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Research Article

Study on the Effect of Crushed Rice-Lotus Seed Starch Reconstituted Rice on Lipid Metabolism Histology in Rats

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The study investigated the changes of lipid metabolism histology in rats under the three groups of dietary modifications after dietary intervention in (Sprague-Dawley, SD) SD rats using lotus seed reconstituted rice, ordinary rice, and high-fat feed made from lotus seed starch-rice flour after extrusion and puffing. It was found that the high-fat feed could lead to the disorder of lipid metabolism in rats, and the accumulation of lipid metabolism substances caused by the high-fat feed was significantly increased; the intervention of ordinary rice and high-dose reconstituted rice revealed that the high-dose reconstituted rice could improve the disorder of lipid metabolism and the accumulation of lipid substances caused by the high-fat feed to a greater extent. The main lipid substances were PC, TAG, Cer, CE, SM, PE, LPC, Acar, DAG, FAHFA, OxPI, PI, SQDG, Cer/NS, GlcADG, HBMP, Cer/NDS, HexCer/NS, etc., and the study confirmed that the reconstituted rice made from lotus seeds in this experiment was better than ordinary rice, and the high-dose reconstituted rice obtained from the study has a better modulating effect on lipid metabolism disorders and organism damage caused by high-fat feed.

1. Introduction

As a key component of plant foods, starch is the most important source of carbohydrates in the human feed. Compared to general natural polymers, starch has unique colloidal properties that can increase the viscosity and form gels in fluid or semifluid systems under suitable conditions. Therefore, in addition to the food field, starch has been widely used in the material chemical field [1]. However, natural starch has limited its scope of application in industry due to its deficiencies such as easy aging, low solubility, poor shear stability, and thermal stability. For a long time, specific chemical, physical, or biological modification of raw starch to meet different processing requirements has been the main way to broaden the functional properties of starch [2]. Lotus seeds are a kind of medicinal food material and are widely used in the chemical food industry as a unique resource in

China. Lotus seeds have a high starch content of more than 60% [3, 4], but they have poor taste, easy aging, and low solubility. Therefore, lotus seed starch needs to be processed to some extent before application and storage, and the current treatment of lotus seed starch mainly includes chemical modification [5], physical modification [6], biological enzyme treatment modification [7, 8], and compound treatment modification methods [9, 10], and the current research on lotus seed starch is mainly focused on the study of starch modification, individual physical properties and processing characteristics, while its effects on the body metabolism or intestinal microflora produced by the human body are less studied, thus greatly limiting the utilization of lotus seed resources and the multifaceted applications of lotus seed starch.

The reconstituted rice made by extrusion and puffing technology is mainly made of starch material matrix as the

raw material, by adding other nutritional elements, in the extrusion and puffing machine, the raw material is processed and matured, cut, dried, and other processes to obtain artificially processed rice products because its form resembles natural rice, so also called engineering rice, artificial rice, and nutritionally enhanced rice. In the process of extruding reconstituted rice, resistant starch, polysaccharides, and other nutritional elements can be added, and the reconstituted rice made by adding other ingredients often has a regulatory effect on common human diseases, such as obesity, diabetes, hyperlipidemia, nutritional deficiencies, and many other diseases [11–15]. However, most of the current research on reconstituted rice is limited to the optimization of process and formulation and its processing and cooking characteristics, and its effects on the body and improvement of diseases need to be characterized and its functional properties clarified by means of animal experiments and simulations. At this stage, the research on reconstituted rice is becoming more and more mechanistic and in-depth, and the benefits of reconstituted rice for human body or the regulation of certain diseases under various conditions are clarified through the research techniques of nutritional medicine and food science, which are more beneficial to the application and processing of reconstituted rice.

Resistant starch is a class of dietary fiber that is not easily digested in the small intestine but can be fermented and digested by intestinal microflora in the large intestine. Recent studies have shown that resistant starch interacts with the human intestinal microflora to produce short-chain fatty acids, which in turn have a regulatory effect on certain diseases of the human intestine and certain abnormal injuries in humans [16, 17]. In addition to this, resistant starch has an important role in improving hyperglycemia, hyperlipidemia and diabetes, insulin sensitivity, etc. Therefore, the study of lipid metabolism *in vivo* is important for the study of body damage and the production of metabolic diseases. Based on this, this project focuses on feeding rats with a composite reconstituted rice of rice and lotus seed starch, which contains a large amount of resistant starch as dietary fiber that can be utilized by intestinal flora. By exploring the improvement of lipid metabolism disorder by lotus seed reconstituted rice, we can provide new ideas for the prevention and treatment of metabolic diseases such as hyperlipidemia and obesity, and also elucidate the metabolic status of lipid substances under different dietary interventions, and provide corresponding basic theoretical support for dietary treatment and prevention of metabolic diseases such as hyperlipidemia and obesity.

2. Materials and Methods

2.1. Materials. The ground rice used in this study was purchased from Wuchang Baoxin Rice Growing Cooperative. Animal feed was prepared by Nanjing Shengmin Research Animal Farm according to the experimental requirements. Anhydrous ethanol, saline, and chloral hydrate were analytically pure. Methanol, acetonitrile, methyl tertbutyl ether, ammonium formate, methylene chloride, and isopropanol were all LC-MS grade.

2.2. Preparation of Reconstituted Rice. Using 30% lotus seed starch addition, a mixture of lotus seed starch and broken rice powder was extruded to obtain reconstituted rice under the conditions of 30% water content of the material, extrusion temperature of 120°C and screw speed of 180 r/min, and dried overnight in an oven at 45°C for backup.

2.3. Preparation of Animal Feeds. The study was reviewed and approved by the Harbin University of Commerce Univ. IRB and informed consent was obtained from each subject prior to their participation in the study.

The first group of feed was high-fat feed (HF): high-fat feed: basal feed, 6.912 g/kg; large oil, 1.98 g/kg, cholesterol, 90 g/kg; pig bile salt, 18 g/kg.

The second group of feed was common rice feed (OR): high-fat feed with 15 g/(kg bw/d) common rice.

The third group of feed was reconstituted rice feed (H-RR): high-fat feed with 15 g/(kg bw/d) reconstituted rice added.

2.4. Animal Feeding Conditions. The experimental animals were 36 healthy male SD rats, purchased from Changchun Yishu Experimental Animal Technology Co. The environmental conditions in the Experimental Animal Management Center of the Faculty of Pharmacy, Harbin University of Commerce were controlled as follows: temperature of 20–22°C, relative humidity of 40–60%, and lighting time of 12 h day and night.

2.5. Animal Feeding and Grouping. 36 healthy male SD rats were fed with basal feed for one week, and their feeds were kept ad libitum during the feeding period, and their water, feed and body weight data were recorded. After no abnormalities in the acclimatization feeding, the rats were numbered using an ear punch and randomly divided into 3 groups of 12 rats each according to the test. That is, (1) High-fat feed group (HF group): that is, fed high-fat feed: (2) Ordinary rice group (OR group): ordinary rice was added to high-fat feed; (3) High-dose reconstituted rice group (H-RR group): reconstituted rice was added to high-fat feed. Feed and water were changed twice a day. Body weight was measured once a week. The overall experiment lasted for a total of 6 weeks.

2.6. Blood Sample Collection and Processing of Rats. The rats were dissected and the blood of each rat in each group was collected into centrifuge tubes and left at 37°C for 1 h to coagulate and stratify. After centrifugation at 3000 rpm for 10 min at room temperature, the supernatant after centrifugation was taken into a clean centrifuge tube and set aside. Then, centrifuged at 12000 rpm for 10 min at 4°C, the supernatant was divided into 1.5 mL centrifuge tubes of 0.2 mL each, (200 μL/sample) and stored frozen at −80°C [18, 19].

2.7. Extraction and Detection of Metabolites. The extraction methods of metabolites from rats involved in this experiment refer to the methods in the paper of [20, 21].

