Effects of Curdlan on the Quality of Cured Pork Hind Leg Meat

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Abstract Pork hind legs have low fat and high protein contents, making cured pork prone to a dry and tough texture. To address this issue, 0.8% (*w/w*) natural polysaccharide curdlan was added to cured pork. Physicochemical indicators, free amino acids, and flavor were tested on days 0, 10, 20, and 30 of curing. The results indicated that curdlan increased product yield by 4.08%, slowed moisture loss during processing, and reduced pH from 6.02 to 5.21. It also decreased the hardness, chewiness, and stickiness in cured pork hind legs, yielding a softer texture. In addition, it slowed the rate of color deterioration and inhibited fat oxidation. Analysis of volatile flavor compounds revealed that curdlan increased the variety of flavor compounds in cured pork hind legs by more than twenty types. The odor activity values of key aroma components (such as linalool and nonanal) also increased to varying degrees, enriching the flavor profile of the cured meat. Thus, curdlan effectively improves the texture, color, and flavor of cured pork hind legs, providing process parameters for industrial production of low-fat cured meat.

Key words Curdlan; Cured pork hind leg meat; Quality; Flavor; Amino acids

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Pork hind leg meat is favored in cured meat production due to its thin fat layer and dense muscle fibers. Its fat content is only about 2.3%, significantly lower than that of pork belly and front leg, while its protein content reaches 25%[1]. However, this "high-protein, low-fat" nutritional advantage presents an unexpected processing challenge: an excessively high lean-to-fat ratio means insufficient fat available for melting. During the lengthy air-drying and baking process, significant moisture evaporation causes the muscle protein network to contract excessively, resulting in muscle integrity loss. This ultimately results in cured pork slices with a coarse surface, high chewing resistance, and a distinctly dry, woody texture, severely compromising the consumer's sensory experience. Traditionally, producers have addressed this by increasing fat-to-lean ratios or adding vegetable oils, but these solutions conflict with contemporary health demands for reduced salt and fat content. Consequently, developing novel methods for improving pork that preserve the low-fat, healthy attributes while imparting juiciness and tenderness to cured pork has become pivotal for industry advancement.

Curdlan is a functional polysaccharide that has entered the research field under this background. It is a linear high-molecular glucan formed by glucose units connected by β-(1, 3)-glycosidic bonds. It is produced by different types of microorganisms in the form of extracellular polysaccharides[2]. Owing to its unique gelling property[3], thickening property[4], and water retention property[5], it has become an important additive for improving the texture and taste of meat products. A large number of studies have found that the triple helix aggregates of curdlan dissolve into single helix chains to form heat-irreversible curdlan and simultaneously cross-link with myofibrillar proteins at the same time to form a stable gel network structure, which can effectively lock in moisture and improve the juiciness and tenderness of the product. Heat-irreversible curdlan can also act as a protective barrier role, further preventing the migration of meat juice to the outside, thereby improving the product yield[6]. Meanwhile, curdlan can simulate the texture and taste of fat, delay and inhibit lipid digestion, and make up for the shortcomings of low-fat meat products, so that they can still maintain a good taste and flavor while reducing fat content[7-8]. In cooked meat products, curdlan can enhance the structural strength of the product, thereby reducing fragmentation during slicing and extending shelf life[9]. Therefore, to better utilize pork resources and improve product value, this study investigated the effect of curdlan addition on the quality of bacon produced from pork hind legs. This approach provides new development ideas for processing cured meat products.

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Materials and Methods

Materials

Pork hind leg meat, Shuanghui Investment Development Co., Ltd. (Henan, China); Curdlan, Shangfang Food Technology Co., Ltd. (Zhejiang, China); sodium D-isoascorbate, Dexing Baiqin Isoascorbic Acid Sodium Co., Ltd. (Jiangxi, China);

sodium nitrite, Yihang Biotechnology Co., Ltd. (Hubei, China); edible salt, Zhongyan Jiaqing Salt Industry Co., Ltd. (Shanghai, China).

Sample preparation

The brine formulation used in this study included sodium nitrite 0.01% (*w/w*), edible salt 2% (*w/w*), glucose 0.8% (*w/w*), sodium D-isoascorbate 0.1% (*w/w*). The experimental group additionally contained curdlan 0.8% (*w/w*).

Sample preparation followed the process flow: raw material trimming and cutting → injection → tumbling → curing → air-drying → packaging. Raw ham was cut into pieces measuring 4 cm wide, 30 cm long, and 4 cm thick, and then injected using a brine injector, with the final yield controlled at 115%. The injected samples were tumbled in a tumbler set to 45 r/min with an 82° tilt angle, while maintaining a 4 ℃ core temperature and a 60% vacuum level. The sequence was 10 min of tumbling → 20 min of pause → 10 min of tumbling, totaling 2 h of tumbling. The semi-finished tumbled raw materials were then cured in a 4 ℃ cold storage room for 12 h. Subsequently, they were first air-dried at 15 ℃ until approximately 13% moisture loss was achieved. Next, they were dried in a low-temperature oven at 60 ℃ and 55% humidity, with the process endpoint controlled to a final moisture content of 55% – 60%. After resting the samples at room temperature for 12 h, they were vacuum-sealed and stored in light-protected conditions at room temperature. Yield was measured immediately, while other parameters were assessed on days 0, 10, 20, and 30 of sample preparation, with three replicates per parameter.

Determination of general physical and chemical properties

Following the analytical methods described by Wen Yu *et al.* [10], measurements were conducted for moisture content, water activity, pH value, color, texture, nitrite content, and thiobarbituric acid reactive substances (TBARS).

