LWT - Food Science and Technology 195 (2024) 115820

Contents lists available at ScienceDirect

LWT

journal homepage: www.elsevier.com/locate/lwt

The taste characteristics and metabolite variations of two Pacific abalone strains with different glycogen contents

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ARTICLE INFO

Keywords:
Pacific abalone
Glycogen
Sensory evaluation
Metabolic analysis
Umami

ABSTRACT

The flavor of shellfish has become one of the key selection goals in aquatic breeding since it influences consumer preferences. Glycogen has been proven to be a primary taste-enhancing component in most shellfish. But fewer studies were reported on Pacific abalone, and the contribution of glycogen to taste is unclear. In this study, the human sensory test, electronic tongue, ultra-high-performance liquid chromatography-tandem mass spectrometry (UHPLC-MS/MS), and multivariate statistical methods were used to investigate differences in flavor between two groups (high and low groups, respectively) of Pacific abalone with different glycogen contents. The results of the two flavor evaluations consistently showed that the scores of umami and sweetness were significantly higher in the high glycogen content group. Pacific abalone with a higher glycogen content has a better flavor. A total of 295 substantially differential metabolites were identified between the two groups. Lysine, glutamic acid, glycine, serine, threonine, nucleotides, phosphatidylcholine (PC), and phosphatidylethanolamine (PE) were considered to be the main taste-enhancing components in the high group. This study proves the significance of glycogen content in Pacific abalone on flavor characteristics and provides new insights into the underlying metabolic causes of flavor differences. Additionally, the findings also provide guidance for selection breeding of quality-related traits in Pacific abalone.

1. Introduction

Abalone, one of the representative marine mollusks that inhabit both tropical and temperate waters worldwide (Morash & Alter, 2016), is a highly valued seafood delicacy for its unique sensory properties and nutritional value, particularly in Asian nations (Liu et al., 2018; Shi et al., 2020). Abalone can enhance physical performance and reduce the risk of cardiovascular disease, as it is rich in protein, low in fat, and contains long-chain polyunsaturated fatty acids (LC-PUFAs), essential vital minerals, and vitamins (Chen, Wang, et al., 2021; Tan & Zheng, 2022). In order to satisfy rising consumer demand, China produced 21, 7831 tons of cultured abalone in 2021, accounting for over 90% of the total global production (FAO, 2023), and Pacific abalone (*Haliotis discus hannai*) is the most commonly farmed species.

With the rapid development of the economy, consumer demand for food is increasingly focusing on the quality and flavor of aquatic food. The flavor is one of the principal ingredients affecting consumers' acceptance. Numerous factors, such as storage treatments (Hughes et al., 2016; Li et al., 2022), cooking methods (Doh et al., 2019; Wang et al., 2018), and feed compounds (Smit et al., 2010), have been shown to influence the sensory experience of abalone. It is worth noting that the characteristics of abalone itself on flavor are also a significant influence factor. Quality-related trait selection breeding projects have been performed in many aquatic species (Lefevre et al., 2015; Liu et al., 2023; Quinton et al., 2005; Tan et al., 2020). Glycogen is the primary storage form of energy and also a taste-active component in shellfish (Fluckiger et al., 2011). Oysters with a higher glycogen content were more often evaluated as sweet or rich based on the sensory evaluation (Murata et al., 2020). According to Brown et al. (2008), glycogen can enhance the scallop muscle's continuity, fullness, complexity, and overall performance. In *Mytilus coruscus*, glycogen was one of the key differential flavor components (Zhu et al., 2023). However, fewer studies on the effect of glycogen on the flavor of Pacific abalone were reported, and the contribution of glycogen to taste is unclear.

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https://doi.org/10.1016/j.lwt.2024.115820
Received 8 December 2023; Received in revised form 9 January 2024; Accepted 30 January 2024
Available online 9 February 2024

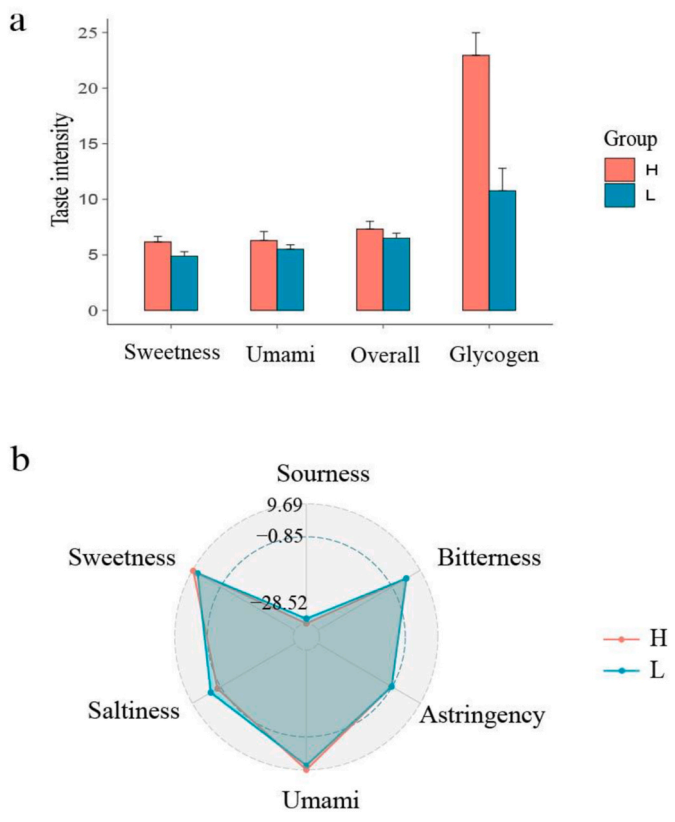

Fig. 1. The human sensory evaluation and electronic tongue analysis of taste intensity of in H and L group of Pacific abalone.

