Broiler's performance and carcass characteristics improvement by prebiotic supplementation

AMENI ASKRI*[1a], AZIZA RAACH-MOUJAHED[1b], NACEUR M'HAMDI[1b], ZIED MAALAOUI[2], HAJER DEBBABI[1a]

[1a] Department of Agro Food Industries, UR17GR01 PATIO; [1b]Department of Animals'Sciences; National Agronomic Institute of Tunisia, University of Carthage, 43 Av. Charles Nicolle, Tunis 1082
[2] Arm & Hammer Animal Nutrition, North Africa, Tunis, Tunisie, Adresse, Tunis 1002

SUMMARY

The objective of the present study was to assess the influence of the supplementation of the increasing levels of *Saccharomyces cerevisiae*-derived prebiotic on broiler's diets on their growth performances and carcass characteristics. A total of 192 male chicks Arbor Acres were randomly distributed into four dietary treatments with six replicates each and were housed in cages (8 birds/cage). Dietary mixtures in the experiments were as follows: the control group (T0) received the basal diet, and the experimental groups (T1, T2, and T3) received a basal diet supplemented with 1; 1.5 and 2 g/kg of prebiotic, respectively. Growth performances are measured; Weight Gain (WG), ADG (Average Daily Gain), Daily Feed Intake (DFI), and Feed Conversion Ratio (FCR) throughout the trial period. The carcass quality was also studied. It was observed that prebiotic supplementation enhanced the body growth rate. On the final day of the experiment, the body weight was significantly increased ($P<0.01$) in the treated groups in comparison with that of the control group. The highest achieved chicken body weight was in treatment T3 (2278.73±188 g) which was followed by treatment T1 (2215.73±179 g) with statistically significant differences ($P <0.05$). In carcass, the highest yield was recorded in dietary treatment T2 (76.21 %) which was statistically significant ($P <0.05$) higher compared to the control group (74.25%). Also, the supplementation of prebiotic to broiler's diet decreases significantly the small intestine weight compared with the control (60.9±9.29 vs 65.7±10.17 g). In conclusion, our study has shown that the supplementation of the increasing levels of *Saccharomyces cerevisiae*-derived prebiotic in a broiler diet can improve growth performance.

KEY WORDS

Broiler, carcass characteristics, levels, feed conversion ratio, prebiotic.

INTRODUCTION

The use of antibiotics as growth promoters (AGPs) in poultry nutrition has been associated with the fast-growing nature of broiler chickens (Puva a et al., 2013; Sarica et al., 2005). Although, Donoghue (2003) affirmed that chicken reared with the addition of antibiotics achieved good performance but their potential side effects became a real public health global problem. Antibiotics lead to drug resistance in bacteria and drug residues in poultry products (Issa and Omer, 2012). Therefore, the wish to decrease the usage of antibiotics in animal production, replacements have been developed, such as probiotics, prebiotics, synbiotics, and herbal medicines (Castanon, 2007). Prebiotics were successfully used in the broiler diet as potential alternatives to antibiotics. By definition, prebiotics is non-digestible food ingredients fermented by intestinal microbiota. It beneficially affects the host by stimulating selectively the growth and/or activity of one or a limited number of bacteria in the colon (Gibson and Roberfroid,1995). Optimal characteristics of prebiotic were described by Patterson and Burkholdar (2003): (1) prebiotics should not be hydrolyzed by animal gastrointestinal enzymes, (2) prebiotics cannot be absorbed directly by cells in the gastrointestinal tract, (3) prebiotics selectively enrich one or limited numbers of beneficial bacteria, (4) prebiotics alter the intestinal microbiota and their activities and (5) prebiotics improve luminal or systemic immunity against pathogen invasion. Several in vivo studies have shown that dietary supplementation of prebiotic had beneficial effects on productive traits and gut health. Prebiotics stimulate the proliferation of beneficial bacteria, inhibit the colonization of pathogenic bacteria, improve nutrient absorption, promote growth rate and feed utilization efficiency (Pourabedin et al., 2015; Mathlouthi et al, 2012). Commercial prebiotics is mainly obtained by enzymatic processes, impacting their cost of production and therefore their price for the farmers (Hajati and Rezaei, 2010). A preliminary study conducted by Askri et al. (2018) indicated that the administration of *Saccharomyces cerevisiae*-derived prebiotic to broilers could enhance growth performances, but has altered meat sensory quality. This study, therefore, was planned with the basic objective to optimize the inclusion levels of commercial prebiotic AVIATOR® in broiler diet for improving growth performance and carcass characteristics when prebiotic was removed one week before slaughter.

