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Influence of yeast hydrolysate supplement on growth performance, nutrient digestibility, microflora, gas emission, blood profile, and meat quality in broilers

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Abstract

A total of 1512 Ross 308 broilers (one - day - old) were assigned (random blocks) to 1of 3 dietary treatments with 28 replicates of 18 chicks/cage. The dietary treatments were Corn-soybean-meal based basal diet supplemented with 0%, 0.1%, and 0.2% of commercial yeast hydrolysate (YH [*Saccharomyces cerevisiae*]). The graded level of YH supplementation has linearly increased broilers body weight gain on d 21, 35, and overall (p = 0.044, 0.029, and 0.036, respectively) experimental period. In addition, the increased level of YH supplementation has linearly reduced feed conversation ratio of broilers on d 21, 35, and overall trial period (p = 0.041, 0.052, and 0.032, respectively). However, the feed intake and mortality of broilers were not affected by the graded level of YH supplementation. Though nutrient digestibility of dry matter (p = 0.012) and nitrogen (p = 0.021) was linearly increased in broilers fed YH supplementation, at the end of the trial it fails to affect the total track digestible energy. Dietary inclusion of YH supplementation showed a beneficial effect on the microbial population as linearly improved *lactobacillus* (p = 0.011) and reduced *Escherichia coli* counts (p = 0.042). An increasing level of YH supplementation has tended to decrease NH_3 (p = 0.069) and linearly decrease H_2S (p = 0.027) of noxious gas emission in broilers. Moreover, dietary YH supplements trend to increase the glucose (p = 0.066) and reduced cholesterol (p = 0.069) level. At the end of the test, YH supplementation elicited a linear reduction in drip loss on days 5 and 7, respectively (p = 0.045, and 0.021). Furthermore, dietary inclusion of YH supplementation had linearly increased villus height (p = 0.051) but fails to affect crypt depth. Therefore, in terms of positive effects on the broiler's overall performance, we suggest that dietary supplements containing graded YH levels in the broilers diet could serve as a potential alternative for growth promoters.

Keywords: Yeast hydrolysate, Brewer yeast, Broilers, Growth performance

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Availability of data and material
Upon on reasonable request, data sets of this study will be available from the corresponding author.

Authors' contributions
Conceptualization: Sampath V, Han K, Kim IH.
Data curation: Sampath V, Han K.
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Writing - review & editing: Han K, Kim IH.

Ethics approval and consent to participate
Prior to the trail, the experimental protocols were revised well and approved by Animal Research Ethics Committee of Dankook University (DK-1-2018).

INTRODUCTION

Poultry production is one of the largest meat producers globally [1] and broilers are raised especially for meat production. Besides, it becomes the best and cheapest source of animal protein (nutritious egg and meat) for human consumption, and plays a significant role in improving the nutritional status of human beings. Compared to other meat-producing animals, modern broilers grow rapidly and meet the protein needs of consumers' in a very short period of time. Such broiler meat demand has been increased due to the growing population. In order to produce high-quality meat, farmers have preferred to use cost-effective antibiotics since 1951 [2]. Previously, Ogle Maureen [3] stated that broilers fed with antibiotics grew 50% faster than the basal diet. However, in the past few decades, antibiotic growth promoters (AGP) uses in poultry feedstuff has become the hottest debate among many researchers due to its bacterial resistance. Consequently, the European Union (EU) has restricted the use of antibiotics in the livestock industry since 2003 [4]. In addition, several publications pointed out a close connection between antibiotic usage and poultry production, thereby increasing the resistance of bacteria that cause health issues to consumers [5]. These anxieties prompted scientists to discover a suitable alternative that could boost the quality of meat and poultry production. As a result, organic acids, probiotics, yeast, and phytogenic additives have been used as an excellent source of substitutes for AGP in monogastric animal nutrition [4]. Subsequently, these additives have been adequately addressed in previous studies.

