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Research Article

Unraveling the molecular basis of regional flavor diversity in Chinese dry-cured bacon through receptor interactions

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Abstract: The present study provides molecular-level insights into the formation of regional flavor in Chinese dry-cured bacons by analyzing key taste-active compounds, aroma-active compounds, and olfactory receptor interactions. The glutamic acid, alanine, valine, methionine, lysine, histidine, arginine, lactic acid, Na^+, Cl^-, and K^+ were identified as key taste-active compounds, varying by region. A total of 71 volatile compounds were identified, with hexanal, heptanal, octanal, hexanoic acid, ethyl hexanoate, 1-hepten-3-one, 1-octen-3-one, 2-heptanone, 2-pentylfuran, and 2-butylfuran as key aroma-active compounds. Anhui bacon showed fatty and grassy notes, Guangdong bacon was dominated by fruity and sweet notes, and Jiangxi bacon exhibited mushroom and nutty characteristics. Molecular docking revealed that aldehydes interact with Asp175, Leu174, and His176 of olfactory receptor family 2 subfamily W member 1, whereas ketones, esters, and furans exhibited diverse binding patterns. These findings provide molecular-level insight into regional flavor formation in Chinese dry-cured bacon, contributing to quality improvement of traditional dry-cured meat products.

Keywords: dry-cured bacon; taste-active compounds; aroma-active compounds; molecular docking

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1 Introduction

Dry-cured bacon, a representative of traditional Chinese fermented meat products, is highly valued for its distinctive flavor, texture, and color[1]. Flavor is a decisive attribute shaping consumer preference and product acceptability[2]. The flavor characteristics of dry-cured bacon are affected by the proteins and lipids in raw meat, as well as curing and ripening parameters such as temperature and time[3–4]. Typically, production of dry-cured bacon involves surface salting and spicing, followed by microbial fermentation, during which lipolytic release of polyunsaturated fatty acids and their subsequent oxidation generate aldehydes and ketones as the dominant contributors to fatty and grassy aromas. Free amino acids (FAAs) and peptides released via proteolysis directly impart umami and sweet tastes, and serve as precursors for branched-chain aldehydes via Strecker degradation and Maillard reactions. Microbial carbohydrate metabolism produces lactic acid, which modulates pH value and supplies reducing sugars for Maillard reactions. The synergistic interplay among these pathways determines the characteristic regional flavors of Chinese dry-cured bacon[5–7]. Considering products from different regions exhibit distinctive flavor profiles, systematic studies are needed to elucidate the regional variations in the flavor of Chinese dry-cured bacon.

The flavor of dry-cured bacon is an integration of aroma and taste, driven by specific active compounds rather than the entire volatile and non-volatile profiles[8–10]. The gas chromatography-olfactometry-mass spectrometry (GC-O-MS) combined with aroma extract dilution analysis (AEDA), omission, and recombination tests represents the commonly used approaches to identify key aroma-active components[11]. The non-volatile compounds, including FAAs, organic acids, and 5′-nucleotides, are critical in shaping basic taste traits (e.g., umami, sourness, sweetness), which can be quantitatively evaluated using taste activity value (TAV) and equivalent umami concentration (EUC)[12–13]. Nevertheless, limited research has elucidated which key aroma- and taste-active compounds collectively shape the distinctive flavor attributes of dry-cured bacon produced across different Chinese regions. Furthermore, the human perception of flavor is governed not only by the concentration of these active compounds but also by their binding affinities to specific olfactory and gustatory receptors[14]. Traditional sensory and chemical analyses lack the capacity to explain flavor formation at the receptor level, highlighting the necessity of molecular docking approaches to reveal deeper interaction mechanisms. Molecular docking has been extensively applied to investigate the perception mechanisms of flavor compounds, enabling the prediction of binding sites, binding modes, and interaction types between ligands and taste/olfactory receptors. This approach establishes structure-perception relationships at the molecular level, providing a theoretical basis for elucidating flavor formation mechanisms[12].

Accordingly, the present study aimed to reveal molecular mechanisms for the regional flavor formation of Chinese dry-cured

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bacon by analyses of key taste-active, aroma-active compounds, olfactory receptor interactions. GC-O-MS coupled with AEDA and flavor dilution (FD) was employed to identify and quantify the key aroma-active compounds, while taste-active compounds were evaluated through analyses of FAAs, organic acids, 5′-nucleotides, TAV and EUC. Furthermore, molecular docking was performed to elucidate the binding sites and interaction mechanisms between key aroma-active compounds and olfactory receptor proteins. The results of this work are expected to provide a scientific basis for understanding flavor formation and guiding the quality improvement of dry-cured bacon.

2 Materials and methods

2.1 Chemicals and reagents

Sulfosalicylic acid, hexane, and phosphoric acid were obtained from Shanghai Aladdin Biochemical Technology Co., Ltd. (Shanghai, China). Perchloric acid ($HClO_4$) and potassium hydroxide (KOH) were purchased from Sinopharm Chemical Reagent Co., Ltd. (Shanghai, China). Standards for FAAs, organic acids, and 5′-nucleotides were supplied by Sigma-Aldrich (St. Louis, MO, USA). The internal standard compound 1,2-dichlorobenzene was procured from Yuanye Biotechnology Co., Ltd. (Shanghai, China). All chemical standards were of high purity (> 99.9%).

2.2 Collection of dry-cured bacon samples

Traditional dry-cured bacon samples were selected based on preliminary sensory evaluations of products from multiple regions from industrial producers in Anhui (pork belly was cut into strips and cured with salt, sucrose, monosodium glutamate (MSG), cooking wine, and a mixture of spices, followed by natural air-drying for 12 days), Jiangxi (pork belly strips were cured with salt and air-dried under natural conditions for 14 days), and Guangdong (pork belly was cut into strips and cured with salt, sucrose, fructose syrup, soy sauce, monosodium glutamate, and sodium nitrite, then naturally air-dried for 8 days) provinces of China. The detailed sensory evaluation methods and results are provided in Tables S1–2. Three independent batches were obtained for each region, with approximately 2 kg per batch. Samples were immediately sealed in sterile ice boxes, transported to the laboratory under refrigerated conditions, and stored at −80 °C until analysis.

2.3 Measurement of taste compounds

2.3.1 Determination of taste compound contents

FAAs were extracted following Hu et al.[15], and the results were expressed as mg/100 g of dry matter. Organic acids were determined according to Liu et al.[16], and expressed as mg/100 g dry matter. Quantification of 5′-nucleotides was performed following Qi et al.[17], and the contents were reported as mg/100 g dry matter. Inorganic ions were analyzed according to Wen et al.[18], and the contents expressed as mg/100 g dry matter.

2.3.2 Calculation of TAV

The TAV for each taste compound was calculated as the ratio of its measured concentration (mg/100 g) to its recognition threshold (mg/100 g). Compounds with TAV ≥ 1 were considered to contribute notably to overall taste, whereas those with TAV < 1 were deemed to have minimal impact[19].

2.3.3 Calculation of EUC

The EUC was evaluated according to the method of Yamaguchi et al.[20]. The EUC represents the amount of MSG equivalent to the umami intensity produced by synergistic interactions between umami amino acids and 5′-nucleotides, calculated according to the following formula:

$$\text{EUC (g/100 g)} = \sum a_i b_i + 1\,218 \times \sum a_i b_i \times \sum a_j b_j$$

Where 1 218 is the synergistic constant; a_i and a_j are the concentrations (g/100 g) of each umami amino acid (aspartic acid (Asp) or glutamic acid (Glu)) and 5′-nucleotides (inosine monophosphate (IMP) or adenosine monophosphate (AMP)), respectively; b_i and b_j represent their relative umami potency coefficients relative to MSG, where Glu = 1, Asp = 0.077, IMP = 1, and AMP = 0.18.