The target compounds were chromatographically separated by a liquid chromatographic column using an ultra-high performance liquid chromatograph. The A phase of the liquid chromatography was 40% water and 60% acetonitrile solution containing 10 mmol/L ammonium formate; the B phase was 10% acetonitrile, 90% isopropanol solution with 50 mL of 10 mmol/L ammonium formate aqueous solution added per 1000 mL. A gradient elution was used: 0~1.0 min, 40% B; 1.0~12.0 min, 40%~100% B; 12.0~13.5 min, 100% B; 13.5~13.7 min, 100%~40% B; 13.7~18.0 min, 40% B. Mobile phase flow rate: 0.3 mL/min, column temperature: 55°C, sample tray temperature: 4°C, injection volume: 2.0 μL for positive ions; 2.0 μL for negative ions [22, 23].

3. Results and Discussion

3.1. Principal Component Analysis (PCA) of Rat Serum. Principal component analysis (PCA) is the transformation of observable and possibly correlated variables into linearly uncorrelated variables by means of orthogonal transformation, i.e., principal components [24]. In the study to investigate the effect of serum lipid metabolites in rats under different dietary interventions, principal component analysis was performed by positive and negative ion patterns as shown in Figures 1 and 2, with two different colored points representing different groups of rats, each within the 95% confidence interval. The difference analysis of lipid metabolism between the high-dose reconstituted rice group and high-fat feed group, high-fat feed group and ordinary rice group, and high-dose reconstituted rice group and ordinary rice group under positive and negative ion mode in the Figure showed that the lipid metabolites of high-fat feed group and high-dose reconstituted rice group, and high-dose reconstituted rice group and ordinary rice group showed large differences under the two different modes of analysis, while the positive and negative ion mode the results of this analysis can roughly indicate that the experimental high-fat rats formed a successful model, and high-dose reconstituted rice can better improve the accumulation of lipid substances in the high-fat feed group rats, and rice alone can improve the damage caused by high-fat feed results are poor, and even in the positive ion mode several groups of rats showed no difference in PCA analysis.

3.2. Preliminary Analysis of Differences in Blood Lipid Types in Rats. In positive ion mode, as in Figure 3(b), high-fat feed group compared with ordinary rice group, the metabolites significantly up-regulated and significantly downregulated are less significant compared with Figures 3(a) and 3(c). This result indicates that the intervention effect of ordinary rice is much less than that of high-dose reconstituted rice compared with rats on pure high-fat feed intervention, and it can be obtained from Figure 3(a) that the intervention of high-dose reconstituted rice significantly reduces the accumulation of lipid substances caused by high-fat feed. Therefore, the metabolite species that were significantly upregulated in both groups in the Figure were significantly more and their content was multiplied compared to each other. Analysis of

Figure 3(b) shows that the improvement of lipid accumulation caused by high-fat feed was not significant in the ordinary rice group because the metabolites significantly upregulated in both groups were not as high as in the high-dose reconstituted rice. As shown in Figure 3(c), comparing the differential metabolites in the ordinary rice group with the high-dose reconstituted rice group, it was found that the types and multiples of significantly upregulated metabolites were more significant, indicating that the intervention effect of high-dose reconstituted rice was significantly better than that of ordinary rice, and the intervention of high-dose reconstituted rice significantly reduced the accumulation of lipid substances in the rats in the ordinary rice group, while comparing Figures 3(a) and 3(c), it was found that the significantly downregulated substances in both Figure were similar, but the significantly upregulated substances The significance of Figure A was greater than that of Figure C. This result further indicated that the ordinary rice group had a certain improvement effect on reducing lipid accumulation in high-fat feed, but compared with the regulation effect of high-dose reconstituted rice, its effect on the regulation of lipid substance accumulation remained inferior to that of high-dose reconstituted rice. Taken together, the above results showed that both ordinary rice and high-dose reconstituted rice groups could improve the accumulation of lipid substances in rat serum after high-fat feed intervention, but the improvement effect of the experimentally prepared high-dose reconstituted rice was much better than that of ordinary rice.

In the negative ion mode, the abovementioned analysis methods were combined to analyze the difference graphs in the negative ion mode, and similar results were obtained. The high-dose reconstituted rice significantly regulated the lipid metabolites in the high-fat feed group, while the ordinary rice group also had a regulating effect on the high-fat feed group, but as can be seen from Figure 4(c), the regulating effect of ordinary rice on the high-fat feed group was much less than that of the high-dose reconstituted rice in the experimental group.

3.3. Screening and Analysis of Blood Lipid Differential Substances in Rats. As shown in supplemental files (Table S1), the lipid differences between the high-fat feed group and the normal rice group in the positive ion mode were 7. 2 PE (phosphatidylethanolamine), 2 Cer (Ceramides), 8 PC (Phosphatidylcholine), 10 TAG (Triacylglycerols), 1 SM (Sphingomyelin), 1 Acar (Acylcarnitine), and 1 LPC(Lyso-phosphatidylcholine). As shown in supplemental files (Table S2), the high-fat feed group vs ordinary rice group in negative ion mode was screened for differential lipids 5, 3 FA (Fatty Acid), 2 LPC, 5 PE, 1 PI (Phosphatidylinositol), and 1 HBMP (Human bone morphogenetic protein).

As shown in supplemental files (Table S3), differential lipids in the high-fat feed group vs high-dose reconstituted rice group in the positive ion mode appeared as 10. 1 DAG (Diacylglycerol), 2 CE (Cholesterol ester), 3 Acar, 2 PE, 1 HexCer (Hexosaccharide ceramide), 4 LPC, 6 SM, 6 Cer/NS, 31 PC, and 35 TAG. As shown in supplemental files
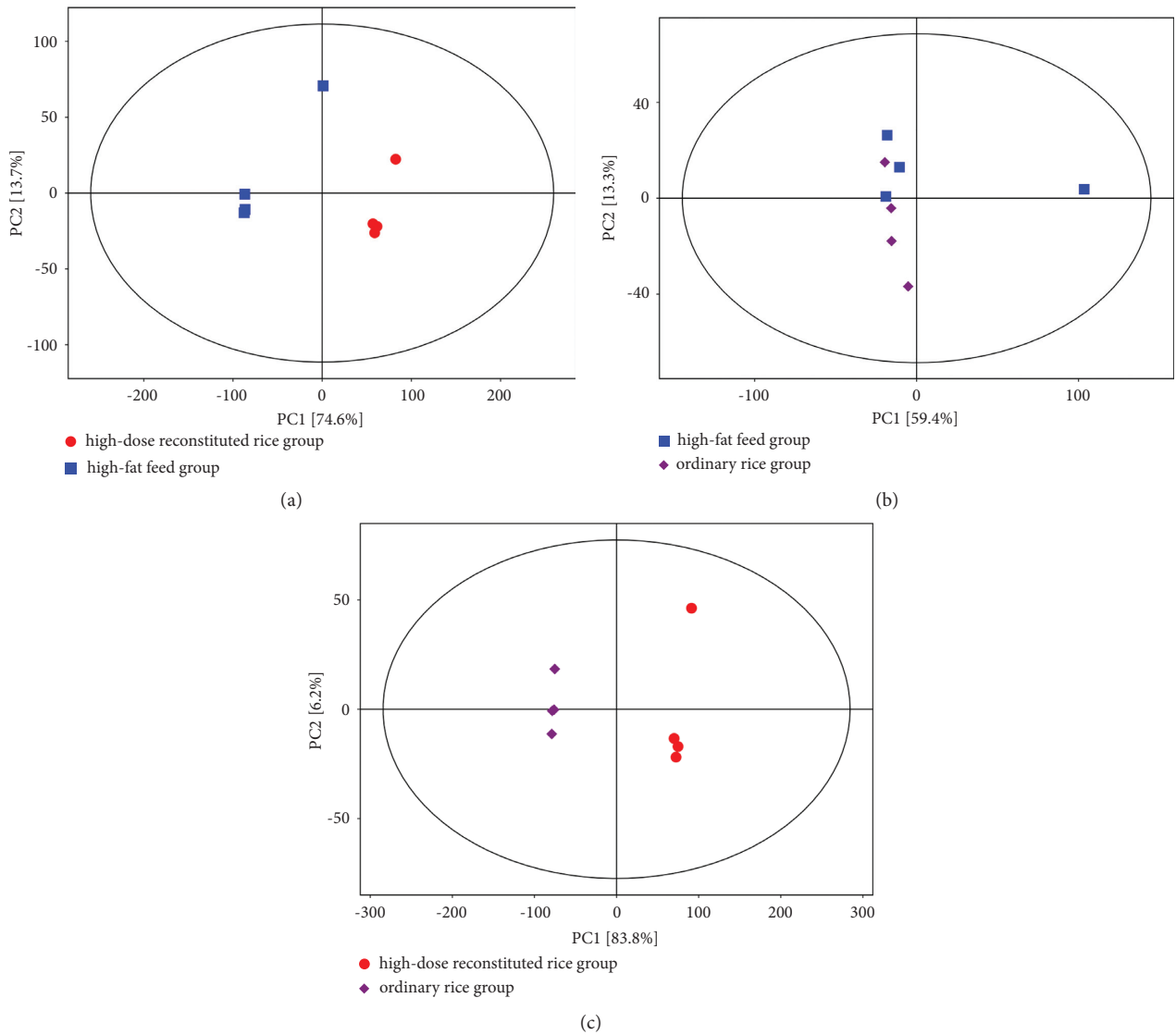
(a)