Determination of total colony count

Total bacterial colony counts were determined according to the method of Zhao *et al.* [11]. Twenty-five grams of sample were added to 225 ml of sterile physiological saline and homogenized for 5 min in a paddle-type homogenizer. The homogenate was diluted, and 100 μl was spread onto plain agar plates. Plates were incubated at 37 ℃ for 48 h, after which colonies were counted. Three parallel replicates were performed for each sample group.

Determination of free amino acids

Each batch of cured pork was homogenized. A 3 g portion of the homogenized sample was weighed and mixed with 15 ml of 6 mol/L hydrochloric acid. The mixture was hydrolyzed at 110 ℃ for 22 h. After hydrolysis, the solution was filtered. The filtrate was diluted with citrate buffer and then passed through a 0.22 μm sterile filter membrane. Following derivatization, the amino acid content was determined using an amino acid analyzer.

Determination of volatile aroma compounds

GC-MS Analysis: A 3 g homogenized meat sample was weighed into a 20 ml headspace vial. Then, 1 μl of the 2, 4, 6-trimethylpyridine internal standard solution (2 μg/μl) was added, and the vial was sealed. Following a 30-min extraction at 40 ℃, the solid-phase microextraction (SPME) fiber head was desorbed in the injection port at 250 ℃ for 5 min in splitless mode. Analysis was performed using an HP-5MSUI column (30 m × 0.25 mm × 0.25 μm) with helium as the carrier gas at a constant flow rate of 1.0 ml/min. The programmed temperature ramp started at 40 ℃ (held for 1 min), increased to 78 ℃ at 3 ℃/min (held for 3 min), then to 115 ℃ at 3 ℃/min (held for 2 min), followed by a ramp to 165 ℃ at 12 ℃/min (held for 1 min), and finally to 280 ℃ at 10 ℃/min (held for 1 min). Mass spectrometry conditions were set as follows: ion source temperature 230 ℃, electron energy 70 eV, quadrupole temperature 150 ℃, and mass scan range *m/z* 40 – 500. Volatile compounds were identified by comparing their mass spectra against the NIST14.L library, and only those with a match confidence greater than 80% were retained.

Electronic nose analysis: A 3 g homogenized meat sample was weighed into a 20 ml headspace vial, and the vial was sealed for manual injection. The analysis was conducted under the following parameters: headspace heating temperature 70 ℃, heating time 300 s, purge time 50 s, data acquisition time 60 s, and injection flow rate 400 ml/min.

Data processing and analysis

Experimental data were compiled using Microsoft Excel 2020 software, with all metric values expressed as mean ± standard deviation. Statistical significance analysis was performed using IBM SPSS Statistics 25.0 software (one-way ANOVA with Duncan's multiple range test, $P < 0.05$). Graphs were generated using Origin 2021 software, and correlation analysis was completed with SIMCA Version 14.1.0.2047 software.

Results and Analysis

Effect of curdlan on the yield of cured pork from pig hind legs

As shown in Table 1, the addition of curdlan in the experimental group resulted in varying degrees of weight loss from fresh meat to finished product due to moisture loss during processing. However, the yield of the experimental group with curdlan addition increased by 4.08% compared with that of the control group, consistent with the findings of Hou *et al.* [7]. It may be attributed to the injected curdlan promoting strong interactions between the gel and myofibrillar proteins under low-temperature baking conditions, forming a denser three-dimensional network structure that enhances the moisture retention capacity of the meat products[12].

Effect of curdlan on moisture content in cured pork legs

The test results are shown in Fig. 1. The moisture content of the control group decreased from 58.24% on day 0 to 51.26% on day 30 as storage time increased. In contrast, the moisture content of the experimental group increased from 55.25% on day 0 to 58.01% on day 30. After vacuum packaging, the difference in moisture content between the experimental and control groups

remained insignificant. Research indicates that carrageenan absorbs free water within the gel network under heating conditions, thereby enhancing the water-holding capacity of meat products[13-14]. Based on moisture content metrics, the addition of carrageenan reduces product moisture loss and maintains product weight, consistent with the yield measurement results.

Table 1 Output rate of products

Group	Fresh meat//kg	After injection//kg	Day 0 air-dried product//kg	Yield rate//%
Control group	10.98 ±0.02	12.54 ±0.01	9.02 ±0.01	82.15 ±0.2
Experimental group	14.02 ±0.02	15.93 ±0.01	12.09 ±0.01	86.23 ±0.2

