Effect of the control of white-blush of fresh-cut carrot and its process optimization

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Abstract: In order to control the whiteness of fresh-cut carrots and optimize the fresh-keeping process of fresh-cut carrots, taking whiteness value, sensory quality evaluation and total carotene content as indicators, a single factor experiment was designed to compare the different concentrations of citric acid and ascorbic acid, and the effect of different packaging materials on fresh-cut carrots was analyzed by grey correlation degree; by using the optimal concentration of color-protecting agents, three packaging materials with good effects, and different cleaning agents as research factors, orthogonal experiments were designed to optimize the fresh-keeping conditions of fresh-cut carrots. The results showed that 0.60% citric acid and 0.40% ascorbic acid can significantly (p < 0.05) inhibit the whitening of fresh-cut carrots. The best fresh-keeping process was that packaging with No. 15 packaging material, water as the cleaning agent, and 0.60% lemon Acid + 0.40% ascorbic acid for color protection.

1. Introduction
Carrots are known as yellow radish and clove radish. It has a wide range of uses, rich nutrition, and good health. However, cutting will change the integrity of carrots and affect the quality of fresh-cut carrots. In addition, fresh-cut carrots lose the bright orange appearance as a result of the whitish aspect on the surface due to dehydration and lignification[1]. Therefore, it is necessary to use appropriate processes to suppress the whitening of fresh-cut carrots and extend the shelf life. At present, Ren Lifang’s[2] research shows that 0.6% citric acid and 0.4% ascorbic acid have the best effect on reducing the whiteness value of fresh-cut carrots. Fan Teng et al.[3] showed the best coating combination for the effect of sodium composite coating on the whiteness of fresh-cut carrots to reduce the whiteness value of fresh-cut carrots, Fan Teng et al.[3] showed the best coating combination for the effect of sodium composite coating on the whiteness of fresh-cut carrots to reduce the whiteness value of fresh-cut carrots and lignin content, delay the disappearance of bright yellow of fresh-cut carrots, but their research did not involve the control of whitening of fresh-cut carrots from the aspects of packaging materials, cleaning agents and so on.

Based on the existing experiments, this test starts with packaging materials, selects good packaging, and designs orthogonal experiments to explore the effects of packaging materials, cleaning agents, color protection agents, etc. on the whiteness of fresh-cut carrots in order to find out a better compounding process to control the whiteness of fresh-cut carrots, so that they can maintain good quality during storage.
2. Materials and methods

2.1 Main materials and instruments

2.1.1 Materials
Carrots, Bei Nong Market; Five kinds of packaging films; commercially available.

Table 1. Detailed parameters of five kinds of packaging materials

| Material number | Material name | O₂ transmission (cm³/m²·24h·M Pa) | Water vapor transmission capacity (g/m²·24h) | Film thickness (mm) |
|-----------------|---------------|------------------------------------|---------------------------------------------|--------------------|
| No. 1 packing material | HDPE          | 0.01830                            | 3.54                                         | 0.037              |
| No. 2 Packing material | PE            | 0.01572                            | 7.67                                         | 0.036              |
| No. 7 packing material | OPP/CPP      | 0.00872                            | 3.13                                         | 0.056              |
| No. 15 packing material | PA/PE        | 0.01437                            | 4.55                                         | 0.044              |
| No. 18 packing material | PD961        | 0.02458                            | 15.97                                        | 0.034              |

2.1.2 Main reagents and instruments
Petroleum ether, guaiacol, disodium hydrogen phosphate, sodium dihydrogen phosphate, acetone, boric acid, mercaptoethanol, EDTA (ethylenediaminetetraacetic acid), phenylalanine; analytical grade, Beijing Chemical Plant.

DGN-06 multifunctional fresh-keeping sealing machine, Ningbo Xiangshan Lvyou Light Industrial Machinery Manufactory; H1850R desktop high speed refrigerated centrifuge, Xiangyi Centrifuge Instrument Co., Ltd; T6 new century spectrophotometer, Beijing Spectrum Analysis General Instrument Co., Ltd.; BCD-288wsl refrigerator, Qingdao Haier Co., Ltd.

2.2 Experimental methods

2.2.1 Pre-treatment of fresh-cut carrots
Select fresh carrots with no damage and no pests, clean, peel, and cut them into carrot slices with a thickness of about 2 mm. Single-factor experiment: Treat fresh-cut carrots with different concentrations of citric acid and ascorbic acid (0%, 0.2%, 0.4%, 0.6%, 0.8%), then measure its whiteness and select the optimal concentration; the packaging materials which can keep the quality of fresh-cut carrots were screened out. Orthogonal experiment: Perform the experiments according to the design in Table 2.

