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ORIGINAL ARTICLE

The impact of white turmeric rhizome extract on the histopathological characteristics of the pancreas in male wistar rats with diabetes

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ABSTRACT

This study investigates the potential of white turmeric (*Curcuma zedoaria* Rosc.) rhizome extract as a cost-effective treatment for managing diabetes, focusing on its impact on pancreatic histopathology and blood glucose levels in diabetic Wistar rats. The research employed a randomized pre-test and post-test control group design, with rats induced with alloxan to simulate diabetes. The treatment groups received varying doses of white turmeric extract (250 mg/kg BW, 500 mg/kg BW, and 750 mg/kg BW) for 14 days. Histopathological analysis of the pancreas revealed that the white turmeric extract groups showed no signs of edema, inflammation, or necrosis, indicating a protective effect. Blood glucose level measurements demonstrated that the 500 mg/kg BW dose exhibited the most optimal results in lowering blood glucose levels. Statistical analysis using ANOVA and Kruskal-Wallis tests indicated significant differences between groups. These findings suggest that white turmeric extract, particularly at a dosage of 500 mg/kg BW, holds promise as a complementary treatment for managing diabetes by improving pancreatic health and reducing blood glucose levels. Further research is warranted to explore the underlying mechanisms and optimize its application.

Keywords: white turmeric, diabetes, pancreatic histopathology, blood glucose levels, wistar rats

Introduction

Diabetes poses a significant and escalating global health challenge. According to multiple authoritative sources, including the International Diabetes Federation (IDF), The Lancet, the World Health Organization (WHO), and Statista, approximately 537 million adults aged 20-79 were living with diabetes in 2021. This figure is projected to rise to 783 million by 2045. This alarming increase is especially pronounced in low- and middle-income countries, where over 75% of individuals with diabetes reside.[1–3] The economic impact of diabetes is substantial, with health expenditures related to the condition estimated at USD 966 billion in 2021, a figure expected to rise significantly in the coming years. These reports highlight the urgent need for enhanced diabetes management and treatment strategies, as a considerable portion of those affected do not have access to adequate care, resulting in severe health complications.[4]

As the costs of conventional diabetes medications continue to rise, there is an increasing interest in exploring herbal alternatives. Herbal medicines, derived from natural sources, present a promising and cost-

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effective solution for managing diabetes. This trend has spurred heightened research efforts aimed at identifying and validating natural ingredients with antidiabetic properties.[5,6] Several studies have explored this trend, examining a variety of traditional herbal treatments, particularly those utilized in India, which includes over 400 plants with some confirmed efficacy.[7] Notable natural products such as cinnamon and Nigella sativa have shown promise in complementing conventional treatments for type 2 diabetes.[8] Comprehensive reviews highlight herbs like Gymnema sylvestre and lychee seed extract for their properties in lowering blood glucose levels and reducing insulin resistance.[9] Research indicates a significant prevalence of herbal remedy use among patients with type 2 diabetes, particularly with herbs like bitter leaves, underscoring the importance of understanding patient preferences in diabetes management.[10]

As a developing agricultural nation, Indonesia is home to a rich diversity of flora that provides benefits beyond mere food and ornamentation. Among these plants are herbal medicinal varieties, which have been utilized by Indonesians for health maintenance and therapeutic purposes. These herbs are often prepared as single remedies or combined with others to enhance their effects.[11] The search for effective and affordable treatments has led to the investigation of herbal plants, including white turmeric (*Curcuma zedoaria* Rosc.). This plant is rich in curcumin, a compound recognized for its antioxidant, anti-inflammatory, and antidiabetic properties.[12–14] Curcumin is believed to enhance insulin sensitivity and inhibit glucose production in the liver, functioning similarly to metformin.[15] This study aims to assess the potential of white turmeric rhizome extract in improving pancreatic histopathology and lowering blood glucose levels in diabetic Wistar rats (*Rattus norvegicus*).

Method

Study design

The study utilized an in vivo experimental approach featuring a randomized pre-test and post-test control group design. This design was selected to effectively control research variables and systematically observe the treatment effects in a controlled environment. The research was conducted at the Universitas Prima Indonesia Laboratory, where the extraction of white turmeric rhizome occurred in the Pharmacology Laboratory, while testing on male Wistar strain rats took place in the Histology Laboratory. The research spanned from March to June 2024.

