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HEALTH STATUS, PERFORMANCE AND CARCASS CARACTERISTICS OF BROILER CHICKS SUPPLEMENTED WITH YEASTS BIOPRODUCTS

Daniela Mihaela GRIGORE[1], Georgeta CIURESCU[2], Nicoleta RADU[1], Narcisa BABEANU[1]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania
[2]National Research-Development Institute for Biology and Animal Nutrition, Calea Bucuresti no. 1, Baloteşti, 077015, Ilfov, Romania

Corresponding author email: dm.grigore@yahoo.com

Abstract

The current study aimed to evaluate the effects of spent brewer's yeast (SBY, Saccharomyces spp.), with or without the addition of Rhodotorula spp. biomass (Rh), as dietary supplements on broiler health status and growth performance. A total of 320 one-day-old, Ross 308 broiler chicks were randomly divided into eight experimental groups with five replicate pens of eight birds/replicate. A 4 by 2 factorial design study was used, with SBY different inclusion levels (0, 0.6, 1 and 1.3 g/kg feed) and Rh supplementation (0 or 0.3 g/kg of feed) as treatments. There were no significant effects between the main factors SBY x Rh on the hematologic profiles (P>0.05) of the broilers. Blood serum biochemical profile of SBY and Rh groups and the interactions between treatments were evaluated and no significant effects were found (P>0.05), except for the glucose (p = 0.023), which was influenced by the SBY addition. Moreover, the SBY addition (0.6 and 1g/kg) resulted in similar productive performances for weight gain and average daily gain, with the control group (Corn-SBM diet). In conclusion, yeast bioactive, nutritive, and pharmacologic compounds could serve as a suitable low-cost option to conventional supplements used in meat poultry nutrition.

***Key words**: brewer's spent yeast, broiler, health, performance, Rhodotorula spp. biomass.*

INTRODUCTION

In the poultry meat production industry, great attention is directed to protein feed resources (Ruiz et al., 2020), considering their essential role in muscular tissue synthesis (Estevez et al., 2020). It is well known that broiler chicks have high protein requirements (Gous et al., 2018), therefore identifying favourable growth promoting additives to support feed efficiency, while boosting the productive performance and muscular synthesis it is required (Alagawany et al., 2021). Natural feeding additives play considerable parts in the broiler rearing industry, serving as growth promoters, with positive health modulative mechanisms (Swaggerty et al., 2022). In order to support early-stage development and avoiding potential pathogenic threats, a common practice was represented by antibiotics administration, as growth promoters in poultry diets (Cuong et al., 2021). However, following the recent banning of using antibiotics as growth promoters in poultry nutrition, several strategies and potential alternatives, such as the use of bio-applications were tested (Al-Baadani et al., 2018; Peralta et al., 2018; dos Santos et al., 2018; Ciurescu et al., 2021).

Utilizing agro-industry by-products as low-cost and available resources (Jaeger et al., 2020) in poultry nutrition is currently of interest for both nutritionists and producers. The nutritive and growth promotion potential of agro-industrial waste, such as spent brewer's yeast (SBY) was recently studied (Ribeirto-Oliveira et al., 2021). With previous studies on the use of SBY showing encouraging results on improving broilers growth performance (Kumar et al., 2019 and Mulatu et al., 2019) and health status (Chuang et al., 2020). SBY has high levels of protein (39-55%, containing all essential amino acids), vitamin B complex, minerals (5-7% of dry biomass), lipids (4.4% of dry biomass), enzymes, β-glucans, mannan-oligosaccharides and selenium (Amoriello & Ciccoritti, 2020; Patel et al., 2018). The SBY is a by-product derived from beer production, through the use of fermentative yeasts (*Saccharomyces cerevisiae*), throughout the production of one hl of beer, it results up to 2-4 kg of SBY (Cimini and Moresi, 2020). Moreover, the SBY waste management and discarding procedures are imply significant time and financial efforts.

