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Effect of Organic Zinc (*Zinc glycinate*) and Probiotic (*Saccharomyces cerevisiae*) Supplementation on Serum Biochemical Profile, Oxidative Stress Indices and Carcass characteristics in Broiler Chickens

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ABSTRACT

The experiment was conducted during May–June, 2018 at the Poultry Shed of the Department of Animal Nutrition, College of Veterinary Science and Animal Husbandry, Anjora, Durg, Chhattisgarh, India to evaluate the effect of dietary supplementation of organic zinc (zinc glycinate) and probiotic *Saccharomyces cerevisiae* on serum biochemical constituents, oxidative stress indices and carcass characteristics in broiler chickens. 180 day old chicks were randomly allocated into 2×3 factorial scheme following 90 chicks in each group and each group was again subdivided into three subgroups having 3 replicates of 10 birds in each subgroup. Six type of diets were formulated: diet T_1, T_2 and T_3 contained inorganic source of zinc ($ZnSO_4$) with 0, 0.5, 1% of probiotic (*S. cerevisiae*) respectively and diet T_4, T_5 and T_6 contained organic source of zinc (Zn-glycinate) with 0, 0.5, 1% of probiotic (*S. cerevisiae*) respectively. Dietary supplementation of organic zinc (zinc glycinate) with probiotic Saccharomyces cerevisiae improved serum high density lipoprotein cholesterol, reduced glucose concentration, and enhanced antioxidant status in broiler chickens. Lipid peroxidation was lowered, while reduced glutathione levels increased, indicating strengthened antioxidant defence. Other biochemical parameters remained unaffected. It was concluded that dietary supplementation of organic zinc with *S. cerevisiae* improved overall haematological status, thereby mitigating oxidative stress in broiler chickens.

KEYWORDS: Zinc glycinate, serum biochemistry, oxidative stress, carcass characteristics

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1. INTRODUCTION

Poultry production is one of the fastest growing sectors of animal agriculture, contributing to food security, rural employment, and income generation. Broiler chicken is critically important for ensuring global food security acting as primary source of protein. They are highly efficient and have a high feed conversion rate. India ranks among the top five global producers of broiler meat and eggs, with per capita consumption steadily increasing (Anonymous, 2013; Hu et al., 2024). Tropical climates, however, impose challenges such as heat stress, oxidative imbalance, and nutritional deficiencies, which impair growth, immunity, and product quality. Nutritional interventions that enhance resilience to oxidative stress are therefore critical for sustainable poultry production (Agarwal and Prabhakaran, 2005). Trace minerals, particularly zinc, are indispensable cofactors for more than 300 enzymes involved in protein, lipid, and carbohydrate metabolism. Zinc plays a central role in antioxidant defense, immune regulation, and epithelial integrity. Conventional supplementation with inorganic salts such as zinc oxide or zinc sulfate often shows poor bioavailability and interferes with absorption of other minerals, leading to excessive excretion and environmental concerns (Powell, 2000; Zhu et al., 2022). Organic forms of zinc, such as zinc glycinate, are chemically stable, less prone to antagonistic interactions, and demonstrate superior absorption. Recent studies confirmed that organic zinc improves intestinal morphology, antioxidant enzyme activity, and lipid metabolism in broilers under heat stress (Hu et al., 2024; Lonkar et al., 2024; Sridhar, 2016). Supplementation with zinc monoglycinate and proteinate also enhanced metallothionein gene expression and bone parameters in commercial broilers (Lonkar et al., 2024). Probiotics are increasingly recognized as effective alternatives to antibiotic growth promoters, which have been banned in many regions due to antimicrobial resistance concerns. Probiotics are defined as live microorganisms that, when administered in adequate amounts, confer health benefits on the host (Anonymous, 2005). Among them, yeast (*Saccharomyces cerevisiae*) is widely used in poultry nutrition. Yeast supplementation improves gut microbial balance, nutrient absorption, and immune modulation. Its cell wall components, including betaglucans and mannan oligosaccharides, act as immunostimulants and antioxidants. Studies demonstrated that *S. cerevisiae* supplementation improved growth performance, feed efficiency, and blood chemistry in broilers fed reducednutrient diets (Rafique, 2020). Yeast fermentation products enhanced gut microflora and immunity, while activated and inactivated yeast preparations provided protection against enteric pathogens such as *Clostridium perfringens* (AlBaadania et al., 2025; Soren, 2024). Yeast probiotics also reduced oxidative damage and improved antioxidant biomarkers under heat stress (Sumanu et al., 2023; Sumanu et al., 2024; Nayak, 2024). Despite these advances, limited information is available on the combined effect of organic zinc and probiotic yeast supplementation on serum biochemical profile and oxidative stress indices in broiler chickens. Most previous studies examined these factors independently, but their synergistic potential remains underexplored. Considering the complementary roles of zinc in enzymatic antioxidant defense and yeast in modulating gut health and immune responses, their combined supplementation may offer a promising nutritional strategy to mitigate oxidative stress and optimize production efficiency in tropical poultry systems. Therefore, the present study was undertaken to evaluate the effect of dietary supplementation of organic zinc (zinc glycinate) and probiotic (*Saccharomyces cerevisiae*) on serum biochemical constituents and oxidative stress markers in broiler chickens. The findings were expected to provide insights into sustainable nutritional approaches that enhanced metabolic resilience, improved antioxidant status, and supported productivity in broiler production.

