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RESEARCH ARTICLE

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STUDY ON NUTRITIONAL COMPONENTS OF THREE COMMON WILD COMMERCIAL LACTARIUS IN GUIZHOU, CHINA

Wang Jing[1], Liu Zhong-Xuan[1], Lu Yao[2] and Yang Yi-Hua*[1]

[1]Guizhou Institute of Biology, Guizhou Academy of Sciences, Guiyang 550009, China;
[2]Guizhou Institute of Analysis and Testing, Guizhou Academy of Sciences, Guiyang 550009, China

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Corresponding author: Yang Yi-Hua,

ABSTRACT

In order to promote the commercial utilization of wild edible fungi resources, the nutritional value of wild *Lactarius vividus*, *L. hatsudake* and *Lactifluus volemus* with good industrialization potential was studied. The water, ash, crude fat, crude protein, crude polysaccharide, amino acid, vitamin and mineral elements were detected by the methods of national standard. The results showed that the crude protein of the three *Lactarius* ranged from 15.8 to 36.9 g/100g, crude polysaccharide from 2.2 to 4.5 g/100g, ash from 2.6 to 12 g/100g, crude fat from 1 to 4 g/100g, essential amino acids from 2320 to 4492 mg/100g. The crude protein, crude polysaccharide, crude fat and essential amino acid contents of *Lf. volemus* were significantly higher than those of *L. vividus* and *L. hatsudake*, but the latter two were better than *Lf. volemus* in terms of mineral elements and vitamin contents. Through principal component analysis, *Lf. volemus* obtained a higher comprehensve score. In terms of function, the intelligence effect, weight loss effect and selenium-rich ability of *Lf. volemus* are better than those of *L. vividus* and *L. hatsudake*. The results provide a basis and reference for the development and utilization of these three kinds of *Lactarius* and the development of large health industry.

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INTRODUCTION

Lactarius Pers. (1797: 63) is one of the largest groups of Agaricomycetes with more than 1589 name records to date (http://www.indexfungorum.org/Names/Names.asp, Apr 2023). The genus *Lactarius* belongs to Basidiomycota, Agaricomycetes, Russulales, Russulaceae, including *Lactarius*, *Lactifluus* and *Multifurca.* Lactarius is distributed all over the world, with the highest species diversity in the north temperate zone and the highest resource richness in southwest China (Wang 2008). *Lactarius* is one of the most accepted commercial species of wild edible mushrooms in China, with high economic value. Known as zihuajun, songshujun, gushujun, in Guizhou, etc. it is distributed in all cities and states of Guizhou Province, with large reserves and a long tradition of consumption. *Lactarius vividus*, *L.hatsudake* and *Lactifluus volemus* are common in Guizhou wild edible fungi market *Lactarius* is a typical ectomycorrhizal fungus with high economic value and edible value, which can form symbiotic relationship with Fagaceae, Pinaceae and other economic tree species (Ying 1994; Verbeken 1996), and plays a vital role in forest ecosystem (Henkel 2000). *Lactarius deliciosus* has strong antioxidant capacity and immune regulation in vitro, and no tumor cell inhibitory activity in vitro (Xu 2019). *L. hatsudake* has the functions of benefiting intestines and stomach, improving appetite, auxiliary treatment of diabetes, anti-cancer, lowering blood lipid, anti-virus and other medicinal health effects (Liu 1995). The inhibition rate of its extract on mouse sarcoma S-180 was 100 %, and the inhibition rate on Ehrlich ascites carcinoma was 90 % (Zhao 2001). *Lf. volemus* has many biological activities such as enhancing immunity, anti-oxidation, anti-radiation, anti-fatigue and so on (Ran 2019). Its extract can significantly improve liver damage, leukocyte damage and DNA damage (Wang 2021; Liu 2007). The rubber content in milk is much higher than that of rubber tree, which provides new rubber resources (Ke 2000). However, the comparative analysis of the nutritional components of the most widespread and common *L. vividus*, *L.hatsudake* and *Lf. volemus* in Guizhou has not been reported. Therefore, on the basis of strict sample collection and accurate species identification, this study comprehensively analyzed the conventional nutrients, amino acid content, vitamins and mineral elements of *L. vividus*, *L.hatsudake* and *Lf. volemus*, and discussed the nutritional value of the three kinds of *Lactarius*, so as to provide basis and reference for the consumption, development and utilization of the three kinds of *Lactarius*.