Sampling

The sample comprised male Wistar strain rats that adhered to specified inclusion and exclusion criteria: adult male rats aged 2-4 months, weighing between 150-220 grams, and in good health. Exclusion criteria included anatomical abnormalities and any rats that died during the adaptation period. The required number of test animals was calculated using the Federer formula. In total, there were 6 treatment groups (negative control, positive control, and 4 white turmeric extract treatment groups), with a minimum of 4 rats per group, resulting in a total of 24 male Wistar strain rats for the study.

Tool and material

The equipment utilized varied according to the research stage. Cages were employed for the habitat and quarantine of test animals. Additional equipment included oral syringes, flasks, volume pipettes, scalpels, surgical scissors, tweezers, wax boards, fixation devices, ointment pots, dishes, mortars, Erlenmeyer flasks, beakers, stirrers, micropipettes, analytical balances, rotary evaporators, electric gram scales, binocular microscopes, cameras, gloves, and documentation tools. The primary ingredient used was white turmeric; supporting ingredients included alloxan, ethanol, and aquabidest.

Preparation of white turmeric simplicia

The preparation of white turmeric simplicia began with cleaning the rhizomes under running water to remove impurities. The cleaned turmeric was then cut into smaller pieces and dried in a drying cabinet for several days until thoroughly dehydrated. Once dried, the turmeric was ground using a blender to produce a fine simplicia powder. The resulting powder was stored in a closed container to maintain its quality.

Preparation of white turmeric extract

The white turmeric extract was prepared using the maceration method. The simplicia powder was macerated in 96% ethanol for 48 hours (two 24-hour periods) at a ratio of 1:10 (turmeric rhizome simplicia to ethanol). After maceration, the mixture was filtered, and the solvent was evaporated using a rotary

evaporator until a near-thick extract was obtained. This extract was then further concentrated using a water bath until a viscous extract was achieved. Experimental animals were administered white turmeric extract orally via an intragastric tube once daily for 14 consecutive days. The animals were divided into three dosage groups: Group K1 received 250 mg/kg body weight (BW), Group K2 received 500 mg/kg BW, and Group K3 received 750 mg/kg BW.

Phytochemical analysis

Phytochemical screening was conducted to identify the active compounds present in the white turmeric extract.

Treatment of experimental animals

This study utilized male Wistar strain rats (Rattus norvegicus) as experimental subjects. The rats were weighed according to research criteria and acclimated in animal cages to adapt to their new environment. During the acclimation period, they were provided with food and water while their general condition was monitored. Healthy rats were then divided into three groups, each consisting of five rats.

Groups P1, P2, and P3 were induced with alloxan at a dose of 180 mg/kg BW for 14 days. Following induction, each treatment group received white turmeric extract according to the predetermined doses for an additional 14 days. On the final day, the testicular organs of the rats were collected for histological slide preparation.

Testicular histological slides were prepared using a standardized protocol that included fixation, dehydration, and clearing. Following these steps, the tissue was infiltrated and embedded. The resulting tissue blocks were sectioned, affixed to slides, stained with hematoxylin and eosin, and subsequently mounted for microscopic observation.

Observation of histopathological features of the pancreas

Histopathological observation of the rat pancreas was performed to evaluate tissue changes before and after treatment. Microscopic examination utilized a binocular microscope focusing on histopathological criteria such as edema, inflammation, and necrosis. This analysis aimed to identify any damage or pathological changes in pancreatic tissue resulting from the treatment.

Data analysis

Data processing and analysis were conducted using computer software. Microsoft Excel was used for data processing, while statistical analysis was performed with SPSS for Windows. Data analysis employed analysis of variance (ANOVA). Prior to conducting ANOVA, data were tested for normality and homogeneity. If the data met the requirements for ANOVA, a Bonferroni post hoc test was performed to analyze differences between treatment groups.

