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OPTIMIZATION OF DISINFECTANT PRETREATMENT CONDITIONS FOR THE SHELF LIFE EXTENSION OF FRESH CUT FRUITS

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ABSTRACT

The study was conducted to optimize the pretreatment conditions for increasing shelf life of the fresh cut fruits. Five different disinfectants viz. sodium hypochlorite, potassium meta bisulphite, citric acid, acetic acid and benzoic acid were evaluated over three fresh cut fruit (guava, papaya and pear) to check their bactericidal efficacy. Considering residual chlorine levels and microbial load reduction, 100ppm concentration of sodium hypochlorite was selected for further optimization process. Optimization of pretreatment conditions viz. temperature, pH and contact time was statistically designed and analyzed using response surface methodology. Numerical optimization of results revealed a temperature of 10°C; pH 7; contact time of 25-30 minutes was found to be optimized for fresh cut guava, papaya and pear disinfection with a desirability level of 93%, 91% and 93%,respectively. Validation of results was done by scaling up the sample size to 3kg scale under all optimized conditions. Shelf life analysis of pretreated (under optimized conditions) and untreated fresh cut fruit stored under refrigeration conditions (4-7°C) revealed enhancement in shelf life of treated fresh cut fruit from 6, 6 and 3 days to 9, 9 and 6 days of fresh cut guava, papaya and pear, respectively. During shelf life period, all physicochemical parameters of pretreated fresh cut fruit were non-significantly differ along with microbial load under acceptable limits and a good sensory score.

Keywords: Disinfectant, Fresh cut fruit, Optimization, Pretreatment, Shelf life, Sodium hypochlorite

The fresh fruit and vegetable industry has been resulted in exponential growth in past decade. Many factors such as increased demand by the consumers for healthy, ready- to-eat products and globalization plays key role in increasing this trend. Presently Kinnow, Guava, Mango, Pear, Sweet Orange, Litchi, Peach and Ber are major fruit; while Limes/Lemons, Amla, Grapes, Plum, Banana, Pomegranate, Phalsa, Sapota, Papaya etc. are the minor fruit grown in the India. Today's society is becoming more responsive about health and role of food for improving and maintaining consumer human health. Increasing demand of nutritious and healthy products, fresh produce is always at the priority of the consumer list because of natural nutritious quality, flavors and freshness. The International Fresh-cut produce association (IFPA) defines as fruit and vegetables that have been trimmed and/or peeled and/or cut into 100% useable product that is bagged pre-packaged to offer consumers high nutrition, convenience and flavor while still maintaining its freshness. The fresh-cut vegetables and fruit are in great demand among the consumers as these are ready-to-eat, fresh and nutritious. Quality of fresh intact fruit depends upon the cultivator, pre harvest and harvesting methods, handling methods while when the factor of "fresh-cut" fruit come into play it renders the shelf life of the produce and making the produce highly perishable. Proper washing/ cleaning of fresh-cut product right after cutting is the most important step in fresh cut production to reduce the pathogenic microflora (Gil and Selma 2009). Washing with water alone is only responsible for the removal of free cellular contents that are released on cutting and peeling which are ineffective in assuring the safety of fresh cut. Use of disinfectant in water is critical step in minimizing the potential transmission of microorganism from water to produce Use of disinfectant in washing water helps in destroying the pathogenic microorganisms and hinder the transfer of microorganisms from contaminated produce to other produce over time and from processed water to produce (Suslow, 2001). Different chlorine based sanitizers are extensively used to reduce microbial population. Apart from these various other sulphur based disinfectants, organic acids are also used as disinfecting agents. Various parameters are responsible for the effectiveness of the disinfectant in water but mainly concentration, temperature, pH and contact time plays important role. (Sapers, 2003). Additionally, use of chemical disinfectant along with cold storage is effective to extend the shelf-life of fresh-cut fruit to reasonable level. Further, there is a necessitate to evaluate various disinfectants for their microbicidal efficacy to reduce microbial load over the fresh cut fruits to enhance the shelf life and quality of fresh-cut fruits. Being the most economic and easy to conduct

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a pretreatment method, washing of the fresh cut fruit with disinfectant under optimized conditions provides the farmers to opt for the new technology to establish the fresh cut market in India.

MATERIALS AND METHODS

Selection, peeling and cutting of fruits

Healthy even sized fruits were selected after manual sorting and discarding of defective fruits. After sorting, fruits were washed with potable water for further processing. After this, fruits were peeled (if necessary), calyx was removed and then fruit were cut into small equal sized pieces with sterilized knife over cutting board (both wiped with 90% ethanol).