2.4 Measurements of volatile compounds

2.4.1 Headspace solid-phase microextraction (HS-SPME) combined with GC-O-MS

Volatile components were extracted from minced dry-cured bacon (3.0 g) using HS-SPME as described by Hu et al.[21] with slight modifications. Samples were placed in 20 mL vials (CNW Technologies, Germany), and 4 μL of 1,2-dichlorobenzene (100 mg/L in methanol) was added as the internal standard. The vials were sealed with polytetrafluoroethylene septums and equilibrated at 45 °C for 25 min. A PDMS/DVB/CAR fiber was then inserted and exposed to the headspace for 30 min at 45 °C. Following extraction, analyses were performed using a GC-O-MS system (8890-5977B, Agilent Technologies, USA) equipped with a Sniffer 9000 olfactory port (Brechbühler, Switzerland). The split ratio was set at 1:1 to deliver equal fractions to the mass spectrometer and olfactory detector. GC conditions: the SPME fiber underwent desorption in the GC injection port (230 °C) for 4 min. The GC separation was performed using a DB-5 MS capillary column (30 m × 0.25 mm, 0.25 μm). The parameters were set as follows: injection port temperature 230 °C, and interface temperature 250 °C. The oven temperature program began at 40 °C and was held for 3 min, then increased to 200 °C at a rate of 5 °C/min, followed by a rise to 230 °C at a rate of 10 °C/min, concluding with a final hold of 2 min. MS conditions: electron ionization source, ionization voltage 70 eV; ion source temperature 230 °C; mass scanning range m/z 40–450. Compounds were identified by comparing their mass spectra with the National Institute of Standards and Technology 20 library and quantified semi-quantitatively by normalizing peak areas to the internal standard[22].

2.4.2 AEDA

The AEDA was conducted following Yang et al.[23] with minor adjustments. Aroma-active fractions were sequentially diluted by modifying the split ratio of the injection port (1:2, 1:4, 1:8, …, $1:2^n$). Each panelist sniffed the dilutions until the odor was no longer detectable, and the FD was recorded for each compound. The sniffing assessment was performed in triplicate by three trained assessors experienced in odor description[24].

2.4.3 Calculation of odor activity value (OAV)

OAVs were calculated to evaluate the relative effect of each volatile compound on overall aroma. The OAV was defined as the ratio of

a compound's concentration to its olfactory threshold. Compounds with OAVs ≥ 1 were considered important odorants, whereas those with OAVs < 1 had limited influence[25].

2.5 Molecular docking

Molecular docking was carried out using Discovery Studio 2021 (BIOVIA, Beijing, China) to explore interactions between key odorants and the olfactory receptor family 2 subfamily W member 1 (OR2W1) (UniProt ID: Q9Y3N9). Protein structures were retrieved from the UniProt database (https://www.uniprot.org), with water molecules and ligands removed and hydrogen atoms added. Three-dimensional structures of 1-hepten-3-one (CID 520420), 1-octen-3-one (CID 61346), 2-butylfuran (CID 20534), 2-heptanone (CID 8051), 2-pentylfuran (CID 19602), ethyl hexanoate (CID 31265), hexanal (CID 6184), hexanoic acid (CID 8892), and octanal (CID 454) were downloaded from PubChem and processed using the "Prepare Ligands" protocol to remove duplicates and generate low-energy conformations. The docking grid was set to cover the entire protein surface, and each ligand was docked in triplicate. The pose with the lowest binding energy was considered the most stable and selected for visualization and interaction analysis.

2.6 Statistical analysis

All experiments were conducted in triplicate using three independent batches of dry-cured bacon. Results were expressed as mean ± standard deviation (SD). Data were analyzed by one-way analysis of variance with Tukey's multiple-comparison test using Statistix 8.1 software. Differences were considered significant at $P < 0.05$. Graphical presentations were prepared using OriginPro 2024 software (Northampton, USA).

3 Results and discussions

3.1 Analysis of taste compounds

3.1.1 FAAs

FAAs are essential contributors to the taste characteristics of fermented meat products. As shown in Table 1, the total FAAs contents in the Anhui sample were markedly higher than those in the Guangdong and Jiangxi samples ($P < 0.05$). The 17 identified FAAs were classified into umami, sweet, and bitter FAAs. All three categories exhibited significantly greater content in the Anhui bacon than in the other two samples ($P < 0.05$). Among all detected FAAs, alanine (Ala) had the highest abundance in Anhui bacon, accounting for 12.71% of total FAAs, with a TAV of 1.68, indicating a major role in sweetness. The Glu ranked second in the contents in the Anhui sample. Furthermore, the TAV of Glu is more than 1 in both Anhui and Guangdong samples, indicating that it can enhance umami intensity[26]. The leucine (Leu) and lysine (Lys) also presented in relatively high contents, especially for Lys with a TAV of 1.41 in the Anhui sample, contributing more prominently to the taste of Anhui bacon. Four additional FAAs with TAV > 1 were identified, including histidine (His), arginine (Arg), valine (Val), and methionine (Met). These FAAs are known to contribute sweet and bitterness to dry-cured bacon[27].

3.1.2 5′-Nucleotides

5′-Nucleotides are crucial umami components that act synergistically with umami-related FAAs[28]. The ATP degradation proceeds sequentially through adenosine diphosphate (ADP), AMP, IMP, hypoxanthine (Hx), and hypoxanthine riboside (HxR)[29]. As shown in Figure 1A, ATP and ADP contents were

Table 1 Contents and TAVs of FAAs in dry-cured bacons from different regions.

FAA	Taste attribute	Taste threshold (mg/100 mL)	Anhui		Guangdong		Jiangxi	
			Content (mg/100 g)	TAV	Content (mg/100 g)	TAV	Content (mg/100 g)	TAV
Glu	Umami	30	88.60 ± 1.89^a	2.95	42.86 ± 0.91^b	1.37	22.26 ± 0.47^c	0.74
Asp	Umami	100	7.65 ± 0.16^a	0.07	5.89 ± 0.12^b	0.05	3.65 ± 0.07^c	0.03
Umami FAAs			96.26 ± 2.05^a		48.75 ± 1.04^b		25.91 ± 0.55^c	
Threonine	Sweet	260	39.18 ± 0.83^a	0.15	18.03 ± 0.38^b	0.06	11.34 ± 0.24^c	0.04
Serine	Sweet	150	48.95 ± 1.04^a	0.32	23.50 ± 0.50^b	0.16	13.28 ± 0.28^c	0.08
Glycine (Gly)	Sweet	130	52.60 ± 1.12^a	0.40	17.35 ± 0.37^b	0.13	13.60 ± 0.29^c	0.10
Ala	Sweet	60	101.32 ± 2.16^a	1.68	41.71 ± 0.89^b	0.71	28.82 ± 0.61^c	0.48
Proline	Sweet	300	27.51 ± 0.58^a	0.09	17.17 ± 0.36^b	0.05	10.37 ± 0.22^c	0.03
Val	Sweet	40	48.04 ± 1.02^a	1.20	30.68 ± 0.65^b	0.80	14.59 ± 0.31^c	0.36
Sweet FAAs			317.64 ± 1.78^a		152.47 ± 2.42^b		91.71 ± 2.03^c	
Met	Bitter	30	32.99 ± 0.70^a	1.09	20.51 ± 0.43^b	0.69	5.67 ± 0.12^c	0.18
Isoleucine	Bitter	90	41.22 ± 0.88^a	0.45	20.91 ± 0.44^b	0.22	9.18 ± 0.19^c	0.10
Leu	Bitter	190	75.78 ± 1.61^a	0.39	28.44 ± 0.60^b	0.14	16.25 ± 0.34^c	0.08
Tyrosine	Bitter	96.6	32.47 ± 0.69^a	0.33	13.01 ± 0.27^b	0.13	7.15 ± 0.15^c	0.07
Phenylalanine (Phe)	Bitter	90	46.74 ± 0.99^a	0.51	11.84 ± 0.25^b	0.13	10.56 ± 0.22^b	0.11
Lys	Bitter/sweet	50	70.69 ± 1.51^a	1.41	32.25 ± 0.68^b	0.62	20.42 ± 0.43^c	0.40
His	Bitter	20	20.64 ± 0.44^a	1.03	5.77 ± 0.12^b	0.32	6.38 ± 0.13^b	0.30
Arg	Bitter/sweet	50	62.37 ± 1.33^a	1.24	27.38 ± 0.58^b	0.53	20.96 ± 0.44^c	0.41
Methionine	Bitter/sweet	23.4	n.d.	n.d.	4.85 ± 0.10^a	0.20	3.92 ± 0.08^b	0.16
Bitter FAAs			382.94 ± 1.99^a		162.00 ± 7.02^b		91.70 ± 5.03^c	
Total FAAs			796.83 ± 17.02^a		362.22 ± 7.73^b		218.48 ± 4.66^c	

Note: Different letters (a–c) in the same line indicate significant differences ($P < 0.05$). The results were expressed as mean values ± SD. n.d., not detectable.

