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Article

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STUDY ON THE EFFECT OF ANTIOXIDANTS ON THE QUALITY AND ANTIOXIDANTS CAPACITY OF DUCK SAUSAGES

Areca taro is a plant of the Araceae family, which is rich in starch and dietary fiber. Taro is boiled and mashed to make a paste, which is called taro paste. The fat content of duck sausages is high, and the nutritional composition of sausages can be improved by adding taro puree and provide the special aroma of taro in the sausages. Thus, the research object is duck sausage with taro paste.

This study aimed to improve the quality and prevent oxidation of duck sausage with taro paste by adding ginger juice, onion juice and sodium erythorbate as safe antioxidants. The quality characteristics of sausages were evaluated by analyzing the cooking loss, colour, texture and sensory changes, and the optimal amount of antioxidants was obtained by analyzing the acid value, TBARS value, and DPPH free radical scavenging rate.

The research results show that adding D-sodium erythorbate to duck sausage can significantly reduce the hardness of the sausage, maintain the elasticity of the sausage, and effectively slow down the pH value of the sausage during the oxidation process. The water retention and oil retention of duck sausage maintain the brightness value of the sausage. The sausage with D-sodium erythorbate has better antioxidant capacity. The acid value and TBARS value of the sausage added with D-sodium erythorbate at 18 h were significantly lower than those of the control group ($P<0.05$), and the DPPH was significantly increased.

This technology can provide data support and reference for food processing companies. The taro paste would be widely used as food ingredients in future.

Keywords: *Areca taro, taro paste, duck sausages, sausage quality, antioxidants.*

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1. Introduction

Meat products contain saturated fatty acids, cholesterol and other components. Excessive intake can easily lead to obesity, diabetes, cardiovascular disease and other health problems [1]. Sausages contain 20–30 % fat, which maintains the unique flavour and texture properties of sausages while increasing satiety. Plant raw materials contain a lot of dietary fiber and are often used by researchers to replace fat in sausages [2]. Researchers are more concerned about the taste and texture changes caused by fat replacement.

Taro is widely distributed in subtropical regions. Because it contains more starch and fibber, it is mashed into taro paste after processing and cooking. The taro paste is glutinous in texture and rich in flavour. It is often used to make milk tea and fillings [3]. Taro puree blends well with fat. Therefore, it is very innovative to use taro paste as a raw material for sausage processing and to replace part of the fat.

Meat is prone to oxidation during processing and storage and the main types of oxidation are lipid oxidation and protein oxidation. Oxidation will reduce the quality of meat, including odour, discoloration, nutrient loss, and the formation of toxic substances. Eating spoiled meat will threaten human health and even life safety [4]. Therefore, it is very necessary to add some natural and safe antioxidants in the sausage making process.

Sodium erythorbate, as a new biological food antioxidant and preservative, has good antioxidant properties, high thermal stability, safety, non-toxicity and high efficiency. It is widely used in the processing of sausages, ham sausages, canned meat and other meat products. In order to delay the oxidative deterioration of the product, maintain the colour and flavour of the product, and prolong the shelf life of the product [5]. Authors of [6] found in the study that different amounts of sodium erythorbate were added, and their antioxidant effects were different. Adding 0.4 % sodium erythorbate could significantly reduce the TBARS value of fish, and its antioxidant effect was better than other groups. Authors of [7] added D-sodium erythorbate to sausages, and measured the oxidation index of sausages at different times. The results found that D-sodium erythorbate can effectively inhibit the oxidation of sausages, and the oxidation effect of sausages with an addition

amount of 0.1 %. It is better than the sausage with the addition amount of 0.05 % [7].

During processing and storage, the lipids and proteins of sausages will be oxidized, which will lead to product deterioration, produce odour and toxic substances, and seriously shorten the shelf life of the product. Therefore, in this study, duck sausage with taro paste was taken as *the research object*. *This study aimed* to improve the quality and prevent oxidation of duck sausage with taro paste by adding ginger juice, onion juice and sodium erythorbate as safe antioxidants.

2. Research methodology

Four treatments were set up in this study. In the duck meat and taro paste sausage, they were control group *Y*1, ginger juice group *Y*2, sodium erythorbate *Y*3, and sodium erythorbate + ginger juice compound group *Y*4. By measuring the accelerated oxidation test (0 h, 3 h, 6 h, 9 h, 12 h, 15 h, 18 h) the acid value, TBARS value, DPPH free radical scavenging rate, and sausage texture, colour, cooking loss and other indicators of sausages in each group to obtain the best taro Antioxidant formula of mud duck meat. To provide theoretical reference and data support for the application of antioxidants in duck taro sausage.

In this study, the characteristic fruit and vegetable Areca taro of south China was used as the experimental material. Firstly, the Areca taro was peeled, sliced, boiled and beaten, and then use hot air drying to dry the water content of taro paste to 50 %, set aside.

