

## Research Article

# Vacuum Concentration Improves the Quality and Antioxidant Capacity of Pear Paste

Yue Li <sup>1,2</sup> Yongxia Wang,<sup>1</sup> Xiaoying Zhang,<sup>1,2</sup> Jiangli Zhao,<sup>2</sup> Yiming Li,<sup>2</sup> Yudou Cheng,<sup>2</sup> and Junfeng Guan <sup>2</sup>

<sup>1</sup>College of Life Science and Food Engineering, Hebei University of Engineering, Handan 056038, Hebei, China

<sup>2</sup>Institute of Biotechnology and Food Science, Hebei Academy of Agricultural and Forestry Sciences, Shijiazhuang 050051, Hebei, China

Correspondence should be addressed to Junfeng Guan; [junfeng-guan@263.net](mailto:junfeng-guan@263.net)

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A vacuum concentration method was established to produce pear paste using fresh pear juice in this study. The optimal condition was determined by comparing the quality indexes, contents of total phenol and flavonoid, and antioxidant properties of the pear paste produced by traditional heating concentration and vacuum concentration. Electronic nose and electronic tongue were introduced in this study to provide digital smell and taste indicators. The results showed that the best vacuum concentration temperature was 65°C, which led to the best sensory evaluation score and pear paste quality. The browning degree and soluble quinones were the lowest in all tested temperatures, and the content were 60.12% and 72.88% compared with the heating method, respectively. While the values were 148.29%, 209.44%, 310.86%, 120.37%, 106.24%, and 181.26% of total phenol, total flavonoid, vitamin C, 1,1-diphenyl-2-trinitrophenylhydrazine (DPPH) and hydroxyl (-OH) radical scavenging rates, and total reducing power, respectively. The electronic nose could effectively distinguish the vacuum-concentrated pear paste from the traditional heating-concentration pear paste and could provide quality guidance on their flavor differences through characteristic sensors. The electronic tongue tests showed that the vacuum-concentrated pear paste had larger freshness and richness kurtosis. The pear paste made by the optimized vacuum concentration method had higher retention of nutritional and functional components and higher antioxidant capacity, which could be clearly differentiated from the traditional process, thus this method had an applicable potential.

## 1. Introduction

Pear paste is an important processing product of pear fruit. “Yali” pear (*Pyrus Bretschneider* Rehd. cv. “Yali”) is a famous Chinese pear variety, which is usually used for producing pear paste. It contains various mineral elements, carbohydrate compounds, phenols, acids, and flavonoids [1–5]. Traditional pear paste is usually prepared by the direct heating concentration of fresh pear juice, which tastes moderately sweet and sour. The pear paste is commonly used in asthma and cough cures and has strong effects on antioxidation, anti-inflammatory, and eliminating human free radicals, et al. [6, 7].

The concentration technologies of fruit juice include heating concentration under normal atmospheric pressure,

vacuum concentration under reduced pressure, membrane concentration, freezing concentration, and ice temperature concentration [8–10]. Vacuum concentration under reduced pressure can quickly evaporate the water of the fruit juice at a lower temperature, thus achieving a short heating process time and high retention of bioactive compounds [11]. It had been shown that the contents of total phenol, ascorbic acid, and total acid are significantly higher in “Dangshan” pear paste prepared by vacuum concentration than those by traditional heating method [12]. Compared with normal pressure heating, vacuum concentration can significantly improve the lycopene content of concentrated tomato juice with higher concentration efficiency and better quality [11]. Meanwhile, the concentrated juice of sour cherry prepared

by vacuum concentration leads to less color change and higher contents of total acid and bioactive components [13]. Therefore, the vacuum concentration technology is more suitable for the quality improvement of fruit juice concentrates.

Appropriate concentration condition is essential for the preparation process of pear paste. In this study, the fresh juice of “Yali” pear was used as raw material, and the traditional heating concentration at normal atmospheric pressure and vacuum concentration were used to prepare pear paste. The sensory quality, total phenol, flavonoid, vitamin C, soluble quinone contents, browning degree, and antioxidant capacity were determined, and the flavor quality was determined by electronic nose and electronic tongue. This study aims to develop the optimal experimental vacuum concentration condition of pear paste and to evaluate the quality parameters by physical chemistry test and electronic property analysis.

## 2. Materials and Methods

**2.1. Samples Preparation.** “Yali” pears (average soluble solids content (SSC) 11.8, °Brix, pH 4.73, titratable acid 0.06%) were picked at an orchard located in Zhaoxian County, Hebei Province at the commercial maturity stage, in which those with uniform maturity without disease and damage were used to prepare pear paste processing.

“Yali” pears were cleaned with running water, removed the inedible part, and cut it into small blocks for juicing. The juice was extracted using a juice extractor (Hurom, Korea) followed by passing through 4 layers of gauze, and was collected in a glass container with an addition of color protection agent (ascorbic acid 0.02% (W/V), citric acid 0.05% (W/V), and potassium metabisulfite 0.02% (W/V)) for color protection. The vacuum concentration technology was as follows: the vacuum degree as 0.9 atm and the rotating speed as 60 rpm were fixed. Then, the concentration temperatures were set as 55°C, 60°C, 65°C, 70°C, and 75°C, respectively. The traditional heating group was concentrated by boiling and cooking at 100°C under normal pressure (hereinafter referred to as CK group). The concentration process was completed after the SSC of the pear paste reached  $70 \pm 1^\circ\text{Brix}$ .

