ORIGINAL ARTICLE

Total and Organic Acid Content of Sour Bamboo Shoots in River Snail Rice Noodles

Na Cui [1,2], Emmy Hainida Khairul Ikram [2,5]*, Jianwen Xiong [1], Wei Chen [1], Azizah Othman [3], Fadhilah Jailani [3], Zhenhua Li [2], and Zhenguo Xu[4]

[1] Department of Food and Chemical Engineering, Liuzhou Institute of Technology, 545616 Liuzhou, Guangxi, China
[2] Centre for Dietetics Studies, Faculty of Health Sciences, Universiti Teknologi MARA, 42300 Cawangan Selangor Kampus Puncak Alam, Selangor, Malaysia
[3] Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
[4] Guangxi Key Laboratory of Superior Timber Trees Resource Cultivation, Guangxi Forestry Research Institute, 530002 Nanning, Guangxi, China
[5] Integrated Nutrition Science and Therapy Research Group (INSPIRE), Faculty of Health Sciences, Universiti Teknologi MARA Cawangan Selangor Kampus Puncak Alam, Selangor, Malaysia

ABSTRACT

Introduction: Sour bamboo shoot is a specialty food product prepared from fermented bamboo shoots. The organic acids are related to the sour flavour of sour bamboo shoots and are one of their main flavour-presenting substances. Thus, this project is aimed to explore the relationship between the total acid and organic acids content of sour bamboo shoots. **Materials and Methods:** Thirty-five types of sour bamboo shoots from various restaurants and brands were studied. The total acid and organic acid contents were determined using acid-base titration and high-performance liquid chromatography (HPLC), respectively, and the correlations between them were analyzed. **Results:** The total acid content of fifteen types of restaurant sour bamboo shoots ranged from 6.47 mg/g to 18.9 mg/g, with the highest in Cao Mei (18.9±0.321 mg/g) and the lowest in Jiao Jie (6.47±0.323 mg/g). The average total acid content was 14.071 mg/g. In twenty types of prepackaged sour bamboo shoots, the total acid content ranged from 4.14 mg/g to 19.07 mg/g, with the highest in Luo Zhuangyuan (19.07±0.162 mg/g) and the lowest in Bai Xiang (4.14±0.649 mg/g). The average total acid content was 10.458 mg/g. **Conclusion:** Six organic acids were detected in the 35 sour bamboo shoot samples, with lactic acid being the most abundant and tartaric acid the least. Tartaric acid and malic acid levels were higher in prepackaged samples, while oxalic, lactic, acetic, and citric acids were higher in restaurant samples.
Malaysian Journal of Medicine and Health Sciences (2025) 21(SUPP5): 217–223. doi:10.47836/mjmhs.21.s5.28

Keywords: Sour bamboo shoots, River snail rice noodles, Total acid, Organic acid, HPLC

Corresponding Author:
Emmy Hainida Khairul Ikram, PhD
Email: emmy4546@uitm.edu.my
Tel: +603-3258 4378
Fax: +603-32584599

INTRODUCTION

The national intangible cultural heritage river snail rice noodle from the industrial city of Liuzhou, Guangxi Zhuang Autonomous Region, a culinary specialty because of its unique flavour, has become increasingly popular among consumers of modern cuisine. The production process of snail noodles is complicated, and the soup base is prepared of snail meat, pork bone, beef bone, chicken bone, etc. The dish also requires peanuts, vegetables, fried bean curd, and other side dishes (1, 2). The key to the unique flavour of snail meal lies in sour bamboo shoots, a Guangxi specialty flavouring food that is sour, mellow, thick, rich and long, and the rapid development of the river snail rice noodle industry with the broadening of online and overseas markets (3-5). As the most crucial ingredient, sour bamboo shoots are of great significance to this research.

Sour bamboo shoots are a traditional fermented vegetable food. The unique flavour and sourness of sour bamboo shoots are highly popular among consumers, total acids and organic acids are related to the sour flavour of sour bamboo shoots and are one of their main flavour-presenting substances (6, 7). A wide range of organic acids, including lactic acid, acetic acid, butyric acid, oxalic acid, succinic acid, citric acid, and malic acid, are produced during the fermentation of sour bamboo shoots; of these, acetic acid has a pungent sour taste and has a certain influence on the aroma of sour bamboo shoots (8-10). River snail rice noodle are exported both in China and abroad, and the development of the industry requires attention to the optimization of the production process of sour bamboo shoots as well as its nutrients. The total acid content of sour bamboo shoots as well as the content of the main organic acids were measured and analysed to further understand the type and content of the main organic acids of sour bamboo shoots, and the ratio of each type of organic acid to the total acid content and its role in the sour flavour of sour bamboo shoots were analysed.