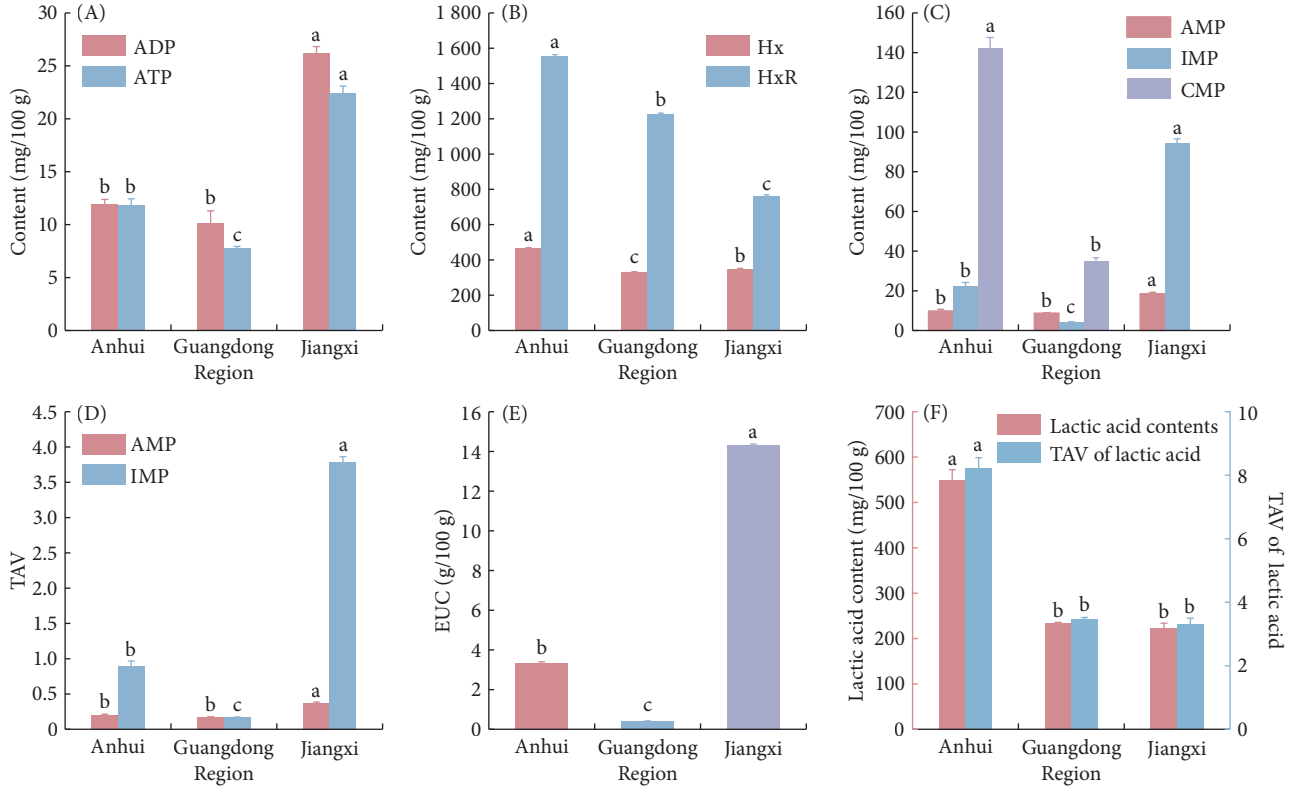


Figure 1 Contents of flavor-related compounds in Chinese dry-cured bacon from Anhui, Guangdong and Jiangxi regions. Contents of (A) ADP, ATP, (B) Hx, HxR, (C) AMP, IMP, and CMP. (D) TAV of AMP and IMP. (E) EUC values. (F) Contents and TAV of lactic acids. Different letters (a–c) indicate significant differences ($P < 0.05$).

significantly higher in the Jiangxi bacon than in the Anhui and Guangdong dry-cured bacons ($P < 0.05$). As shown in Figure 1B, the Hx and HxR, associated with bitterness, were more abundant in Anhui bacon ($P < 0.05$), implying a slightly higher bitter intensity. In contrast, the IMP and AMP were significantly elevated in the Jiangxi bacon ($P < 0.05$). The IMP exhibited a TAV greater than 1 only in the Jiangxi bacon, suggesting enhanced umami intensity (Figures 1C–D). The cytidine monophosphate (CMP) was present at significantly higher levels in the Anhui bacon ($P < 0.05$), suggesting that it could increase the umami taste of Anhui bacon. This is due to that the CMP exhibits relatively weak umami taste on its own, yet it can significantly enhance the overall umami intensity when synergistically acting with other umami taste compounds[30]. The EUC was calculated to assess the synergistic contribution of UFAAs and 5′-nucleotides[31]. As shown in Figure 1E, Jiangxi bacon exhibited the highest EUC value ($P < 0.05$), mainly attributed to the combined effects of Glu, Asp, IMP, and AMP. Similarly, Fan et al.[32] found that as primary 5′-nucleotides responsible for taste in aquatic products, the AMP and IMP can synergize with UFAAs such as Asp and Glu. Notably, the process differences may significantly influence the composition and content of taste compounds in air-dried beef, thereby affecting the flavor characteristics of air-dried beef from different regions.

3.1.3 *Organic acids*

Organic acids enhance flavor while simultaneously inhibiting microbial growth, thus improving product safety[33]. As shown in Figure 1F, lactic acid was the only organic acid detected in all the dry-cured bacons. Derived primarily from glycolysis and glycogenolysis[34], the lactic acid content was significantly higher in the Anhui bacon ($P < 0.05$), suggesting a stronger sour note and greater contribution to flavor complexity.

3.1.4 *Inorganic ions*

Cations and anions such as Na^+, K^+, and Cl^- are key modulators of saltiness in foods[35]. As shown in Figures 2A–B, the K^+ had highest contents and TAV in the Anhui sample compared to the Guangdong and Jiangxi samples ($P < 0.05$). As presented in Figures 2C–F, the Na^+ and Cl^- exhibited highest contents and TAV compared to that of the other inorganic ions ($P < 0.05$), indicating their dominant role in saltiness perception of the dry-cured bacons. Notably, the Jiangxi sample exhibited the highest contents and TAV of Na^+ and Cl^- among all the samples ($P < 0.05$), indicating a synergistic enhancement of the salty taste of the Jiangxi bacon, as Na^+ and Cl^- frequently interact to influence flavor perception[36]. Inorganic ions can also enhance umami perception through interactions with FAAs and 5′-nucleotides[16]. Elevated Na^+ suppresses acidity and bitterness while amplifying umami taste[37]. Therefore, higher Na^+ levels likely contribute to the enhanced umami and overall flavor of dry-cured bacon. As presented in Figures 2G–J, the Mg^{2+} and Ca^{2+} contributed minimally to taste of the dry-cured bacons due to their low TAV, but they can modulate flavor balance by interacting with umami or bitter compounds[38].

Overall, the Glu was key taste-active UFAA in both Anhui and Guangdong dry-cured bacons. In the Anhui dry-cured bacon, the Ala and Val were the major taste-active SFAAs, while Met, Lys, and His contributed mainly to the bitterness. Conversely, IMP was the characteristic umami compound in the Jiangxi dry-cured bacon. According to the EUC results, the Jiangxi dry-cured bacon exhibited the highest umami intensity, followed by Anhui and