MATERIALS AND METHODS

L. vividus, *L.hatsudake* and *Lf. volemus* were purchased from Guanyin wild mushroom trading market in Longli County, Guizhou Province. The moisture content was determined according to GB

5009.3-2016; The ash content was determined according to GB 5009.4-2016; The crude fat content was determined according to GB 5009.6-2016; The crude protein was determined according to GB 5009.5-2016; The content of crude polysaccharide was determined by SN/T 4260-2015; Amino acid content was determined according to GB 5009.124-2016; Calcium content was determined according to GB 5009.92-2016; Potassium content was determined according to GB 5009.91-2017; Iron content was determined according to GB 5009.90-2016; Selenium content was determined according to GB 5009.93-2017; Zinc content was determined according to GB 5009.14-2017; Germanium content was determined according to GB 5009.268-2016; The contents of Vitamin A and Vitamin E were determined according to GB 5009.82-2016; The content of β-carotene was determined according to GB 5009.83-2016; The content of vitamin B1 was determined according to GB 5009.84-2016; The content of vitamin B2 was determined according to GB 5009.85-2016; Vitamin C content was determined according to GB 5009.86-2016; Excel software was used to sort out the data, and IBM SPSS Statistics 26.0 statistical software was used for data analysis. One-way ANOVA was used for significant difference comparison and principal component analysis (Yan 2019). ns indicated no significant difference ($P > 0.05$), * indicated significant difference ($P < 0.05$); the difference of * * was extremely significant ($p < 0.01$).

RESULTS AND DISCUSSION

In the fruiting bodies of the three kinds of *Lactarius*, the largest proportion of the component is water, accounting for 88.6%-94.2% of the total mass. Among them, the water content of *L. vividus* (94.2 ± 0.27) % is the highest, *L.hatsudake* (92.5 ± 0.22) % is the second, *Lf. Volemus* (88.6 ± 0.41) % is significantly lower than that of the other two kinds of *Lactarius*, and the difference is extremely significant, indicating that the dry matter content of *Lf. Volemus* is much higher than that of the other two kinds of *Lactarius*. The results showed that the three kinds of fresh *Lactarius* had high water content and high requirements for storage and transportation conditions. According to Fig.1, the content of crude protein in the conventional nutrients of *L. vividus*, *L.hatsudake* and *Lf. volemus* was higher than that of other components. The crude protein and crude polysaccharide of *Lf. volemus* were significantly higher than those of the other two *Lactarius* ($P < 0.01$), and the crude fat was significantly higher than that of the other two *Lactarius* ($P < 0.05$). There was no significant difference in ash content among the three species ($P > 0.05$). There was no significant difference in ash, crude fat, crude protein and crude polysaccharide between *L. vividus* and *L. hatsudake* ($P > 0.05$). The conventional nutrients of *Lf. volemus* were significantly higher than those of *L. vividus* and *L. hatsudake*, especially the crude fat content, and the content did not exceed 5%, which confirmed that *Lf. volemus* was a fragrant species among the three kinds of *Lactarius*. It can also provide a higher sense of satiety, reduce the burden of gastrointestinal tract, and will not cause diarrhea adverse reactions, indicating that *Lf. volemus* can be used as a good weight loss food choice.

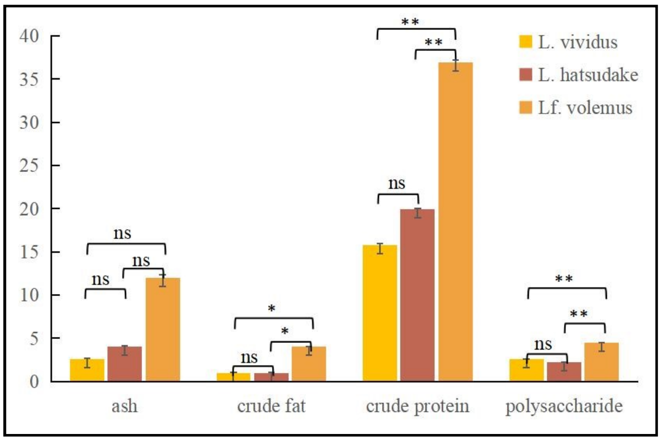

Fig. 1 Basic nutritional composition of three *Lactarius* (g/100g, dry weight)