Optimization of temperature, pH and contact time for disinfectant pretreatment

Disinfection of fresh cut fruits were done by dipping them in 100ppm sodium hypochlorite solution (selected from previous studies, unpublished data) based upon its maximum microbicidal efficacy and residual chlorine level of 2.25-4.02 mg/ kg (Permissible limit 12-14 mg/ kg in raw foods)

In order to optimize the dipping treatment conditions viz. temperature, pH, contact time, Response Surface methodology (RSM) was designed using Design expert 12.0 software to design the experiment statistically (Table 1). A five-level two-factor central composite rotatable design (CCRD) was employed for the three factors namely temperature, pH, contact time. Physicochemical and microbial parameters (TSS, Firmness pH, Total sugars (g/100g), Titratable acidity (%), Total phenols (mg/100g), Total Plate Count (% reduction), Yeasts and mold (% reduction), Total coliforms (% reduction) against each combination were estimated. An optimized condition in terms of temperature, pH and contact time that reduces maximum microbial count (required for longer shelf life) over the Fresh Cut Fruits (FCF) was selected for the disinfectant pre-treatment.

Validation of optimized result

After optimization of pretreatment conditions, a validation experiment of scale up studies was conducted on 3 kg scale of each fruit under optimized pretreatment conditions.

Physicochemical parameters

For physicochemical parameters estimation, a homogenized sample from 250g sample size was taken. Firmness of FCF was measured by using Penetrometer device ().The pH of the sample was determined with pocket size pH meter (Hanna HI96017). Total soluble solids (% TSS) of the fruit sample were determined by using Erma hand refractometer of 0-32ºB. Titratable acidity was analyzed using the method of Amerine *et al.* (1967). Total phenols of the fruit sample were determined by method of Malik and Singh (1991). Total sugars were estimated by Dubois method (Dubois *et al.,* 2002).

Table 1. Process design for optimization of pretreatment conditions

Run	Temperature (°C)	pH	Contact time (min)
1	6.5	5.5	19
2	6.5	5.5	37.49
3	6.5	2.97	19
4	3	7	30
5	6.5	5.5	19
6	10	4	8
7	3	4	30
8	10	7	8
9	10	7	30
10	6.5	5.5	19
11	6.5	5.5	19
12	6.5	5.5	19
13	12.38	5.5	19
14	6.5	5.5	0.50
15	10	4	30
16	6.5	5.5	19
17	0.61	5.5	19
18	6.5	8.02	19
19	3	7	8
20	3	4	8

Microbial count

The quantitative estimation of the microbial count in pre and untreated samples was carried out by serial dilution technique (Ben-David and Davidson, 2014). Samples (250g) were properly homogenized before microbial analysis. Plate count agar, yeast & mould agar and EMB agar, SS agar, MacConkey agar was used for the enumeration of selective microflora on the fresh cut fruits.

10g of fresh cut (treated and untreated) homogenized fruit sample was suspended into the 90ml of sterile water blank to make 10^{-1} dilution. Afterwards, 1ml of supernatant was accurately pipette out into the 9 ml test tube to get 10^{-2} dilution and in the same way the sample were serially diluted to10^{-5} dilution . 1ml of the sample was taken from desired dilution in the Petri plate and selective media was pour onto it. Microbial count was taken after 24-48h of incubation. Plates kept at an incubation temperature of 30°C, 28°C and 37°C for TPC, Y&M and coliforms, respectively.

$$\text{No. of colony forming units per gram of sample (cfu/g)} = \frac{\text{Total No. of colony formed} \times \text{dilution factor}}{\text{Aliquot taken}}$$

Percentage microbial reduction was calculated by using following formulae:

$$\% \text{ reduction} = \frac{A - B}{B} \times 100$$

Where,

A = Number of initial microbial colonies

B = Number of final microbial colonies

Results were analyzed using triplicate plates for each type of microbial count and mean count was taken.

Shelf life study of pretreated fresh cut fruit

Pretreated (with sodium hypochlorite under optimized conditions) and untreated (control) samples of FCF were packed in the air tight food grade containers and was stored under refrigeration conditions (4-7°C) for shelf life studies. Physicochemical and microbial parameters were analyzed at regular interval of 3 days for 15 days or till the samples were deteriorated.

RESULTS AND DISCUSSION

After selecting and optimizing the concentration of NaOCl @ 100ppm (unpublished data), further

Table 2. Effect of temperature, pH and contact time combinations on physicochemical and microbiological quality of FC guava