The pear paste was diluted by sterile deionized water to the same SSC 11.8°Brix of the original pear juice and centrifuged at 6000 rpm. The supernatant was used for later physical chemistry, antioxidant capacity, sensory evaluation, and electronic property tests which were described as pear paste samples in material and methods. The values were calculated to the actual equivalence of the concentrated pear paste and used for data analysis in the result and discussion.

### 2.2. Determination of Physical and Chemical Indexes

**2.2.1. Browning Degree.** The determination of the browning degree was according to Pinto et al. [14] with slight modifications. Briefly, adopting ultraviolet-visible

spectrophotometry, 4 mL of a diluted sample of pear paste was measured, and deionized water was used as a blank control. The browning degree was expressed at  $\text{OD}_{420}$ .

**2.2.2. Total Phenol, Flavonoid Content.** Total phenol content was determined as described by Gerardi et al. [15] with the Folin-phenol method. 0.5 mL each above diluent sample solution with 0.5 mL Folin-phenol reagent were mixed, followed by adding 1.0 mL of 7% (m/V) sodium carbonate. The final volume was adjusted to 6 mL with deionized water and reacted at room temperature for 1 hour. The samples were measured with the absorbance value at  $\text{OD}_{765}$ . Deionized water was used as a blank control. 0, 0.2, 0.4, 0.6, 0.8, 1.0 mL gallic acid standard solutions (0.5 mg/mL) were added into the 1.0 mL system with deionized water to make the concentration gradient standard solution. The standard curve was drawn by Excel 2016. The obtained results were brought into the regression equation  $y = 0.0812x + 0.1082$  ( $R^2 = 0.999$ ) to calculate the total phenol content of the sample. The content of total flavonoid was determined by Zawawi et al. [16] under a sodium nitrite-aluminum nitrate color reaction. 0.1, 0.2, 0.3, 0.4, and 0.5 mL of 1 mg/mL rutin standard solution were adjusted volume to 1 mL with 70% ethanol. 0.3 mL of each concentration gradient standard solution was mixed with 0.3 mL of 5% (m/V) sodium nitrite in a 50 mL colorimetric tube. After 6 min, 0.3 mL 10% (m/V) aluminum nitrate was mixed and let stand. After 6 min, 4 mL sodium hydroxide (1 mol/L) was added into the standard solution and stood for 10 min. The absorbance was measured at  $\text{OD}_{510}$ , and the standard curve was performed by Excel 2016. 0.3 mL of each sample was measured with the same operation above, respectively. The obtained results were brought into the regression equation  $y = 4.923x + 0.1133$  ( $R^2 = 0.9993$ ) to calculate the total flavonoid content of the samples.

**2.2.3. Vitamin C Content.** The content of vitamin C was determined by the 2,6-dichloroindophenol titration method [17]. Briefly, a 10 mL sample was titrated with 2,6-dichloroindophenol titration with sodium indophenol solution. The consumed volume was  $V$ . At the same time, a blank test using metaphosphoric acid solution was carried out and the consumption volume was  $V_0$ . The calculation formula was as follows:

$$X = \frac{(V - V_0) \times A \times 100}{m} \quad (1)$$

X: vitamin C content, mg/100 mL, A: dilution multiple; 100: conversion coefficient; m: sample mass, g, V: volume of 2,6-dichloroindophenol sodium solution consumed when titrating the sample, mL, and  $V_0$ : volume of 2,6-dichloroindophenol sodium solution consumed in blank control, mL.

**2.2.4. Soluble Quinone Content.** 10 mL of each pear paste sample was homogenized in 20 mL of methanol. The homogenate was filtered and centrifuged at 12000 rpm for

20 min. The obtained supernatant was measured with absorbance at OD<sub>437nm</sub>. The OD<sub>437</sub> value was used to represent the soluble quinone content [18].

### 2.3. Determination of Antioxidant Capacity

**2.3.1. DPPH Radical Scavenging Capacity.** 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging capacity was determined as Romanet et al. described [19]. 2 mL of pear paste sample was reacted with 2 mL DPPH-ethanol solution (0.02 mg/mL) at room temperature without light for 30 min. The sample was centrifuged at 6000 rpm for 15 min. The supernatant was measured absorbance at OD<sub>517</sub>, ethanol meanwhile was taken as blank. DPPH radical scavenging rate (%) =  $A_c - (A_i - A_j)/A_c \times 100$ , where:  $A_i$  was the sample absorbance,  $A_j$  was the background absorbance, and  $A_c$  was the blank absorbance.

**2.3.2. OH Radical Scavenging Capacity.** Hydroxyl ( $\cdot$ OH) radical scavenging capacity was performed according to the method of Zacarias et al. [20]: 2 mL of pear paste sample was added with 2 mL H<sub>2</sub>O<sub>2</sub> (6 mmol/L) and 2 mL FeSO<sub>4</sub> (6 mmol/L) and stabilized for 10 min. Then the sample was added 2 mL of salicylic acid (6 mmol/L) and taken water bath at 37°C for 1 h. The sample was centrifuged at 6000 rpm for 15 min. The supernatant was measured with its absorbance at OD<sub>510nm</sub> and deionized water was taken as blank.  $\cdot$ OH radical scavenging rate (%) =  $A_0 - (A_1 - A_2)/A_0 \times 10$ , where:  $A_1$  was the sample absorbance,  $A_2$  was the background absorbance, and  $A_0$  was the blank absorbance.

