 8: Effect of vacuum sealing and temperature on pepper color retention after 60 days

Pericarp color	Benchtop (20–22°C)	Chiller (7–8°C)	Freezer (–16°C)
Red	10	50	100
Green	0	0	100
Yellow	0	40	100
Brown	0	20	100

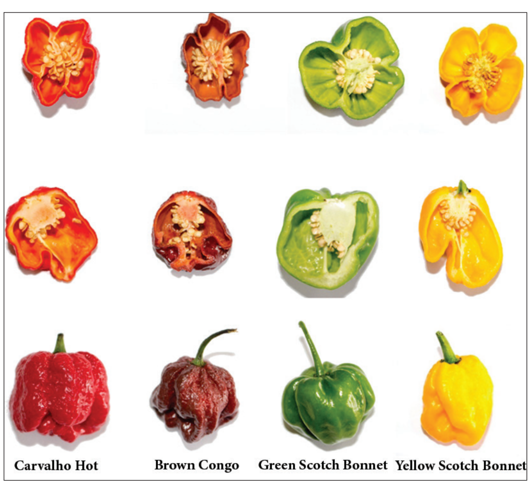

Plate 2: Color standards of Caribbean hot peppers.

complete bleaching effect on all varieties except bird pepper where it was improved compared to the acetic acid solution. Scotch Bonnet and Congo peppers which are yellow were not affected by both solutions and did not lose much pigment.

There was a positive b value for yellow pigmentation (56.23) in the standard. The Scotch bonnet coloration was reduced to 8.42 and 14.36 for both acetic acid and ethanol, respectively. Scorpion and Bhut Jolokia both with red pericarps were able to maintain some degree (30%) of their original fresh state color in acetic acid [Plate 2].

Acetic acid or ethanoic acid (60 g/mol) is a monobasic weak acid that is found mainly in vinegar and used in the preservation for several fruits and vegetables, including pepper in hot sauces. Supposedly, it can assist in the retention of the color, flavor, and pungency of the pepper.[16] Ethanol which is the simplest member of the alcohol family is used as organic solvents and is less acidic than ethanoic acid. It was expected that ethanol would exhibit a more bleaching effect on the pigments as observed by Mohammed *et al*.[32] Color may also be specified in connection with the grade, providing that 90% of peppers show the amount of the specified color.[8] The Hue angle was determined for 9 red peppers in both acetic acid and ethanol. Of the red color peppers, only two peppers in acetic acid, namely Carvalho Hot (44.1^0) and 7-Pot (32.20), maintained Hue angles similar to the fresh state (34.4^0) close to the commercial paprika, taking into consideration that paprika coloration is due almost exclusively to the carotenoid fraction and perhaps small amounts of polyphenols.[28] All others were completely bleached of their coloration in the alcohol [Table 8].

Pepper color retention after 60 days when vacuumed sealed is temperature dependent [Table 9]. Color retention of vacuum sealed pepper is notably effective (100%) when stored at freezing temperature of − 16°C compared to fruits stored at refrigerated temperatures (7–8°C). While the chlorophyll pigment in the green peppers did not retain color neither at refrigeration nor bench top or ambient temperatures [Table 10], only red peppers were able to retain color at bench top temperatures when vacuum sealed after 60 days.

The HPLC determination of pungency revealed that the capsaicinoids content of both Trinidad scorpion (2.08 mg) and Carvalho hot (1.07 mg) are considered as highly pungent, and the computed Scoville heat units (SHUs) were 32 and 16 million SHUs, respectively [Table 10].

Study 3: Effect of pre-processing on color retention in hot pepper products

Both Chili and Carvalho hot peppers were selected for testing at the fresh green, ripe, and dried stages and also in the processed forms of flakes or powder. The results [Table 11] indicated that there were no changes in color from 100 to 1000 days after processing. However, there were observable visual changes from the fresh mature fruits to the processed states [Table 11]. The chili in the fresh and whole (aged) dry state maintained L*= 43–44, but this was significantly decreased in the dry (L*=29) state.