Run	Temperature (°C)	pH	Contact time (min)	R1	R2	R3	R4	R5	R6	R7	R8	R9
1	6.50	5.50	19.00	10.70	64.05	4.41	3.71	0.11	300.4	58.40	98.40	25.48
2	6.50	5.50	37.49	10.90	59.15	3.77	3.56	0.24	338.9	52.54	87.56	41.90
3	6.50	2.97	19.00	10.90	61.38	3.32	3.31	0.29	329.1	55.96	23.70	26.31
4	3.00	7.00	30.00	10.90	60.49	3.92	3.56	0.21	342.1	70.79	62.49	37.27
5	6.50	5.50	19.00	10.90	61.82	4.31	3.71	0.17	312.4	49.24	98.90	21.05
6	10.00	4.00	8.00	10.70	58.26	3.81	3.58	0.26	328.2	79.30	47.50	32.41
7	3.00	4.00	30.00	10.80	61.82	3.66	3.38	0.21	334.9	25.48	29.22	26.28
8	10.00	7.00	8.00	10.60	60.49	3.97	3.32	0.27	316.9	52.31	37.38	51.35
9	10.00	7.00	30.00	10.40	59.15	3.8	3.39	0.29	325.8	79.39	96.25	62.37
10	6.50	5.50	19.00	10.90	64.05	4.28	3.51	0.11	300.4	49.37	100.00	21.05
11	6.50	5.50	19.00	10.90	63.60	4.31	3.51	0.11	300.5	55.37	100.00	21.06
12	6.50	5.50	19.00	10.90	64.05	4.31	3.51	0.18	300.5	49.20	96.25	21.04
13	12.38	5.50	19.00	10.70	60.49	4.00	3.50	0.21	311.7	67.96	90.10	41.37
14	6.50	5.50	0.50	10.50	58.71	3.78	3.56	0.26	336.4	41.37	40.42	37.34
15	10.00	4.00	30.00	10.60	61.38	3.74	3.42	0.28	327.3	55.80	75.10	21.69
16	6.50	5.50	19.00	10.90	64.05	4.31	3.51	0.17	300.5	49.30	96.60	21.05
17	0.61	5.50	19.00	10.70	60.49	4.13	3.56	0.16	334.5	18.30	54.80	34.25
18	6.50	8.02	19.00	10.70	60.93	3.61	3.19	0.22	328.2	60.84	32.76	42.10
19	3.00	7.00	8.00	10.30	61.82	4.03	3.41	0.19	339.7	33.49	36.73	29.69
20	3.00	4.00	8.00	10.70	57.82	3.48	3.48	0.25	339	21.08	36.10	42.15

R1- TSS, R2- Firmness (N), R3- pH, R4- Total sugars(g/100g), R5- Titratable acidity(%), R6- Total phenols(mg/100g), R7- TPC(% reduction) R8- Y&M (% reduction), R9- coliforms (% reduction) Control sample count-4.96 log cfu/g (TPC), 3.89 log cfu/g (Y&M) and 3.41 log cfu/g coliforms

optimization of disinfectant pretreatment parameters viz. temperature, pH and contact time was carried out. In the study, Response Surface Methodology (RSM) was opted to design experimental plan statistically (Table 1). RSM plan combinations along with response parameters in terms of physicochemical parameters (explained in Materials and Methods) are presented in Tables 2, 3 and 4 for FC guava, papaya and pear, respectively.

Fresh cut fruit sample of each fruit was taken and immersed in the 100ppm NaOCl solution at different pH levels and kept at different temperatures for mentioned contact time according to RSM design. Samples were taken out and drained for further analysis. Maximum % reduction of TPC, Y&M and coliforms was reported at 10°C temperature, pH 7 for all three FCF and 30, 30 and 25.5 minutes contact time for guava, papaya and pear, respectively. Chlorine (sodium hypochlorite) is one of the most widely used disinfectants of vegetables, fruits and fresh-cut produce. It maintains quality by reducing microbial populations and controlling their growth. Table 5 inferred the responses of the experimental design were in accordance with the results optimized by the RSM with all significant Model values and the predicted R^2 value is in reasonable agreement with adjusted R^2 i.e. the difference is less than 0.2 that implies the significance of data. The recommended concentrations of sodium hypochlorite for dipping of fresh cut fruits and vegetables range from 50 to 200 mg/L (Karapinar and Sengun, 2007). However, the efficacy of chlorine in reducing pathogenic microorganism is limited under commercial washing conditions (Cherry, 1999). The use of acidified sodium chlorite (ASC) has been approved by the US FDA for the purpose of disinfecting food products, including minimally processed fruits and vegetables, as a component of a dip or spray solution at levels of 500 to 1,200 mg/L (Anonymous, 2000). The bactericidal effect of ASC has mainly been demonstrated on pathogenic organisms such as *E. coli* O157:H7 and *Listeria monocytogenes* (Ruiz-Cruz *et al.,* 2007, Allende *et al* 2009 and Ruiz-Cruz *et al.,* 2010).

3D surface interaction graphs showed that, there is positive interaction between the temperature-contact

Table 3. Effect of temperature, pH and contact time combinations on physicochemical and microbiological quality of FC papaya