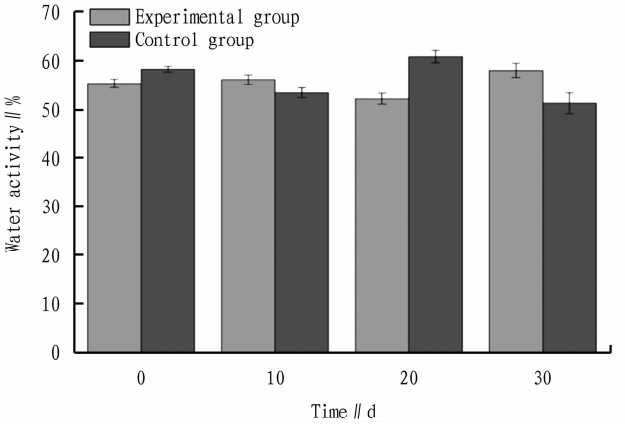

Fig. 1 Change in moisture content of cured pork leg meat

Effect of curdlan on the pH value of cured pork legs

As shown in Fig. 2, the addition of carrageenan affects the pH of the product. The pH values in the experimental group were consistently lower than those in the control group at each time point. The experimental group's pH decreased from 6.02 at day 0 to 5.21 at day 30, while the control group's pH dropped from 6.08 at day 0 to 5.78 at day 30. It may be attributed to the gel network of carrageenan encapsulating protein molecules, reducing their contact with endogenous enzymes. This slows the rate of enzymatic hydrolysis, producing alkaline substances during cured meat storage, thereby enhancing the dominant role of acid-producing microorganisms[15]. Alternatively, the gel network may restrict the activity space of spoilage microorganisms (*e.g.*, molds), allowing acid-tolerant lactic acid bacteria to dominate. Simultaneously, the water bound within the gel network provides a moist growth environment for lactic acid bacteria[16].

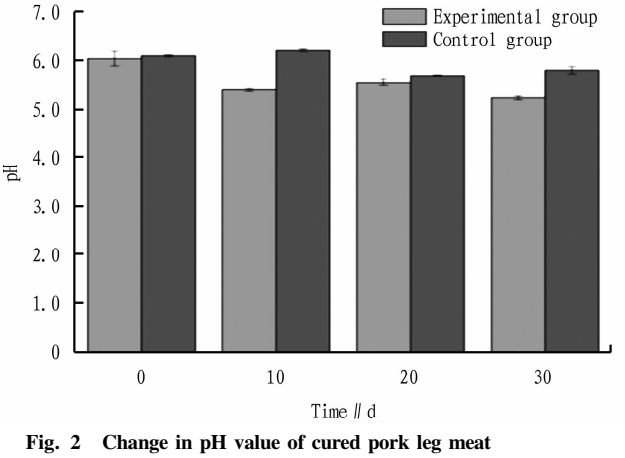

Fig. 2 Change in pH value of cured pork leg meat

Effect of curdlan on the color of cured pork legs

During cured meat processing, nitrites react with myoglobin to form red nitroso derivatives, increasing the redness value ($a*$ value) of the cured meat (Fig. 3). This effect was more pronounced in the experimental group, where color values rose from day 0 to day 10. After day 20, both the experimental and control groups exhibited decreasing color intensity as storage time increased. This may result from the oxidation of lipids and proteins in the cured pork, either independently or synergistically, causing the color to become duller[17]. This indicates that prolonged storage has a certain impact on the product's sensory appearance. The $a*$ value, $b*$ value, and $L*$ value of the experimental group were all higher than those of the control group in the later stages of the experiment. These results suggest that carrageenan has a certain positive effect in delaying the color deterioration of cured pork.

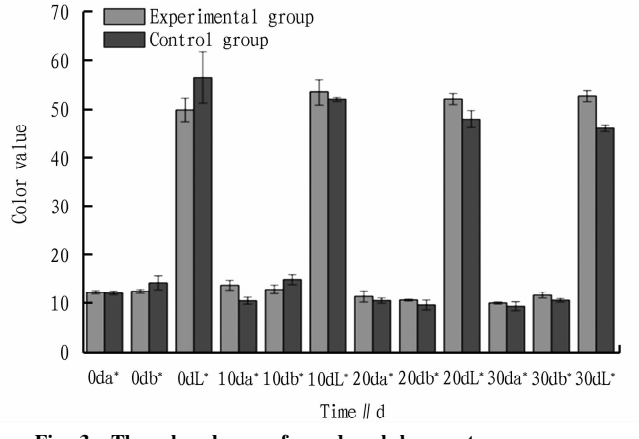

Fig. 3 The color change of cured pork leg meat

Effect of curdlan on the texture of cured pork legs

Textural analysis of the samples revealed that carrageenan improved the texture properties of cured pork. As shown in Fig. 4, the test group exhibited decreasing trends in hardness, stickiness, and chewiness values during textural analysis. Overall, the experimental group exhibited a 1 488.73 increase in hardness (577.59 lower than the control group), a 558.72 increase in stickiness (1 171.95 lower than the control group), and a 382.82 increase in chewiness (1 249.38 lower than the control group). This indicated that the cured meat became softer in texture, easier to chew, and less prone to sticking to the teeth. These changes primarily resulted from the three-dimensional network structure formed by curdlan in the meat product, which enhanced water retention and consequently improved the overall mouthfeel of the cured meat.

Curdlan not only increased the water-holding capacity of the cured meat but also imparted superior textural properties in terms of hardness, chewiness, and stickiness. As storage time increased, both the experimental and control groups showed a trend towards higher hardness, stickiness, and chewiness, peaking at 30 d. This likely resulted from gradual water loss during storage.