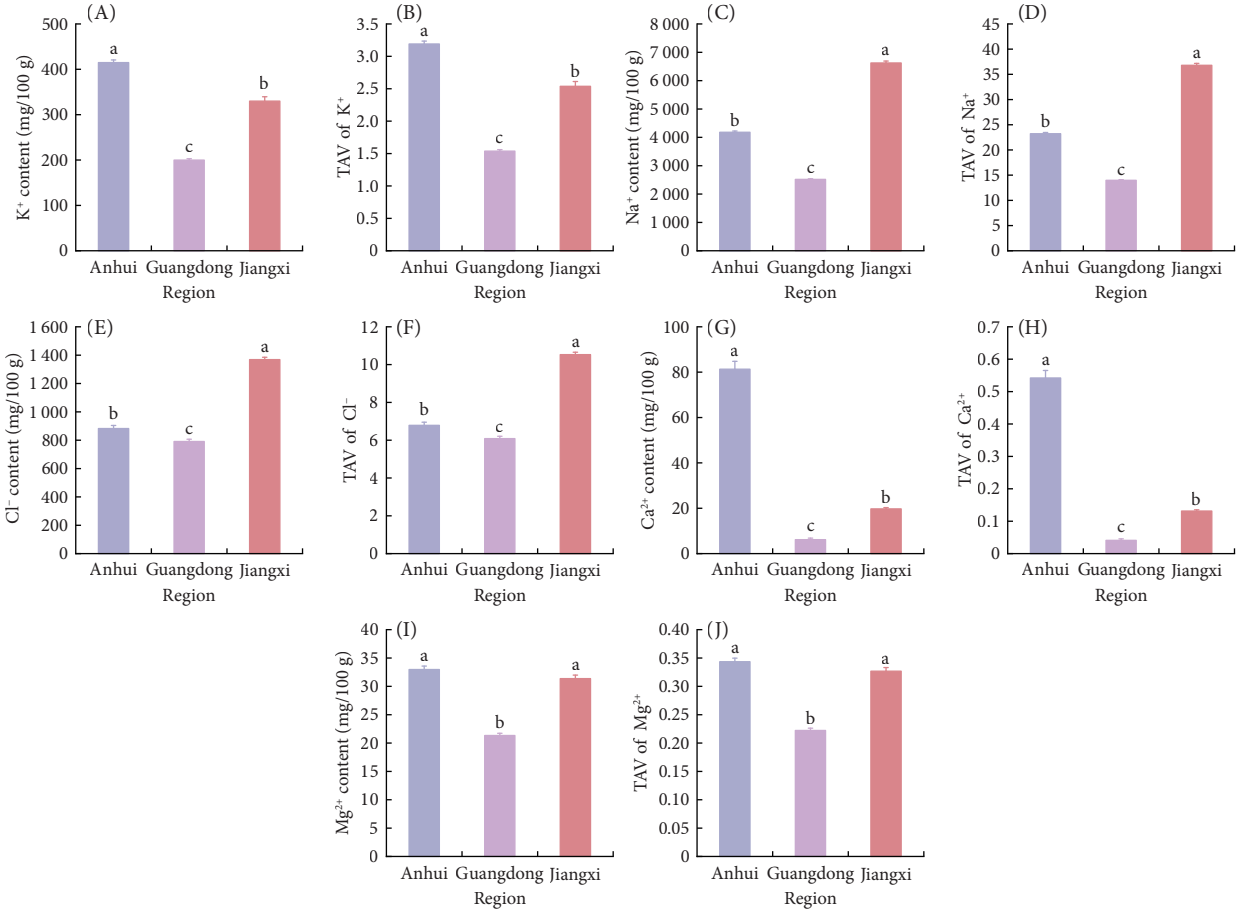


Figure 2 The variation in the contents and TAV of inorganic ions in Chinese dry-cured bacons from different regions. (A) K^+ content; (B) TAV of K^+; (C) Na^+ content; (D) TAV of Na^+; (E) Cl^- content; (F) TAV of Cl^-; (G) Ca^{2+} content; (H) TAV of Ca^{2+}; (I) Mg^{2+} content; (J) TAV of Mg^{2+}. Different letters (a–c) indicate significant differences ($P < 0.05$).

Guangdong dry-cured bacons. The lactic acid was found to be the major determinant of sourness in all dry-cured bacons, with its effect being particularly prominent in the Anhui bacon. The Na^+, Cl^-, and K^+ contributed to the perception of saltiness across all dry-cured bacons, and also indirectly modulate overall flavor through interactions with umami- and bitter-related compounds[35,38]. Collectively, these results indicated that the Anhui dry-cured bacon possessed a complex taste profile including umami, sweetness, bitterness, sourness, and saltiness, whereas Guangdong dry-cured bacon was dominated by umami, sour, and salty notes, and Jiangxi dry-cured bacon showed a more pronounced umami and saltiness.

3.2 Analysis of volatile compounds

3.2.1 Contents of volatile compounds

A total of 71 volatile compounds were detected in the dry-cured bacon samples, including alcohols, aldehydes, acids, esters, ketones, phenols, alkanes, alkenes, and furans (Table 2). The aldehydes constituted the major group (62.58%–83.47%), followed by ketones (8.24%–14.11%), esters (1.26%–8.69%), and alkanes (2.69%–7.68%) (Figure 3A). Minor constituents included alcohols, acids, furans, and phenols. These volatile compounds originated primarily from lipid oxidation, carbohydrate fermentation, amino acid catabolism, and seasoning ingredients[39]. The clustered heat map analysis (Figure 3B) revealed that the Guangdong and Jiangxi dry-cured bacons shared similar aroma profiles, distinct from Anhui dry-cured bacon.

Aldehydes, ketones, esters and alkanes are common compounds in dry-cured bacons. Linear-chain aldehydes (e.g., hexanal, octanal, and decanal) were derived from the oxidation of long-chain fatty acids and major aroma contributors[7]. The Jiangxi dry-cured bacon had higher heptanal and octanal, whereas Guangdong dry-cured bacon contained more hexanal ($P < 0.05$). The nonanal levels were comparable in the Anhui and Guangdong dry-cured bacons but higher in the Jiangxi bacon ($P < 0.05$). These aldehydes, with low odor thresholds, impart fatty and green aromas typical of cured meat[40]. The branched-chain aldehydes (e.g., 2-methylbutanal, 3-methylbutanal, and benzaldehyde), produced via Strecker degradation of FAAs[41], contributed chocolate-like and meaty notes. 2-Methylbutanal occurred only in the Jiangxi dry-cured bacon, 3-methylbutanal only in Anhui, and benzaldehyde in Anhui and Guangdong dry-cured bacons, imparting fruity or almond-like aroma[42].

Ketones, derived mainly from amino acid degradation, lipid oxidation, and Maillard reactions[43], also played crucial roles due to their low odor thresholds[44]. 2-Heptanone was detected in the dry-cured bacons from different regions, imparting fatty and fruity aromas[45], with the highest levels in Guangdong dry-cured bacon ($P < 0.05$). Esters are mainly generated through the esterification of alcohols and acids, which can occur via either non-enzymatic

Table 2 Volatile compounds content of dry-cured bacons from different regions of China.