MATERIALS AND METHODS

Samples

The samples of sour bamboo shoots were mainly collected from two channels: pre-packaged sour bamboo shoots in river snail rice noodles and sour bamboo shoots ingredients in popular river snail rice noodle restaurants, as shown in Table I. An appropriate amount of sour bamboo shoots was removed, placed in a crusher until homogenized, refrigerated in a plastic bag, and set aside.

Determination of total acid and organic acids content of sour bamboo shoots

The total acid content of the samples was determined via the first method of acid-base indicator titration in GB 12456-2021, "Determination of Total Acid in Foods, National Standard for Food Safety" (11). The organic acids content of the samples were determined via the method published by Li Xiaoyi (12). Five grams of sour bamboo shoots were weighed into a 50 mL centrifuge tube, and 45 mL of ultrapure water was added to soak the sample. The sample was ultrasonicated for 30 min, transferred to a centrifuge tube and centrifuged at 4300 r/min for 10 min. The supernatant was filtered through filter paper, and then an appropriate amount of filtrate was removed with a syringe, which was injected into the injection vial through a 0.45 μm membrane and stored until analysis. The standards were prepared as follows: 0.04 g of acetic acid, 0.05 g of lactic acid, 0.04 g of

Table I: Samples of sour bamboo shoots

Serial number	Brand name	Manufacturer (of a product)
		A: prepackaged river snail rice noodles
A1	Luo Zhuangyuan	Guangxi Luo Zhuangyuan Food Technology Co.
A2	Xi Luohui	Guangxi Hugui Food Group Co.
A3	Zhi Touluowan	Guangxi Fen Sheng Supply Chain Management Co.
A4	Dong Ayi	Liuzhou Lechuan Technology Co.
A5	Luo Bawang	Guangxi Snail King Food Technology Co.
A6	Bai Xiang	White Elephant Foods Co.
A7	Hao Huanluo	Liuzhou Dehua Food Co.
A8	Liu Quan	Guangxi Quanhui Food Co.
A9	Chou Bao	Hangzhou Weinian Innovation Industry Co.
A10	Shi Fenla	Liuzhou Jin Yida Food Processing Co.
A11	Li Ziqi	Guangxi Xingliu Food Co.
A12	Human happiness	Liuzhou Salted Fish Food Co.
A13	Jia Weiluo	Guangxi Shanyuan Foods Co.
A14	Luo Mandi	Liuzhou Spiral Land Foods Co.
A15	Shi Shangluo	Liuzhou Foodsun Snail Food Technology Co.
A16	Liu Jiangrenjia	Guangxi Zhongliu Food Technology Co.
A17	Yu Jianluo	Guangxi Meet Snail Food Co.
A18	Shi Zhanjia	Guangxi Hugui Food Group Co.
A19	He Weifang	Guangxi Heweifang Foodstuffs Co.
A20	Huang Guan	Liuzhou Crown Snail Catering Management Co.
		B: river snail rice noodle restaurants in LIUZHOU
B1	Wu Xingluo	F1/F, Chengzhong Wanda, No.256 Donghuan Avenue, Chengzhong District
B2	Xi Huanfeizai	No.27, Xiayang Road, Chengzhong District
B3	Xiao Qi	No. 12, Lane 1, Tianshan Road South, Yufeng District
B4	Xin Yue	2/F, Building 1, Yixin Garden, No. 228 Shuguang East Road, Chengzhong District
B5	Hao Xiang	50 metres north-east of the north gate of Junling Factory Life Zone 3, Central District
B6	Ju Bao	1-6, Building 2, Hongxing Street, Longcheng Road, Chengzhong District
B7	Liujiang Renjia	Rm 3, Bldg 19, Wanda East Street, Kangshun Rd, Chengzhong District
B8	Ajiao	5 Baisha Road, Liu Bei District
B9	Liu Pinfang	No. 5, Lane 3, Park Road North, Chengzhong District
B10	Nai Lao	West Zhongshan Road
B11	Alime	South of North Lane 1 and Dushui Road, Tanzhong West Road, Liunan District
B12	Cao Mei	Liu Zinc District, Liu Bei District
B13	Yinxiang Aniu	35 Beijiao Road, Liu Bei District
B14	Jin Wang	No.89, West Zhongshan Road, Chengzhong District
B15	Jiao Jie	412 Yaru Road, Liubei District

oxalic acid, 0.04 g of citric acid, 0.04 g of malic acid, and 0.02 g of tartaric acid were accurately weighed in 10 mL volumetric flasks on a scale and dissolved in 0.2 mL, 0.4 mL, 0.8 mL, 2.4 mL, and 4 mL of ultrapure water. The sample was then passed through a 0.45 μm filter membrane to the autosampler vial measurement. The chromatographic conditions used were as follows: column, C18; column temperature, 30 °C; wavelength, 210 nm; injection volume, 20 μL; and mobile phase, 0.5% aqueous phosphoric acid-methanol; HPLC elution time procedure, phosphoric acid solution: methanol (98:2).

