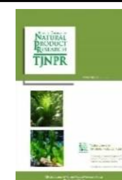
Trop J Nat Prod Res, December 2023; 7(12):5415-5419 ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

Tropical Journal of Natural Product Research

Available online at https://www.tjnpr.org

Original Research Article


The Potential of UV-B Irradiated Oyster Mushroom (*Pleurotus ostreatus*) Powder on Plasma Glucose and TNF-*α* Levels in Type 2 Diabetic Rats

Siti N Hasanah[1], Chodidjah Chodidjah[2], Atina Hussaana[3]*

[1]*Postgraduate of Biomedical Science, Faculty of Medicine, Universitas Islam Sultan Agung, Semarang Indonesia, 50112*
[2]*Department of Anatomy, Faculty of Medicine, Universitas Islam Sultan Agung, Semarang Indonesia, 50112*
[3]*Department of Pharmacology, Faculty of Medicine, Universitas Islam Sultan Agung, Semarang Indonesia, 50112*

ARTICLE INFO

Article history:
Received 14 June 2023
Revised 08 November 2023
Accepted 30 November 2023
Published online 01 January 2024

Copyright: © 2023 Hasanah *et al*. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

ABSTRACT

The study aimed to investigate the impact of UV-B irradiated oyster mushroom powder (referred to as Oyster-D) on blood sugar and TNF-α levels in type 2 diabetic rats induced with streptozotocin (STZ) over 28 days. Twenty-five male rats were divided into five groups: (A) negative control with STZ induction, (B), (C), (D) treated with Oyster-D at doses of 2000 IU, 4000 IU, 8000 IU, and (E) a normal group without STZ induction.
Following treatment, blood samples were collected to analyze fasting plasma glucose (FPG) levels using the GOD-PAP method, while TNF-α levels were assessed using the ELISA method. Statistical analysis included One-Way ANOVA and Post Hoc LSD for mean FPG level differences and Kruskal Wallis and Mann-Whitney tests for mean TNF-α levels.
The results revealed a significant reduction in mean FPG levels after treatment in the negative control compared to the Oyster-D treatment groups at doses of 2000 IU, 4000 IU, and 8000 IU ($p<0.05$). Additionally, a notable increase in mean TNF-α levels was observed in the negative control group relative to the Oyster-D treatment group at a dose of 8000 IU ($p<0.05$).
Overall, Oyster-D exhibited potential in reducing blood sugar levels and elevating TNF-α levels in male Wistar rats induced with STZ, suggesting its possible utility in managing hyperglycemia and TNF-α expression in diabetes.

Keywords: Plasma glucose, Tumor Necrosis Factor-*α*, *Pleurotus ostreatus*, oyster mushroom, vitamin D, diabetic rat

Introduction

Vitamin D deficiency is associated with various non-specific chronic diseases, including type 2 diabetes mellitus, cardiovascular diseases, cancer, and autoimmune disorders.[1] This health condition is a predisposition to insulin resistance as well as pancreatic *β*-cell damage, contributing to the growth of diabetes mellitus due to the importance of vitamin D pancreatic *β*-cells role, insulin sensitivity, and secretion. The vitamin D receptor directly activates insulin gene transcription, leading to increased insulin secretion and stimulating receptor expression, thereby improving insulin sensitivity. Indirectly, this vitamin also acts as a modulator of pancreatic *β*-cells to secrete an adequate amount of insulin.[2] Hyperglycemia in diabetic patients causes an increase in the production of ROS, which can cause oxidative tension.[3,4] The elevated production of ROS can lead to an increase in the term of Tumor Necrosis Factor-*α* (TNF-*α*), inducing oxidative stress and potentially causing life-threatening complications.[5] Hyperglycemia or high blood glucose levels result in inflammation, triggering a non-specific immune response that activates macrophages to release the proinflammatory cytokine TNF-*α*. High levels of TNF-*α* also contribute to insulin resistance, causing endothelial dysfunction and complications in type two diabetes mellitus patients.[6]