Colorant food additives used in meat production, are well known to improve visual characteristics of animal product, throughout modulating the appearance of meat to meet consumers demand (Faustino et al., 2019). To develop healthier alternatives to synthetic colorants, natural resources such as yeasts (e.g., *Rhodotorula* spp.) represent potential candidates (Aman et al., 2021). *Rhodotorula* spp. are known to synthesize large amounts of valuable xanthophylls and carotenoids (Kreusch & Duarte, 2021) in up to 96 h of fermentation, while using low-cost substrates. The genus includes a variety of colours, starting from pale pink and as far as dark red (Shengnan et al., 2017), while creating gram-positive round-shaped colonies (Soliman et al., 2018). The current study aimed to evaluate the effects of spent brewer's yeast (SBY, *Saccharomyces* spp.), with or without the addition of *Rhodotorula* spp. biomass (Rh), as dietary supplements on broiler health status and growth performance.

MATERIALS AND METHODS

The experimental design and protocol used were in accordance with the EU Directive 2010/63/EU and Romanian Law on Experimental Animal Protection.

Birds, design, husbandry and experimental diets

Day-old 'Ross 308' broiler chick (n = 320) of mixed sexes, produced in a commercial hatchery, were randomly distributed at the start of the trial. The chicks (average body weight 43.11 ± 0.7 g/bird/group) were randomly allocated into 8 dietary treatments groups (see Table 1), during 42 days feeding trial. Each treatment was subdivided into 5 replicates per pens (experimental units) of equal size, with pens being arranged in longitudinal lines in the brooder house. The chicks were vaccinated against New Castle disease (NCD), Marek disease and anti-infectious bursal disease, as the conventional veterinary schedule requires. All birds were reared on a permanent deep litter (using wood shavings), with environmentally controlled conditions (air and temperature), according to birds age (Aviagen, 2019). Temperature was maintained at 32°C at placement followed by a 3°C decrease/week, up-to 20-21°C, using thermostatically controlled heaters, fans and adjustable sidewall inlets. Lighting was provided for 23 hours/day from 1day to 7 days, and then from the 8th day, the light decreased by 1 hour/day until 20 hours, according to EU legislation (EU Council Directive 2007/43/EC).

Table 1. Experimental design and dietary treatments

Group	Dietary treatments
1	Negative control group - fed with basal diet (Corn-soybean meal);
2	Basal diet + SBY 0.6 g/kg feed;
3	Basal diet + SBY 1.0 g/kg feed;
4	Basal diet + SBY 1.3 g/kg feed;
5	Positive control group - fed with basal diet (Corn-soybean meal) + Rh (0.3 kg/t feed);
6	Basal diet + SBY 0.6 g/kg feed + Rh (0.3 kg/t feed);
7	Basal diet + SBY 1.0 g/kg feed + Rh (0.3 kg/t of feed);
8	Basal diet + SBY 1.3 g/kg feed + Rh (0.3 kg/t feed);

The diets were arranged in a bifactorial design, with the variables being SBY supplement at four levels (0, 0.6, 1 and 1.3 g/kg diet, respectively) with (+) or without (−) of *Rhodotorula spp*. (Rh) supplement at two levels (0 and 0.3 g/kg diet). The SBY was procured as by-product from a local brewery and inactivated using successive thermic induced stress, lyophilised (0.39 mBar, -50°C), mashed and stored at -20°C. The SBY was evaluated for viability and vitality. The proximal composition and amino acid profile of the SBY was determined (Tables 2 and 3). In order to improve the nutritional value of the dietary protein, up to the level of digestible protein, in the diets structure, biosynthetic/ synthetic amino acids were added, respectively L-lysine HCl and DL-methionine, in variable proportions, depending on the level of inclusion of this ingredient in the manufacture of feed (Table 2). All the nutrients met or exceed the nutrient requirements according to the broilers age (Aviagen, 2019).

Table 2. Experimental basal diets of broiler chicks, per each growth period

	Starter	Grower	Finisher
Ingredients (g/kg)			
Corn	557.9	567.3	629.6
Soybean meal	331.0	311.0	255.0
Corn gluten	43.0	43.0	35.0
Soybean oil	14.6	29.8	34.0
Monocalcium phosphate	16.9	16.6	14.5
Calcium carbonate	16.9	14.6	13.2
Salt	2.8	2.8	2.8
L-lysine HCl	3.3	1.8	2.7
Dl-methionine	2.8	2.3	2.5
Choline-chloride 50%	0.8	0.8	0.7
Vitamin - mineral mixture*	10.0	10.0	10.0
Rhodotorula[1]	+/-	+/-	+/-
Calculated composition			
ME (MJ/kg)	12.55	13.02	13.40
CP (%)	23.0	22.0	20.0
Lysine, total (%)	1.41	1.24	1.05
Lysine, digestible (%)	1.28	1.16	0.98
Methionine + cysteine, total (%)	1.02	0.95	0.86
Methionine + cysteine, digestible (%)	0.94	0.87	0.75
Ca (%)	1.00	0.90	0.80
Available P (%)	0.45	0.45	0.45
Crude fat (%)	4.34	5.85	6.23
Crude fiber (%)	2.85	2.77	2.56