Analysis of the sensory properties of sour bamboo shoots
Twenty students were invited as panellists to rate twenty different brands of sour bamboo shoots according to standard Table II. The approval and ethical clearance from the Department of Food and Chemical Engineering Liuzhou Institute of Technology was attained upon commencement of the study [Reference No:4502070011751].

Table II: Sensory evaluation score table

Scoring items	Marking scheme	Value of a score
Acid strength (9 points)	Less acidic	1-3
	Moderate acidity	4-6
	Stronger acidity	7-9
Preference (9 points)	Dislike	1-3
	Conveniently situated	4-6
	Love	7-9
Acceptability (9 points)	Unacceptable	1-3
	Acceptable	4-6
	Very acceptable	7-9

Data processing and statistics
The data was organized and processed using EXCEL, while IBM SPSS Statistics 25 was employed for analyzing the mean, standard deviation, variance, differences, and correlations. Origin 2018 was used to plot the standard curve of organic acids and generate related data graphs.

RESULTS

Results of the total acid content of sour bamboo shoots
The total acid content of twenty kinds of prepackaged sour bamboo shoots ranged from 4.14 mg/g to 19.07 mg/g, with an average total acid content of 10.458 mg/g. Among them, the highest total acid content of Luo Zhuangyuan samples was 19.07±0.162 mg/g, the lowest total acid content of Bai Xiang samples was 4.14±0.649 mg/g. The total acid content of fifteen kinds of sour bamboo shoots in the river snail rice noodle restaurants ranged from 6.47 mg/g to 18.9 mg/g, with an average total acid content of 14.071 mg/g. Among them, Cao Mei's sour bamboo shoots had the highest total acid content of 18.9±0.321 mg/g; Qiao Jie's sour bamboo shoots had the lowest total acid content of 6.47±0.323 mg/g, with a large difference in the size of the contents. (Table III)

Table III: Total acid content of sour bamboo shoots in river snail rice noodles

Serial number	Brand name	Total acid content (mg/g)
A6	Bai Xiang	4.14±0.649^{l}
A15	Shi Shangluo	4.68±0.360^{l}
A5	Luo Bawang	6.60±0.375^{k}
A17	Yu Jianluo	6.79±0.649^{jk}
A13	Jia Weiluo	6.76±0.315^{jk}
A12	Human happiness	7.15±0.198^{jk}
A8	Liu Quan	7.44±0.375^{ij}
A19	He Weifang	7.96±0.062^{i}
A7	Hao Huanluo	8.09±0.181^{i}
A20	Huang Guan	10.62±0.180^{h}
A3	Zhi Touluowan	10.92±0.208^{gh}
A9	Chou Bao	11.22±0.453^{gh}
A10	Shi Fenla	11.34±0.476^{g}
A18	Shi Zhanjia	12.17±0.38^{1f}
A11	Li Ziqi	12.72±0.208^{ef}
A4	Dong Ayi	13.14±0.18^{de}
A16	Liu Jiangrenjia	13.74±0.104^{d}
A14	Luo Mandi	16.62±0.375^{c}
A2	Xi Luohui	18.00±0.785^{b}
A1	Luo Zhuangyuan	19.07±0.162^{a}
B15	Jiao Jie	6.47±0.323^{j}
B11	Alime	10.20±0.208^{i}
B4	Xin Yue	11.76±0.375^{h}
B7	Liujiang Renjia	11.52±0.18^{h}
B9	Liu Pinfang	12.78±0.476^{g}
B3	Xiao Qi	12.84±0.208^{g}
B10	Nai Lao	13.74±0.275^{f}
B13	Yinxiang Aniu	14.46±0.275^{e}
B6	Ju Bao	15.06±0.375^{de}
B8	Ajiao	15.30±0.312^{d}
B2	Xi Huanfeizai	15.30±0.180^{d}
B14	Jin Wang	17.16±0.208^{c}
B1	Wu Xingluo	17.58±0.453^{c}
B5	Hao Xiang	18.00±0.180^{b}
B12	Cao Mei	18.90±0.321^{a}

Note: Different lowercase letters in the same column indicate significant differences ($p < 0.05$).

Results of the organic acid content of sour bamboo shoots
Oxalic acid, tartaric acid, malic acid, lactic acid, acetic acid, and citric acid were detected in thirty-five kinds of sour bamboo shoots. The analysis of twenty types of prepackaged sour bamboo shoots revealed that the average contents of organic acids were 1.276 mg/g, 0.609 mg/g, 1.583 mg/g, 1.387 mg/g, 1.149 mg/g and 0.942 mg/g, respectively. The average content decreased in the following order: lactic acid > malic acid > acetic acid > oxalic acid > citric acid > tartaric acid. The analysis of fifteen types of sour bamboo shoots in the river snail rice noodle restaurants revealed that the average concentrations of organic acids were 1.276 mg/g, 0.609 mg/g, 1.583 mg/g, 1.387 mg/g, 1.149 mg/g, and 0.942 mg/g, respectively. The average concentrations of these organic acids decreased in the following order: lactic acid > malic acid > acetic acid > oxalic acid > citric acid > tartaric acid. (Fig.1. & 2.)