Table 9: Carvalho peppers oleoresin extractable color (2 min) and total extractable color (16 h)

Sample	Oleoresin extractable color (@ 2 min)		Total extractable color (@ 16 h)	
	Absorbance (460 nm)	ASTA units	Absorbance (460 nm)	ASTA units
Ground paprika	0.146	23.944	1.519	2491.16
Whole air-dried	0.037	6.068	0.228	373.92
Sliced air-dried	0.051	8.364	1.29	2115.6
Freeze dried	0.109	17.876	1.795	2943.8
Milled air-dried	0.116	19.024	1.881	3084.8
x	0.0918	15.06	1.343	2202
SE	0.0206	3.38	0.298	3.38

ASTA: American Spice Trade Association

Table 10: CIEB for 12 Caribbean hot peppers in various solutions after 100 days

Hot pepper varieties	Pericarp color	(Capsaicinoid) mg	SHU[1]	Solution									
				Acetic acid					Ethanol				
				L*	a*	b*	Hue angle	PACI	L*	a*	b*	Hue angle	PACI[2]
7- Pots	Red	1.09	16.3	35.0	12.0	7.6	32.2	377.1	40.5	5.3	17.0	72.5	204.64
Cayenne				37.5	2.0	7.2	73.8	129.5	35.7	8.6	10.4	50.4	292.08
Large bird pepper		0.14	2.1	32.3	13.4	3.9	16.3	432.8	34.6	16.1	7.4	24.7	491.39
Jalapeno		0.16	2.5	40.6	7.9	13.7	60.1	254.8	41.7	0.4	9.2	87.01	98.51
Habanero		0.35	5.3	33.8	14.6	6.3	23.4	455.0	39.8	0.9	7.0	81.9	106.83
Chilli		0.16	2.5	40.1	1.8	9.2	78.6	124.7	41.2	0.5	8.6	86.2	100.06
Carvalho hot		1.07	16.0	33.8	10.7	10.47	44.1	362.1	32.9	7.4	11.1	56.3	282.35
Trinidad Scorpion		2.08	31.2	43.2	1.8	14.0	82.5	125.1	42.7	0.7	8.4	84.9	102.50
Bhut Jolokia		0.51	7.7	46.9	0.7	11.7	86.2	102.6	44.9	0.7	11.8	86.2	103.59
Scotch bonnet	Yellow	0.23	3.5	48.0	0.8	8.4	84.5	101.2	50.1	2.1	14.3	81.3	124.88
Congo	Brown			38.0	2.1	8.2	75.5	131.0	36.9	1.2	5.6	77.1	112.00
x		0.643	0.643	39.0	0.62	9.1	59.75	377.12	37.45	4.51	9.75	71.68	183.5
se		0.219	0.219	1.60	1.68	0.93	7.89	2.96	6.00	1.26	0.926	6.00	37.9

[1]SHU: Scoville Heat Units in. ’000’000, [2]PACI: Paprika color index

Carvalho hot in all the states maintained L*values similar to the fresh red state (42) but lost some of its lightness in the processed (30) mash. Chili kept its greenness (a*= −16.93) for long period (21 days) at chilled temperatures but became brown (a*= 5.4–16) after 400 days due to the drying. Carvalho maintained and retained a high level of redness (a* reduced from 38 to 25) over the 1200 days' experimental period. However, in the mash form, this was significantly reduced (a*= 8.30) and appeared more brownish. All forms of the processed samples displayed the lower end of the yellow spectrum (b*= 4.9–15.2) [Table 11].

The ASTA paprika varied, color varied between 2154 and 2438 units, and the ICU International color varies between 86,186 and 97,538.[36] The commercial paprika used in this study fell within this range. Total extractable color after 16 h indicated that Carvalho hot maintained its color both as freeze-dried and milled air-dried [Table 9].

In general, there were no significant changes in L*, a*, and b* from the fresh to freeze dry processed stage, and oven drying had a lighter color (L*), but blending into mash caused pigment degradation, resulting in a reduction in a* and b* values. However, the mash created over 50% loss in color