*Corresponding author. E mail: atinahussaana@unissula.ac.id
Tel: +6281326686222

Citation: Hasanah SN, Chodidjah C, Hussaana A. The Potential of UV-B Irradiated Oyster Mushroom (*Pleurotus ostreatus*) Powder on Plasma Glucose and TNF-*α* Levels in Type 2 Diabetic Rats. Trop J Nat Prod Res. 2023; 7(12):5415-5419. http://www.doi.org/10.26538/tjnpr/v7i12.7

Official Journal of Natural Product Research Group, Faculty of Pharmacy, University of Benin, Benin City, Nigeria

To address this issue, vitamin D supplementation has shown potential to improve *β*-pancreatic cell function and insulin secretion by modulating cytokine formation and regulating calbindin production, a calcium-binding protein in the cytosol of *β* cells. This phenomenon indirectly increases insulin secretion in patients with type 2 diabetes mellitus.[7]

Mushrooms are a dietary seed of vitamin D, containing the precursor ergosterol, which is transformed into ergocalciferol (vitamin D2) when exposed to UV light.[8] Various types of mushrooms, such as maitake, shiitake, oyster, and other species, have high levels of vitamin D precursor when exposed to sunlight.[9] According to Hussana,[5] the exposure of oyster mushrooms to UV-B light increased the vitamin D2 level to more than 11 micrograms/gram. UV-B light exposure enhances vitamin D production in mushrooms without altering their nutritional composition, making the process safe to carry out. Consequently, the European Union has approved the UV light irradiation method for mushrooms, as stated in regulation (EU) 2015/2283.[10] The previous method incorporates exposure to UV radiation, including UV-A, UV-B, as well as UV-C. Meanwhile, only UV-B exposure was used in this research for more effectiveness in converting ergosterol into ergocalciferol (vitamin D2).

This study builds on previous investigations by providing a comprehensive understanding of the connection between vitamin D deficiency as well as diabetes mellitus, including its complications. Furthermore, it offers a practical approach to increase the content of the vitamin in mushrooms through safe UV light exposure. The approval of this method by the European Union further supports its safety and effectiveness. This study examines the function of vitamin D in type 2 diabetes mellitus and its associated complications, indicating the potential benefits of the supplementation through the consumption of mushrooms exposed to UV-B radiation.

© 2023 the authors. This work is licensed under the Creative Commons Attribution 4.0 International License

 ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

Materials and Methods

This study protocol was authorized by the Medical Ethics Committee of the Faculty of Medicine at Universitas Islam Sultan Agung, under the number 527/VIII/2019/Bioethics Commission. A total of 25 male Wistar rats, aged 2-3 months weighing 200-300 grams were used and split into 5 classes. Except for the normal group, all groups were induced with STZ (streptozotocin) at a dosage of 45 mg/kgBW. Group A acted as the negative control, while Groups B, C, and D were administered Oyster-D at dosages of 2000 IU, 4000 IU, and 8000 IU for 28 days, respectively. Furthermore, Group E served as the normal group and all treatment groups received the standard diet simultaneously.

In this study, anesthesia was induced in all rats by administering a 50 mg/kg dose of ketamine hydrochloride (Ketalar) through intramuscular injection. Blood samples were obtained by inserting a microhematocrit tube into the ophthalmic vein in the periorbital corner of the eyeball of the rats. Subsequently, the tube was slowly rotated until up to 5 cc of blood was collected for GDP level evaluation through the GOD-PAP method and TNF-α levels using the ELISA approach.

Preparation of UV-B Irradiated Oyster Mushrooms Powder

The white oyster mushrooms used were harvested in 2020 from a cultivation site in Banyumanik (-7.063516, 110.413995), Central Java, Indonesia. The harvested samples (FKSA-OM1-IX20) were identified at the Department of Biology, Medicine Faculty, Sultan Agung Islamic University, Semarang, Indonesia, and induced with UV-B light for 90 minutes per day. According to Ruslan et al.,[11] the highest formation of ergocalciferol was found after exposure to UV-B light for 90 minutes. Subsequently, 2000 grams of white oyster mushroom sample that had been exposed to UV-B were cut into thin slices and parched in an oven at 40°C for 72 hours. These dried samples were ground in a blender for 5 minutes and filtered through a 120-mesh sieve. The fine white oyster mushroom powder (referred to as Oyster-D) obtained was dissolved in 1% Na-CMC and administered orally using a sonde.