*Supplied per kg diet: 12000 IU vitamin A, 5000 IU vitamin D3, 75 mg vitamin E, 3 mg vitamin K3, 3 mg vitamin B1, 8 mg vitamin B2, 5 mg vitamin B6, 0.016 mg vitamin B12, 13 mg pantothenic acid, 55 mg nicotinic acid, 2 mg folic acid, 0.2 mg biotin, 120 mg Mn, 100 mg Zn, 40 mg Fe, 16 mg Cu, 1.25 mg I and 0.3 mg Se, 70 mg Monteban G100. [1]*Rhodotorula* spp. – lyophilised biomass 0.3kg/T0 feed. - = not included in the diet; + = included in the diet.

The Rh supplement was isolated and developed in the laboratory of the Biotechnology Faculty from Bucharest, from a wild strain identified as belonging to the *Rhodotorula* genus. Previously, the strain was isolated from waste milk subproducts, by successive passages on PDA (potato dextrose agar) and maintained at 4°C. The reactivation was conducted on potato dextrose broth, incubated at 28°C on an orbital shaker (100 rpm, 48 h). An optimised process for nutritive substrates and optimal fermentative conditions (aeration, time and temperature) were developed. The best productivity stage (orbital shaker) was found at 96 h of fermentation (on potato waste substrate), at 30°C, pH = 5.15 ± 0.198, showing 849.6 mg/L^{-1} wet biomass. Thermic inactivation (five times of freezing-defreezing cycles for each fermented batch, n = 5) and lyophilisation were developed to ensure the health safety requirements and in order to avoid the potential opportunistic expression of the strain. The developed product was further lyophilised and mashed (powdered, having 77.9mg/L^{-1}) and added in broiler chicks' diets at 0 and 300g/t of feed.

Feeding program was divided into 3 phases: starter (0 to 10 days), grower (11 to 22 days), and finisher (23 to 42 days). Diets for each feeding phase were formulated to be isocaloric, isonitrogenous, with similar content of total essential amino acids (Table 3). The feed and water were provided *ad libitum* throughout the entire trial.

Laboratory Analysis, Sampling and Measurements

Samples of SBY, and feeds were analysed in triplicate, for content in dry matter (ISO 5984:2002), crude protein (SR EN ISO 5983-2:2009), crude fat (SR EN ISO 6492:2001) and fiber content (SR EN ISO 6865:2002). Amino acids were analysed using a HPLC System (Surveyor Plus, Thermo Fisher Scientific Inc., San Jose, CA, USA), according to the method described by Ciurescu and Pana, 2017). Flame atomic absorption spectrometry (SOLAAR M6 Dual Zeeman Comfort; Thermo Electron Corp., Waltham, MA, USA) was used to determine the macro and micro-mineral concentrations according to the method described by Ciurescu et al. (2018). Nitrogen-free extract (NFE) content was calculated as follows: NFE (%) = dry matter % – (crude protein % + crude fat % + crude ash % + crude fibre %). The content of dietary fibre fraction – neutral detergent fiber (NDF), and acid detergent fiber (ADF) – was determined with the classical semi-automatic Fibertec method (FOSS – Tecator AB, Hoganas, Sweden) as previously described by Ciurescu et al., 2018.

Growth parameters

The body weights (BW, n = 40/dietary treatment) were recorded throughout periodic weights at 1, 10, 22 and 42 days, in order to calculate the average daily gain (ADG) for each of the feeding periods and diets (starter, grower and finisher).

