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Mushroom *volvariella volvacea* reduces lipids and obesity in high-fat-fed wistar rats

Abstract

Background: A diet high in pig fat induces obesity. This study examined the effects of the mushroom *Volvariella volvacea* (Vv) on the prevention of weight gain, alterations in plasma lipid and carbohydrate profiles and inflammation in preventive treatment.

Materials and methods: To carry out the study, 32 male albino rats divided into 4 groups of weights between 85g and 95g were used. The rats were fed a normal diet (ND), a diet enriched with pork fat (HF), then the previous diet supplemented with *Volvariella volvacea* (Vv5% and Vv10%). During the experiment, blood samples were taken on day 1 and day 42 to measure biochemical parameters.

Results : The results showed that rats consuming this fatty diet incorporated at 5% and 10% of Vv mushroom (treated rats) respectively had a significant ($p < 0.05$) lower body weight gain compared to the groups of positive control rats receiving only the fatty diet, i.e. 23.15%, 16.50% vs 41.25%. In the same order, these two doses in rats respectively prevented the significant rise ($p < 0.05$) in blood glucose and CRP levels compared to the positive control rats where there is hyperglycemia, i.e. 35.9%, 44.10% vs 65.15%. This observation was also made with the CRP level, i.e. 32%, 39% vs 92.1%. Supplementation of 5% and 10% Vv mushroom fatty diet in rats showed significantly ($p < 0.05$) lower increase rates in total cholesterol (21.20%, 24.60% vs 49.2%), triglycerides (16.01%, 22.02% vs 37.5%) and low-density lipoprotein (LDL) (24%, 29%vs 86,80%) respectively compared to the positive control group. In addition, a significant increase ($p < 0.05$) in high-density lipoprotein (HDL) was observed in rats treated with 5% and 10% doses respectively compared to the positive control rats, i.e., 16.42%, 25% vs 14,8%.

Conclusion: In this study, bioactive secondary metabolites such as flavonoids from Vv mushroom are involved in lipid metabolism by decreasing caloric intake, which could explain the observed improvement in dyslipidemia in treated rats unlike in obese rats induced by the fatty diet. Thus, Vv mushroom at doses of 5% and 10% could be considered effective in the preventive treatment of dyslipidemia in obesity.

Keywords: Preventive treatment, *volvariella volvacea* mushroom, weight, antihyperlipidemia, wistar rats

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Introduction

Hyperlipidemia is a medical condition where levels of lipids (fats), such as cholesterol (especially LDL) and triglycerides, are abnormally high in the blood. This condition can be caused by a combination of genetic and lifestyle factors. Poor diet, lack of physical activity, obesity, smoking, excessive alcohol consumption, and certain medical conditions (such as diabetes and kidney disease) can contribute to the development of hyperlipidemia.[1] In some cases, genetic factors may also play a significant role. Management of hyperlipidemia usually involves lifestyle changes as well as medications as needed. However, lifestyle changes include adopting a heart-healthy diet rich in fruits, vegetables, whole grains, and lean protein, and reducing saturated and trans fats, engaging in regular physical activity and managing weight, and avoiding smoking and excessive alcohol consumption.[2] Management of hyperlipidemia is important to reduce the risk of cardiovascular disease and promote overall heart health.[2]

Volvariella volvacea, also known as rice straw mushroom, is a type of edible mushroom with a tropical and subtropical distribution worldwide.[3] It belongs to the family Pluteaceae of the order Agaricales under the division Basidiomycetes.[4] Straw mushroom is world-famous, due to its pleasant flavor, taste, high protein content, and short cultivation time.[5]

