

Study on the Effects of Ginger Extract on the Degree of Hydrolysis, Sensory Evaluation, Color Difference, and Volatile Flavor Components of Oyster Enzymatic Hydrolysate

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Abstract. To investigate the impact of ginger extract on the quality of oyster enzymatic hydrolysate (OEH), the effects of adding 4% and 8% ginger juice on hydrolysis degree, sensory evaluation, color difference, and volatile flavor components were analyzed. The results indicated that the highest hydrolysis degree of OEH, achieved by adding 8% ginger juice, was 25.27%, and the highest sensory score reached 85.6. Furthermore, 24 and 36 compounds were identified in OEH with 4% and 8% ginger juice added, respectively.

Keywords: Oyster; ginger juice; enzymatic hydrolysate; volatile flavor components.

1. Introduction

Ginger, a perennial herbaceous rhizome belonging to the genus *Zingiber officinale* Roscoe, is a dual-purpose plant used both for medicinal and culinary purposes. The essential oil and pungent components in ginger are the active ingredients that contribute to its therapeutic effects. The chemical compositions and contents of ginger varieties vary across different producing areas. Ginger contains monoterpenes, sesquiterpenes, phenolic compounds and their derivatives, aldehydes, ketones, alcohols, esters, and other compounds. It is widely used due to its rich bioactive components and diverse processing methods [1-4].

Oysters are the predominant economic shellfish species cultivated extensively in China's coastal regions [5]. Due to their rich protein content and high nutritional value, oyster deep-processing products have great potential. Nevertheless, the elucidation of the underlying mechanisms causing fishy odor in oysters, during processing, and in enzymatic hydrolysis products, as well as effective mitigation strategies, constitute pivotal challenges in achieving high-value utilization of oysters [6]. Presently, there is a scarcity of research reports focusing on the application of ginger extract for seafood odor management. Li Yinta et al. [7] proposed that ginger possesses potent odor-masking properties, particularly against fishy and unpleasant odors, while imparting a robust aroma and discernible spiciness. Huang Dongxiang et al. [8] utilized fresh ginger juice to study the hydrolysis of tilapia protein, concluding that the optimal conditions for ginger juice hydrolysis of tilapia protein were a solid-to-liquid ratio of 1:3 (m/v, g/mL), ginger juice dosage of 0.3mL/g (E/S), reaction temperature of 45°C, duration of 2.0 hours, and pH 8.0. Zhang Meichao [9] employed 2% ginger juice to improve the flavor of oyster protein hydrolysate, resulting in a reduction in fishy and rancid odors and a notable increase in fruity aroma.

In this study, oyster meat was combined with various concentrations of ginger juice and subjected to enzymatic digestion at predetermined ratios. By analyzing the changes in hydrolysis degree, sensory evaluation, color difference value, and volatile flavor components, the impact on the quality of oyster enzymatic hydrolysis solution is explored.

2. Materials and Methods

2.1. Material and Reagents

Oyster meat was sourced from Raoping, Chaozhou, while ginger was procured from the Shangshe Market in Longdong, Guangzhou. Trypsin (with an enzyme activity of 4000 U/g) and flavor protease (with an enzyme activity of 50000 U/g) were supplied by Henan Wanbang Industrial Co., Ltd. Sodium hydroxide and hydrochloric acid were both analytical grade reagents.

2.2. Instruments and equipment

KS-1053 multi-functional cooking machine: Guangzhou Qihe Electric Appliance Co., Ltd., China., ATX224 analytical balance: Shimadzu Instruments (Suzhou) Co., Ltd., FE22-Standard pH meter: Mettler-Toledo International Inc., DKZ-3B electric thermostatic oscillating water bath: Shanghai Yiheng Scientific Instrument Co., Ltd., H1850R medical centrifuge: Hunan Xiangyi Centrifuge Instrument Co., Ltd., NS810 colorimeter: Shenzhen Sanenchi Technology Co., Ltd., GCMS-QP2010Ultra gas chromatography-mass spectrometry system: Shimadzu Institute, Japan. K9840 Kjeldahl nitrogen analyzer: Jinan Haineng Instrument Co., Ltd., 50 μ m diethylphenyl/carbon molecular sieve/polydimethylsiloxane (DVB/CAR/PDMS) extraction head: Supelco, USA. Manual SPME injection handle: Supelco, USA.