The total amino acid content of *L. vividus*, *L.hatsudake* and *Lf. volemus* were 6110 mg/100 g, 8130 mg/100 g and 13642 mg/100 g, respectively. The essential amino acid content and total amino acid content of *L. vividus*, *L.hatsudake* and *Lf. volemus* were significantly different, *Lf. Volemus* □ *L.hatsudake* □ *L. vividus*. It can be seen from Fig. 2 that the essential amino acids (methionine, threonine, isoleucine, leucine, valine) of *L. vividus*, *L.hatsudake* and *Lf. volemus* accounted for 38.0 %, 38.1 % and 32.9 % of the total, respectively. The ratio of essential amino acids to total amino acids in *L. vividus* was similar to Xu Z, Feng S, *et al*. (2019). The ratio of essential amino acids to total amino acids in *L. hatsudake* is similar to Deng BW (2004). The ratio of essential amino acids to total amino acids in *Lf. volemus* was similar to Xu DX (2012). The content of leucine in essential amino acids was the highest, and the content of leucine in *Lf. volemus* was significantly higher than that in *L. vividus* and *L. hatsudake* ($P < 0.01$). Valine and threonine were second, the content of valine in *L. vividus* was significantly lower than that in *L. hatsudake* and *Lf. volemus* ($P < 0.01$), and the content of threonine in *Lf. volemus* was significantly higher than that in *L. vividus* and *L. hatsudake* ($P < 0.01$). The content of isoleucine and methionine was the lowest, and the methionine content of *Lf. volemus* was significantly lower than that of the other two kinds of *Lactarius* ($P < 0.01$), and it was the only amino acid type lower than the other two kinds of *Lactarius*. The results showed that all three kinds of *Lactarius* had hypoglycemic effect, and the effect of *Lf. volemus* was higher than that of the other two, but the effect of *L.hatsudake* on burning visceral fat was higher.

The sweet amino acids (serine, alanine, glycine) of *L. vividus*, L. hatsudake and *Lf. volemus* accounted for 26.4 %, 26.9 % and 25.4 % of the total amino acids. The content of serine and glycine in *Lf. volemus* was significantly higher than that of *L. vividus* and *L. hatsudake*, and the content of alanine was also significantly higher than that of *L. vividus* and *L. hatsudake* ($P < 0.05$). The content of serine and glycine in *L. hatsudake* was significantly higher than that of *L. vividus* ($P < 0.05$), and the content of alanine was similar to that of *L. vividus* ($P > 0.05$). The umami amino acids (glutamic acid and aspartic acid) of *L. vividus*, *L. hatsudake* and *Lf. volemus* accounted for 22.1 %, 23.9 % and 31.5 % of the total amino acids, respectively. Among the 12 amino acids, the content of glutamic acid was the highest. Glutamic acid is a umami amino acid, which is also the reason for the umami taste of the three kinds of *Lactarius*. Glutamate is not only a umami amino acid, but also improves the learning and memory function of the brain and plays a role in promoting children's intellectual development (Chuang, Y, *et al*. 2011).