The dose of Oyster-D was converted from adult body weight (70 kilograms) to rat body weight (200 grams). This was followed by the administration of 0.08 g/day, 0.16 g/day, and 0.32 g/day in groups B, C, and D once daily for 28 days, respectively.

HPLC analysis of vitamin D2 levels

The vitamin D2 content of UV-B irradiated oyster mushrooms was assessed using a standard procedure. In this process, the sample was saponified and the residue was dissolved in 10 ml ethanol, followed by filtration via a 0.45 nm filter. Hence, 20 µl of the filtered sampling was infiltrated into the HPLC system (Waters 2690; Waters Corp.). The components used in the HPLC system included a UV-486 detector, a C18 column (2.66250 mm, 5 mm, mobile phase of acetonitrile/methanol (75:25, v/v) at a flow rate of 1.0 mL/minute, UV detection achieved at 264 nm, a 10 µl injection, and a temperature of 30°C. Vitamin D2 levels were decided by comparing the retention times with those of established normals and quantified based on a calibration curve.

Measurement of Blood Glucose Levels and TNF-α

In this study, TNF-α levels were measured using the ELISA method, while blood glucose levels were measured through the GOD-PAP approach. A 1.0 mL sample of rat blood was taken and placed in an Eppendorf tube that had been treated with one drop of EDTA anticoagulant solution. The blood example was centrifuged at 3,000 rpm for 3 minutes, and 20.0 µL of serum was collected, followed by mixing with TCA 10 mL. Subsequently, the combination was enzymatically responded with 2.0 mL of GOD-PAP reagent and homogenized for approximately 10 seconds. The mix was incubated at 37 °C for 105 minutes as well and the absorbance was read at a wavelength of 505 nm using a spectrophotometer.[12] The blood glucose levels were calculated using the GOD-PAP technique, as expressed below:

$$C = \frac{A}{Ast} \times 100\, mg\, dL$$

where:

C = blood glucose concentration (mg/dL)
A = absorbance of the blood sample
Ast = absorbance of the standard glucose solution

Statistical Analysis

Data that met the assumptions of normality and homogeneity were examined using the One-Way ANOVA test, observed by the LSD Post Hoc test. For data that did not meet the normality assumptions, non-parametric analysis was carried out using the Kruskal-Wallis test, observed by the Mann-Whitney test. Moreover, a significance level (α) of 5% was used in all tests.

Results and Discussion

Vitamin D deficiency plays a significant role in the pathogenesis of kind 2 diabetes mellitus. Moreover, the presence of hyperglycemia in patients with type 2 diabetes mellitus is characterized by an increased display of free radicals and a decrease in antioxidant levels in the body. Several studies have indicated that vitamin D inhibits the formation of free radicals and plays a crucial part in the functioning of pancreatic β-cells, insulin sensitivity, as well as secretion through direct or indirect mechanisms.[13] Vitamin D supplementation is an approach to meeting the required nutrients in patients with diabetes mellitus. Vitamin D has the ability to enhance insulin sensitivity by directly interacting with receptors, thereby facilitating glucose transport across cells and activating peroxisome proliferator-activated receptor D. Additionally, it stimulates insulin secretion through direct interaction with vitamin D receptors on β cells and indirectly regulating calcium transport within β cells.[14]

Vitamin D is a lipid-based steroid hormone comprising two distinct forms, namely vitamin D2 (ergocalciferol) and vitamin D3 (cholecalciferol). These two forms are initially inactivity and require a dual hydroxylation process within the liver as well as kidneys to become biologically active.2 Cholecalciferol is synthesized in human skin upon exposure to sunlight, while ergocalciferol (vitamin D2) is obtained from various natural food sources. The provitamins for vitamin D include ergosterol and 7-dehydrocholesterol. The ergosterol serves as a precursor for vitamin D2 and, passes through photolysis when exposed to UV light to yield vitamin D2 along with other photo radiation products such as lumisterol and tachysterol. Meanwhile, 7-dehydrocholesterol, found in animal fat tissue, acts as a precursor for provitamin D. [15,16]