Run	Temperature (°C)	pH	Contact time (min)	R1	R2	R3	R4	R5	R6	R7	R8	R9
1	6.50	5.50	19.00	7.10	70.72	4.51	4.16	0.23	23.26	56.92	99.40	38.11
2	10.00	4.00	8.00	8.68	68.05	4.52	4.43	0.23	21.49	33.67	48.50	30.60
3	10.00	4.00	30.00	8.31	70.27	4.47	4.28	0.25	20.87	29.00	76.10	37.50
4	6.50	5.50	37.50	8.59	69.38	4.47	4.24	0.27	22.19	33.31	88.56	39.10
5	3.00	4.00	30.00	8.50	68.49	4.47	4.12	0.24	22.81	25.00	30.22	26.50
6	3.00	7.00	30.00	8.60	68.05	4.47	4.34	0.22	23.08	51.06	63.49	25.30
7	6.50	5.50	0.50	8.40	68.05	4.52	4.07	0.24	22.79	20.25	41.42	13.04
8	0.61	5.50	19.00	8.63	67.60	4.51	3.96	0.23	24.57	26.39	55.80	45.00
9	3.00	4.00	8.00	8.60	67.16	4.47	3.75	0.28	22.59	25.38	36.10	27.30
10	10.00	7.00	30.00	8.09	69.38	4.42	4.08	0.29	21.06	60.50	97.25	59.00
11	6.50	5.50	19.00	8.00	70.27	4.51	4.04	0.22	23.26	56.92	100.00	34.90
12	6.50	8.02	19.00	8.06	68.49	4.38	4.15	0.22	21.17	55.80	33.76	13.04
13	10.00	7.00	8.00	8.16	68.94	4.49	4.11	0.22	21.99	40.80	38.38	26.08
14	6.50	5.50	19.00	7.90	70.72	4.51	4.05	0.23	23.26	56.92	97.60	30.11
15	6.50	5.50	19.00	8.00	70.27	4.52	4.05	0.23	23.26	51.06	97.25	30.11
16	6.50	2.98	19.00	8.50	68.49	4.43	4.24	0.23	20.52	33.42	24.70	27.39
17	3.00	7.00	8.00	8.62	68.49	4.46	3.95	0.21	23.19	23.28	37.73	26.00
18	12.39	5.50	19.00	8.29	69.38	4.52	4.35	0.23	21.95	39.92	91.10	45.25
19	6.50	5.50	19.00	7.90	70.72	4.51	4.04	0.25	23.27	56.92	99.90	30.10
20	6.50	5.50	19.00	7.99	70.72	4.51	4.04	0.23	23.26	55.00	100.00	30.11

R1- TSS, R2- Firmness (N), R3- pH, R4- Total sugars(g/100g), R5- Titrtable acidity(%), R6- Total phenols(mg/100g), R7- TPC (% reduction) R8- Y&M (%reduction), R9- coliforms (% reduction)

Control sample count- 4.69 log cfu/g (TPC), 3.89 log cfu/g (Y&M) and 3.51 log cfu/g coliforms

Table 4. Effect of temperature, pH and contact time combinations on physicochemical and microbiological quality of FC pear

Run	Temperature (°C)	pH	Contact time (min)	R1	R2	R3	R4	R5	R6	R7	R8	R9
1	6.50	5.50	37.50	10.50	59.60	4.50	5.50	0.29	270.10	44.32	49.90	30.10
2	3.00	4.00	30.00	10.60	60.93	4.36	5.27	0.30	253.20	30.53	33.20	22.95
3	3.00	4.00	8.00	10.20	59.60	4.58	5.08	0.33	288.70	30.04	29.50	29.80
4	10.00	7.00	30.00	10.40	60.93	4.61	5.38	0.29	272.00	55.95	72.50	51.60
5	10.00	4.00	8.00	10.40	59.15	4.64	5.26	0.35	243.10	15.19	54.70	54.12
6	3.00	7.00	30.00	10.50	60.49	4.49	5.41	0.31	236.10	44.49	60.66	30.70
7	6.50	2.98	19.00	10.50	60.04	4.35	5.14	0.32	274.50	27.11	49.40	35.71
8	6.50	5.50	19.00	10.90	60.93	4.42	5.67	0.29	286.40	12.29	38.13	13.31
9	6.50	5.50	19.00	10.80	60.49	4.42	5.67	0.29	286.40	12.29	38.46	31.31
10	6.50	8.02	19.00	10.90	61.38	4.47	5.47	0.29	256.10	45.97	62.10	34.30
11	10.00	7.00	8.00	10.80	61.38	4.67	5.52	0.31	238.20	23.66	43.25	35.92
12	6.50	5.50	0.50	10.30	58.71	4.73	5.44	0.33	271.60	16.76	30.93	34.00
13	6.50	5.50	19.00	10.80	60.49	4.42	5.67	0.29	286.40	12.29	38.60	13.20
14	0.61	5.50	19.00	10.40	61.38	4.39	5.24	0.33	255.70	30.45	36.70	24.71
15	6.50	5.50	19.00	10.90	60.49	4.42	5.67	0.29	286.40	12.29	3.32	13.35
16	6.50	5.50	19.00	10.80	60.49	4.45	5.68	0.28	276.30	12.20	38.10	13.32
17	3.00	7.00	8.00	10.60	61.38	4.43	5.47	0.35	277.90	31.40	44.88	27.42
18	6.50	5.50	19.00	10.90	60.49	4.42	5.67	0.29	286.40	12.20	38.12	13.30
19	10.00	4.00	30.00	10.50	60.04	4.35	5.39	0.33	279.10	34.50	62.24	38.22
20	12.39	5.50	19.00	10.40	60.93	4.62	5.38	0.33	248.80	27.57	59.50	42.08

R1- TSS, R2- Firmness (N), R3- pH, R4- Total sugars(g/100g), R5- Titratable acidity(%), R6- Total phenols(mg/100g), R7- TPC(% reduction) R8- Y&M (% reduction), R9- coliforms (% reduction)