**2.3.3. Total Reduction Capacity.** According to the method of Wan et al. [21]: 1 mL of pear paste sample was added with 2.5 mL of phosphoric acid buffer solution (pH 6.6) and 2.5 mL of potassium ferricyanide (1 g/100 mL) and reacted in a water bath at 50°C for 20 min. The sample was added with 2.5 mL of trichloroacetic acid (10 g/100 mL) and centrifuged at 6000 rpm for 15 min. 2.5 mL supernatant was mixed with 2.5 mL deionized water and 0.5 mL of ferric chloride solution (0.1 g/100 mL) and left still for 10 min. Finally, the sample was determined for absorbance at OD<sub>700</sub> and the value indicated the total reduction capacity.

**2.4. Sensory Evaluation.** An evaluation team was organized by five food professionals to evaluate the color, smell, taste, and organizational status of pear paste samples [22]. The scoring criteria were showed in Table 1.

### 2.5. Electronic Property Analysis

**2.5.1. Electronic Nose Odor Determination.** The determination of electronic nose was referred to Hong et al. [23]. 6 mL pear paste sample was heated at 40°C for 30 min in a headspace bottle. The sample was directly detected using portable electronic nose PEN3 (Airsense, Germany) by headspace sampling. Determination conditions of the electronic nose were as

follows: cleaning time: 100 s, zeroing time: 5 s, preparation time: 5 s, air flow: 400 mL/min, determination time: 120 s, and response value of 100–102 s for 3 seconds were selected for result analysis. The response characteristics of 10 sensors of portable electronic nose PEN3 were shown in Table 2.

**2.5.2. Electronic Tongue Taste Determination.** Taste Sensing System CB402208 (Insent, Japan), the determination of electronic tongue taste was referred to by Guan et al. [24]. 40 mL of pear paste sample, reference solution (30 mmol/mL potassium chloride, 0.3 mmol/mL tartaric acid), positively charged membrane washing solution (10 mmol/mL potassium hydroxide, 100 mmol/mL potassium chloride, 30% (V/V) ethanol) and negatively charged membrane washing solution (100 mmol/mL hydrochloric acid 30% (V/V) ethanol) were taken into transparent samples cups respectively and then placed at the positions as required for the determination of electronic tongue. Taste indexes include sour, bitter, astringent, salty, fresh, sweet, richness, astringent aftertaste, and bitter aftertaste. The taste test condition was shown in Table 3.

**2.6. Statistical Analysis.** Each experiment was repeated three times. The data were processed and analyzed by Origin Pro 2021 software (OriginLab, USA), the significance and correlation were analyzed by SPSS Statistics 20 software (IBM, USA), the electronic tongue was analyzed and plotted by Excel 2016 (Microsoft, USA), and the electronic nose was analyzed and loaded by its own Winmuster software (Airsense, Germany).

## 3. Results and Discussion

**3.1. Effect of Concentration Temperatures on Sensory Score of Pear Paste.** Compared with the CK group, vacuum-concentrated pear paste had the higher sensory evaluation scores. Under the decompressor condition, the sensory scores became stably high from 55°C to 65°C. However, it generally showed a trend of decreasing after the concentration temperature exceeded 70°C (Figure 1). There was no significant difference among the 55°C, 60°C, and 65°C groups, the highest sensory score was obtained at 8.28, which was 1.19 times higher than that of the CK group, and in which the color of the paste was uniform, bright yellow paste, sweet and sour, delicious and stable. This might be the result that some heat-sensitive pigments decreased [25] and melanoidin increased under high temperatures [26, 27], thus affecting the sensory score. Therefore, the concentration temperatures of 55°C, 60°C, and 65°C were more suitable for maintaining the sensory quality of pear paste.

**3.2. Effect of Concentration Temperatures on Browning Degree of Pear Paste.** Browning degree is an important index to evaluate the apparent color of pear paste. The browning degree of pear paste under vacuum concentration temperature was lower than that in the CK group. With the increase

TABLE 1: Sensory evaluation of “Yali” pear paste.

Grade	Color (2 points)	Smell (2 points)	Taste (3 points)	Organization status (3 points)
Better	Bright yellow and uniform color (1.6–2.0 points)	With fresh pear, light caramel flavor, and no peculiar smell (1.6–2.0 points)	Sweet and sour taste delicious (2.1–3.0 points)	Translucent paste and stable state (2.1–3.0 points)
Good	Bright yellow and more uniform color (1.1–1.5 points)	With fresh pear, caramel flavor, and no peculiar smell (1.1–1.5 points)	Sweet and sour taste moderate (1.1–2.0 points)	Translucent paste and more stable state (1.1–2.0 points)
Common	Slight yellow and uneven color (0.5–1.0 points)	No fresh pear, strong caramel taste, and slightly peculiar smell (0.5–1.0 points)	Sour and sweet imbalance (0.5–1.0 points)	The paste is opaque and unstable (0.5–1.0 points)

TABLE 2: Response characteristics of electronic nose sensor PEN3.

