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Optimization of Pretreatment for Prevention of Enzymatic Browning of Fresh-Cut Lotus Root Slices

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ABSTRACT

The experiments were carried out optimized the chemical concentration as pre-treatments prior to drying of fresh-cut lotus root slices. The lotus root slices were pretreated by chemicals with Potassium metabisulphite (0.1, 0.2, and 0.3 % (w/v)), sodium bicarbonate (2, 4, and 6 % (w/v)), and ascorbic acid (0.5, 1 and 1.5 % (w/v)). The quality parameters of lotus root slices were taken as color parameters such as lightness (L*), redness (a*), and (b*) along with the browning index. The best treatment was decided based on the browning index. The experimental results indicated that the color parameters of fresh-cut lotus root slices and chemicals deteriorate over the time span of 0h to 5h. Besides that, chemically treated samples were improved over the fresh-cut lotus root slices. The lightness (L*), redness (a*), and yellowness (b*) of 0.30% potassium metabisulphite samples varies from 136 to 116, 1.17 to 248, and 2.87 to 5.34 for a period of time 0h to 5h, respectively. Which is the lowest as compared to all other samples. The browning index pre-treated samples was much lower than samples without treatment. The browning index increased with elapsed time and highly increase in untreated (fresh-cut lotus root slices) samples than pre-treated samples (chemicals treated). The optimized browning index was minimum (1.498 to 4.963) for 0.3 % KMS as compared to 5.337 to 16.02 and 2.73 to 9.227 for 6 % (w/v) sodium bicarbonate and 1.5 % (w/v) ascorbic acid solutions, respectively.

KEYWORDS

Browning index, Enzymatic Browning, Lotus root slices, Optimization, Pretreatment

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INTRODUCTION

Lotus is an aquatic perennial plant of the family Nelumbo nucifera. Lotus plants are widely cultivated for food production, ornamental horticulture, and traditional medicine. It has several common names such as Indian lotus, Chinese water lily, and sacred lotus (Sheikh, 2014). Its edible parts like flowers, buds, anthers, fruits, leaves, stamens, stalks, and rhizomes (roots). Among rhizome vegetables, lotus roots are widely planted over the world and more than 90 % part of the lotus root is edible (Guo, 2009). The lotus rhizomes are 2.4, 6, and 0.2 mg/100 g of iron, calcium, and zinc, respectively (Ogle *et al*, 2001). It is popular worldwide because of its crispiness in texture, sensory attributes, white color, attractive aroma, and nutritional value such as starch, proteins, fat, alkaloids, riboflavin (vitamin B2), flavonoids, lecithin, carotene, niacin, sugars, vitamin C, vitamin B6, thiamine, copper, manganese, titanium, phosphorus, chlorogenic acid and other phenolic compounds, and antioxidants (Chiang and Luo, 2007; Deng *et al*, 2013; Huang *et al*, 2011). The consumption/ production of lotus root has continuously increased as more consumers demand convenient and ready-to-eat foods (Sun *et al*, 2015; Zhang *et al*, 2014).

The exterior of the lotus root is smoothly covered with a peel that is white or reddish-brown in color and internally, the root has white, crunchy flesh with a mildly sweet, water chestnut-like flavor. Enzymatic browning strongly affects the shelf-life and quality of fresh-cut fruits and vegetables, and consumer's acceptance, especially white-fleshed commodities. The fresh-cut lotus root slices are usually challenged by browning problems (Su *et al*, 2003). The browning of lotus root slices is mainly due to the oxidation of phenol to quinone which then polymerized (Hu *et al*, 2014). However, catechol is traditionally regarded as the primary substrate in browning of fresh-cut lotus roots slices (Xu *et al*, 2008; Yu *et al*, 2002), Gallic acid is also an optimum phenolic substrate for polyphenol oxidase (PPO) (Sun *et al*, 2015; Zhang *et al*, 2014). Therefore, rapid browning is the most important problem for fresh-cut lotus roots during storage and processing. It limits the development of the lotus root industry because limited by their shorter shelf-life and declining post-processing quality (Jiang *et al*, 2014). So various methods of food preservation are used to prolong the length of time for which the fruit and vegetable retain quality and appeal. Therefore, preventing enzymatic browning should be an important way to extend storage life and maintain quality (Zhang *et al*, 2014).