Results

Histopathological description of the pancreas of rats after treatment

This study investigates the histopathological characteristics of the pancreas in male Wistar rats with induced diabetes, following 28 days of treatment with white turmeric extract . The histopathological findings revealed significant differences among the various treatment groups. The normal control group (K1) exhibited no histopathological abnormalities. The pancreatic tissue appeared intact, showing no signs of edema, inflammation, or necrosis. This indicates a healthy pancreatic structure in the normal control group. In the negative control group (K2), which was induced with alloxan and administered distilled water, some rats (B2 and B3) displayed inflammation characterized by lymphocyte infiltration. Although there were no signs of edema or necrosis, this infiltration suggests pancreatic damage due to alloxan induction. The positive control group (K3), also induced with alloxan but treated with a positive drug, did not exhibit significant histopathological changes. There were no signs of edema, inflammation, or necrosis, indicating that the positive drug provided a protective effect against pancreatic damage caused by alloxan. The treatment groups receiving white turmeric extract at doses of 250 mg/kgBW (P1), 500 mg/kgBW (P2), and 750 mg/kgBW (P3) showed no damage to pancreatic tissue. All treatment groups maintained intact cellular structures without signs of edema, inflammation, or necrosis.

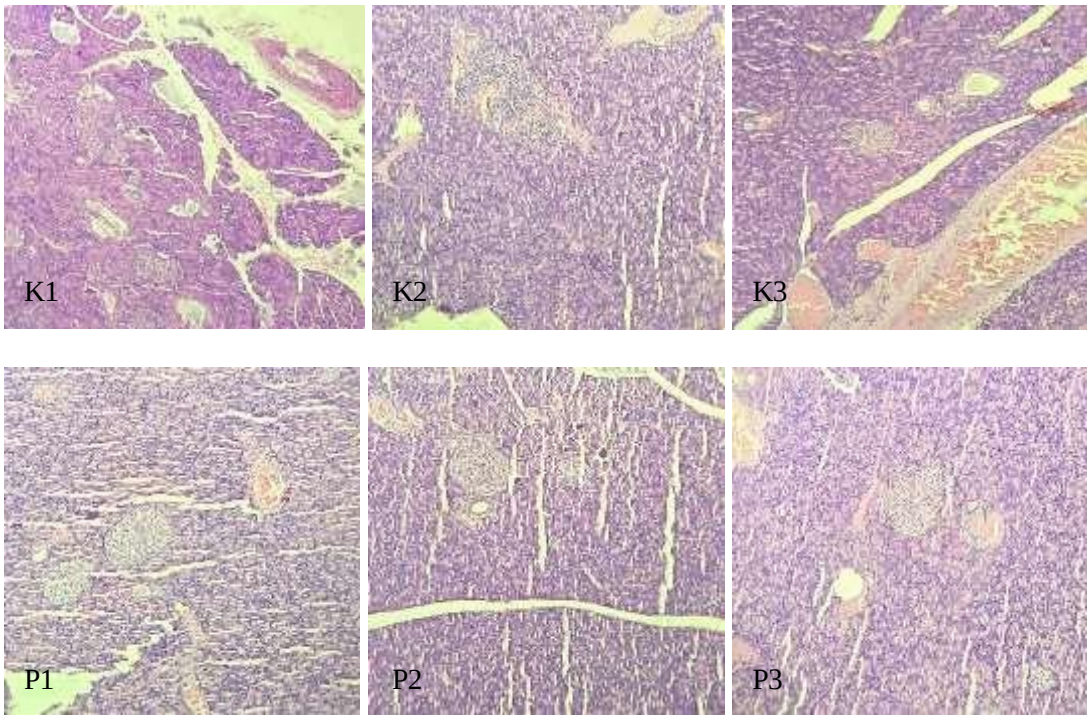

Figure 1. Histopathological features of the pancreas of male Wistar strain diabetic rats treated with white turmeric extract.

Administration of white turmeric extract for reducing blood sugar levels

Table 1 presents data on the average blood glucose levels of male Wistar diabetic rats before and after alloxan induction and treatment with white turmeric extract (Curcuma zedoaria Rosc.). In the normal group, which did not receive alloxan induction or treatment, the initial blood glucose level of 99.60 ± 7.23 mg/dL slightly decreased to 97.72 ± 7.96 mg/dL after observation, indicating stable blood glucose levels without the influence of alloxan or treatment. The negative control group, which received alloxan induction and only aquadest, exhibited a significant increase in blood glucose levels from 494.40 ± 99.73 mg/dL before induction to 337.64 ± 225.20 mg/dL after induction, reflecting the success of alloxan in inducing hyperglycemia. Furthermore, in the positive control group, which received alloxan induction along with antidiabetic drugs, the initial blood glucose level of 96 ± 7.07 mg/dL increased to 168.16 ± 146.25 mg/dL; although this remained lower than the negative control group, it indicated the effectiveness of the drug in controlling hyperglycemia.