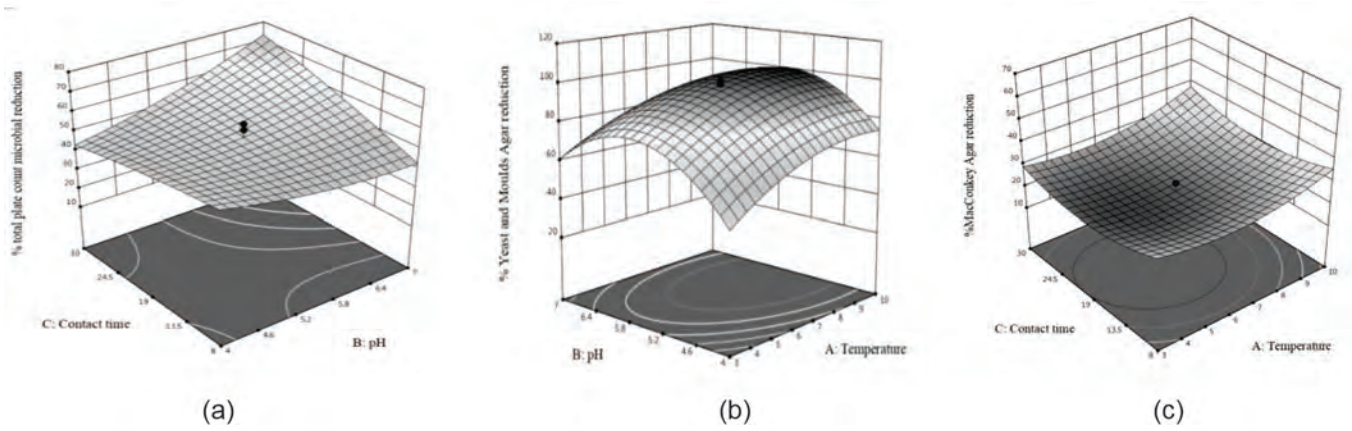
Control sample count- 4.81 log cfu/g (TPC), 3.94 log cfu/g (Y&M) and 3.68 log cfu/g coliforms

time and pH-contact time to reduce the microbial count over FCF. Fig. 1 (b, c), 2 (a, b) and 3 (a, b) depicts that with during pre-treatment an increase in temperature up to 10°C significant reduction in microbial count was observed. At temperature range of 4-10°C for all pretreated FCF, microbial reduction was significantly higher than the temperature falling outside the specified range. Temperature plays an important role in the survival of pathogen on the surface of fruit and vegetables (Gawande and Bhagwat, 2000). A low water temperature is more effective at disinfecting processing equipment and surfaces of the fresh fruit and vegetables (Beuchat, 2000). Chlorine based disinfectants showed their maximum bactericidal effect at low temperature because maximum solubility of it in water is achieved at about 4-10°C (Beuchat, 2000).

pH also plays the important role in determining the bactericidal efficacy of NaOCl as pH effects the release of OCl^- ions. Figs. 1 to 3 (a, b) showed the effect of pH to reduce the microbial count over FCF. It represents that maximum microbial % reduction was observed in the range of pH 6-7. At low pH range of <6, chlorine gas may be formed while at higher pH level (> 7.5), the activity of NaOCl decreases because of more inactive hypochlorite (OCl^-) ions production (Sapers, 2001).

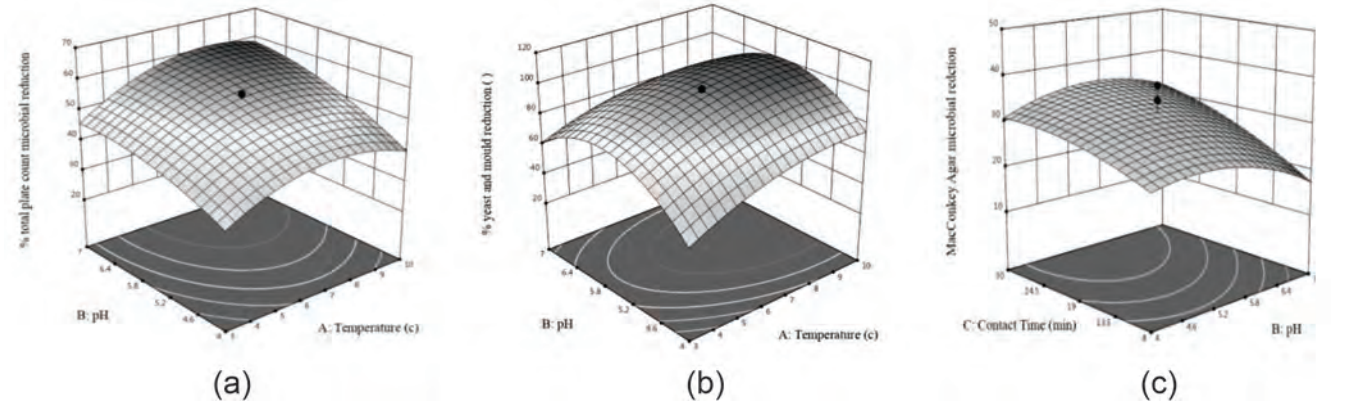
Contact time of 25-30 min is required for the disinfection pretreatment of FCF. It has been observed, after contact time of 25-30 min the % microbial reduction do not changes as it reaches maximum value. Studies revealed that the disinfectant pretreatment depends upon the commodity and concentration of the disinfectant (Jay, 1992). Generally, sodium NaOCl is used in the concentration of 50-200ppm for disinfectant pretreatment. Economic and efficacy are needed to be considered. If lower concentration is equally effective to the higher concentration, lower concentration is preferred considering safety and economics. Lower concentration can be preferred for longer contact time for eradication of microbes over the fresh cut (Amith, 2012).