Different mushroom species have varying concentrations of ergosterol and vitamin D2. Specifically, wild mushrooms possess higher levels of vitamin D2 compared to cultivated mushrooms, which tend to have greater ergosterol content. This variation occurs because wild mushrooms are directly exposed to UV radiation, while the cultivated ones are grown indoors. The conversion of vitamin D2 through UV light includes three distinct wavelength sub-regions, namely UV-C (190-290 nm), UV-B (290-320 nm), and UV-A (320-400 nm). Jasinghe & Perera,[17] investigated the conversion of vitamin D2 in shiitake, oysters, abalone, and button mushrooms under UV-A, UV-B, and UV-C light. The highest yield was observed through UV-B light irradiation, presenting a viable approach to enhance the nutritional value of mushrooms and augment their functionality as a source of vitamin D2.[18] Karadeniz et al.,[19] also showed the efficacy of UV-B radiation in elevating the levels of vitamin D2 in mushrooms.

This study showed that the negative control had higher fasting plasma glucose (FPG) levels compared to the treatment group. The paired t-test results presented in Table 1 indicated a significant mean difference in FPG levels before and after treatment, as shown by the p-value (<0.05). Meanwhile, for both the negative and normal control groups, the p-values were >0.05, indicating no significant difference in mean FPG levels before and after treatment.

The variation in result was attributed to the negative control group, which was solely subjected to streptozotocin (STZ) induction without any form of treatment. STZ induction selectively exerted a toxic effect on pancreatic β-cells, leading to the development of diabetic

© 2023 the authors. This work is licensed under the Creative Commons Attribution 4.0 International License

 ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

conditions. The chemical structure of STZ contains a glucose moiety, enabling its entry into pancreatic β-cells through the Glucose transporter type 2 (GLUT-2) in the plasma membrane. Generally, STZ acts as a diabetogenic substance by functioning as a nitric oxide (NO) donor within pancreatic β-cells, resulting in aconitase inhibition, DNA alkylation, and DNA damage. Furthermore, NO has been shown to enhance guanylate cyclase activity, leading to the production of cyclic Guanosine Monophosphate (cGMP).[20]

In the treatment group, a significant decrease in blood glucose levels was observed, consistent with previous studies. Specifically, Oyster-D potentially influenced glucose metabolism by enhancing insulin sensitivity and secretion within the body. This effect occurred through the activation of vitamin D receptors present on pancreatic β-cells, as suggested by Kardina *et al.*[21] Additionally, vitamin D possessed the ability to mitigate systemic inflammation and enhance insulin resistance, as highlighted by Lee *et al*.[22]

Purbowati *et al*.,[9] stated that the administration of oyster mushroom extract at a dosage of 200 mg/kg body weight showed greater efficacy in lowering blood glucose levels. This result provided evidence of the impact of white oyster mushroom powder, rich in vitamin D, on reducing blood glucose. The decrease in blood glucose was attributed to an increase in insulin levels induced by the consumption of white oyster mushrooms.

Other studies showed that the use of oyster mushrooms significantly decreased blood glucose levels.[23,24] This effect was attributed to the enhancement of glucokinase levels, thereby accelerating glucose metabolism in the body. The upregulation of glucokinase levels stimulated the release of insulin by the body. To assess the potential differences between groups, the average variation for each group was calculated. The results showed that as the treatment dosage increased, the blood glucose levels significantly reduced. However, the negative and normal control groups showed no decrease but an increase in blood glucose levels. The One-Way ANOVA test yielded a p-value of 0.013, indicating a statistically significant mean difference in blood glucose levels among the five groups ($p<0.05$). To further examine the significance, an LSD post hoc analysis was performed, as presented in Table 2.