Table 11: Chilli and Carvalho pepper in flakes and powder

Pepper	Thermal	Physical	Product	L*	a*	b*	Hue angle	PACI
Chilli peppers	None	None	Fresh (green)	43.15	–16.93	27.34	58.23	450.5
	Heat	Cutting	Air-dried sliced	27.90	16.43	20.61	51.43	640.3
	Heat	None	Whole (aged) dry	44.97	5.46	5.59	45.67	167.0
	Heat	Grinding	Ground powder	46.98	15.09	17.18	48.70	369.9
	freeze	Chopping	Freeze-dried flakes	44.22	15.35	7.76	44.93	488.2
Carvalho hot	Heat	Heat	Grinding	36.62	27.79	12.20	23.70	782.5
	Heat	None	Whole (aged) dry	28.00	21.29	4.93	13.03	773.3
	Heat	None	Air-dried sliced	36.62	27.79	12.20	23.70	782.5
	Freeze	Chopping	Freeze-dried flakes	46.53	25.35	15.22	30.98	575.7
	Heat	Grinding	Ground powder	44.22	25.35	6.76	14.93	588.2
	X (SE+-)			39.92 2.30	16.30 4.32	12.98 2.29	23.9 10.2	472 120

Table 12: Effects of preserving agents and capping on color retention

Sealant cap	Preserving agent	L*	a*	b*	hue	PACI
Oil	Acetic acid	31.83	11.79	6.54	29.01	399.42
	Alcohol	33.46	10.03	6.10	31.30	331.06
	Citric acid	36.16	7.69	13.48	60.29	272.96
	Control	36.24	6.59	13.29	63.62	245.46
	Sodium benzoate	31.35	9.08	6.21	34.36	324.00
Salt	Acetic acid	33.43	5.63	6.16	47.57	215.98
	Alcohol	31.09	8.44	5.82	34.58	306.05
	Citric acid	31.50	10.36	6.49	32.06	360.95
	Control	32.67	6.31	6.35	45.18	238.32
	Sodium benzoate	30.96	7.12	5.84	39.35	269.33
zero	Acetic acid	35.95	5.76	13.33	66.63	226.85
	Alcohol	32.65	9.58	6.34	33.49	326.91
	Citric acid	32.01	16.92	9.63	29.64	558.23
	Control	31.37	11.40	6.37	29.19	392.59
	Sodium benzoate	28.95	8.85	5.15	30.19	335.89
	X (SE)	33.2 (0.479)	7.8 (0.594)	8.7 (0.743)	29.01	399.42

Plate 3: Carvalho hot pepper colors in various processed forms

Plate 4: Color degradation of Carvalho hot in acetic acid and ethanol after 360 days

and similarly, any processing or slicing resulted in significant color loss [Plate 3].

Study 4: Effects of preserving agents and capping on color retention

In this study, the fresh color pigmentation was recorded and the final color changes conducted after 1 year [Table 12]. It was observed that, regardless of the sealant, "L" value differences remained consistent [Table 12]. However, sodium benzoate-treated samples had approximately 25% reduction in "L" compared to the freshly harvested fruits. The oil cap in both the citric acid and control (L*=36) retained similar color intensity to the fresh state. Further, in all treatments, the level of redness as indicated by a* was reduced by > 75% and bordered on more brownish appearance with less red pigmentation probably due to oxidative reactions. On the b* axis, all the treatments were between 5 and 13 and were at a lower degree of yellow coloration hue associated with this axis.

There was an interaction between sealant and preserving solution in that oil x acetic acid and oil x sodium benzoate maintained Hue angles of 29^0 and 34^0, respectively. Similarly, salt x citric acid and zero x sodium benzoate had Hue angles of 32^0 and 30^0, respectively. Oil cap x acetic acid maintained the same coloration as the control for the entire duration of the study, unlike the control which did not as spoilage occurred much earlier. This treatment had no chemical additives/

Plate 5: Color degradation of 5 Caribbean hot peppers in acetic acid (top) and ethanol (bottom) after 360 days

preservatives and did not exhibit any color change or pigment deterioration, i.e., no observable levels of microbial contamination or fermentation compared to salt and zero cap. This suggested that oil cap was more tightly fixed on the pure/mash resisted air contact suppressing the growth of that may resulted in aerobic microorganism [Plate 4 and 5].