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The browning is controlled either by heat (blanching) or by chemical inhibition. Several methods, such as thermal processing, exclusion of oxygen, and anti-browning agents, have been studied to inhibit polyphenol oxidase-related enzymatic browning.

The processing of fresh-cut fruits and vegetables promotes a faster physiological deterioration, biochemical changes, and microbial degradation of the product, which may result in degradation of the color, texture, and flavor. The quality and consumer acceptance of fresh-cut lotus root is often limited by cut surface browning. Browning is the process of colored quinine formation, in which the polyphenols are oxidized by polyphenol oxidase (PPO) and peroxidase (POD) (Toivonen and Brummell, 2008). It limits the development of the lotus root industry (Jiang *et al* (2014) because limited by their short shelf-life and declining in post-processing quality. Therefore, preventing enzymatic browning is an important way to extend storage life and maintain quality (Zhang *et al*, 2014). The browning is controlled either by heat (blanching) or by chemical inhibition.

Knowledge of the type of pre-treatment methods that can improve the quality of dried products is necessary in order to optimize the drying process. Pre-treatment of food materials which includes; blanching, chemical, and chemical as well as for blanching. Blanching is a pre-treatment is a short-time heat-treatment generally applied to fruits and vegetables primarily to inactivate natural enzymes the reduction of possible initial microbial contamination, the remove undesirable flavors and aromas (Carroad *et al*, 1980; Odland and Eheart, 1975; Voirol, 1980). A common approach for preventing enzymatic browning is the use of anti-browning agents (Dogan and S, 2005). Therefore, pre-attempts that are chlorine dioxide (Du *et al*, 2009), carbon monoxide (Zhang *et al*, 2014), hydrogen Sulphide (Sun *et al*, 2015), and combined application of the chitosan-based coating and modified atmosphere packaging and synergistic effect of ascorbic acid, heat treatment and modified atmosphere packaging (Du *et al*, 2009; Son *et al*, 2015) have been examined with satisfactory results. The proper combination of time and temperature of blanching (Adams, 1978; Krokida *et al*, 2000) and chemical concentration is very important to retain the nutrients and quality. The control of enzymatic browning during processing is very important to preserve the appearance of lotus root slices. Therefore, in this study, the use of anti-browning agents (ascorbic acid, potassium metabisulphite (KMS), sodium bicarbonate) was investigated in an attempt to find the most effective treatment to inhibit enzymatic browning of lotus root slices and to optimize browning conditions of lotus root slices regarding the quality parameters to determine acceptable product quality.

MATERIALS AND METHODS

The experiment was conducted in the Department of Post-Harvest Process and Food Engineering, GBPUAT, Pantnagar, for optimization of chemicals concentration for prevention of enzymatic browning of fresh-cut lotus root slices to obtain quality products. The lotus roots were procured from the local market of Pantnagar (U.S. Nagar), Uttarakhand, for the purposed study and to keep the same variety as far as possible (Figure 1). The lotus roots were washed thoroughly in running water to remove adhering soil and extraneous matters. The washed lotus roots were stored at 4 ^{0}C in the refrigerator.

Fig. 1: Raw lotus roots

The lotus roots were taken out from the refrigerator as per the requirement for the experiment and left in the contact with ambient temperature to reach equilibrium with the ambient environment. The Uniform diameter of lotus roots was selected for the experiment. The nodes of selected lotus root of almost equal diameter trimming of both ends were done manually by using stainless steel knife. After cutting nodes, then lotus roots were peeled by using a peeler then peeled roots were cut into slices.

Chemical treatment on lotus root slices

The three level of concentrations of each chemical such as 2 %, 4 % and 6 % (w/v) of Ascorbic acid; 0.1 %, 0.2 % and 0.3 % (w/v) of potassium meta bisulphite (KMS), and 0.5 %, 1 % and 1.5 % (w/v) sodium bicarbonate solutions were used and samples dipped for 10 minutes. The control samples consisted as samples without any treatment.