(b)

(c)

FIGURE 1: PCA analysis of blood samples from rats under different feedary interventions (positive ion mode). (Remarks: (a) high-dose reconstituted rice group vs. high-fat feed group; (b) high-fat feed group vs. ordinary rice group; and (c) high-dose reconstituted rice group vs. ordinary rice group).
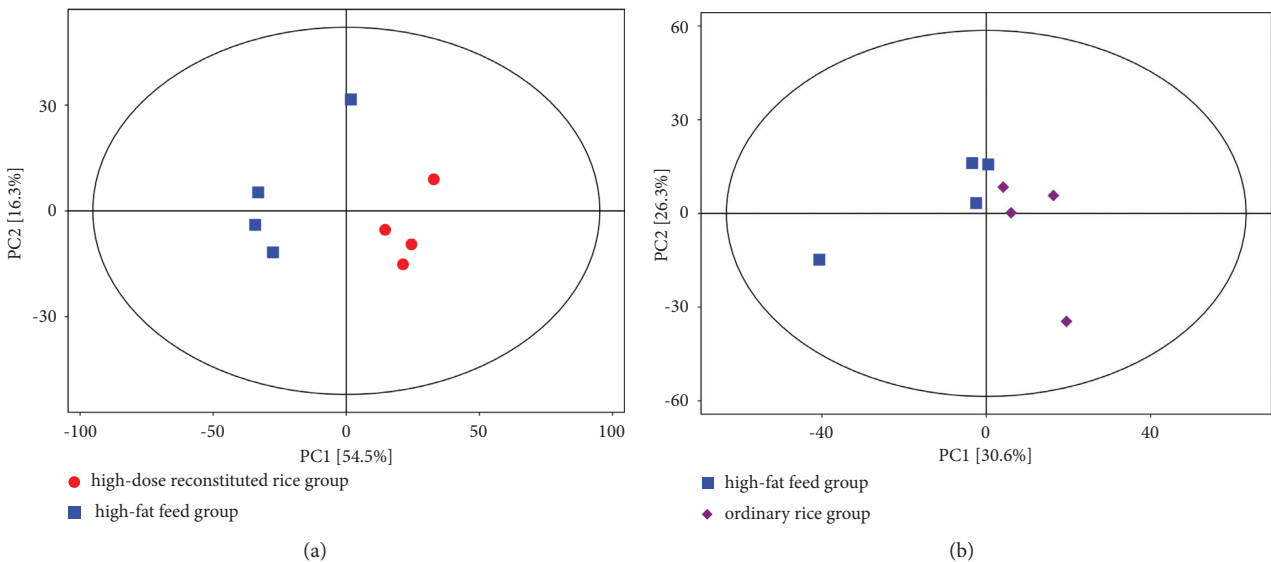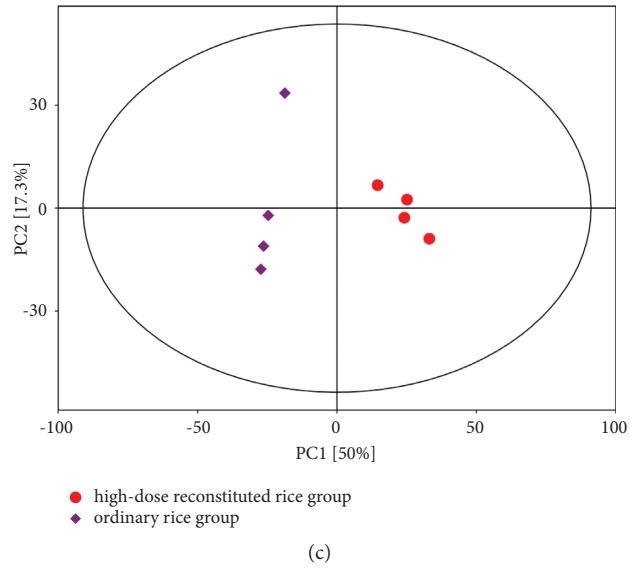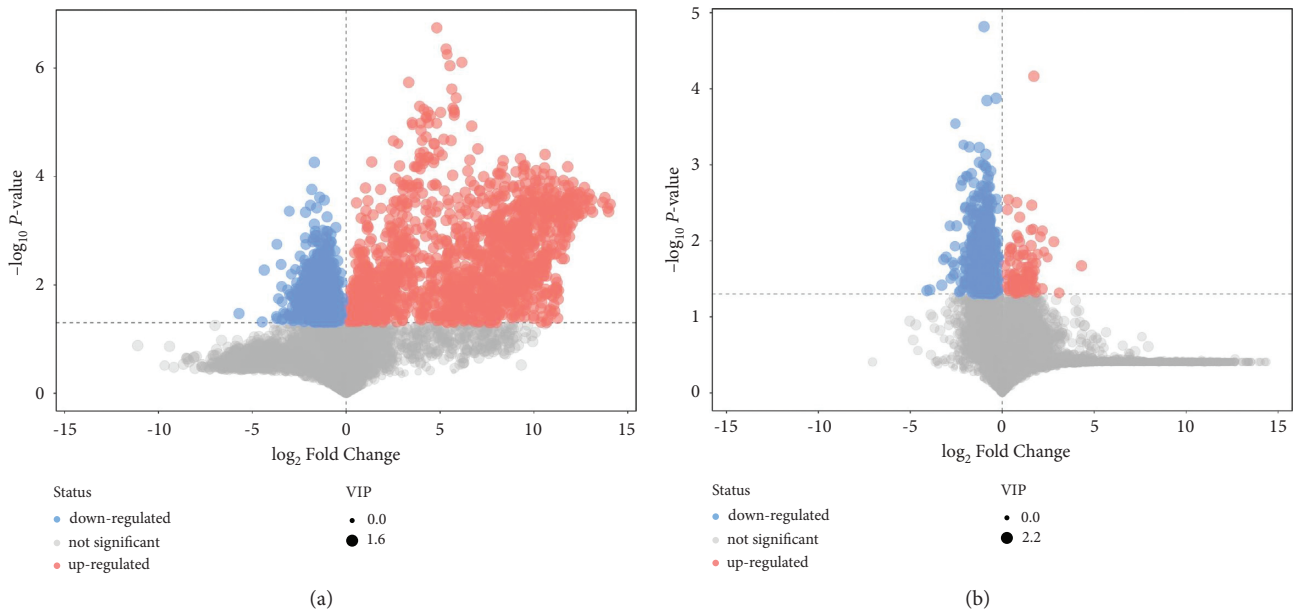

(a)

(b)

FIGURE 2: Continued.