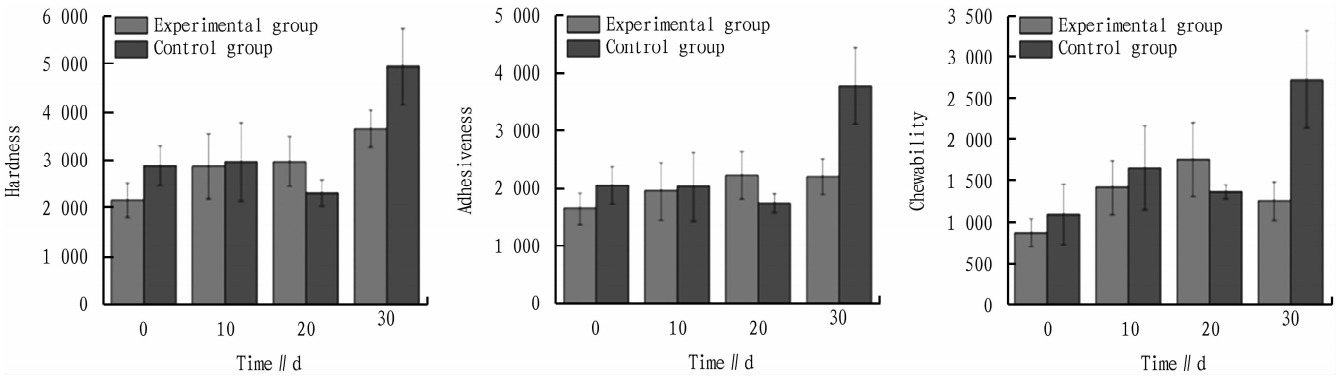

Fig. 4 Change in the texture of cured pork leg meat

Effect of curdlan on nitrite levels in cured pork hams

As shown in Fig. 5, both the experimental and control groups exhibited a trend of initially increasing nitrite residue levels followed by a gradual decline over time. On day 0, the control group's nitrite residue was slightly higher than that of the experimental group. By day 10, nitrite residues in the experimental group rose significantly to approximately 0.08 mg/kg and reached a peak. Nitrite residues in the control group also increased, but to a lesser extent, reaching about 0.07 mg/kg. On days 20 and 30, nitrite residues began to decline in both groups, reaching approximately 0.05 mg/kg in the experimental group and 0.04 mg/kg in the control group by day 20. By day 30, the experimental group further decreased to about 0.04 mg/kg, while the control group dropped to approximately 0.03 mg/kg. The oxidation of nitrite to nitrate was delayed under low-temperature and vacuum conditions, promoting its full binding with proteins to form stable nitrosomyoglobin or nitrosothiol compounds, thereby reducing free nitrite levels[18]. Alternatively, microbial metabolic activity further degrades nitrite into other nitrogen-containing compounds, such as nitrate or ammonia[19], thereby reducing nitrite levels.

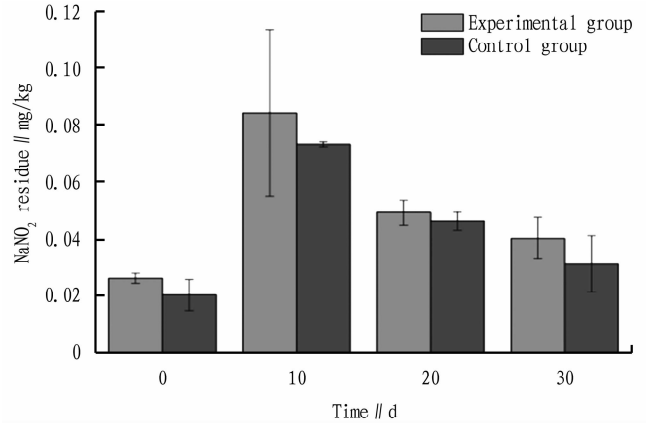

Fig. 5 Nitrite change in cured pork leg meat

Effect of curdlan on TBARS values in cured pork hind legs

Fig. 6 shows the change in TBARS values of cured pork over time. The data revealed that both the experimental and control groups exhibited an upward trend in TBARS values throughout the storage period. As time progressed, the fats in the cured pork underwent oxidative reactions, generating more oxidation products and leading to increasing values. However, the trends differed between the two groups. Overall, the experimental group supplemented with carrageenan exhibited a certain degree of inhibition on fat oxidation, as evidenced by lower TBARS values than the control group. Carrageenan, a polysaccharide with antioxidant activity, may inhibit fat oxidation through mechanisms such as free radical scavenging and metal ion chelation[20]. Consequently, the experimental group exhibited relatively lower TBARS values. Nevertheless, both groups showed an upward trend in TBARS values over time, indicating that fat oxidation remains unavoidable even under low-temperature and vacuum-packaged conditions.

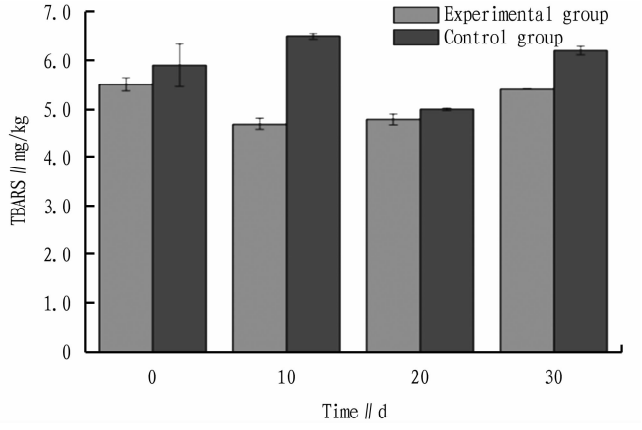

Fig. 6 Change in TBARS value of cured pork leg meat

Effect of curdlan on total colony count in cured pork legs

At the initial stage on day 0, the total colony count in the experimental group was significantly higher than that in the control group (approximately 1.46 log 10 CFU/g). This may be attributed to carrageenan, a fermentatively produced microbial polysaccharide that provides nutrients for the growth and multiplication of certain microorganisms[21]. Alternatively, carrageenan may not

have exhibited pronounced antibacterial effects in the short term. Instead, its interaction with myofibrillin to form a dense three-dimensional network structure may have effectively enhanced water retention, temporarily creating favorable conditions for bacterial proliferation[13]. Microbial growth accelerated rapidly during days 0 – 10, exhibiting a logarithmic growth phase. As fermentation progressed, the pH of cured pork steadily decreased, suggesting that lactic acid bacteria became the dominant microbial group in later stages. After day 10, microbial counts declined markedly, reaching 5.87 log CFU/g by day 30. This reduction likely resulted from prolonged storage, where microbial interactions led to the dominance of specific bacterial strains and a subsequent decrease in microbial diversity.