2. MATERIALS AND METHODS

The experiment was conducted during May–June, 2018 at the Poultry Shed of the Department of Animal Nutrition, College of Veterinary Science and Animal Husbandry, Anjora, Durg, Chhattisgarh (21.18°N, 81.28°E).

2.1. *Birds and housing*

Day old Ross AP strain broiler chicks (n=180) from the same hatch were procured from M/s Indian Broiler Group, Baldeobagh, Rajnandgaon. The chicks were reared under deep litter system. Total duration of experiment was 35 days. The experimental period was divided into 3 phase pre starter (0–14 d), starter (14–21 d) and finisher (21–35 d) on the basis of stipulated growth rate and nutrients requirements. Throughout the experiment, all birds of test groups received similar feeding and other management practices including vaccination, lighting and watering. Birds were immunized against Marek's disease at hatchery, Newcastle disease at 7 and 21 days, and infectious bursal disease at 14 days. The experiment was conducted in accordance with the guidelines of the Institutional Animal Ethics Committee (Anonymous, 2013).

2.2. *Experimental diets*

Six diets (1–6) were formulated for each growth phase pre starter, starter and finisher phase as per ICAR (2013) specification. Diet 1, 2 and 3 contained basal diet with inorganic source of zinc ($ZnSO_4$) @ 60 ppm (basal 27.6 ppm+32.4 ppm inorganic zinc) and 0%, 0.5% and 1% level of probiotic (Saccharomyces cerevisiae) respectively. Similarly diet 4, 5 and 6 contained basal diet with organic source of zinc {Zn Glycinate (Zn-gly)} @ 60ppm (basal

27.6 ppm+32.4 ppm organic zinc) and 0%, 0.5% and 1% level of probiotic (Saccharomyces cerevisiae) respectively. The ingredient compositions of experimental diets for pre starter, starter and finisher phase are presented in Table 2, 3 and 4 respectively.

2.3. Experimental design

The experiment was planned as per 2x3 factorial design, were birds were divided in to 2 broad groups i.e. (GP-I) and (GP-II). Each broad group further divided into three sub groups i.e. treatment subgroups T_1, T_2, T_3 (GP-I) and T_4, T_5, T_6 (GP-II) respectively. Each subgroup had 3 replicates of 10 chicks in each i.e. 30 chicks per treatments subgroups and the birds of group I (T_1, T_2 and T_3) were fed with diet containing inorganic zinc ($ZnSO_4$) @ 60 ppm (basal 27.6 ppm+32.4 ppm inorganic zinc) with probiotic (Saccharomyces cerevisiae) added at levels of 0, 0.5 and 1% respectively and birds of groups II (T_4, T_5 and T_6) were fed with diet containing organic zinc {(zinc glycenate) (Zn-Gly)} @ 60 ppm (basal 27.6 ppm+32.4 ppm organic zinc) with probiotic (Saccharomyces cerevisiae) added at levels of 0, 0.5 and 1% respectively (Table 1).