Table 1. Mean blood glucose levels before and after induction with white turmeric extract

Treatment Group	Blood glucose levels (mg/dl)	
	Before induction	After induction
	X ± SD	X ± SD
Normal, no induction or treatment	99.60 ± 7.23	97.72 ± 7.96
Negative, induced with alloxan and distilled water	494.40 ± 99.73	337.64 ± 225.20
Positive, induced with alloxan and treated with medication	96 ± 7.07	168.16 ± 146.25
Treatment 1, induced with alloxan and 250mg/KgBW white turmeric extract	136.40 ± 15.43	135.24 ± 35.86
Treatment 2, induced with alloxan and 500mg/KgBW white turmeric extract	119.40 ± 20.02	128.48 ± 33.13
Treatment 3, induced with alloxan and 750mg/KgBW white turmeric extract	113.80 ± 9.23	137.40 ± 38.23

In the treatment group receiving white turmeric extract at a dose of 250 mg/kg body weight (BW), the initial blood glucose level was 136.40 ± 15.43 mg/dL, which slightly decreased to 135.24 ± 35.86 mg/dL after extract administration, indicating a non-significant treatment effect. Meanwhile, in the group receiving a dose of 500 mg/kg BW, the initial blood glucose level of 119.40 ± 20.02 mg/dL decreased to 128.48 ± 33.13 mg/dL, showing better results than other doses. Conversely, the group with a dose of 750 mg/kg BW

exhibited an initial blood glucose level of 113.80 ± 9.23 mg/dL, which slightly increased to 137.40 ± 38.23 mg/dL; despite this increase, the results were still better than those of the negative control group. This data indicates that administration of white turmeric extract has potential for lowering blood glucose levels, with the 500 mg/kg BW dose demonstrating the most optimal results.

Normality and homogeneity testing results

The Shapiro-Wilk normality test indicated that the data collected at 21 days post-induction (H+21) for both the Negative group ($p = 0.011$) and Treatment 3 group ($p = 0.044$) were not normally distributed. In contrast, all other groups satisfied the normality assumption ($p > 0.05$). Consequently, further analysis for H+21 will be conducted using the Kruskal-Wallis test. Data from other time points that met the normality assumption will be analyzed using ANOVA.The homogeneity of variance test revealed that the data for Pre-Induction ($p = 0.010$), H+14 ($p < 0.001$), H+21 ($p = 0.004$), and H+28 ($p = 0.007$) did not meet the assumption of homogeneity of variance ($p < 0.05$). Therefore, subsequent analyses for these data groups will utilize the Games-Howell post hoc test. Conversely, the data for Post-Induction ($p = 0.246$) and H+7 ($p = 0.200$) met the assumption of homogeneity of variance ($p > 0.05$). Thus, the Bonferroni test will be employed for post hoc analysis of these groups.

ANOVA analysis

The ANOVA results indicate that the Pre-Induction ($p = 0.000$), H+14 ($p = 0.000$), and H+28 ($p = 0.000$) data exhibit statistically significant differences between groups ($p < 0.05$). Therefore, post hoc tests will be conducted for these time points, contingent upon the results of the homogeneity of variance testing. In contrast, the Post-Induction ($p = 0.445$) and H+7 ($p = 0.273$) data do not show statistically significant differences between groups ($p > 0.05$).

Table 2. ANOVA results

		ANOVA				
		Sum of Squares	df	Mean Square	F	Sig.
Before induction	Between Groups	611269.600	5	122253.920	68.087	.000
	Within Groups	43093.600	24	1795.567		
	Total	654363.200	29			
After induction	Between Groups	400.000	5	80.000	.988	.445
	Within Groups	1942.800	24	80.950		
	Total	2342.800	29			
H+7	Between Groups	133.467	5	26.693	1.362	.273
	Within Groups	470.400	24	19.600		
	Total	603.867	29			
H+14	Between Groups	618547.867	5	123709.573	16.813	.000
	Within Groups	176593.600	24	7358.067		
	Total	795141.467	29			
H+28	Between Groups	622014.167	5	124402.833	46.993	.000
	Within Groups	63534.800	24	2647.283		
	Total	685548.967	29			

For the H+21 data, which violated the assumption of homogeneity of variance, ANOVA could not be performed. Consequently, the non-parametric Kruskal-Wallis test was employed to assess differences between groups at this time point.