(c)

Figure 2: PCA analysis of blood samples from rats under different feedary interventions (negative ion mode). (Remarks: (a) high-dose reconstituted rice group vs. high-fat feed group; (b) high-fat feed group vs. ordinary rice group; and (c) high-dose reconstituted rice group vs. ordinary rice group).
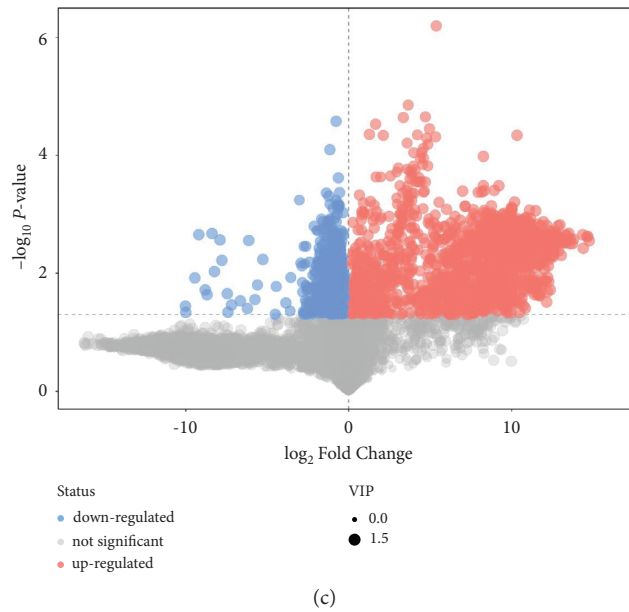

(a)

(b)

Figure 3: Continued.

(c)

FIGURE 3: Screening volcano plot of differential lipids between the two groups of rats with different feedary interventions (positive ion mode). (Remarks: (a) high-fat feed group vs. high-dose reconstituted rice group; (b) high-fat feed group vs. ordinary rice group; and (c) high-dose reconstituted rice group vs. ordinary rice group).
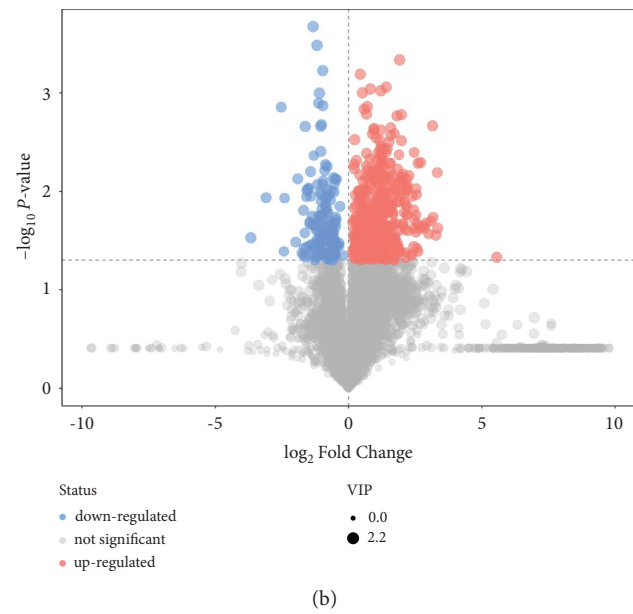

(a)

(b)

FIGURE 4: Continued.

(c)

Figure 4: Screening volcano plot of differential lipids between two groups of rats with different feedary interventions (negative ion mode). (Remarks: (a) high-fat feed group vs. high-dose reconstituted rice group; (b) high-fat feed group vs. ordinary rice group; and (c) high-dose reconstituted rice group vs. ordinary rice group).
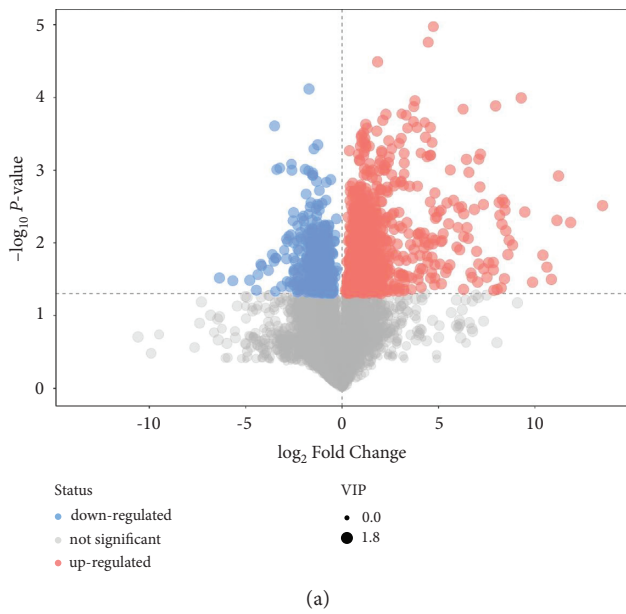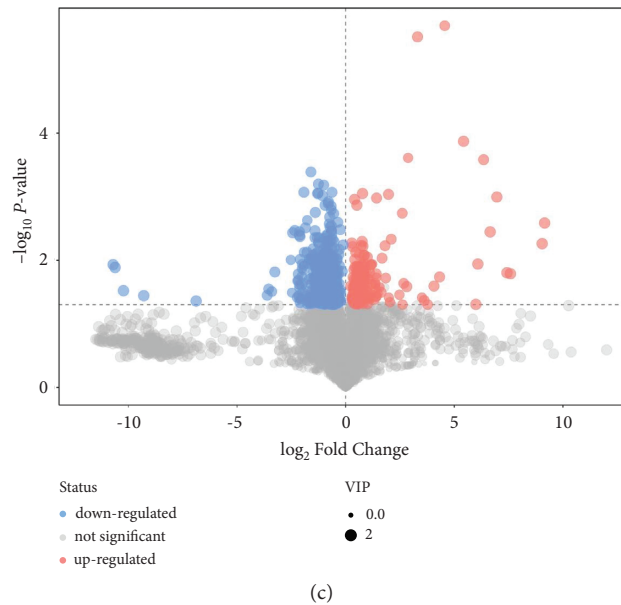
(Table S4), the results of detection in the negative ion mode 5 FA, 10 PC, 3 LPC, 3 FAHFA (Fatty acid esters of hydroxy fatty acids), 2 OxPI, 4 PE, 3 PI, 1 SQDG (Sulfoquinovo-syldiacylglycerol), 4 Cer/NS, 1 GlcADG (Glucur-onosyldiacylglycerol), 3 HBMP, 1 Cer/NDS, 1 HexCer/NS.

As shown in supplemental files (Table S5), the changes of differential lipids in the ordinary rice group vs high-dose reconstituted rice group in the positive ion mode 9 differential lipids appeared. 30 PC, 38 TAG, 3 Cer, 6 CE, 2 SM, 1 PE, 2 LPC, 1 Acar, and 1 DAG. As shown in supplemental files (Table S6), 9 differential lipids were detected in the two groups compared in the negative ion mode, 11 PC, 1 OxPI, 1 Cer/ADS, 2 PI, 2 HBMP, 1 SM, 2 GlcADG, 1 PE, and 1 HexCer/NS.

The TAG analogs were the most abundant in the high-fat feed group and the high-dose reconstituted rice group, the high-fat feed group and the ordinary rice group, and the ordinary rice group and the high-dose reconstituted rice group in a two-by-two comparison, indicating that the intervention of high-fat feed elevated the TAG of lipid substances in the serum of rats and increased the synthesis of TAG in hepatocytes. As TAG is an effective energy donor, and relevant studies have shown [25, 26] that TAG accumulates transiently in lipids at the early stage of liver regeneration to provide the energy required for hepatocyte proliferation, therefore, the results of the comparative analysis showed that both the high-fat group and the high-dose reconstituted rice group increased the content of TAG in the lipids of rats, i.e., increased the energy synthesis capacity of their liver. Among the lipid metabolites, except for TAG, which had the highest content, PC and PE accounted for a larger proportion of the lipid content in rats after TAG. While PE and PC, as important components of cell membrane phospholipids, their content has an important role in transmembrane transport and cell membrane

integrity [27]. It has been shown that the size of PC/PE ratio correlates with the permeability of the cell membrane, and if the ratio of PC/PE in lipid substances decreases, it increases the permeability of the cell membrane, which leads to the leakage of contents from hepatocytes and thus activates inflammatory factor-mediated liver injury [28]. The results of analysis indicate that the PC/PE ratio was higher in the high-dose reconstituted rice group than in the high-fat feed group versus the regular rice group, and slightly higher in the regular rice group than in the high-fat feed group, according to the results indicating that a high-fat feed increases hepatocyte membrane permeability and thus activates inflammatory factor-mediated liver injury, while both the intervention with high-dose reconstituted rice and the regular rice intake improved liver injury caused by a high-fat feed, and the high-dose reconstituted rice group had an effect of the high-dose reconstituted rice group on the improvement of inflammatory factors under the influence of high-fat feed and the degree of significance need to be further investigated.