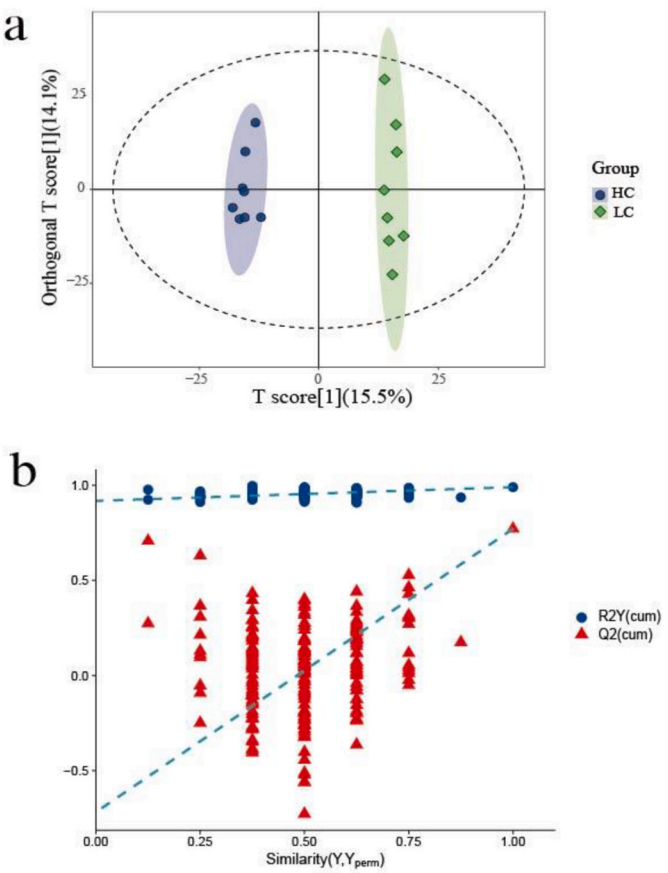

Fig. 2. The OPLS-DA score chart (a) and permutation test results (b) of H and L group in Pacific abalone.

Human sensory evaluation is the simplest method for determining the quality and likeability of a product (Mihafu et al., 2020), which can provide comprehensive and direct information about the target attributes. Electronic tongue systems can mimic the sensory perception of human taste to automatically assess the taste of complicated compositions in samples and identify their characteristic properties (Baldwin et al., 2011; Ismail et al., 2020). Currently, electronic tongues are widely used in various food products, such as tea (He et al., 2009), beef (Liu et al., 2022), rainbow trout (Duan et al., 2020), and loquat (Zou et al., 2020). Metabolomics is a promising strategy for mechanism pathways and identifying flavor markers in the field of food as it allows for the characterization of many compounds with small molecular metabolites (Cheng et al., 2021; Shen et al., 2021). Mass spectrometry (MS) methods such as liquid chromatography-tandem mass spectrometry (LC-MS/MS) with higher sensitivity and throughput of samples can effectively detect most of the metabolites in aquatic products, such as tilapia fillets (Li et al., 2021), Chinese mitten crab (Wang et al., 2023), grouper (Chu et al., 2023), and Pacific oyster (Chen et al., 2023).

In the study, the high- and low-glycogen-content Pacific abalone were selected from 20 full-sib families to evaluate the taste characteristics by human sensory and electronic tongue as first. Then ultra-high-performance liquid chromatography-tandem mass spectrometry (UHPLC-MS/MS) was used to identify differential metabolites and investigate the causes of metabolic differences between two groups of Pacific abalone. The study can provide a theoretical basis and evidence for the umami substances in the high glycogen content of Pacific abalone and guidance for selection breeding of quality-related traits in Pacific abalone.

2. Materials and methods

2.1. Pacific abalone

A breeding program of Pacific abalone with glycogen content as the breeding target was conducted in autumn 2021, and 20 full-sib families were constructed. Because glycogen content cannot be detected in a living individual, the flavor test was based on the family at the beginning, and the 3 families with the highest and lowest glycogen content were mixed as groups high-glycogen (H) and low-glycogen (L), respectively. A total of 20 samples of the same size in the H and L groups were selected at random to use sensory evaluation tests and further analysis, respectively. After the experiment, the glycogen content of each individual was measured. All samples were obtained from a commercial breeding company, Fuda Abalone Aquaculture Co., Ltd. Jinjiang, China. And abalones were acclimated in the lab for 3 days, half of the filtered seawater was replaced, and excrement was removed daily.