Table 2. Factor levels of orthogonal experiments

| factor          | Level 1                     | Level 2                     | Level 3                     |
|-----------------|-----------------------------|----------------------------|-----------------------------|
| A Packaging material | No. 15 Packing material | No. 18 Packing material | No. 2 Packing material |
| B cleaning agent | H₂O                          | 60ppm NaClO solution      | 100ppm NaClO solution    |
| C color protectant | 0.6% citric acid          | 0.4% ascorbic acid        | 0.6% citric acid + 0.4% ascorbic acid |

2.2.2 Determination of sensory indicators
Using the scoring method [5].

Table 3. Evaluation criteria for sensory quality of fresh-cut carrots

| Rating (points) | odour | Color | Organizational structure |
|-----------------|-------|-------|--------------------------|
|                 |       |       |                          |
A touch of freshness and sweetness

|   |                       |   |   |
|---|-----------------------|---|---|
| 9 | A touch of freshness and sweetness | red | close |
| 7 | Lose fresh taste without rot | Light red without whitening | Decreased tightness |
| 5 | Loss of sweetness but no rot | Whitening | Slight softening |
| 3 | Slightly rotten | Slight whitening in red | Slightly rotten |
| 1 | rot | Severe whitening | rot |

2.2.3 Determination of peroxidase (POD) activity

The guaiacol method \(^6\) was used for determination.

2.2.4 Determination of phenylalanine ammonia lyase (PAL) activity

Refer to the method of Sun Guangyu \(^7\) for measurement.

2.2.5 Determination of total carotene content

Refer to the method of Fan Teng \(^1\) et al for determination.

2.2.6 Determination of color difference

Refer to the method of Bolin et al. for measurement \(^8\). Whiteness index (Wi) were calculated as follows: 

\[
Wi = \frac{100 - \sqrt{(100 - L)^2 + a^2 + b^2}}{100}.
\]

2.2.7 Data processing

The above experiments were repeated three times, and the measured data were processed by Excel software.

3. Results and analysis

3.1 Results and analysis of single-factor experiment

3.1.1 Effect of different concentrations of citric acid treatment on whiteness of fresh-cut carrots during storage

The higher the whiteness index is, the more serious the lignification of the carrot surface is, and the lower the whiteness index is, the better the color quality is. From Fig1, it can be seen that with the increase of storage time, the whiteness of fresh-cut carrots treated with different concentrations of citric acid is increasing, when the citric acid concentration is greater than 0.20%, the whiteness is inhibited. When stored to the 9th day, the whiteness value of fresh-cut carrots treated with 0.60% citric acid was significantly (p<0.05) lower than 0.80% citric acid treatment group, so citric acid with a concentration of 0.60% was selected for the next orthogonal experiment.
3.1.2 Effect of ascorbic acid treatment on whiteness of fresh-cut carrots during storage

As can be seen from Fig 2, different concentrations of ascorbic acid can inhibit the whiteness of fresh-cut carrots. When the concentration is higher than 0.20%, the inhibition effect is significant good (p < 0.05). When the concentration of ascorbic acid is 0.40%, compared with other concentrations of ascorbic acid, it had the strongest inhibition effect and the most significant effect (P < 0.05). Therefore, ascorbic acid with a concentration of 0.40% was selected for the next orthogonal experiment.

3.2 Grey correlation analysis between sensory qualities of different packaging materials and fresh-cut carrots

The closer the change trends between the two factors or the two systems is, the greater the correlation degree is; otherwise, the smaller the correlation degree is. The ideal sensory quality of fresh-cut carrots is set to 10 points, which constitutes the reference sequence $X_0$, and different packaging materials constitute the comparison sequence $X_i$, $i$ represents any kind of packaging material ($i = 1, 2, 3, 4, 5$). Calculate the correlation coefficient ($L_i(k)$) and correlation degree ($R_i(k)$) between different packaging materials and sensory quality by formulas (1) and (2), respectively.

$$
L_i(k) = \frac{\min_k \min_i |X(k) - X_0(k)| + \rho \max_k \max_i |X(k) - X_i(k)|}{\max_k \max_i |X(k) - X_i(k)|}
$$

$$
R_i(k) = \frac{1}{n} \sum_{k=1}^{n} L_i(k)
$$

In formula (1), $|X(k) - X_0(k)| = \Delta i(k)$ represents the absolute difference between $X_0$ and $X_i$ series at $k$ points, $\rho$ is the resolution factor, $0 < \rho < 1$, $\min_k \min_i \Delta i(k)$ and $\max_k \max_i \Delta i(k)$ represent the second-level minimum difference and maximum difference. In Equation (2), $n$ represents the number of factors examined, and $n = 4$. The results of different packaging materials on the sensory quality of fresh-cut carrots are shown in Table 4.

| Code | Packaging Materials       | 1  | 3  | 5  | 7  | 9  |
|------|---------------------------|----|----|----|----|----|
| $X_0$| Ideal sensory quality     | 10.0| 10.0| 10.0| 10.0| 10.0|
| $X_1$| No. 1 packing material    | 9.0 | 8.5 | 7.5 | 6.5 | 5.5 |
| $X_2$| No. 2 packing material    | 9.0 | 8.5 | 7.9 | 6.5 | 5.2 |
| $X_3$| No. 7 packing material    | 9.0 | 8.3 | 7.3 | 6.1 | 4.9 |
| $X_4$| No. 15 packing material   | 9.0 | 8.9 | 8.1 | 7.1 | 6.5 |
| $X_5$| No. 18 packing material   | 9.0 | 8.7 | 7.8 | 6.7 | 6.0 |