In addition to the abovementioned lipid substances, many unnamed lipid substances were also detected, and most of the unnamed lipid substances were upregulated in the high-fat feed group and downregulated in the ordinary rice group and the high-dose reconstituted rice group, which indicated that the high-dose reconstituted rice had a relevant regulatory effect on improving the accumulation of lipid substances in the high-fat feed.

3.4. Analysis of Intergroup Variation of Lipid Differential Substances in Rats. Analysis of the bar graphs and bubble plots in Figures 5 and 6 for the lipid group of high-fat feed vs high-dose reconstituted rice group shows that the content of
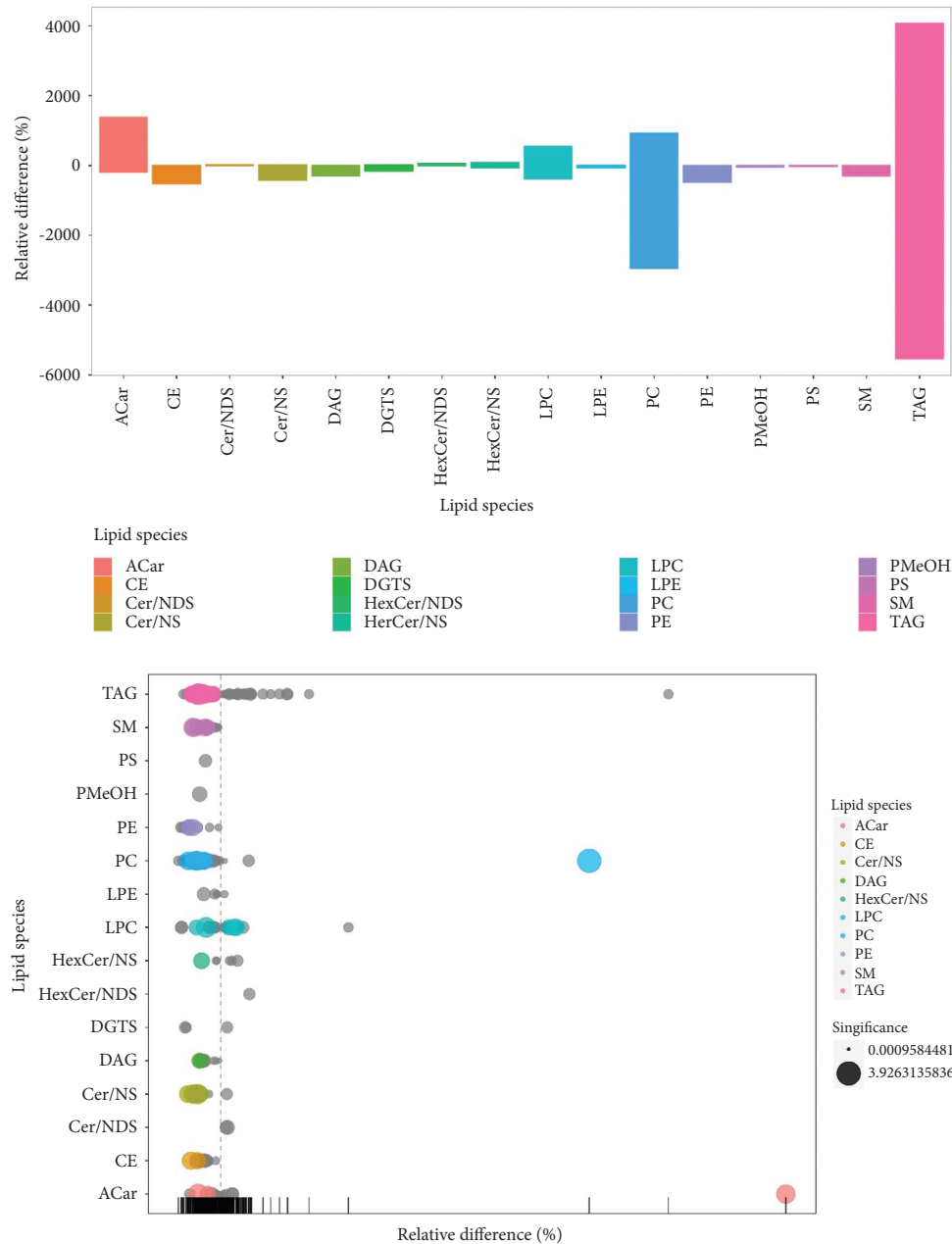
Figure 5: Histogram and bubble plot of lipid group in high-fat feed group-high-dose reconstituted rice group (Positive ion mode). Note: take Figure 5 as an example: the different colors in the bar graph of lipid groups represent the different lipid metabolizing substances screened out respectively. The vertical coordinate in the graph indicates the relative percentage change of each lipid metabolizing substance in that assay group. If its value is zero, it indicates that the substance is present in the same amount in both groups, if its value is positive, it indicates that the substance is present in a higher amount in the high lipid feed group, and if its value is negative, it indicates that the substance is present in a higher amount in the high dose reconstituted rice group. The horizontal coordinates of the lipid group bar graph indicate the classification information of lipids. A point in the lipidome bubble plot and represents a lipid metabolite. The size of the dot represents the P-value of the t-test (taken as the negative of the logarithm with a base of 10), with larger dots representing smaller P-value values. Gray dots indicate non-significantly different lipid substances for $P > 0.05$, and colored dots indicate significantly different lipid substances for $P < 0.05$. The horizontal coordinates in the graph represent the relative percentage change in the content of each lipid metabolite for the group comparison. The vertical coordinates in the figure indicate the classification information of lipids. The black line segments at the bottom demonstrate the density of metabolite distribution (one segment represents one metabolite).