Correlation analysis of organic acid content in prepackaged and restaurant sour bamboo shoots

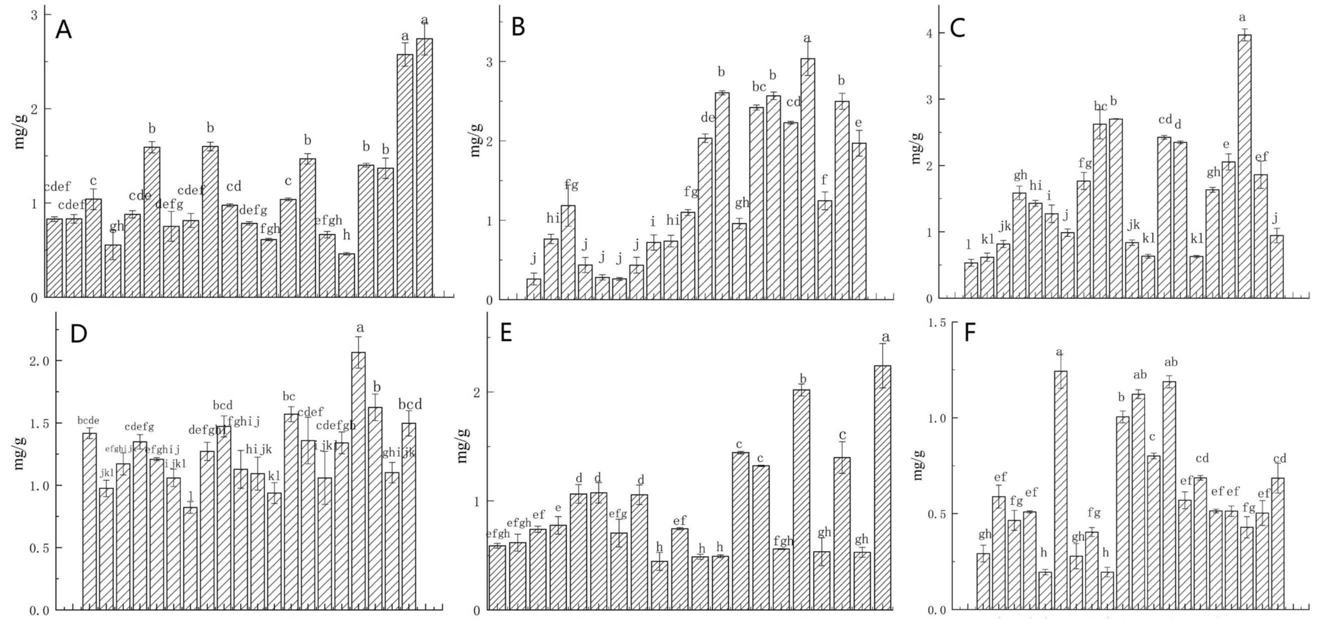

Fig. 1: Organic acid content (mg/g) of sour bamboo shoots in prepackaged river snail rice noodles. The samples are A6, A15, A5, A17, A13, A12, A8, A19, A7, A20, A3, A9, A10, A18, A11, A4, A16, A14, A2, A1 from left to right. (A) Acetic acid content. (B) lactic acid content. (C) Malic acid content. (D) Oxalic acid content. (E) Citric acid content. (F) Tartaric acid content. Different lowercase letters indicate significant differences (p< 0.05).