Corresponding Author:
Ameni Askri (askria.ing@gmail.com)

Table 1 - Ingredient and nutritive values of the basal diet (g/kg).

Ingredients (%)	Starter (d1-14)	Grower-Finisher (d15-42)
Corn	64	69
Soybean meal	32	27
Mineral[A] and vitamin[B] mixture	4	4
Anticoccidial	None	None
Total	100	100
Calculated nutrient Content		
ME[C](Kcal/Kg)	2900	2970
Crude Protein %	20.5	19.5
Crude fiber %	3	3
Ash %	6.5	6.5
Fat %	3	4
Calcium %	1	0.9
Available Phosphorus %	0.67	0.66
Methionine %	0.5	0.44
Threonine %	0.8	0.78
Tryptophan %	0.3	0.25

[A]Mineral mixture supplied (mg·kg-1 of diet): CF1: Mn. 80; Fer. 50; Cu. 25; Zn. 65; Co. 0.2; Se. 0.3; I. 1.2/ CF2: Mn. 70; Fer. 40; Cu. 20; Zn. 52; Co. 0.16; Se. 0.24; I. 0.69. [B]Vitamin mixture supplied per kg of diet: CF1: Vit A. 13000 IU; Vit D3. 3500 IU; Vit E. 40 mg/ CF2: Vit A. 10400 IU; Vit D3. 2800 IU; Vit E. 32 mg. [C]ME: metabolizable energy.

MATERIALS AND METHODS

Ethical considerations

All procedures related to animal care, handling, and sampling were conducted under the approval of the Official Animal Care and Use Committee of National Agronomic Institute of Tunisia (protocol N° 05/15) before the initiation of research and followed the Tunisian guidelines.

Birds and housing

This experiment was carried out in the poultry unit of the National Agronomic Institute of Tunisia. One hundred and ninety-two male day-old chicks from the "Arbor Acres" strain (average body weight: 45.53 ± 3.59 g) were used in the current trial over 42 days. All birds were individually identified, weighed, divided into four groups and were housed in individual cages. There were six replicates for each group with 8 chicks per cage. All birds were vaccinated against Newcastle Disease, Infectious Bronchitis, and Gumboro. The room temperature was gradually decreased from 33°C at day 3 to 24°C until the end of the experiment and continuous light was provided. Feed and water were supplied *ad libitum* throughout the experiment.

Dietary treatments

The basal diet composition is presented in Table 1. It was composed of corn and soybean meal and was formulated according to the nutritional requirements for chickens (National Research Council, 1994). All chicks were fed starter and grower-finisher diets from 1 to 14 d and 15 to 42 d age, respectively. All diets were given in the floury form (fine particles) and did not contain antimicrobial growth promoters or coccidiostats. The prebiotic AVIATOR® is based on a yeast culture and products of the enzymatic hydrolysis of the yeast wall: *Saccharomyces cerevisiae* such as mannan oligosaccharides (MOS), mannose, beta-glucans, and galactosamines. Following results found by Askri et al (2018), the prebiotic was removed one week before slaughter to avoid meat sensory quality alteration. The dietary treatments were: The control group received a basal diet (T0) without prebiotic. The experimental groups (T1, T2, and T3) received a basal diet supplemented with, respectively, 1; 1.5 and 2 g/kg of prebiotic. All experimental diets had the same nutrient level.