TNF-α levels in the Oyster-D treatment group increased significantly, as presented in Table 3. This outcome was unexpected, as it differed from the results of Jedinak et al.,[6] suggesting that oyster mushrooms inhibited TNF-α secretion. The disparity in results was likely due to differences in the treatment of white oyster mushrooms. In this study, white oyster mushrooms were exposed to UV-B radiation to enhance their vitamin D content, while previous investigations did not apply UV-B exposure.

Table 1: Average Fasting Plasma Glucose (FPG) Levels Before and After Oyster-D Treatment

Group	FPG Mean ± SD		p-value *Shapiro Wilk Test*		Dependent T-test
	Before	**After**	**Before**	**After**	
A (Negative control)	318.2 ± 85.7	320.4 ± 127.8	0.662	0.973	0.959
B (Oyster-D 2000 IU)	338.9 ± 51.8	279.0 ± 109.2	0.127	0.995	0.033
C (Oyster-D 4000 IU)	411.0 ± 113.7	299.4 ± 112.3	0.053	0.604	0.030
D (Oyster-D 8000 IU)	310.6 ± 50.9	189.4 ± 101.6	0.329	0.727	0.023
E (Normal)	85.2 ± 11.3	95.0 ± 13.7	0.739	0.936	0.231

Table 2: Post Hoc Test Results for FPG Levels

(I) Group	(II) Group	*P*
Negative control	Oyster-D 2000 IU	0.022*
	Oyster-D 4000 IU	0.020*
	Oyster-D 8000 IU	0.013*
	Normal	0.870
Oyster-D 2000 IU	Oyster-D 4000 IU	0.983
	Oyster-D 8000 IU	0.819
	Normal	0.015*
Oyster-D 4000 IU	Oyster-D 8000 IU	0.836
	Normal	0.014*

Note: *There is a significant difference between the groups ($p<0.05$)

The UV-B exposure in white oyster mushrooms also increases the content of a 15-kDa cytolytic protein, namely ostreolysin A. This protein binds to lipid membranes and forms pores,[25] disrupting cell membrane integrity and causing cells to lyse.[26] The disruption in membrane structure causes cell damage, triggering lipid peroxidation, and increasing oxidative stress,[27] which results in inflammation. Inflammation can stimulate a non-specific immune response, thereby activating macrophages to release the proinflammatory cytokine TNF-α. In the cytokine cascade of several inflammatory diseases, TNF-α plays an important role in regulating inflammatory production.[28] Consequently, the content of ostreolysin A in white oyster mushrooms can increase oxidative stress and enhance the formation of Tumor Necrosis Factor-α (TNF-α).

The highest average TNF-α levels were observed in the treatment group with a dose of 8000 IU, while the lowest was obtained in the normal control group. The Kruskal-Wallis test yielded a p-value of 0.084 ($p>0.05$), indicating no significant difference in the average TNF-α levels among the five groups. Subsequently, a Mann-Whitney test, as presented in Table 4, was conducted and the results showed significant differences between the 8000 IU and the 2000 IU treatment groups. Furthermore, there was between the control (negative) and the normal control groups, with a significance level of <0.05.

Table 3: Average TNF-α levels in all groups

Group	Mean ± SD	*p-value* *Shapiro Wilk*	*Levene test*	*Kruskal Wallis*
A (Negative control)	83.129 ± 21.416	0.455*	0.019	0.084
B (Oyster-D 2000 IU)	113.479 ± 16.914	0.047		
C (Oyster-D 4000 IU)	102.329 ± 30.085	0.764*		
D (Oyster-D 8000 IU)	70.835 ± 45.882	0.624*		
E (Normal)	47.600 ± 57.813	0.056*		

Note: *Normal distribution, **variance of data is homogeneous ($p<0.05$)

© 2023 the authors. This work is licensed under the Creative Commons Attribution 4.0 International License

ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

Table 4: Mann-Whitney Test for TNF-*α* Levels

(I) Group	(II) Group	*P*
Negative control	Oyster-D 2000 IU	0.917
	Oyster-D 4000 IU	0.175
	Oyster-D 8000 IU	0.028*
	Normal	0.602
Oyster-D 2000 IU	Oyster-D 4000 IU	0.175
	Oyster-D 8000 IU	0.028*
	Normal	0.602
Oyster-D 4000 IU	Oyster-D 8000 IU	0.602
	Normal	0.175
Oyster-D 8000 IU	Normal	0.047*