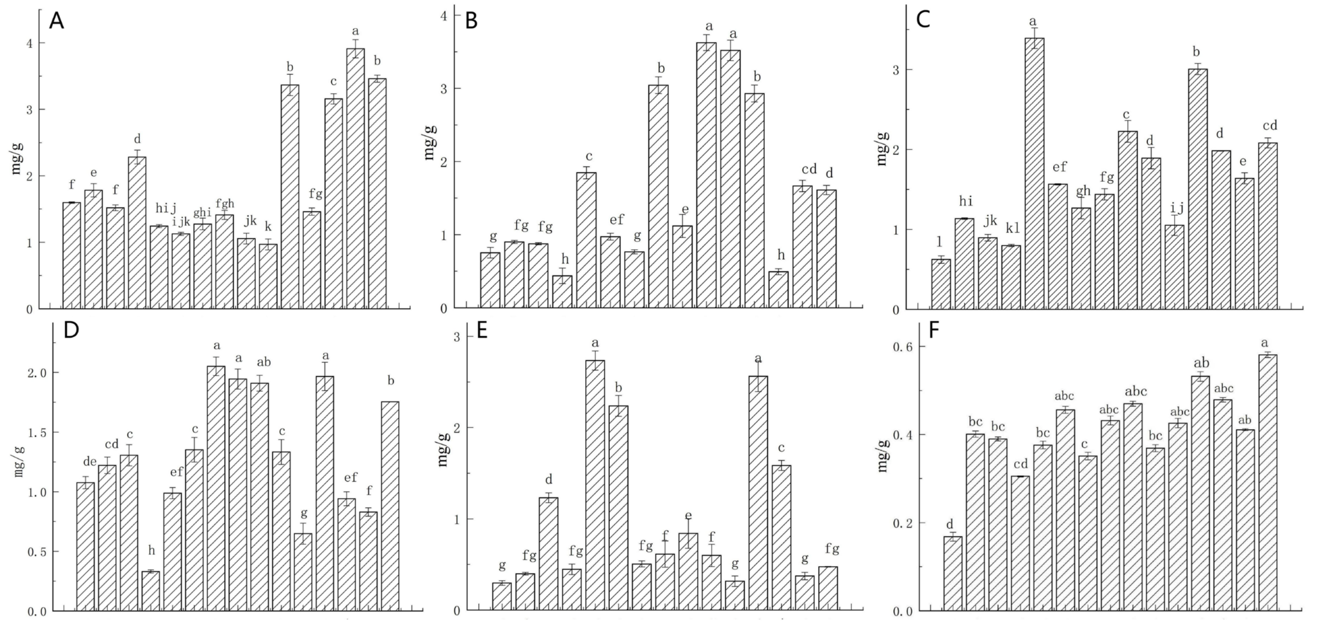

Fig. 2: Organic acid content (mg/g) of sour bamboo shoots in river snail rice noodles restaurants. The samples are B15, B11, B4, B7, B9, B3, B10, B13, B6, B8, B2, B14, B4, B5, B12 from left to right. (A) lactic acid content. (B) Acetic acid content. (C) Oxalic acid content (D) Malic acid content. (E) Citric acid content. (F) Tartaric acid content. Different lowercase letters indicate significant differences (p< 0.05).

revealed distinct patterns. In prepackaged sour bamboo shoots, oxalic acid content was significantly correlated with malic acid content (r=0.548), while no correlation was found between oxalic acid and other organic acids. In contrast, in sour bamboo shoots from restaurants, oxalic acid content showed a highly significant correlation with tartaric acid content (r=0.577), a significant positive correlation with acetic acid content (r=0.452), and a highly significant positive correlation with citric acid content (r=0.623).

Tartaric acid content was significantly positively correlated with both malic acid (r=0.369) and citric acid (r=0.384) contents. Malic acid showed a highly significant negative correlation with lactic acid content (r=-0.552), while lactic acid content exhibited a significant negative correlation with citric acid content (r=-0.332) (Fig.3.). Correlation analyses of different organic acids in 35 kinds of sour bamboo shoots with their total acid contents were carried out. The oxalic acid content showed a highly significant correlation with the total acid content (p<0.01), with a correlation coefficient of 0.569; the lactic acid content showed a highly significant correlation with the total acid content (p<0.01), with a correlation coefficient of 0.633; the acetic acid content showed a highly significant

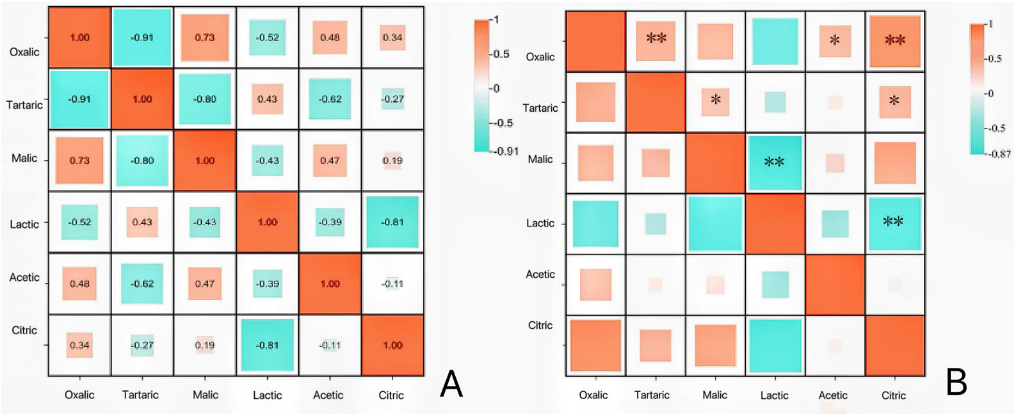

Fig. 3: Heat-map of the organic acids correlation of sour bamboo shoots from different channels. The heat-map datas show the correlation correlation coefficients between the various organic acids. A: the prepackaged samples; B: the restaurants samples. *Significant correlation (p< 0.05); **highly significant correlation (p< 0.01).

correlation with the total acid content (p< 0.01), with a correlation coefficient of 0.490; and all other organic acids did not correlate with the total acid content.