Sausage production process: peeling raw meat (duck breast, chicken breast) ground → add accessories → mix evenly → enema → place in a ventilated place to dry the surface moisture of casings → oven 60 °C bake for 60 min → → after cooling, boil in 80–85 °C water for 30 min → → finished product.

Sausage formula composition: The design of duck sausage formula see Table 1. Among them, the addition of ginger juice in the duck sausage formula with sodium isoascorbate was adjusted by changing the amount of ice water, so as to ensure that the total weight of ginger juice and ice water in each group was 80 g. The accelerated oxidation test of sausage refers to the method of Yang Yifang et al. [8]. Sausages are placed in an oven at 50 °C for accelerated oxidation treatment, and the accelerated oxidation is 0 h, 3 h, 6 h, 9 h, 12 h, 15 h and 18 h, respectively.

Table 1

Duck-chicken sausage recipe with different additions of mashed taro instead of potato starch

Ingredients (g)	Treatment			
	*Y*1	*Y*2	*Y*3	*Y*4
Duck meat	600	600	600	600
Chicken breast	400	400	400	400
Taro paste	160	160	160	160
Wheat bran	12	12	12	12
Potato starch	70	70	70	70
Rice wine	20	20	20	20
Onion Juice	20	20	20	20
Ice water	80	50	80	50
Other ingredients	28	28	28	28
Sodium D-isoascorbate	0	0	2	2
Ginger Juice	0	30	0	30

Note: other ingredients include 14 g of salt, 2 g of complex phosphate, 6 g of complex spices, 4 g of pepper and 2 g of beet red

Cooking loss: Refer to the method of Jiang Shuai [9]. Weigh 35 g minced meat into a 50 ml centrifuge tube and centrifuge (3000 rpm, 5 min) to remove air bubbles in the tube. Then, heat it in a water bath (75 °C, 30 min), cool the heated sample at room temperature for 1 hour, weigh it after cooling, and record its mass.

The calculation of cooking loss is shown in formula:

$$C = \frac{W_{rmb} - W_{cmb}}{W_{rmb}} \cdot 100\ \%, \quad (1)$$

where C – cooking loss (%); W_{rmb} – weight of raw meat batters (g); W_{cmb} – weight of cooked meat batters (g).

Emulsion stability: Pour the liquid lost during cooking (centrifuge tube upside down for 40 minutes) into a glass dish. Moisture loss is the weight of the liquid lost by cooking and drying after heating at 105 °C for 16 hours, while fat loss is the mass of the sample remaining after the drying of the liquid lost by cooking [9]. The calculation of water loss and fat loss is shown in formulas:

$$M_l = \frac{W_{cl} - R_{wah}}{W_{rmb}} \cdot 100\ \%, \quad (2)$$

$$F_l = \frac{R_{wah}}{W_{rmb}} \cdot 100\ \%, \quad (3)$$

where M_l – moisture loss (%); W_{cl} – weight of cooking liquid; R_{wah} – remaining weight after heating; W_{rmb} – weight of raw meat batter; F_l – fat loss (%).

Determination of color: Remove the casing of the sausage cooled to room temperature and cut it into a 2 cm cylinder. Use CR-400 color difference meter (Changzhou Shoufeng Instrument Technology Co., LTD, China) for determination. Calibrate the sausage with white board before determination.

Hardness and elasticity measurement: Referring to the method of Chen Yichun et al. [10], the sausage casing was first peeled off and cut into a 2 cm high cylinder. Specific measurement parameters were set as follows: measurement mode was TPA, probe model was P/50, pre-measurement rate was 5 mm/s, test and post-measurement rates were 1 mm/s, compression ratio was 50 %, and trigger force was 5 g.

Determination of acid value: Refer to the method of Li Yalei et al. [11]. Add 50 mL neutral diethyl ether-ethanol (2:1) solution, mix well, add 3 drops phenolphthalein, and titrate with 0.05 mol/L potassium hydroxide standard solution. The mixture in the conical bottle appears reddish and does not fade within 30 s, which is the end point of titration. Record the consumed volume of the standard solution. The calculation formula of acid value is as follows:

$$A_v = \frac{v \cdot c \cdot 56.1}{m}, \quad (4)$$

where A_v – acid value (mg/kg); v is the volume (mL) of potassium hydroxide standard solution consumed by the sample for determination; c is the concentration (mol/L) of potassium hydroxide standard solution; m is the weight (g) of the sample; 56.1 is the molar mass (g/mol) of potassium hydroxide.

TBARS measurement: Refer to the method of Li Yalei et al. [11] and make slight changes. 10 g of the sample was ground, and 50 mL of 7.5 % trichloroacetic acid solution was added. The sample was placed in a shaking table and mixed

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evenly for 30 min. Then the supernatant of the sample was extracted with double-layer qualitative filter paper. 5 mL supernatant was taken into the test tube, 5 mL thiobarbituric acid solution was added and placed in a water bath at 90 °C for 40 min. After taking out, the solution was placed in room temperature for cooling. Centrifuge speed was set at 4000 r/min and centrifuged for 5 min.