Health status

At of the end of the trial, broilers (n=5/group) were randomly selected for haematologic and metabolic sampling and determinations. Blood samples were collected from the bird's brachial vein, on EDTA and heparin tubes. Haematologic profile was performed by using an automatic analyser (Abacus Junior Vet 5, Diatron, Austria) and included: white blood cell (WBC), red blood cell (RBC), haemoglobin concentration (HGB), haematocrit (HCT), mean corpuscular volume

(MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC).

The blood samples collected on gel and clot activator tubes were centrifugated (3000 rpm, 15 min, SIGMA), and serum was collected in 1.5 ml Eppendorf tubes and stored at -20°C, for 7 days. Metabolic blood serum profile: glucose (Glu), total cholesterol (Cho), triglycerides (Tg), total protein (Tpro), albumin (Alb), total bilirubin (Tbil), creatinine (Cre), urea, uric acid (UA), alanine-aminotransferase (TGP), aspartate- aminotransferase (TGO), and gamma glutamil-transferase (GGT) were investigated using a semi-automatized analyser (StarDustMC15, DiaSys, Spain).

Statistical analyses

Data were analysed employing a mixed-effects model, using the GLM and ANOVA procedures with SPSS software (version 20 Inc. Chicago, IL, USA). Levels of SBY, Rh and their interactions were included in the statistical model. For growth performance (BWG and ADG), each pen was considered as the experimental unit. When comparing treatments means, Post hoc Tukey's multiple range test was carried out to assess any significant differences for the measured parameters. Differences were considered significant at a level of $P \leq 0.05$, while the tendency was set at $P \leq 0.10$.

RESULTS AND DISCUSSIONS

Nutrient composition of brewers spent yeast

As expected, the SBY dietary supplement was found to have high levels of crude protein (39.6 ± 3.5%) and amino acids (Tables 3 and 4). Although, the amount of limitative amino acids such as methionine (1.18 ± 0.02 g/100 g of protein) and lysine (5.22 ± 0.03 g/100 g of protein) found in SBY, were lower than in the soybean meal (SBM), where lysine represents 6.38 g/100 g of protein and methionine accounts 1.26 g/100 g of protein, as previously reported by Saleh (2020).

The reported ether extract (EE) in SBY was lower than the basal energetic ingredient represented by corn, showing not more than 3.6% (Mateos et al., 2019). Furthermore, due to the low EE content, SBY might positively influence the visceral adiposity (Beisek et al., 2020), leading to a better health status and lowering the incidence of heart related disorders in broilers (Wang et al., 2021). However, considering the chemical composition of SBY, it is well known that the utilization in monogastric species, including humans, should be limited, due to the high levels of the nucleic acid ratio, that could cause a rise of the serum blood uric acid levels, damaging the tissues (Farcas et al., 2017).

Table 3. Nutritional basal composition of the dietary SBY supplement

SBY	ME* (MJ/kg)	DM	EE	NDF	ADF	CP	Ash
	2030±7.5	95.8±6.1	1.9±0.7	6.1±0.8	1.8±0.9	39.6±3.5	6.7±1.3

Data expressed as mean (n=3) ± standard deviation; *Metabolizable Energy value was calculated based on regression equations (NRC, 1994). DM – dry matter; EE – ether extract; NDF – non detergent fiber; ADF – acid detergent fiber ; CP – crude protein

Table 4. SBY amino acid profile

Amino acid* (g/100 g protein)			
Arginine	2.13±0.01	Lysine	5.22±0.03
Cysteine	0.49±0.02	Methionine	1.18±0.02
Histidine	0.93±0.1	Phenylalanine	1.64±0.01
Izoleucine	1.9±0.02	Threonine	1.88±0.01
Leucine	2.73±0.02	Valine	2.25±0.04

Data expressed as mean (n=3) ± standard deviation.

Growth performance

As reported in Table 5, there was no significant effect ($P < 0.05$) of the interaction between the main factors (SBY x Rh) on the growth performance of birds in the overall trial. Live body weight and average daily gain of broiler chick supplemented with 0.6 g/kg feed (groups 2 and 6) recorded similar values of live body weight and average daily gain as groups 1 and 5. Increased SBY levels (≥1 g/kg feed) in the broiler diet showed a linear (P<0.05) decrease at all ages. The highest concentration of SBY (groups 4 and 8) supplemented resulted in negative growth performances values, compared with all experimental groups. The Rh addition had no effects on broiler growth performance. Although, the dietary *Rhodotorula* spp. was proposed with concern to the desired appearance of the final product (meat colour) (Mata-Gomez et al., 2014; Barreiro et al., 2018; Duffose L., 2018) also with economic implications by using a natural low-cost alternative to the conventional synthetic colorant resource.