Sensory scoring results of the sour bamboo shoots

The results of the sensory evaluation of twenty kinds of sour bamboo shoots are shown in Table IV. The acid strength score ranged from 3.50 to 8.43, the highest score was observed for Xi Luohui sample, and the lowest score was observed for Shi Shangluo sample. The scores of preference and acceptability ranged from 2.75 to 7.73 and 2.83 to 7.00, respectively. The scores of Hao Xiang samples were the highest, and the scores of Luo Mandi samples were the lowest.

Table IV: Sensory evaluation scores (mean ± standard deviation)

Serial number	Acid strength (1-9)	Preference (1-9)	Acceptability (1-9)
A15	3.50±0.63	4.00±1.00	4.83±0.29
A5	5.05±0.67	6.68±0.58	6.17±1.04
A17	4.05±0.67	6.00±1.00	5.33±0.76
A12	6.15±0.80	5.67±1.53	5.35±1.04
A9	6.98±0.66	6.63±1.15	6.17±0.76
A14	8.15±0.80	2.75±1.05	2.83±1.22
A3	5.10±0.70	6.73±0.58	6.15±0.76
A18	7.95±0.74	4.67±0.48	5.00±1.00
A2	8.43±1.00	3.33±0.66	3.67±0.63
A4	6.08±0.71	6.68±0.58	6.33±0.67
B15	4.55±0.67	6.33±0.80	6.00±1.00
B11	4.98±0.60	5.65±0.58	5.67±1.15
B4	6.00±0.54	6.00±1.00	6.00±1.00
B9	6.43±0.52	3.33±0.58	4.00±1.00
B2	7.00±0.40	7.00±1.00	6.67±0.58
B12	8.05±0.67	6.68±0.78	6.17±0.80
B5	8.00±0.63	7.73±0.58	7.00±0.50
B3	6.08±1.12	4.67±0.67	5.33±0.76
B14	7.93±0.65	3.70±0.58	4.35±0.70
B6	7.00±0.71	6.00±1.00	5.30±0.58

DISCUSSION

A comparison between fifteen types of restaurant sour bamboo shoot samples and twenty types of prepackaged sour bamboo shoots revealed that the total acid content in the restaurant samples (14.071 mg/g) was higher than in the prepackaged samples (10.458 mg/g). The total acid content can vary for several reasons. Differences in the pickling process or variations in salt concentration can influence the total acid content. Higher salt concentrations can reduce lactobacilli activity, resulting in lower acid levels. Additionally, the sterilization process is a crucial step in producing prepackaged foods, as it impacts both the shelf life and quality of the product (13-15). Under the conditions of sterilization, esters are decomposed, which leads to a rise in the content of acids (16). Fermentation time also impacts the total acid content. The longer the fermentation period, the more acid is produced, and the acid content tends to stabilize over time (17).

It was found that the oxalic acid content of prepackaged bamboo shoots (1.276 mg/g) was lower than the oxalic acid content of bamboo shoots obtained in the restaurants (1.665 mg/g). This is probably because the oxalic acid content was related to the raw materials of bamboo shoots (18), and the oxalic acid content of bamboo shoots of different kinds of raw materials led to this difference (19). The tartaric and malic acid content of prepackaged bamboo shoots is greater than the content of bamboo shoots in restaurants, which is probably due to the difference in malic acid content caused by the length of fermentation (20).

Present results found that the lactic and acetic acid content of prepackaged bamboo shoots is lower than the lactic acid content of bamboo shoots in restaurants, which is related to many factors, such as the growth rate of lactobacilli (20), the length of fermentation time, whether the fermentation is natural or salted, and the size of the salting salt content (20). Lactic acid and acetic acid are two organic acids with high yields in the process of acid production (21). Moreover, the citric acid content in prepackaged sour bamboo shoots is lower compared to the citric acid content in sour bamboo shoots served in restaurants, likely due to differences in the raw materials used.

Correlation analysis revealed a highly significant correlation between total acid content and sensory acid strength scores (r=0.972), suggesting that higher total acid content in sour bamboo shoots is associated with a stronger perceived acidic flavor. Additionally, preference and acceptability sensory scores were strongly positively correlated (r=0.973). However, malic acid content was significantly negatively correlated with both preference (r=-0.456) and acceptability, indicating that an excessively high malic acid content can negatively impact the taste of sour bamboo shoots. While a moderate amount of malic acid can enhance flavor by providing a lasting taste, an excessively high content may result in a sharp and overly stimulating taste. The citric acid content showed a highly significant negative correlation with preference (r=-0.604) and acceptability, indicating that an excessively high citric acid content can result in an undesirable flavor, with a strongly stimulating sour taste that makes the product less appealing (22, 23). The lactic acid content showed a significant positive correlation with preference and acceptability. Conversely, lactic acid content demonstrated a significant positive correlation with both preference and acceptability. In the twenty types of sour bamboo shoots analyzed, the lactic acid content was generally moderate, contributing to a unique aroma and refreshing sour flavor. However, if the lactic acid content is too high, it may lead to excessive acidity, a soft texture, and reduced firmness, resulting in a less favorable taste (24, 25).