Recently, yeast and its byproducts such as yeast cell wall, yeast extract, and yeast hydrolysate (YH) have become a popular additive in poultry diets due to its nutritional ingredients, and immunological properties [6,7]. Besides, YH has a strong fermentation capacity, high nutritional value, and can reduce potential toxicity. It is an end product of hydrolysis extraction and naturally comprises of yeast extracts and cell walls [8]. In addition, YH contains ample of B-vitamins, amino acids, nucleotides, β-glucan, and mannan-oligosaccharides (MOS). However, β-glucan and MOS were commonly used as prebiotics in order to regulate the immune response of animals [9]. Likewise, nucleotides are considered as one of the most essential YH ingredients as it regulates the immune function to enhance the growth performance and repairs the digestive tract of animals [10,11]. Moreover, dietary nucleotides can satisfy the corporal needs in the exponential growth, malnourishment, and immune challenge. Previously, many studies showed the positive effects of yeast cells [12,13] and cell wall components [14,15] on the intestinal health of poultry under various conditions. However, the application of YH supplement in broiler feed is still scarce. Therefore, we aimed to assess the efficacy of YH supplementation into broilers diet to examine their growth performance, nutrient digestibility, fecal microflora, noxious gas emission, blood profile, villi length and crypt depth (CD), and meat quality.

MATERIALS AND METHODS

Prior to the trail, the experimental protocols were revised well and approved by Animal Research Ethics Committee of Dankook University (DK-1-2018).

Composition of main supplement

The main supplement YH (*Saccharomyces cerevisiae*) used in this experiment was commercially prepared in the name of CALMORIN. It was obtained from Daeho (Hwaseong, Korea) and added to broiler feed at a prescribed level. The active ingredients presented in YH supplement were 40% of crude protein, 4.9% of glutamic acid, 3.5% of nucleotides, 23% of β-glucans, and 15% MOS.

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Broiler husbandry

This experiment was conducted at Dankook University "Poultry farm" located at Jeonui (Korea). Before the trial, all equipment and rearing houses were disinfected. A total of 1512 Ross308 a day-old broiler chick (mixed sex) with an initial weight of 42.23 ± 0.05 g (mean ± SD) were procured from Cherry-Buro hatchery (Cheonan, Korea) and reared in multi-layer battery cages for 35-days in a pleasant environment of 33 ± 1℃ room temperature for first 3 days. Later the room temperature was slowly reduced up to 24℃ (60% humidity) and maintained until the end of the trail. The nipple type water troughs and feeder were attached to each cage that allows birds to enjoy *ad libitum* water and feed throughout the experiment. To maintain a hygienic environment the rearing room was routinely cleaned until the end of the test.

Experimental design and diet

Chickens were randomly distributed (28 replicates/treatment, 18 chickens/cage) into one of 3 different treatment groups and fed with Corn-soybean-meal based basal diet supplemented with 0%, 0.1%, and 0.2% of commercial YH. The experimental diets of broiler starter (1–7 d), grower (7–21 d), and finisher (21–35 d) were formulated to the norms of NRC [16] (Table 1). Basal diet

Table 1. Ingredient composition of experimental diets as-fed basis

Ingredient (%)	Starter (1–7 d)	Grower (7–21 d)	Finisher (21–35 d)
Corn	54.19	55.38	56.77
Soybean meal	33.80	26.1	18.23
Canola meal	5.00	10.0	15.0
Soybean oil	2.10	3.62	5.07
MDCP	-	1.28	1.12
DCP	1.70	-	-
Limestone	1.15	1.34	1.22
L-Lysine	0.50	0.65	0.81
DL-Methionine	0.46	0.47	0.52
L-Threonine	0.20	0.25	0.32
L-Tryptophan	-	0.01	0.04
$NaHCO_3$	0.10	0.10	0.10
Salt	0.30	0.30	0.30
Vitamin premix[1)]	0.20	0.20	0.20
Mineral premix[2)]	0.20	0.20	0.20
Choline	0.10	0.10	0.10
Nutrient composition			
ME (kcal/kg)	3,000	3,100	3,200
CP (%)	23.0	21.5	20.0
Lys (%)	1.50	1.40	1.30
Met + Cys (%)	1.08	0.99	0.94
AP (%)	0.48	0.44	0.41
Ca (%)	0.96	0.87	0.81

[1)]Provided per kg of complete diet: 11,025 IU vitamin A; 1,103 IU vitamin D_3; 44 IU. vitamin E; 4.4 mg vitamin K; 8.3 mg riboflavin; 50 mg niacin; 4 mg thiamine; 29 mg d-pantothenic; 166 mg choline; 33 μg vitamin B_{12}.