Measurements

Performances

Broiler chickens were weighed individually each week at the same time. Daily Feed intake (DFI) was calculated, during the whole experiment for each treatment, by the following mathematical formula:

$$\text{DFI (g/d/b)} = \frac{\text{Feed supplied (g)-Feed refused (g)}}{\text{Number of days (d)}}$$

The average daily weight gain (ADG) was calculated as follow:

$$\text{ADG (g/d/b)} = \frac{\text{Final Body Weight (g)-Initial Body Weight (g)}}{\text{Number of days (d)}}$$

And the feed conversion ratio (FCR) were calculated subsequently:

$$\text{FCR (g/g)} = \frac{\text{Daily Feed Intake (DFI)}}{\text{Average Daily Gain (ADG)}}$$

Carcass characteristics

At the end of the experiment, all birds had fasted for a period of 12 h with only water allowed. Birds were weighed individually and slaughtered by Halal Muslim method. Afterward, broiler organs including gizzard, liver, and heart were then extracted carefully. For the gizzards, after removing the surrounding fat, they were then opened and the contents were removed. All organs were weighed jointly. Thus, all eviscerated carcasses were refrigerated at 4°C for 24 h and weighed individually to calculate the eviscerated carcass yield (ECY). After cutting, chicken muscles (breast and thighs) were also weighed.

$$\text{Eviscerated carcass yield (\%)} = \frac{\text{Eviscerated carcass weight}}{\text{Live weight at slaughter}} \times 100$$

Data analysis

A cage was the experimental unit for performance traits while the individual bird was the experimental unit for carcass and organ characteristics. Data were analyzed using the GLM general factorial ANOVA procedure using SAS 9.1.3 Statistical Analysis Software for Windows (SAS Institute: Cary, NC, USA, 2008). Prior analysis the residuals of the traits were tested for normal distribution. Dunnet's test was applied to compare every mean to a control mean. Statistical significance was considered at $P < 0.05$. Additionally, regression (linear, cubic and quadratic) models were run to study dose-dependent responses.

RESULTS

At arrival, birds showed an average body weight of 45.53 ± 3.59

Table 2 - Effects of prebiotics on productive traits (WG, ADG, FI and FCR) in broilers on 42nd day of the experiment.