CONCLUSION

In this paper, the acid-base titration indicator method was used to determine the total acid contents of fifteen different sour bamboo shoot snail rice noodles obtained from restaurants and twenty prepackaged snail rice noodle sour bamboo shoot packages. The total acid content of fifteen sour bamboo shoots from restaurants ranged from 6.47 mg/g to 18.9 mg/g, with an average total acid content of 14.071 mg/g; the brand with the highest content was Cao Mei (18.9±0.321 mg/g); the brand with the lowest content was Jiao Jie (6.47±0.323 mg/g); the total acid content of twenty prepackaged snail rice noodle sour bamboo shoots ranged from 4.14 mg/g to 19.07 mg/g; the average total acid content was 10.458 mg/g; the brand with the highest total acid content was Luo Zhuangyuan (19.07±0.162 mg/g), and that with the lowest content was Bai Xiang (4.14±0.649 mg/g). The comparison revealed that the average total acid content of sour bamboo shoots from restaurants was greater than the average total acid content of prepackaged sour bamboo shoots. A sensory evaluation experiment was performed to correlate the total acid content of sour bamboo shoots of different brands with their corresponding sensory evaluation scores, and $p=0.003<0.05$ was obtained; the correlation coefficient was 0.972, suggesting that the magnitude of the total acid content of sour bamboo shoots may be related to the magnitude of the degree of acidity in the tasting.

Based on HPLC analysis, six organic acids, namely, oxalic acid, tartaric acid, malic acid, lactic acid, acetic acid, and citric acid, were detected in thirty-five sour bamboo shoot samples, and the results showed that lactic acid had the highest content of organic acids in sour bamboo shoots obtained through commercial channels; tartaric acid had the lowest content of organic acids, and the average prepackaged organic acid content was 1.276 mg/g, 0.609 mg/g, 1.583 mg/g, 1.387 mg/g, 1.149 mg/g, and 0.942 mg/g; the content decreased in the order of lactic acid>acetic acid>oxalic acid>malic acid>citric acid>tartaric acid; the average content of the organic acids in the restaurants was 1.665 mg/g, 0.41 mg/g, 1.31 mg/g, respectively, 1.974 mg/g, 1.637 mg/g, and 1.014 mg/g; the order of the average content was lactic acid>acetic acid>oxalic acid>malic acid>citric acid>tartaric acid; the correlation analysis of the organic acid content in the two different commercial groups found that only the oxalic acid and malic acid contents in the prepackaged samples were correlated, and the others were not; the oxalic acid content in the restaurants was significantly correlated with the tartaric acid, acetic acid, and citric acid contents; the tartaric acid content was correlated with the malic acid and citric acid contents; the malic acid content was correlated with the lactic acid and citric acid contents; and the lactic acid content was correlated with the citric acid content. Correlation analyses were also conducted between thirty-five types of sour shoots and their corresponding total acid contents, and the three most important organic acids in sour shoots, namely, oxalic acid, lactic acid, and acetic acid, were correlated with the total acid content. Finally, the correlation between the organic acid content of sour shoots and their preferences and acceptability was analysed, and the correlation was found to be significantly negative between the malic acid content, citric acid content and sensory indices and significantly positive between the lactic acid content and sensory indices.

ACKNOWLEDGMENTS

This work was supported by the Guangxi University Young and Middle-aged Teachers' Scientific Research Basic Ability Improvement Project (2021KY1709), China; Liuzhou City Vocational Education Teaching Reform Project (LZJ2024C034), China; Liuzhou Institute of Technology Education and Teaching Reform Project (2023JG016), China. The authors have declared no competing interests for this article.

REFERENCES

1. Ming-Yi Q, Yin-Feng Y, Yu-Can L, Qing-qing C, Xin-Yao Y, Mei-Jin L, et al. Research Progress on Source of Flavoring Substances in River Snails Rice Noodle. Science and Technology of Cereals, Oils and Foods. 2023;31(6):91-97.