each lipid substance in rats in the high-fat feed and high-dose reconstituted rice groups in the positive ion mode is less different, with Acar being higher in the high-fat feed group, PC and TAG in the high-fat feed and high-dose reconstituted rice groups, while the ratio of PC/PE was detected in the positive ion mode The PC/PE ratio was found to be significantly higher in the high-dose reconstituted rice group than in the high-fat feed group, and the high-dose
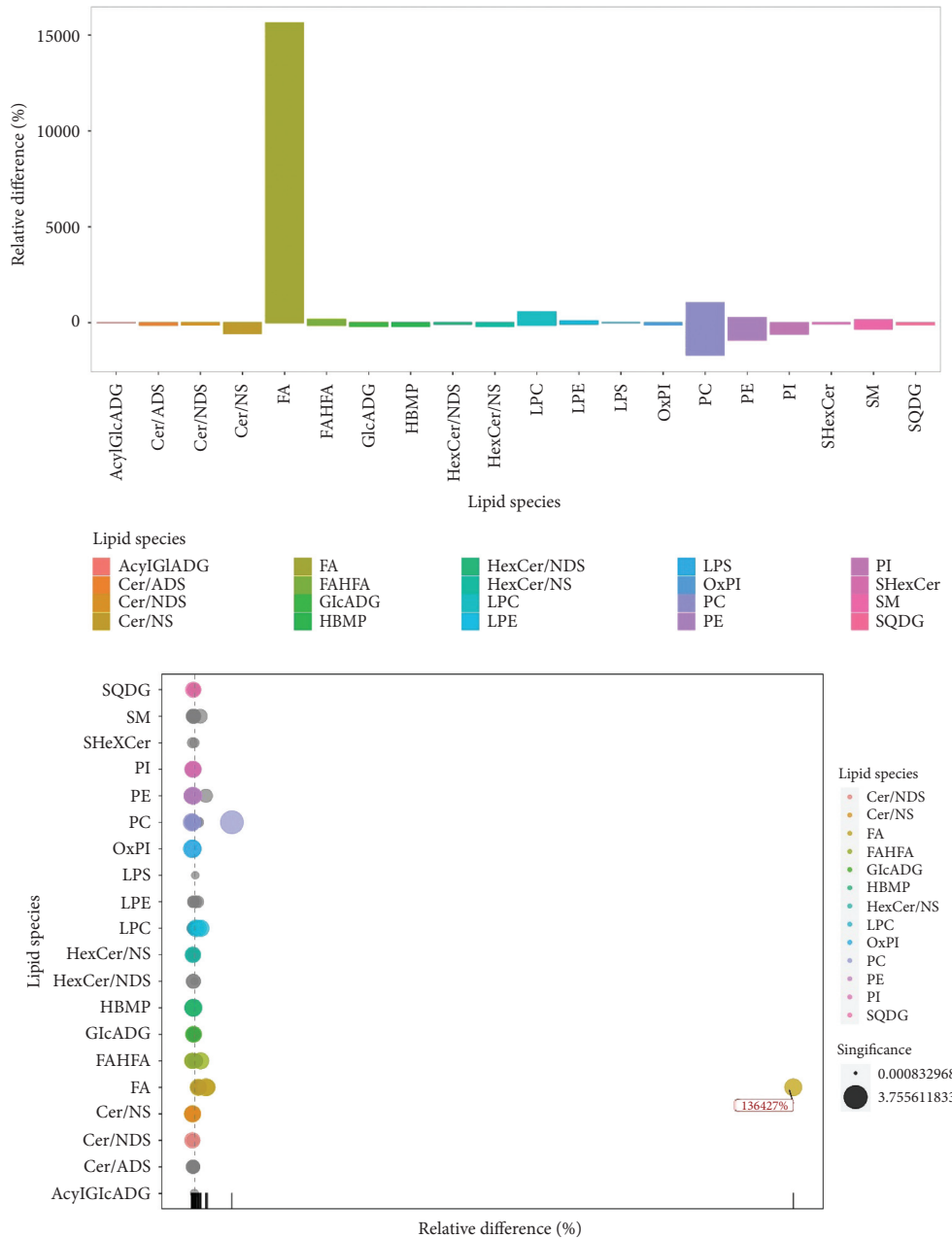
FIGURE 6: Histogram and bubble plot of lipid group in high-fat feed group-high-dose reconstituted rice group (negative ion mode).

reconstituted rice group had a certain alleviating effect on the liver injury and inflammation caused by high-fat feed. In the negative ion mode, it was obvious that FA substances accumulated in the rats under the high-fat feed intervention, but other lipid substances were less different, and the PC/PE ratio was less different in this mode, but still showed that the high-dose reconstituted rice group was slightly higher than the high-fat feed group. The percentage change of FA content in the negative ion mode in the lipid bubble diagram

was as high as 132467%, and this result also further confirmed that the high-fat feed caused a large accumulation of fatty acyl substances, which in turn may cause damage to the organism.

From the analysis of Figures 7 and 8, it can be seen that in the high-fat feed group in positive and negative ion mode compared with the ordinary rice group, a variety of lipid substances occurred in the high-fat feed rats abnormally than those in the ordinary rice feed intervention rats, and a
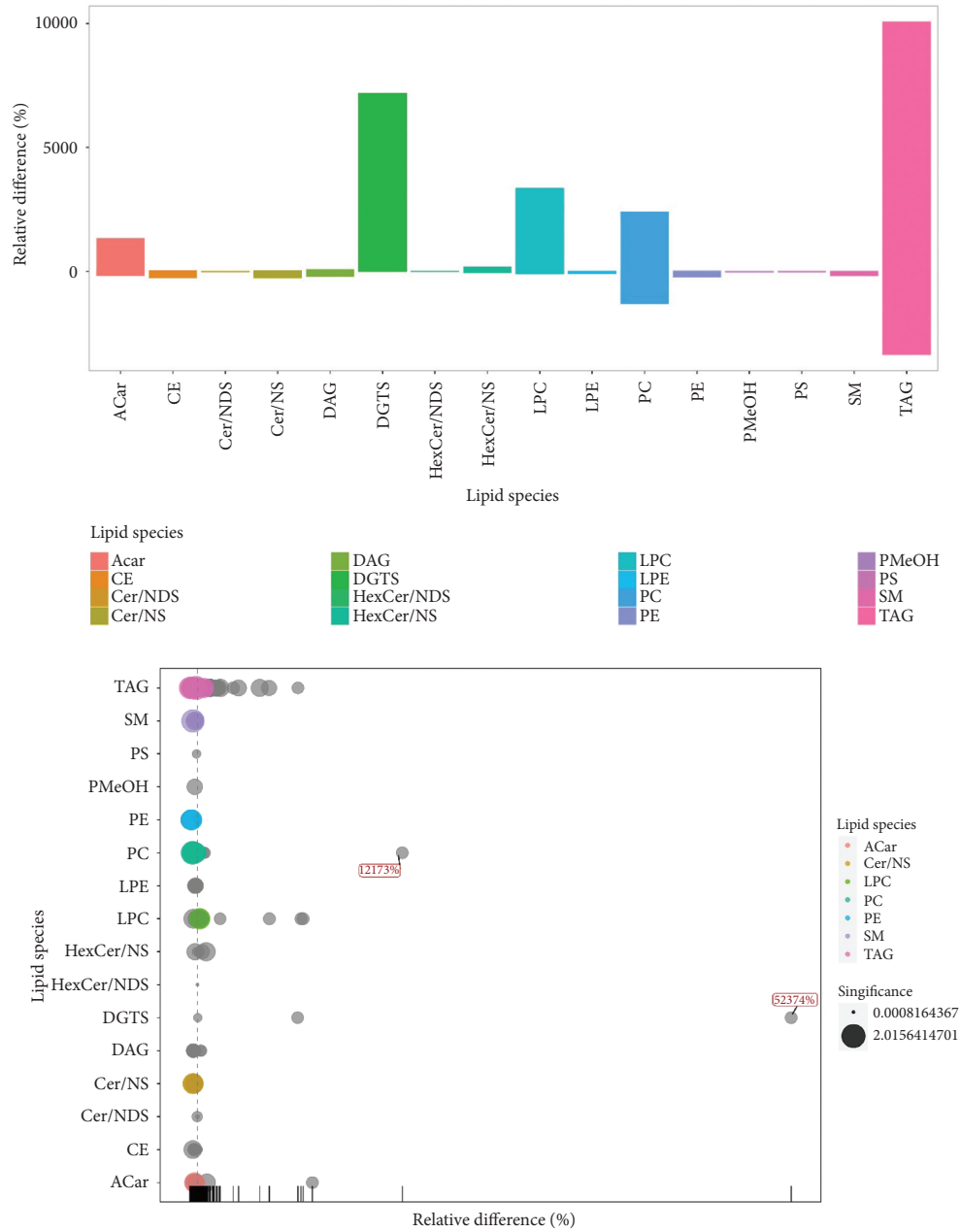
FIGURE 7: Histogram and bubble plot of lipid group in high-fat feed-ordinary rice group (positive ion mode).