Table 2 Changes in total bacterial count (log CFU/g)

Group	Control group	Experimental group
0 d	7.05 ±0.08	5.59 ±0.03
10 d	7.42 ±0.03	7.55 ±0.04
20 d	5.08 ±0.06	5.77 ±0.02
30 d	5.87 ±0.02	6.33 ±0.01

Effects of curdlan on free amino acids in cured pork legs

Amino acids are a class of organic compounds containing both amino and carboxyl groups that are the fundamental building blocks of proteins. They exist in both bound and free forms. Bound amino acids cannot be immediately hydrolyzed during consumption and thus have a limited impact on flavor. In contrast, free amino acids (FAA) serve not only as precursors for volatile compounds like alcohols, aldehydes, and esters, as well as medicinal flavonoids, but also act as active substances that directly influence fruit flavor[22]. Umami ranks alongside sweet, salty, bitter, and sour as one of the five primary tastes. Subsequent research revealed that different amino acids can also impart the other four tastes beyond umami. Composition and content directly influence a food's savory quality and confer unique flavor characteristics[23-24]. Therefore, the types and levels of FAAs serve as a crucial indicator for evaluating the nutritional value and flavor profile of cured meats.

Free amino acids were determined in samples collected on day 0 and day 30, with results shown in Table 3.

Table 3 Composition of free amino acids in each group (g/100 g)

Number		Types	Experimental group 0 d	Experimental group 30 d	Control group 0 d	Control group 30 d
Essential amino acids	1	Thr	1.11 ±0.02	0.75 ±0.03	0.72 ±0.02	0.77 ±0.03
	2	Val	0.90 ±0.01	0.99 ±0.03	0.97 ±0.03	1.01 ±0.02
	3	Met	1.30 ±0.03	1.24 ±0.02	1.34 ±0.03	1.40 ±0.04
	4	Ile	0.89 ±0.01	1.01 ±0.03	1.00 ±0.02	1.04 ±0.04
	5	Leu	1.58 ±0.02	1.78 ±0.03	1.80 ±0.03	1.82 ±0.02
	6	Phe	0.80 ±0.03	0.90 ±0.02	0.93 ±0.04	0.94 ±0.04
	7	Lys	1.69 ±0.02	1.88 ±0.01	1.85 ±0.02	1.90 ±0.01
Nonessential amino acids	1	Ser	0.70 ±0.04	0.69 ±0.02	0.70 ±0.04	0.72 ±0.03
	2	Glu	2.18 ±0.02	2.17 ±0.03	2.07 ±0.01	2.16 ±0.03
	3	Gly	0.89 ±0.04	1.02 ±0.02	1.08 ±0.04	1.10 ±0.02
	4	Ala	0.72 ±0.01	1.20 ±0.02	1.34 ±0.01	1.26 ±0.03
	5	Asp	1.18 ±0.03	1.16 ±0.02	1.06 ±0.04	1.14 ±0.01
	6	Tyr	0.68 ±0.02	0.76 ±0.03	0.78 ±0.03	0.80 ±0.02
	7	His	0.70 ±0.02	0.80 ±0.01	0.74 ±0.02	0.80 ±0.03
	8	Arg	1.19 ±0.03	1.26 ±0.01	1.29 ±0.02	1.31 ±0.03
	9	Pro	0.06 ±0.01	0.47 ±0.02	0.41 ±0.03	0.48 ±0.02
	TAA		16.57 ±0.02	18.07 ±0.03	18.08 ±0.01	18.64 ±0.02

Among the 16 free amino acids detected, all four groups of cured pork contained seven essential amino acids (Thr, Val, Met, Ile, Leu, Phe, and Lys) and nine nonessential amino acids (Ser, Glu, Gly, Ala, Asp, Tyr, His, Arg, and Pro). The key taste contributors were categorized into sweet (glycine, alanine, serine, proline, threonine) and umami (aspartic acid, glutamic acid, glycine, alanine) amino acids. Regarding essential amino acid (EAA) content, samples from both the experimental and control groups on day 30 generally exhibited higher EAA levels than those on day 0. Among the EAA changes in the experimental group, leucine enrichment was most pronounced, increasing by 0.20 g/100 g from day 0 to day 30. In the control group, methionine exhibited the most pronounced change, increasing by 0.06 g/100 g from day 0 to day 30. Across all four groups, the EAA/total amino acid (TAA) ratio ranged from 47.34% to 49.93%, while the EAA/non-essential amino acid (NEAA) ratio ranged from 50.07% to 52.66%. The EAA with the highest content across all four groups was lysine (Lys). In the experimental group, phenylalanine had the lowest content at 0 d, while threonine had the lowest content in the other three groups. The highest NEAA content across the four groups was glutamic acid (Glu) and arginine (Arg). In the experimental group, NEAA increased from 8.30 g/100 g on day 0 to 9.52 g/100 g on day 30, representing an enrichment of 1.22 g/100 g. Alanine showed the most pronounced enrichment, increasing by 0.49 g/100 g. Alanine functions as a sweet amino acid in food, enhancing the gustatory complexity of cured meats. In the control group, NEAA levels increased from 9.47 g/100 g on day 0 to 9.77 g/100 g on day 30, an enrichment of 0.30 g/100 g.