Color measurement

A combination of digital camera, computer, and graphics software provide a less expensive and more versatile way to determine the color of the food products than traditional color measuring instruments. This color measurement technique involves setting up a lighting system, a high-resolution digital camera to capture images of food samples, and Adobe Photoshop 7.0 software to obtain color parameters (Spyridon *et al*, 2000).

The image of each sample was taken in the presence of a uniform light source with the help of a digital camera. The samples were kept on a petri dish. The L (lightness), a (red color), and b (yellow color) values of each sample were calculated. The L*, a*, and b* values of dried samples were calculated using L, a, and b values obtained from Adobe Photoshop.

L*, a*, and b* values were obtained from the following formula:

$$L^* = \frac{L}{250} \times 100 \quad (1)$$

$$a^* = \frac{240 \times a}{255} - 120 \quad (2)$$

$$b^* = \frac{240 \times b}{255} - 120 \quad (3)$$

Where, L* = Lightness, a* = redness, b* = yellowness.

Browning index (BI)

The browning index (BI) represents the purity of brown color and is reported as an important parameter in processes where enzymatic or non-enzymatic browning takes place, were calculated according to the following equation (Zhang *et al*, 2017):

$$BI = [100 \times (X - 0.312)] / 0.172 \quad (4)$$

BI= [100 x (X - 0.312)]/0.172

Where, X = (a* + 1.75L*) / (5.645L* + a* - 3.012b*).

Optimization of anti-browning agents

The term optimization has been commonly used as a means of discovering conditions at which to apply a procedure that produces the finest possible responses (Araujo and Brereton, 1966). Optimization refers to improving the performance of a system, process, or product with the intention of obtaining the maximum benefit from it. The optimized the browning index for deciding the pretreatment and drying process parameters to the obtained good quality dried product of lotus root slices. The process described by Gupta *et al* (2013) was followed for the optimization. The numerical optimization technique (Design-Expert 12.0.1.0 software) was used to get the optimum concentration of the anti-browning agents.

RESULTS AND DISCUSSION

Colour parameters of fresh and chemicals treated lotus root slices

Lightness (L*)

The results of color parameters L*, a*, and b* for each sample were determined using photoshop software-7. The lightness (L*), redness (a*), and yellowness (b*) of all samples i.e., fresh-cut lotus root slices and chemicals treated are shown in Figures 2, 3 and 4 respectively. The color parameters were determined for 5 hours period as 0h, 1h, 2h, 3h, 4h, and 5h. As shown in Figure 2 , the lightness parameter (L*) decreased from 101.50 to 44.78, 136.21 to 112, 132.58 to 78.08, and 108.52 to 774.52, over the period of time from 0 h to 5 h (hours) of fresh cult slices and chemicals treated with potassium metabisulphite, ascorbic acid, and sodium bicarbonate, respectively. It was observed that the pretreatment improves the lightness of slices as compared to without chemically treated samples. Although the lightness parameter of the 0.3 % potassium metabisulphite (KMS) samples was higher than other fresh and chemicals treated samples, it shows that remarkable stability of lightness over a period of time (0h to 5h). The lightness of samples also improved as chemical concentration increased of potassium metabisulphite and ascorbic acid, but in samples treated with sodium bicarbonate, there were no significant improvements observed.

Redness (a*)

The redness (a*) values of fresh and chemicals treated lotus root slices increased are shown in Figure 3. The redness varies from 3.51 to 7.14, 1.17 to 3.47, 1.25 to 3.18, and 1.89 to 5.24 for fresh, potassium metabisulphite, ascorbic acid, and sodium bicarbonate. The redness of slices increased over the time span from 0h to 5h of all samples with and without chemicals. The redness of fresh and chemicals treated with potassium metabisulphite, ascorbic acid, and sodium bicarbonate. The maximum increased for fresh-cut slices and minimum for 0.30 % followed by ascorbic acid and sodium bicarbonate chemicals treated samples. Thus, the chemicals treatment prevents the redness of the product. As lightness, the concentration of chemicals increasing the redness of chemical treated samples decreased. The redness of potassium metabisulphite and ascorbic acid-treated samples indicated a similar pattern but potassium metabisulphite was slightly better than ascorbic acid.