Parameters	T0 (Control)	T1 (1 g/kg)	T2 (1.5 g/kg)	T3 (2 g/kg)	*P-value* (ANOVA)	*P-values of regression model*		
						Linear	Quadratic	Cubic
				d 7-7				
WG (g/b)	76.51±7.82	77.03±10.74	78.92±8.91	78.49±9.27	0.139	0.171	0.088	0.129
ADG (g/d/b)	10.93±1.12	11.00±1.53	11.27±1.27	11.21±1.31	0.317	0.131	0.320	0.321
DFI (g/d/b)	12.27±1.51	12.17±1.34	12.72±1.42	11.74±1.70	0.628	0.264	0.427	0.654
FCR (g/g)	1.21±0.05	1.12±0.05	1.13±0.09	1.04±0.13	0.892	0.798	0.867	0.892
				d 7-14				
WG (g/b)	169.33±16^{b}	161.73±22^{c}	162.29±20^{c}	175.54±14^{a}	0.043	0.047	0.038	0.031
ADG (g/d/b)	24.18±2.31^{ab}	23.10±3.23^{b}	23.18±2.97^{b}	25.07±2.11^{a}	0.037	0.041	0.032	0.028
DFI (g/d/b)	37.28±4.7^{b}	36.47±3.7^{b}	34.38±2.5^{c}	37.81±1.8^{a}	0.044	0.054	0.042	0.045
FCR (g/g)	1.54±0.15^{a}	1.59±0.18^{a}	1.49±0.12^{ab}	1.51±0.16^{ab}	0.048	0.051	0.046	0.042
				d 14-21				
WG (g/b)	267.66±52^{c}	275.45±43^{b}	296.22±19^{a}	277.86±15^{b}	0.041	0.054	0.037	0.039
ADG (g/d/b)	38.23±7.45^{b}	39.35±6.22^{ab}	42.31±2.81^{a}	39.69±2.15^{ab}	0.039	0.047	0.052	0.038
DFI (g/d/b)	71.41±7.6^{b}	74.52±10.931^{a}	70.53±8.31^{b}	60.73±3.71^{c}	0.044	0.043	0.048	0.042
FCR (g/g)	1.91±0.25^{a}	1.94±0.16^{a}	1.67±0.19^{b}	1.53±0.13^{b}	0.048	0.048	0.040	0.039
				d 21-28				
WG (g/b)	362.26±52^{b}	366.93±61^{ab}	367.45±24^{ab}	391.41±32^{a}	0.048	0.042	0.034	0.031
ADG (g/d/b)	51.75±7.51^{b}	52.41±8.73^{b}	52.49±3.55^{b}	55.91±4.64^{a}	0.039	0.041	0.055	0.032
DFI (g/d/b)	108.19±14^{a}	107.79±20^{a}	102.34±11^{b}	105.63±11^{ab}	0.050	0.047	0.043	0.039
FCR (g/g)	2.09±0.08^{a}	2.11±0.64^{a}	1.96±0.28^{b}	1.90±0.36^{b}	0.042	0.051	0.047	0.046
				d 28-35				
WG (g/b)	454.03±62^{b}	422.15±38^{c}	426.27±29^{c}	473.55±71^{a}	0.051	0.045	0.043	0.038
ADG (g/d/b)	64.86±8.90^{b}	60.30±5.44^{c}	60.89±4.15^{c}	67.65±10.21^{a}	0.046	0.047	0.049	0.043
DFI (g/d/b)	138.43±18^{a}	124.37±12^{b}	115.49±16^{b}	133.01±11^{a}	0.043	0.044	0.053	0.035
FCR (g/g)	2.14±0.18^{a}	2.07±0.24^{a}	1.92±0.34^{b}	1.98±0.17^{b}	0.049	0.047	0.052	0.043
				d 35-42				
WG (g/b)	487.05±118^{ab}	533.77±56^{a}	460.11±51^{b}	531.73±119^{a}	0.047	0.052	0.046	0.039
ADG (g/d/b)	69.57±16.94^{ab}	76.25±8.03^{a}	74.59±9.62^{b}	75.96±17.09^{a}	0.043	0.047	0.040	0.041
DFI (g/d/b)	105.67±9^{b}	128.33±9^{a}	108.34±14^{b}	118.07±11^{a}	0.045	0.051	0.047	0.036
FCR (g/g)	1.61±0.48^{b}	1.69±0.21^{a}	1.71±0.35^{a}	1.62±0.38^{b}	0.042	0.052	0.049	0.045
				d 1-42				
WG (g/b)	1816.83±310.12^{b}	1837.08±232.48^{b}	1791.29±155.36^{b}	1928.61±262.76^{a}	0 .034	0 .046	0 .028	0 .017
ADG (g/d/b)	43.25±7.38^{b}	43.74±5.53^{b}	42.46±4.08^{b}	45.91±6.25^{a}	0 .005	<0.001	<0.001	<0.001
DFI (g/d/b)	78.86±9.37^{a}	80.60±9.74^{a}	73.96±9.11^{b}	77.83±6.98^{a}	0 .048	0 .051	0 .043	0 .035
FCR (g/g)	1.73±0.20^{a}	1.74±0.24^{a}	1.64±0.23^{b}	1.61±0.22^{b}	0 .057	0 .0 48	0 .041	0 .038

WG= Weight gain (g/b); ADG= Average Daily Gain (g/d/b); DFI= Daily Feed Intake (g/d/b); FCR= Feed conversion ratio (g/g)
$^{a–c}$ Means within a row with different superscripts are significantly different (p<0.05). Values represent the Mean ± SEM of six replicates.

g. The results relative to performance parameters are presented in Table 2. During the starter period, the weight gain (WG) of prebiotic-supplemented birds did not significantly differ when compared with the control group (P=0.139). Moreover, no significant difference was noticed regarding feed intake (FI; P=0.628) and feed conversion ratio (FCR; P= 0.892) between birds fed increasing doses of prebiotic and control ones. Nevertheless, at week 3 the FI of the group receiving 2 g of prebiotic was significantly reduced as compared to the control group (P<0.05; 60.73 vs 71.41). Besides, FCR was significantly lower (P<0.05) in birds supplemented 2 g/kg of prebiotic (1.53) in comparison with the control group (1.91). At week 5 results showed a significant difference in FI between the control group and the group receiving 1.5 g of prebiotic: the treated group presented a lower FI (138.43 vs 115.49). At the end of the experiment, results showed that the prebiotic supplementation had a significant effect on weight gain (P<0.05). Furthermore, the group receiving 2 g of prebiotic presented a higher weight gain compared to the control group, respectively 1928.61 and 1816.83 g. The average daily gain (ADG) of the treated group (2 g) was significantly (P=0 .005) higher (45.91 g) than the control group (43.25). Concerning the FI, results showed a significant difference between control and different groups fed prebiotic (P<0.05). Remarkably, WG was distinctly greater with the incorporation of 2 g of prebiotic in the broiler diet. Also, our study showed that FCR was significantly improved

Table 3 - Effects of prebiotic supplementation on carcass and organs characteristics.