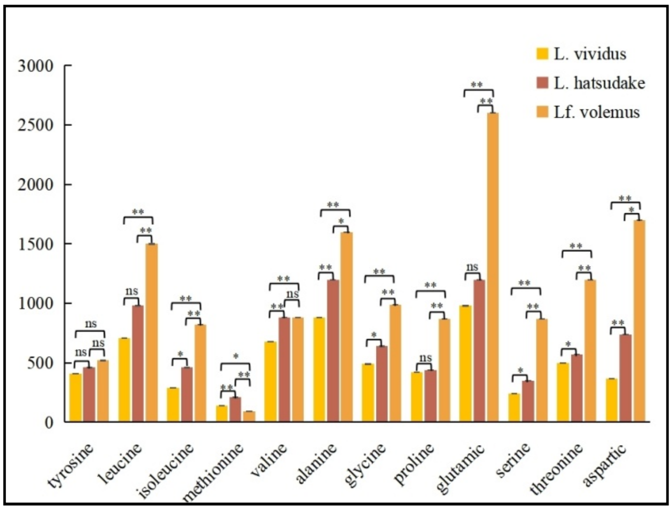

Fig. 2 Comparison of amino acid content of three Lactarius

The content of glutamic acid in *Lf. volemus* was significantly higher than that of *L. vividus* and *L. hatsudake* ($P < 0.01$), and the content of aspartic acid was also significantly higher than that of *L. vividus* and *L. hatsudake* ($P < 0.05$). The content of aspartic acid in *L. hatsudake* was significantly higher than that of *L. vividus* ($P < 0.05$), and the content of glutamic acid was similar to that of *L. vividus* (P > 0.05). Therefore, the umami taste and intelligence effect of *Lf. volemus* are better than that of *L. vividus* and *L. hatsudake*, and the sweet taste is slightly worse than that of *L. hatsudake* and *Lf. volemus*; The bitter amino acids (tyrosine, leucine, isoleucine, methionine and valine) of *L. vividus*, L. hatsudake and *Lf. volemus* accounted for 37 %, 37 % and 28 % of the total amino acids, respectively. The tyrosine content of *L. vividus*, *L. hatsudake* and *Lf. volemus* was similar (P > 0.05). The content of mineral elements in the three kinds of *Lactarius* is shown in Fig.3. The content of mineral elements in *Lactarius* is different. The content of calcium in *L. vividus* and *L. hatsudake* is the highest, followed by iron, and the content of selenium is the lowest, which is significantly higher than that of *Lf. volemus* (P < 0.01). The potassium content of *Lf. volemus* was the highest, which was significantly higher than that of *L. vividus* and *L. hatsudake* (P < 0.01). The mineral element calcium content of *L. vividus* is much higher than that of other mineral elements, which is consistent with the characteristics of Xu Z, Feng S, *et al*. (2019). The mineral element potassium content of *Lf. volemus* is much higher than that of other mineral elements, which is consistent with Xu DX (2012). Although mineral elements are low in the human body, they cannot be synthesized by themselves, must be taken from the outside world, and play an important role in the physiological activities of the human body. Three kinds of *Lactarius* can be used as food mineral resources.

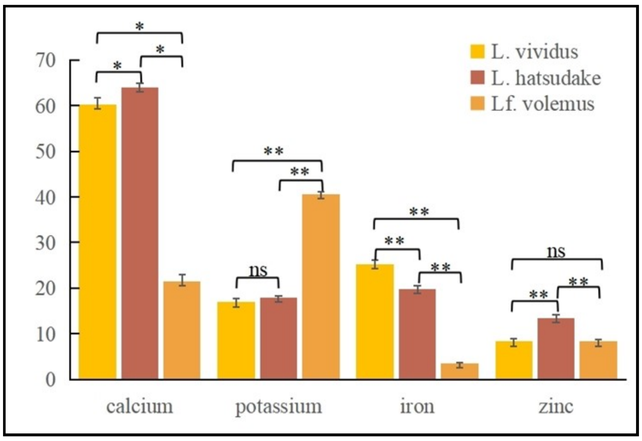

Fig. 3 Comparison of Mineral elements content of three *Lactarius*

Selenium is one of the essential trace elements for the human body (Shin, Y., *et al*. 2007; Zhang, HX., Zhang, P. 2011; Shazia, Q., *et al*. 2012; Kapur, M., *et al*. 2017). It can prevent hepatitis, pneumonia, diabetes, cancer and other diseases and improve human immunity (Li HM 2022; Zhang YS 2018). The highest selenium content in cauliflower (cauliflower) was 2.86 μg/100 g (fresh juice) in the 'China Food Composition Table'.

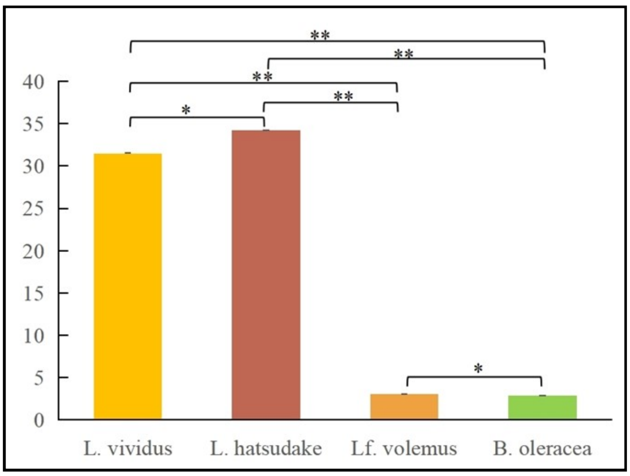

Fig. 4. Comparison of selenium content

The test results such as Fig. 4 showed that the selenium content of *L. vividus*, *L. hatsudake* and *Lf. volemus* was 11 times, 12 times and 1.1 times that of *Brassica oleracea* (cauliflower), respectively. It provides a high selenium-rich food source for low selenium countries and regions, especially China as a selenium-deficient country (Xu LL 2016), three kinds of *Lactarius* can be used as an important food selenium source. It can be seen from Table 1 that among the six vitamins measured, only vitamin B2 was detected in all three kinds of *Lactarius*, and *L. hatsudake* was the highest, followed by *L. vividus*, and *Lf. volemus* was the least. The contents of vitamin C, vitamin A and β-carotene were lower than the detection limit of the national standard method and could not be detected. Vitamin E was only detected in *L. vividus*, and vitamin B1 was only detected in *L. hatsudake*. It can be seen that vitamins B2 is the main vitamin components in three kinds of *Lactarius* (Kalac P 2009; Yang Y 2012).