Its industrial cultivation is very well known in Asia even though it is difficult to transfer the technology to tropical Africa.[6] *Volvariella volvacea* is one of the species widely distributed in the tropical zone. The species is widely consumed in Cote d'Ivoire, Benin and many other countries, where it is locally called "the palm mushroom". Indeed, this species is harvested from natural habitats for consumption by local populations. The availability of this species in the coastal areas of West and Central Africa dominated by palm trees[7,8] would be a reason for the low interest in its cultivation. However, *V. volvacea* grows very well on cellulosic substrates and can therefore be cultivated on a wide range of substrates available in tropical Africa such as rice and wheat straw, grass, banana leaves and palm waste. *V. volvacea* also grows at high temperatures (up to 35 °C) and is therefore an interesting and suitable candidate for cultivation in the context of tropical Africa.[9] Medicinally, *V. volvacea* is distinguished by its potent antioxidant properties, attributed to high levels of phenolic compounds and its notable DPPH free radical scavenging activity[10] like most horticultural crops.[6]

The aim of this study was to evaluate the ability of dietary supplementation with local *V. volvacea mushroom* to improve obesity and associated metabolic alterations in Wistar rats fed pig fat.

Material and methods

Animals and livestock

The study on animals (rats) was carried out in accordance with experimental protocols developed according to the principles of ethics and welfare in accordance with the guidelines for the protection of experimental animals of the European Directive 2010/63/EU.[11] This experiment was approved by the Ethics Committee for Experimental Animals of Nangui Abrogoua University. The 32 rats, divided into 4 groups of 8, were housed in the breeding room of the Laboratory of Physiology, Pharmacology and Pharmacopoeia of the UFR-SN Nangui Abrogoua University at a temperature of 25 ± 2 °C, a humidity (65 ± 5%) and a 12-hour light-dark cycle. All rats had free access to tap water.

The experiment consists of an induction of obesity and dyslipidemia for 42 days with a fatty diet of 30% pig fat.[12] The two doses (5% and 10%) of incorporation of the Vv mushroom are prepared according to those previously defined in works[13,14] with a slight modification and in accordance with preliminary studies carried out within the laboratory. The food was prepared at the beginning of each experiment at the same time and placed in the cages. Rats aged 7 to 8 weeks and with a homogeneous average body weight of 114.02 ± 4.2 g are fed for batch 1 with pellets (FACI ®, Abidjan, Côte d'Ivoire) and for batch 2 with pellets added to 30% pig fat. Batches 4 and 5, in addition to the fatty diet, consumed the Vv mushroom (Figure 1) supplemented at 5% and 10% respectively.

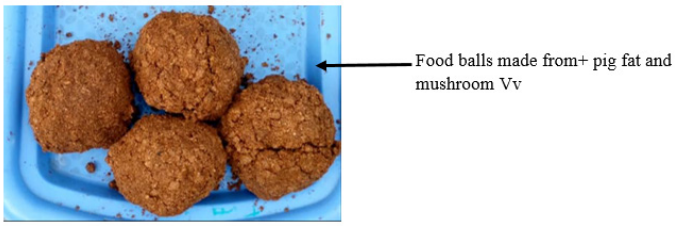

Figure 1 Granulated feed (FACI ®) incorporating pig fat and the mushroom *volvariella* volvacea (Vv) purchased at the Abobo market in Abidjan-Cote d'Ivoire.

Technical equipment

The technical equipment includes an electronic balance, a reagent (alcohol, ether), an anesthetic bell, cotton, a Pasteur pipette, dry tubes and samples.

Preparation of the aqueous extract of *Volvariella volvacea*

The aqueous extract of *Volvariella volvacea* was prepared using the slightly modified traditional extraction methods of Daoudi and Kré.[15,16] The *Volvariella volvacea* samples were washed and then dried in thin layers away from sunlight for 25 days. Once dried, the fungal material was ground. For decoction extraction, 100 ml of water was added to 10 g of powdered fungal material and boiled for 15 minutes, then filtered through filter paper and Wattman filter paper before being dried in an oven at 46°C for 24 hours. The brown-colored dried *Volvariella volvacea* evaporates were collected and stored in sterile boxes to be incorporated into the diet of Wistar rat.