Cho *et al*.[19] reported that fermentation did not affect the capsaicinoids in pepper mash stored in plastic and oak wood barrel. Significant color changes can occur in the fresh peppers during processing and storage, and color retention is an important criterion for pepper products and pungency. Consumers prefer the dark-colored pepper products because of the aging process induced by fermentation which intrically would result in a sauce with a desirable pH according to Bozurt and Erkmen.[13]

In commercial pepper sauce production, pasteurization of the mash and addition of 12–15% salt have promoted color enhancement.[13] In addition to heat treatment, it is accepted that lactic acid and oxygen are other important factors that would contribute to the attainment of color development.[13] Many factors affect pepper color change during storage, and the most important is oxidative degradation of carotenoids, caused by exposure to heat, light, and oxygen.[3,18,45]

Previous studies have shown that the main quality contributing factors to color and pungency are influenced by agronomic, insects and microorganisms, and postharvest practices. Mohammed *et al*.[32] Seyoum and Woldetsadik[43] demonstrated that post-processing and storage can result in major deterioration. Vacuum packaging can maintain quality for a relatively longer period and result in reduced

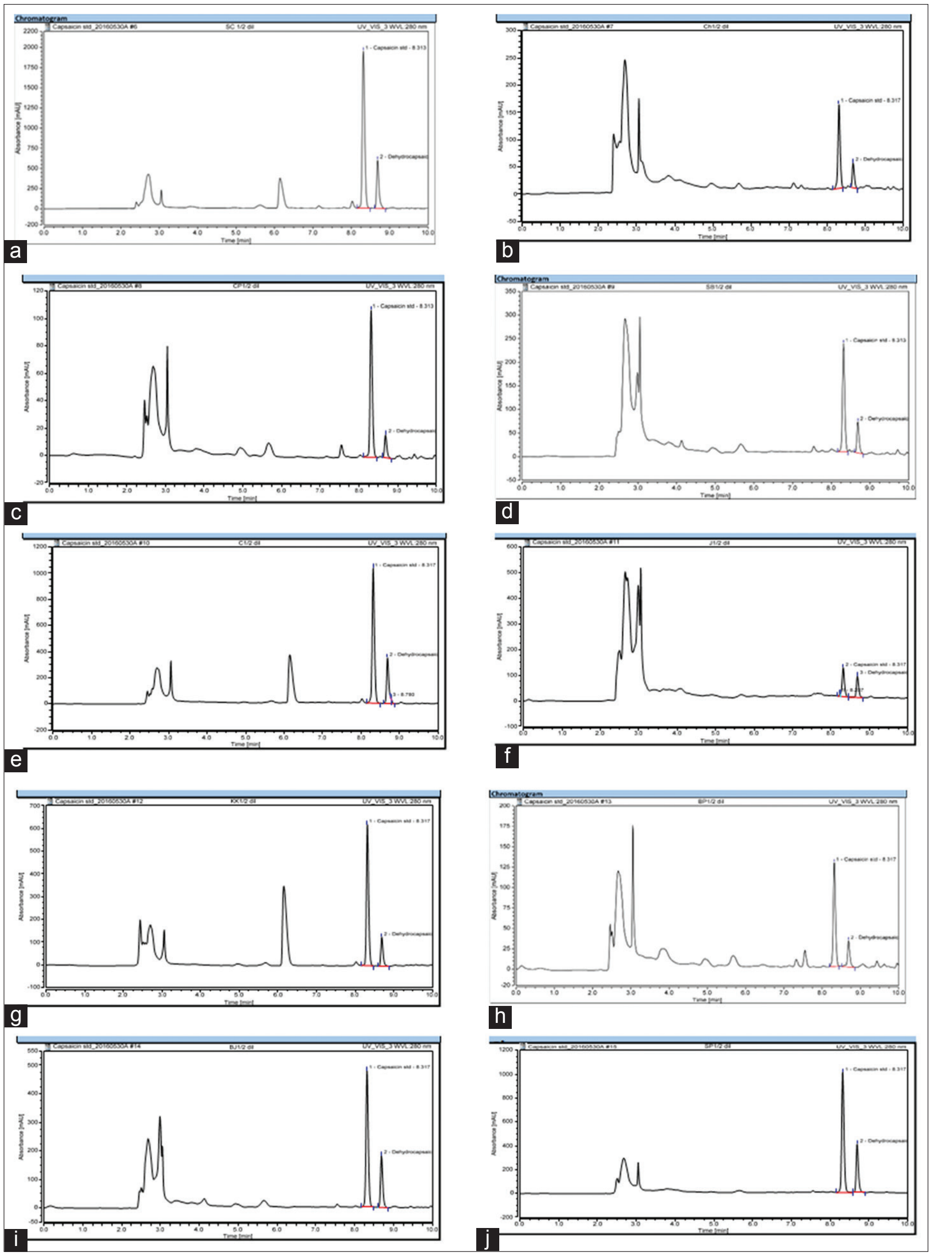

Figure 2: Capsaicin and dihydrocapsaicin (μg/g) contents of the various hot peppers: (a) Trinidad scorpion, (b) chilli, (c) cherry, (d) Scotch Bonnet, (e) Carvalho hot, (f) Carvalho hot, (g) Kiri Kiri, (h) bird, (i) Bhut Jalokia, and (j) Seven pot peppers landrace using the high-performance liquid chromatography method