Similar to our findings, low levels of inactive yeast supplementation had no effects on broilers' growth performance (Wang et al., 2021). Current results are somewhat contrasting with reports from the literature, Ahiwe et al. (2020) and Sampath et al. (2021) studies showed that the increased levels of inactive yeast and yeast cell wall in the diets improved the broilers growth performances.

Other authors found that administrating live yeasts as probiotics, might enhance the live body weight in broiler chicks (Macelline et al., 2017) and quails (Sharif et al., 2018).

The growth-promoting effects of adequate levels of yeast supplementation on broiler chicks' diet could trigger a complex synergic system in boosting the immune and anti-inflammatory responses via vitaminic and amino acid abundance (Alagawany et al., 2021) along with balancing the nutrient availability and feed efficiency (Macelline et al., 2017).

Table 5. Effects of dietary SBY level and Rh addition on growth performance of broiler chickens[1]

			BW(g)				**ADG (g)**			
Group	**SBY[2]**	**Rh[3]**	**1st day**	**10th day**	**22nd day**	**42nd day**	**Starter**	**Grower**	**Finisher**	**Overall**
1	0	No	43.42	268.88	953.44	2769.32	22.55	57.04	90.79	64.90
2	0.6	No	43.03	266.48	922.40	2688.00	22.34	54.66	88.28	62.98
3	1	No	42.88	259.80	892.44	2637.52	21.69	52.72	87.25	61.78
4	1.3	No	43.84	238.36	865.16	2501.68	19.45	52.23	81.83	58.82
5	0	Yes	43.13	270.92	952.84	2739.64	22.78	56.83	89.34	64.20
6	0.6	Yes	42.43	266.16	924.68	2672.68	22.37	54.88	87.40	62.63
7	1	Yes	43.46	254.80	865.24	2589.68	21.13	50.87	86.22	60.62
8	1.3	Yes	42.77	241.44	845.40	2467.88	19.87	50.33	81.12	57.74
SEM			0.366	2.672	9.235	33.687	0.270	0.786	1.808	0.803
Main effects										
SBY level										
0			43.28	269.90[a]	953.14[a]	2754.00[a]	22.66[a]	56.94[a]	90.07[a]	64.55[a]
0.6			42.73	266.32[a]	923.54[b]	2680.34[ab]	22.36[a]	54.77[b]	87.84[a]	62.80[ab]
1			43.17	257.30[b]	855.28[c]	2613.60[b]	21.42[b]	51.80[c]	87.25[a]	61.20[b]
1.3			43.30	239.90[c]	878.84[c]	2484.78[c]	19.66[c]	51.28[c]	81.48[b]	58.13[c]
Rh addition										
Yes			42.95	258.33	897.04	2617.47	21.54	53.23	86.02	61.30
No			43.29	258.38	908.36	2649.13	21.51	54.17	87.03	62.04
p-value										
SBY effect			0.366	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Rh effect			0.180	0.979	0.085	0.185	0.876	0.093	0.427	0.191
SBYxRh			0.971	0.304	0.440	0.146	0.303	0.406	0.997	0.969

Different superscript within the same column is different (P<0.05). [1]Data are means of 40 broilers for each treatment. [2]SBY dietary supplementation g/kg diet. [3]*Rhodotorula spp.* lyophilised biomass 0.3kg/T feed. SEM - standard error of the mean. Starter period – from day 1 to 10th day of experimental trial. Grower period – between the 11th day to 22nd day. Finisher period, between the 23rd day to 42nd day of the trial. Overall period, the 42 days of experimental trial.

Haematologic profile

Blood hematologic parameters are often employed to evaluate the clinical status of birds. Table 6 shows the broiler hematologic profile that was not affected by the dietary SBY or Rh supplementation (p>0.05).

The levels of blood constitutive elements were similar between all the experimental groups and fell within the physiologic range for broiler chicks at 42 d of age (Al-Nedawi, 2018). With the lack of statistical differences, we could highlight that tested inactive yeasts products did not affect the broiler's hematologic constituents. However, live yeast administration might have an effect on broiler immune and hematologic profiles via the synergic relation between the host and dietary live foreigner, enhancing blood white cells (lymphocytes and monocytes) and immunoglobulin G (Ahiwe et al., 2020).

