PREDICTION OF PRODUCTION INDICES OF BOSCHVELD CHICKENS ON DIETARY PROBIOTIC-YEAST SUPPLEMENTATION LEVELS USING QUADRATIC OPTIMISATION MODEL

MAOBA, S.[1] – OGBUEWU, I. P.[1,2*] – OGUTTU, J. W.[1] – MBAJIORGU, C. A.[1]

[1]*Department of Animal Agriculture and Animal Health, University of South Africa, Florida 1710, Republic of South Africa*

[2]*Department of Animal Science and Technology, Federal University of Technology, P.M.B. 1526, Owerri, Nigeria*

[*]*Corresponding author*
e-mail: dr.ogbuewu@gmail.com; Ifeanyi.ogbuewu@futo.edu.ng;
ORCID No: https://orcid.org/0000-0003-4895-7867

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Abstract. The dose response effect of yeast on productive indices of indigenous Boschveld chickens was investigated. 600 unsexed Boschveld chickens were divided into 6 groups of 100 and each group replicated five times. Chickens received starter mash (1 to 49 days) and grower mash (50 - 91 days) supplemented with probiotic-yeast at 0, 2.5, 5.0, 7.5, 10.0 and 12.5 g/kg feed. Data were collected on productive indices and analysed using a one-way analysis of variance, and significant means were compared using Duncan's test for multiple comparisons. A quadratic model was used to determine probiotic-yeast levels for optimum production parameters which differed at $p < 0.05$. Dietary yeast levels that supported the optimum feed conversion efficiency (FCE), average daily gain (ADG) and nitrogen retention for Boschveld chickens aged 1 - 49 days were higher than the levels that optimised the same production variables at 50 - 91 days and 1 - 91 days, except for FCE that was higher at 1 – 91 days. This has implications in diet formulation for Boschveld chickens. It is concluded that probiotic-yeast at 7.4 - 9.0, 7.1-7.3 and 7.1 - 9.0 g/kg supported optimum productivity in Boschveld chickens reared from 1 - 49, 50 - 91 and 1- 91 days of age, respectively.
Keywords: *local chicken, Saccharomyces cerevisiae, dose response, regression analysis, performance*

Introduction

Indigenous chickens play a vital part in enhancing food security and improving the nutritional status (meat and eggs) and income of several smallholder farmers in many developing countries. In South Africa like in other developing countries, the cost of feeding chickens for optimal productivity is on the increase because of the direct competition for grains between chickens, humans, and the industry. This trend has led to a decrease in the contribution of indigenous chickens in reducing food insecurity in developing nations because of their productivity, and the continuous increase in the cost of eggs and meat from commercially produced exotic poultry breeds has exacerbated these problems. Imported chicken breeds are highly prolific, resulting in a quick return on investment. This improvement in the productivity of imported chicken breeds was achieved through improved genetics and enhanced intensive management strategies. The nutrient requirements of indigenous chickens differ from that of imported breeds, with the imported breeds requiring grains such as maize and soybean which are directly consumed by humans. As a result, resource-poor rural farmers find the rearing of imported breeds such as broilers to be unsustainable and prefer to rear native chicken strains that are adapted to free-range rearing systems. These chicken strains are known to

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be products of their environment and can be produced at a low cost. However, research to improve the productivity of indigenous chickens under confinement is still limited. Thus, to contribute effectively to food security, it is important to improve and promote the production of indigenous chicken breeds such as Boschveld chickens. Boschveld chicken is a hybrid of three South Africa native breeds (Venda, Ovambo, and Matabele chickens) and is the only locally developed indigenous breed in Africa (Bosch, 2018). Earlier studies in our research station found significant improvement in gut health, blood characteristics, and carcass quality of Boschveld chickens fed yeast (*Saccharomyces cerevisiae*) supplemented diets (Maoba et al., 2021a,b). A quadratic optimization model is increasingly being used in the animal science discipline to determine the inclusion levels of feedstuffs for optimal productivity (Mbajiorgu et al., 2011; Ogbuewu and Mbajiorgu, 2020; Anyanwu et al., 2021). The knowledge will help in the formulation of a diet to optimise growth and productivity in livestock and chickens. Therefore, knowing yeast requirements for optimal productivity will help in the formulation of diets to optimize the productivity of the indigenous Boschveld chickens. This study was therefore designed to determine the probiotic-yeast supplementation levels that supported optimum productivity of Boschveld chickens reared from aged 1-91 days of age using a regression optimisation model.