oxygen levels in sealed packages. The removal of air due to vacuum sealing caused the package to collapse around the product creating an anaerobic environment which eventually prevented the growth of mainly aerobic spoilage microorganisms responsible for off odor and texture changes.[18,37]

CONCLUSIONS

This study has demonstrated that, from the wide selection of Caribbean hot peppers, there are potential varieties which have met the standards set by ASTA for red color and pungency. Carvalho hot which is the second most pungent pepper cultivar (1.07 mg capsaicinoids and 16 m SHU) has no significant variation in Hue angle (13–30^0) and is similar to commercially graded paprika [Figure 2]. The ASTA values for it in acetic acid (377 ASTA units) and ground state are similar to the bright red state (366 ASTA units) in the fresh mature hot fruit. The pepper fruit can be used for industrial processing as mash, flakes, or powder without loss of color or pungency, thereby pinpointing a new avenue for investment.

ACKNOWLEDGMENTS

The authors are grateful for the technical and scientific support of the following University of Trinidad and Tobago staff: Kimberly Singh (Research Technician), Karlene Fortune (Laboratory Technician), Puran Jaikarn and Robbin (Balroop), and Besson Harpaul (Operator). The authors are appreciative of the Support of Keshwar John of the University of the West Indies. Special acknowledgments to Abigail Le Gendre and Selena Khan for typing the manuscript and photography assistance.