Parameters	T0 (Control)	T1 (1 g/kg)	T2 (1.5 g/kg)	T3 (2 g/kg)	*P-Value* (ANOVA)	*p-values of regression model* Linear	Quadratic	Cubic
Weight at slaughter (g)	2154.41±189^{b}	2215.73±179^{a}	2087.35±184^{b}	2278.73±188^{a}	0.024	0.035	0.026	0.024
Hot Eviscerated Carcass (g)	1598.53±144^{b}	1673.26±187^{ab}	1589.52±144$_{b}$	1727.36±175^{a}	0.026	0.043	0.045	0.026
Hot Carcass yield (%)	74.25±3.36^{b}	75.47± 5.69^{ab}	76.21±3.90^{a}	76.13±4.86^{a}	0.047	0.041	0.036	0.048
Cold Eviscerated Carcass (g)	1542.17±143b	1614.52±179^{a}	1514.32±140^{b}	1642.84±78^{a}	0.035	0.029	0.044	0.035
Cold Carcass yield (%)	71.63±3.49^{b}	72.82±5.37^{a}	72.62±4.37^{a}	72.38±4.45^{a}	0.043	0.058	0.047	0.038
Thighs (g)	440.57±69^{c}	470.80±54^{a}	452.70±45^{b}	475.13±35^{a}	0.036	0.034	0.025	0.021
Breast (g)	502.60±48^{b}	546.00±75^{a}	509.00±61^{b}	551.00±48^{a}	0.027	0.038	0.029	0.022
Liver (g)	39.06±14^{a}	39.45±10^{a}	38.54±11^{b}	37.62±12^{b}	0.049	0.064	0.043	0.039
Heart (g)	9.98±1.69	11.77±1.78	10.78±3.34	10.87±2.23	0.082	0.079	0.074	0.069
Gizzard (g)	50.61±9.13^{a}	48.46±10.14^{b}	45.46±9.34^{c}	46.76±7.87^{c}	0.025	0.029	0.038	0.028
Gastrointestinal tract (g)	65.70±10.17^{a}	65.80±8.56^{a}	60.66±10.47^{b}	60.90±9.29^{b}	0.038	0.042	0.036	0.027
Small Intestine (cm)	178.76 ±0.19	183.42±0.17	172.63±0.10	170.16±0.24	0.497	0.643	0.438	0.392

Weight at slaughter (g); Hot Eviscerated Carcass (g); Hot Carcass yield (%); Cold Eviscerated Carcass (g); Cold Carcass yield (%); Thighs (g); Breast (g); Liver (g); Heart (g); Gizzard (g); Gastrointestinal tract (g); Small intestine (cm). Eight birds were evaluated from each group.
$^{a-c}$ Means within a row with different superscripts are significantly different (p<0.05). Values represent the Mean ± SEM of six replicates.

(P=0.048; 1.53 g/g) by the administration of the highest dose of prebiotic during week 3.
The effects of prebiotic on internal organs weight and carcass are presented in Table 3. Differences have been recorded when comparing the values for the different treatments to the control group on 42nd days of age. The highest achieved a weight of chicken at slaughter was observed in treatment T3 (2278.73±188 g) which was followed by treatment T1 (2215.73±179 g) with statistically significant differences (P= 0.024) compared to control group (T0). Treatments with the addition of prebiotics (T1, T3) achieved eviscerated carcass weight of 1673.26±187 g and 1727.36±175 g and which were statistically significantly (P<0.05) higher than the eviscerated carcass of broilers in control group (T0) (1598.53±144 g) and T2 (1589.52±144 g). The highest cold eviscerated carcass was observed in broilers in treatments T3 (1642.84±78 g). The cold carcass yield ranged from 71.63% for the control group (T0) to 72.82% for T1. Similarly, the weights of the thighs (475.13±35 g) and breast (551±48 g) were concluded to be the highest (P < 0.05) in the broiler's receiving a basal diet complemented with 2 g of prebiotic. Regarding, the liver weight, the highest average value was noted in the control group (T0) compared to experimental broilers (P< 0.05). Nevertheless, no significant difference in heart weight among treatment group broilers (P=0.082) was observed. For the gizzard and gastrointestinal tract weight, a significant decrease (P< 0.05) was noticed in supplemented prebiotic broilers.

