



## Yeast fermented additive enhances broiler growth

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**ABSTRACT** - We investigated the effects of dietary supplementations of yeast (YFA) or non-yeast fermented additives (NYFA) at 5.0 and 10 g kg<sup>-1</sup> on the performance parameters and the size of digestive organs of broiler chickens. An isocaloric and isonitrogenous basal diet used as negative control was added with 5.0 or 10.0 g kg<sup>-1</sup> of YFA or NYFA. Each of five experimental diets was given to broiler chickens kept in three randomized floor pens, each with 21 birds, from one-day old to 42 days old. Although the feed intake of broiler chickens was not significantly influenced by the diets, there were significant increases in weight gain and improvements in feed conversion ratio and carcass yield in broiler chickens fed the diets supplemented with 5.0 and 10 g kg<sup>-1</sup> of YFA and NYFA. The rate of improved weight gain and feed conversion ratio by the dietary treatments was proportional to their viable yeast counts. The diet containing 10 g kg<sup>-1</sup> of NYFA was not recommended due to remarkably reduced carcass yield as a result of increased weights of digestive tract. The remaining dietary treatments generally caused a reduced length and relative weight of the digestive tract. Of the dietary treatments, the diet containing 10 g kg<sup>-1</sup> YFA caused a significant increase in digesta viscosity with the diet. Significant growth-promoting effects were obtained from the dietary supplementations of 5.0 g kg<sup>-1</sup> NYFA or 5.0 and 10 g kg<sup>-1</sup> YFA.

Key Words: broiler, fermentation, microbial additive, yeast

### Introduction

Yeast-containing additives could be used as alternatives to the feed antibiotics due to their beneficial performance and health effects on monogastric animals (Dhama et al., 2015; Wang and Xu, 2008; Dębski et al., 2004), especially under heat stress (Haldar et al., 2011). In poultry, yeast probiotics have been found more effective than other probiotics to improve performance of birds (Reisinger et al., 2012; Yasar and Desen, 2014). Furthermore, a new report testing several probiotics of *Lactobacillus* spp. showed no favorable effects on broiler performance (Olnood et al., 2015). Nevertheless, the supplementation of the diets with yeast probiotics at 0.15 to 0.3% have been shown to improve the performance of birds to a level achieved by the use of dietary antibiotic levels (Onifade et al., 1999). It has been recently shown that this kind of effect is due to the bacteriocin-producing

effects of yeast probiotics when used single or together with lactic acid bacteria species in the diet of broiler chickens (Chen et al., 2016).

In general, the fermented products are the microbial products of solid-state fermentation (SSF) utilized from generally regarded as safe microorganisms. It is well known that the microbial enzymes and several types of feed probiotic additives are produced through the SSF process, in which the production yield is higher than that in liquid state fermentation (Nigam and Pandey, 2009). In such SSF process, the optimization of fermentation conditions is very important. For instance, an unaffected broiler performance was reported with a feed fermented at the conditions of low water content of 250 g kg<sup>-1</sup> and pH above 5.0 without use of microbial inoculants. However, when the feed fermented at the same conditions with the use of microbial inoculants, it comparatively induced improved broiler performance (Chen et al., 2009). This result clearly indicates that low water activity and high pH values (more than 5.0) are not suitable for the activation of endogenous natural microbiota of the fermenting substrate, in which the addition of exogenous microbial inoculant is necessary. Based on our recent findings (Yasar et al., 2016; Yasar and Gok, 2014), an optimised SSF process using no exogenous microbial inoculation was used to produce fermented products, which improved nutritional value in poultry. These feed materials were also good carriers for direct-fed

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microbial (*Saccharomyces* spp., and *Lactobacillus* spp.). The optimization of SSF process in these studies was managed under the conditions of moisture content not less than 600 g kg<sup>-1</sup> and pH of less than 5.0 (Yasar et al., 2016; Yasar and Gok, 2014). In these studies, it was shown that the fresh liquid whey could be used instead of water to yield the required amount of moisture content and citrus pomace as acidifying agent for lowering pH.