Table 1: Details of experimental design

Particulars	Group-I Inorganic source of Zn ($ZnSO_4$)			Group-II Organic source of Zn (Zn glycinate)		
	S. cerevisiae (0%)	*S. cerevisiae* (0.5%)	*S. cerevisiae* (1%)	*S. cerevisiae* (0%)	*S. cerevisiae* (0.5%)	*S. cerevisiae* (1%)
Treatments	T_1	T_2	T_3	T_4	T_5	T_6
Total no. of chicks/groups	30	30	30	30	30	30
No of replicate/sub group	3	3	3	3	3	3
No. of chicks/Replicate	10	10	10	10	10	10

Table 2: Ingredient composition of broiler pre starter feed (% as fed basis)

Ingredient (%)	T_1	T_2	T_3	T_4	T_5	T_6
Maize	55.72	55.72	55.72	55.72	55.72	55.72
Soy DOC	37.95	37.95	37.95	37.95	37.95	37.95
Soy.Oil	2.86	2.86	2.86	2.86	2.86	2.86
DCP	1.28	1.28	1.28	1.28	1.28	1.28
LSP	1.08	1.08	1.08	1.08	1.08	1.08
Lysine	0.42	0.42	0.42	0.42	0.42	0.42
Methionine	0.14	0.14	0.14	0.14	0.14	0.14
Choline-60%	0.08	0.08	0.08	0.08	0.08	0.08
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Premix	0.42	0.42	0.42	0.42	0.42	0.42
Soda-bi-carb	0.09	0.09	0.09	0.09	0.09	0.09
Zinc	$ZnSO_4$ @ 60 ppm	$ZnSO_4$ @ 60 ppm	$ZnSO_4$ @ 60 ppm	Zn-glycinate @ 60 ppm	Zn-glycinate @ 60 ppm	Zn-glycinate @ 60 ppm
S. cerevisiae	0%	0.5%	1%	0%	0.5%	1%
ME (kcal kg^{-1})	3000	3000	3000	3000	3000	3000
Protein (%)	22	22	22	22	22	22
Calcium (%)	0.94	0.94	0.94	0.94	0.94	0.94
Available P (%)	0.48	0.48	0.48	0.48	0.48	0.48
Lysine (%)	1.25	1.25	1.25	1.25	1.25	1.25
Methionine (%)	0.58	0.58	0.58	0.58	0.58	0.58
ME:CP	136.36	136.36	136.36	136.36	136.36	136.36
Ca:P	1.95	1.95	1.95	1.95	1.95	1.95

Table 3: Ingredient composition of broiler starter feed (% as fed basis)

Ingredient (%)	T_1	T_2	T_3	T_4	T_5	T_6
Maize	52.72	52.72	52.72	52.72	52.72	52.72
Soy DOC	37.92	37.92	37.92	37.92	37.92	37.92
Soy.Oil	5.24	5.24	5.24	5.24	5.24	5.24
DCP	2.17	2.17	2.17	2.17	2.17	2.17
LSP	0.78	0.78	0.78	0.78	0.78	0.78
Lysine	0.01	0.01	0.01	0.01	0.01	0.01
Methionine	0.23	0.23	0.23	0.23	0.23	0.23
Choline-60%	0.10	0.10	0.10	0.10	0.10	0.10
Salt	0.39	0.39	0.39	0.39	0.39	0.39
Premix	0.42	0.42	0.42	0.42	0.42	0.42
Soda-bi-carb	52.72	52.72	52.72	52.72	52.72	52.72
Zinc	$ZnSO_4$ @ 60 ppm	$ZnSO_4$ @ 60 ppm	$ZnSO_4$ @ 60 ppm	Zn-glycinate @ 60 ppm	Zn-glycinate @ 60 ppm	Zn-glycinate @ 60 ppm
S. cerevisiae	0%	0.5%	1%	0%	0.5%	1%
ME (kcal kg^{-1})	3100	3100	3100	3100	3100	3100
Protein (%)	21.50	21.50	21.50	21.50	21.50	21.50
Calcium (%)	0.94	0.94	0.94	0.94	0.94	0.94
Available P (%)	0.48	0.48	0.48	0.48	0.48	0.48
Lysine (%)	1.14	1.14	1.14	1.14	1.14	1.14
Methionine (%)	0.53	0.53	0.53	0.53	0.53	0.53
ME:CP	144.18	144.18	144.18	144.18	144.18	144.18
Ca:P	1.95	1.95	1.95	1.95	1.95	1.95

2.4. Blood collection and biochemical analysis

At day 35, blood samples were collected aseptically from the wing vein of two randomly selected birds replicate^{-1} in nonheparinized tubes. Serum was separated following standard procedures and analyzed for glucose, total protein, albumin, total cholesterol, HDL cholesterol, ALT, and AST using a semiautomated analyzer with commercial diagnostic kits (Anonymous, 2012). Serum biochemical assays were performed using validated commercial kits, consistent with recent poultry nutrition trials (AlBaadania et al., 2025).