Table 3. *Kruskal-Wallis* results

Test Statistics	H+21
Kruskal-Wallis	23.952
df	5
Asymp. Sig.	.000

The Kruskal-Wallis test results demonstrate a statistically significant difference between groups for the H+21 data (Asymp. Sig. = 0.000). With a significance value less than 0.05, this result indicates a substantial difference in the distribution of values across groups at this time point.

Post Hoc test

Before induction, Group 1 (Normal) exhibited significant differences compared to Group K2 (Negative) and Group K4 (Treatment 1), but there were no significant differences when compared to Group K3 (Positive), Group K5 (Treatment 2), and Group K6 (Treatment 3). In contrast, Group K2 (Negative) demonstrated significant differences relative to all other groups. Group K3 (Positive) only showed a significant difference compared to Group K4 (Treatment 1). No significant differences were observed between Group K4 (Treatment 1) and Group K5 (Treatment 2), nor between Group K5 (Treatment 2) and Group K6 (Treatment 3).

At 14 days post-induction, Group K1 (Normal) showed significant differences compared to Groups K2 (Negative), K4 (Treatment 1), K5 (Treatment 2), and K6 (Treatment 3), but not compared to Group K3 (Positive). Group K2 (Negative) continued to show significant differences compared to all other groups. Group K3 (Positive) had a significant difference only when compared to Group K4 (Treatment 1). Additionally, Group K4 (Treatment 1) exhibited significant differences compared to Groups K1 (Normal) and K2 (Negative). Groups K5 (Treatment 2) and K6 (Treatment 3) also showed significant differences when compared to Groups K1 (Normal) and K2 (Negative).

Table 4. Post Hoc test results (Games-Howell)

Dependent variable	(I) Treatment group	(J) Treatment group	Mean difference (I-J)	Std. Error	Sig.
Before induction	Group 1	Group 2	-394.800*	44.719	.005
		Group 3	3.600	4.523	.960
		Group 4	-36.800*	7.624	.024
		Group 5	-19.800	9.519	.415
		Group 6	-14.200	5.244	.180
	Group 2	Group 1	394.800*	44.719	.005
		Group 3	398.400*	44.714	.005
		Group 4	358.000*	45.133	.007
		Group 5	375.000*	45.492	.005
		Group 6	380.600*	44.793	.006
	Group 3	Group 1	-3.600	4.523	.960
		Group 2	-398.400*	44.714	.005
		Group 4	-40.400*	7.593	.016
		Group 5	-23.400	9.495	.286
		Group 6	-17.800	5.200	.073
	Group 4	Group 1	36.800*	7.624	.024
		Group 2	-358.000*	45.133	.007
		Group 3	40.400*	7.593	.016
		Group 5	17.000	11.306	.673
		Group 6	22.600	8.044	.173
	Group 5	Group 1	19.800	9.519	.415
		Group 2	-375.000*	45.492	.005
		Group 3	23.400	9.495	.286
		Group 4	-17.000	11.306	.673
		Group 6	5.600	9.859	.990
	Group 6	Group 1	14.200	5.244	.180
		Group 2	-380.600*	44.793	.006
		Group 3	17.800	5.200	.073
		Group 4	-22.600	8.044	.173
		Group 5	-5.600	9.859	.990
H+14	Group 1	Group 2	-378.600*	59.327	.018
		Group 3	-325.400	69.518	.052
		Group 4	-69.600*	13.835	.033
		Group 5	-64.200*	13.372	.039
		Group 6	-83.400*	12.201	.009