[2)]Provided per kg of complete diet: 12 mg Cu (as $CuSO_4 \cdot 5H_2O$); 85 mg Zn (as $ZnSO_4$); 8 mg Mn (as MnO_2); 0.28 mg I (as KI); 0.15 mg Se (as $Na_2SeO_3 \cdot 5H_2O$).

MDCP, monodicalcium phosphate; DCP, dicalcium phosphate; ME, metabolizable energy; CP, crude protein; Lys, lysine; Met, methionine; Cys, cystine; AP, available phosphorus.

and YH supplements were mixed using feed mixer DDK-801 (Daedong Tech, Anyang, Korea).

Sampling and chemical analysis

The nutritional diet was offered to broilers for 35 days. At initial, days 7, 21, and 35 broilers were weighed. The amount of diet consumed and residual (each cage) were recorded on each day to evaluate the feed intake (FI). At the end of the trail, body weight (BW), FI, feed conversion ratio (FCR) was calculated, as well mortality rate was also recorded.

From day 28–35, broilers diet was mixed with 0.2% of chromium oxide. On day 35, fresh excreta samples (56 birds/treatment) were randomly collected (2 birds/ cage) using stainless steel collection tray. The excreta samples were pooled and transported to the laboratory, and stored at −20℃ to examine the nutrient digestibility of dry matter (DM), nitrogen (N), and energy (E). Prior to analysis, freeze-dried samples were placed in a digital hot air-drying convection oven at 105℃ for 24 hours. The samples were then taken out from the oven, pulverized well and sieved using a 1 mm screen sieve. DM procedures was carried out according to the method of Upadhaya et al. [4]. N was determined by Tecator™ Kjeltec8400 (Hoeganaes, Skåne, Sweden) analyzer. To determine E feed and a fecal sample was taken and placed in Parr 6400 (Parr instrument, Moline, IL, USA) oxygen bomb calorimeter, and the heat combustion in the sample was measured. The chromium absorption was identified by UV-1201 spectrophotometry (Shimadzu, Kyoto, Japan) and the results were recorded for statistical analysis. The total digestibility (cumulative result) was calculated using the equations of Upadhaya et al. [4].

At the end of the trial (day 35), 56 broilers/treatment were randomly selected and the fresh excreta samples were collected (2 birds/cage) in micro-tubes and placed in sterile plastic bags. The samples were then placed in an insulated ice container and taken to the research laboratory for microbial study. To confirm the existence of microbes, 1gm of fresh excreta sample was taken and diluted 9 mL of 1% peptone broth and mixed well with a vortex mixer. Then 0.02% of peptone solution was poured into (*Salmonella*-Shigella, MacConkey and *Lactobacilli* medium III) agar plates, respectively. The *Salmonella*-Shigella and MacConkey agar plates were incubated at 37℃ for 1 day. A day later the plates were taken out from the incubator and bacterial colonies were counted. At once, *Lactobacilli* medium III agar plates which incubated at 39℃, for 2 days were taken out and counted immediately.

On day 35, fresh excreta samples (approximately 300 g) were randomly collected from 56 birds/ treatment (2 birds/cage), pooled well and stored in an airtight plastic box of 2.6 L with a slight hole on one side, fasten tightly with adhesive tape and fermented at 25℃ for 7 days. On 8th day, a 100 mL sample was taken away from the headspace (2 cm) for the air circulation, and the box was re-sealed. To know the crust formation on the surface the sample container was manually shaken for about 30 seconds. Finally, NH_3, H_2S, Methyl mercaptans, CO_2, and acetic acid concentrations were measured using the methods of Nguyen and Kim [17].