DPPH determination: The free clearance rate of *DPPH* (1, 1-diphenyl-2-trinitrophenylhydrazine) was determined by referring to Sridhar Kandi's method [12, 13]: 2.0 mL of extract was accurately removed and 1, 1-diphenyl-2-trinitrophenylhydrazine solution (2.0 mL) was added to avoid light reaction. The absorbance value *A*1 (517 nm) was determined after 20 min. Under the same conditions, the absorbance value of the control group was *A*2 (anhydrous ethanol instead of *DPPH*), and that of the blank group was *A*0 (anhydrous ethanol instead of sample). Calculate sample pairs according to the following formula *DPPH* free radical scavenging rate:

$$DPPH = \left[1 - \frac{A1 - A2}{A0}\right] \cdot 100\ \%, \quad (5)$$

where *A*0 is the absorption value of the blank group; *A*1 is the absorption value of the sample; *A*2 is the absorption value of the control group.

Each data was measured three times, and the results were expressed in the form of «mean ± standard deviation». Excel was used for data statistical processing, SPSS 25 was used for single factor analysis (ANOVA), Duncan method was used for significance difference test, and Origin software was used for plotting.

3. Research results and discussion

The results of cooking loss were shown in Table 2. The results showed that at 0 h, compared with the control group *Y*1, the cooking loss of sausages in *Y*2 and *Y*4 groups was significantly increased ($P<0.05$), while the cooking loss of sausages in *Y*3 group was significantly decreased ($P<0.05$). The cooking loss of sausages in *Y*1 and *Y*3 groups showed a gentle downward trend as a whole, while the cooking loss of sausages in *Y*2 and *Y*4 groups decreased sharply at 12 h, suggesting that the addition of D-isoascorbate sodium could reduce the cooking loss of sausages, while the addition of ginger juice could increase the cooking loss of sausages.

The changes of emulsifying stability of duck sausage were shown in Table 3 and Table 4. At 0 h, compared with the control group *Y*1, the moisture loss of sausage in *Y*2 and *Y*4 groups was significantly increased, while that in *Y*3 group was the lowest ($P<0.05$). There was no significant difference in fat loss in *Y*2 and *Y*3 groups at 0 h ($P<0.05$). These results indicate that the addition of D-isoascorbate sodium can improve the water loss and fat loss of sausage, and improve the emulsifying stability of sausage.

Table 2

Changes in cooking loss (*C*) during accelerated oxidation of duck sausage

Treatment	Cooking loss						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
*Y*1	0.24 ± 0.02^{c}	0.16 ± 0.02^{c}	0.11 ± 0.00^{c}	0.08 ± 0.02^{d}	0.07 ± 0.02^{b}	0.05 ± 0.02^{a}	0.04 ± 0.02^{a}
*Y*2	0.66 ± 0.00^{a}	0.61 ± 0.02^{a}	0.54 ± 0.03^{a}	0.47 ± 0.01^{a}	0.14 ± 0.03^{a}	0.07 ± 0.01^{a}	0.04 ± 0.01^{a}
*Y*3	0.18 ± 0.02^{d}	0.15 ± 0.02^{c}	0.13 ± 0.02^{c}	0.12 ± 0.02^{c}	0.08 ± 0.02^{b}	0.07 ± 0.02^{a}	0.04 ± 0.02^{a}
*Y*4	0.53 ± 0.02^{b}	0.42 ± 0.02^{b}	0.41 ± 0.02^{b}	0.37 ± 0.03^{b}	0.12 ± 0.02^{a}	0.07 ± 0.01^{a}	0.05 ± 0.01^{a}

Note: different letters in the same column indicate significant difference ($P<0.05$)

Table 3

Changes in moisture loss (M_l) during accelerated oxidation of duck sausage

Treatment	Moisture loss						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
*Y*1	0.17 ± 0.00^{c}	0.10 ± 0.02^{c}	0.08 ± 0.02^{c}	0.06 ± 0.00^{c}	0.05 ± 0.02^{b}	0.04 ± 0.02^{a}	0.03 ± 0.00^{a}
*Y*2	0.56 ± 0.02^{a}	0.54 ± 0.00^{a}	0.48 ± 0.02^{a}	0.42 ± 0.03^{a}	0.10 ± 0.02^{a}	0.05 ± 0.01^{a}	0.03 ± 0.01^{a}
*Y*3	0.14 ± 0.00^{d}	0.11 ± 0.03^{c}	0.10 ± 0.02^{c}	0.09 ± 0.03^{c}	0.05 ± 0.02^{b}	0.06 ± 0.00^{a}	0.03 ± 0.00^{a}
*Y*4	0.47 ± 0.02^{b}	0.37 ± 0.03^{b}	0.37 ± 0.00^{b}	0.33 ± 0.02^{b}	0.10 ± 0.02^{a}	0.05 ± 0.01^{a}	0.04 ± 0.01^{a}