Blood sampling and biochemical analysis

Blood samples were collected from healthy rats at the beginning (1 day) and at the end (42 days). At each collection, the animals were fasted for 12 hours. In ether-anesthetized animals, blood was collected from the retro-orbital sinus using a sterile Pasteur pipette. Blood samples were collected in dry tubes. After centrifugation at 4000 rpm for 20 minutes, the serum was collected for biochemical analyses. The biochemical parameters measured with an automated spectrophotometer (Randox, France) from the serum were: blood glucose, C-reactive protein (CRP), total cholesterol (TC), HDL cholesterol (HDL), LDL cholesterol (LDL), and triglycerides (TG). In addition, before blood glucose assessment, the animals fasted for 8 hours.

Statistical analysis

Statistical analysis of the data was performed using Graph Pad prism Version 8.4.3 (San Diego, California, USA). Results were expressed as the mean followed by the standard error of the mean (M ± SEM). Comparison of means between control and test rats was performed using ANOVA and the likelihood test was performed using the Dunnett test. The significance threshold was set at $p < 0.05$.

Results

Effects of Vv mushroom consumption on body weight of rats

Figure 2 shows that the weight gain of rats consuming only animal fat (positive controls or batch 2) is significantly higher compared to rats consuming Vv mushroom incorporated respectively at 5% and 10% (24.1% vs. 16%, 14.1%, $p < 0.05$). Thus, it was observed that the consumption of the mushroom at the different doses prevented weight gain in rats obtained by making the difference between the initial and final weights.

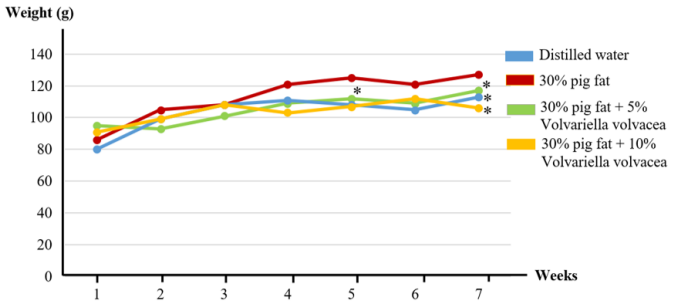

Figure 2 Effects of *volvariella volvacea* (Vv) mushroom consumption on body weight in wistar rats.

Effects of Vv mushroom consumption on blood sugar and CRP

Consumption of 30% pork fat in the prepared diet caused a significant increase ($P < 0.05$) in the fasting blood glucose level of the positive control group of rats compared to the negative control group of rats using distilled water (Table 1). The results of the hypoglycemic effect indicated that the group of rats consuming 5%Vv and 10%Vv presented a significant decrease (35.90% and 44.10%, $p < 0.05$) in fasting blood glucose levels, respectively, compared to the positive control group where blood glucose levels changed little at the 7th week. However, a significant, greater reduction in CRP (39%) was observed in rodents consuming 10%Vv at the 42nd day (Table 1).

Effects of Vv mushroom consumption on lipid parameters

The results (Table 2) showed a significant reduction ($p < 0.05$) in the plasma concentration of total cholesterol in rats consuming Vv 5% and Vv10% mg/kg respectively 25.21% and 24.6% unlike the

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groups of positive control rats (+) where the level of this metabolite is increasing at the end of the experiment (D42). This decrease is also significant ($p < 0.05$) with the incorporation rates Vv5% and Vv10% respectively for LDL (24%, 29%) and triglycerides (16.2%, 22.1%) compared to the animals having consumed the fatty food where an increase in these lipid parameters was observed during the previous period. However, the HDL-cholesterol content in the groups of rats incorporating Vv 5% and Vv10%, respectively, showed a significant increase ($p < 0.05$) of 18.4% and 20.7% on the 42nd day, respectively.

Table 1 Variation in blood glucose (g/l) and CRP (g/l) in rats consuming Vv mushroom at doses of 5% and 10% and control rats

	Blood sugar (g/l)		CRP (g/l)	
	D1	**J42**	**D1**	**J42**
Water	2.3 ± 0.42	2.71 ± 0.14	2.5 ± 0.2	2.83± 0.14
Fat-30%	2.18 ± 0.2	3.6 ± 0.18 (65.15%)	2.40 ± 0.12	4.60 ± 0.7 (92.1%)
Vv5%	2.90 ± 0.16	*1.86 ± 0.33 (35.90%)	2.2 ± 0.24	*3.24 ± 0.11 (32%)
Vv10%	2.63 ± 0.19	*1.47 ± 0.15 (44.10%)	1.8 ± 0.11	*2.95 ± 0.12 (39%)

Results are expressed as mean ± standard deviation (n = 8).