Note: *There is a significant difference between the groups ($p<0.05$)

Conclusion

In conclusion, this study showed that the use of UV-B irradiated oyster mushroom powder (Oyster-D) effectively lowered fasting blood sugar levels and elevated TNF-α levels. These results suggested that Oyster-D could be a promising therapeutic option for managing diabetes. However, caution should be exercised in cases of inflammation or other diseases with TNF-*α* elevations.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

Acknowledgments

The authors are grateful to the Ministry of Research and Technology of Indonesia for providing the Thesis Magister 2020 Research Grant.

References

1. Kayaniyil S, Vieth R, Retnakaran R, Knight JA, Qi Y, Gerstein HC, et al. Association of vitamin D with insulin resistance and beta-cell dysfunction in subjects at risk for type 2 diabetes. Diabetes Care. 2010;33(6):1379–81.
2. Sanda A, Bahrun U, Pakasi RD, Aman AM. Analysis of Vitamin D in Patients with Diabetes Mellitus Type 2. Indones J Clin Pathol Med Lab. 2019;25(2):150.
3. Saif-Elnasr M, Ibrahim IM, Alkady MM. Role of vitamin D on glycemic control and oxidative stress in type 2 diabetes mellitus. J Res Med Sci. 2017;22(1):1-5.
4. Dewi I, Chodidjah C, Atina H. Evaluation of *Clitoria ternatea* L. Flower Extract in Preventing Complications of Diabetes Mellitus. Trop J Nat Prod Res. 2023;7(10):4908–11.
5. Hussana A, et al. Reaction Order Analysis fot Changing Provitamin D to Vitamin D2 by Ultraviolet-B (UVB) Radiation in White Oyster Mushrooms (*Pleurotus ostreatus*). Semarang; 2018.
6. Jedinak A, Dudhgaonkar S, Wu Q-L, Simon J, Sliva D. Anti-inflammatory activity of edible oyster mushroom is mediated through the inhibition of NF-κB and AP-1 signaling. Nutr J. 2011;10(1):52.
7. Harinarayan CV. Vitamin D and diabetes mellitus. Hormones. 2014;13(2):163–81.
8. Sánchez C. Reactive oxygen species and antioxidant properties from mushrooms. Synth Syst Biotechnol. 2017;2(1):13–22.
9. Purbowati P, Johan A, RMD RK. Pengaruh jamur tiram putih (*Pleurotus ostreatus*) terhadap kadar glukosa darah, profil lipid dan kadar MDA pada tikus (*rattus norvegicus*) diabetes melitus. J Gizi Indones. 2016;4(2):131–7.
10. Malik MA, Jan Y, Al-Keridis LA, Haq A, Ahmad J, Adnan M, et al. Effect of Vitamin-D-Enriched Edible Mushrooms on Vitamin D Status, Bone Health and Expression of CYP2R1, CYP27B1 and VDR Gene in Wistar Rats. J Fungi. 2022;8(8):1–15.
11. Ruslan K, Reza RA, Damayanti S. Effect of Ultraviolet Radiation On The Formation Of Ergocalciferol (Vitamin D2) In *Pleurotus ostreatus*. Bionatura. 2011;13(3):255-261.
12. Anas Y, Rositasati R, Fitriani MR, Suharjono S. Pengembangan Model Hewan Percobaan Tikus Diabetes Mellitus Tipe 2 Karena Resistensi Insulin Yang Diinduksi Dengan Human Insulin Jangka Panjang. J Ilmu Farm dan Farm Klin. 2015;12:16–23.
13. Wardani IS, Aliza Raudatin Sahly, Indana Eva Ajmala, Dewi Suryani. Vitamin D and Type 2 Diabetes Mellitus: Role in Insulin Resistance, Glycemic Control and Long Term Complications. Unram Med J. 2022;11(2):942–5.
14. Bhat MH, Mohd M, Dar IH, Bhat JA. Role of vitamin D deficiency in type 2 diabetes: Association or coincidence? Clin Diabetol. 2021;10(2):188–94.