No.	Volatile compounds	Content (μg/kg)		
		Anhui	Guangdong	Jiangxi
	Alcohols (4)			
V1	1,2-Butanediol	6.45 ± 0.18[b]	39.72 ± 1.14[a]	n.d.
V2	1,4-Butanediol	95.11 ± 2.74	n.d.	n.d.
V3	3-Hepten-1-ol	n.d.	52.43 ± 1.51[a]	15.53 ± 0.44[b]
V4	Homovanillyl alcohol	0.25 ± 0.01	n.d.	n.d.
	Total	101.84 ± 2.94[a]	92.16 ± 2.66[a]	15.54 ± 0.45[b]
	Aldehydes (18)			
V5	(*E*)-2-Heptenal	83.78 ± 2.41[a]	7.17 ± 0.20[b]	19.80 ± 0.57[c]
V6	(*E*)-2-Decenal	31.63 ± 0.91	n.d.	n.d.
V7	(*E*)-2-Nonenal	20.85 ± 0.60[b]	88.74 ± 2.56[a]	n.d.
V8	(*E*)-2-Octenal	6 937.88 ± 200.27	n.d.	n.d.
V9	2-Hexenal	149.87 ± 4.32[b]	n.d.	405.50 ± 11.70[a]
V10	2-Methylbutanal	n.d.	n.d.	426.49 ± 12.31
V11	2-Undecenal	20.07 ± 0.57	n.d.	n.d.
V12	3-Methylbutanal	40.20 ± 1.16	n.d.	n.d.
V13	Benzaldehyde	500.10 ± 14.43[a]	35.10 ± 1.01[b]	n.d.
V14	Propionaldehyde	95.63 ± 2.76	n.d.	n.d.
V15	Succinaldehyde	75.54 ± 2.18	n.d.	n.d.
V16	Heptanal	47.75 ± 1.37[c]	110.34 ± 3.18[b]	561.00 ± 16.19[a]
V17	Hexanal	1 800.20 ± 51.96[c]	8 146.00 ± 235.15[a]	3 431.30 ± 99.05[b]
V18	Furfural	n.d.	0.37 ± 0.01	n.d.
V19	Nonanal	109.04 ± 3.14[a]	106.61± 3.07[a]	68.97 ± 1.99[b]
V20	Pentanal	265.07 ± 7.65	n.d.	n.d.
V21	Octanal	65.03 ± 1.87[b]	33.77 ± 0.97[c]	226.84 ± 6.54[a]
V22	Glyoxal	1.49 ± 0.04[b]	n.d.	73.66 ± 2.12[a]
	Total	9 885.29 ± 258.36[a]	8 439.39 ± 243.62[b]	4 425.74 ± 127.76[c]
	Acids (2)			
V23	Hexanoic acid	321.65 ± 9.28	n.d.	n.d.
V24	2-Furoic acid	n.d.	n.d.	0.45 ± 0.01
	Total	321.65 ± 9.28[a]	n.d.	0.45 ± 0.01[b]
	Esters (14)			
V25	Ethyl 3-butenoate	7.30 ± 0.21	n.d.	n.d.
V26	4-Methoxy-benzoic acid phenyl ester	n.d.	n.d.	0.30 ± 0.01
V27	Formic acid 1-propen-2-yl ester	n.d.	n.d.	9.34 ± 0.26
V28	Dipropyl succinate	10.23 ± 0.29	n.d.	n.d.
V29	Ethyl caprate	53.99 ± 1.55	n.d.	n.d.
V30	Dibutyl adipate	10.05 ± 0.29	n.d.	n.d.
V31	Methyl hexanoate	14.39 ± 0.41[c]	142.84 ± 4.12[b]	494.68 ± 14.28[a]
V32	Pentyl hexanoate	50.30 ± 1.45	n.d.	n.d.
V33	Ethyl hexanoate	n.d.	132.51 ± 3.82[b]	218.2 ± 6.29[a]
V34	Tetrahydrofurfuryl acetate	n.d.	n.d.	0.92 ± 0.02
V35	Butyl acetate	n.d.	9.26 ± 0.26	n.d.
V36	Methyl acetate	n.d.	36.61 ± 1.05	n.d.
V37	Vinyl acetate	n.d.	n.d.	0.41 ± 0.01
V38	Sabinylacetate	8.36 ± 0.24	n.d.	n.d.
	Total	154.66 ± 4.46[c]	321.23 ± 9.27[b]	723.88 ± 20.89[a]
	Ketones (15)			
V39	1,4-Pentadien-3-one	663.48 ± 19.15	n.d.	n.d.
V40	1-Hepten-3-one	4.86 ± 0.14[b]	32.72 ± 0.94[a]	n.d.
V41	1-Hydroxy-2-butanone	n.d.	14.93 ± 0.43	n.d.
V42	1-Penten-3-one	3.53 ± 0.01	n.d.	n.d.
V43	1-Octen-3-one	117.15 ± 3.38[b]	n.d.	646.17 ± 18.65[a]
V44	2,4-Dimethyl-3-heptanone	n.d.	5.87 ± 0.16	n.d.

Table 2 (*Continued*)

No.	Volatile compounds	Content (μg/kg)		
		Anhui	Guangdong	Jiangxi
V45	2-Heptanone	28.43 ± 0.82^{c}	478.29 ± 13.80^{a}	123.19 ± 3.55^{b}
V46	2-Methyl-3-pentanone	n.d.	n.d.	159.1 ± 4.59
V47	3,6-Heptanedione	n.d.	n.d.	3.69 ± 0.10
V48	3-Methyl-4-penten-2-one	n.d.	5.24 ± 0.15	n.d.
V49	3-Pentanone	0.10 ± 0.01^{b}	n.d.	6.80 ± 0.19^{a}
V50	3-Penten-2-one	n.d.	1.01 ± 0.02	n.d.
V51	3-Octen-2-one	188.98 ± 5.45	n.d.	n.d.
V52	4,5-Octanedione	5.52 ± 0.15	n.d.	n.d.
V53	Acetone	n.d.	837.40 ± 24.17^{a}	236.38 ± 6.82^{b}
	Total	1 012.09 ± 29.22^{c}	1 375.49 ± 39.70^{a}	1 175.35 ± 33.93^{b}
	Phenols (3)			
V54	3,5-Dimethylphenol	0.18 ± 0.01	n.d.	n.d.
V55	4-*N*-Heptylphenol	0.25 ± 0.01	n.d.	n.d.
V56	4-Ethyl-*O*-cresol	0.24 ± 0.01	n.d.	n.d.
	Total	0.68 ± 0.02	n.d.	n.d.
	Alkanes (9)			
V57	2,2-Dimethylhexane	n.d.	28.78 ± 0.83	n.d.
V58	2,5,5-Trimethylheptane	n.d.	24.02 ± 0.69	n.d.
V59	2-Methylpentane	n.d.	n.d.	12.44 ± 0.35
V60	3,3,5-Trimethylheptane	n.d.	20.98 ± 0.60	n.d.
V61	Methylcyclopentane	n.d.	25.31 ± 0.73	n.d.
V62	Dodecane	27.37 ± 0.79^{c}	86.85 ± 2.50^{a}	78.38 ± 2.26^{b}
V63	Hexadecane	31.07 ± 0.89	n.d.	n.d.
V64	Tridecane	272.16 ± 7.85^{b}	604.72 ± 17.45^{a}	291.01 ± 8.40^{b}
V65	Undecane	n.d.	71.18 ± 2.05^{a}	61.75 ± 1.78^{b}
	Total	330.62 ± 9.54^{c}	861.88 ± 24.88^{a}	443.59 ± 1.80^{b}
	Alkene (2)			
V66	3-Methoxy-1-heptene	n.d.	6.58 ± 0.19	n.d.
V67	3-Ethyl-3-heptene	n.d.	n.d.	650.46 ± 18.77
	Total	n.d.	6.58 ± 0.19^{b}	650.46 ± 18.77^{a}
	Furans (4)			
V68	2-Propionylfuran	1.21 ± 0.03	n.d.	n.d.
V69	2-Methylfuran	n.d.	14.10 ± 0.39	n.d.
V70	2-Pentylfuran	35.51 ± 1.02^{b}	18.99 ± 0.54^{c}	107.45 ± 0.45^{a}
V71	2-Butylfuran	70.62 ± 2.03	n.d.	n.d.
	Total	106.14 ± 3.06^{a}	33.10 ± 0.49^{b}	107.45 ± 3.10^{a}

Note: Different letters (a–c) in the same line indicate significant differences ($P < 0.05$). The results were expressed as mean values ± SD. n.d., not detectable.

reactions or enzyme-mediated pathways associated with microorganisms[40]. Owing to their low odor thresholds, these compounds play a pivotal role in shaping the characteristic flavor profile of dry-cured bacons[46]. A relatively high proportion of esters was observed in all the dry-cured bacons, likely attributed to prolonged natural drying and fermentation, which facilitated ester formation[47]. Notably, the ethyl caprate and pentyl hexanoate were unique to the Anhui dry-cured bacon, whereas butyl acetate and methyl acetate appeared only in the Guangdong dry-cured bacon. In contrast, methyl hexanoate was detected across all regional samples. These esters are responsible for imparting floral and fruity notes to dry-cured bacons from different origins[48].

Alkanes, formed through oxidation of unsaturated fatty acids[49], showed relatively high concentrations but little effect on the flavor due to high odor thresholds. The levels of alcohols, acids, furans, alkenes, and phenols were relatively low in all the bacon samples. The alcohols in dry-cured bacon are generally formed from amino acid and lactose metabolism, as well as through the reduction of acids and methyl ketones[50]. Among the four detected alcohols, the 1,2-butanediol was present in the Anhui and Guangdong dry-cured bacons, while 1,4-butanediol and homovanillyl alcohol were unique to the Anhui bacon, and 3-hepten-1-ol was found in the Guangdong and Jiangxi dry-cured bacons. Acids, typically generated from aldehyde oxidation and carbohydrate metabolism[51]. The hexanoic acid was unique to the Anhui dry-cured bacon, while 2-furoic acid appeared only in the Jiangxi dry-cured bacon. Hexanoic acid, a medium-chain fatty acid derived from β-oxidation of long-chain fatty acids, has been reported to impart characteristic fermented notes to cured meats[52]. Notably, the 2-propionylfuran, 2-methylfuran, 2-pentylfuran, 2-butylfuran were also detected in dry-cured bacon from different regions, and these furans mainly originated from the Maillard reaction, which is beneficial for the improvement of dry-cured bacon flavor[53]. In addition to core flavor-generating reactions such as lipid oxidation, regional