Numerical optimization of the data was done by considering six physicochemical parameters namely firmness, TSS, pH, titratable acidity, total phenol and total sugars in range and three microbial parameter



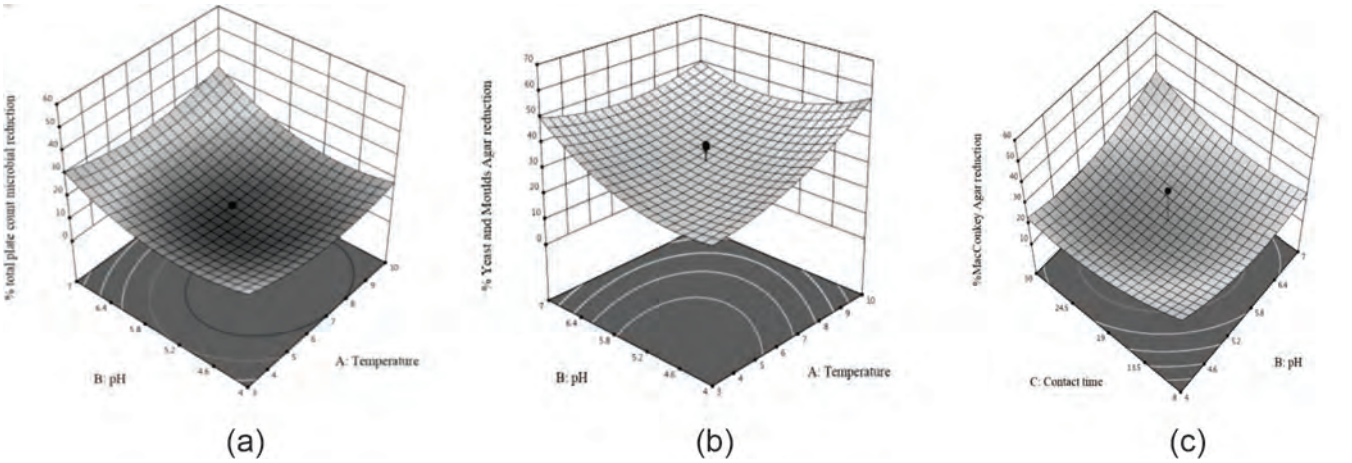
(a) (b) (c)

Fig. 1. Interaction graphs between variable parameters for Fresh Cut guava
(a) contact time and pH for % TPC reduction
(b) pH and temperature for % Y&M reduction
(c) contact time and temperature for % coliform reduction



(a) (b) (c)

Fig. 2. Interaction graphs between variable parameters for Fresh Cut papaya
(a) pH and temperature for % TPC reduction
(b) pH and temperature for % Y&M reduction
(c) contact time and pH for % coliform reduction



(a) (b) (c)

Fig. 3. Interaction graphs between variable parameters for Fresh Cut pear
(a) pH and temperature for % TPC reduction
(b) pH and temperature for % Y&M reduction
(c) contact time and pH for % coliform reduction

Table 5. Response Surface Methodology model values for all physicochemical and microbial parameters of guava, papaya and pear

Parameter	Model value			Adjusted R^2			Predicted R^2		
	Guava	Papaya	Pear	Guava	Papaya	Pear	Guava	Papaya	Pear
Firmness	13.40	70.64	50.46	0.8545	0.9706	0.9591	0.7362	0.9462	0.8868
TSS	4.00	3.37	28.31	0.5868	0.5285	0.9282	0.4331	0.4810	0.8084
pH	39.22	122.22	22.54	0.9477	0.9829	0.9107	0.8209	0.9433	0.7226
Titratable acidity (%)	7.35	11.49	128.76	0.7505	0.8325	0.9837	0.5603	0.6862	0.7226
Total phenols (mg/100g)	40.39	116.6	70.05	0.9491	0.9980	0.9703	0.9575	0.9999	0.9516
Total sugars (g/100g)	5.25	22.68	388.98	0.6681	0.9112	0.9993	0.7363	0.7874	0.9698
% TPC reduction	22.57	65.02	790.86	0.9109	0.9681	1.0000	0.7327	0.9174	0.9999
%Y&M reduction	378.62	402.70	3.36	0.9944	0.9948	0.5283	0.9828	0.9821	0.6417
% coliform reduction	39.60	5.05	7.73	0.9481	0.6576	0.7468	0.8319	0.1789	0.5547

namely % TPC, Y&M and coliforms reduction maximum (Tables 2,3,4). Results indicated that the pretreatment disinfectant solution kept at temperature 10°C, pH 7 and contact time 30 min for FC guava, temperature 9°C pH 6 and contact time 25.4 min for FC papaya and at temperature 10°C pH 7 and contact time 30 min for FC pear as optimized levels for the pretreatment with the desirability of 93%, 91% and 93% respectively for guava, papaya and pear.