Glutamic acid content increased by 0.09 g/100 g. As the primary umami-active compound in food, glutamic acid also inhibits Ca^{2+} signaling in taste receptors, reducing the intensity of bitter amino acids and thereby enhancing the savory flavor of cured pork.

Effect of curdlan on volatile flavor compounds in cured pork hind leg

The flavor of cured pork primarily originates from fat oxidation, degradation of precursor substances, the Maillard reaction, and their interactions, with phenolic compounds being the main volatile components[25]. Using SPME-GC-MS to determine the volatile flavor compounds in cured pork yielded the following results:

Table 4 indicates that cured pork with added curdlan exhibited a greater variety of volatile flavor compounds detected at each sampling point (0, 10, 20, 30 d) than the blank control group. The addition of curdlan effectively enhances the diversity of volatile flavor compounds in cured pork. Among the characteristic volatile flavor compounds present in the experimental group, the alcohol fraction contained additional compounds compared to the control group: isopropanol, (2S,3S)-(+)-2, 3-butanediol, 4-methyl-2-pentanol, 3-methylthiopropanol, cis-α,α-5-trimethyl-5-vinyl-tetrahydrofuran-2-methanol, n-heptanol, diisobutylmethanol, and furfuryl alcohol. Among aldehydes, it contained additional tetracetaldehyde, pentadecanal, and 2-methyl-2-butenal. Acids included ethyl boronic acid, 4-vinylacetic acid, and sorbic acid. Ketones now included 2-(formyloxy)-1-phenylacetone. Esters now included methyl isocyanate, butyl lactate, ethyl isobutyrate, 4-methyl-γ-butyrolactone, vinyl acetate, ethyl propionate, ethyl valerate, and methyl acetate. Among other categories, a total of 23 additional flavor compounds were identified, including phenolic compounds such as ethyl maltol, guaiacol, and p-cresol. Based on relative abundance, olefins and other compounds constituted the highest proportion. Alcohols constituted the second most abundant compound group. Aldehydes served as primary flavor compounds, typically formed through lipid oxidation, indicating that adding curdlan promotes greater flavor compound production during the cured meat's fat oxidation process. Alkenes significantly influenced cured meat flavor, contributing characteristic aromas. Alcohols exerted a lesser influence on cured meat flavor due to their higher detection thresholds. Although acids, esters, and ketones were present in smaller quantities, they still contributed to flavor formation. These findings indicate that curdlan enhances the total quantity and diversity of aldehydes, esters, olefins, and volatile flavor compounds in cured meat, thereby improving its overall flavor profile.

Table 4 Relative content and types of flavor substances (μg/kg)

Group	Alcohols	Aldehydes	Acids	Ketones	Esters	Others	Total
CK 0 d	Types	16	14	7	10	13	38
	Relative content//%	36.64	10.76	3.22	0.87	3.74	46.77
JK 0 d	Types	15	16	8	9	14	46
	Relative content//%	31.58	7.83	1.44	1.19	4.66	53.30
CK 10 d	Types	15	13	7	7	11	38
	Relative content//%	35.34	8.52	3.50	0.59	4.65	47.40
JK 10 d	Types	15	15	7	7	10	38
	Relative content//%	35.38	9.18	2.16	1.00	4.05	48.24
CK 20 d	Types	14	10	11	7	9	33
	Relative content//%	41.38	5.82	3.12	0.37	3.28	46.04
JK 20 d	Types	15	11	12	5	15	30
	Relative content//%	14.48	50.24	6.21	1.55	3.21	24.31
CK 30 d	Types	14	11	10	7	11	38
	Relative content//%	31.36	7.11	8.64	1.31	4.60	46.98
JK 30 d	Types	18	13	12	7	16	31
	Relative content//%	23.84	9.61	19.19	2.58	6.06	38.72

Based on the volatile flavor compound content in two groups of cured pork samples collected on different days, principal component analysis (PCA) was performed using an automatically adjusted standardized calculation method. Two principal components with eigenvalues greater than 1 were selected for statistical analysis, yielding the PCA score plot shown in Fig. 7. The figure indicates differences between groups, with the day 30 samples distinctly separated from the others. This significant divergence in volatile flavor compounds confirms that storage duration substantially influences cured pork flavor.

Following GC-MS analysis, a cluster heatmap was generated based on the absolute content of each volatile flavor compound, with results shown in Fig. 8. During the later stages of cured pork fermentation (20 d, 30 d), volatile flavor compounds exhibited significant enrichment compared to 0 and 10 d, with discernible differences observed between groups.