Dependent variable	(I) Treatment group	(J) Treatment group	Mean difference (I-J)	Std. Error	Sig.
	Group 2	Group 1	378.600*	59.327	.018
		Group 3	53.200	91.277	.989
		Group 4	309.000*	60.747	.032
		Group 5	314.400*	60.643	.031
		Group 6	295.200*	60.396	.039
	Group 3	Group 1	325.400	69.518	.052
		Group 2	-53.200	91.277	.989
		Group 4	255.800	70.734	.108
		Group 5	261.200	70.644	.101
		Group 6	242.000	70.432	.128
	Group 4	Group 1	69.600*	13.835	.033
		Group 2	-309.000*	60.747	.032
		Group 3	-255.800	70.734	.108
		Group 5	5.400	18.689	1.000
		Group 6	-13.800	17.870	.965
	Group 5	Group 1	64.200*	13.372	.039
		Group 2	-314.400*	60.643	.031
		Group 3	-261.200	70.644	.101
		Group 4	-5.400	18.689	1.000
		Group 6	-19.200	17.514	.870
	Group 6	Group 1	83.400*	12.201	.009
		Group 2	-295.200*	60.396	.039
		Group 3	-242.000	70.432	.128
		Group 4	13.800	17.870	.965
		Group 5	19.200	17.514	.870
H+21	Group 1	Group 2	-415.600*	65.151	.018
		Group 3	-24.200*	5.348	.019
		Group 4	-62.200*	9.066	.006
		Group 5	-50.600*	11.203	.044
		Group 6	-61.200*	12.861	.039
	Group 2	Group 1	415.600*	65.151	.018
		Group 3	391.400*	65.210	.022
		Group 4	353.400*	65.620	.030
		Group 5	365.000*	65.949	.026
		Group 6	354.400*	66.251	.029
	Group 3	Group 1	24.200*	5.348	.019
		Group 2	-391.400*	65.210	.022
		Group 4	-38.000*	9.481	.050
		Group 5	-26.400	11.540	.336
		Group 6	-37.000	13.156	.203
	Group 4	Group 1	62.200*	9.066	.006
		Group 2	-353.400*	65.620	.030
		Group 3	38.000*	9.481	.050
		Group 5	11.600	13.667	.949
		Group 6	1.000	15.056	1.000
	Group 5	Group 1	50.600*	11.203	.044
		Group 2	-365.000*	65.949	.026
		Group 3	26.400	11.540	.336
		Group 4	-11.600	13.667	.949
		Group 6	-10.600	16.431	.983

Dependent variable	(I) Treatment group	(J) Treatment group	Mean difference (I-J)	Std. Error	Sig.
	Group 6	Group 1	61.200*	12.861	.039
		Group 2	-354.400*	66.251	.029
		Group 3	37.000	13.156	.203
		Group 4	-1.000	15.056	1.000
		Group 5	10.600	16.431	.983
H+28	Group 1	Group 2	-409.800*	53.938	.009
		Group 3	-5.800	4.585	.795
		Group 4	-49.800*	8.736	.014
		Group 5	-34.000	10.739	.147
		Group 6	-43.200*	9.829	.045
	Group 2	Group 1	409.800*	53.938	.009
		Group 3	404.000*	53.939	.010
		Group 4	360.000*	54.449	.014
		Group 5	375.800*	54.806	.011
		Group 6	366.600*	54.635	.013
	Group 3	Group 1	5.800	4.585	.795
		Group 2	-404.000*	53.939	.010
		Group 4	-44.000*	8.742	.023
		Group 5	-28.200	10.743	.248
		Group 6	-37.400	9.834	.077
	Group 4	Group 1	49.800*	8.736	.014
		Group 2	-360.000*	54.449	.014
		Group 3	44.000*	8.742	.023
		Group 5	15.800	13.066	.821
		Group 6	6.600	12.329	.993
	Group 5	Group 1	34.000	10.739	.147
		Group 2	-375.800*	54.806	.011
		Group 3	28.200	10.743	.248
		Group 4	-15.800	13.066	.821
		Group 6	-9.200	13.820	.981
	Group 6	Group 1	43.200*	9.829	.045
		Group 2	-366.600*	54.635	.013
		Group 3	37.400	9.834	.077
		Group 4	-6.600	12.329	.993
		Group 5	9.200	13.820	.981

Note: Group 1 (Normal control, received no induction or treatment); Group 2 (Negative control, induced with alloxan and aquadest); Group 3 (Positive control, induced with alloxan and treated with medication); Group 4 (Treatment 1, induced with alloxan and 250mg/KgBW white turmeric extract); Group 5 (Treatment 2 induced with alloxan and 500mg/KgBW white turmeric extract); Group 6 (Treatment 3, induced with alloxan and 750mg/KgBW white turmeric extract)

At 21 days post-induction, both Groups K1 (Normal) and K2 (Negative) displayed significant differences compared to all other groups. Furthermore, Group K3 (Positive) showed significant differences relative to Groups K1 (Normal), K2 (Negative), and K4 (Treatment 1). Similarly, Group K4 (Treatment 1) had significant differences compared to Groups K1, K2, and K3. Groups K5 (Treatment 2) and K6 (Treatment 3) also showed significant differences when compared to Groups K1 and K2.