Our results share similarities with Rafique et al. (2020), and Osita et al. (2020) studies that used *Saccharomyces cerevisiae* as a dietary supplement and observed no effect on the broilers hematologic profile.
In contrast to our findings, the inclusion of live yeast in broilers diets significantly improved the levels of hematologic components (Maoba et al., 2021; Mousa et al., 2018).

Feeding supplements such as SBY and Rh are generally considered safe (Farkas et al., 2020) and widely used in laying hens' diets (Sun et al., 2020; Thanapal et al., 2021) and other poultry species (Barreiro & Barredo, 2018).
Although, no studies are reporting the effects of active or inactive Rh biomass dietary supplementation on broiler blood profiles.

Table 6. Effects of dietary SBY levels and Rh addition on haematologic profile of broiler chickens[1]

Group	SBY[2]	Rh[3]	WBC	RBC	HGB	HCT	MCV	MCH	MCHC
1	0	No	24.63	2.35	6.94	33.48	114.36	46.56	26.04
2	0.6	No	25.33	2.39	7.05	34.22	113.98	47.76	25.84
3	1	No	25.08	2.36	6.83	33.76	113.32	43.98	25.38
4	1.3	No	24.96	2.45	6.95	34.92	112.62	46.02	26.15
5	0	Yes	25.19	2.29	6.90	34.31	112.88	43.68	25.20
6	0.6	Yes	25.39	2.39	6.92	34.96	113.60	45.55	25.74
7	1	Yes	25.24	2.42	7.07	34.05	113.76	46.38	24.97
8	1.3	Yes	25.37	2.37	6.94	34.83	113.28	45.64	25.95
SEM			0.401	0.064	0.309	1.283	1.336	1.137	0.832
Main effects									
SBY level									
0			24.91	2.32	6.92	33.90	112.95	45.12	25.17
0.6			25.16	2.39	6.95	33.91	113.54	45.18	25.62
1			25.16	2.39	6.95	34.59	113.62	45.83	25.79
1.3			25.36	2.41	6.98	34.87	113.79	46.66	26.05
Rh addition									
Yes			25.30	2.37	6.96	34.54	113.38	45.31	25.46
No			25.00	2.39	6.94	34.10	113.57	46.08	25.85
p-value									
SBY effect			0.760	0.542	0.998	0.829	0.929	0.507	0.760
Rh effect			0.303	0.636	0.631	0.937	0.347	0.842	0.514
SBY effect x Rh effect			0.401	0.064	1.283	0.309	1.137	1.336	0.832

[1]Data are means of 5 broilers for each treatment. [2] SBY supplementation in g/kg diet. [3] *Rhodotorula* spp. lyophilised biomass 0.3 kg/T feed.

Serum biochemical parameters

The interaction between the main factors (SBYxRh) did not affect the broiler blood serum profile (P>0.05) (Table 7). Serum biochemical constituents had similar values (P>0.05), except for the energetic profile.
A significant difference between the experimental SBY treated groups was recorded (P<0.05) for the serum glucose parameter. The linear decrease was displayed, having the lowest serum glucose values on groups 4 and 8, compared with all experimental groups (P<0.05). As a supposition, managing the broilers health by decreasing serum glucose it might increase insulin production (Chougule et al., 2020), that may enhance glycogenesis and improve glycolysis pathways (Givisiez et al., 2020). Previous studies (Rafique et al., 2020; He et al., 2021; Wang et al., 2021; Liu et al., 2021) had suggested that dietary yeasts supplementation decrease the broilers serum glucose, triglycerides and low density -lipids and enhances the high-density lipids values, while improving the lipid metabolism function.