2.5. Antioxidant status

For oxidative stress indices, blood samples from six birds group-1 (two replicate-1) were collected in tubes containing acid citrate dextrose. Erythrocytes were separated by centrifugation (3000 rpm, 15 min, 4°C), washed thrice with phosphate buffer saline, and processed to prepare haemolysates. Lipid peroxidation was measured as malondialdehyde (MDA) concentration (Placer et al., 1966), while reduced glutathione (GSH) was estimated according to Prins and Loos (1969). These classical assays remained standard in recent oxidative stress studies in poultry (Anonymous, 2025).

2.6. Statistical analysis

Data were analyzed using oneway ANOVA (Anonymous, 1994). Differences among means were tested using Duncan's multiple range test (Duncan, 1955), with significance considered at $p<0.05$. Statistical analyses were performed using SPSS v.22.

3. RESULTS AND DISCUSSION

3.1. Serum biochemical profile

The effect of supplementation of organic and inorganic zinc with or without probiotic (*S. cerevisiae*) on serum biochemical parameters has been presented in table 5.

There were significant ($p<0.05$) increase in the serum albumin due to overall effect of 1% *S. cerevisiae* and the values were 1.66 g dl^{-1} where as no significant difference was noticed in serum protein and globulin due to supplementation of zinc and S. cerevisiae in combination or alone. Were interaction effect was not significant.

Table 4: Ingredient composition of broiler finisher feed (% as fed basis)

Ingredient (%)	T_1	T_1	T_1	T_1	T_1	T_1
Maize	60.66	60.66	60.66	60.66	60.66	60.66
Soy DOC	31.14	31.14	31.14	31.14	31.14	31.14
Soy.Oil	4.00	4.00	4.00	4.00	4.00	4.00
DCP	2.25	2.25	2.25	2.25	2.25	2.25
LSP	0.78	0.78	0.78	0.78	0.78	0.78
Lysine	0.04	0.04	0.04	0.04	0.04	0.04
Methionine	0.18	0.18	0.18	0.18	0.18	0.18
Choline-60%	0.10	0.10	0.10	0.10	0.10	0.10
Salt	0.03	0.03	0.03	0.03	0.03	0.03
Premix	0.38	0.38	0.38	0.38	0.38	0.38
Soda-bi-carb	0.42	0.42	0.42	0.42	0.42	0.42
Zinc	$ZnSO_4$ @ 60 ppm	$ZnSO_4$ @ 60 ppm	$ZnSO_4$ @ 60 ppm	Zn-glycinate @ 60 ppm	Zn-glycinate @ 60 ppm	Zn-glycinate @ 60 ppm
S. cerevisiae	0%	0.5%	1%	0%	0.5%	1%
ME (kcal kg^{-1})	3100	3100	3100	3100	3100	3100
Protein (%)	19.50	19.50	19.50	19.50	19.50	19.50
Calcium (%)	0.94	0.94	0.94	0.94	0.94	0.94
Available P (%)	0.48	0.48	0.48	0.48	0.48	0.48
Lysine (%)	1.00	1.00	1.00	1.00	1.00	1.00
Methionine (%)	0.45	0.45	0.45	0.45	0.45	0.45
ME:CP	158.97	158.97	158.97	158.97	158.97	158.97
Ca:P	1.95	1.95	1.95	1.95	1.95	1.95

Reduction in total cholesterol was significantly (p<0.01) high due to overall effect of 1% *S. cerevisiae* (145.91 mg dl^{-1}) and 0.5% *S. cerevisiae* (161.50 mg dl^{-1}) while lowest value was observed in group (T_6) fed with combination of organic zinc and 1% *S. cerevisiae* (142.82 mg dl^{-1}). Supplementation of inorganic zinc with 1% *S. cerevisiae* also significantly (p<0.01) reduced the total cholesterol (149.00 mg dl^{-1}) level in serum. Were interaction effect was not significant.

There was significant (p<0.01) increment in the good cholesterol value i.e. HDL cholesterol due to supplementation of organic zinc with 1% *S. cerevisiae* (75.27 mg dl^{-1}) followed by supplementation of inorganic zinc with 1% *S. cerevisiae* (68.90 mg dl^{-1}). Whereas overall effect of 1% *S. cerevisiae* also significant (p<0.01). Results revealed highest value due to organic zinc and 1% *S. cerevisiae* interaction (T_6).