Number	Model	Sensors	Response characteristics
1	W1C	Aromatic	Sensitive to aromatic compounds
2	W5S	Broad range	Sensitive to nitrogen oxides
3	W3C	Aromatic	Sensitive to ammonia and aromatic compounds
4	W6S	Hydrogen	Sensitive to hydrogen
5	W5C	Aliph-arom	Sensitive to alkane and aromatic compounds
6	W1S	Broad-methane	Sensitive to methane
7	W1W	Sulphur-organic	Sensitive to sulfides and terpenes
8	W2S	Broad-alcohol	Sensitive to alcohols and some aromatic compounds
9	W2W	Sulphachlor	Sensitive to organic sulfides and aromatic compounds
10	W3S	Methane-aliph	Sensitive to alkanes

TABLE 3: Electronic tongue taste determination conditions.

Order	Time
Cleaning solution 1 (sec)	90
Cleaning solution 2 (sec)	120
Cleaning solution 3 (sec)	120
Conditioning solution	30 sec, 20 min: 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5 mv
Sample solution (sec)	30
Cleaning solution 4 (sec)	3
Cleaning solution 5 (sec)	3
CPA solution (sec)	30

of concentration temperature, the browning degree generally decreased first and then increased after rising to 70°C and 75°C (Figure 2). When the concentration temperature was 65°C, the browning degree of pear paste was the lowest at 0.404 (OD<sub>420</sub>), which was only 60.12% of that in the CK group. The lower temperature was not suitable for the inhibition of the browning of pear paste, probably due to the longer concentration time [12]. In contrast, the higher concentration temperature might accelerate the Maillard reaction and caramelization rate, and then generate a large amount of melanoidin [26, 27], resulting in a higher browning degree. Previous studies have shown that the browning index of “Dangshan” pear paste was the smallest prepared by vacuum concentration at 70°C [12]. Similarly, here the concentration temperature at 65°C can more effectively control the browning of “Yali” pear paste during the concentration process.

**3.3. Effect of Concentration Temperatures on Vitamin C Content of Pear Paste.** Vitamin C has strong antioxidant activity in food, but poor thermal stability, which is easy to

be oxidized and destroyed by high temperatures during processing [28]. The vitamin C content of pear paste under different temperature conditions was higher than that of the CK group. With the increase in concentration temperature, the vitamin C content of pear paste generally tended to increase first and then decrease (Figure 3). When the concentration temperature was 65°C, the vitamin C content reached the peak of 64.97 mg/100 mL, which was 310.86% of that in the CK group. When the concentration temperature continuously rose to more than 70°C, the vitamin C content decreased significantly ( $p < 0.05$ ). Previous studies have shown that the loss rate of vitamin C content in concentrated tomato juice prepared at 70°C and 80°C vacuum concentration temperature was higher than that in the 90°C groups [29]. Similarly, Zhao et al. showed that the vitamin C content of “Dangshan” pear paste prepared by vacuum concentration method was significantly higher than that by traditional boiling, which was the highest when the vacuum concentration temperatures were 60°C and 70°C, while the content decreased significantly when concentration temperature rise to 80°C. The vitamin C oxidation reaction was limited when concentrated in vacuum due to the extremely low oxygen

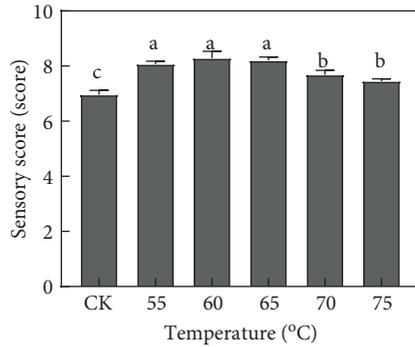


FIGURE 1: Sensory scores of “Yali” pear paste prepared under traditional heating concentration and vacuum concentration with different temperatures. CK: pear paste under traditional heating concentration; 55°C, 60°C, 65°C, 70°C, and 75°C: pear paste at different vacuum concentration temperatures; different letters indicated significant differences among groups ( $p < 0.05$ ).

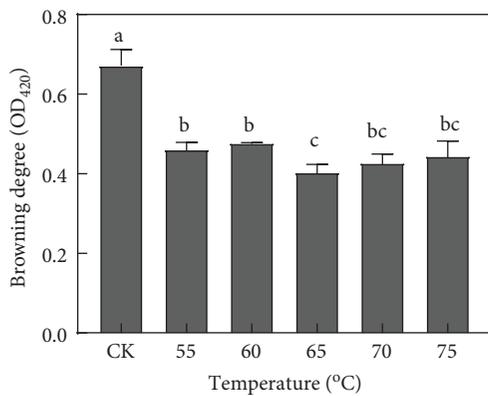


FIGURE 2: Browning degree of “Yali” pear paste prepared under traditional heating and vacuum concentration with different temperatures. CK: pear paste under traditional heating concentration; 55°C, 60°C, 65°C, 70°C, and 75°C: pear paste at different vacuum concentration temperatures; different letters indicated significant differences among groups ( $p < 0.05$ ).

concentration in the environment, which was one of the main reasons for the higher vitamin C content in vacuum groups. On the other hand, vitamin C will lose as a heat-sensitive substance with the increasing temperature and heating time. Hence, the amount of vitamin C may be the result of the joint action of temperature and heating time [12]. The vacuum concentration time was shortened with the increasing temperature, and the vitamin C was well maintained mainly benefiting from the shortened heating time before 70°C but severely damaged after that. Therefore, the concentration temperature of 65°C can effectively retain the vitamin C content in pear paste.