2.2. Sensory evaluation

Live abalone were transported to the Fujian Key Laboratory of Refrigeration and Conditioning Aquatic Products Processing, Xiamen, China, for sensory testing. During transportation (1 h), the abalone is continuously oxygenated to maintain its vitality. Every marked abalone was shucked and washed at room temperature, and the bottom muscle part was cut in half, with one half reserved for electronic tongue and glycogen content determination and the other steamed for 5 min in saucepans with a strainer insert. Two abalone groups of high and low glycogen content were steamed separately. Ten trained panelists (4 males and 6 females, aged 20–30) selected from Anjoy Foods Group Co.,

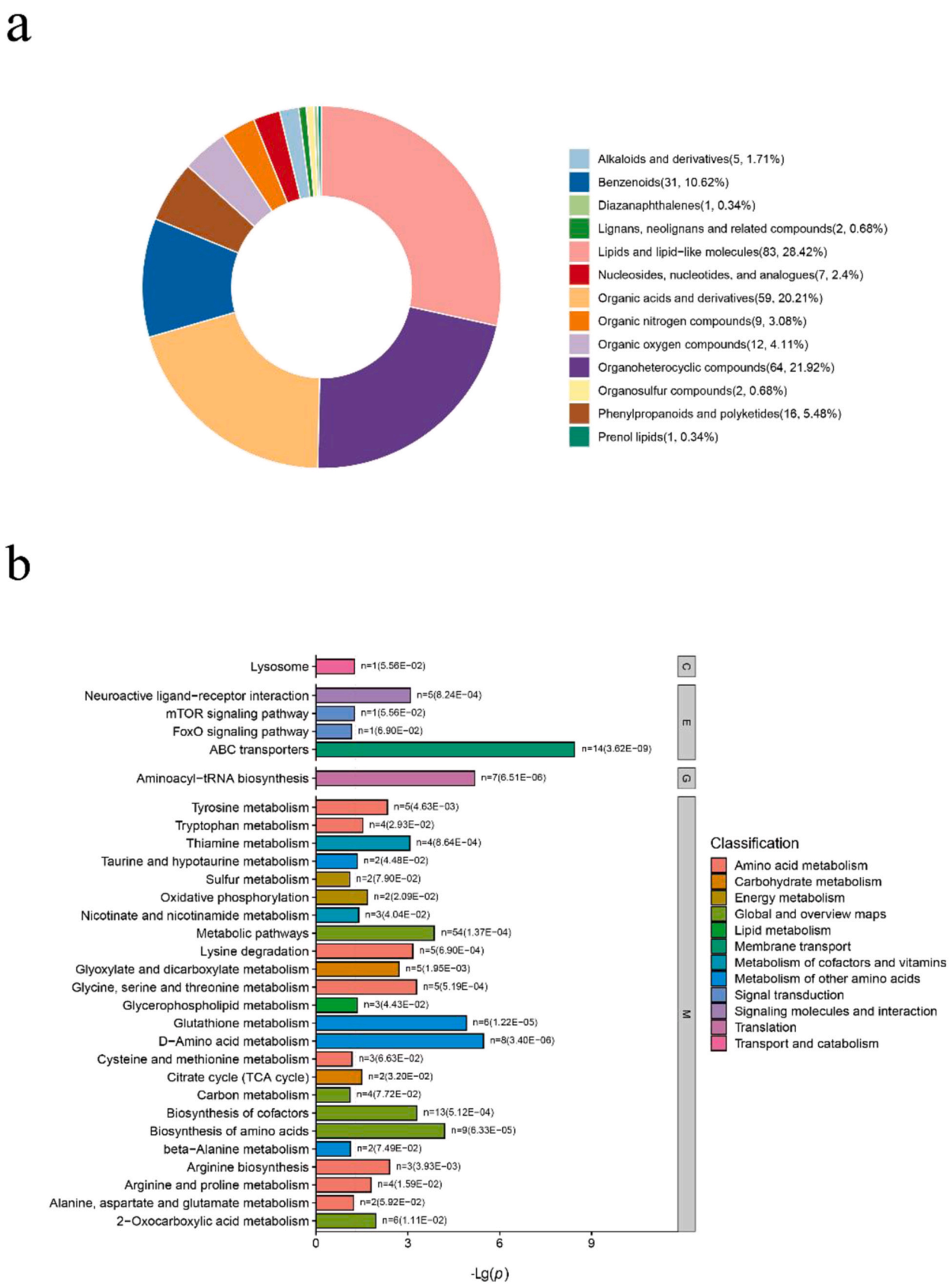

Fig. 3. The classification of differential metabolites (a) and KEGG pathway enrichment analysis (b, up to 30).