Note: different letters in the same column indicate significant difference ($P<0.05$)

Table 4

Changes in fat loss (F_l) during accelerated oxidation of duck sausage

Treatment	Fat loss						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
*Y*1	0.07 ± 0.02^{ab}	0.06 ± 0.00^{a}	0.04 ± 0.02^{a}	0.02 ± 0.02^{a}	0.02 ± 0.02^{a}	0.01 ± 0.02^{a}	0.01 ± 0.02^{a}
*Y*2	0.10 ± 0.02^{a}	0.07 ± 0.02^{a}	0.07 ± 0.02^{a}	0.05 ± 0.01^{a}	0.04 ± 0.02^{a}	0.02 ± 0.02^{a}	0.01 ± 0.01^{a}
*Y*3	0.04 ± 0.02^{b}	0.04 ± 0.02^{a}	0.04 ± 0.02^{a}	0.04 ± 0.02^{a}	0.03 ± 0.00^{a}	0.01 ± 0.02^{a}	0.01 ± 0.02^{a}
*Y*4	0.07 ± 0.02^{ab}	0.05 ± 0.02^{a}	0.04 ± 0.02^{a}	0.04 ± 0.02^{a}	0.02 ± 0.02^{a}	0.02 ± 0.02^{a}	0.01 ± 0.02^{a}

Note: different letters in the same column indicate significant difference ($P<0.05$)

In conclusion, the addition of D-isoascorbate sodium can improve the water retention, oil retention and emulsification stability of duck meat sausage, and improve the quality characteristics of sausage.

The color value can measure the quality of meat products. The changes of the color value of sausage (L^*, A^*, B^*) were shown in Tables 5–7.

L^* represents the brightness value of the product. The larger the L^* value, the brighter the sausage; the smaller the L^* value, the darker the sausage. As can be seen from Table 5, L^* values of the four groups of sausages showed an overall downward trend, indicating that the oxidation degree of sausages became more serious with the extension of accelerated oxidation time. Compared with the control group, the sausage added with D-isoascorbate sodium (*Y*3 group) had the least change in L^*, followed by the sausage added with ginger juice combined with D-isoascorbate sodium (*Y*4 group), indicating that the addition of D-isoascorbate sodium can better maintain the brightness of the sausage.

A^* represents the redness value of the product. The larger the value is, the sausage is red; otherwise, it is green. As can be seen from Table 6, the A^* value of sausages in group *Y*3 was higher than that in group *Y*1 in the whole accelerated oxidation process. In the accelerated oxidation process, a^* of each group showed a decreasing trend. At 0 h, the levels of *Y*3 group were significantly higher than those of the other three groups ($P<0.05$), which indicated that the addition of D-isoascorbic acid could maintain the color of sausage. Group *Y*2 had the lowest A^*, which may be due to the ginger color of the ginger juice itself affecting the color of the sausage.

B^* represents the yellowness value of the product. The higher the value is, the more yellow the sausage is; otherwise, the bluer the sausage is. It can be seen from Table 7 that the B^* value of sausages in the four groups fluctuated between 11 and 14. At 18 h, there was no significant difference in the B^* value of sausages in each group, among which the B^* value of group *Y*3 was the lowest, while the B^* value of group *Y*2 was higher than that of the other three groups, which may be due to the ginger color of ginger juice, thus affecting the yellowness of sausages. The results showed that sodium D-isoascorbate could delay the oxidation and keep the good color of sausage during the accelerated oxidation process.

Texture is an important index to evaluate the quality of meat products. Table 8 and Table 9 respectively showed the changes of hardness and elasticity of sausages in each group during accelerated oxidation. As shown in the Table 9, compared with control group *Y*1, adding antioxidant substances can significantly reduce the hardness and elasticity of sausage ($P<0.05$), and the value of sausage in group *Y*3 is closer to that in group *Y*1, followed by group *Y*2.