Result revealed that there was no significant difference in the activity of ALT and AST due to overall effect of organic and inorganic zinc supplementation. Significantly (p<0.05) increased activity of ALT and AST was noticed due overall effect of 1% *S. cerevisiae*. The interaction of zinc and *S. cerevisiae* were nonsignificant for both ALT and AST activity.

There were significant (p<0.01) difference in glucose concentration due to overall effect of 1% *S. cerevisiae*, but combined effect of inorganic zinc and 1% *S. cerevisiae* also significantly (p<0.01) decreased glucose concentration whereas significant (p<0.05) difference was noticed due to supplementation of organic zinc with 1% *S. cerevisiae* while interaction effect was nonsignificant for glucose.

These findings were consistent with earlier reports that organic zinc complexes improved lipid metabolism and elevated plasma high density lipoprotein cholesterol in chickens (Zhu et al., 2022). Probiotic supplementation has also been shown to reduce serum cholesterol and increase high density lipoprotein levels in a dose dependent manner (Kara et al., 2008). Recent studies further confirmed that zinc glycinate improved serum biochemical indices and intestinal morphology in broilers (Hu et al., 2024), while combined supplementation of zinc, selenium, and vitamin E enhanced serum lipid profile and antioxidant status (Hossain et al., 2025). The hypoglycemic effect observed in the present study agrees with Uyanik et al. (2001) and Yalcinkaya et al. (2012), who reported reduced glucose

Table 5: Effect of organic and inorganic zinc with or without probiotic (*S. cerevisiae*) supplementation on certain blood biochemical constituents at day 35

Particulars		Protein ($g\ dl^{-1}$)	Albumin ($g\ dl^{-1}$)	Globulin ($g\ dl^{-1}$)	Cholesterol ($mg\ dl^{-1}$)	HDL cholesterol ($mg\ dl^{-1}$)	ALT ($IU\ dl^{-1}$)	AST ($IU\ dl^{-1}$)	Glucose ($mg\ dl^{-1}$)
Inorganic zinc ($ZnSO_4$)	T_1 (0% *S. cerevisiae*)	5.50± 1.25	1.31± 0.09	4.18± 1.35	184.16± 2.58^{a}	51.08± 1.20^{c}	11.97± 3.64	233.90± 2.11	260.53± 5.01^{a}
	T_2 (0.5% *S. cerevisiae*)	6.66± 0.16	1.45± o.17	5.21± 0.31	168.23± 4.80^{b}	55.91± 0.77^{b}	9.03± 3.27	229.35± 9.30	231.80± 6.63^{b}
	T_3 (1% *S. cerevisiae*)	6.71± 0.36	1.65± 0.16	5.06± 0.49	149.00± 3.92^{c}	68.90± 1.39^{a}	5.95± 2.02	219.83± 4.63	206.00± 5.56^{c}
	Sig.	NS	NS	NS	**	**	NS	NS	**
Organic zinc (Zn glycinate)	T_4 (0% *S. cerevisiae*)	6.13± 0.02	1.34± 0.07	4.79± 0.07	180.61± 5.33	54.03± 0.99^{c}	11.81± 3.65	232.57± 5.91	252.43± 10.22^{a}
	T_5 (0.5% *S. cerevisiae*)	6.73± 0.37	1.52± 0.16	5.20± 0.52	154.78± 8.03	66.68± 2.19^{b}	8.31± 4.16	226.49± 5.89	240.21± 10.58^{ab}
	T_6 (1% *S. cerevisiae*)	6.80± 0.39	1.67± 0.11	5.12± 0.47	142.82± 16.51	75.27± 1.54^{a}	4.68± 1.58	220.73± 8.02	208.91± 12.69^{b}
	Sig.	NS	NS	NS	NS	**	NS	NS	*
Zn effect	Inorganic Zn	6.29± 0.42	1.47± 0.08	4.82± 0.45	167.13± 5.44	58.63± 2.72	8.99± 1.76	227.69± 3.69	232.78± 8.38
	Organic Zn	6.55± 1.18	1.51± 0.07	5.04± 0.21	159.40± 7.84	65.33± 3.19	8.26± 1.95	226.59± 3.75	233.85± 8.57
	Sig.	NS	NS	NS	NS	NS	NS	NS	NS
0% *S. cerevisiae* effect	Inorganic Zn	5.50± 1.25	1.31± 0.09	4.18± 1.35	184.16± 2.58	51.08± 1.20	11.97± 3.64	233.90± 2.11	260.53± 5.01
	Organic Zn	6.13± 0.02	1.34± 0.07	4.79± 0.07	180.61± 5.33	54.03± 0.99	11.81± 3.65	232.57± 5.91	252.43± 10.22
	Sig.	NS	NS	NS	NS	NS	NS	NS	NS
0.5% *S. cerevisiae* effect	Inorganic Zn	6.66± 0.16	1.45± 0.17	5.21± 0.31	168.23± 4.80	55.91± 0.77^{b}	9.03± 3.27	229.35± 9.30	231.80± 6.63
	Organic Zn	6.73± 0.37	1.52± 0.16	5.20± 0.52	154.78± 8.03	66.68± 2.19^{a}	8.31± 4.16	226.49± 5.89	240.21± 10.58
	Sig.	NS	NS	NS	NS	*	NS	NS	NS
1% *S. cerevisiae* effect	Inorganic Zn	6.71± 0.36	1.65± 0.15	5.06± 0.49	149.00± 3.92	68.90± 1.31^{b}	5.95± 2.02	219.83± 4.63	206.00± 5.56
	Organic Zn	6.80± 0.39	1.67± 0.11	5.12± 0.47	142.82± 16.51	75.27± 1.54^{a}	4.68± 1.58	220.73± 8.02	208.91± 12.69
	Sig.	NS	NS	NS	NS	*	NS	NS	NS
Overall effect of *S. cerevisiae*	0% *S. cerevisiae*	5.81± 0.58	1.32± 0.5^{b}	4.48± 0.61	182.39± 2.76^{a}	52.55± 0.96^{c}	11.89± 2.31^{a}	233.23± 2.82^{b}	256.48± 5.40^{a}
	0.5% *S. cerevisiae*	6.69± 0.18	1.48± 0.11^{ab}	5.21± 0.27	161.50± 5.15^{b}	61.29± 2.62^{b}	8.67± 2.37^{ab}	227.92± 4.96^{ab}	236.01± 5.89^{b}
	1% *S. cerevisiae*	6.75± 0.24	1.66± 0.08^{a}	5.09± 0.30	145.91± 7.71^{b}	72.08± 1.70^{a}	5.31± 1.18^{b}	220.28± 4.14^{b}	207.45± 6.23^{c}
	Sig.	NS	*	NS	**	**	*	*	**
Zn and *S. cerevisiae* interaction	Sig	NS	NS	NS	NS	NS	NS	NS	NS