On day 35, 0.5 mL blood samples was collected from brachial vein of 56 birds (randomly selected) using a sterilized syringe and stored in (K_3EDTA) (Becton, Dickinson and, Franklin Lakes, NJ, USA) heparinized and non-heparinized tubes for blood urea nitrogen (BUN) analysis and serum creatinine analysis, respectively. Within one hour of collection, all samples centrifuged (3,000×g) at 4℃ for 15 min to separate the serum. Abbott Spectrum urea Series II -nitrogen test kit (Abbot Laboratories, Dallas, TX, USA) was used to analyze BUN. In addition, Astra-8 (CA 92621) Analyzer kit (Beckman Instruments, Brea, CA, USA) was used to determine creatinine concentrations. The total cholesterol and triglyceride concentration in the serum samples were determined using an automatic biochemical analyzer RA-1000 (Bayer, Tarrytown, NY, USA). The immunoglobulin (IgG) was determined using HITACHI 747 automatic biochemistry analyzer

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(HITACHI, Tokyo, Japan). After blood collection same broilers were weighed individually and taken to slaughtering room and killed by cervical dislocation. The abdominal fat, liver, gizzard, spleen, bursa of fabricius, and breast muscle were carefully removed by the experts. The relative organ weight was weighed individually and estimated as the mass BW. The respective meat samples were taken to laboratory, and breast meat was separated for meat quality analysis. The color parameters such as redness, lightness, and yellowness standards of each sample (surface) were measured at 3 locations with a portable Konica Minolta CR-400 chroma meter (Konica Minolta, Osaka, Japan). The pH, water holding capacity (WHC), and cooking loss were calculated following the detailed methods of Sampath et al. [18]. Drip loss was carried out according to the procedure of Honikel [19].

On day 35, 2 cm intestinal tract tissue samples were collected from the ileocolic junction (ileum), mid-gut (jejunum), and duodenum region and placed into neutral buffered formalin for fixation and intestinal segments were fixed for morphometric analysis and histochemical staining in 10% buffered formalin solutions, respectively. The classification criteria for villus height (VH) was based on the appearance of lamina propria intact. Histological experiment samples were performed on 5 μm sections, stained by haematoxylin and eosin, and examined by Olympus AX70 microscope (Olympus, Tokyo, Japan). The intestinal VH and CD were measured according to the methods of Hampson [20].

Statistical analysis

The cage was defined as the experimental unit during the trial period. The test data was analyzed in a randomized complete block design using the General Linear Model procedure (SAS Institute, Cary, NC, USA). The polynomial contrasts of increased dietary YH supplementation was examined by linear and quadratic effects. Mean values of less than 0.05 were considered as significant, and 0.10 were considered as trends.

RESULTS

The growth performance of broilers fed YH supplement is presented in Table 2. The dietary inclusion of YH supplementation has linearly increased broilers body weight gain (BWG) on d 21, 35, and overall (p = 0.044, 0.029, and 0.036 respectively) experimental period. In addition, the increased level of YH supplementation has linearly reduced broilers FCR on d 21, 35, and overall trial period (p = 0.041, 0.052, and 0.032). However, FI and mortality of broilers were not affected by the graded level of YH supplementation. Though apparent total digestibility of DM (p = 0.012), and N (p = 0.021) showed linear improvement in broilers fed YH supplementation at the end of the trial, it failed to affect the energy (Table 3). Dietary inclusion of YH supplementation showed a beneficial effect on the microbial population as linearly improved *lactobacillus* (p = 0.011), reduced *Escherichia coli* (p = 0.042), and no effect on *salmonella* counts (Table 4). Throughout the experiment, dietary YH supplementation has failed to affect the gas emission of methyl mercaptans, acetic acid, and CO_2. However, the increased level of YH supplement has tended to linearly reduce NH_3 (p = 0.069) and H_2S (p = 0.027), respectively (Table 5). Though, dietary supplement with YH has trend to increase glucose (p = 0.066) and decreased cholesterol (p = 0.069) they did not affect BUN, creatinine, calcium, growth hormone (GH), insulin-like growth factor (IGF), and triglyceride throughout the trail (Table 6). YH supplementation elicited a linear reduction in drip loss (p = 0.045, and 0.021) on day 5 and 7, respectively (Table 7). Furthermore, dietary inclusion of YH supplement had linearly increased VH (p = 0.051), but had no effect on CD (Table 8).