DISCUSSION

Several researchers have demonstrated the positive effects of prebiotic supplementation on growth performances. Our results are in agreement with those of Bednarczyk et al. (2016) that indicated prebiotics addition could significantly increase body weight gain during the first three weeks. The result showed that chickens fed prebiotic supplementation had better final body weight in comparison with those received only basal diet. These results are in agreement with those of Biggs et al. (2007), Taherpour et al. (2009) and Murshed et al. (2015). Moreover, the current study confirm results found by Askri et al. (2019) highlighted that this prebiotic should be present in broiler diet during the whole period for optimum growth performance. Nevertheless, many studies demonstrated that prebiotics had no significant effects on body weight, body weight gain, feed conversion ratio and feed intake (Mountzouris et al., 2007; Morales-López et al., 2009 and Houshmand et al., 2012a). The beneficial effects of prebiotic on FCR are in good agreement with previous studies (Oliva Das et al., 2017; Ahmed et al., 2015 and Mokhtari et al., 2015).
On the other hand, Sohail et al. (2012) and Sherif et al. (2012) noted that the usage of prebiotic in broiler diet had no significant effect on feed intake and feed conversion ratio. Also, Midilli et al. (2008) observed no significant improvement in productive traits.
Our study showed that the prebiotic administration impacted positively the carcass of broilers and the relative weight of some internal organs. Indeed, the cold carcass yield was more than the value observed by Abdel-Raheem and Abd-Allah (2011) who reported 64.45 to 70.68% in broilers at 42 days. Our findings are in agreement with those of Li and Zhang (2007) who stated that the use of prebiotic in broiler's diet improves the breast muscle. Likewise, a study conducted by Maiorano et al., (2017) showed that birds supplemented with prebiotics had a higher breast muscle weight. Also, the latest researches found that prebiotic administration had a positive effect on breast muscle weight (Dankowiakowska et al., 2019; Tavaniello et al., 2018). In contrast, Wang et al. (2015) reported no significant effects of prebiotic-supplemented to broiler diet on breast muscle. Our results support the findings of Parsa, (2018); Wang and Gu. (2010); Çınar et al., (2009) and Mateova et al., 2008 who confirmed the growth-promoting effect of prebiotics supplementation. Likewise, Wang et al. (2015) found the highest liver weight when prebiotic was added at 0.13%. However, some other researchers held opposite views and stated that adding prebiotic to broilers diet did not affect liver and heart weight (Houshmand et al. 2012b; Li and Zhang, 2007; Bozkurt et al. 2008).
These results agree with the findings of Waqas et al. (2018) who reported that all the carcass parameters including breast, liv-

er, heart and gizzard weight presented significant (P≤0.05) variations among supplemented prebiotic groups. Contrarly, Baurhoo et al. (2007) found no significant effect of different prebiotic supplementation on liver, heart and gizzard weights. On the other hand, results revealed no significant effect of prebiotic supplementation on intestinal weight corroborating the findings of Hosseini et al. (2016). Well established evidence by many researchers (Çınar et al., 2009; Lutfullah et al., 2011) showed that dietary containing additives reduced intestine weight and length. According to the above analysis, the results of group T3 broilers were optimal. Consequently, the optimum adding levels of dietary prebiotic were 2 g/kg.

CONCLUSION

The presented data showed that the supplementation of *Saccharomyces cerevisiae*-derived prebiotic in broiler diet has a positive result on productive traits and in the improvement of broilers carcass yield. The use of prebiotics in the feeds for broilers determined the improvement of the slaughter yield by 1.9% for the supplemented group compared to the control group. These results confirm the favorable effects of prebiotic « AVIATOR®» on meat production. However, further investigations are needed to evaluate meat quality traits and consumers acceptance.

DATA AVAILABILITY

The data sets are available upon request from the corresponding author.

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