Materials and methods

Study site and source of test probiotics

The study was done in Portion 22 of the farm Elandsfontein 334 IQ (26.3898 S 27.9235 E) in Gauteng Province, South Africa during January to April 2019 in strict adherence to the guidelines of the Animal Ethics Committee, University of South Africa's (approval number: 2018/CAES/101). Baker's yeast used for this study was procured from Anchor Yeast 22 Bunsen Street, Industria, Johannesburg, South Africa. Six hundred (600) unsexed day-old Boschveld chicks (27.8±1.07 g/bird) were purchased at Boschveld Ranching Limited in Bela Bela, Limpopo Province, South Africa.

Experimental procedures

The poultry house is partitioned into 30 pens with equal surface area (2 square metres per pen) and divided into three rows of 10 pens. The floor of the pens was covered with wood shavings to a depth of 7 cm. The pens were preheated for 12 hours with infra-red lamps before the arrival of the chicks, in the first week of age, brooding temperature (33°C) was sustained and moderately reduced by 2°C per week to around 20°C on completion of the trial. 600 unsexed Boschveld chickens were randomly divided into 6 treatment groups of 100 chickens with five replicates, each replicate having 20 chickens. Chickens were fed starter mash (1 to 49 days) and grower mash (50 - 91 days) supplemented with probiotic-yeast at 0, 2.5, 5.0, 7.5, 10.0 and 12.5 g/kg feed for 91 days. Birds were fed starter mash (1 - 49 days) and grower mash (50 - 91 days) as shown in *Table 1*. Birds were offered diets and water *ad libitum* throughout the feeding trial. Twenty-four hours of light was available per day throughout the study. The birds were vaccinated following the Boschveld chicken management guide (Bosch, 2018). We used unsexed chickens in the present study to reflect the current production practices of smallholder farmers, who are the primary target audience.

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Table 1. *Proximate composition of the experimental diets*

Nutrients (g/kg)	Starter feed (1 – 49 days)	Grower feed (50 - 91 days)
Crude protein*	200.00	180.00
Lysine*	13.30	10.50
Methionine*	4.70	4.40
Moisture*	120.00	120.00
Crude fat*	25.00	25.00
Crude fibre*	50.00	60.00
Calcium*	10.50	9.50
Phosphorus*	6.00	4.52
Determined analysis		
Dry matter	914.63	912.53
Moisture	85.37	87.47
Crude protein	229.96	193.19
Ash	58.96	47.79
Nitrogen free extract	55.06	58.65
Gross energy MJ/kg	17.74	17.17
Metabolisable energy, Kcal/kg	3009.98	3001.38

* As illustrated in the feed label, Kcal – kilocalorie

Data collection

The weight of the chicks was recorded at the beginning of the feeding trial and thereafter on a weekly interval per pen. The average voluntary feed consumption per chicken was recorded daily using an electronic weighing scale for the duration of the trial. The mean live weight per chicken was determined weekly per pen by dividing the total live weight by the total number of chickens in each pen. ADG was calculated as weight gain divided by the duration of the feeding trial, whereas FCE was calculated as feed intake divided by weight gain. Digestibility assay was done between days 42 - 49 days and 84 - 91 of feeding trial. On days 42 and 84, two birds per replicate were transferred to a metabolic cage equipped with a drinker and feeder. A 3-day stabilization period was allowed before a daily faecal collection period of 3 days commenced. Faeces voided by each bird were collected at 0900 h and weighed daily. Care was taken to avoid contamination from feathers, feed, scales and other debris. Faecal samples were analysed for apparent metabolisable energy (AME) and nitrogen retention contents using a standard method (AOAC, 2008). Proximate composition of experimental diets was analysed for dry matter, ash, ether extract (EE), crude fibre (CF), crude protein (CP) in triplicates following the procedures of AOAC (2008). Metabolisable energy (ME) was calculated using the prediction equation of Pauzenga (1985) as follows: ME = 37 × CP % + 81.8 × EE % + 35.5 × nitrogen-free nitrogen (NFE) %. The gross energy (GE) of the diets was determined (AOAC, 2008) using bomb calorimeter.

Data analysis

The responses in final live weight (FLW), ADG, FCE and nitrogen retention to dietary probiotic yeast supplementation levels were modeled using the following quadratic optimisation equation (SAS, 2010): $Y = a + b_1x + b_2x^2$. Where, Y is the dependent variable (FLW, ADG, FCE and nitrogen retention); a is the intercept on Y-axis; b_1 and b_2 are coefficients of the quadratic function; x is the independent variable (yeast inclusion level) and $-b_1/2b_2$ is the x value for optimum response. The quadratic model was used because of the adequacy of fit compared to other regression types. The quadratic model was determined to

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be the best-fit model of the data based on the coefficient of determination (r^2) and thus optimum levels for data were based on this model.