Table 5

Changes of L^* in accelerated oxidation of duck sausage

Treatment	L^*						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
*Y*1	64.70 ± 0.63^{b}	64.56 ± 0.37^{a}	64.01 ± 0.13^{b}	62.90 ± 0.30^{a}	61.55 ± 2.37^{a}	59.28 ± 0.66^{b}	56.44 ± 1.14^{b}
*Y*2	66.01 ± 0.29^{a}	64.03 ± 0.17^{b}	64.70 ± 0.16^{a}	62.14 ± 0.16^{b}	61.71 ± 0.10^{a}	60.64 ± 0.81^{a}	58.50 ± 0.50^{a}
*Y*3	63.47 ± 0.12^{c}	63.43 ± 0.12^{c}	61.23 ± 0.10^{d}	63.18 ± 0.18^{a}	62.91 ± 0.21^{a}	60.06 ± 0.64^{ab}	59.32 ± 0.48^{a}
*Y*4	63.54 ± 0.10^{c}	62.46 ± 0.18^{d}	62.38 ± 0.24^{c}	62.95 ± 0.15^{a}	62.11 ± 0.37^{a}	60.42 ± 0.64^{a}	58.97 ± 0.28^{a}

Note: different letters in the same column indicate significant difference ($P<0.05$)

Table 6

Changes of a^* in accelerated oxidation of duck sausage

Treatment	a^*						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
*Y*1	9.20 ± 0.28^{c}	9.76 ± 0.12^{c}	8.79 ± 0.16^{b}	8.06 ± 0.28^{c}	7.96 ± 0.10^{c}	7.13 ± 0.04^{c}	7.70 ± 0.18^{a}
*Y*2	7.31 ± 0.09^{d}	7.28 ± 0.15^{d}	8.07 ± 0.07^{c}	8.08 ± 0.13^{c}	8.35 ± 0.15^{c}	6.88 ± 0.10^{c}	6.80 ± 0.73^{b}
*Y*3	12.00 ± 0.34^{a}	10.76 ± 0.11^{a}	10.83 ± 0.29^{a}	10.18 ± 0.10^{a}	9.12 ± 0.24^{b}	9.06 ± 0.16^{a}	8.15 ± 0.42^{a}
*Y*4	11.45 ± 0.33^{b}	10.32 ± 0.24^{b}	10.79 ± 0.11^{a}	9.73 ± 0.17^{b}	9.92 ± 0.41^{a}	8.14 ± 0.43^{b}	7.86 ± 0.34^{a}

Note: different letters in the same column indicate significant difference ($P<0.05$)

Table 7

Changes of b^* in accelerated oxidation of duck sausage

Treatment	b^*						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
*Y*1	12.16 ± 0.12^{ab}	12.70 ± 0.07^{a}	12.33 ± 0.39^{a}	12.57 ± 0.16^{ab}	12.99 ± 0.52^{a}	13.05 ± 0.16^{b}	12.25 ± 1.06^{a}
*Y*2	12.51 ± 0.10^{a}	12.36 ± 0.22^{a}	12.63 ± 0.16^{a}	12.72 ± 0.19^{a}	12.75 ± 0.06^{a}	13.67 ± 0.27^{a}	13.04 ± 0.28^{a}
*Y*3	11.95 ± 0.07^{b}	12.38 ± 0.07^{a}	11.75 ± 0.32^{b}	12.40 ± 0.48^{ab}	12.08 ± 0.39^{a}	12.57 ± 0.11^{b}	11.74 ± 1.59^{a}
*Y*4	11.77 ± 0.37^{b}	10.65 ± 0.38^{b}	12.45 ± 0.03^{a}	12.10 ± 0.27^{b}	12.65 ± 1.02^{a}	12.62 ± 0.49^{b}	12.86 ± 0.65^{a}

Note: different letters in the same column indicate significant difference ($P<0.05$)

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Table 8

Duck sausage accelerates the change in hardness during oxidation

Treatment	Hardness, *N*						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
*Y*1	7711.98±236.01^{a}	9345.14±39.51^{a}	10474.60±407.13^{a}	10994.38±474.39^{a}	11948.30±565.13^{a}	16553.41±750.76^{a}	18171.63±48.55^{a}
*Y*2	5372.17±93.25^{c}	8175.06±474.74^{b}	8701.91±186.04^{b}	9177.80±876.23^{b}	9377.24±437.44^{b}	11117.87±1380.22^{b}	12445.76±1331.83^{b}
*Y*3	6078.62±107.59^{b}	8579.89±152.80^{b}	9038.24±288.89^{b}	10079.42±683.89^{ab}	11804.25±1600.67^{a}	15343.77±433.56^{a}	18583.34±1248.98^{a}
*Y*4	3916.46±171.60^{d}	4770.97±54.94^{c}	5365.27±281.38^{c}	7300.15±423.05^{c}	8022.55±318.84^{b}	11020.07±1019.66^{b}	10591.80±404.94^{c}

Note: different letters in the same column indicate significant difference ($P<0.05$)