According to the data in Table 4 and formula (2), calculate the correlation degree and correlation order between different packaging materials treatment and the sensory quality of ideal fresh-cut carrots. $\rho = 0.5$, the results are shown in Table 5.
Table 5. The correlative degree and its order between different packaging materials and ideal sensory quality of fresh-cut carrots

| Packaging Materials      | Correlation | Association order |
|--------------------------|-------------|-------------------|
| No. 1 packing material   | 0.720       | 4                 |
| No. 2 Packing material   | 0.736       | 3                 |
| No. 7 packing material   | 0.706       | 5                 |
| No. 15 packing material  | 0.764       | 1                 |
| No. 18 packing material  | 0.738       | 2                 |

Through the comprehensive evaluation of the gray correlation analysis method, it can be seen from Table 5 that the sensory quality of the fresh-cut carrots packaged in the packaging material No.15 is most closest to the ideal sensory quality. The gray correlation is 0.764. The packaging quality of fresh-cut carrots packed with packaging materials No. 15, No. 18, No. 2 and No. 1 is better than the quality of No.7. The results show that the sensory quality of fresh-cut carrots packed with NO.15 packaging material was the best, followed by NO.18 and NO.2 packaging material.

3.3 Effect of different packaging materials on total carotene of fresh-cut carrots

![Fig3. The total carotene content of fresh-cut carrots packed with different packaging materials](image)

During storage, the total carotene content of fresh-cut carrots showed a downward trend. On the 9th day, the total carotene content of carrots packed in No. 15 packaging material was the highest at 7.31 mg/100g, followed by the carrots packed in No. 2 and No. 18. As can be seen from Fig 3, during the whole storage period, the content of total carotene in the fresh-cut carrots packaged with NO.15, NO.2 and NO.18 was higher, they were more suitable for the packaging of fresh-cut carrots, which could reduce the loss of total carotene and maintain good color of fresh-cut carrots.

3.4 Sensory scores and whiteness values of different treatment groups in orthogonal experiments

Table 6. Orthogonal experiment results

| Experiment number | A  | B  | C  | Empty column | Sensory evaluation | Whiteness value | PAL enzyme |
|-------------------|----|----|----|---------------|-------------------|----------------|------------|
| 1                 | 1  | 1  | 1  | 1             | 6.1               | 33.7           | 0.74       |
| 2                 | 1  | 2  | 2  | 2             | 5.0               | 34.6           | 0.85       |
| 3                 | 1  | 3  | 3  | 3             | 3.0               | 32.8           | 0.71       |
| 4                 | 2  | 1  | 2  | 3             | 5.9               | 35.4           | 0.91       |
| 5                 | 2  | 2  | 3  | 1             | 5.1               | 36.9           | 0.79       |
| 6                 | 2  | 3  | 1  | 2             | 3.8               | 36.2           | 0.83       |
| 7                 | 3  | 1  | 3  | 2             | 5.5               | 36.5           | 0.83       |
| 8                 | 3  | 2  | 1  | 3             | 4.6               | 37.1           | 0.96       |
| 9                 | 3  | 3  | 2  | 1             | 3.1               | 36.0           | 1.05       |

K1 14.1 14.5 14.3
K2 14.8 14.0 14.3
As can be seen from Table 6, when sensory evaluation is used as an index, the order of influencing factors is B>A>C, the best combination is A₂B₁C₁. When the whiteness value is used as an indicator, by comparing the extremely poor R, the influence of various factors on the whiteness value of fresh-cut carrots is A>B>C, the best compounding process is A₁B₃C₂. From the perspective of affecting PAL enzyme activity, the primary and secondary order of influencing factors is A>C>B, the best compounding process is A₁B₁C₃, which is the best effect to use the NO.15 packing materials. Combine the three indicators to determine the best compound process is A₁B₁C₃, that is, packaging with No. 15 packaging material, washing with clean water, and adding 0.6% citric acid + 0.40% ascorbic acid as color protection agent, stored at 4 °C, the whiteness value of fresh-cut carrots treated with the best process is lower, and the sensory quality is better. This extends the shelf life of fresh-cut carrots for 2 to 3 days.

4. Conclusion
This experiment first designed a single factor experiment, using whiteness value, sensory quality evaluation and total carotene as evaluation indicators, to compare and analyze the effects of different concentrations of citric acid and ascorbic acid and different packaging materials on the quality of fresh-cut carrots; an orthogonal experiment was designed based on the conclusion of single factor experiment to obtain the best preservation process for fresh-cut carrots. Packaging with No. 15 packing materials, washing with clean water, and add 0.40% ascorbic acid and 0.60% citric acid as color protection agent, stored at 4 °C, the whiteness value of fresh-cut carrots treated with the best process is lower, and the sensory quality is better. This extends the shelf life of fresh-cut carrots for 2 to 3 days.

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