At 28 days post-induction, Group K1 (Normal) exhibited significant differences compared to Groups K2 (Negative), K4 (Treatment 1), and K6 (Treatment 3), but not when compared to Groups K3 (Positive) and K5 (Treatment 2). Group K2 continued to show significant differences relative to all other groups. Additionally, Group K3 demonstrated significant differences when compared to Groups K2 and K4. Finally, Group K4 showed significant differences relative to Groups K1, K2, and K3, while Group K5 had significant differences only in comparison with Group K2. Lastly, Group K6 displayed significant differences when

compared to Groups K1 and K2. Bonferroni post hoc analysis showed significant differences between treatment groups after induction and at H+7 (Table 5).

Table 5. Bonferroni post hoc analysis

Dependent variable	(I) Treatment group	(J) Treatment group	Mean difference (I-J)	Std. Error	Sig.
After induction	Group 1	Group 2	2.800	5.690	1.000
		Group 3	-.400	5.690	1.000
		Group 4	-4.600	5.690	1.000
		Group 5	-5.800	5.690	1.000
		Group 6	-7.600	5.690	1.000
	Group 2	Group 1	-2.800	5.690	1.000
		Group 3	-3.200	5.690	1.000
		Group 4	-7.400	5.690	1.000
		Group 5	-8.600	5.690	1.000
		Group 6	-10.400	5.690	1.000
	Group 3	Group 1	.400	5.690	1.000
		Group 2	3.200	5.690	1.000
		Group 4	-4.200	5.690	1.000
		Group 5	-5.400	5.690	1.000
		Group 6	-7.200	5.690	1.000
	Group 4	Group 1	4.600	5.690	1.000
		Group 2	7.400	5.690	1.000
		Group 3	4.200	5.690	1.000
		Group 5	-1.200	5.690	1.000
		Group 6	-3.000	5.690	1.000
	Group 5	Group 1	5.800	5.690	1.000
		Group 2	8.600	5.690	1.000
		Group 3	5.400	5.690	1.000
		Group 4	1.200	5.690	1.000
		Group 6	-1.800	5.690	1.000
	Group 6	Group 1	7.600	5.690	1.000
		Group 2	10.400	5.690	1.000
		Group 3	7.200	5.690	1.000
		Group 4	3.000	5.690	1.000
		Group 5	1.800	5.690	1.000
H+7	Group 1	Group 2	1.600	2.800	1.000
		Group 3	3.600	2.800	1.000
		Group 4	-1.400	2.800	1.000
		Group 5	.800	2.800	1.000
		Group 6	-3.000	2.800	1.000
	Group 2	Group 1	-1.600	2.800	1.000
		Group 3	2.000	2.800	1.000
		Group 4	-3.000	2.800	1.000
		Group 5	-.800	2.800	1.000
		Group 6	-4.600	2.800	1.000
	Group 3	Group 1	-3.600	2.800	1.000
		Group 2	-2.000	2.800	1.000
		Group 4	-5.000	2.800	1.000
		Group 5	-2.800	2.800	1.000
		Group 6	-6.600	2.800	.404
	Group 4	Group 1	1.400	2.800	1.000
		Group 2	3.000	2.800	1.000
		Group 3	5.000	2.800	1.000
		Group 5	2.200	2.800	1.000
		Group 6	-1.600	2.800	1.000
	Group 5	Group 1	-.800	2.800	1.000
		Group 2	.800	2.800	1.000
		Group 3	2.800	2.800	1.000

Dependent variable	(I) Treatment group	(J) Treatment group	Mean difference (I-J)	Std. Error	Sig.
		Group 4	-2.200	2.800	1.000
		Group 6	-3.800	2.800	1.000
	Group 6	Group 1	3.000	2.800	1.000
		Group 2	4.600	2.800	1.000
		Group 3	6.600	2.800	.404
		Group 4	1.600	2.800	1.000
		Group 5	3.800	2.800	1.000