Table 7. Effects of dietary SBY levels and Rh addition on blood biochemical profile of broiler chickens[1]

Group	SBY[2]	Rh[3]	Glu	Cho	Tg	T-pro	Alb	T-bill	Cre	UA	Urea	TGP	TGO	GGT
1	0	No	278.67	124.67	59.33	2.53	1.07	0.20	0.70	5.70	2.00	11.33	267.33	50.33
2	0.6	No	266.33	127.33	57.00	2.60	1.00	0.20	0.63	4.90	2.00	9.33	205.00	48.33
3	1	No	247.33	149.00	55.00	2.97	1.07	0.20	0.57	5.17	2.00	9.33	229.33	52.67
4	1.3	No	235.00	123.47	54.33	2.67	0.97	0.27	0.57	5.40	2.00	11.33	265.00	57.67
5	0	Yes	301.00	136.33	48.67	2.70	1.03	0.23	0.63	6.00	2.33	10.00	200.00	48.00
6	0.6	Yes	252.67	123.67	54.67	2.57	1.03	0.20	0.63	5.67	2.00	11.00	311.67	43.00
7	1	Yes	244.33	127.67	56.00	2.60	1.07	0.20	0.60	5.23	2.00	9.00	239.00	51.67
8	1.3	Yes	260.67	134.00	58.67	2.77	1.03	0.20	0.53	5.43	2.00	11.00	263.33	51.67
SEM			6.064	2.734	1.199	0.059	0.030	0.011	0.018	0.180	0.042	0.364	11.33	1.832
							Main effects SBY level							
0			289.84^{a}	130.50	54.00	2.62	1.05	0.22	0.667	5.85	2.17	10.67	233.67	49.17
0.6			259.50^{ab}	125.50	55.83	2.58	1.02	0.20	0.583	5.28	2.00	10.17	258.33	45.67
1			245.83^{b}	138.33	55.50	2.78	1.07	0.20	0.583	5.2	2.00	9.17	234.17	52.17
1.3			247.84^{ab}	128.73	56.50	2.72	1.00	0.23	0.550	5.42	2.00	11.17	264.17	54.67
							Rh addition							
Yes			256.83	131.12	56.42	2.69	1.03	0.217	0.617	5.29	2.00	10.33	241.67	52.25
No			264.67	130.12	54.5	2.66	1.04	0.208	0.600	5.58	2.08	10.25	253.50	48.58
							p-value							
SBY effect			0.023	0.365	0.902	0.665	0.901	0.715	0.134	0.673	0.418	0.300	0.638	0.426
Rh effect			0.472	0.893	0.441	0.794	0.814	0.728	0.644	0.477	0.332	0.912	0.581	0.363
SBY effect x Rh effect			0.828	0.120	0.195	0.466	0.962	0.516	0.775	0.909	0.418	0.554	0.066^{T}	0.963

^{a,b} Means within a column with no common superscript differ significantly (*P*<0.05). ^{T} - tendency, P<0.1.

[1]Data are means of 5 broilers for each treatment. [2]SBY dietary supplementation in g/kg diet. [3]*Rhodotorula* spp. lyophilised biomass 0.3 kg/T feed. Glu - glucose. Cho - total cholesterol. Tg - triglycerides. Tpro -total protein. Alb - albumin. Tbil - total bilirubin. Cre - creatinine. UA - uric acid. TGP - alanin-aminotransferase. TGO - aspartate-aminotransferase. GGT - gamma glutamiltransferase.

Opposite to these findings, Nelson et al. (2020) reported that the dietary inclusion of live yeast in the stressed broiler diets had no significant effect on serum protein profile.

There were no effects of SBY dietary supplementation, with or without Rh, on broilers protein, mineral or enzymatic serum profile. Although, a tendency (P = 0.066) was observed, due to the main factor's interaction as dietary supplements in broilers might increase the serum GOT enzyme.

Further studies are necessary to investigate the mechanism through which the SBY dietary supplement lowers serum glucose in broilers.

CONCLUSIONS

The SBY dietary supplementation at levels of 0.6 g/kg feed, resulted in similar growth performance during the overall trial, compared with chicks reared on corn-soybean diet. The SBY in broiler chicks' diets decreased the serum glucose, which could increase the broilers energetic metabolism. Higher levels of SBY supplementation had negative effects on growth performance and tended to affect the enzymatic serum profile, as a result these interactions could cause hepatic disturbance. *Rhodotorula* spp. supplement had no favourable effect on BW, ADG, haematologic and serum biochemical profiles of the broilers.

Further studies are required to evaluate the impacts of dietary SBY supplementation with or without Rh on broiler meat quality and sensorial attributes of carcasses.

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