The Odor Activity Value (OAV) indicates each aroma compound's contribution to the overall profile. Compounds with OAV ≥1 significantly influence the overall flavor, while those with OAV < 1 have minimal impact. Aroma compounds with greater OAV values contribute more substantially to the overall flavor. Using OAV > 1 as the criterion, key volatile flavor compounds were identified as shown in Table 5. Detailed analysis follows:

A total of 26 aroma compounds with OAV values ≥1 were screened from the cured pork in the experimental group, including 5 alcohols, 6 aldehydes, 9 esters, 2 alkenes, and 4 other types. In the control group, 25 aroma compounds with OAV values ≥1 were identified, comprising 4 alcohols, 7 aldehydes, 7 esters, 2

Table 5 Summary of key volatile flavor compounds

Compound Name	CAS Number	Threshold μg/kg	OAV							
			CK 0 d	CK 10 d	CK 20 d	CK 30 d	JK 0 d	JK 10 d	JK 20 d	JK 30 d
1-Hexanol	111-27-3	5.6	0.43 ± 0.04	0.63 ± 0.10	6.83 ± 8.03	1.23 ± 1.01	1.54 ± 0.28	1.29 ± 0.17	1.76 ± 0.67	29.70 ± 0.82
1-Nonene-3-ol	3391-86-4	1	4.34 ± 0.47	7.08 ± 0.18	5.06 ± 4.99	21.37 ± 2.78	7.12 ± 0.67	4.28 ± 2.01	–	14.47 ± 2.10
Linalool	78-70-6	0.22	2 678.27 ± 316.03	4 320.89 ± 3.80	23 110.09 ± 26 099.34	727.41 ± 1 007.99	6 689.12 ± 1 513.29	4 187.97 ± 2 268.81	3 368.15 ± 851.48	2 096.55 ± 1 089.77
Eucalyptol	470-82-6	1.1	87.60 ± 13.44	184.36 ± 1.38	1 299.13 ± 1 460.02	366.07 ± 56.34	283.80 ± 75.64	201.56 ± 92.65	215.90 ± 54.89	528.38 ± 81.26
1-Heptanol	111-70-6	10	–	–	–	–	–	–	–	28.98 ± 0.42
Phenylacetaldehyde	122-78-1	6.3	0.54 ± 0.12	1.42 ± 0.04	24.54 ± 5.19	20.28 ± 3.15	6.97 ± 1.63	4.46 ± 0.44	627.01 ± 98.57	294.42 ± 9.50
(E)-2-Nonenal	18829-56-6	0.19	8.32 ± 0.16	–	–	–	–	–	–	–
3-Methylbutanal	590-86-3	1.1	5.09 ± 2.30	11.01 ± 1.01	111.29 ± 125.39	81.24 ± 15.83	20.34 ± 6.09	17.91 ± 2.19	18.60 ± 6.37	29.31 ± 1.38
Hexanal	66-25-1	5	4.85 ± 0.04	8.34 ± 0.19	16.25 ± 19.67	3.14 ± 0.52	9.14 ± 1.80	8.08 ± 1.79	3.37 ± 1.25	19.65 ± 0.56
Octanal	124-13-0	0.587	70.54 ± 2.45	110.84 ± 7.14	165.48 ± 198.26	90.13 ± 22.16	94.04 ± 38.86	67.44 ± 5.47	22.10 ± 9.05	164.35 ± 84.25
Nonanal	124-19-6	1.1	110.20 ± 9.39	112.00 ± 6.32	317.92 ± 377.28	125.95 ± 29.25	179.66 ± 60.29	110.89 ± 4.24	47.66 ± 16.74	457.31 ± 81.10
2-Methylbutyraldehyde	96-17-3	1	–	–	41.94 ± 47.28	26.81 ± 4.06	6.32 ± 4.47	5.93 ± 1.44	6.91 ± 5.02	–
Ethyl acetate	141-78-6	5	0.45 ± 0.01	1.00 ± 0.13	20.94 ± 23.91	3.55 ± 0.66	2.57 ± 0.62	2.43 ± 0.25	5.86 ± 4.30	131.65 ± 2.39
Ethyl butyrate	105-54-4	0.9	10.36 ± 3.31	15.56 ± 0.87	–	33.66 ± 14.76	24.92 ± 6.00	16.09 ± 3.58	16.27 ± 12.07	53.63 ± 17.93
Ethyl isovalerate	108-64-5	0.01	38.10 ± 4.08	153.91 ± 150.42	9 611.81 ± 11 931.15	1 503.47 ± 322.55	61.29 ± 43.34	115.51 ± 70.91	1 069.81 ± 372.25	18.93 ± 2.23
Ethyl hexanoate	123-66-0	40	0.23 ± 0.02	0.33 ± 0.01	4.77 ± 5.44	1.66 ± 0.39	61.29 ± 43.34	0.52 ± 0.04	2.33 ± 1.01	116.11 ± 0.66
Ethyl decanoate	110-38-3	5	0.22 ± 0.03	0.47 ± 0.17	0.31 ± 0.23	2.26 ± 0.16	0.59 ± 0.11	0.01 ± 0.01	2.78 ± 1.64	19.69 ± 0.85
Ethyl heptanoate	106-30-9	1.9				1.34 ± 0.95	0.51 ± 0.02	–	0.61 ± 0.43	3.52 ± 1.34
Butyl lactate	138-22-7	0.000 029	–	–	–	–	111 386.94 ± 31 148.13	–	–	–
Ethyl 2-methylpropanoate	97-62-1	0.02	–	–	–	–	–	–	152.58 ± 54.57	–
Ethyl 2-methylbutyrate	7452-79-1	0.063	–	–	888.65 ± 1 009.15	169.71 ± 130.12	–	–	39.40 ± 25.64	13.67 ± 61.55
Myrcene	123-35-3	1.2	7.34 ± 2.14	21.43 ± 1.90	48.43 ± 49.21	44.30 ± 7.99	30.16 ± 6.79	23.77 ± 3.13	5.21 ± 4.25	80.35 ± 6.91
(+)-Limonene	5989-27-5	34	7.34 ± 2.14	4.44 ± 0.06	7.78 ± 8.40	8.89 ± 1.05	9.99 ± 1.59	3.63 ± 0.14	1.04 ± 0.39	415.47 ± 1.95
Anethole	104-46-1	21.8	2.83 ± 0.18	6.34 ± 0.05	2.95 ± 1.10	12.28 ± 3.06	10.12 ± 1.60	5.43 ± 0.07	3.26 ± 0.74	388.11 ± 1.66
Eugenol	97-53-0	2.5	21.73 ± 3.28	20.60 ± 14.57	25.83 ± 8.69	45.06 ± 32.01	51.34 ± 11.63	19.17 ± 0.54	23.90 ± 21.01	180.72 ± 22.17
o-Isopropylbenzene	527-84-4	4	1.32 ± 0.93	3.89 ± 0.28	20.33 ± 23.57	–	7.39 ± 1.77	4.97 ± 0.52	0.83 ± 0.68	–
4-Isopropyltoluene	99-87-6	5.01	–	–	–	5.22 ± 3.76	–	–	–	42.70 ± 6.03
Hexanenitrile	628-73-9	3.2	–	–	–	1.49 ± 1.10	–	–	–	–