We herein proposed to determine the efficacy of yeast (YFA) and non-yeast fermented additives (NYFA) produced according to an optimized SSF process in a broiler feeding trial.

## Material and Methods

The study was conducted in Isparta, Isparta Province, Turkey (37°45'45.536" N and 30°33'13.338" E).

A mixture of cereal grain flour, whey, and tomato pomace was prepared in two batches, each with 40 kg. The ratio of fermentation ingredients used is confidential of an on-going patent application, not provided herein. The first batch of YFA was produced by the inoculation of *Saccharomyces cerevisiae* at 9×10<sup>9</sup> cfu (colony-forming unit) per kg, whereas no microbial inoculants were used for the production of second batch of NYFA. Two batches of fermentation were conducted in a 90-L laboratory bioreactor under fixed and controlled conditions for 24 h at 35 °C, pH <5.0 and 60% total moisture. Fine powder of rosemary leaves was homogenously mixed with final products before drying. Total titratable acidity of the fermentation product at 0 and 24 h was measured by the titration of 10 times diluted samples with 0.02 M NaOH until an endpoint of pH 8.2 was reached and the results were calculated as percentage of the total mass (w/w). The fermented mixture was immediately dried at 24 °C for 72 h. The viable cell counts of *Saccharomyces* spp. in YFA and NYFA and the diets containing YFA and NYFA were enumerated as cfu by a pour plate method (ISO, 2009), using yeast extract dextrose chloramphenicol agar (CGYE) incubated at 35 °C for 48 h.

Dried YFA and its positive control of NYFA were added to a basal diet (negative control) at 5.0 or 10.0 g kg<sup>-1</sup> at the expense of wheat grain (Table 1). Thus, these five isocaloric and isonitrogenous diets were tested in a broiler feeding trial, which was approved by the local Animal Ethic committee of 26/02/2013 (tarih ve 01 sayı).

Three hundred fifteen one-day-old birds (Ross 308PM), kept on 15 randomized floor pens, each with 21 chicks were fed the diets. The experimental model was of five diets by

three randomized pen replicates. The trial lasted from 1 to 42 days of age. Feed and water were freely accessible to the birds. Room temperature was 34±1 °C at the beginning of the experiment and gradually decreased to 24 °C on 21st day of the experiment. The amount of consumed feed (feed intake, FI) of birds kept in each pen was daily recorded. The birds were weighted at the end of every week to measure individual body weight (BW). Weight gain (WG) and feed conversion ratio (FCR) were calculated from the weekly FI and BW values per pen.

The carcass yield, length, and weight of digestive tract (TDT), foregut (esophagus, crop, gizzard, proventriculus), small intestine, ceacae, and colon were measured in three birds from each replicate pen at 21 days of age and in all birds at the age of 42 days.

The ileal contents were collected and centrifuged to obtain supernatants for the measurements of its viscosity using a Brookfield LVTD-CP-40, USA) and its pH using a digital pH meter.

The data regarding growth performance was subjected to analysis of variance according to general linear model (GLM) using the SPSS statistical program (SPSS, version 22), in which a least significant difference test (P<0.05) was applied to the treatment means.

Table 1 - Compositions of basal diet (negative control)

Percentage of feed material (g kg <sup>-1</sup> as fed)	Starter period (from 0 to 21 days of age)	Grower and finisher periods (from 21 to 42 days of age)
Yellow corn	300.0	400.0
Soybean meal	250.0	213.0
Wheat	283.0	250.0
Vegetable oil	45.0	60.0
Fish meal	90.0	50.0
Calcium carbonate	10.0	9.0
Dicalcium phosphate	13.0	10.0
Salt	3.0	3.0
Vitamin-mineral mixture <sup>1</sup>	4.0	4.0
DL-methionine	2.0	1.0
Analyzed nutrient (g kg <sup>-1</sup> )		
Dry matter	889.0	900.0
Protein	230.0	200.0
Fat	67.0	59.0
Total fiber	33.0	50.0
Metabolizable energy (kcal kg <sup>-1</sup> ) (calculated)	3,122	3,250
Ca (calculated)	10.0	9.0
Available P (calculated)	5.0	4.2