Table 2. The effect of dietary yeast hydrolysate supplementation on the growth performance of broilers

Items	YH supplementation (%)			SEM	*p*-value	
	0	0.1	0.2		Linear	Quadratic
d 1 to 7						
BWG (g)	159	175	187	2	0.789	0.313
FI (g)	186	185	187	2	0.562	0.553
FCR	1.167	1.198	1.192	0.011	0.141	0.218
d 7 to 21						
BWG (g)	583	610	684	9	0.044	0.131
FI (g)	849	871	861	9	0.372	0.157
FCR	1.459	1.433	1.428	0.013	0.041	0.402
d 21 to 35						
BWG (g)	814	884	928	15	0.029	0.102
FI (g)	1,711	1,724	1,717	15	0.893	0.650
FCR	2.113	2.012	1.983	0.035	0.052	0.122
Overall						
BWG (g)	1,557	1,618	1,794	15	0.036	0.164
FI (g)	2,745	2,780	2,766	17	0.582	0.299
FCR	1.766	1.731	1.719	0.017	0.032	0.142
Mortality (%)	3.37	2.98	2.98	-	-	-

YH, yeast hydrolysate; BWG, body weight gain; FI, feed intake; FCR, feed conversion ratio.

Table 3. The effect of dietary yeast hydrolysate supplementation on total tract digestibility of broilers

Items (%)	YH supplementation (%)			SEM	*p*-value	
	0	0.1	0.2		Linear	Quadratic
Day 35						
Dry matter	71.52	73.13	74.74	0.52	0.012	0.138
Nitrogen	68.66	69.54	71.43	1.05	0.021	0.627
Digestible energy	72.24	74.12	73.43	0.67	0.232	0.140

YH, yeast hydrolysate.

Table 4. The effect of dietary yeast hydrolysate supplementation on microbial of broilers

Items (Log_{10}CFU/g)	YH supplementation (%)			SEM	*p*-value	
	0	0.1	0.2		Linear	Quadratic
Day 35						
Lactobacillus	8.75	8.97	9.12	0.02	0.011	0.182
Escherichia coli	6.39	6.20	6.16	0.04	0.042	0.589
Salmonella	4.47	4.26	4.14	0.05	0.102	0.589

YH, yeast hydrolysate.

DISCUSSION

Recently, YH has become a trending supplement in broiler feed and showed a potential approach in enhanced feed intake and reduced environmental pollution [21,22]. In this trial, we observed that dietary supplement with YH had linearly increased BWG of broilers which was consistent with Emmanuel et al. [23] who noted that broilers fed yeast products as yeast cell wall (1.5 g/kg) and autolyzed whole yeast (2.0 g/kg) had increased the BWG during starter, grower, and finisher

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Table 5. The effect of dietary yeast hydrolysate supplementation on gas emission of broilers

Items (ppm)	YH supplementation (%)			SEM	*p*-value	
	0	0.1	0.2		Linear	Quadratic
Day 35						
NH_3	14.5	13.8	11.5	1.6	0.069	0.941
H_2S	2.8	2.1	1.5	0.4	0.027	0.708
Methyl mercaptans	9.0	7.3	6.5	1.8	0.371	0.831
CO_2	1,725	1,525	1,425	248	0.426	0.875
Acetic acid	4.5	3.3	2.5	0.9	0.164	0.827

YH, yeast hydrolysate.

Table 6. The effect of dietary yeast hydrolysate supplementation on blood profile of broilers

Items	YH supplementation (%)			SEM	*p*-value	
	0	0.1	0.2		Linear	Quadratic
Day 35						
BUN (mg/dL)	1.3	1.2	1.2	0.1	0.249	0.496
Creatinine (mg/dL)	0.3	0.3	0.4	0.1	0.525	0.741
Calcium (mg/dL)	9.9	10.3	10.1	0.2	0.439	0.374
Glucose (mg/dL)	145.3	215.2	211.5	17.0	0.066	0.202
Growth hormone (ng/mL)	0.06	0.07	0.07	0.01	0.247	0.367
IGF-1 (ng/mL)	14.3	14.5	13.9	0.5	0.635	0.479
Cholesterol (mg/dL)	137.8	127.8	119.7	6.3	0.069	0.908
Triglyceride (mg/dL)	51.0	39.3	35.0	7.1	0.142	0.681

YH, yeast hydrolysate; BUN, blood urea nitrogen; IGF, insulin-like growth factor.