alkenes, and 5 other types.

As shown in Table 5, linalool contributed most significantly to flavor in both the experimental and control groups. Except for the 30-day sample in the control group, OAV values exceeded 1 000, with experimental group averages consistently higher than those of the control group. Linalool, a chain-type terpenol perceived as woody and fruity aromas, indicates that adding curdlan induces perceptible flavor changes. Compounds with $100 \leqslant \text{OAV} \leqslant 1\,000$ in the experimental group included eucalyptol, nonanal, ethyl isovalerate, ethyl n-hexanoate, butyl lactate, ethyl isobutyrate, (+)-limonene, anethol, and eugenol. This suggests these compounds collectively contribute to the aroma profile of curdlan-cured pork.

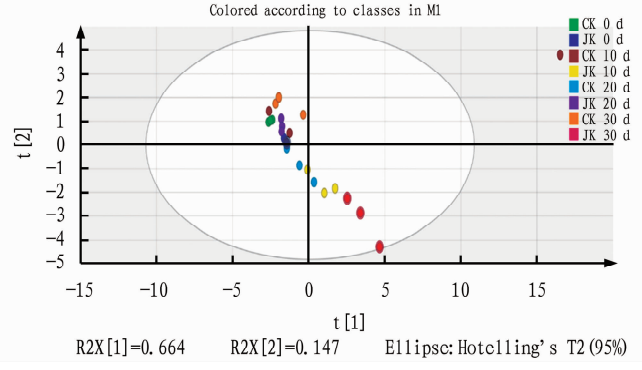

Fig. 7 PCA score plot of curable gum bacon

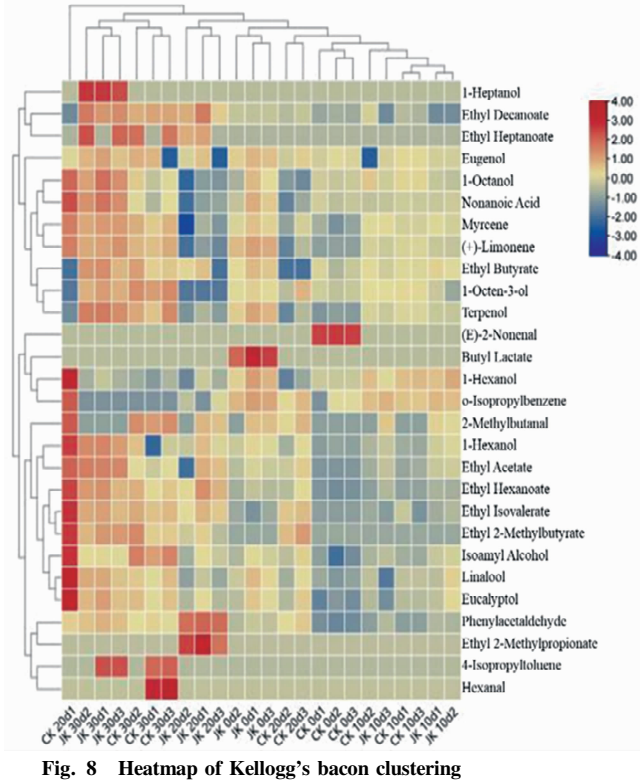

Fig. 8 Heatmap of Kellogg's bacon clustering

Conclusions

The results of this study demonstrated that adding 0.8% (*w*/*w*) curdlan effectively improved the sensory quality and physicochemical properties of low-fat cured pork hind legs. By forming a gel network structure, curdlan increased the moisture content in cured pork by 2.66%, effectively enhancing its water-holding capacity. The pH value decreased to 5.21 by day 30, providing a slightly acidic environment that inhibited harmful bacterial growth and increased the yield of cured pork by 4.08%. Nitrite content showed an initial increase followed by a decrease, reaching 0.04 mg/kg by day 30. Curdlan also optimized the textural properties of cured pork hind legs, reducing hardness (577.59), stickiness (1 171.95), and chewiness (1 249.38) for a softer, more palatable mouthfeel. Furthermore, curdlan delayed myoglobin oxidation, slowed color deterioration, and maintained the fresh appearance of cured meat. By inhibiting fat oxidation and promoting the formation of key volatile flavor compounds such as aldehydes and esters, it increased over twenty flavor components, effectively enhancing the product's flavor profile. In summary, the addition of curdlan optimizes the quality of hind leg cured pork and holds broad prospects for practical application in low-fat cured pork production.

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