2.3. Method

2.3.1. Experimental operation process.

Wash ginger → Chunking → Beating (mass ratio 1:1) → Filter and extract juice (4%, 8%)

Fresh oyster meat → Beaten (1:1, pH 7.0, Ratio: Trypsin: Flavor protease=2:1) → Enzyme hydrolysis (55°C, 2h) → Enzyme inactivation (boiling water for 20 minutes) → Centrifugation (8000r/min, 10 minutes) → Supernatant taken

2.3.2. Preparation of Ginger Juice.

Ginger extract was prepared following the method described by Zhang Meichao [9]. The ginger was first washed and then cut into small pieces. A pulp was created by mixing the ginger with distilled water in a 1:1 mass ratio. The mixture was filtered, and the filtrate was collected for subsequent use.

2.3.3. Preparation of Ginger Juice.

OEH was prepared in accordance with the method described by Huang Kexin [10].

2.4. Determination of hydrolysis degree

In accordance with the methods outlined by Huang Dongxiang et al. [8], the formaldehyde titration method and the Kjeldahl nitrogen determination method were employed to quantify amino acid nitrogen and total nitrogen, respectively.

2.5. Sensory evaluation

The method was adapted with reference to Zhang Meichao [9]. The scoring criteria were presented in Table 1. A panel of five evaluators was assembled to conduct a sensory evaluation of the oyster enzyme digest of ginger extract, scoring the appearance (20%), taste (40%), and odor (40%). The sensory evaluation was carried out in a standard sensory laboratory, and the final scores were calculated accordingly.

Table 1. Sensory Scoring Table

Project	Standard	Score
Appearance (20 points)	Light yellow, clear posture	17-20
	Light colored, with a clear body shape	13-16
	Yellow, with a cloudy body shape	9-12
	Yellow is darker and the body is cloudy	5-8
	Dark yellow, with a cloudy body shape	0-4
Taste (40 points)	Oysters have distinctive fresh and ginger flavors, with no fishy or bitter taste	33-40
	Oysters have a prominent fresh and ginger flavor, while the fishy and bitter flavors are relatively mild	25-32
	Oysters have an average freshness and ginger flavor, with a fishy and bitter taste	17-24
	Oysters have a lighter freshness and ginger flavor, but a stronger fishy and bitter taste	9-16
	No oyster flavor or ginger flavor, with a stronger fishy and bitter taste	0-8
Odor (40 points)	The aroma is harmonious, and the characteristic aromas of oysters and ginger are rich and odorless	33-40
	The aroma is harmonious, and the characteristic aromas of oysters and ginger are relatively rich, with a slight odor	25-32
	The aroma is not harmonious, and the characteristic aromas of oysters and ginger are average, with an unpleasant odor	17-24
	The aroma is not harmonious, and the characteristic aromas of oysters and ginger are lighter, with a stronger odor	9-16
	The aroma is not harmonious, with no characteristic aroma of oysters and ginger, and a strong odor	0-8

2.6. Determination of chromaticity

Referring to the method of Shi Wen [11], the samples were dispensed into a liquid container, and the L* value (brightness), a* value (reddish-greenish), and b* value (yellowish-blue) of the sample solutions were measured directly using a colorimeter. Each sample was measured five times, and the average value was taken as the result.

2.7. Determination of volatile flavor components

2.7.1. Analysis of volatile flavor components.

According to the research method of Yang Zhao et al. [12], the volatile flavor components in the OEH with ginger juice were detected using headspace solid-phase microextraction gas chromatography-mass spectrometry.

2.7.2. Identification of volatile flavor components.

The peaks were searched through the NIST 11 spectral library and substances with a similarity greater than 80% were selected. Combined with literature reports, the volatile substances were qualitatively identified. Compounds with a relative content of $\geq 0.1\%$ were selected for statistical analysis, and the relative contents of various volatile flavor components were determined using area normalization [13].