REFERENCES

1. Addala R, Vasavada M, Dong J, Subramanian S. Effect of storage conditions on rate of color degradation of paprika based products. J Food Process Technol 2015;6:423.
2. Akhtar J, Pandey RK. Quality changes of vacuum packed meat and meat products: A review. Int J Appl Pure Sci Agric 2015;1:26-31.
3. Anderson K, Lingnert H. Influence of oxygen concentration on the storage stability of cream powder. Lebensm Wiss Technol 1997;30:147-54.
4. Anonymous. Official Analytical Methods of the American Spice Trade Association. 4th ed. 1997. Available from: https://www.google.com/search?source=hp&ei=iIkCXPaTKtKC5wKT0JKQDQ&q=Anonymous.+Official+Analytical+Methods+of+the+American+Spice+Trade+Association. +4th+ ed.+1997.+
5. Anonymous. USDA. United States Standards for Grades of Peppers (Other Than Sweet Peppers; 2007. Available from: http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5051220. [Last accessed on 2015 Jan 16].
6. Anonymous. Insight on Colour. Hunter L. a. b Versus CIE 1976 L*a*b*. Hunter Lab. Applications Note; 2008. p. 2.
7. Anonymous. Western Farm Press. US Chile Pepper Industry under Assault from Foreign Imports; 2012. Available from: http://www.westernfarmpress.com/vegetables/us-chile-pepper-industry-under-assault-foreign-imports. September 2012. [Last accessed on 2015 Jan 16].
8. Anonymous. USDA. United States Standards for Grades of Peppers (Other Than Sweet Peppers): Effective March, 2007; 2015. Available from: https://www.google.com/search?ei= jIkCXJazNMqP5wKej5q4Cw&q= Anonymous.+USDA.+United+States+Standards+for+Grades+of+Peppers+%28Other+Than+Sweet+Peppers%29%3A+Effective+March%2C+ 2007%3 B+2015.
9. Anonymous. 2017. Available from: https://www.google.com/search?ei=jIkCXJazNMqP5wKej5q4Cw&q=Anonymous.+2017.+Available+from%3A+https%3A%2F%2Fwww.fda.gov%2F+forindustry+%2Fcoloradditives%2Fcoloradditiveinventories&oq=Anonymous.+2017.
10. ASTA. Method 21.3.Pungency of Capsicum and their Oleoresins (HPLC Method-Preferred); 2004. Available from: https://www.google.com/search?ei=jIkCXJazNMqP5wKej5q4Cw&q=ASTA.+Method+21.3.Pungency+of+Capsicum+and+their+Oleoresins+%28HPLC+Method%E2%80%91Preferred %29 % 3B+2004
11. Awad AR. Chemical and Physical Characteristics of Pepper Mash and Hot Pepper Sauce. LSU Historical Dissertations and Theses 4217; 1986. Available from:https://www.google.com/search?ei= jIkCXJazNMqP5wKej5q4C w&q=Awad+AR.+Chemical+and+Physical+Characteristics+of+Pepper+Mash+and+Hot+Pepper+Sauce.+LSU+Historical+Dissertations+and+Theses+ 4217%3B+1986.
12. Awole K, Tilahun T. Postharvest quality and shelf life of some hot pepper varieties. Food Sci Technol 2011;50:842-55.
13. Bozurt H, Erkmen O. Effects of production techniques on the quality of hot pepper paste. J Food Eng 2004;64:173-8.
14. Bridgemohan P, Mohamed M, Mohammed M, Bridgemohan RS. Hot peppers: VI. Effect of a biostimulant, selected agronomic practices and fruit characteristics on the relative pungency in Caribbean hot peppers. Acad J Agric Res 2017;5:255-60.
15. Bridgemohan P, Mohamed M, Mohammed M. Hot peppers IV. Relative pungency of the carvalho hot selection. Int J Res Sci Innov 2016;3:17-29.
16. Bridgemohan P, Mohammed M, Bridgemohan RS. Fruit and vegetable phytochemicals: Capsicums. In: Yahia EM, editor. Chemistry and Human Health. 2nd ed., Ch. 45. John Wiley and Sons, Ltd.; 2017. p. 957-68.
17. Chakraverty A, Mujumdar SA, Raghavan SG, Ramaswamy SH. Handbook of Postharvest Technology: Cereals, Fruits, Vegetables Tea and Spices. New York: Marcel Deker Inc.; 2003.
18. Chetti MB, Deepa GT, Antony RT, Khetagoudar MC, Uppar DS, Navalgatti CM. Influence of vacuum packaging and long term storage on quality of whole chilli (*Capsicum annuum* L.). J Food Sci Technol 2014;51:2827-32.
19. Cho W, Yi JI, Chung M. Pasteurization of fermented red pepper paste by ohmic heating. Innov Food Sci Emerg Technol 2016;34:180-6.
20. Foong M, Koh BS. A Thesis: Physiochemical Properties of Pepper Mash Fermented in Wood and Plastic. Louisiana State University; 2003.
21. Horváth ZH, Hodúr C. Colour of paprika powders with different moisture content. Int Agrophysics 2007;21:67-72.
22. Hu X, Xia YB. An improved sensory comprehensive evaluation method for chopped hot pepper based on fuzzy mathematics. J Food Sci 2001;1:1-24.
23. Hunter RS, Harold RW. The Measurement of Appearance. 2nd ed. New York, USA: John Wiley and Sons, Inc.; 1987.
24. Jasim A, Shivhare US, Ramaswamy HS. Fraction conversion kinetic model for thermal degradation of color in red chili puree and paste. Lebensm Wiss Technol 2002;35:497-503.
25. Jung JY, Kim JS, Yoo KS, Chung D, Han NS. Rapid colorimetric determination of yellow seed content in red pepper (*Capsicum annuum* L.) powder. Food Anal Methods 2011;4:23-7.
26. Kim KH, Chun JK. The effects of the hot air drying of red pepper on the quality. Korean J Food Sci Technol 1975;7:69-73.
27. Marques LG, Ana M, Silveira AM, Freire JT. Freeze-drying characteristics of tropical fruits. Drying Technol 2006;24:457-63.
28. Mínguez-Mosquera MI, Pérez-Gálvez A. Colour quality in paprika oleoresins. J Agric Food Chem 1998;46:5124-7.
29. Minguez-Mosquera MI, Jaren-Galan M, Garrido-Fernandez J. Colour quality in paprika. J Agric Food Chem 1992;40:2384-8.
30. Mohamed M, Bridgemohan P. Hot peppers IV: Rapid