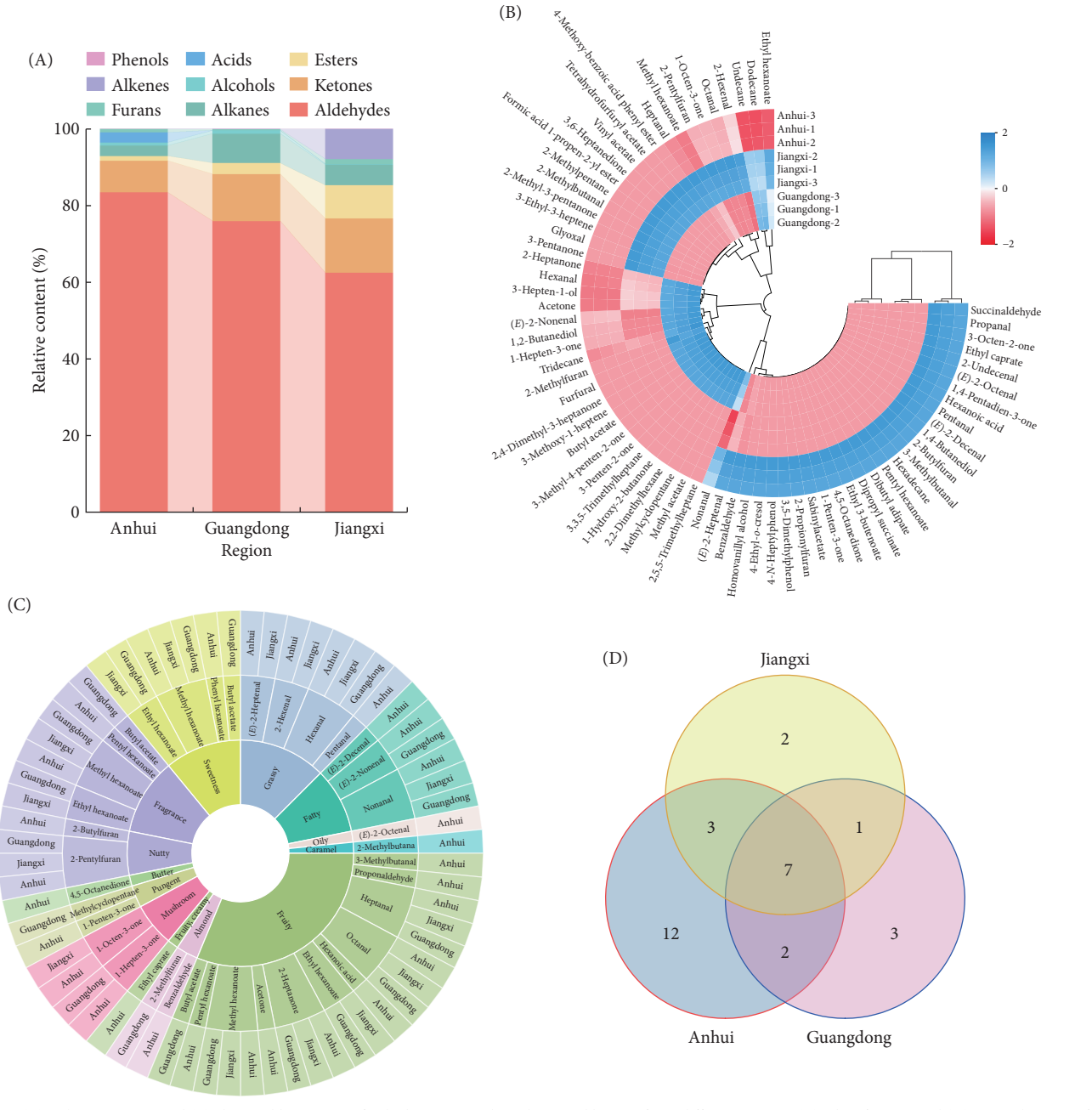


Figure 3 (A) Relative content and (B) clustered heat maps of volatile compounds in dry-cured bacons from different regions. (C) Classification and (D) Venn diagram of aroma compounds with OAV > 1 in dry-cured bacons from different regions.

disparities in processing parameters represent a crucial modulator of the composition and abundance of volatile compounds in dry-cured bacon from different producing regions.

3.2.2 *Screening of the key aroma-active compounds*

The GC-O-MS coupled with AEDA was applied to identify aroma-active compounds responsible for the characteristic flavor of dry-cured bacons. The OAV calculated as the ratio of the compound concentration to its odor threshold in water[54], was used to assess their relative contribution to the overall aroma profile. Since the perceived aroma intensity is determined by OAV rather than concentration alone, volatiles with OAV ≥ 1 were recognized as aroma-active[55], whereas those with OAV ≥ 10 were considered key odorants exerting a dominant influence on the aroma profile[56].

According to the GC-O-MS analysis, the compounds with OAV ≥ 1 were categorized into 13 aroma types as shown in Figure 3C, such as fatty, grassy, fruity, sweetness, fragrance, and nutty aromas that played a key role in dry-cured bacons, followed by mushroom, almond, caramel, pungent, and other aromas. Typically, volatiles with higher FD generally exert stronger contributions to overall aroma than those with lower ones[57]. Compounds showing FD ≥ 8 are typically considered the major aroma-active volatiles[58]. Therefore, a combined approach of OAVs and FD provides a more accurate identification of key odorants contributing to the characteristic flavor[59]. The detected OAV and FD of the dry-cured bacon from different regions of China are listed in Table 3. The 30 aroma-active compounds were first screened on the basis of OAV ≥ 1, including 14 aldehydes (3-methylbutanal, (*E*)-2-heptenal,

Table 3 Analysis of aroma-active compounds in dry-cured bacons from different regions of China.

No.	Volatile compound	Odor descriptions[a]	Odor threshold (μg/kg)[b]	OAV			FD		
				Anhui	Guangdong	Jiangxi	Anhui	Guangdong	Jiangxi
1	(*E*)-2-Heptenal	Grassy	13	6.44	< 1	1.52	4	n.d.	4
2	(*E*)-2-Decenal	Fatty, fried	0.30	105.43	< 1	< 1	8	n.d.	n.d.
3	(E)-2-Nonenal	Fatty, nutty	0.10	208.59	887.42	< 1	8	8	n.d.
4	(*E*)-2-Octenal	Oily, nutty	900	7.70	< 1	< 1	8	n.d.	n.d.
5	2-Hexenal	Grassy, fatty	15	9.99	< 1	27.03	2	n.d.	4
6	2-Methylbutanal	Caramel	130	< 1	< 1	3.28	n.d.	n.d.	8
7	3-Methylbutanal	Fruity	8	< 1	< 1	5.02	n.d.	n.d.	4
8	Benzaldehyde	Almond	350	1.42	< 1	< 1	4	n.d.	n.d.
9	Propionaldehyde	Fruity, nutty	68	1.40	< 1	< 1	n.d.	n.d.	n.d.
10	Heptanal	Fatty	2.8	17.05	39.40	200.35	16	8	8
11	Hexanal	Green, fatty	8	400.04	1 810.22	762.51	64	64	64
12	Nonanal	Fatty	1	109.04	106.61	68.97	8	8	8
13	Pentanal	Grassy, fatty	30	8.83	< 1	< 1	2	n.d.	n.d.
14	Octanal	Fruity, lemon	0.7	92.91	48.24	324.06	32	32	8
15	Hexanoic acid	Fatty	8.9	36.14	< 1	< 1	16	n.d.	n.d.
16	Ethyl caprate	Fruity, creamy	20	2.69	< 1	< 1	n.d.	n.d.	n.d.
17	Methyl hexanoate	Fruity, fragrance, sweetness	10	1.43	14.28	49.46	4	4	8
18	Pentyl hexanoate	Fruity, fragrance, sweetness	1.4	35.93	< 1	< 1	8	n.d.	n.d.
19	Ethyl hexanoate	Fruity, fragrance, sweetness	5	< 1	26.5	43.64	n.d.	16	8
20	Butyl acetate	Fruity, fragrance, sweetness	1	< 1	9.26	< 1	2	n.d.	n.d.
21	1-Hepten-3-one	Mushroom	0.04	123.73	818.15	< 1	16	32	n.d.
22	1-Penten-3-one	Pungent	3.2	1.10	< 1	< 1	8	n.d.	n.d.
23	1-Octen-3-one	Mushroom, metallic	3	39.05	n.d.	215.39	16	n.d.	32
24	2-Heptanone	Fruity, fatty	6	4.73	79.71	20.53	2	16	2
25	4,5-Octanedione	Butter	2.5	2.21	< 1	< 1	2	n.d.	n.d.
26	Acetone	Fruity	100	8.37	< 1	< 1	n.d.	n.d.	n.d.
27	Methylcyclopentane	Pungent	1.7	< 1	14.89	< 1	n.d.	8	n.d.
28	2-Methylfuran	Almond, roasted, smoky	6	< 1	2.23	< 1	4	n.d.	n.d.
29	2-Pentylfuran	Nutty	0.84	42.28	22.61	127.92	8	8	32
30	2-Butylfuran	Nutty	0.3	235.42	< 1	< 1	16	n.d.	n.d.