2. Deng X, Wang Q, Wang A, Su C, Liang Z, Ding F, et al. Impacts of river snails rice noodle ingredients addition on the kitchen waste anaerobic digestion performances, microbial communities and metabolic pathways. Biochemical Engineering Journal. 2023;200: 109093.
3. Xu G, Suwandej N, Thongves M. The Relationship Among Brand Culture, Marketing Strategy, Technical Innovation and Customer Engagement Behavior Toward Liuzhou Snail Noodle: Mediating of Service Quality and Trust. Utilitas Mathematica. 2023;120:1356-1378.
4. Tang H, Ma JK, Chen L, Jiang LW, Kang LZ, Guo YY, et al. Characterization of key flavor substances and their microbial sources in traditional sour bamboo shoots. Food Chemistry. 2024;437:137858.
5. Guan Q, Huang T, Peng F, Huang J, Liu Z, Peng Z, et al. The microbial succession and their correlation with the dynamics of flavor compounds involved in the natural fermentation of suansun, a traditional Chinese fermented bamboo shoots. Food Research International. 2022;157:111216.
6. Yuli H, Nan Z, Qing H, Qian M, Kun H, Huajia L, et al. Research progress on the formation mechanism and influencing factors of flavor substances in fermented vegetables. Food and Fermentation Industry. 2021;47(24):279-285.
7. Xinyue Q, Tao X, Shijin X, Zhanggen L, Mingyong X, Qianqian G. Metatranscriptomics unravel the formation mechanism of key flavors during the natural fermentation of suansun, a Chinese traditional fermented bamboo shoot. Food Bioscience. 2024;57: 103436.
8. Hao-Sen F, Xiang-Luan L, Ai-Jun F, Wenhong Z, Min Q, Weidong B, et al. Advances in microbiology and flavor formation of sour bamboo shoots. Journal of Food Safety and Quality. 2023;14(22):91-99.
9. Xiang Z, Dongdong W, Jianying M, Gong C, Gui T, Heng L, et al. Changes in material composition of Sichuan kimchi and Northeast sauerkraut during fermentation. China Seasoning. 2021;46(04):78-81.
10. Zhang X, Wang A, Yao H, Zhou W, Wang M, Liang B, et al. Research advancements on the flavor compounds formation mechanism of pickled bamboo shoots in river snails rice noodles. LWT. 2023;115226.
11. General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Standardization Administration of China. Determination of total acid in foods. GB/T 12456-2008.
12. Xiaoyi L. Study on the changes of microflora and main components in the natural fermentation of sour bamboo shoots. Master's thesis, Hunan Agricultural University. 2020. DOI:10.27136/d.cnki.ghunu.2020.001103.
13. Hui M. Research on product development and sterilization process of soft canned cauliflower. Master's thesis, Ningxia University. 2023. DOI:10.27257/d.cnki.gnxhc.2023. 001330.
14. Yang X, Hong J, Wang L, Cai C, Mo H, Wang J, et al. Effect of Lactic Acid Bacteria Fermentation on Plant-Based Products. Fermentation. 2024;10(1):48.
15. Abdel-Rahman MA, Tashiro Y, Sonomoto K. Recent advances in lactic acid production by microbial fermentation processes. Biotechnology advances. 2013;31(6):877-902.
16. Yanrui M, Hong Y, Le C, Yan Z, Fengtao Z, Fatao H, et al. Changes in flavor, nutrition, and active components of apple cider vinegar under different sterilization conditions. China Brewing. 2021;40(11):188-193.
17. Qiu S, Dengpeng Y, Jiang Y, Zheng X, Pu YY, Zhang JM, et al. Effects of direct-pitch fermentation process on nitrite content and quality of guava kimchi. China Seasoning. 2023;48(02):87-91.
18. Zhaohua Z. Detection of the nutrient composition of sour bamboo shoots and research on its main flavor substances. Master's thesis, Guangxi University. 2014.
19. Meibei S, Yalong W, Pengjun L, Dongdong W, Qisheng Z, et al. Effects of different lactic acid bacteria inoculated fermentation on physicochemical characteristics and flavor of sour cabbage. Food and Fermentation Industry. 2024;50(01):80-88.
20. Ciai H, Xu Y, Quanyou G, Baoguo L, Rao Z. Isolation and identification of lactic acid bacteria in radish kimchi mother water and comparison of fermentation characteristics. Food and Fermentation Industry. 2023;49(23):111-119.
21. Fleet GH, Zhao J. Unravelling the contribution of lactic acid bacteria and acetic acid bacteria to cocoa fermentation using inoculated organisms. International journal of food microbiology. 2018;279:43-56.
22. Taotao B, Guanghui W, Yiyang W, Yumei T, Li L, et al. Development of hawthorn beverage with bamboo shoots. Agricultural Products Processing. 2023;(22):16-20.
23. Junge JY, Bertelsen AS, Mielby LA, Zeng Y, Sun YX, Byrne DV, et al. Taste interactions between sweetness of sucrose and sourness of citric and tartaric acid among Chinese and Danish consumers. Foods. 2020;9(10):1425.
24. Jiangpang Y. Screening of lactic acid bacteria from fermented mustard and its applicability. Master's thesis, Guizhou University. 2022.
25. Badwaik LS, Borah PK, Borah K, Das AJ, Deka SC, Sharma HK. Influence of fermentation on nutritional compositions, antioxidant activity, total phenolic and microbial load of bamboo shoot. Food Science and Technology Research. 2014;20(2), 255-262.