<sup>1</sup> A kg of premix provided: vitamin A, 5,000,000 IU; vitamin D<sub>3</sub>, 750,000 IU; vitamin E, 25,000 ppm; vitamin K<sub>3</sub>, 2,000 ppm; vitamin B<sub>1</sub>, 2,500 ppm; vitamin B<sub>2</sub>, 5,000 ppm; vitamin B<sub>6</sub>, 2,500 ppm; niacin, 30,000 ppm; calcium D-pantotenate, 10,000 ppm; folic acid, 1,000 ppm; biotin, 100 ppm; Mn, 37,500 ppm; Fe, 50,000 ppm; Zn, 40,000 ppm; Cu, 7,500 ppm; I, 250 ppm; Co, 100 ppm; Se, 100 ppm.

## Results

Average moisture content of both SSF batches (YFA and NYFA) at 0 h of fermentation period was 600 g kg<sup>-1</sup>, which was reduced to 580 g kg<sup>-1</sup> by the end of 24 h of fermentation. This is an expected increase in dry matter during the SSF process. The final wet products were dried for 72 h at room temperature. The moisture levels of both SSF batches did not differ significantly ( $P>0.05$ ) at 24, 48, and 72 h. The averaged corresponding moisture contents at 24, 48, and 72 h were 180, 140, and 100 g kg<sup>-1</sup>, respectively. At 0 h fermentation, YFA and NYFA products had a pH of 5.88±0.5 and 5.99±0.3, respectively, and the corresponding values were reduced to 3.90±0.7 in YFA and 4.08±0.2 in NYFA product by the end of 24 h of fermentation. The reduction in the pH was parallel to the titratable acidity values of both feed additives, which were almost the same, 56±1.55 g kg<sup>-1</sup>, as compared with the value of 5.0±0.5 g kg<sup>-1</sup> of the same substrates at 0 h of the fermentation period.

There was a significant ( $P<0.05$ ) difference in viable yeast counts between the NYFA and YFA. Non-yeast fermented additives have an active yeast count of  $3\times 10^{10}\pm 0.15$  cfu kg<sup>-1</sup>, which was significantly ( $P<0.05$ ) higher than that of YFA, measured as  $9\times 10^8\pm 0.017$  cfu kg<sup>-1</sup>. Microbial activity was reduced nearly by a 1.0 log in YFA, while YFA was initially inoculated with  $9\times 10^9$  cfu yeast per kg. The differences in viable yeast counts of YFA and NYFA were well reflected on the yeast counts of the diets supplemented with these additives. The diet supplemented with NYFA at 5.0 g kg<sup>-1</sup> has a  $1.52\times 10^7\pm 0.045$  cfu kg<sup>-1</sup> and the diet supplemented with NYFA at 10.0 g kg<sup>-1</sup> had a  $3.10\times 10^7\pm 0.25$  cfu kg<sup>-1</sup> active yeast counts, respectively. Similarly, the diet supplemented with YFA at 5.0 g kg<sup>-1</sup> had a yeast count of  $4.55\times 10^5\pm 0.75$  cfu kg<sup>-1</sup> and the diets supplemented with YFA at 10.0 g kg<sup>-1</sup> had a yeast count of  $9.20\times 10^5\pm 0.10$  cfu kg<sup>-1</sup> (Table 2).

The birds fed the test diets had almost similar FI at both 21 and 42 days of age (Table 3), except that the birds fed the diet supplemented with NYFA at 10 g kg<sup>-1</sup>

Table 2 - Active yeast cell counts (cfu kg<sup>-1</sup>) of the diets supplemented with NYFA and YFA at 5.0 and 10.0 g kg<sup>-1</sup>

	Treatment (g kg <sup>-1</sup> )				
	NC	NYFA		YFA	
		5.0	10.0	5.0	10.0
Yeast cells (cfu kg <sup>-1</sup> )		$1.52\times 10^7$	$3.10\times 10^7$	$4.55\times 10^5$	$9.20\times 10^5$

NC - negative control; NYFA - non-yeast fermented additives; YFA - yeast-fermented additives; cfu - colony-forming units.