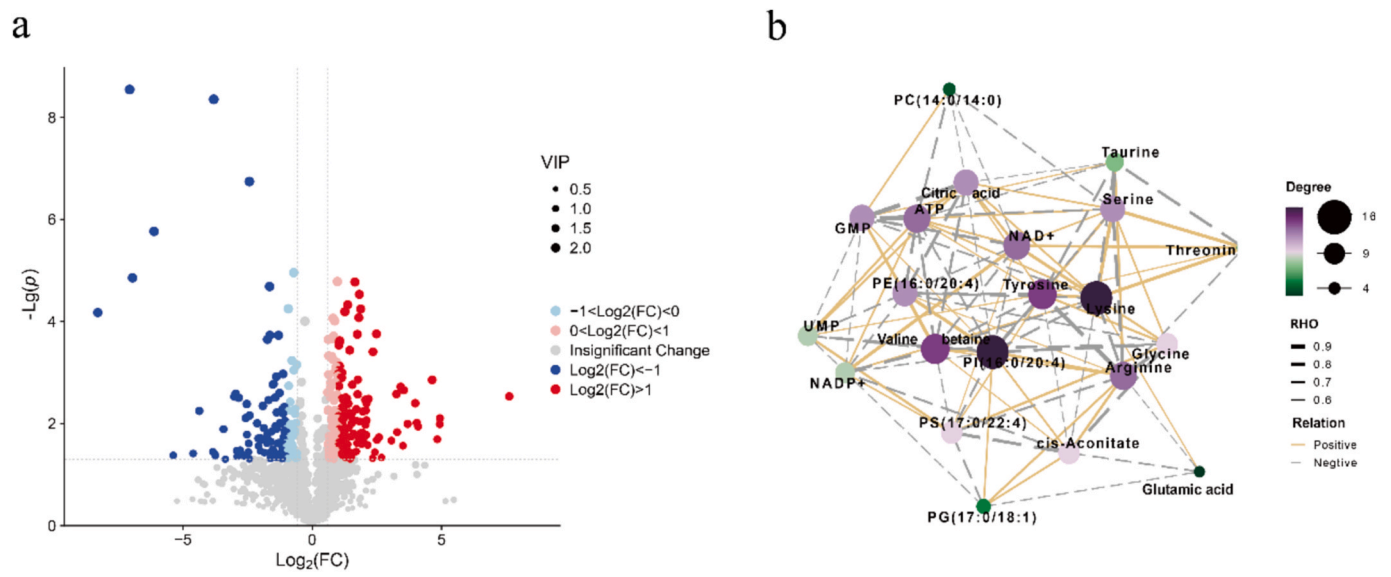

Fig. 4. The volcano plot of metabolites (a) and interaction network analysis of part significant metabolites (b). RHO: Spearman's rank correlation coefficient.

LTD. and graduate students of Xiamen University participated in the sensory evaluation. Each cooked abalone was cut into six uniform pieces for three evaluation personnel.

Sensory evaluation was conducted according to Cochet et al. (2013), Zhang et al. (2019), with some modifications. The overall hedonic sensory liking, umami intensity, and sweet intensity were measured using a 9-point scale from 1 to 9 (Zhang et al., 2019). As for sweet intensity, it means that the residual sweet flavor after the sample has been masticated carefully. Each abalone was monadically coded with three random numbers, and participants were asked to rinse their mouths with pure water before evaluation.

The remaining half-abalone samples were freeze-dried under vacuum for 48 h using a Labconco FreeZone 4.5 L. And then freeze-dried samples were ground into a fine powder that could pass through a 60-mesh screen. The mixed 2 g powder samples were homogenized with 40 mL of ultrapure water and then centrifuged at 8000 rpm for 10 min. The filtered supernatant was evaluated by a Taste-Sensing System SA 402 B (Intelligent Sensor Technology Co. Ltd., Japan). Prior to the tests, all sensors were preconditioned in a reference solution for 24 h. The preparation of the reference solution followed (Phat et al., 2016). Six taste parameters, including umami, sweetness, saltiness, sourness, bitterness, and astringency, were determined. The samples were determined four times, and after the initial determination, the average value was obtained.

2.3. Metabolomic profiling

The foot muscles of abalone in the H and L groups (8 replicates in each group) were performed to metabolomic analysis, with the H and L groups serving as the experimental group and control group, respectively. Abalone samples were weighed, lyophilized, and then ground in a 2 mL Eppendorf tube containing a 5 mm tungsten bead for 1 min at 65 Hz in a grinding mill. Using 1 mL of precooled solutions of methanol, acetonitrile, and water (v/v/v, 2:2:1), metabolites were extracted and then deposited in ice baths for 1 h of ultrasonic shaking. The mixture was then centrifuged at 14,000 g for 20 min at 4 °C after spending an hour at −20 °C. The supernatants were collected and vacuum-concentrated to dryness. The UPLC-ESI-Q-Orbitrap-MS system (UHPLC, Shimadzu Nexera X2 LC-30AD, Shimadzu, Japan) is coupled with Q-Exactive Plus (Thermo Scientific, San Jose, USA) for metabolomics profiling analysis. An ACQUITY UPLC® HSS T3 column (2.1 × 100 mm, 1.8 μm) (Waters, Milford, MA, USA) was used for liquid chromatography (LC) separation of the samples. Electrospray ionization (ESI) in both positive and negative modes was applied for MS data acquisition.