Results

The effect of probiotic yeast on the productive traits of Boschveld chickens is shown in *Table 2*. Results indicate differences among means for various traits under consideration in Boschveld chickens following probiotic-yeast supplemental level. However, probiotic-yeast supplementation levels had a quadratic effect on the productive traits of Boschveld chickens (*Table 3*). The effect of probiotic-yeast level on optimum production variables of indigenous Boschveld chickens 1 to 49 days of age are presented in *Figures 1-4*. Results of the quadratic analyses demonstrated that different dietary yeast levels of 7.7 and 7.4 g/kg feed supported optimum FLW (*Figure 1*) and FCE (*Figure 2*), while yeast levels of 7.7 and 9.0 g/kg feed optimised ADG (*Figure 3*) and nitrogen retention (*Figure 4*), respectively. There is little or no information in the literature on ideal dietary yeast levels for optimal production responses in Boschveld chickens. Results of the effect of yeast level on optimum production variables of Boschveld chickens aged 50 - 91 days are presented in *Figures 5-7*. Dietary yeast had a quadratic effect ($p<0.05$) on ADG (*Figure 5*), FCE (*Figure 6*) and nitrogen retention (*Figure 7*), and were optimised at yeast levels of 7.1, 7.3 and 7.3 g/kg feed, respectively. Curve estimation of the influence of yeast level on optimum production parameters of Boschveld chickens aged day-old up to 91 days is presented in *Figures 8-11*. As the dietary yeast level increased, FLW, FCE, N-retention and ADG of Boschveld chicken aged day-old up to 91 days also increased until they were optimized at different dietary yeast levels. The yeast level of 7.3 g/kg feed supported optimum FLW and ADG as shown in *Table 3*.

Table 2. *Effect of probiotic yeast on production indices of Boschveld chickens reared from 1 to 91 days*

Parameters	Probiotic-yeast supplementation levels (g/kg)						SEM
	SC0	SC2.5	SC5.0	SC7.5	SC10.0	SC12.5	
d 1 - 49							
Initial live weight (g/bird)	28.4	26.4	27.7	27.0	29.4	27.5	0.44
Final live weight (g/bird)	540.5^{c}	548.3^{c}	633.3^{ab}	646.9^{a}	634.6^{ab}	583.7^{b}	19.1
Feed intake (g/bird/d)	38.1	36.8	34.8	37.2	36.4	37.3	0.45
FCE	3.7^{a}	3.5^{a}	2.8^{c}	2.9^{c}	3.0^{bc}	3.3^{ab}	0.14
ADG (g/bird/d)	10.5^{c}	10.7^{c}	12.4^{ab}	12.7^{a}	12.4^{ab}	11.4^{bc}	0.40
AME (MJ ME/kg)	11.3	10.7	11.9	11.7	11.6	10.8	0.20
N-retention (g/bird/d)	1.84^{c}	1.90^{c}	2.26^{b}	2.54^{a}	2.42^{ab}	2.26^{b}	0.11
d 50 - 91							
Final live weight (g/bird)	1313.8^{d}	1388.6^{c}	1587.8^{b}	1634.6^{ab}	1685.6^{a}	1380.4^{c}	63.67
Feed intake (g/bird/d)	76.0	75.7	74.4	75.3	74.4	72.6	0.50
FCE	4.1^{a}	3.9^{a}	3.3^{b}	3.2^{b}	3.0^{b}	3.9^{a}	1.10
ADG (g/bird/d)	18.4^{b}	20.0^{b}	22.7^{a}	23.5^{a}	25.0^{a}	19.0^{b}	0.19
AME (MJ ME/kg)	10.7	11.0	10.8	11.4	11.9	10.8	0.19
N-retention (g/bird/d)	1.8^{c}	2.2^{b}	2.4^{a}	2.4^{a}	2.5^{a}	2.1^{b}	0.10
d 1 - 91							
Final live weight (g/bird)	1313.8^{d}	1388.6^{c}	1587.8^{b}	1634.6^{ab}	1685.6^{a}	1380.4^{c}	63.67
Feed intake (g/bird/d)	57.1	56.2	54.6	56.2	55.4	54.9	0.38
FCE	4.0^{a}	3.7^{ab}	3.1^{c}	3.1^{c}	3.0^{c}	3.6^{ab}	0.16
ADG (g/bird/d)	14.4^{c}	15.3^{c}	17.6^{b}	18.1^{ab}	18.7^{a}	15.2^{c}	0.73
AME (MJ ME/kg)	10.96	10.84	11.35	11.56	11.71	10.80	0.16
N-retention (g/bird/d)	1.84^{d}	2.03^{c}	2.34^{ab}	2.48^{a}	2.46^{a}	2.20^{bc}	0.10