**3.4. Effect of Concentration Temperatures on Total Phenol and Flavonoid Content of Pear Paste.** Polyphenols and flavonoids are the main components that determine the antioxidant capacity of concentrated fruit juice. They often participate in a free radical scavenging reactions to reduce the oxidative stress

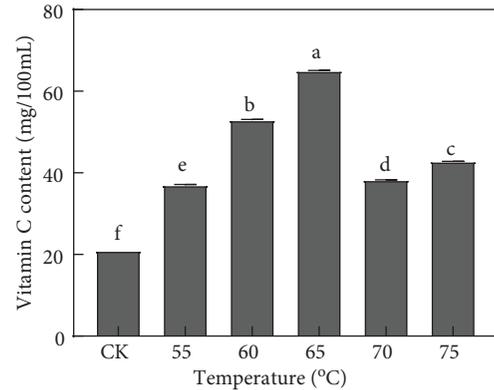


FIGURE 3: Vitamin C content of “Yali” pear paste prepared under traditional and vacuum concentrations with different temperatures. CK: pear paste under traditional heating concentration; 55°C, 60°C, 65°C, 70°C, and 75°C: pear paste at different vacuum concentration temperatures; different letters indicated significant differences among groups ( $p < 0.05$ ).

of organisms. However, polyphenols and flavonoids are easy to be oxidized and decomposed during processing due to their thermal instability, resulting in reduced product quality [30]. The total phenol and flavonoid contents of pear paste prepared under vacuum concentration were higher than those in the CK group. With the increase of concentration temperature, all vacuum concentration groups showed a trend of increase at first and then decrease (Figure 4). When the concentration temperature was 65°C, the contents of total phenol and flavonoid reached the peak, which was 148.24% and 209.44% of the CK group, respectively. When the concentration temperature continued to rise to 70°C and 75°C, the total phenol and flavonoid decreased the contents significantly ( $p < 0.05$ ). On the one hand, the concentration of fruit juice in an appropriate temperature range can promote the change of the noncovalent bond between polyphenols and other macromolecules in fruit juice, dissociating from the binding state, and leading to the increase of polyphenol content [31]. In addition, during the vacuum concentration process with the appropriate temperature, the thermal decomposition content of sucrose decreases, and the phenolic synthesis substrate increases, which will also increase the total phenolic content [32]. On the other hand, high temperature will degrade the variety of polyphenols and reduce the total phenol content, which was consistent with the research results of Liu et al. It was also reported that heating treatment significantly reduced the content of phenols in carrot juice with the temperature rising [33]. In this study, the total phenol and flavonoid contents of pear paste fluctuated at 60°C, 70°C, and 75°C, which may be a dynamic influence of multiple factors of concentration temperature, time, and polyphenol oxidase (PPO) enzyme activity. Roman Buckow et al. once reported that the PPO enzyme activity of apple juice was lost by 62% when treated at 55°C for 10 min, while it lost by more than 95% when treated at 65°C, 70°C for 10 min and 1 min [34], which may cause the decrease of phenol content. Therefore, the concentration temperature of 65°C was more suitable for the highest total phenol and flavonoid in pear paste.

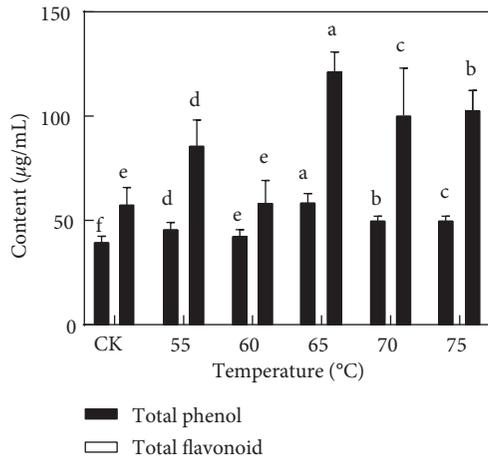


FIGURE 4: Total phenol and flavonoid content of “Yali” pear paste prepared under traditional and vacuum concentrations with different temperatures. CK: pear paste under traditional heating concentration; 55°C, 60°C, 65°C, 70°C, and 75°C: pear paste at different vacuum concentration temperatures; different letters indicated significant differences among groups ( $p < 0.05$ ).

**3.5. Effect of Concentration Temperatures on Soluble Quinone Content of Pear Paste.** Soluble quinone is a kind of enzymatic browning product, which is affected by temperature, pH value, and other factors [18]. The content of soluble quinones in “Yali” paste prepared by vacuum concentration was significantly lower than that in the CK group ( $p < 0.05$ ) except 70°C groups, and with a trend that decreased at first and then increased with the concentration temperature (Figure 5). When the concentration temperature was 65°C, the content of soluble quinone in pear paste was the lowest as 0.086 ( $OD_{437}$ ), scilicet 72.88% of that in the CK group. There was a reversible reaction between phenols and quinones, while appropriate temperature conditions can reduce the browning intermediate quinones to phenols [35]. The contents of total phenol and soluble quinone showed an inverse trend in this study since soluble quinone was the intermediate product of phenolic substance browning. Therefore, the concentration temperature of 65°C can more effectively prevent the accumulation of soluble quinones, which will contribute to reducing browning.