* Significant difference between rats tested with Vv mushroom and positive control rats (+); $p < 0.05$

CRP: C-reactive protein

VV5%: *Volvariella volvacea* mushroom incorporated at 5% in the food formulation;

VV10%: *Volvariella volvacea* mushroom incorporated at 10% in the prepared food

D1: treatment; **D42** : and treatment

Table 2 Variation in lipid parameter levels (mg/dl) in rats consuming Vv mushroom at doses of 5% and 10% and control rats

	TG (mg/dl)		TC (mg/dl)		HDLc (mg/dl)		LDLc (mg/dl)	
	D1	**J42**	**D1**	**J42**	**D1**	**J42**	**D1**	**J42**
Water (-)	121± 0.1	134.5± 0.19	123.1 ± 0.11	131.9 ± 0.21	69.5 ± 0.11	78.2 ± 0.13	29.8 ± 0.21	33.6± 0.15
Fat (+)	138± 0.9	221.2 ± 0.61	101.1 ± 0.99	199.2 ± 0.38	46.1± 0.13	54.4 ± 0.1(14.8%)	37.46 ± 0.42	69.95± 0.26
Fat + Vv (5%)	123.1± 0.7	*103.3 ± 0.8 (16.10%)	127.3 ± 0.17	*100.31 ± 0.11 (21.25%)	72.5 ± 0.18	*87.2 ± 0.1 (20.70%)	30.4 ± 0.53	*22.8 ± 0.16 (24%)
Fat + Vv (10%)	124.3±1.6	*96.72 ± 0.10 (22.20%)	122± 0.14	*92.16 ± 0.11 (24.60%)	69.2 ± 0.13	*86.45± 0.16 (18.40%)	24.5 ± 0.1	*17.30±0.18 (29%)

TG: triglycerides; TC: total cholesterol; HDLc: HDL cholesterol; LDLc: LDL cholesterol; Vv: Volvariella volvacea mushroom; D1: before treatment; D42: after treatment

Results are expressed as mean ± standard deviation (n = 8).

* Significant difference between rats tested with Vv mushroom and positive control rats (+);

$p < 0.05$.

Discussion

The use of dietary supplements is an option that is more used in the management of metabolic diseases (obesity, dyslipidemia, and diabetes) due to their low cost and accessibility. In addition, these foods contain bioactive compounds such as polyphenols, dietary fiber, saponins and peptides that have additional health benefits beyond their nutritional value.[17]

In this work, consumption of Vv mushroom incorporated at 10% in the diet significantly slowed down body weight gain in rats compared to rats consuming the fatty or positive control diet (16.50% vs 41.25%; $p < 0.05$). This finding was also made by Zoho[18] who showed 75% and 100% of this Vv mushroom in the diets caused a decrease in body weight and abdominal fat in Wistar rats, so it can be proposed as a dietary regimen for obese people.[16] Again, body weight gain was significantly reduced by 25% when adding 20% *Shiitake* mushroom powder to a hypercholesterolemic diet for 25 weeks in obese rats.[19]

Indeed, the fatty acid composition of dietary fats may therefore play an important role in regulating body weight, especially in obese individuals. Animal and human studies have shown that polyunsaturated fatty acids (PUFAs) from mushrooms[20] are more readily used as fuel, while saturated fatty acids (SFAs) are more likely to be accumulated in adipose tissue.[21] The observation in this work that consumption of 10% Vv prevented weight gain could be explained by a reduction in energy intake leading to weight loss as has been reported with mushroom.[20] Better, the *Volvariella volvacea* polysaccharide, one of the main bioactive components, exerts a fat-reducing effect at low doses (250 µg/ml) through fatty acid synthesis and oxidation pathways in nematodes.[22]