3. Result and Analysis

3.1. Analysis of Hydrolysis Degree of OEH

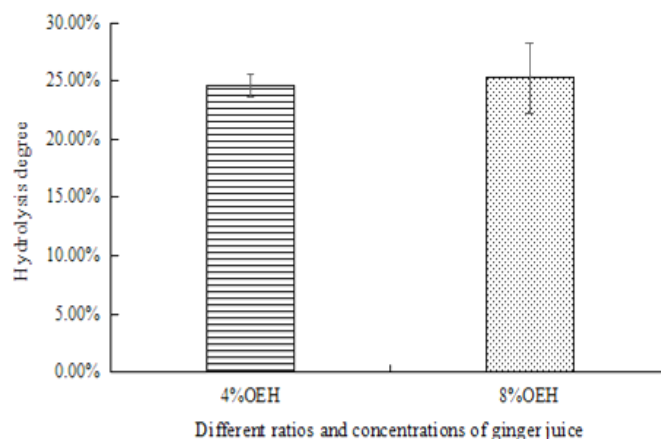


Figure 1. Hydrolysis degree of OEH

As shown in Fig. 1, the hydrolysis degrees of OEH prepared with different concentrations of ginger juice (4% and 8%) were 24.65% and 25.27%, respectively. The 8% OEH has the highest hydrolysis degree, followed by a 4% OEH, indicating that the degree of hydrolysis gradually increases from 4% to 8%. However, the overall difference in hydrolysis degree was not significant.

3.2. Sensory evaluation analysis of OEH

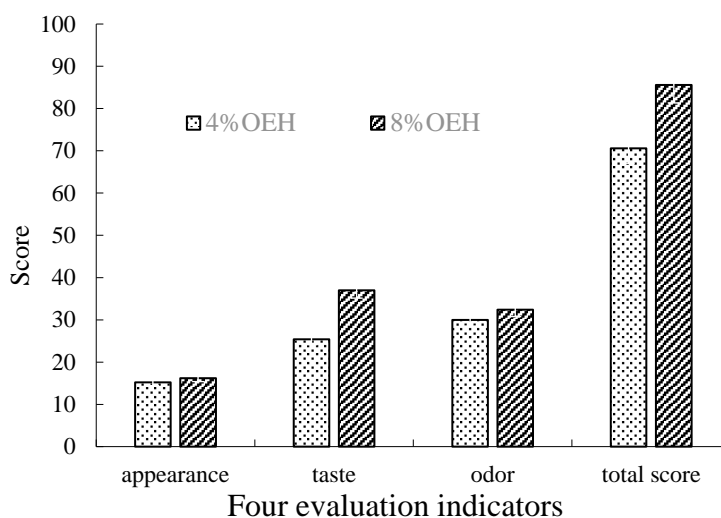


Figure 2. Sensory evaluation of OEH

The results of the sensory evaluation were presented in Fig. 2, where the sensory scores for the OEH prepared with two different concentrations of ginger juice (4% and 8%) show a significant difference. The scores increase gradually with increasing concentration. The sensory scores for appearance, taste, odor, and total score of OEH at concentrations of 4% and 8% were 15.2 and 16.2, 25.4 and 37, 30 and 32.4, and 70.6 and 85.6, respectively.

The results indicate that the 8% OEH achieved the highest score, followed by the 4% OEH, as determined by the three scoring indicators and their total scores. The inherent fishy taste of oysters and the degradation of lipids and proteins during enzymatic hydrolysis can be masked to some extent by the combination of ginger juice and oyster meat. In terms of taste, the 8% OEH scored slightly higher than the 4% OEH.