Yellowness (b*)

Similar to the behavior of redness (a *) value, yellowness (b*) also increased with elapse of time from 0h to 5h as shown in Figure 4 . The yellowness varies from 8.36 to 43.67, 2.81 to 6.31, 4.36 to 8.23, and 6.02 to 11.97 of fresh cult lotus root slices and chemicals treated with potassium metabisulphite, ascorbic acid, and sodium bicarbonate samples, respectively. These values increased faster for the fresh samples, followed by sodium bicarbonate, ascorbic acid, and potassium metabisulphite chemicals treated samples. The maximum prevention of yellowness was observed for 0.30% potassium metabisulphite and minimum with 2% sodium bicarbonate. It was also observed that the yellowness prevention improve as chemicals concentration increased.

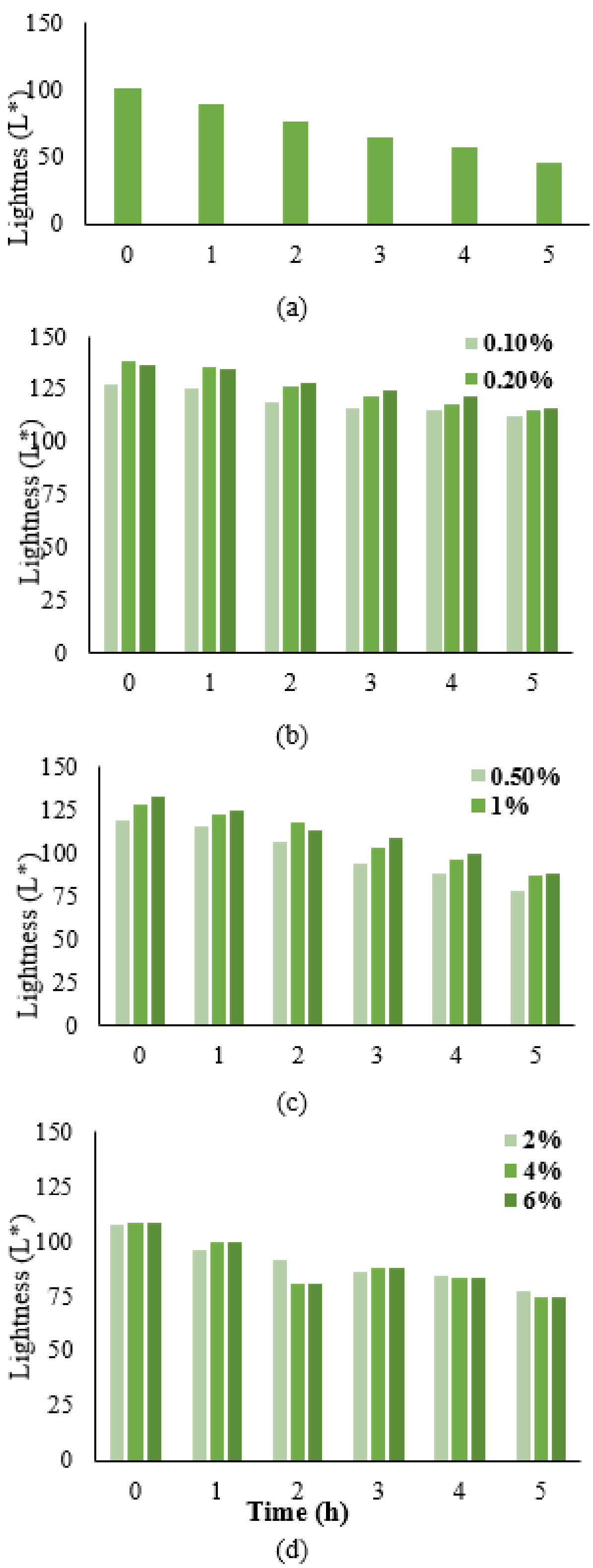

Fig. 2: Lightness values (L*) of lotus root slices (a) Fresh-cut, (b)Ascorbic acid-treated, (c) potassium meta bisulfite-treated, and (d) sodium bicarbonate treated

Overall, it was observed that remarkable stability of lightness (L*), redness (a*), and yellowness (b*) of chemicals treated samples as compared to fresh (without chemical treated) cut lotus root slices. The maximum stability of color parameters was observed for potassium metabisulphite treated samples followed by ascorbic acid and sodium bicarbonate treated samples. As per the goal to obtained maximum lightness (L*), and minimum redness (a*) and yellowness (b*) were observed with 0.30 % potassium meta bisulfite.