Table 9

Changes in elasticity during oxidation of duck sausage are accelerated

Treatment	Elasticity						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
*Y*1	0.85±0.03^{a}	0.80±0.01^{ab}	0.79±0.02^{a}	0.77±0.02^{a}	0.89±0.08^{a}	0.85±0.01^{a}	0.82±0.00^{b}
*Y*2	0.73±0.01^{b}	0.75±0.03^{b}	0.85±0.05^{a}	0.80±0.11^{a}	0.78±0.06^{b}	0.86±0.02^{a}	0.86±0.00^{a}
*Y*3	0.83±0.01^{a}	0.82±0.04^{a}	0.84±0.03^{a}	0.80±0.03^{a}	0.83±0.03^{ab}	0.81±0.01^{b}	0.79±0.01^{c}
*Y*4	0.68±0.07^{b}	0.77±0.02^{ab}	0.77±0.04^{a}	0.79±0.03^{a}	0.78±0.03^{b}	0.82±0.01^{b}	0.82±0.01^{b}

Note: different letters in the same column indicate significant difference ($P<0.05$)

It can be seen from Table 8 that with the extension of accelerated oxidation time, the hardness of sausages in each group presents an increasing trend, which may be due to the water loss of sausages caused by accelerated oxidation treatment at 50 °C, which leads to the gradual increase in the hardness of meat products. During the whole oxidation process, compared with the control group *Y*1, the hardness of sausage in *Y*2 and *Y*4 groups was significantly decreased ($P<0.05$), while the hardness of sausage in *Y*3 group was significantly different from that in *Y*1 group from 0 to 6 h, and was not significantly different from that in the control group afterwards, and surpassed that in the control group at 18 h.

As can be seen from Table 9, at 0 h, compared with the control group *Y*1, the elasticity of sausages in *Y*2 and *Y*4 groups was significantly reduced ($P<0.05$), while there was no significant difference between *Y*3 group and the control group ($P>0.05$), indicating that D-isoascorbate sodium could maintain the elasticity of sausages. There was no significant difference in the elasticity of sausages among all groups at 3–12 h ($P>0.05$), and at 18 h, the elasticity of sausages in *Y*3 group was the lowest, which may be due to the loose internal structure of sausages caused by severe water loss, which reduced the elasticity of sausages.

The change results of acid value in the accelerated oxidation process of duck sausage were shown in Table 10. In the process of accelerated oxidation, the acid value of sausages in each group showed a trend of gradual increase, indicating that the oxidation of sausages became more and more serious, and fat was continuously degraded to form fatty acids and accumulated. The results showed that there was no significant difference in the acid value of sausage between the treatment groups and the control group *Y*1 in the early stage ($P>0.05$), and the change was not significant, indicating that the antioxidant effect was not obvious in the early stage. As the extension of oxidation time, the treatment group increased, when 18 h, the acid value of sausage had significant difference ($P<0.05$), which the acid value of sausage *Y*3 group are among the lowest in the whole process of oxidation, the second is the *Y*2 groups, suggesting that *D* – different ascorbic acid sodium and ginger can effectively restrain the production of free fatty acids, in order to delay the oxidation of sausage.

However, after the combination of the two, its antioxidant effect was reduced, which may be due to the improper proportion of the combination. The acid value of sodium isascorbate was the best among the three treatment groups.

Table 10

Change of acid value during accelerated oxidation of duck sausage

Treatment	Acid value, mg/kg						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
*Y*1	1.79±0.11^{a}	1.83±0.13^{a}	1.95±0.07^{a}	2.05±0.12^{a}	2.23±0.05^{a}	2.92±0.09^{a}	3.50±0.13^{a}
*Y*2	1.77±0.09^{a}	1.81±0.09^{a}	1.85±0.06^{ab}	1.99±0.09^{ab}	2.02±0.11^{b}	2.28±0.14^{bc}	2.79±0.11^{c}
*Y*3	1.62±0.06^{a}	1.66±0.09^{a}	1.74±0.06^{b}	1.85±0.06^{b}	1.96±0.06^{b}	2.13±0.11^{c}	2.43±0.06^{d}
*Y*4	1.68±0.11^{a}	1.69±0.09^{a}	1.76±0.06^{b}	1.96±0.06^{ab}	2.09±0.09^{ab}	2.48±0.09^{b}	3.01±0.11^{b}

Note: different letters in the same column indicate significant difference ($P<0.05$)

The *TBARS* results were shown in Table 11. The *TBARS* values of sausages in the four groups show a gradually rising trend, and the *TBARS* values of sausages in the three treatment groups are significantly lower than those in the control group *Y*1 during the whole oxidation process ($P<0.05$). At 0 h, the *TBARS* values of sausages in *Y*2 and *Y*3 groups were significantly decreased compared with the control group ($P<0.05$), while the *TBARS* values of sausages in *Y*4 group were also significantly different from those in *Y*1 group, but the difference was not significant, indicating that ginger juice and D-isoascorbate sodium could both inhibit lipid oxidation of sausages, but the combination of the two would reduce the antioxidant capacity of sausages. There was no significant difference between the treatment groups at 3–12 h ($P>0.05$), but there was a significant difference between the treatment groups and the control group at *Y*1 ($P<0.05$). At 18 h, the *TBARS* value of sausage in *Y*3 group was significantly lower than that in control group *Y*1, treatment group *Y*2 and *Y*4 ($P<0.05$). Compared with the TBARS values of the four groups, the sausages in *Y*3 group have better antioxidant capacity, that was, D-isoascorbate sodium can effectively inhibit the lipid oxidation of sausages and prolong the storage time of sausages.