qualitative assessment methodology to determine postharvest levels of capsaicinoid content in ornamental hot pepper crosses. Acta Hort 2014;1047:69-73.
31. Mohamed M, Bridgemohan P. Hot peppers V: Breeding multi-purpose hot peppers for increased capsaicinoids content. Acta Hort 2014;1047:63-8.
32. Mohammed M, Wilson LA, Gomes PI. Postharvest sensory and physiochemical attributes of processing and non-processing tomato cultivar. J Food Qual 1999;22:167-82.
33. Mohammed M, Wickham LD. Effect of modified atmosphere packaging and ethanol on the deastringency process in jamun (*Syzygium cuminii*) fruit. J Appl Hort 1999;2:105-7.
34. Mohammed M, Wilson LA, Gomes PI. Sodium hypochlorite combined with calcium chloride and modified atmosphere packaging reduces postharvest losses of hot pepper. Int J Res Sci Innov 2016;3:1-9.
35. Mohammed M, Wilson LA, Gomes PI. Occurrence, manifestation and alleviation of chilling injury of hot peppers (*Capsicum chinense* L.). Acta Hort 2014;1016:89-94.
36. Nash D. Recipe for Hot Pepper Mash; 2013. Available from: https://www.google.com/search?source=hp&ei=iIkCXPaTKtKC5wKT0JKQ DQ &q= Nash+D.+Recipe+for+Hot+Pepper+Mash%3B+2013.+ Available+from %3A+http% 3A%2 F%2 Fwww. tngan. com.&btnK=Google+Search&oq=Nash+D.+Recipe+ for+Hot+Pepper+Mash%3B+2013.+Available+from% 3A+http%3A%2F%2Fwww.tngan.com.&gs_l=psy-ab.3... 2643.2643.. 4030...1.0..0.143.259.0j2......0....1j2..gws-wiz..... 0.2G1LGJorQdM.
37. Nieto-Sandoval JM, Fernández-López JA, Almela L, Munõz JA. Dependence between apparent color and extractable color in paprika. Color Res Appl 1999;24:93-7.
38. Nunez MP, Gaya M, Madena M, Rodriguezmarian MA, Garcia-Acer C. Changes in microbiological, chemical, rheological and sensory characteristics during ripening of vacuum packaged Manchego cheese. J Food Sci 1986;21:112-5.
39. Pershing LK, Reilly CA, Corlett JL, Crouch DJ. Assessment of pepper spray product potency in Asian and Caucasian forearm skin using transepidermal water loss, skin temperature and reflectance colorimetry. J Appl Toxicol 2006;26:88-97.
40. Raji A, Falade KO, Abimbolu F. Effect of sucrose and binary solution on osmotic dehydration of pepper varieties (*Capsicum* spp.). J Food Sci Technol 2010;47:305-9.
41. Romano G, Argyropoulos D, Nagle M, Khan MT, Müller J. Combination of digital images and laser light to predict moisture content and color of bell pepper simultaneously during drying. J Food Eng 2012;109:438-48.
42. Romano G, Nagle M, Argyropoulos D, Müller J. An innovative laser-based optical technology to predict moisture content and color of Bell pepper (*Capsicum annuum* L.) during drying. Am Soc Agric Biol Eng 2011;2011:1.
43. Seyoum T, Woldetsadik K. Forced ventilation evaporative cooling: A case study on banana, papaya, orange, mandarin, and lemon. Trop Agric 2004;81:1-6.
44. Smith D. Understanding Good Manufacturing Practices for Sauces and Dressings: University of Nebraska-Lincoln Extension, Institute of Agriculture and Natural Resources GI599; 2006. p. 4.
45. Sreenarayanam KP. Studies on storage of dehydrated onion flakes. Indian Food Package 2000;54:72-5.
46. Tucker G. Pasteurization: Principles and applications. In: Encyclopedia of Food and Health. Atlanta, GA: CDC; 2016. p. 266-9.

How to cite this article: Bridgemohan P, Mohammed M, Bridgemohan RSH, Mohammed Z. Hot peppers: vii. Efficacy of chemical preservatives on quality and stability in red hot peppers (*Capsicum chinensis* L.). Clin J Nutr Diet 2018;1 (2):1-12.