Table 3 - Effects of NYFA and YFA supplementations at 5.0 and 10.0 g kg<sup>-1</sup> on body weight, weight gain, feed intake, and feed conversion ratio of birds at the ages of 21 and 42 days

	Treatment (g kg <sup>-1</sup> )					SEM	P-value	
	NC	NYFA		YFA				
		5.0	10.0	5.0	10.0			
n	63	63	63	63	63	-	-	
	Body weight (g/bird)							
Day 0	54.7	54.8	55.0	54.2	54.5	0.5	0.172	
Day 21	907a	968b	964b	895a	918a	19	0.0001	
Day 42	2276a	2406b	2502b	2286a	2374ab	72	0.0001	
	Weight gain (g/bird)							
Day 21	852a	914b	909b	840a	863a	19	0.0001	
Day 42	2221a	2351ab	2447b	2232ab	2320ab	72	0.0001	
	Feed intake (g/bird)							
Day 21	1561	1569	1557	1532	1519	33	0.361	
Day 42	4890	4934	5088	4842	4906	104	0.117	
	Feed conversion ratio							
Day 21	1.83a	1.72b	1.72b	1.82a	1.76ab	0.04	0.015	
Day 42	2.20a	2.10b	2.08b	2.17ac	2.11bc	0.03	0.003	
	Dead							
0-42 days	1	3	3	0	1	-	-	

NC - negative control; NYFA - non-yeast fermented additives; YFA - yeast-fermented additives; SEM - standard error of the mean.  
a-c - Different letters indicate significant ( $P<0.05$ ) difference between the means of treatment groups.

numerically increased FI at 42 days of age. Effects of YFA and NYFA on BW, WG, and FCR on broilers were significant ( $P<0.05$ ) at 21st and 42nd days of experiment (Table 2). Comparing with the values obtained with the birds fed the negative control diet, there was a significant increase ( $P<0.05$ ) in BW and WG of the birds fed the diets containing NYFA at 5 and 10 g kg<sup>-1</sup> at the 21st day and 42nd day. Significantly ( $P<0.05$ ) improved FCR values were obtained from the 21-day-old birds fed diets of NYFA at both supplementation doses, compared with FCR of the birds fed the negative control diet. Similarly, the FCR values of 42-day-old birds fed the diets of NYFA of both doses and the diet supplemented with YFA at 10 g kg<sup>-1</sup> were remarkably ( $P<0.05$ ) higher than the FCR value of birds fed the negative control diet. Furthermore, the number of dead birds fed the different diets was found insignificant in our study (Table 2).

Carcass yield of broilers was not influenced by dietary treatments at the 21st day (Table 4). But, there was a significant ( $P<0.05$ ) reduction in the carcass weight of 42-day-old broilers fed the diet supplemented with NYFA at 10 g kg<sup>-1</sup>.

The weight of TDT was not influenced by the dietary diets at 21st day of the study, but significantly ( $P<0.05$ ) influenced at the 42nd day of this study (Table 4). Of the birds at 42 days old, the birds fed the diet supplemented with NYFA at 5.0 g kg<sup>-1</sup> and YFA at 10.0 g kg<sup>-1</sup> had significantly ( $P<0.05$ ) reduced weight of TDT. Highest TDT weight was obtained from the birds fed the diet supplemented with NYFA at 10 g kg<sup>-1</sup>. When compared with the negative control diet, all the dietary treatments at the 21st day of

the study and only the diets supplemented with NYFA at 5.0 g kg<sup>-1</sup> and YFA at 10.0 g kg<sup>-1</sup> at the 42nd day of the study caused a significant ( $P<0.05$ ) reduction in heart weight. The diet supplemented with NYFA at 5.0 g kg<sup>-1</sup> significantly ( $P<0.05$ ) reduced liver weight as opposed to a significantly increased liver weight ( $P<0.05$ ) in the birds fed the diet supplemented with NYFA at 10.0 g kg<sup>-1</sup>, only at the age of 42 days. These effects of treatments were, however, sporadic.