Browning index of fresh and chemicals treated lotus root slices

The values of the browning index were determined by using Equation (4)Figure 5 shows that the average values of the browning index of the fresh (untreated) and chemically treated sample such as potassium metabisulphite, ascorbic acid, and sodium bicarbonate with different concentrations and at different times. It was observed that the browning index of fresh lotus root slices increased with the increase of time (elapsed time) i.e. 9.63 and 205.14 was minimum and maximum at the time 0 h and 5 h, respectively. The browning index of potassium metabisulphite treated samples ranged from 2.76 to 6.65, 1.79 to 5.68, and 1.51 to 4.19 for 0.1%, 0.2 %, and 0.3 % solutions, respectively. This indicated that the browning index was minimum at 0.3 % potassium metabisulphite solutions and maximum at 0.1 % potassium metabisulphite solutions. Similarly, the browning index ranged from 8.10 to 20.14, 6.98 to 17.18, and 5.35 to 16.63 for samples treated with 0.5, 1, and 1.5 % ascorbic acid, respectively. The minimum and maximum values of the browning index at 1.5 and 0.5 % of ascorbic acid-treated samples. Besides that, the browning index ranging from 4.29 to 12.55, 3.41 and 2.74 to 9.27 at 2, 4, and 6 % of sodium bicarbonate treated samples, respectively. Similarly, the minimum and maximum browning index values were found at 0.5 and 1.5 % of ascorbic acid solutions, respectively. Overall, it was concluded that the values of the browning index increased with elapse of time (0 h to 5 h) for all chemicals greeted samples with all concentrations. On the other hand, the browning index decreased with increasing the concentration of solutions for all chemicals. Thus, the browning index was minimum (1.51 to 4.91) at 0.3 % KMS solutions as compared to fresh and all other treated samples.

Optimization of pretreatment for prevention of browning

The standardization of pre-treatments was carried out to determine the optimum values of the parameters that would yield the best quality products. The numerical optimization technique (Design-Expert 12.0.1.0 software) was used to get the optimum concentration of chemical solutions of the pre-treatments for lotus root slices. The process described by Gupta *et al* (2013) was followed for the optimization of pre-treatment parameters. Second-order polynomial models were used in this study to obtain the optimized concentration of chemical solutions and blanching temperature and duration to meet the above-stated criteria. The response variables were selected for optimization were the browning index