Note: Group 1 (Normal control, received no induction or treatment); Group 2 (Negative control, induced with alloxan and aquadest); Group 3 (Positive control, induced with alloxan and treated with medication); Group 4 (Treatment 1, induced with alloxan and 250mg/KgBW white turmeric extract); Group 5 (Treatment 2 induced with alloxan and 500mg/KgBW white turmeric extract); Group 6 (Treatment 3, induced with alloxan and 750mg/KgBW white turmeric extract)

Statistical analysis using a post hoc Bonferroni test revealed no significant differences between any of the treatment groups for the parameters measured. This suggests that the treatments administered did not have a significant effect on the observed parameters. Specifically, pairwise comparisons between all groups (K1 [Normal], K2 [Negative], K3 [Positive], K4 [Treatment 1], K5 [Treatment 2], and K6 [Treatment 3]) yielded no significant differences ($p > 0.05$ for all comparisons).

Discussion

Based on pancreatic histopathology observations, significant differences existed between the treated and control groups. In group 1 (K1 - Normal), the pancreatic tissue exhibited no signs of damage, such as edema, inflammation, or necrosis, indicating that the tissue remained healthy and unaffected. Conversely, group 2 (K2 - Negative), which underwent alloxan induction and received aquadest, showed inflammation characterized by lymphocyte inflammatory cell infiltration in some rats (B2 and B3), although edema or necrosis were absent. This suggests that alloxan has a damaging effect on the pancreas, but without severe cellular damage such as necrosis. In group 3 (K3 - Positive), which received antidiabetic drug treatment, no significant histopathological changes were observed, and the pancreas remained intact, suggesting a protective effect of the drug against pancreatic tissue damage induced by alloxan.

In the treatment group with white turmeric extract (Curcuma zedoaria Rosc.) at doses of 250 mg/kgBW (P1), 500 mg/kgBW (P2), and 750 mg/kgBW (P3), pancreatic tissue also remained intact without signs of edema, inflammation, or necrosis. This indicates that white turmeric extract can protect the pancreas from damage caused by alloxan induction. All treatment groups demonstrated favorable histopathology results, with no visible tissue damage, suggesting that white turmeric has a protective effect on the pancreas.

Based on histopathology data and blood glucose level analysis, white turmeric extract has the potential to prevent pancreatic tissue damage and reduce blood glucose levels in alloxan-induced diabetic rats. These results align with the theory that white turmeric contains curcumin, which exhibits antioxidant activity and antidiabetic effects. Curcumin may accelerate the reaction of insulin with glucose and reduce glucose production in the liver, thus helping to lower blood sugar levels. Previous research supports these findings, indicating that a dose of 500 mg/kgBB of white turmeric extract is the most effective in reducing blood sugar levels in rats.[16]

The results of the ANOVA test and post hoc test, which revealed significant differences between groups before and after induction, further support the conclusion that white turmeric extract has a significant effect in reducing blood glucose levels and protecting the pancreas from damage1. The 500 mg/kgBW dose (P2 group) showed the most optimal results in reducing blood glucose levels, consistent with previous studies on the effectiveness of this dose. Thus, white turmeric extract can be used as an alternative therapy to prevent pancreatic damage and control blood sugar levels in diabetics, especially at a dose of 500 mg/kgBW, which yields the best results.

Conclusion

This study suggests that white turmeric extract may serve as a protective agent for the pancreas and effectively regulate blood glucose levels in rats with induced diabetes. Specifically, administering white turmeric extract at dosages of 250 mg/kgBW, 500 mg/kgBW, and 750 mg/kgBW protected pancreatic tissue from alloxan-induced damage, with no signs of edema, inflammation, or necrosis observed. Additionally, white turmeric extract demonstrated a capacity to lower blood glucose levels in diabetic rats. A dosage of

500 mg/kgBW yielded the most favorable results in reducing blood glucose, which aligns with earlier research that has demonstrated the efficacy of this dosage in managing hyperglycemia. Overall, the findings of this study indicate that white turmeric extract holds promise as an alternative therapeutic strategy for preventing pancreatic damage and managing blood sugar levels in individuals with diabetes. A dosage of 500 mg/kgBW was the most effective in safeguarding the pancreas and regulating blood glucose. Further research is warranted to validate the efficacy and safety of white turmeric extract as a diabetes treatment in humans.

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