Table 12 showed the results of *DPPH* free radical scavenging ability of duck meat sausage. In the oxidation process, *DPPH* free radical scavenging rate of the four groups of sausages showed a decreasing trend as a whole.

The clearance rate of *Y*2 and *Y*3 groups was not significantly different from that of control group *Y*1 at 0–6 h ($P>0.05$), and then was significantly different from that of control group *Y*1 ($P<0.05$). However, there was no significant difference between *Y*1 and *Y*4 group at 0 and 3 h, and there were significant differences between *Y*1 group and *Y*4 group at 0 h and 3 h. At 18 h, the DPPH free radical scavenging rate of the three treatment groups was higher than that of the control group, and the scavenging rate of group *Y*3 was slightly lower than that of group *Y*2 and group *Y*4. These results indicated that ginger juice, D-isoascorbate sodium and ginger juice combined with D-isoascorbate sodium could inhibit the oxidation of sausage well in the early stage, but the antioxidant capacity of sausage in the three groups decreased gradually in the late stage, but was significantly higher than that in the control group *Y*1 ($P<0.05$).

In theory, ginger juice can not only remove the fishy smell of duck meat and improve the taste of sausage, but also have antioxidant effects. However, the antioxidant capacity of erythorbic acid+ginger juice treatment group (*Y*4) in this study is not the strongest, especially *TBARS*. The results are not ideal. In addition, the total number of colonies and *E. coli* counts of the sausage were not tested, which is the work that needs to be done in the next stage.

4. Conclusions

Adding D-isoascorbate sodium to duck sausage can significantly reduce the cooking loss of sausage, improve the water retention, oil retention and emulsification stability of duck sausage, and improve the quality of sausage. The addition of D-isoascorbate sodium cannot improve the brightness value of sausage, but can increase the redness value of sausage, reduce the yellow value of sausage, and maintain the brightness and good color of sausage in the oxidation process can significantly reduce the hardness of sausage and maintain the elasticity of sausage.

In addition, the sausage supplemented with D-isoascorbate had better antioxidant capacity, and the acid value and *TBARS* value of the sausage supplemented with D-isoascorbate were significantly lower than those of the control group at 18 h ($P<0.05$), which significantly improved the scavenging ability of *DPPH* free radical. In conclusion, D-isoascorbate sodium can improve the quality of sausage, but also has good antioxidant capacity.

This study provides a possibility for the application of potato paste in sausage and provides data support for the selection of antioxidant of potato paste sausage.

Table 11

Change of *TBARS* value during accelerated oxidation of duck sausage

Treatment	*TBARS*, mg/100 g						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
*Y*1	0.49 ± 0.00^{a}	0.58 ± 0.00^{a}	0.60 ± 0.02^{a}	0.64 ± 0.00^{a}	0.68 ± 0.00^{a}	0.71 ± 0.02^{a}	0.85 ± 0.02^{a}
*Y*2	0.40 ± 0.02^{c}	0.45 ± 0.00^{b}	0.48 ± 0.01^{b}	0.52 ± 0.01^{b}	0.56 ± 0.00^{b}	0.58 ± 0.00^{c}	0.68 ± 0.01^{c}
*Y*3	0.39 ± 0.00^{c}	0.46 ± 0.00^{b}	0.47 ± 0.00^{b}	0.51 ± 0.01^{b}	0.54 ± 0.00^{c}	0.57 ± 0.00^{c}	0.64 ± 0.01^{d}
*Y*4	0.46 ± 0.01^{b}	0.46 ± 0.02^{b}	0.48 ± 0.00^{b}	0.52 ± 0.01^{b}	0.55 ± 0.01^{bc}	0.63 ± 0.01^{b}	0.76 ± 0.00^{b}

Note: different letters in the same column indicate significant difference ($P<0.05$)

Table 12

Changes of *DPPH* free radical scavenging rate during accelerated oxidation of duck sausage