In the present study, daily consumption of 10% Vv mushroom effectively reduced total cholesterol, triglyceride and LDL levels compared to rats fed a high-fat diet by 24.6%, 22.1% and 29% respectively (tab 2). This reduction was more pronounced in preventive treatment with crushed mushrooms incorporated at 10% in the diet of rats made obese by a fatty diet for 6 months with total

cholesterol (44.1%), triglyceride (51.6%) and LDL (71.1%) levels.[16] The difference in the above-mentioned results could be explained by the nature (Vv vs. mixture of 3 mushrooms), the period of the experiments (5 weeks vs 6 months) and especially the composition of the mushrooms tested. As for HDL, it was increased by 20.7% and this value is lower than 60.2% observed in obese rats consuming the mushroom *Agaricus brasiliensis*, rich in fiber after 4 weeks.[23]

In the medical industry, bioactive compounds present in *Volvariella volvacea*, such as polysaccharides, flavonoids and terpenes, offer a wide range of therapeutic applications.[24] Therapeutic activities such as the antihyperlipidemic effects observed in our experiment are attributable to bioactive compounds such as flavonoids. The latter can inhibit weight gain directly or through their metabolites using various potential pathways.[25] In fact, the effects of flavonoids on obesity can be observed via various mechanisms, including decreased caloric intake and fat absorption, increased energy expenditure, altered lipid metabolism, increased inflammation and oxidation, and altered gut microbial profile. Flavonoids also help restore the lost balance caused by dysregulated lipogenesis and lipolysis. They are involved in the activation of AMP-activated protein kinase (AMPK), a key enzyme involved in the control of lipid metabolism and adipogenesis.[26]

This decrease in triglyceride levels may be due to increased activity of endothelium-bound lipoprotein lipase, which hydrolyzes triglyceride into fatty acids, or to inhibition of lipolysis so that fatty acids are not converted into triglycerides.

The hyperlipidemia observed in these positive control rats (Table 2) can be explained by the high lipid content in the diet. Several authors have found that an increase in the lipid content of food causes an increase in plasma cholesterol concentration, and modifies the composition of plasma lipoproteins, notably by increasing the portion of cholesterol esters in VLDL and LDL. Changes in lipoprotein composition are mainly linked to the activities of HNG-CoA reductase (an enzyme involved in cholesterol synthesis). In terms of synthesis, intracellular cholesterol exerts a negative feedback regulation on HMG-CoA, the rate-limiting enzyme of cholesterol synthesis. Excess cholesterol in cells leads to the suppression of HMG-CoA reductase activity.[27]

Obese rats fed a diet rich in pork fat showed an increase in blood glucose compared to the normal group, while supplementation with Vv mushroom was able to reduce blood glucose in these rats (Table 1). Similarly, elevated CRP levels were correlated with blood glucose in obese rats (Table 1) compared to normal rats. With Vv mushroom consumption, the reduction in CRP levels showed that this mushroom has an anti-inflammatory effect. Along the same lines, authors have indicated a notable effect of *Volvariella volvacea* as a potential anti-inflammatory and anticancer resource, by inhibiting the expression of IL-8, the excess of which can lead to several tissue lesions.[6,28]

In summary, the results of the study proved that at a low dose of 5%, the hypoglycemic, anti-inflammatory and antihyperlipidemic activities of the Vv mushroom are effective in rats made obese by fat consumption. *Volvariella volvacea* in addition is rich in bioactive compounds, including antioxidant enzymes, beta-glucans (polysaccharides), polypeptides, phenolics, and terpenes, which contribute to its health-promoting effects. These components support reducing lipid levels by potentially inhibiting fat accumulation and promoting fatty acid oxidation pathways, while its high fiber content and low-calorie profile contribute to weight reduction by increasing satiety and improving gut health.[29–32]

Conclusion

Consumption of *Volvariella volvacea* (Vv) mushroom demonstrated hypoglycemic, anti-inflammatory and antihyperlipidemic effects in obese rats at low doses (5% and 10%), which justifies ethnobotanical use, and therefore can be used as a good insight for a new source of drugs for dyslipidemia and diabetes with further studies.

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Conflicts of interest

None.

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