concentration in broilers supplemented with Zn and prebiotics. Mechanistically, Zn played a role in insulin synthesis, storage, and secretion (Salgueiro et al., 2001), while *S. cerevisiae* might suppress glucagon activity, thereby maintaining glucose homeostasis (Rafique et al., 2018).

3.2. Oxidative stress

3.2.1. Lipid peroxidation (LPO)

The lipid peroxidation in erythrocytes was determined in terms of malondialdehyde production and expressed as mM MDA/mg Hb. The lowest concentration of MDA (2.10 mM/mg Hb) observed due to combined effect of organic zinc and 1% *S. cerevisiae* (T_6) followed by value was noticed significantly (p<0.05) lowered (2.19 mM MDA/mg Hb) due to overall effect of 0.5 and 1% *S. cerevisiae*. Similarly overall effect of organic zinc supplementation also reduced the MDA content (2.19 mM MDA/mg Hb). Interaction effect between Zn and S. cerevisiae also showed highly significance difference (p<0.01) (Table 6).

3.2.2. Reduced glutathione (GSH)

Reduced glutathione activity was significantly (p<0.01) increased due to overall effect of 1% *S. cerevisiae* (0.22 M/g Hb). However non-significance difference showed due to overall effect of organic and inorganic zinc. There was also significance (p<0.01) observed due to supplementation of 1% *S. cerevisiae* with combination of either organic or inorganic zinc. The interaction was obtained highly significance (p<0.01) difference.

The reduction in MDA levels with Zn and probiotic supplementation indicated enhanced antioxidant defense. Zinc stabilized lipid membranes and prevented peroxidation by free radicals (Powell, 2000). It also acted as a cofactor for CuZn superoxide dismutase (SOD), which suppressed free radical formation and protected against glutathione depletion (Marklund et al., 1982). The higher GSH levels observed in T_3 might be explained by the role of glutathione peroxidase (GPx) in conjunction with SOD, utilizing GSH to neutralize oxidative stress (Agarwal and Prabhakaran, 2005).