2.4. MS data preprocessing

Peak alignment, retention time correction, and peak area extraction were performed using MS-DIAL on the raw MS data. The metabolites were identified by accuracy mass (mass tolerance <10 ppm) and MS/MS data (mass tolerance <0.02Da), which were matched with HMDB, Massbank, and other public databases and a self-built metabolite standard library. In the extracted-ion features, only the variables having more than 50% of the nonzero measurement values in at least one group were kept. Orthogonal partial least-square discriminant analysis (OPLS-DA) was conducted for over fitting with methods of permutation tests. The variable importance on projection (VIP) value was used to indicate the contribution of each variable to the classification. Metabolites with a fold change ≥1.5 (upregulated) or a fold change ≤0.6 (downregulated), VIP ≥1, and $p \leq 0.05$ (two-tailed student's *t*-test) were considered to be significantly different metabolites.

2.5. Statistical analysis

Anthrone colorimetry was used to determine the glycogen content, as described by Liu et al. (2023). All results were shown by the average ± standard deviation. One-way analysis of variance in SPSS 27.0 was used to evaluate the data obtained in the glycogen content determination, sensory test, and electronic tongue analysis at a 0.05 significance level. The differential metabolite data were enriched in the KEGG database to identify biological pathways. Additionally, SIMCA-P (version 14.1) was used to conduct partial least squares analysis (PLS) to demonstrate the relationship between taste and metabolites.

3. Results

3.1. Glycogen content and sensory analysis

Three families with the highest and lowest glycogen contents were chosen from 20 families for sensory evaluation initially (Fig. S1). After the sensory evaluation, the glycogen content of each sample was determined based on the remaining half of the abalone (Fig. 1a). A considerable difference could be seen in the glycogen contents of the H and L groups, which were respectively 22.95 ± 2.05 and 10.76 ± 2.03.

Table 1
Taste-related differential metabolites identified in the H and L group of Pacific abalone.

Class	Name	VIP	p	FC
Amino acids	Lysine	2.07	0.01	2.06
	Glutamic acid	1.51	0.02	3.87
	Glycine	2.10	0.01	1.54
	Serine	1.74	0.01	2.36
	Threonine	1.52	0.03	2.04
	Arginine	2.0	0.01	0.60
	Tyrosine	2.11	0.01	1.82
	Taurine	1.34	0.04	0.60
Nucleotides	ATP	1.17	0.05	15.95
	GMP	1.38	0.02	0.29
	UMP	1.25	0.04	1.67
	NAD+	1.49	0.02	2.46
	NADP+	1.36	0.03	2.25
Glycerophospholipids	PC (14:0/14:0)	1.32	0.04	0.07
	PC (14:0/16:0)	1.67	0.01	1.93
	PC (15:0/16:0)	2.11	0.01	3.66
	PC (15:0/20:5)	1.48	0.02	2.22
	PC (16:0/15:1)	1.93	0.01	0.38
	PC (16:0/16:0)	1.63	0.01	2.07
	PC(16:0/18:1)	1.83	0.01	3.37
	PC (16:0/18:2)	1.64	0.01	3.20
	PC (16:0/20:4)	1.77	0.01	4.25
	PC (16:0/20:5)	1.74	0.01	2.62
	PC (16:1/16:1)	2.43	0.01	0.07
	PC (17:0/20:4)	1.77	0.01	10.71
	PC (17:0/20:5)	1.58	0.01	2.64
	PC (17:0/22:6)	2.06	0.01	5.58
	PC (17:1/18:2)	1.65	0.01	2.25
	PC (18:0/20:3)	2.13	0.01	3.13
	PC (18:1/14:0)	1.34	0.03	1.57
	PC (18:1/18:1)	1.72	0.01	4.52
	PC (18:1/18:2)	1.74	0.01	4.14
	PC (18:1/20:1)	1.44	0.02	1.82
	PC (18:2/18:2)	1.76	0.01	2.45
	PE (16:0/20:4)	1.34	0.03	0.14
	PE (16:0/20:5)	1.68	0.01	4.27
	PE (16:0/22:6)	2.40	0.01	0.01
	PE (16:1/20:4)	2.27	0.01	0.01
	PE (17:0/20:4)	1.37	0.03	0.13
	PE (18:1/20:4)	1.64	0.01	0.05
	PE (18:1/20:5)	1.39	0.02	3.57
	PE (20:3/16:0)	2.21	0.01	0.01
	PE (21:0/22:6)	1.71	0.01	3.40
	PE (P-16:0/22:5)	1.38	0.03	2.21
	PG (17:0/18:1)	1.26	0.04	0.40
	PI (16:0/20:4)	2.23	0.01	0.61
	PS (17:0/22:4)	1.51	0.01	4.24
Organic acid	Valine betaine	1.59	0.01	0.41
	Citric acid	1.71	0.01	1.78
	cis-Aconitate	1.44	0.02	0.46

The results of human sensory evaluation displayed that significantly higher scores were obtained in H compared to L in overall hedonic sensory liking, umami, abd sweetness intensity. Consistent results were obtained in electronic tongue analysis, including scores for sweetness, sourness, bitterness, astringency, umami, and saltiness (Fig. 1b). Generally, abalone meat showed a high sweetness and umami intensity, followed by bitterness. Sourness and astringency intensity were negative. A significantly higher umami and sweetness intensity were obtained in H (umami: 9.69 and sweetness: 9.37) compared to L (umami: 8.32 and sweetness: 7.76). And the saltiness and sourness intensity in H (saltiness: 0.34 and sourness: 28.52) was significantly lower than that in L (saltiness: 2.85 and sourness: 26.98).