Table 7. The effect of dietary yeast hydrolysate supplementation on organ weight and meat quality of broilers

Items	YH supplementation (%)			SEM	*p*-value	
	0	0.1	0.2		Linear	Quadratic
Relative organ weight (%)						
Breast muscle	19.66	20.27	20.17	0.88	0.694	0.754
Liver	3.00	3.28	2.87	0.10	0.404	0.134
Spleen	0.08	0.10	0.09	0.01	0.357	0.197
Abdominal fat	1.13	1.17	1.19	0.04	0.404	0.821
Bursa of fabricius	0.16	0.17	0.20	0.03	0.495	0.774
Gizzard	1.25	1.17	1.39	0.08	0.243	0.151
Breast muscle color						
CIE L*	56.22	53.23	56.61	1.40	0.852	0.112
CIE a*	12.78	12.60	11.66	0.99	0.453	0.764
CIE b*	12.32	12.48	12.14	0.52	0.815	0.711
pH value	5.54	5.58	5.65	0.09	0.440	0.901
Cooking loss (%)	31.69	29.20	27.02	2.02	0.153	0.952
WHC (%)	51.44	53.94	56.56	3.19	0.299	0.989
Drip loss (%)						
d 1	2.02	1.82	1.52	0.53	0.703	0.394
d 3	5.94	5.41	5.21	0.77	0.666	0.474
d 5	12.21	11.41	10.02	0.71	0.045	0.821
d 7	15.27	14.53	13.72	0.74	0.021	0.966

YH, yeast hydrolysate; WHC, water holding capacity.

Table 8. The effect of dietary yeast hydrolysate supplementation on villus height and crypt depth in broilers

Items	YH supplementation (%)			SEM	*p*-value	
	0	0.1	0.2		Linear	Quadratic
Day 35						
Villus height	657.93	668.99	683.06	36.00	0.051	0.883
Crypt depth	130.44	160.36	145.12	9.96	0.309	0.077

YH, yeast hydrolysate.

phases. Furthermore, Onifade, [24] reported that dried yeast containing *S. cerevisiae* had improved the BWG of broilers. Only a few documents were found in the addition of YH in broilers, so we made comparisons with other yeast products and other monogastric animal such as pig. In 2012, Zhao et al. [25] observed that the nursery pigs' diet contains yeast extract had improved average daily gain (ADG) and average daily feed intake (ADFI). Likewise, the findings of Li et al. [26] showed that live yeast (*S. cerevisiae*) supplement had significantly enhanced BW, ADG, and feed intake of weaner pigs during the overall experiment. In contrast, this study revealed that dietary YH supplementation has failed to affect the FI of broilers, during the entire experiment. The reason for increased feed intake in Li et al. [26] study may be due to the enhanced palatability of dietary yeast supplements. The enhanced BWG with the increased YH level in this study may have been linked to improving intestinal health leading to better FCR, which is associated with increased enzyme activities and led to increase the protein absorption and nutritional utilization. In 2018, Araujo et al. [27] demonstrate that YH supplement had significantly improved the BWG and FCR of breeder hens (35 wk old). In contrast, our study reveals that broiler fed dietary supplement with YH had linearly decreased FCR compare to those fed with control diet. The inconsistent results may be due to the difference in YH dosage, quantity, or animal's age. Thus, it should be further explored in the future using different dosages, methods, and techniques.

As described by Zhang et al. [28] the yeast products often enhance feed intake and nutrient digestibility of broilers. Furthermore, soybean-meal diets contain oligosaccharides and non-starch polysaccharides (NSP) as β-glucans, cellulose, and arabinoxylans could positively affect their digestibility and utilize all nutrients [29]. In 2014, studies of Li and Kim [30] showed that dietary supplementation with yeast cell wall extract (0.10%) had improved the digestibility of pigs, similarly our research also showed an increased digestibility of DM, and N with the graded level of (0%, 0.1%, and 0.2%) YH which contributes to the growth performance of broilers. Additionally, Keimer et al. [31] noted that 1% of hydrolyzed yeast supplement had increased the nutrient digestibility of energy in weaning pigs. However, in this study a dietary supplement with 0.1%, 0.2% of YH has failed to affect broilers nutrient digestibility of energy. The inconsistent results regarding nutrient digestibility of energy may be due to the difference in yeast types, dosage levels or animals.