15. J. G, A. K, Szabó A. Increasing the vitamin D level of oyster mushrooms by UV light. Int J Hortic Sci. 2011;17.
16. Keflie TS, Nölle N, Lambert C, Nohr D, Biesalski HK. Impact of the natural resource of UVB on the content of vitamin D2 in oyster mushroom (*Pleurotus ostreatus*) under subtropical settings. Saudi J Biol Sci. 2019;26(7):1724–30.
17. Jasinghe VJ, Perera CO. Ultraviolet irradiation: The generator of Vitamin D2 in edible mushrooms. Food Chem. 2006;95(4):638–43.
18. Banlangsawan N, Sanoamuang N. Effect of UV-B irradiation on contents of ergosterol, vitamin D2, vitamin B1 and vitamin B2 in Thai edible mushrooms. Chiang Mai J Sci. 2016;43(1):45–53.
19. Karadeniz M, Ünal S, Bakır T, Sancı RS. Examination of Vitamin D2 Change of *Agaricus bisporus* and *Pleurotus ostreatus* Under The (UV) B Radiaton. Int J Res Sci Manag. 2019;6(1):13–7.
20. Eleazu CO, Eleazu KC, Chukwuma S, Essien UN. Review of the mechanism of cell death resulting from streptozotocin challenge in experimental animals, its practical use and potential risk to humans. J Diabetes Metab Disord. 2013;12(1):60.
21. Kardina RN, Nuriannisa F, Andini A, Anita A. Hubungan Asupan Bahan Makanan Sumber Vitamin D Dan Vitamin C Terhadap Penurunan Glukosa Darah Pada Responden Terindikasi Diabetes Mellitus Tipe II. J Islam Med. 2021;5(1):20–6.
22. Lee CJ, Iyer G, Liu Y, Kalyani RR, Bamba N, Ligon CB, et al. The effect of vitamin D supplementation on glucose metabolism in type 2 diabetes mellitus: A systematic review and meta-analysis of intervention studies. J Diabetes Complications. 2017;31(7):1115–26.
23. Jayasuriya WJABN, Wanigatunge CA, Fernando GH, Abeytunga DTU, Suresh TS. Hypoglycaemic Activity of Culinary *Pleurotus ostreatus* and *P. cystidiosus* Mushrooms in Healthy Volunteers and Type 2 Diabetic Patients on Diet Control and the Possible Mechanisms of Action. Phyther Res [Internet]. 2015;29(2):303–9.
24. Nweze CC, Ubhenin AE, Lay TU, Muhammad AU. Hypoglycemic, hepatoprotective and hypolipidemic effects of *Pleurotus ostreatus* in alloxan-induced hyperglycemic rats. Trop J Nat Prod Res. 2017;1(4):163–7.
25. Schlumberger S, Kristan KČ, Ota K, Frangež R, Molgó J, Sepčić K, et al. Permeability characteristics of cell-

© 2023 the authors. This work is licensed under the Creative Commons Attribution 4.0 International License

ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

membrane pores induced by ostreolysin A/pleurotolysin B, binary pore-forming proteins from the oyster mushroom. FEBS Lett. 2014;588(1):35–40.
26. Frangež R, Šuput D, Molgó J, Benoit E. Ostreolysin A/pleurotolysin B and equinatoxins: Structure, function and pathophysiological effects of these pore-forming proteins. Toxins. 2017;9(4):1–10.
27. Gaschler MM, Stockwell BR. Lipid peroxidation in cell death. Biochem Biophys Res Commun. 2017;482(3):419–25.
28. Yuniarti E. Perbedaan Kadar Tumor Necrosis Factor - Alfa Antara Diabetes Mellitus Tipe 2 Terkontrol Dengan Tidak Terkontrol. Bioscience. 2017;1:18.

© 2023 the authors. This work is licensed under the Creative Commons Attribution 4.0 International License