Note: Different letters (a–c) in the same line indicate significant differences ($P < 0.05$). The results were expressed as mean values ± SD. n.d., not detectable. Superscript a, odor description perceived at the GC sniffing port by assessors. Superscript b, the odor thresholds in water were obtained from online database (http://www.vcf-online.nl/VcfHome.cfm).

(*E*)-2-decenal, (*E*)-2-nonenal, (*E*)-2-octenal, 2-hexenal, 2-methylbutana, benzaldehyde, propanal, heptanal, hexanal, nonanal, pentanal, and octanal), 1 acid (hexanoic acid), 5 esters (ethyl caprate, methyl hexanoate, pentyl hexanoate, ethyl hexanoate, and butyl acetate), 7 ketones (1-hepten-3-one, 1-penten-3-one, 1-octen-3-one, 2-heptanone, 3-penten-2-one, 4,5-octanedione, and acetone), 1 alkane (methylcyclopentane), and 3 furans (2-methylfuran, 2-pentylfuran, and 2-butylfuran). As shown in Figure 3D, among these aroma-active compounds, 7 compounds were detected in the Anhui, Guangdong, and Jiangxi samples including heptanal, hexanal, nonanal, octanal, methyl hexanoate, 2-heptanone, and 2-pentylfuran, suggesting their potential role as shared key contributors to the overall aroma profile of dry-cured bacons. Among these common aroma-active compounds, hexanal was identified as the predominant shared volatile in Anhui, Guangdong, and Jiangxi dry-cured bacons, owing to its highest FD and OAV values (FD = 64, OAV = 400.04–1 810.22), consistent with previous observations[4]. Hexanal imparts a characteristic fresh and grassy note to the product. Other shared volatiles, including heptanal, nonanal, octanal, and 2-pentylfuran (FD ≥ 8, OAV = 17.05–324.06), also made significant contributions to the overall aroma of the dry-cured bacons. These results suggested that dry-cured bacons from different regions exhibited comparable aroma characteristics (mainly fatty, grassy, fruity, and lemon-like), particularly dominated by fatty notes, in agreement with earlier reports[3,10].

The key aroma-active compounds that contribute significantly to the flavor of dry-cured bacons from different regions by OAV ≥ 10 and FD ≥ 16 were screened. The heptanal (FD = 16, OAV = 17.05), hexanal (FD = 64, OAV = 400.04), octanal (FD = 32, OAV = 92.91), hexanoic acid (FD = 64, OAV = 36.14), 1-hepten-3-one (FD = 16, OAV = 123.73), 1-octen-3-one (FD = 16, OAV = 39.05), and 2-butylfuran (FD = 16, OAV = 235.42) were identified as contribute significantly key aroma-active compounds for Anhui dry-cured bacon. Similarly, the hexanal (FD = 64, OAV = 1 810.22), octanal (FD = 32, OAV = 48.24), ethyl hexanoate (FD = 16, OAV = 26.5), 1-hepten-3-one (FD = 32, OAV = 818.15), and 2-heptanone (FD = 16, OAV = 79.71) were identified as contribute significantly key aroma-active compounds for Guangdong dry-cured bacon. The hexanal (FD = 64, OAV = 762.51), 1-octen-3-one (FD = 32, OAV = 215.39), and 2-pentylfuran (FD = 32, OAV = 127.92) were identified as aroma-active compounds with key contributions for Jiangxi dry-cured bacon.

The results demonstrated significant differences in the composition of key aroma-active compounds among dry-cured bacons from different regions, reflecting the distinctive flavor characteristics of each type. The Anhui dry-cured bacon exhibited the most diverse composition of key aroma-active compounds, characterized by fatty, grassy, fruity, lemon-like, mushroom, and nutty notes, resulting in a more complex and unique aroma profile. In contrast, the Guangdong dry-cured bacon showed a slightly simpler aroma composition, lacking heptanal and hexanoic acid but containing ethyl hexanoate and 2-heptanone with high OAV and FD values, contributing to its fruity and sweet aromas. The Jiangxi dry-cured bacon contained only hexanal, 1-octen-3-one, and 2-pentylfuran, indicating fewer key aroma-active compounds. Nevertheless, hexanal provided a fundamental fatty note, while 1-octen-3-one and 2-pentylfuran contributed mushroom-like and nutty aromas. Collectively, Anhui dry-cured bacon displayed the richest and most complex aroma dominated by fatty and grassy notes, Guangdong dry-cured bacon was dominated by fruity and sweet notes, and Jiangxi dry-cured bacon exhibited a simpler profile dominated by mushroom-like and nutty attributes.

Current research on Chinese bacon flavor is largely restricted to smoked bacon and aroma compound identification of single-origin products. Liu et al.[3] validated volatile compounds as the primary cause of geographic flavor differences in multi-region bacon via GC-ion mobility spectrometry and electronic sensory analysis. Wu et al.[4] compared volatile profiles of non-smoked traditional bacon across Southwest and East China, and Qu et al.[43] demonstrated distinct chemical signatures between smoked and Guangxi non-smoked bacon, with phenols predominant in smoked bacon and esters abundant in Guangxi samples. Collectively, these studies support the significant regional flavor heterogeneity of Chinese bacon, consistent with our results. Notably, compared with prior work mostly limited to smoked bacon or single-region samples, this study integrates taste-active compound analysis, aroma-active compound identification and molecular docking simulation, and further reveals the synergistic mechanism underlying regional flavor divergence at both compositional and receptor-binding levels.

3.2.3 Molecular docking of key aroma-active compounds to olfactory receptor

Odor perception occurs through the activation of olfactory receptors by specific odorants. To investigate the molecular mechanisms underlying the perception of fatty, grassy, fruity, lemon, mushroom, nutty, and sweet notes, ten key aroma-active compounds were selected for molecular docking with OR2W1, an olfactory receptor. The calculated average binding energies of heptanal, hexanal, octanal, hexanoic acid, ethyl hexanoate, 1-hepten-3-one, 1-octen-3-one, 2-heptanone, 2-pentylfuran, and 2-butylfuran were −52.63, −51.37, −56.52, −77.32, −60.94, −50.24, −46.23, −47.82, −31.92, and −30.10 kcal/mol, respectively. Among these compounds, the hexanoic acid exhibited the strongest binding affinity, whereas 2-butylfuran showed the weakest. Binding energies reflect the strength of intermolecular interactions, with lower values indicating stronger affinity and greater complex stability[60]. The 2D interaction diagrams presented in Figure 4 illustrate that all compounds interacted with OR2W1 through a combination of hydrogen bonding and hydrophobic contacts, with Asp175, Leu174, and His176 identified as recurrent residues critical for