The intestinal tract of the chicken is not only highly complex but also contains dynamic microbial populations [32] which plays a significant role in improving intestinal health. In the current study, excreta *Lactobacillus* and *E. coli* counts were positively affected by YH supplementation. Besides, Boontiam et al. [8] found an increased *lactobacillus* count of fecal microbial shedding in weaner pigs fed hydrolyzed yeast supplementation. The increased *lactobacillus* counts and decreased *E. coli* counts in this study with the inclusion of YH supplement was agreed with the results of Sweeney [33] who noted a significant reduction in *E. coli* counts with yeast supplement. Throughout the experiment *Salmonella* counts remain unaffected with a dietary YH supplement. The discrepancies between our study and earlier studies may be due to the dose of YH supplementation, feeding type, as well as intestinal morphology and functions of broilers. Therefore, further study is needed to know the exact mechanisms of dietary YH supplement on excreta microflora of broilers. Ammonia (NH_3),

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Methane (CH_4), Hydrogen sulfide (H_2S), and Carbon dioxide (CO_2) were considered as the most hazardous gases in poultry [34]. In addition, odor emission from livestock industries contributes to civil complains thereby affecting the environment, animals' health and production [35]. Such hazardous gas of H_2S, and NH_3 was linearly reduced in broilers fed dietary YH supplement. Yan et al. [36] stated that harmful gas emission has close relation with nutrient digestibility. We assume that increased digestibility may lower the bacterial fermentation in the large intestine, thereby it reduces the NH_3, and H_2S gas emissions.

The humoral immune response of animals could be identified by serum IGF. Boontiam et al. [8] stated that serum protein level variations could affect animal productivity and immunity. In addition, Zhang et al. [28] reported that the yeast extract had decreased the blood cholesterol content in pigs and this statement was agreed with our findings that dietary supplement with YH has linearly reduced cholesterol content in broilers. A study by Zhang et al. [28] noted that dietary supplement with yeast had enhanced the GH and the immune response of pigs. Also, Kim et al. [37] stated that the dietary inclusion of 1.0% of the yeast in rats' diet had enhanced its GH level. However, in this study except for a linear increase in glucose and linear reduction in cholesterol level, no significant effects were observed on other measured blood indices with the graded level of YH supplement. To date, the influence of supplementing YH to the broiler, obtain a high effect on the blood profile has not been elucidated. Thus, comparisons could not be made with other studies.

It is a complex concept to determine poultry meat quality because it always depends on consumer preferences [38]. In 2007, Duclos et al. [39] stated that the carcass must have maximum meat yield with low-fat content to produce good meat quality. However, this statement was agreed with our study that broilers fed YH supplement has reduced cholesterol content. According to Lee et al. [40] chicks fed yeast supplement has enhanced the water holding capacity and tenderness. However, in this study, the YH supplementation failed to affect WHC. The quality of meat can be assessed by drip loss. Such drip loss had linearly reduced in this study at days 5 and 7 with YH supplementation, and this finding was correlated with the study of Li et al. [41] who noted a significant reduction in drip loss (day 7) in pigs fed increased level of yeast supplement. Intestinal VH and CD indicate the proliferation and absorptive capacity [42] of developed intestinal components [43]. Such, intestinal villus to crypt ratios is commonly used to assess the effects of dietary regimens on gut microanatomy. Keimer et al. [31] demonstrate that weaner pigs had significantly increased VH, and reduced CD in the colon when fed with 1% hydrolyzed yeast, and this result agreed with our findings graded level of YH supplement linearly increased VH. Our study showed that CD was not affected by YH supplement, but a controversial result was observed in the study of Carlson et al. [44] who observed shorter CDs in nursery pigs fed a yeast diet. The dissimilarity between our study and previous studies, may be due to the complex effects of YH supplement or intestinal VH and CD of different animals.

CONCLUSION

Our findings showed that incorporating YH supplement in the diet of broilers could significantly enhance the growth performance of BWG and nutrient digestibility of DM and N, shifted microbiota by raising excreta *Lactobacillus* counts and decreased *E. coli* counts. In addition, YH supplement had linearly decreased drip loss, noxious gas (NH_3 and H_2S), and cholesterol level. Based on the positive results, we recommend that YH supplement could be used as an excellent alternative solution to boost the production performance of broilers.

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