**3.6. Effect of Concentration Temperatures on Antioxidant Capacity of Pear Paste.** Free radicals are the intermediate products of physiological and biochemical reactions in body tissues. Normally, less than 3% excess free radicals can be cleared by the human free radical scavenging system except for some free radicals involved in normal metabolism. Excess accumulation of free radicals is an important risk factor for inducing diseases [36]. Therefore, the free radical scavenging capacity together with the total reducing capacity was selected to evaluate the antioxidant activity of “Yali” paste. While antioxidant capacity is one of the important biological functional indicators to evaluate product quality in pear paste. In this study, DPPH free radical, ·OH free radical scavenging rate, and total reducing capacity were

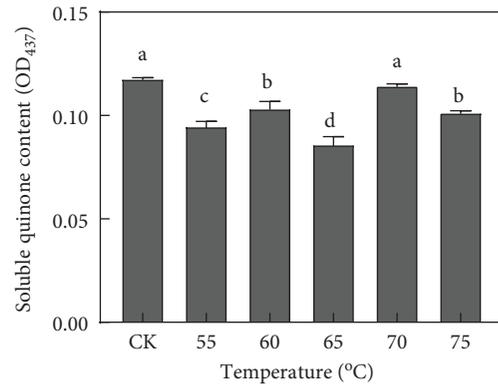


FIGURE 5: Soluble quinone content of “Yali” pear paste prepared under traditional and vacuum concentrations with different temperatures. CK: pear paste under traditional heating concentration; 55°C, 60°C, 65°C, 70°C, and 75°C: pear paste at different vacuum concentration temperatures; different letters indicated significant differences among groups ( $p < 0.05$ ).

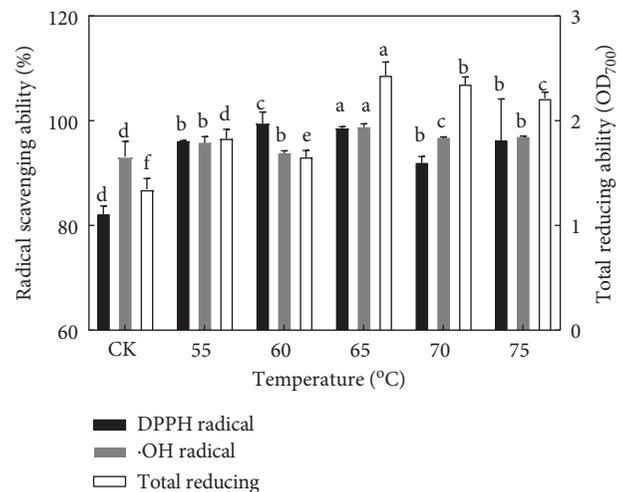


FIGURE 6: Antioxidant capacity of “Yali” pear paste prepared under traditional and vacuum concentrations with different temperatures. CK: pear paste under traditional heating concentration; 55°C, 60°C, 65°C, 70°C, and 75°C: pear paste at different vacuum concentration temperatures; different letters indicated significant differences among groups ( $p < 0.05$ ).

tested to evaluate the antioxidant capacity of “Yali” paste under different vacuum concentration temperatures. The DPPH free radical, OH free radical scavenging rate and total reduction capacity of “Yali” paste made by vacuum concentration were significantly higher than those of the CK group (Figure 6), and in which there were highest at 65°C of the concentration temperature. When the vacuum concentration temperature rose to 70°C and 75°C, the antioxidant capacity of the “Yali” paste decreased significantly ( $p < 0.05$ ). This result was consistent with the changes in total phenol, total flavonoid, and vitamin C content under different concentration temperatures since they were antioxidant components and determines the strength of antioxidant capacity [37]. Therefore, the concentration temperature of 65°C could more effectively improve the antioxidant capacity of pear paste.