The dietary treatments had a significant ( $P<0.05$ ) effect on the lengths of TDT, foregut, and small intestine of broilers at the 42nd day of the study, but not at the 21st day (Table 5). A significant ( $P<0.05$ ) and constant reduction in the lengths of various digestive segments (TDT, foregut, small intestine, caeca, and colon) was observed in the birds fed the diets supplemented with NYFA at 5.0 g kg<sup>-1</sup> as opposed to a significant reduction of these parameters in the birds fed the diet supplemented with NYFA at 10.0 g kg<sup>-1</sup> at the 42nd day of this study (Table 5). The effects of the diet supplemented with NYFA and YFA at other doses were sporadic, not consistent. In this study, the viscosity and pH of ileal contents of broilers were not affected by the dietary treatments, although there was an increased ileal viscosity in the broilers fed the diet supplemented with YFA at 10 g kg<sup>-1</sup> (Table 6).

## Discussion

The SSF in this study lasted for 24 h by a successful optimization of the fermentation conditions. During SSF, the temperature ranged from 37 to 39 °C, pH from 5.0 at 0 h

Table 4 - Effects of NYFA and YFA supplementations at 5.0 and 10.0 g kg<sup>-1</sup> on carcass yield (kg per 100 kg BW) and weights (g per bird) of total digestive tract (TDT) and digestive organs of birds at days 21 and 42

	Treatment (g kg <sup>-1</sup> )					SEM	P-value
	NC	NYFA		YFA			
		5.0	10.0	5.0	10.0		
Carcass yield							
Day 21	59.2	60.1	59.3	59.2	60.4	1.2	0.112
Day 42	73.8a	74.4a	71.8b	73.4ab	75.0a	0.8	0.001
TDT weight							
Day 21	112.9	116.3	110.6	111.0	108.0	4.7	0.12
Day 42	236.5ab	220.6b	258.8a	247.0ab	226.4b	14.1	0.001
Heart weight							
Day 21	6.8a	5.9b	5.7bc	5.1c	5.6bc	0.3	0.001
Day 42	16.8a	14.5b	17.5a	17.5a	14.8ab	1.0	0.001
Liver weight							
Day 21	27.9	28.0	28.6	25.8	26.4	1.4	0.65
Day 42	57.7a	48.0b	63.4a	57.0a	57.9a	2.4	0.001

BW - body weight; NC - negative control; NYFA - non-yeast fermented additives; YFA - yeast-fermented additives; SEM - standard error of the mean.  
a-c - Different letters indicate significant ( $P<0.05$ ) difference between the means of treatment groups.

to around 4.0 and moisture content from 600 to 580 g kg<sup>-1</sup>. The pH under 5.0 is suitable for inhibition of pathogenic microorganisms. Further decrease in pH of the fermented substrate was normally caused by the productions of organic acids (Canibe and Jensen, 2003; Canibe et al., 2006), whose levels were significantly high (56 g kg<sup>-1</sup>) in this study. Overall, the results of fermentation parameters in this SSF process were similar to the results obtained previously (Yasar et al., 2016; Yasar and Gok, 2014; Chen et al., 2013).

No increased FI of the birds by the dietary treatments in this study was observed with the supplementations of poultry diets with similar feed additive products, suggesting that the beneficial performance effects of probiotic additives are not regulated by the changes in voluntary feed intake in poultry (Gao et al., 2008; Sarica et al., 2009).