Table 1 Comparison of Vitamin content of three *Lactarius*

Types	*L. vividus*	*L.hatsudake*	*Lf. volemus*
Vitamin C	-	-	-
Vitamin A	-	-	-
Vitamin E	1.65	-	-
β-carotene	-	-	-
Vitamin B1	-	0.173	-
Vitamin B2	0.671	0.735	0.287

The original nutritional index data were standardized by Spss, and then the eigenvalues, variance contribution rate, cumulative contribution rate and principal component load matrix of the principal components were obtained by principal component analysis, as shown in Table 3 and Table 4. The results of Table 3 show that the eigenvalues of the first two principal components are 11.397 and 2.603, respectively, which are greater than 1. The variance contribution rate of the first principal component was 81.41%, the variance contribution rate of the second principal component was 18.59%, and the cumulative contribution rate was 100 % (greater than 85%), indicating that these two principal components could reflect nearly 100 % information of 14 nutritional indicators of three wild *Lactarius* species. The first two principal components were extracted to replace the original 14 nutritional indicators to achieve the purpose of dimensionality reduction.

Table 2 Z-score of nutritional component

Types	*L. vividus*	*L. hatsudake*	*Lf. volemus*
ash	-0.70985	-0.4338	1.14365
crude fat	-0.57735	-0.57735	1.1547
crude protein	-0.75081	-0.38434	1.13515
polysaccharide	-0.40689	-0.73241	1.1393
essential amino-acid	-0.89432	-0.18541	1.07973
total amino-acid	-0.81671	-0.29857	1.11528
calcium	0.49698	0.65415	-1.15113
potassium	-0.61798	-0.53575	1.15372
iron	0.80339	0.31658	-1.11997
selenium	0.49733	0.65383	-1.15116
zinc	-0.57735	1.1547	-0.57735
Vitamin E	1.1547	-0.57735	-0.57735
Vitamin B1	-0.57735	1.1547	-0.57735
VitaminB2	0.44023	0.70436	-1.14459

The principal component loading matrix shows the weight coefficients of the two principal components. It can be seen from Table 4 that the nutritional indicators with positive load symbols in the first principal component are crude fat (0.3), potassium (0.3), ash (0.29), crude protein (0.29), crude polysaccharide (0.29), total amino acid (0.29), and essential amino acid (0.28). The weight coefficients of these seven indicators are similar and have a greater positive impact on the first principal component. The nutritional indexes with higher load and negative symbol were calcium (-0.29), iron (-0.29), selenium (-0.29) and vitamin B2 (-0.29), which had a greater negative impact on the first principal component. The results showed that the contents of crude fat, potassium, ash, crude protein, crude polysaccharide, total amino acid and essential amino acid were higher when the first principal component was large, while the contents of calcium, iron, selenium and vitamin B2 were lower.

Table 3 Total variance explained table

Component	Initial eigenvalue			Extract the load sum of squares		
	Eigenvalue	Variance contribution rate%	Accumulative contribution rate%	Eigenvalue	Variance contribution rate%	Accumulative contribution rate%
1	11.397	81.410	81.410	11.397	81.410	81.410
2	2.603	18.590	100.000	2.603	18.590	100.000
3	2.513e-15	1.795e-14	100.000	-	-	-
4	6.541e-16	4.672e-15	100.000	-	-	-
5	3.901e-16	2.787e-15	100.000	-	-	-
6	3.212e-16	2.294e-15	100.000	-	-	-
7	1.911e-16	1.365e-15	100.000	-	-	-

Table 4 Loading matrix of principal component

Nutritional ingredient	Principal component 1	Principal component 2
ash	0.29	0.03
crude fat	0.3	-0.01
crude protein	0.29	0.04
polysaccharide	0.29	-0.06
essential amino-acid	0.28	0.1
total amino-acid	0.29	0.07
calcium	-0.29	0.03
potassium	0.3	0
iron	-0.29	-0.06
selenium	-0.29	0.03
zinc	-0.14	0.26
Vitamin E	-0.16	-0.25
Vitamin B1	-0.14	0.26
Vitamin B2	-0.29	0.05