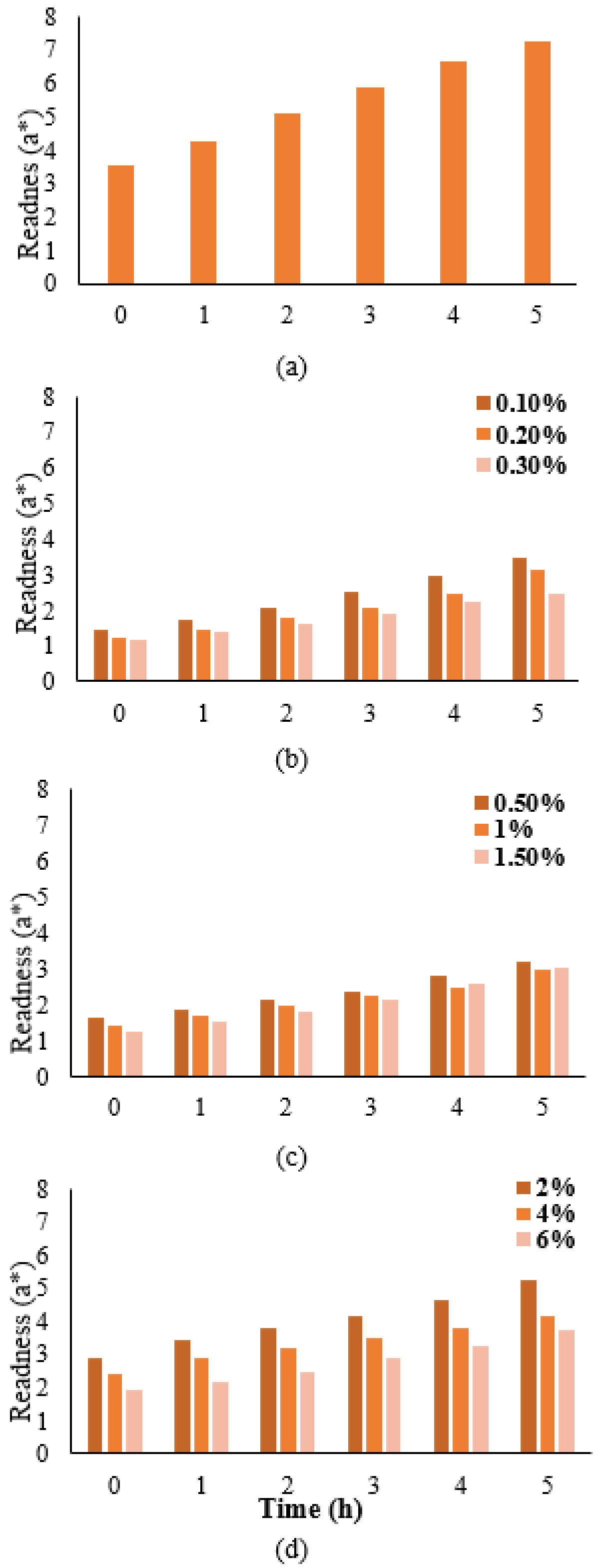

Fig. 3: Redness values (a*) of lotus root slices (a) Fresh-cut, (b)Ascorbic acid-treated, (c) potassium metabisulphite treated, and (d) sodium bicarbonate treated

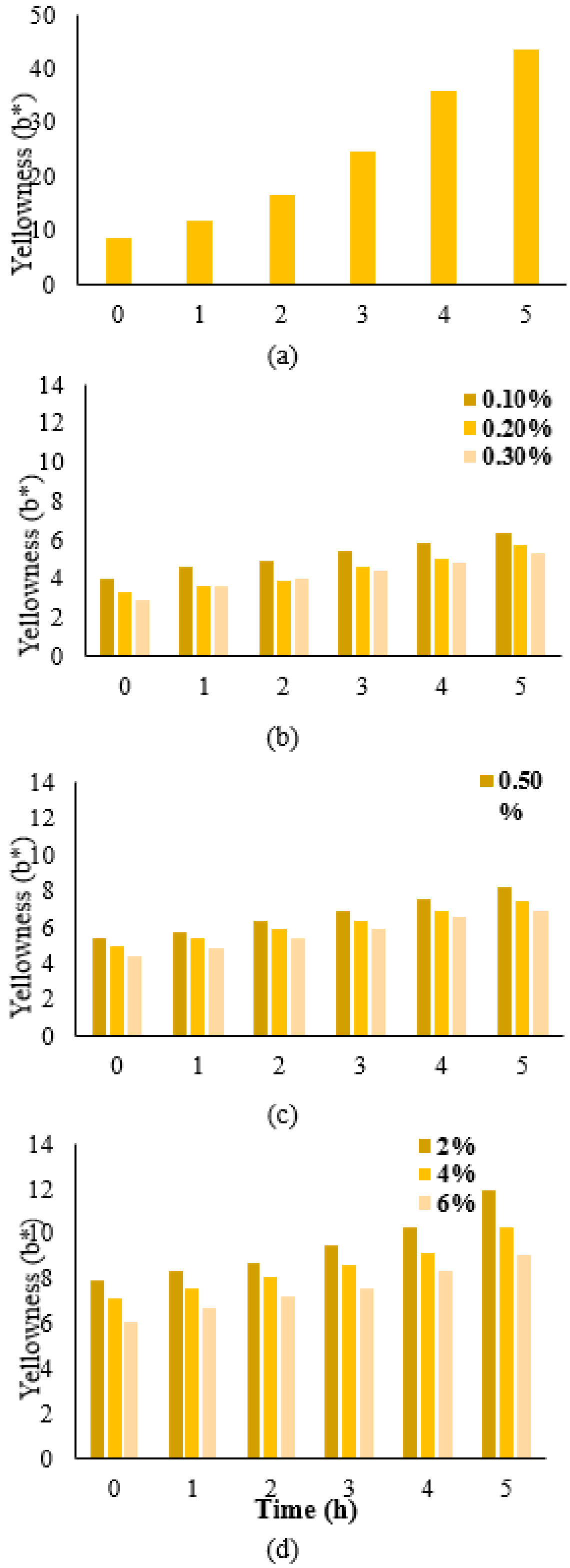

Fig. 4: Redness values (a*) of lotus root slices (a) Fresh-cut, (b)Ascorbic acid-treated, (c) Potassium metabisulphite treated, and (d) Sodium bicarbonate treated