The reduction in malondialdehyde levels with zinc and probiotic supplementation indicated enhanced antioxidant defense, consistent with previous studies (Sumanu et al., 2023). The higher glutathione levels observed in the yeastsupplemented group supported the role of glutathione peroxidase in conjunction with superoxide dismutase, utilizing glutathione to neutralize oxidative stress (Sumanu et al., 2024). Similar findings were reported by Sridhar et al. (2016), who observed reduced lipid peroxidation and improved antioxidant enzyme activity in broilers supplemented with organic zinc.

Table 6: Effect of organic and inorganic zinc with or without probiotic (*S. cerevisiae*) supplementation on oxidative stress indices at day 35

Particulars		Lipid peroxidation (MDATnM/ mg Hb)	GSH (M/g Hb)
Inorganic zinc ($ZnSO_4$)	T_1 (0% *S. cerevisiae*)	2.45±0.01^a	0.15±0.01^b
	T_2 (0.5% *S. cerevisiae*)	2.27±0.01^b	0.15±0.00^b
	T_3 (1% *S. cerevisiae*)	2.27±0.01^b	0.22±0.01^a
	Sig.	**	*
Organic zinc (Zn glycinate)	T_4 (0% *S. cerevisiae*)	2.35±0.02^a	0.17±0.01^b
	T_5 (0.5% *S. cerevisiae*)	2.11±0.02^b	0.18±0.00^b
	T_6 (1% *S. cerevisiae*)	2.10±0.08^b	0.23±0.01^a
	Sig.	*	*
Zn effect	Inorganic Zn	2.33±0.03^a	0.17±0.01
	Organic Zn	2.19±0.04^b	0.19±0.01
	Sig.	*	NS
0% *S. cerevisiae* effect	Inorganic Zn	2.45±0.01^a	0.15±0.01
	Organic Zn	2.35±0.02^b	0.17±0.01
	Sig.	*	NS
0.5% *S. cerevisiae* effect	Inorganic Zn	2.27±0.01^a	0.15±0.00
	Organic Zn	2.11±0.02^b	0.18±0.00
	Sig.	*	NS
1% *S. cerevisiae* effect	Inorganic Zn	2.27±0.01	0.22±0.01
	Organic Zn	2.10±0.08	0.23±0.01
	Sig.	NS	NS
Overall effect of *S. cerevisiae*	0% *S. cerevisiae*	2.40±0.02^a	0.16±0.00^b
	0.5% *S. cerevisiae*	2.19±0.03^b	0.17±0.00^b
	1% *S. cerevisiae*	2.19±0.05^b	0.22±0.00^a
	Sig.	**	**
Zn & S. cerevisiae interaction	Sig.	**	**

Superscripts are read column wise for comparison of means. Means in the same column with different superscript a, b, c are significantly different (p*<0.05) or (p**<0.01), NS: Non significant

3.3. Effect on carcass characteristics

The dressing % of carcass and weight of its various cuts have been presented in table 7. No Significance difference was observed on percentage weight of carcass cuts (Dressed weight, liver, intestine, breast, thigh, wing, back & neck and giblet) except gizzard weight. Gizzard weight showed Significance ($p<0.05$) difference due to overall effect of organic zinc supplementation. However Significance ($p<0.05$) difference also observed on percentage weight of back & neck due to overall effect of 1% *S. cerevisiae*. There were highly Significance ($p<0.01$) difference was observed on percentage weight of gizzard and least Significance ($p<0.05$) difference was observed on percentage weight of back and neck in T_6 group due to combine effect of organic zinc and 1% *S. cerevisiae*. Combined effect of inorganic zinc with 1% *S. cerevisiae* (T_3) also showed Significance ($p<0.05$) difference on percentage weight of wing and giblet. Significantly higher percentage weight was also observed on liver, gizzard, wing and giblet due supplementation of 0.5% *S. cerevisiae* with organic zinc. Interaction effect of zinc and *S. cerevisiae* was observed on percentage weight of liver, gizzard and giblet.