Table 5 Scores of the principal component factors

Types	r1*Z1	r2*Z2	Z	sort
L. vividus	-1.678	-0.294	-1.972	3
L.hatsudake	-1.494	0.306	-1.188	2
Lf. volemus	3.172	-0.011	3.160	1

In the second principal component, zinc (0.26) and vitamin B1 (0.26) had higher load and positive symbol, which had a greater positive impact on the second principal component. The nutritional indexes with high load and negative signs were crude polysaccharide (-0.06) and iron (-0.06), which had a great negative effect on the second principal component. It shows that when the second principal component is large, the content of zinc and vitamin B1 is higher, while the content of crude polysaccharide and iron is lower. The principal component load (Table 3) of each index variable is divided by the square root of the eigenvalue corresponding to the principal component, and the coefficient (eigenvector) corresponding to each index in the 2 principal components is obtained. The function expression of the 2 principal components is constructed with the eigenvector as the weight:

Z_1=0.295X_1+0.296 X_2+0.293 X_3+0.291 X_4+0.280 X_5+0.289 X_6-0.294 X_7+0.296 X_8-0.290 X_9+-0.294 X_{10}-0.140 X_{11}-0.157 X_{12}-0.140 X_{13}-0.292 X_{14}

Z_2=0.065 X_1-0.021 X_2+0.093 X_3-0.121 X_4+0.200 X_5+0.141 X_6+0.069 X_7+0.005 X_8-0.131 X_9+0.069 X_{10}+0.547 X_{11}-0.526 X_{12}+0.547 X_{13}+0.102 X_{14}

In the above four expressions, X1 ~ X14 were the data standardization values of ash, crude fat, crude protein, crude polysaccharide, essential amino acid, total amino acid, calcium, potassium, iron, selenium, zinc, vitamin E, vitamin B1 and vitamin B2, respectively.

Taking the variance contribution rate corresponding to each principal component as the weight, the comprehensive score is obtained by linear weighted sum of the principal component score and the corresponding weight. Its comprehensive score function is:

Z=0.814 Z_1+0.186 Z_2

According to the comprehensive score function, the comprehensive scores and ranking results of the three kinds of Lactarius are shown in Table 5, and the comprehensive scores are as follows: *Lf. volemus* > *L. hatsudake* > *L. vividus*. In the first principal component, the indexes of crude fat, ash, crude protein, crude polysaccharide, potassium, total amino acid and essential amino acid play a greater positive impact. The content was as follows: *Lf. volemus* > *L. hatsudake* > *L. vividus*, which is consistent with the first principal component factor score. In the second principal component, the indicators of zinc and vitamin B1 played a greater positive impact. The data showed that the content of *L. hatsudake* was the largest, and the content of *L. vividus* and *Lf. volemus* was similar, which was consistent with the ranking of the second principal component factor scores.

CONCLUSION

In summary, the comprehensive quality of *Lf. volemus* is the highest. Among the fruiting bodies of *L. vividus*, *L. hatsudake* and *Lf. volemus*, the dry matter of *Lf. volemus* was the highest, followed by *L. hatsudake* and *L. vividus*. The content of crude protein in dry matter was the highest, which was 15.8, 1.99 and 36.9 g/100g respectively, followed by crude polysaccharide, which was 2.6, 2.2 and 4.5 g/100g respectively, followed by ash, which was 2.6, 4 and 12 g/100g respectively, and finally crude fat, which was 1, 1 and 4 g/100g respectively. The essential amino acids in the three kinds of *Lactarius* were 2320, 3100 and 4492 mg/100g, accounting for 38.0 %, 38.1 % and 32.9 % of the total amino acids, respectively. The flavor amino acids were 2960, 4130 and 7760 mg/100 g, accounting for 48.4 %, 50.8 % and 56.9 % of the total amino acids, respectively, which were much higher than the essential amino acid content. The ratio of essential amino acids to total amino acids and the ratio of essential amino acids to non-essential amino acids in the three kinds of *Lactarius* are close to the ideal protein standard proposed by FAO / WHO, indicating that the three kinds of *Lactarius* are high-quality protein resources. In addition, the three kinds of *Lactarius* are also rich in mineral elements. The calcium content of *L. vividus* and *L. hatsudake* is the highest, and the potassium content of Lactarius volemus is the highest. Three kinds of *Lactarius* contain a certain amount of vitamin B2. Therefore, the three kinds of *Lactarius* can be regarded as high protein, low fat, rich in flavor amino acids, especially umami amino acids, and rich in a variety of mineral elements.

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