The results of promoted growth rate and improved FCR in the case of diets supplemented with NYFA and YFA in our study were in good agreement with the results reported earlier (Yasar and Desen, 2014; Reisinger et al., 2012; Haldar et al., 2011). On the other hand, there were other studies reporting different results with the use of the same probiotic product in broiler chickens. Although there was no influence of 0.5 and 1.0% supplementation of a probiotic additive (protexin) neither on growth performance nor on carcass yield in Japanese quails (Ayaşan, 2016), the same additive significantly ( $P < 0.05$ ) increased the body weight of broiler chickens (Fallah, 2016). This is typically due to the differences between the poultry species; the probiotic feed additives are specifically designed and formulated for each species by the manufacturers.

Table 5 - Length (cm per bird) of total digestive tract (TDT), foregut (esophagus, crop, proventriculus, and gizzard), small intestine, caeca, and colon of birds of 21 and 42 days old fed the negative control diet and the diets supplemented with NYFA and YFA at 5.0 and 10.0 g kg<sup>-1</sup>

	Treatment (g kg <sup>-1</sup> )					SEM	P-value
	NC	NYFA		YFA			
		5.0	10.0	5.0	10.0		
	TDT						
Day 21	157.5	154.8	160.9	153.4	155.8	4.9	0.85
Day 42	209.5ab	179.5c	221.6a	212.6a	195.9b	6.9	0.001
	Foregut						
Day 21	14.8	14.6	14.2	14.5	15.5	0.7	0.78
Day 42	23.0a	20.0b	23.2a	21.7ab	20.9b	0.9	0.001
	Small intestine						
Day 21	126.4	123.7	130.5	123.7	124.8	5.8	0.99
Day 42	166.8ab	142.6c	176.7a	171.0a	155.9bc	7.6	0.001
	Caeca						
Day 21	13.2ab	12.7b	12.9b	12.7b	14.1a	0.4	0.001
Day 42	17.5ac	13.5b	19.83a	18.8a	16.9c	0.8	0.001
	Colon						
Day 21	6.3a	6.5a	6.1a	5.4b	5.6b	0.3	0.001
Day 42	8.4ab	7.3a	10.0c	10.5c	8.9b	0.5	0.001

NC - negative control; NYFA - non-yeast fermented additives; YFA - yeast-fermented additives; SEM - standard error of the mean.

a-c - Different letters indicate significant ( $P < 0.05$ ) difference between the means of treatment groups.

Table 6 - Viscosity (cPs) and pH of ileal contents of birds of 21 and 42 days old fed the negative control diet and the diets supplemented with NYFA and YFA at 5.0 and 10.0 g kg<sup>-1</sup>

	Treatment (g kg <sup>-1</sup> )					SEM	P-value
	NC	NYFA		YFA			
		5.0	10.0	5.0	10.0		
	Viscosity						
Day 21	2.4a	2.6a	2.5a	2.5a	2.9b	0.1	0.015
Day 42	2.2	2.3	2.1	2.2	2.6	0.3	0.65
	pH						
Day 21	6.8	6.7	6.6	6.7	6.6	0.1	0.47
Day 42	6.1	6.1	6.1	6.1	6.3	0.1	0.83

NC - negative control; NYFA - non-yeast fermented additives; YFA - yeast-fermented additives; SEM - standard error of the mean.

a-c - Different letters indicate significant ( $P < 0.05$ ) difference between the means of treatment groups.