variety of lipids accumulated in the high-fat feed intervention rats, such as Acar, DGTS, LPC, PC, and TAG detected in the positive ion mode, and FA and LPC found by detection in negative ion mode. All of these substances accumulated in the rats of the high-fat feed group, and the comparison with the rats of the ordinary rice group further indicates that the long-term high-fat feed will impair the balance of lipid metabolism in the body, causing disorders in the metabolism of some lipid substances, and then the accumulation of lipid substances in the body, which will cause damage to the body, and in serious cases, it will also produce hyperlipidemia, liver damage, inflammation and other harmful effects on the body. In serious cases, it can produce diseases that are harmful to the health of the organism, such as hyperlipidemia, liver damage, and inflammatory effects [29]. The difference between the PC/PE ratios of lipid
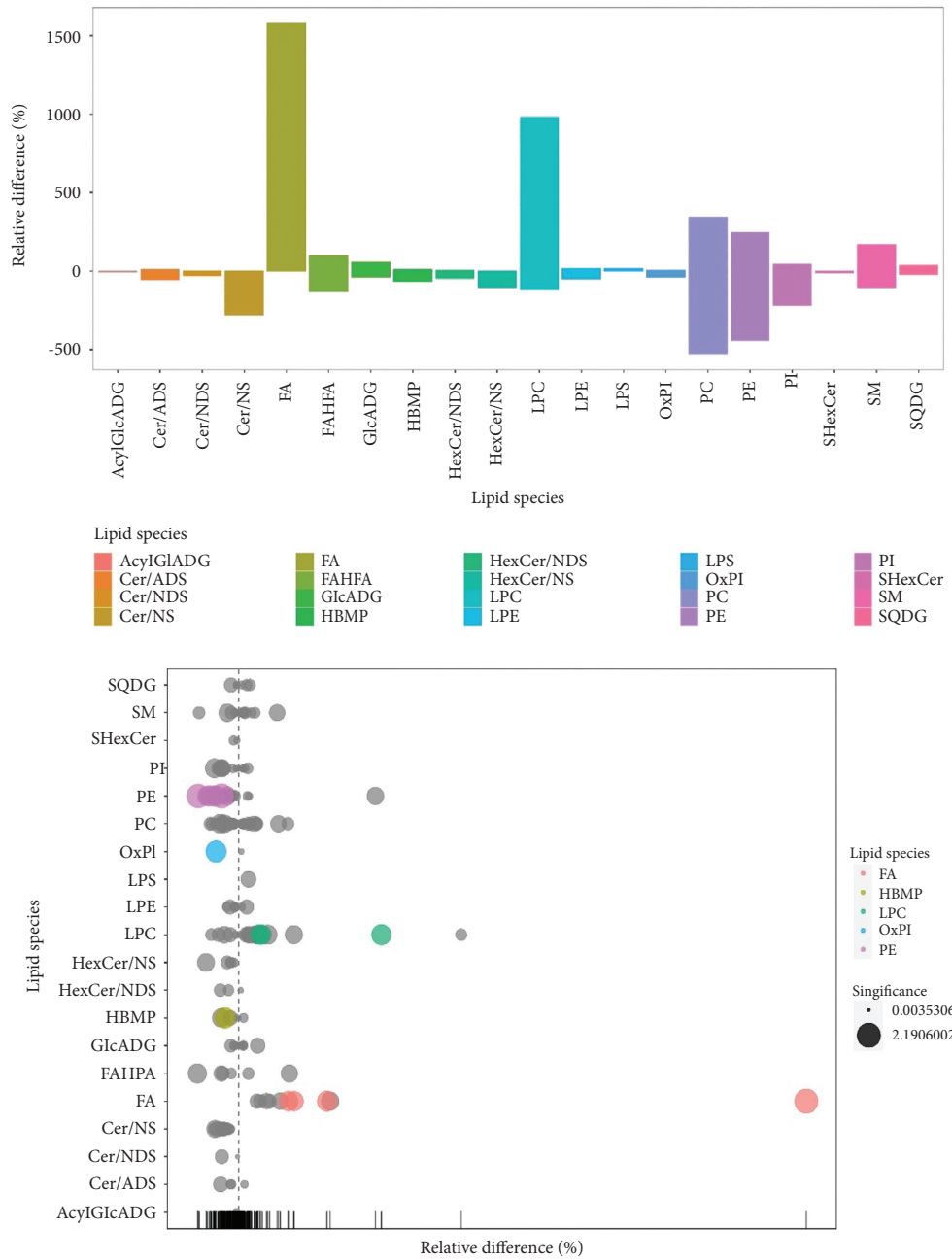
FIGURE 8: Histogram and bubble plot of lipid group in high-fat feed-ordinary rice group (negative ion mode).

substances in the two models is small, and this result indicates that ordinary rice has less effect on improving the damage caused by high-fat feed, but the effect of improving the accumulation of lipid substances is still good, and the daily rice food safety is healthy, and most normal people in long-term healthy low-fat rice daily food will not produce damage to the body from lipid accumulation.

In Figures 9 and 10, it can be obtained from the multiplicative relationship that the apparent accumulation of lipid substances is less, and most of the lipid substances are slightly higher in high-dose reconstituted rice, but do not reach the accumulation level of abnormally large multiplication, and only in the negative ion mode the FA of the

ordinary rice group is significantly higher than that of the high-dose reconstituted rice group, and that of the PC high-dose reconstituted rice group is higher than that of the ordinary rice group. Analysis of the histogram of the effect of lipid groups in the ordinary rice group-high-dose reconstituted rice group clearly showed that the PC/PE ratio in the positive and negative ion mode was smaller in the ordinary rice group than in the high-dose reconstituted rice group, and this result also indicated that the intake of high-dose reconstituted rice improved the inflammatory factor-mediated liver injury induced by the high-fat feed intervention in rats, and the intervention of high-dose reconstituted rice improved better than the ordinary rice group.
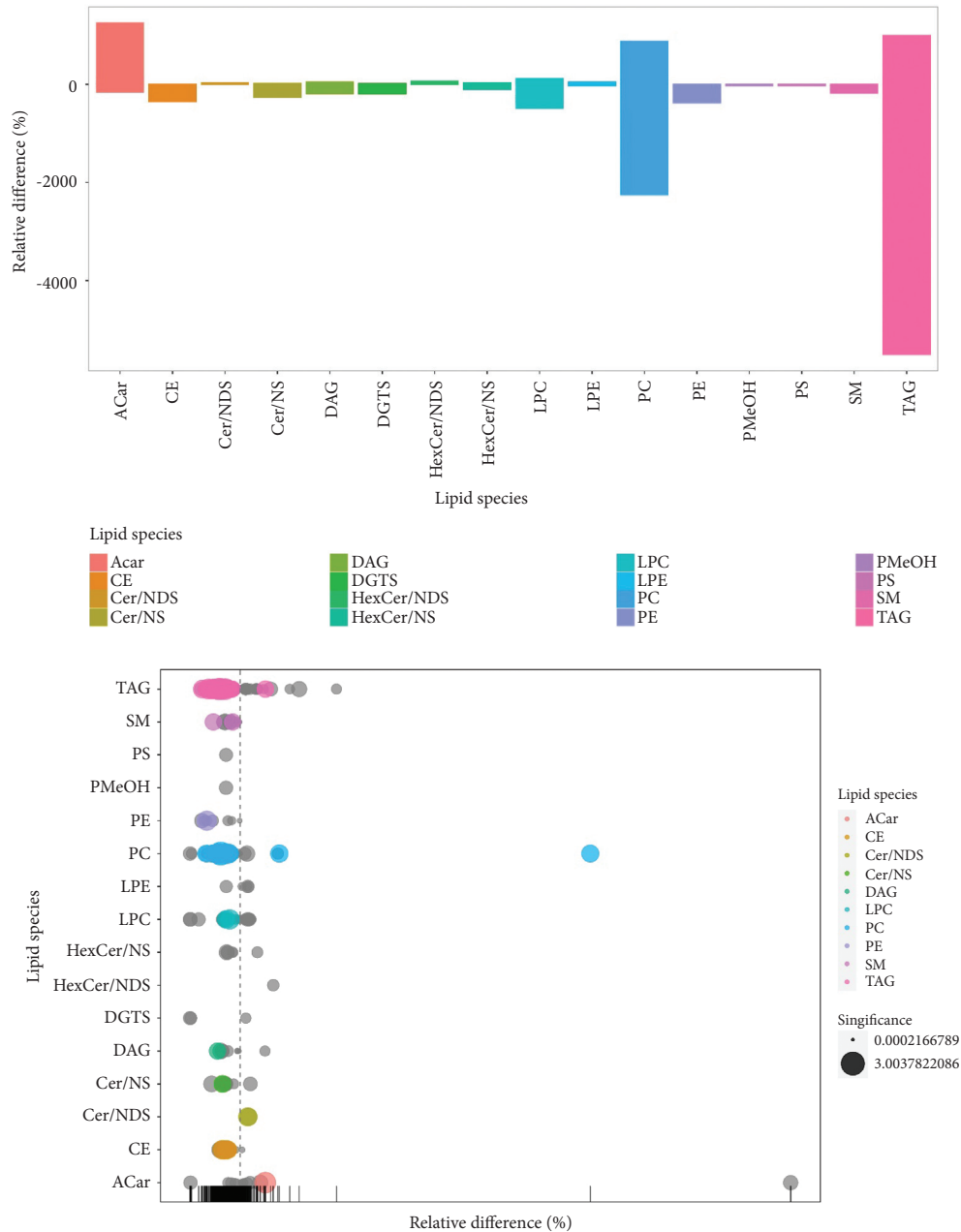
FIGURE 9: Histogram and bubble plot of lipid group in ordinary rice group-high dose reconstituted rice group (positive ion mode).