3.3. Color difference value analysis of OEH

Table 2. The color difference value of OEH

Samples	L*	a*	b*
4%OEH	33.73±0.11	-1.42±0.02	-2.19±0.04
8%OEH	33.70±0.01	-1.31±0.02	-1.84±0.05

The L* value serves as an index for brightness in a solution, with larger values indicating higher brightness. In the context of enzymatic hydrolysates, the difference in brightness between different concentrations was minimal. The data indicates that as the concentration of ginger juice increases, the brightness of the solution decreases. The a* value represents the redness-greenness of a solution, with positive values indicating a red tint and negative values suggesting a green tint. Enzymatic hydrolysates with varying concentrations exhibit a* value leaning towards green, with the 8% OEH displaying a more pronounced tendency (-1.31) compared to the 4% OEH (-1.42). The b* value is an indicator of the yellow-blue color in a solution, with positive values suggesting a yellow hue and negative values indicating a blue hue. The b* value of enzymatic hydrolysates with different concentrations tends to lighten as the concentration increases.

3.4. Analysis of volatile flavor components of OEH

Table 3. Types and relative content of volatile flavor components of OEH

Category	Name	Molecular formula	CAS No.	Relative content (%)	
				4%OEH	8%OEH
Alcohols	1-Octen-3-ol	C ₈ H ₁₆ O	3391 - 86 - 4	8.06	3.81
	1-(1-Butynyl) cyclopentanol	C ₉ H ₁₄ O	0 - 00 - 0	0.4	—
	Eucalyptol	C ₁₀ H ₁₈ O	470 - 82 - 6	21.14	20.13
	Linalool	C ₁₀ H ₁₈ O	78 - 70 - 6	3.28	4.83
	Bicyclo[2.2.1]heptan-2-ol, 1,7,7-trimethyl-, (1S-endo)	C ₁₀ H ₁₈ O	464 - 45 - 9	6.67	6.35
	Fenchyl alcohol	C ₁₀ H ₁₈ O	1632 - 73 - 1	—	0.13
	Trans-2-Pinanol	C ₁₀ H ₁₈ O	4948 - 29 - 2	—	0.13
	3-Cyclohexen-1-ol, 4-methyl-1-(1-methylethyl)-, (R)	C ₁₀ H ₁₈ O	20126 - 76 - 5	1.23	1.29
	L-.alpha.-Terpineol	C ₁₀ H ₁₈ O	10482 - 56 - 1	4.02	5.16
	Elemol	C ₁₅ H ₂₆ O	19078 - 36 - 5	0.29	—
	Citronellol	C ₁₀ H ₂₀ O	106 - 22 - 9	—	0.33
	Eudesmol <gamma->	C ₁₅ H ₂₆ O	1209 - 71 - 8	—	0.16
	(-)-Globulol	C ₁₅ H ₂₆ O	489 - 41 - 8	—	0.23
	2-Naphthalenemethanol, decahydro-.alpha.,.alpha.,4a-trimethyl-8-methylene-, [2R-(2.alpha.,4a.alpha.,8a.beta.)]	C ₁₅ H ₂₆ O	473 - 15 - 4	0.24	0.39
Subtotal				45.33	42.94
Aldehydes	Benzaldehyde	C ₇ H ₆ O	100 - 52 - 7	0.68	1.29
	(Z)-4-Heptenal	C ₇ H ₁₂ O	6728 - 31 - 0	—	3.72
	Octanal	C ₈ H ₁₆ O	124 - 13 - 0	0.5	0.38
	Neral	C ₁₀ H ₁₆ O	106 - 26 - 3	0.43	0.47
Subtotal				1.61	5.86
Ketones	5-Hepten-2-one, 6-methyl	C ₈ H ₁₄ O	110 - 93 - 0	16.99	15.49
	2-Heptanone	C ₇ H ₁₄ O	110 - 43 - 0	—	0.14