The finding of present experiment was in accordance with other worker Kwiecien et al. (2016) who recorded a significantly higher weight of gizzards in chickens receiving Zn-Glycinate. In addition, Rossi et al. (2007) reported that carcass yield was not influenced by supplementation of increasing levels of dietary organic zinc. But relative organ weights (liver, spleen, pancreas) were significantly higher in organic Zn group than those in other treatment groups ($p<0.001$). Also Jahanian et al. (2008) fed chicks on increasing levels of organic Zn, (40-80-120 mg kg^{-1}) and

Table 7: Effect of organic and inorganic zinc with or without probiotic (*S. cerevisiae*) supplementation on carcass characteristics

Particulars		Weight of immune organ (g)		
		Bursa of fabricius	Spleen	Thymus
Inorganic zinc ($ZnSO_4$)	T_1 (0% *S. cerevisiae*)	0.83±0.16	1.33±0.16	2.50±0.00
	T_2 (0.5% *S. cerevisiae*)	0.83±0.16	1.50±0.00	3.50±0.28
	T_3 (1% *S. cerevisiae*)	1.33±0.60	1.53±0.26	5.16±1.33
	Sig.	NS	NS	NS
Organic zinc (Zn Glycinate)	T_4 (0% *S. cerevisiae*)	0.83±0.16	1.33±0.33	$3.00±0.00^{b}$
	T_5 (0.5% *S. cerevisiae*)	1.00±0.00	1.50±0.28	$4.66±0.33^{ab}$
	T_6 (1% *S. cerevisiae*)	1.16±0.16	2.00±0.00	$5.16±0.92^{a}$
	Sig.	NS	NS	*
Zn effect	Inorganic Zn	1.00±0.20	1.45±0.09	3.72±0.55
	Organic Zn	1.00±0.08	1.61±0.16	4.27±0.43
	Sig.	NS	NS	NS
0% *S. cerevisiae* effect	Inorganic Zn	0.83±0.16	1.33±0.16	2.50±0.00
	Organic Zn	0.83±0.16	1.33±0.33	3.00±0.00
	Sig.	NS	NS	NS
0.5% *S. cerevisiae* effect	Inorganic Zn	0.83±0.16	1.50±0.00	3.50±0.28
	Organic Zn	1.00±0.00	1.50±0.28	4.66±0.33
	Sig.	NS	NS	NS
1% *S. cerevisiae* effect	Inorganic Zn	1.33±0.60	1.53±0.26	5.16±1.33
	Organic Zn	1.16±0.16	2.00±0.00	5.16±0.92
	Sig.	NS	NS	NS
Overall effect of *S. cerevisiae*	0% *S. cerevisiae*	0.83±0.10	1.33±0.16	$2.75±0.11^{b}$
	0.5% *S. cerevisiae*	0.91±0.08	1.50±0.12	$4.08±0.32^{ab}$
	1% *S. cerevisiae*	1.25±0.28	1.76±0.15	$5.16±0.72^{a}$
	Sig.	NS	NS	**
Zn and *S. cerevisiae* interaction	Sig.	NS	NS	NS

demonstrated that dietary zinc source affect liver weight. The heaviest livers were found in chicks fed on 80 mg kg^{-1} Zn-Met supplemented diets. In addition, Yalcinkaya et al. (2012) found that carcass yield was not influenced by addition of Mannanoligosaccharide (MOS) and organic zinc (OZn) (p>0.05). But combined supplementation of MOS and OZn reduced liver weight and the increase found in OZn group. The finding was also in accordance with other worker Onifade et al. (1999); Kannan et al. (2005) and Paryad and Mahmoudi (2008) who reported higher dressed weight, breast weight, back and neck weight due to yeast supplementation. Farhoomand and Dadvend (2007) obtained a higher (p<0.05) liver weight from broilers fed a diet containing 0.5% SC compared to the broilers fed SC with low level (<0.5%) from hatch today 42. Similarly Macelline et al. (2017) observed that the NC+1.4S (Negative control with 1.4% SC for short time) diet fed broilers showed a higher (p<0.01) liver weight compared to the other treatment groups while showing the dosage- feeding interval effect of SC. Paryad and Mahmoudi (2008) suggested that the inclusion of different levels S. cerevisiae in broiler chicks rations affect significantly all carcass characteristics parameters measured (dressing percentage, breast, leg, liver, heart, gizzard, and abdominal fat percentage).

4. CONCLUSION

Dietary supplementation of organic zinc (zinc glycinate) with probiotic Saccharomyces cerevisiae improved serum high density lipoprotein cholesterol, reduced glucose concentration, and enhanced antioxidant status in broiler chickens. Lipid peroxidation was lowered, while reduced glutathione levels increased, indicating strengthened antioxidant defense. Other biochemical parameters remained unaffected. Combined supplementation of organic zinc and probiotic yeast effectively mitigated oxidative stress and supported metabolic resilience in broilers under tropical conditions.

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