3.2. Untargeted metabolomics analysis in abalone

To better understand flavor differences between the H and L groups in Pacific abalone, metabolite profiling was performed using an untargeted UHPLC-MS/MS; a total of 1598 metabolites were identified. A supervised OPLS-DA analysis was used to describe the separation trend in the H and L groups. The model evaluation parameters were as follows: R2X (cum) = 0.297, R2Y (cum) = 0.99, and Q2 (cum) = 0.77, and as can be seen in Fig. 2a–H and L were clearly separated on both sides of PC1. These results indicated that the model was stable and the metabolic differences between the H and L groups were robust. Additionally, the model displacement tests 200 times showed that there was no overfitting of the model and that it could be used in further metabolite screening (Fig. 2b).

3.3. Differential metabolites and KEGG enrichment analysis

With the criteria of VIP >1, $p < 0.05$, and FC > 1.5 or FC < 0.6, there were 295 substantially different metabolites in total, comprising 166 upregulated and 129 downregulated metabolites (Fig. 4a). As displayed in Fig. 3a, lipids and lipid-like molecules made up the majority of these metabolites (28.42%), followed by organocyclic compounds (21.92%), organic acids and derivatives (20.21%), benzenoids (10.62%), and nucleosides, nucleotides, and analogues (2.4%). Metabolites that are likely to be major contributors to the taste were focused on in our study. Some taste-related differential metabolites and interaction network analysis were shown in Table 1 and Fig. 4b, mainly including amino acids, nucleotides, glycerophospholipids, organic acids, and carbohydrates. Based on the weighted threshold value of (≥0.5, positive; <=-0.5, negative), this network of metabolite relationships is largely consistent with the pathway of biosynthesis. Similarly, KEGG enrichment analysis showed that these metabolites were significantly enriched in amino acid metabolism, carbohydrate metabolism, energy metabolism, lipid metabolism, membrane transport, and signal transduction pathways.

3.4. Correlations between taste intensity and metabolites

The relationship between chemical composition and taste characteristics was examined using PLS regression analysis. The X and Y variables were set to the mass intensity of the metabolites and the taste intensity. Numerous flavor-enhancing metabolites of Pacific abalone, such as glutamic acid, lysine, serine, nucleotides, phosphatidylcholine, and phosphatidylethanolamine, were close to samples of the H group and were positively correlated with the umami characteristics, as shown by biplot loadings (Fig. 5). These substances might be proven to be the primary causes of the umami characteristics in the H group of Pacific abalone.

4. Discussion

The flavor of ocean shellfish has become one of the key selection goals in breeding since it influences consumer preferences. Glycogen has been proven to be a primary taste-enhancing component in most shellfish. In abalone, Konosu (Konosu, 1973) reported that glycogen improves the characteristic taste of abalone, but the contribution of glycogen to taste is unclear. In this study, a targeted sensory evaluation experiment was conducted on two strains of Pacific abalone with different glycogen contents, and then metabolomic analysis was also performed to better elucidate the flavor characteristics and causes of metabolic of the high glycogen content of Pacific abalone.

The sensory evaluation findings demonstrate a considerable difference between the H and L groups in the umami and sweetness of the abalone meat flavor; abalone with a high glycogen content has a better flavor. The results were consistent with studies in *Crassostrea gigas* (Murata et al., 2020), *Mytilus coruscus* (Zhu et al., 2023), sea urchin (Komata, 1964), and *Hinnites multirugosus* (Phleger et al., 1978). In the study on the taste quality of *Mytilus coruscus*, glycogen proved to be the key differential flavor component (Zhu et al., 2023). *C. gigas* evaluation tests more frequently classified oysters with a higher glycogen content as sweet or rich from 30 brands of oysters (Murata et al., 2020). Low molecular sugar-related metabolites are produced when glycogen is