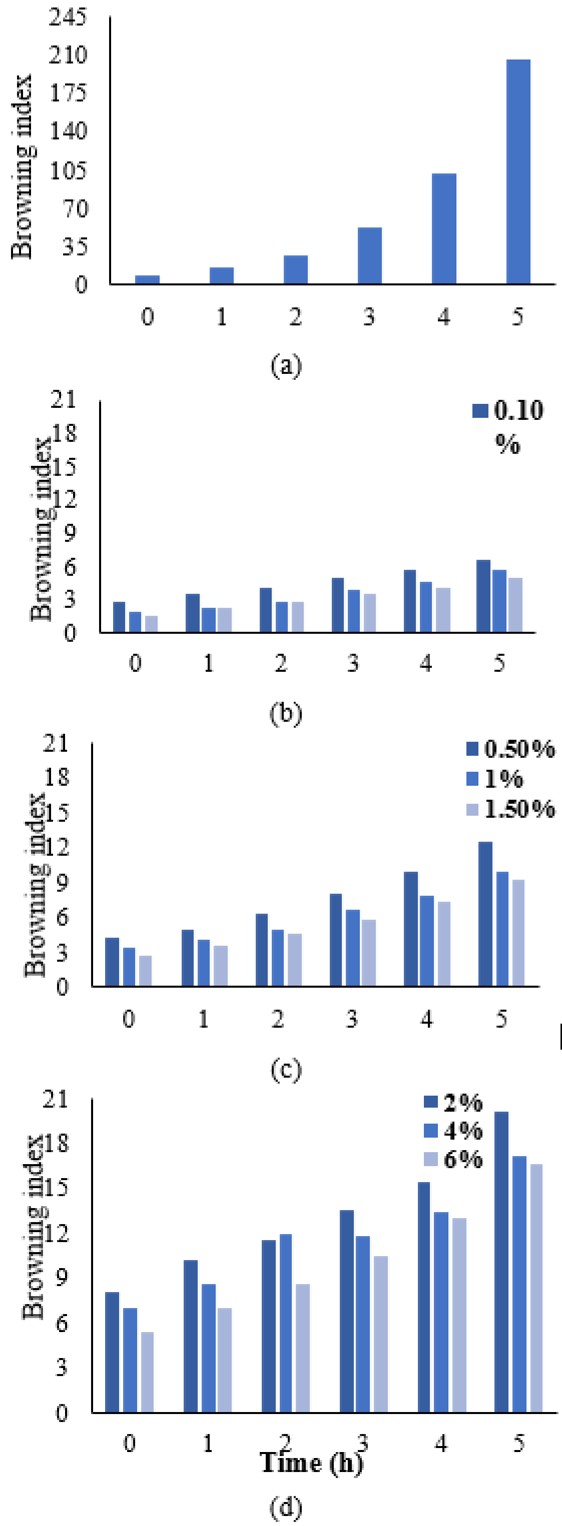

Fig. 5: Browning index of fresh and different chemically treated lotus root slices (a) Fresh-cut, (b)Ascorbic acid-treated, (c) Potassium metabisulphite treated, and (d) Sodium bicarbonate treated

that was calculated every 1-hour interval up to 5 hours. The optimum condition was found by the goal set up for process optimization for process constraints such as minimizing browning index, concentration in the range, and the upper and lower limit of process constraints are shown in Table 1, respectively.
Polynomial desirability function was applied and 2, 1, and 1 optimized combination of pretreatment parameters were obtained for potassium metabisulphite, ascorbic acid, and sodium bicarbonate are shown in Tables 2, 3 and 4 , respectively. It was observed that the optimized concentration of the chemical solution was 0.29, 1.5, and 6 % of potassium metabisulphite, ascorbic acid, sodium bicarbonate, with corresponding browning index ranging from 1.50 to 4.95, 2.73 to 9.28, and 5.34 to 16.02, respectively.