Subtotal				16.99	15.63
Hydrocarbons	2-Hexene, 3,5,5-trimethyl	C ₉ H ₁₈	26456 - 76 - 8	10.81	5.75
	2,2-Dimethyl-5-methylene norbornane	C ₁₀ H ₁₆	497 - 32 - 5	0.54	0.85
	Tetradecane	C ₁₄ H ₃₀	629 - 59 - 4	0.2	—
	Cubebene <alpha->	C ₁₅ H ₂₄	31141 - 66 - 9	0.14	0.15
	Bisabolene <beta->	C ₁₅ H ₂₄	4891 - 79 - 6	0.85	1.58
	1,6-Heptadiene, 2,5,5-trimethyl	C ₁₀ H ₁₈	62238 - 28 - 2	—	2.16
	2-((3,3-Dimethyloxiran-2-yl)methyl)-3-methylfuran	C ₁₀ H ₁₄ O ₂	92356 - 06 - 4	—	3.42
	Funebreene <alpha->	C ₁₅ H ₂₄	50894 - 66 - 1	—	0.27
	Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl	C ₁₅ H ₂₂	644 - 30 - 4	—	3.83
	Hexadecane <n->	C ₁₆ H ₃₄	544 - 76 - 3	—	0.15
Subtotal				12.54	18.17
Esters	2,2,4-Trimethyl-1,3-pentanediol diisobutyrate	C ₁₆ H ₃₀ O ₄	6846 - 50 - 0	—	0.16
	Bornyl acetate	C ₁₂ H ₂₀ O ₂	76 - 49 - 3	0.25	0.4
	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	C ₁₆ H ₂₂ O ₄	84 - 69 - 5	0.24	0.2
	Subtotal				0.49
Eerpenes	(+)-2-Bornanone	C ₁₀ H ₁₆ O	464 - 49 - 3	0.75	0.65
	Isoborneol	C ₁₀ H ₁₈ O	124 - 76 - 5	0.34	0.12
	Cyclohexane, 1-ethenyl-1-methyl-2,4-bis (1-methylethenyl)-, [1S-(1.alpha., 2.beta., 4.beta.)]	C ₁₅ H ₂₄	515 - 13 - 9	0.15	0.26
	Copaene	C ₁₅ H ₂₄	3856 - 25 - 5	—	0.17
	Sesquisabinene	C ₁₅ H ₂₄	58319 - 04 - 3	1.43	2.96
Subtotal				2.68	4.16
Heterocycles	Trans-2-(2-Pentenyl) furan	C ₉ H ₁₂ O	70424 - 14 - 5	—	0.26
Subtotal				0	0.26

Note: "-" indicates none.

Table 4. The number and relative content of various compounds in the volatile flavor components of OEH

Category	4%OEH		8%OEH	
	relative content (%)	number	relative content (%)	number
Alcohols	45.33	9	42.94	12
Aldehydes	1.61	3	5.86	4
Ketones	16.99	1	15.63	2
Hydrocarbons	12.54	5	18.17	9
Esters	0.49	2	0.76	3
Eerpenes	2.68	4	4.16	5
Heterocycles	—	—	0.26	1
Total	79.63	24	87.78	36

As detailed in Tables 3 and 4, 24 compounds were identified from 4% OEH, primarily composed of 9 alcohols (45.33%), 3 aldehydes (1.61%), 1 ketone (16.99%), 5 hydrocarbons (12.54%), 2 esters (0.49%), and 4 terpenes (2.68%). In comparison, 36 compounds were identified from 8% OEH, primarily composed of 12 alcohols (42.94%), 4 aldehydes (5.86%), 2 ketones (15.63%), 9 hydrocarbons (18.17%), 3 esters (0.76%), 5 terpenes (4.16%), and 1 heterocyclic (0.26%).

The volatile flavor components contained in both OEH at two different concentrations were four types, containing an alcohol (1-octen-3-ol), an aldehyde (Benzaldehyde), a hydrocarbon (2-Hexene, 3,5,5-trimethyl), and an ester (1,2-Benzenedicarboxylic acid, bis (2-methylpropyl) ester). Elemol was a unique volatile flavor component in the enzymatic hydrolysate of 4% OEH. Fenchyl alcohol, Trans-2-Pinanol, Citronellol, Eudesmol <gamma>, (-)-Globulol, (Z)-4-Heptenal, 2-Heptanone, 1,6-Heptadiene, 2,5,5-trimethyl, 2-((3,3-Dimethyloxiran-2-yl)methyl)-3-methylfuran, Funebrene <alpha>, Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl, Hexadecane <n>, Copaene, and Trans-2-(2-Pentenyl)furan were unique volatile flavor components in the enzymatic hydrolysate of 8% OEH.