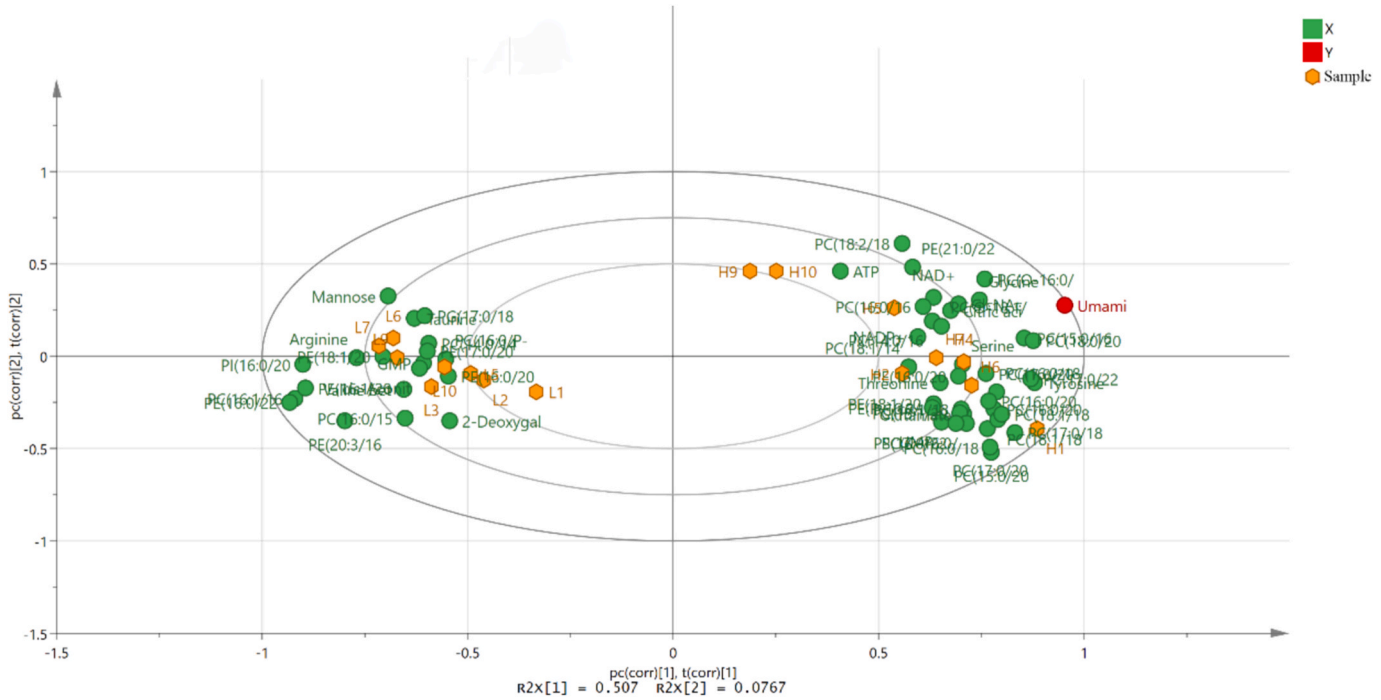

Fig. 5. PLS analysis of taste characteristic and metabolites (the mass intensity of the metabolite was the X variable, and the taste intensity of umami was the Y variable).

depleted; these reducing sugars can produce pleasant and umami flavor and react and couple with amino acids to generate the volatile aroma compounds (Dashdorj et al., 2015). Additionally, compared with artificial sensory evaluation, the electronic tongue can perform qualitative and quantitative sensory analysis more simply and accurately and avoid subjective effects simultaneously (Marx et al., 2017). In the report of Wang et al. (2023), it was suggested that signal sensing enabled the electronic tongue to analyze taste parameters in *Eriocheir sinensis* with greater sensitivity. Therefore, the current findings suggest that the electronic tongue can take on the role of human tasters in the evaluation of Pacific abalone flavor.

In this study, it is important to note that umami and sweet amino acids (lysine, glutamic acid, glycine, serine, and threonine) are strongly upregulated in the H group while significantly downregulating bitter amino acids (arginine). Consistent results were found in the oyster study (Li et al., 2017). Glucogenic amino acids (gluconeogenic substrates) are transformed into the corresponding ketonic acid via a deamination reaction. These ketonic acids are changed into pyruvic acid by the TCA cycle, which is subsequently changed into oxaloacetate, which produces glucose (Méndez-Lucas et al., 2013; Rognstad, 1979). Amino acids and their derivatives are crucial components of nutrients and also have a significant role in determining the flavor of food (Chen, Huang, et al., 2021). In the analysis of Manila clams (*Ruditapes philippinarum*), it was shown that alanine, glutamic acid, glycine, and aspartic acid contributed to the sweet and umami flavor and were the most abundant free amino acid (FAAs) in clams (Zhou et al., 2021). Sweet amino acids can promote umami taste and make the meat of puffer fish (Yang et al., 2019) and *E. sinensis* (Belitz et al., 2004) more intense. And more, higher total FAAs and serine content were linked to higher oyster evaluated scores of sweet and rich (Murata et al., 2020). On the other hand, a higher concentration of bitter amino acids will inevitably cover umami flavor and make it less delicious, as reported in pufferfish (Zhang et al., 2019) and *E. sinensis* (Wang et al., 2023). Taurine was the dominant FAA in abalone (Tsai et al., 2018), and it was revealed that high taurine content significantly improved the postharvest quality characteristics of European seabass (Kotzamanis et al., 2020) and Pearl Oyster Pinctada *fucata martensii* (Zhang et al., 2022). However, in our research, taurine did not appear to enhance the flavor of Pacific abalone, which was consistent with the study by Hatae et al. (1995).