Shelf life analysis of different FCF (viz. guava, papaya and pear) was studied by treating them under optimized conditions of disinfectant concentration, pH, temperature and contact time followed by storage under refrigeration conditions (4-7°C). Tables 6, 7 and 8 shows the results of shelf life analysis of FC pretreated fruit under refrigeration conditions that indicated the extension in the shelf life of the treated fresh cut fruits as compared to their control.

In similar research, Gupta and Kumari (2015) studied the shelf life of FCF pretreated with chemical preservatives. They reported that inspite of the chemical pretreated fruit showed an increase in microbial load; yeast and mould being most prevalent over the FCF during the storage time. However, slow increase in microflora was observed over FCF pretreated with NaOCl. Antimicrobial action of NaOCl leads to reduction in pH and an increase in acidity that adds to the hurdles in the proliferation of the microorganisms during the storage period. Food processing techniques stabilize the product and lengthen their storage and shelf life, production of fresh cut fruit increases their perishability (Beauchat, 2000). Efficacy of NaOCl and acidified sodium chlorite (ASC) on FC produce stored at 4° and 10°C was studied. At 4° there was non-significant difference between NaOCl and ASC treatment. At 10°, aerobic plate count was in controlled limits (below 3 log value) till 3rd day, beyond this, there was 1.5 log average increase in microbial population. Treating FC carrot with NaOCl and ASC prevented growth of aerobes upto 4th day. Coliforms were not reported after washing with both the disinfectants in FC carrots, potatoes and cucumbers. After 5th day there was significant increase

Table 6. Shelf life analysis of pretreated FC guava under refrigeration conditions

Parameter	Control	Pretreated 0 day	Storage under refrigeration at 5-7°C (days)				CD (5%)
			3	6	9	12	
TSS (◦B)	10.9±1.3	10.7±0.6	11.1±0.9	11.1±0.4	11.3±1.2	11.4±1.3	NS
pH	4.42±0.3	4.51±1.6	4.69±1.2	4.71±1.2	4.79±0.3	4.81±0.9	NS
Titrable Acidity (%)	0.29±0.9	0.28±0.3	0.25±0.7	0.24±0.5	0.19±0.5	0.18±0.7	NS
Firmness (lb)	14.4±1.2	14.4±1.2	14.2±1.4	14.3±1.2	14.2±1.4	14.4±1.4	NS
Total Phenols (mg/100g)	338.4±3.6	341.6±4.2	344.9±2.9	345.1±5.6	345.7±5.2	346.1±2.9	NS
Total Sugars (g/100ml)	3.89±1.2	3.71±1.4	3.92±0.4	3.94±1.6	3.99±1.2	4.01±1.4	NS
TPC (log cfu/g)	3.53	3.0	3.3	3.39	3.44	3.5	0.91
Yeast & Mould count (log cfu/g)	2.2	1.5	1.77	2.67	2.90	3.00	0.12
Coliform count (log cfu/g)	2.34	2.0	2.20	2.39	2.87	3.32	0.66
Sensory score (out of 9)	8	8	7	7	7	5	1.23

Table 7. Shelf life analysis of pretreated FC papaya under refrigeration conditions

Parameter	Control	Pretreated 0 day	Storage under refrigeration at 5-7°C (days)				CD (5%)
			3	6	9	12	
TSS (◦B)	7.1±1.2	7±0.9	7.3±1.2	7.6±1.2	7.9±1.5	8.0±0.6	NS
pH	4.71±0.6	4.68±1.2	4.73±1.3	4.79±0.9	4.81±0.4	4.86±0.9	NS
Titrable Acidity (%)	0.28±0.6	0.25±0.3	0.20±0.4	0.20±0.4	0.19±0.9	0.18±1.1	NS
Firmness (lb)	14.1±1	14.2±0.6	13.9±1.3	13.8±1.2	13.8±1.3	13.2±1.3	NS
Total Phenols (mg/100g)	23.36±2.3	24.37±2.1	24.91±0.9	25.04±1.2	25.66±1.6	25.8±1.2	NS
Total Sugars (g/100ml)	4.28±1.2	4.24±0.6	4.30±0.5	4.39±1.3	4.44±1.1	4.49±1.2	NS
TPC (log cfu/g)	3.41	3.07	3.17	3.32	3.41	3.48	0.61
Yeast & Mould count (log cfu/g)	2.89	2.38	2.58	2.61	2.99	3.20	0.10
Coliform count (log cfu/g)	2.33	1.87	2.01	2.32	3.00	3.32	0.65
Sensory score (out of 9)	8	8	8	7	7	6	1.33