Treatment	*DPPH* free radical scavenging rate, %						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
*Y*1	93.29 ± 0.12^{ab}	90.58 ± 0.98^{a}	92.50 ± 0.40^{b}	92.72 ± 0.12^{a}	85.94 ± 1.68^{b}	84.21 ± 0.49^{b}	73.61 ± 0.78^{c}
*Y*2	93.69 ± 0.28^{a}	90.54 ± 2.02^{a}	92.69 ± 0.15^{b}	92.24 ± 0.24^{b}	92.34 ± 0.18^{a}	89.04 ± 0.41^{a}	88.96 ± 0.49^{a}
*Y*3	93.57 ± 0.61^{a}	91.77 ± 0.54^{a}	92.83 ± 0.13^{ab}	90.81 ± 0.03^{c}	91.37 ± 0.07^{a}	89.48 ± 0.32^{a}	85.78 ± 0.14^{b}
*Y*4	92.65 ± 0.28^{b}	91.61 ± 0.32^{a}	93.17 ± 0.13^{a}	89.50 ± 0.27^{d}	92.28 ± 0.08^{a}	89.30 ± 0.76^{a}	88.40 ± 0.83^{a}

Note: different letters in the same column indicate significant difference ($P<0.05$)

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References

1. Choi, Y.-S., Kim, H.-W., Hwang, K.-E., Song, D.-H., Jeong, T.-J., Kim, Y.-B. et. al. (2015). Effects of fat levels and rice bran fiber on the chemical, textural, and sensory properties of frankfurters. *Food Science and Biotechnology, 24 (2),* 489–495. doi: http://doi.org/10.1007/s10068-015-0064-5
2. Zaini, H. B. M., Sintang, M. D. B., Pindi, W. (2020). The roles of banana peel powders to alter technological functionality, sensory and nutritional quality of chicken sausage. *Food Science & Nutrition, 8 (10),* 5497–5507. doi: http://doi.org/10.1002/fsn3.1847
3. Sun, D. Y., Shang, F. F., Pan, Z. T., Xie, Y. H., Liu, Y. (2020). Influence on the effect of electron beam irradiation on BinLangYu storage. *Journal of food and machinery, 4 (8),* 135–140. doi: http://doi.org/10.13652/j.iSSN.1003-5788.2020.08.024
4. Xu, H. J., Zhou, B. (2022). Research progress on oxidation control methods of meat and meat products. *Preservation and Processing, 22 (3),* 111–120. Available at: https://kns.cnki.net/kcms/detail/detail.aspx?FileName=BXJG202203016&DbName=CJFQ2022
5. Sun, W., Zhou, F., Sun, D.-W., Zhao, M. (2012). Effect of Oxidation on the Emulsifying Properties of Myofibrillar Proteins. *Food and Bioprocess Technology, 6 (7),* 1703–1712. doi: http://doi.org/10.1007/s11947-012-0823-8
6. Qing, M. M., Chen, P., Zang, J. N. (2021). Effects of compound antioxidant on quality of frozen yellow Croaker Fillet. *Preservation and Processing, 21 (2),* 13–19. doi: http://doi.org/110.3969/j.issn.1009-6221.2021.02.003
7. Shang, X. L., Chen, Z. X., Shan, X. T., Li, Y., Liu, Y. Y. (2020). Effects of sodium d-isoascorbate on lipid and protein oxidation in salami. *Food research and development, 41 (6),* 38–42. Available at: https://kns.cnki.net/kcms/detail/detail.aspx?FileName=SPYK202006010&DbName=CJFQ2020
8. Yang, Y. F., Luo, M. N., Hu, Q. H. et. al. (2022). Comparative analysis of three methods for accelerated lipid oxidation. *Food Science, 43 (6),* 337–346.
9. Jiang, S., Niu, H. L., Liu, Q. et. al. (2018). Effect of curdlan and water addition on quality characteristics of frankfurters. *Food Science, 39 (14),* 57–66. doi: http://doi.org/10.7506/spkx1002-6630-201814009
10. Chen, Y. C., Jiang, S., Cao, C. A., Chen, J. X., Kong, B. H., Liu, Q. (2019). Evaluation of the Quality of Frankfurters Prepared with Highly Stable Vegetable Oil-in-Water Pre-Emulsion as a Partial Replacer of Pork Back Fat. *Food Science, 40,* 86–93. doi: http://doi.org/10.7506/spkx1002-6630-20180906-060
11. Li, Y. L., Luo, C., Fan, Y. L., Ju, N. (2016). Study on antioxidant effect of extracts of shallot on mutton sausage. *Food research and development, 37 (9),* 6–10. doi: http://doi.org/10.3969/j.issn.1005-6521.2016.09.002
12. Kandi, S., Charles, A. L. (2019). Statistical comparative study between the conventional DPPH spectrophotometric and dropping DPPH analytical method without spectrophotometer: Evaluation for the advancement of antioxidant activity analysis. *Food Chemistry, 287,* 338–345. doi: http://doi.org/10.1016/j.foodchem.2019.02.110
13. Wang, Y., Jia, J., Ren, X., Li, B., Zhang, Q. (2018). Extraction, preliminary characterization and in vitro antioxidant activity of polysaccharides from Oudemansiella radicata mushroom. *International Journal of Biological Macromolecules, 120,* 1760–1769. doi: http://doi.org/10.1016/j.ijbiomac.2018.09.209

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