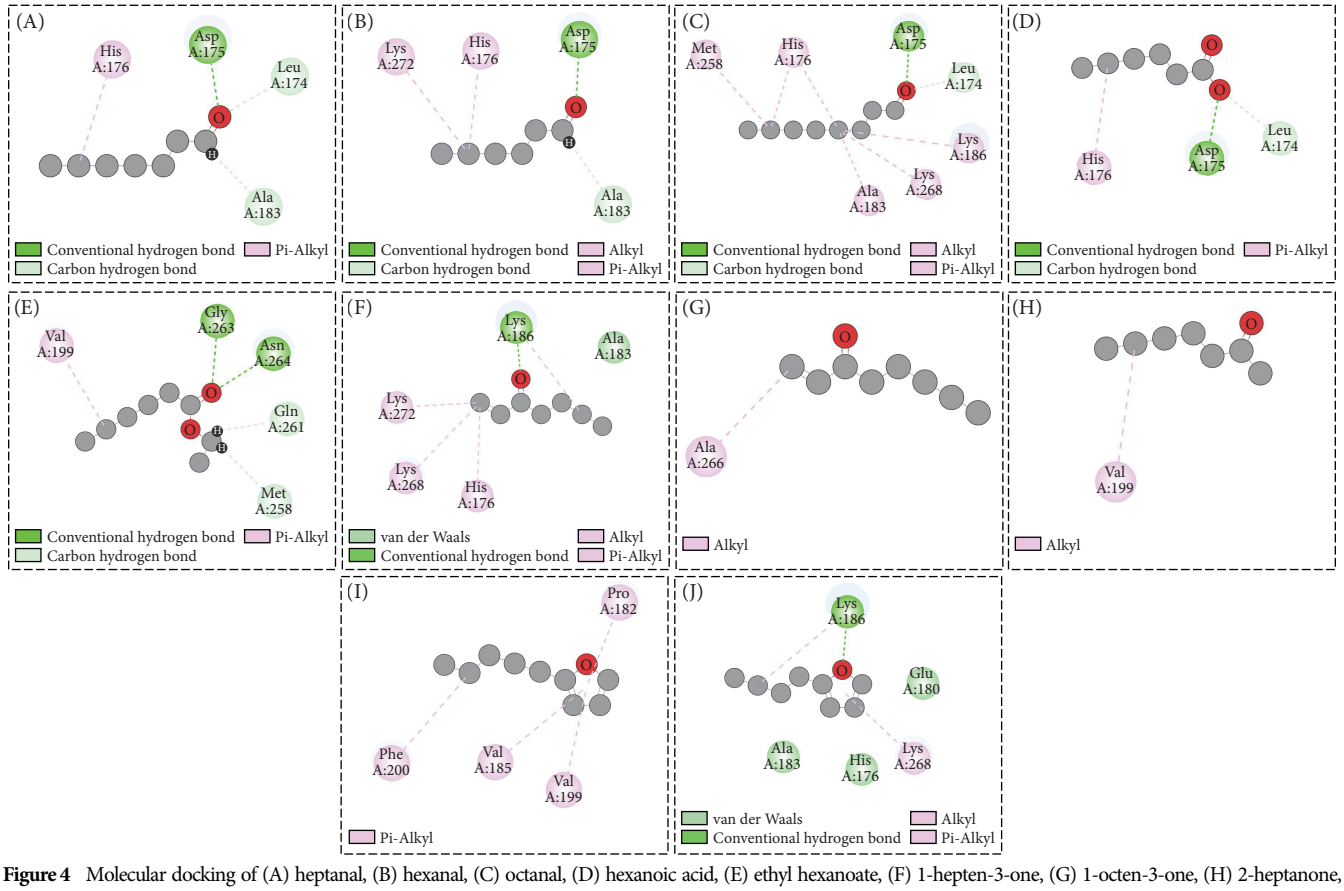


Figure 4 Molecular docking of (A) heptanal, (B) hexanal, (C) octanal, (D) hexanoic acid, (E) ethyl hexanoate, (F) 1-hepten-3-one, (G) 1-octen-3-one, (H) 2-heptanone, (I) 2-pentylfuran, (J) 2-butylfuran with OR2W1.

ligand recognition. These residues likely constitute key interaction sites for the binding of aliphatic aldehydes, acids, and ketones to the receptor.

The heptanal and octanal were able to establish stable hydrogen bonds with Asp175 and Leu174, while simultaneously engaging in hydrophobic contacts with residues such as His176, Ala183, and Met258. The extended carbon chain of octanal further enabled additional hydrophobic contacts (e.g., Lys186 and Lys268), indicating that increasing chain length may enhance binding stability by occupying a larger hydrophobic pocket. In contrast, hexanal exhibited fewer interactions, forming hydrogen bonds with Asp175 and Ala183, and limited hydrophobic contacts with His176 and Lys272, indicating a relatively weaker binding affinity. Hexanoic acid displayed a binding pattern similar to short-chain aldehydes, forming hydrogen bonds with Asp175 and Leu174, along with hydrophobic interactions with His176. Its carboxyl group may strengthen hydrogen bonding, yet the limited hydrophobic network could restrict overall binding stability. Ethyl hexanoate, however, predominantly interacted with polar residues (Gly263, Asn264, Gln261, Met258) via hydrogen bonds, complemented by hydrophobic interactions with Val199, highlighting the critical role of its ester functionality in receptor binding. Ketones demonstrated diverse binding modes. 1-Hepten-3-one formed multiple hydrogen bonds (Lys186, Ala183) together with extensive hydrophobic interactions (Lys272, Lys268, His176), suggesting that the unsaturated ketone structure provides favorable complementarity with the receptor hydrophobic cavity. By contrast, 1-octen-3-one and 2-heptanone exhibited markedly weaker binding, engaging in hydrophobic interactions only with Ala266 or Val199, respectively. Furan derivatives displayed more complex binding patterns. 2-Pentylfuran was stabilized mainly through hydrophobic interactions with Pro182, Val185, Val199, and Phe200, underscoring the role of its aromatic heterocycle in hydrophobic recognition. In contrast, 2-butylfuran not only established multiple hydrogen bonds with Lys186, Glu180, His176, and Ala183, but also engaged in hydrophobic interactions with Lys 268, indicating a more diverse and stable binding profile.

In summary, aldehydes primarily relied on Asp175, Leu174, and His176 for hydrogen bonding, ketones displayed variable binding capacities depending on chain length and unsaturation, whereas esters and furans employed a combination of polar and hydrophobic interactions to stabilize receptor binding. Abundant aldehydes in Anhui dry-cured bacon bind to OR2W1 mainly via hydrogen bonds with Asp175, Leu174 and His176, accounting for its fatty and grassy notes. Markedly enriched esters in Guangdong dry-cured bacon interact with receptors through hydrogen bonds with polar residues, matching its fruity and sweet profile. In Jiangxi dry-cured bacon, 1-octen-3-one and 2-pentylfuran serve as dominant odorants, with combined hydrogen-bonding and hydrophobic binding modes corresponding to its mushroom and nutty aroma traits. These findings suggest that structural diversity among volatile compounds governs distinct binding modes, which may underlie their differential contributions to odor perception. Notably, these docking findings are limited to the single receptor OR2W1 and represent only *in silico* predictions. Future studies employing multi-receptor panels and cellular functional assays are required for experimental validation.

4 Conclusions

This study elucidated the molecular mechanisms responsible for the regional flavor formation of Chinese dry-cured bacon. The Glu, Ala, Val, Met, Lys, His, Arg, lactic acid, Na^+, Cl^-, and K^+ were identified as the major taste-active compounds to the taste profile of Anhui dry-cured bacon, imparting umami, sweetness, bitterness, sourness, and saltiness, with sourness being particularly pronounced. The Glu, lactic acid, Na^+, Cl^-, and K^+ were the identified as key taste-active compounds in the Guangdong dry-cured bacon, primarily contributing to umami, sourness, and saltiness. The lactic acid, IMP, Na^+, Cl^-, and K^+ were the key taste-active compounds in Jiangxi dry-cured bacon, conferring more intense umami and saltiness characteristics. The Anhui sample was dominated by fatty and grassy aroma, the Guangdong sample was dominated by fruity and sweet aroma, and the Jiangxi sample was dominated by nutty aroma. Molecular docking results of key aroma-active compounds to olfactory receptor indicated that aldehydes primarily relied on Asp175, Leu174, and His176 for hydrogen bonding, ketones displayed variable binding capacities depending on chain length and unsaturation, whereas esters and furans employed a combination of polar and hydrophobic interactions to stabilize receptor binding. Notably, molecular docking only provides theoretical predictions of binding patterns and cannot replace functional validation of olfactory receptor activation. Follow-up cellular-level experiments are thus required to verify these interactions. The findings highlight regional differences in flavor compounds and their interactions with olfactory receptors, thereby offering fundamental insights for the scientific characterization and targeted regulation of flavor quality in dry-cured meat products.

Conflict of interest

The authors declared that they have no conflict of interest to this work.

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Author contributions

Feibiao Huang: Writing-original draft, validation, data curation. Ziwen Yang: Writing-original draft, investigation, review & editing. Ziwei Wang: Methodology, validation. Siwen Yin: Conceptualization, resources. Zhenni Li: Writing review, editing. Cuicui Li: Investigation, software. Lang Zhang: Project administration, supervision.

Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.265 99/FSAP.2026.9240191.

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