Table 8. Shelf life analysis of pretreated FC pear under refrigeration conditions

Parameters	Control	Pretreated 0 day	Storage under refrigeration at 5-7°C (days)		CD (5%)
			3	6	
TSS (◦B)	10.8±1.2	10.6±1.1	10.8±1.1	10.9±0.6	NS
pH	4.36±0.3	4.30±1.1	4.36±0.9	4.39±0.6	NS
Titratable Acidity (%)	0.29±1.3	0.25±1.1	0.20±0.9	0.19±0.6	NS
Firmness	13.4±1.1	13.3±1.3	13.4±1.2	13.5±1.1	NS
Total Phenols (mg/100g)	288.7±3.6	292.4±4.6	299.6±5.5	301.4±3.6	1.88
Total Sugars (g/100g)	5.27±1.6	5.25±1.2	5.29±1.6	5.34±0.6	NS
TPC (log cfu/g)	3.47	3.25	3.31	3.41	0.32
yeast & Mould count (log cfu/g)	1.99	1.58	2.76	2.95	0.14
Coliform count (log cfu/g)	2.34	2.11	2.95	3.01	0.74
Sensory score (out of 9)	8.5	8.0	7.5	7.0	1.09

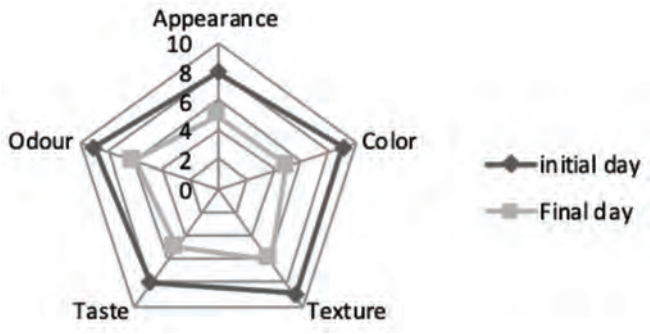


Fig. 4. Radar graph for sensory score of Guava

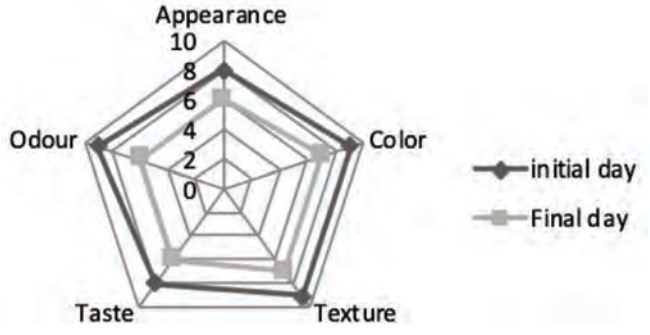


Fig. 5. Radar graph for sensory score of papaya

in coliforms in all the three FC produce after treating with NaOCl and ASC (Sun *et al.,* 2012).

Sensory analysis (on a hedonic scale of 9 score) revealed that there is a non-significant change in the aromatic, taste, odor and overall acceptability of the treated fresh cut fruits as compared to un treated fresh cuts. Figs. 4, 5 and 6 represents the radar graphs for sensory score at the initial and final day during the shelf life study that revealed the treated fresh cut fruits retain their sensorial characteristics in terms of aroma, appearance, color, taste and texture with microbial counts under permissible limits. Consumers accepted the treated fresh cut fruits even after storage for 9 days under refrigeration conditions.

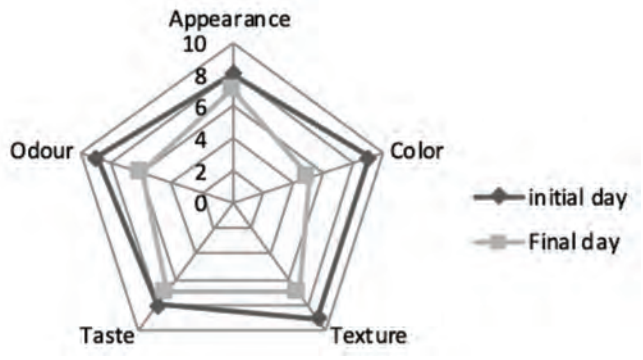


Fig. 6. Radar graph for sensory score of pear

This is the study on optimization of disinfectant pretreatment conditions for the quality maintenance and shelf life study of fresh cut fruit under refrigeration conditions**.** Temperature, pH and contact time was optimized using central composite rotatable design (CCRD) of response surface methodology under Design Expert 12.0 for dipping for FC guava, papaya and pear. Temperature in range of 9-10°C, pH 6-7 and contact time 25-30 min @100ppm sodium hypochlorite concentration was optimized. Results depict that dipping FC under above mentioned conditions results in maximum reduction of microflora and increase in shelf life as compared to untreated sample.

Authors' contribution

Conceptualization of research work and designing of experiments (P); Execution of field/lab experiments(SS); Data analysis and interpretation of results (P, SS); Preparation of manuscript (P, SS)

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