Improved growth rate and FCR in our study seemed to be due to high inclusion levels of NYFA and YFA products. The levels of 5.0 and 10.0 g kg<sup>-1</sup> were relatively high as compared with the rates tested in previous studies, ranging from 0.45 to 3.0 g kg<sup>-1</sup> of the diet (Yasar and Desen, 2014; Fasina and Thanissery, 2011; Sarica, et al., 2009; Zhang et al., 2005). On the other hand, improved growth performance was much more associated with the active yeast counts of diets to which the probiotics were added. A kilogram of diet containing yeast probiotic at 2.3×10<sup>5</sup> cfu (Chen et al., 2009), 1.3×10<sup>7</sup> cfu (Zhang et al., 2005), and 4.3×10<sup>7</sup> cfu (Shim et al., 2012) were found very effective to induce significant improvements in broiler performance. All the above indicated that the higher yeast counts (up to 10<sup>9</sup> cfu kg<sup>-1</sup>), the higher performance improvement in broilers (Shim et al., 2012; Kim et al., 2012). Yeast fermented additives were produced by the use of yeast inoculant at 9×10<sup>9</sup> cfu kg<sup>-1</sup> at the start of SSF, while the final dried product of YFA at the end of 24-h fermentation has only an active yeast count of 9×10<sup>5</sup> cfu kg<sup>-1</sup>. In contrary, the final product of NYFA, to which no yeast inoculant was initially added, reached to a high active yeast number of 3×10<sup>7</sup> cfu kg<sup>-1</sup> at the end of fermentation. This is normally explained by the fact that the level of yeast inoculation in YFA was already too high and the microbial phase was quickly entered to the dead phase by the end of 24 h, thereby reducing the number of viable cells. Having considered the levels of active yeast counts in the diets, the differences between the diets were well reflected on the bird performance in this study. There were significant improvements both in the growth rate and FCR of the birds fed the diet supplemented with NYFA at 5 and 10 g kg<sup>-1</sup>, whereas there was only a significant improvement in the FCR of the birds fed the diet supplemented with 10 g kg<sup>-1</sup> of YFA. Furthermore, the fermentation process in this study was done with the help of value-adding co-products, i.e., whey, pomaces of tomato and citrus, and rosemary, which could have added new functionalities to the final products. The fermented feed materials produced from this SSF process were found with high efficacies in broilers due to organic acids, flavoring agents, endogenous enzymes, probiotics, and antioxidants from these co-products (Yasar et al., 2016; Yasar and Gok 2014; Chen et al., 2013; Dhillon et al., 2012, Canibe et al., 2006; Canibe and Jensen, 2003).

Birds fed diets containing yeast probiotics had increased carcass yield and increased weights of digestive organs (gizzard, heart, and liver), despite the reduced abdominal fat (Zhang et al., 2005; Panda et al., 2000; Paryad and Mahmoudi, 2008; Onifade et al., 1998). Contrary to these studies, there were increases in carcass weights of the birds

fed the yeast-supplemented diets in our study, except that the diet supplemented with NYFA at 10 g kg<sup>-1</sup> reduced carcass weight. Nevertheless, the dietary yeast supplementation generally improves carcass yield in broiler chickens, which was well correlated with reduced weights of digestive organs. In our study, the reduced carcass yield by the diet supplemented with NYFA at 10 g kg<sup>-1</sup> was due to increased weight of TDT. Furthermore, in our study, there were sporadic changes in heart and liver weights affected by the dietary treatments. Similar changes in digestive organ weights were previously reported with the diet fermented with yeast inoculant at 10<sup>6</sup> cfu kg<sup>-1</sup> (Chen et al., 2013, Hossain et al., 2012 Chen et al., 2009). In our study, the changes in digestive organ weights were similarly reflected on the changes in the lengths of entire digestive tract, foregut, and small intestine (Table 5).

The diets with yeast probiotic products had a positive effect on the development of intestinal epithelial region (Adebiyi, et al., 2012; Gao et al., 2008) and improved immune system (Solis de los Santos et al., 2007). These effects were also reported in young growing chicks (Fasina and Thanissery, 2011). Therefore, it can be concluded that improved growth rate and FCR with the diet supplemented with NYFA at 5.0 g kg<sup>-1</sup> may have been modulated by early maturations of intestinal segments and remained intact. Furthermore, the weight of digestive organs remained relatively low in the birds fed the diets supplemented at the above doses due to an increased growth rate and FCR.

## Conclusions

Supplementing the diets with 5.0 and 10 g kg<sup>-1</sup> of yeast fermented additives or 5.0 g kg<sup>-1</sup> of non-yeast fermented additives is highly recommended for enhancing growth rate due to its high level of active yeast cells, while a 10 g kg<sup>-1</sup> dietary supplementation of non-yeast fermented additives cannot be used due to decreased carcass weights.

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