Glycogen serves as a form of energy storage. The liberated glucose is completely metabolized to CO_2 and H_2O through glycolysis and oxidative metabolism, along with the release of ATP. Adenosine triphosphate (ATP)-related substances can react and couple with amino acids to generate the taste-enhancing characteristics of aquatic products (Yamaguchi et al., 1971). The umami taste has a taste-enhancing synergism between L-glutamate and Inosine-5′-monophosphate (IMP). IMP and 5′- adenosine monophosphate (AMP) were identified as the primary flavor components influencing the umami in most aquaculture species, such as pufferfish, E. sinensis, and scallop (*patinopecten yessoensis*) (Sun, Lin, Zeng, Deng, & Guidi, 2023; Wang et al., 2023; Zhang et al., 2019). In our study, the ATP in the H group was substantially higher than that in the L group (FC = 15.95), which was consistent with the corresponding glycogen contents. However, no significant difference was detected in AMP or IMP between the two groups. As we all know, ATP is quickly degraded to adenosine diphosphate, AMP, IMP, and guanosine monophosphate after cell death. Numerous factors, such as species, storage, and handing, can affect the rate of action of the different ATP degradation enzymes. According to reports, fresh fish often has relatively little umami flavor and little free IMP. Several hours later, as the slow decomposition of ATP starts, the umami flavor of fish will rise (Hong et al., 2017). Similar results were obtained in the study of tilapia, the nucleotide contents showed an overall increase after thermal processing (Li et al., 2021). In current research, fresh abalone foot muscles were used to experiment, which may cause a slower degradation of ATP. Therefore, more research should be conducted to investigate the influence of nucleotides.

Lipids and glycogen are two of the body's primary energy components. They share metabolites and metabolic pathways, which allow them to interact and change into one another (Haman et al., 2002; Lu et al., 2014). In fetal and newborn rat lungs, the results showed that the development of phosphatidylcholine synthesis, content, and activities of enzymes involved were correlated with patterns of glycogen content, glycogen synthase activity, glycogen phosphorylase activity, and glucose oxidation (Maniscalco et al., 1978). In current study, amounts of

upregulated glycerophospholipids, which mainly consist of phosphatidylcholine (PC) and phosphatidylethanolamine (PE), were found in the H group compared to the L group. Numerous aquatic species depend on phospholipids as a vital nutrient because they help cells carry out a variety of physiological processes (Yan et al., 2020). Additionally, phospholipids are crucial in the production of volatile flavoring components like alcohols, ketones, and aldehydes in meat. According to Cui et al. (2023), the synthesis of volatile taste compounds is connected to the variations in PCs and PEs in abalone muscle. In the study of crab (*Portunus trituberculatus*), it was revealed that the flavor of crab muscle could be modified by dietary lipid sources. Some organic acids such as betaine, succinic acid, and citric acid, proved to be the main taste substances in marine shellfish (Bi et al., 2023; Cui et al., 2023). In our study, citric acid was found to be upregulated in the H group. Citric acid can quickly provide ATP by participating in the tricarboxylic acid cycle (TCA cycle) and promoting the growth and survival of marine animals. At present, citric acid is now thought of as a flavoring additive in diets or the rearing water of marine animals (Sarker et al., 2005).

In addition to conventional detection of amino acid metabolism and lipid metabolism from KEGG enrichment, such energy- and antioxidant-related pathways as ABC transport, oxidative phosphorylation, glutathione metabolism, membrane transport, and the TCA cycle were also identified. The finding is expected to contribute to the ability of the high-glycogen Pacific abalone to cope with stress, like heat stress, hypoxia, and disease. In the Pacific oyster *Crassostrea gigas*, (Li et al., 2017) reported that oysters with a higher glycogen content can supply energy and improve stress tolerance. In the Manila clam *Ruditapes philippinarum* (Sun, Nie, & Yan, 2023), the study showed that glycogen-related genes may have roles in the immunological response to the *Vibrio parahaemolyticus* challenge.

5. Conclusion

In this work, our study suggests that the Pacific abalone with a higher glycogen content has a better flavor in umami and sweetness. Lysine, glutamic acid, glycine, serine, threonine, nucleotides, PCs, and PEs were the main taste-enhancing components. The main enrichment pathways for significant differences in metabolites were amino acid metabolism, carbohydrate metabolism, energy metabolism, lipid metabolism, membrane transport, and signal transduction pathways. Subsequently, transcriptome analysis and verification experiments can be performed to identify the associated genes and SNPs, which offer useful information for molecular selective breeding.

CRediT authorship contribution statement

Junyu Liu: Writing – original draft, Software, Methodology. **Ziheng Yin:** Methodology, Formal analysis, Data curation. **Wenchao Yu:** Visualization, Validation, Software. **Xuan Luo:** Writing – review & editing, Resources, Funding acquisition. **Caihuan Ke:** Writing – review & editing, Supervision, Resources, Funding acquisition, Conceptualization. **Weiwei You:** Writing – review & editing, Supervision, Resources, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

This work was supported by grants from the National Natural Science Foundation of China (Nos. 32172961 and U22A20530), National Key R&D Program of China (2018YFD0901400), Seed Industry Innovation and Industrialization in Fujian Province (No.2021FJSCZY02), Fujian Provincial S & T Project (2020N5001), Earmarked Fund for CARS (No. CARS-49) and Fundamental Research Funds for the Central Universities (2072022). Thanks for the support from the Germplasm resources sharing platform of aquatic species in Fujian Province, XMU-MRB abalone research center, and Anjoy Foods Group Co., LTD.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.lwt.2024.115820.

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