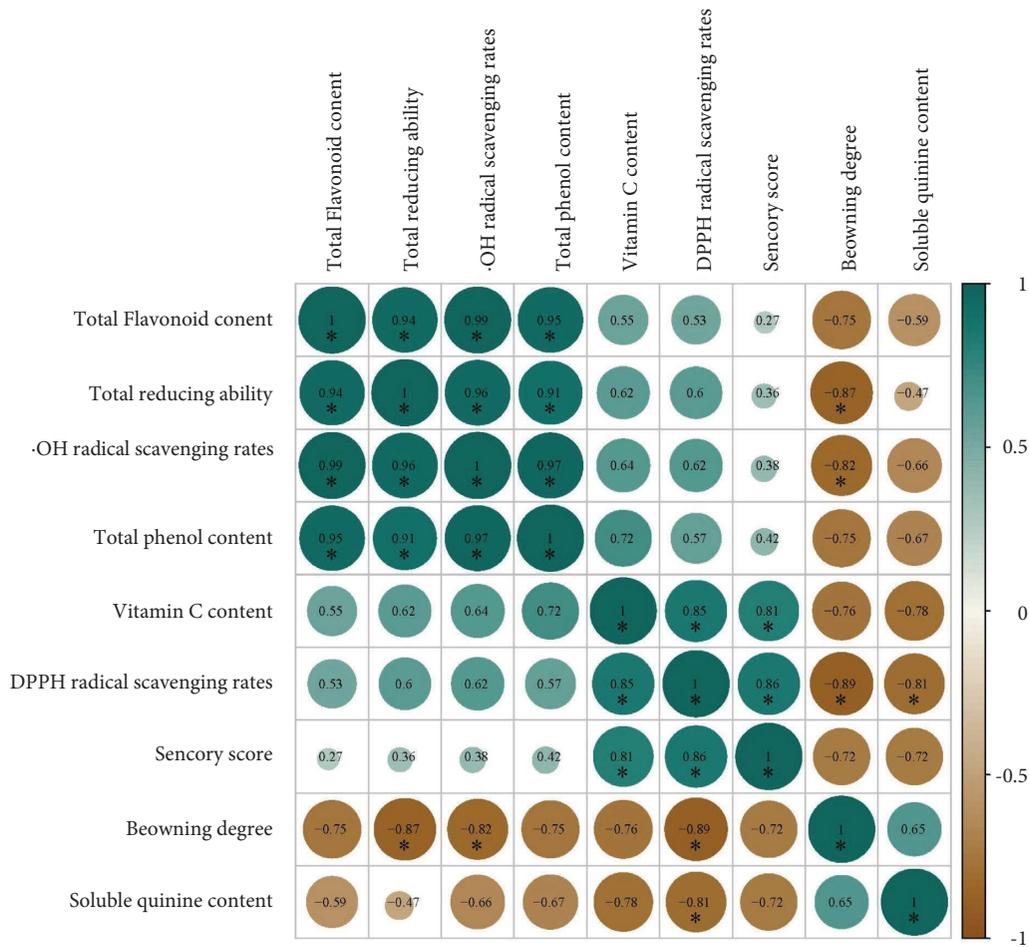


FIGURE 7: Pearson correlation analysis of various indexes under traditional heating and vacuum concentration temperatures. \*indicated significant correlation ( $p < 0.05$ ).

3.7. Correlation Analysis among Variables of “Yali” Pear Paste at Concentration Temperatures. The results (Figure 7) showed that there was a very significant positive correlation among the total phenol content, total flavonoid content, OH radical scavenging rates, and total reducing ability, demonstrating that phenol, and flavonoid were closely related to antioxidant ability. It should be noted that the Vitamin C content was positively correlated with DPPH radical scavenging rate, indicating that vitamin C might be involved in DPPH radical scavenging. Meanwhile, the browning degree was negatively correlated with DPPH radical scavenging rate, OH radical scavenging rates, and total reduction ability. The content of soluble quinones was negatively correlated with DPPH radical scavenging rate since the browning degree was an important indicator of fruit oxidation. The research results of Jahan et al. showed that the of total phenol content, total flavonoid content and the antioxidant activity of honey samples showed a strong correlation before and after heating treatment [38]. Rietjens et al. considered that the phenols, flavonoids, vitamin C, vitamin E, and other compounds in fruits and their products were the important functional antioxidant components [39]. Nowak et al. found that there was a significant correlation between the content of vitamin C in fruit juice and its DPPH radical scavenging

capacity when studying the antioxidant properties of different fruit juices, with the correlation coefficient reaching  $R^2$  to 0.886 [40]. In general, vitamin C, phenols, and flavonoids were the basic substances for “Yali” pear paste to exert its antioxidant activity, while browning degree and soluble quinones were related to soluble quinones oxidation.

3.8. Analysis of Electronic Nose Odor Measurement Results. The principal component analysis was carried out by using the Winmuster software provided by the electronic nose. The signal results of 10 sensors were divided into the first principal component (PC1) and the second principal component (PC2). The total contribution rate of volatile substances in “Yali” pear paste could reach 98.95%, which fully covered the main information of pear paste samples. The group distribution characteristics of data on PC1 were the main factors that determined the discrimination effect (Figure 8). The model showed that the first principal component of vacuum-concentrated pear paste and CK group pear paste could be completely separated, indicating that there were significant differences in smell indexes between the two kinds of “Yali” pear paste.

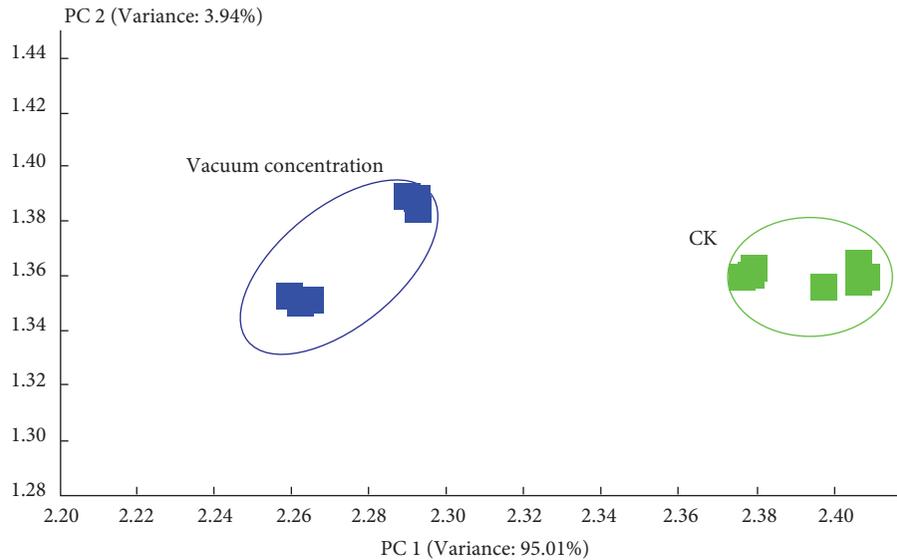


FIGURE 8: PCA model analysis diagram of “Yali” pear paste prepared under traditional heating and vacuum concentration temperatures. CK: pear paste prepared by traditional heating concentration; Vacuum concentration: pear paste prepared at 65°C of vacuum concentration.