The abovementioned results further indicated that the high-fat feed altered the hepatocyte permeability of rats, which in turn activated inflammatory factor-mediated liver injury, by analyzing the group differences in lipid substances. Compared with the ordinary rice group and the high-dose reconstituted rice group, the content of each lipid class was significantly higher in the high-dose reconstituted rice group, but the content of each lipid class did not show similarly high levels in the high-fat feed group. The comparative results progressed to indicate that the intake of high-dose reconstituted rice improved the liver injury and the accumulation of lipid classes caused by the high-fat feed and had a positive regulatory effect on the metabolic disorders induced by the high-fat feed.
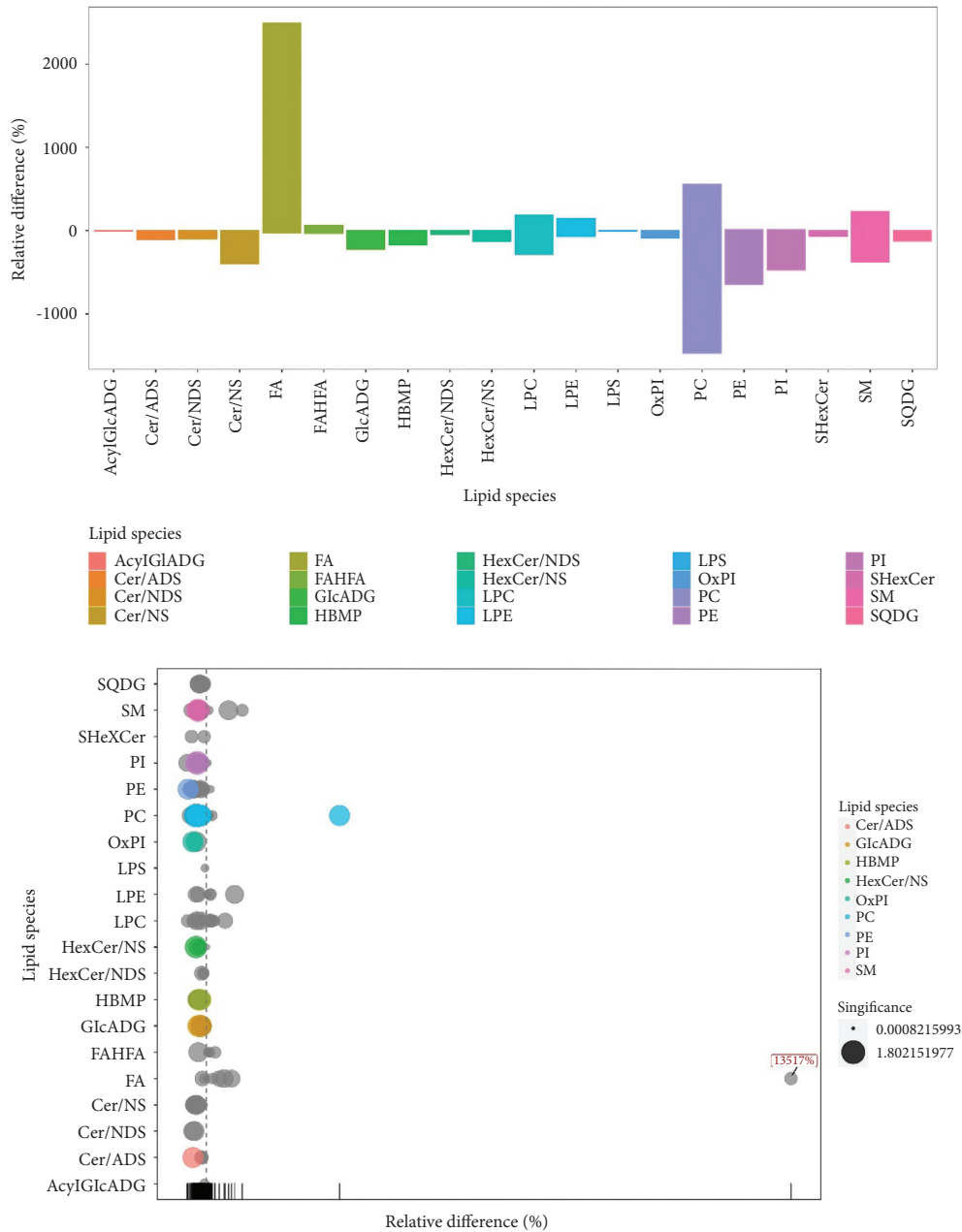
FIGURE 10: Histogram and bubble plot of lipid group in ordinary rice group-high dose reconstituted rice group (negative ion mode).

4. Conclusions

It was shown by this study that there were significant differences in serum lipid types in rats between the high-fat feed group and the high-dose reconstituted rice group, the high-fat feed group and the ordinary rice group, and the ordinary rice group and the high-dose reconstituted rice group. The comparison of serum differential lipid substances in rats after the three dietary interventions showed that the differential lipids after the dietary interventions were mainly PC, TAG, Cer, CE, SM, PE, LPC, Acar, DAG, FAHFA, OxPI, PI, SQDG, Cer/NS, GlcADG, HBMP, Cer/NDS, HexCer/NS,

etc. The comparison of the type and content ratio changes of specific differential lipids showed that high accumulation of individual lipid substances occurred in the rats of the high-fat feed group and that the high-fat diet had a disturbed effect on lipid metabolism in the rats. Reduction in high-fold change or accumulation of lipid substances in rats after intervention by ordinary rice versus high-dose reconstituted rice compared to the high-fat feed group high levels and large multiples of lipid accumulation and disorders were improved, and it was found that the improvement effect of the intervention by high-dose reconstituted rice was better than that of the ordinary rice group. The comprehensive

study found that high-dose reconstituted rice could improve the disruption of hepatocyte permeability and liver injury mediated by activation of inflammatory factors by high-fat feed and had a moderating effect on the metabolic disorders caused by high-fat feed.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Conceptualization and resources were performed by Ji-jun Liu and Zhi Zhang; methodology and investigation was done by Yan Wang; validation and writing of original draft was done by Yun-liang Zhang. Reviewingand editing were performed by Bo-xin Dou and Ying Liu; funding acquisition was done by Na Zhang. All authors have read and agreed to the published version of the manuscript.

Acknowledgments

Supplementary Materials

Table S1: changes in differential lipids in high-fat feed group vs. ordinary rice group (positive ion mode). Table S2: changes in differential lipids in the high-fat feed group vs. ordinary rice group (negative ion mode). Table S3: changes in differential lipids in the high-fat feed group vs. high-dose reconstituted rice group (positive ion mode). Table S4: changes in differential lipids in the high-fat feed group vs. high-dose reconstituted rice group (negative ion mode). Table S5: changes in differential lipids in the ordinary rice group vs. high-dose reconstituted rice group (positive ion mode). Table S6: changes in differential lipids in the regular rice group vs. high-dose reconstituted rice group (negative ion mode). (*Supplementary Materials*)

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