To assess the impact of varying concentrations of ginger juice on the volatile flavor profile of oyster enzymatic hydrolysis products, a comparative analysis was performed on the volatile compounds present in two ginger juice oyster enzymatic hydrolysates. The detected components in both 4% OEH and 8% OEH include 1-octen-3-ol (8.06%, 3.81%), Benzaldehyde (0.68%, 1.29%), 2-Hexene, 3,5,5-trimethyl (10.81%, 5.75%), and 1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester (0.24%, 0.20%). Liang Zhili et al [14] showed that 1-Octen-3-ol is a degradation product of linoleate or linolenate hydroperoxides and is known to be abundant in freshwater and marine fish with a strong volatile odor, oily, earthy, and mushroomy taste.

Eucalyptol and 5-Hepten-2-one, 6-methyl were presented in high concentrations in OEH, with concentrations of 4% and 8% containing Eucalyptol (21.14%, 20.13%) and 5-Hepten-2-one, 6-methyl (16.99%, 15.49%), respectively. Among them, the volatile components in OEH (4%, 8%) include Linalool (3.28%, 4.83), Bicyclo[2.2.1]heptan-2-ol, 1,7,7-trimethyl-, (1S-endo) (6.67%, 6.35%), 3-Cyclohexen-1-ol, 4-methyl-1-(1-methylethyl)-, (R) (1.23%, 1.29%), L-.alpha.-Terpineol (4.02%, 5.16%), 2-Naphthalenemethanol, decahydro-.alpha.,.alpha.,4a-trimethyl-8-methylene-, [2R-(2.alpha.,4a.alpha.,8a.beta.)] (0.24%, 0.39%), Octanal (0.50%, 0.38%), Neral (0.43%, 0.47%), 2,2-Dimethyl-5-methylene norbornane (0.54%, 0.85%), Cubebene <alpha> (0.14%, 0.15%), Bisabolene <beta> (0.85%, 1.58%), Bornyl acetate (0.25%, 0.40%), (+)-2-Bornanone (0.75%, 0.65%), Isoborneol (0.34%, 0.12%), Cyclohexane, 1-ethenyl-1-methyl-2,4-bis(1-methylethenyl)-, [1S-(1.alpha.,2.beta.,4.beta.)] (0.15%, 0.26%), and Sesquisabinene (1.43%, 2.96%).

However, Fenchyl alcohol (0.13%), Trans-2-Pinanol (0.13%), Citronellol (0.33%), Eudesmol <gamma> (0.16%), (-)-Globulol (0.23%), (Z)-4-Heptenal (3.72%), 2-Heptanone (0.14%), 1,6-Heptadiene, 2,5,5-trimethyl (2.16%), 2-((3,3-Dimethyloxiran-2-yl)methyl)-3-methylfuran (3.42%), Funebrene <alpha> (0.27%), Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl (3.83%), Hexadecane <n> (0.15%), 2,2,4-Trimethyl-1,3-pentanediol diisobutyrate (0.16%), Copaene (0.17%), Trans-2-(2-Pentenyl)furan (0.26%) were present only in 8% OEH, probably because they were not present in the enzyme digest or small relative amounts.

4. Conclusion

The enzymatic digestion of oyster meat with ginger extract at varying concentrations revealed that the sensory score for the 8% OEH was the highest at 85.6. The degree of hydrolysis exhibited an increasing trend with the rise in concentration. 39 compounds were identified as volatile flavor components, with 24 compounds and 36 compounds identified in the enzymatic digestion of oysters with ginger juice at concentrations of 4% and 8%, respectively. In the 4% OEH, 24 compounds were identified, mainly consisting of 9 alcohols (45.33%), 3 aldehydes (1.61%), 1 ketone (16.99%), 5 hydrocarbons (12.54%), 2 esters (0.49%), and 4 terpenes (2.68%). In the 8% OEH, 36 compounds were identified, including 12 alcohols (42.94%), 4 aldehydes (5.86%), 2 ketones (15.63%), 9 hydrocarbons (18.17%), 3 esters (0.76%), 5 terpenes (4.16%), and 1 heterocyclic (0.26%).

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