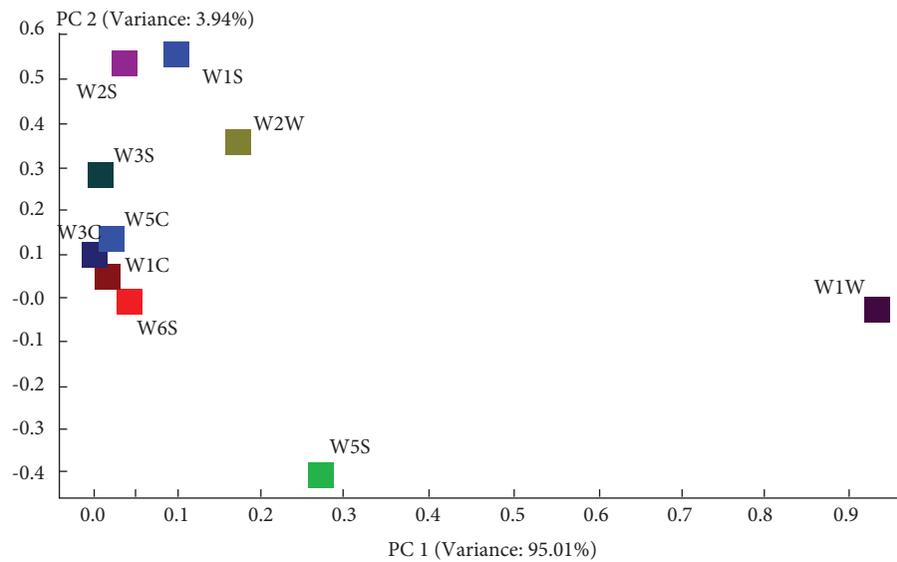


FIGURE 9: Loading load analysis diagram of “Yali” pear paste prepared under traditional heating and vacuum concentration temperatures.

The loading analysis was used to analyze the discrimination effect of each sensor (Figure 9). The contribution rate of the first principal component (PC1) was 95.01%. The discrimination effect was more effective while the characteristic value of PC1 increased. When the distribution was close to the origin (0, 0), the discrimination effect of the sensor on the samples became smaller [41]. The results showed that the three sensors W1W, W5S, and W2W had obvious distinguishing effects.

Among them, the W1W sensor (sensitive to sulfides and terpenes) had the largest contribution rate, accounting for 98.95% of the total variables. It was the main sensor used to distinguish vacuum-concentrated “Yali” pear paste from the CK group.

*3.9. Analysis of Electronic Tongue Taste Test Results.* It can be seen from Figure 10 that the richness and freshness de-

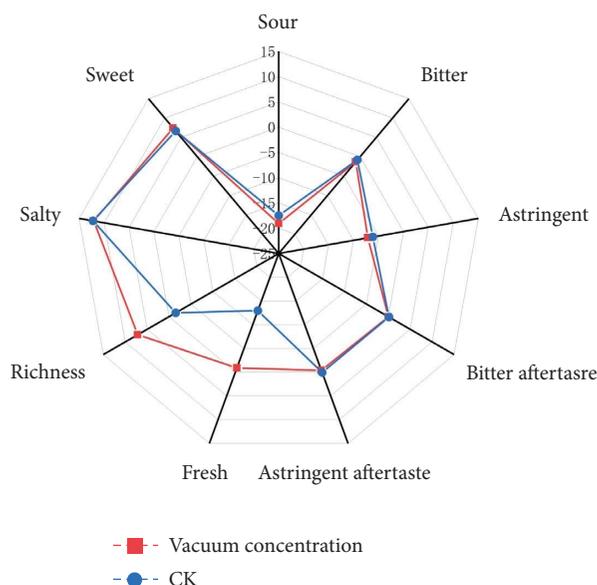


FIGURE 10: Taste radar map of “Yali” pear paste prepared under traditional and vacuum concentration temperatures.

tection sensor response values of the vacuum-concentrated sample were significantly higher than those of the CK group, but there were no significant changes in saltiness, sweetness, acidity, bitterness, astringency, astringent aftertaste, and bitter aftertaste. This result indicated that under suitable vacuum concentration conditions, the characteristic flavor substances of “Yali” pear paste could be better retained [42].

#### 4. Conclusion

In this study, “Yali” pear was used as the raw material to prepare “Yali” pear paste by vacuum concentration and traditional heating method. The physicochemical indexes and antioxidant capacity were measured and compared. According to the comprehensive consideration of multiple indexes, the optimal concentration temperature of vacuum-concentrated “Yali” pear paste was determined to be 65°C. Under the optimum condition of vacuum concentration, “Yali” pear paste had the lowest browning degree and soluble quinone content, the highest content of total phenol, total flavonoid, and vitamin C, antioxidant capacity, and sensory quality evaluation. The results of correlation analysis showed that there were significant correlations among the contents of total phenol, flavonoid, vitamin C, and antioxidant ability. The electronic nose could effectively distinguish between vacuum-concentrated “Yali” pear paste and traditional heating-concentrated “Yali” pear paste, and the electronic tongue test showed that the changes of richness and freshness of vacuum-concentrated “Yali” pear paste were significantly higher. Thus, the optimized vacuum concentration condition was suitable for the preparation of “Yali” pear paste and had good applicable potential.

#### Data Availability

All basic data supporting the results of this study were available through the corresponding author.

#### Conflicts of Interest

The authors declared that they have no conflicts of interest.

#### Authors’ Contributions

Yue Li and Yongxia Wang have contributed equally to this work.

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