Table 1: Constraints for optimization of the browning index on the basis of process parameters of chemically treated samples

S. No.	Parameters	Goal	Potassium metabisulphite		Sodium bicarbonate		Ascorbic acid	
			LL	UL	LL	UL	LL	UL
1	Concentration of chemicals (%)	in range	0.1	0.3	0.5	1.5	2	6
2	BI at 0 hours	minimize	1.46	2.86	5.24	8.46	2.66	4.39
3	BI at 1 hours	minimize	2.1	3.44	6.68	10.23	3.45	5
4	BI at 2 hours	minimize	2.75	4.24	8.45	12.28	4.57	6.41
5	BI at 3 hours	minimize	3.43	5.01	10.27	13.75	5.59	8.27
6	BI at 4 hours	minimize	3.96	5.77	12.7	16.15	7.2	10.17
7	BI at 5 hours	minimize	4.78	6.9	16.24	20.21	9.14	12.67

LL=Lower limit, UL=Upper limit, BI=Browning index

Table 2: Optimized value of the browning index of potassium metabisulphite

S.No.	KMS	Browning index						Desirability
		0 h	1 h	2 h	3 h	4 h	5 h	
1	0.294	1.50	2.13	2.74	3.43	4.10	4.95	0.96
2	0.295	1.50	2.14	2.75	3.43	4.10	4.95	0.96

KMS: potassium metabisulphite (%)

From the above-optimized results, it was concluded that the pre-treatment as the chemical concentration, the optimized concentration was 0.29 % potassium metabisulphite was lowest browning index as compared to all concentrations. Nevertheless, it is concluded that the 0.30 % potassium metabisulphite is effective for the prevention of browning of fresh-cut lotus root slices. Therefore, it can be used as pretreatment prior to the drying operation of lotus root slices.

CONCLUSION

The experiments were carried out optimized the chemicals concentration as pre-treatments prior to drying of fresh-cut lotus root slices. The lotus root slices were pretreated by chemicals with Potassium metabisulphite (0.1, 0.2, and 0.3 % (w/v)), sodium bicarbonate (2, 4, and 6 % (w/v)), and ascorbic acid (0.5, 1 and 1.5 % (w/v)). The quality parameters of lotus root slices were taken as color parameters such as lightness (L*), redness (a*), and (b*) along with the browning index.

Table 3: Optimized value of the browning index of ascorbic acid

S.No.	ASC	Browning index						Desirability
		0 h	1 h	2 h	3 h	4 h	5 h	
1	6	2.73	3.49	4.68	5.727	7.30	9.28	0.958

ASC: ascorbic acid (%)

Table 4: Optimized value of the browning index of sodium bicarbonate

S.No.	SBC	Browning index						Desirability
		0 h	1 h	2 h	3 h	4 h	5 h	
1	1.5	5.34	6.94	8.65	10.51	13.02	16.63	0.93

SBC: sodium bicarbonate (%)

The best treatment was decided based on the browning index. On the basis of color parameters and browning index, the following conclusions are drawn:

- The color parameters of fresh-cut lotus root slices and chemicals deteriorate over the time span of 0h to 5h. Besides that, chemicals treated samples were improved over the fresh-cut lotus root slices.

- The lightness (L*), redness (a*), and yellowness (b*) of 0.30% potassium metabisulphite samples varies from 136 to 116, 1.17 to 248, and 2.87 to 5.34 for the period of time 0h to 5h, respectively. Which is the lowest as compared to all other samples.
- The browning index pre-treated samples was much lower than samples without treatment. The browning index increased with elapsed time and highly increase in untreated (fresh-cut lotus root slices) samples than pre-treated samples (chemicals treated).
- The optimized browning index was minimum (1.498 to 4.963) for 0.3 % KMS as compared to 5.337 to 16.02 and 2.73 to 9.227 for 6 % (w/v) sodium bicarbonate and 1.5 % (w/v) ascorbic acid solutions, respectively.

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