^{a,b,c,d} Means in the same row not sharing a common superscript are significantly different ($p < 0.05$). FCE: feed conversion efficiency, ADG: average daily gain, AME: apparent metabolisable energy, SD: standard deviation, CV: coefficient of variation, SEM: standard error of the mean

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Table 3. *Probiotic-yeast levels for optimal productivity of Boschveld chickens aged 1 to 91 days*

Variable	Formula	Optimal X-value	Optimal Y-value	r^2	p-value
d 1 - 49					
FLW (g/bird)	$Y = 522.35 + 29.969x - 1.951x^2$	7.7	637.5	0.82	0.001
FCE	$Y= 3.7821 - 0.2424x + 0.0163x^2$	7.4	2.9	0.86	0.001
ADG (g/bird/d)	$Y = 10.143 + 0.6131x - 0.04x^2$	7.7	12.4	0.83	0.001
N-retention(g/bird/d)	$Y =1.7214 + 0.1551x - 0.0086x^2$	9.0	2.4	0.90	0.001
d 50 - 91					
ADG (g/bird/d)	$y = 17.543 + 1.7434x - 0.1223x^2$	7.1	23.7	0.75	0.001
FCE	$y = 4.2607 – 0.297x + 0.0203x^2$	7.3	3.2	0.78	0.005
N-retention(g/bird/d)	$y = 1.8 + 0.1846x – 0.0126x^2$	7.3	2.5	0.94	0.001
d 1 - 91					
FLW (g/bird),	$Y = 1259.3 + 103.55x - 7.1223x^2$	7.3	1635.7	0.80	<.001
FCE	$Y = 4.0964 - 0.279x + 0.0186x^2$	7.5	3.0	0.90	<.001
ADG (g/bird/d)	$Y = 13.786 + 1.1966x - 0.0823x^2$	7.3	18.1	0.80	<.001
N-retention (g/bird/d)	$Y = 1.7818 + 0.1644x - 0.0102x^2$	8.1	2.4	0.94	<.001

FLW: final live weight; ADG: average daily gain; FCE: feed conversion efficiency; N: nitrogen; r^2: coefficient of determination

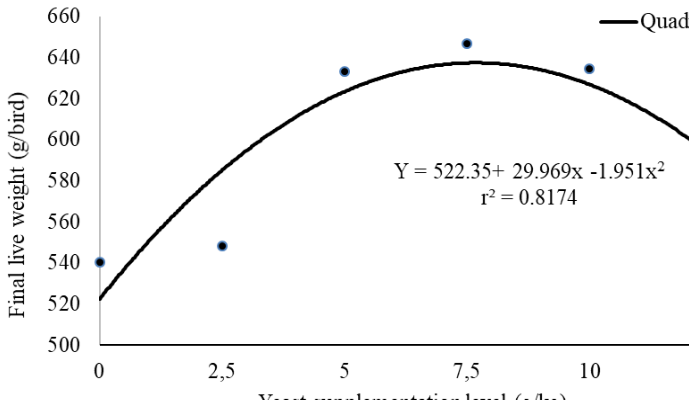

Figure 1. *Effect of probiotic-yeast on FLW in Boschveld chickens aged 1 to 49 days*

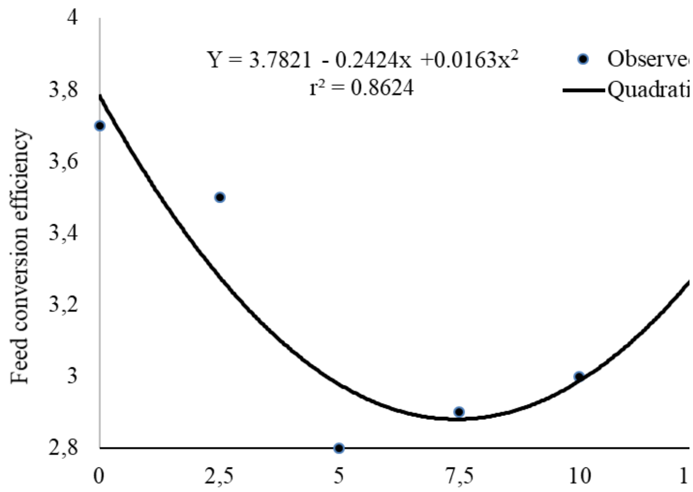

Figure 2. *Effect of probiotic-yeast on FCE in Boschveld chickens aged 1 to 49 days*

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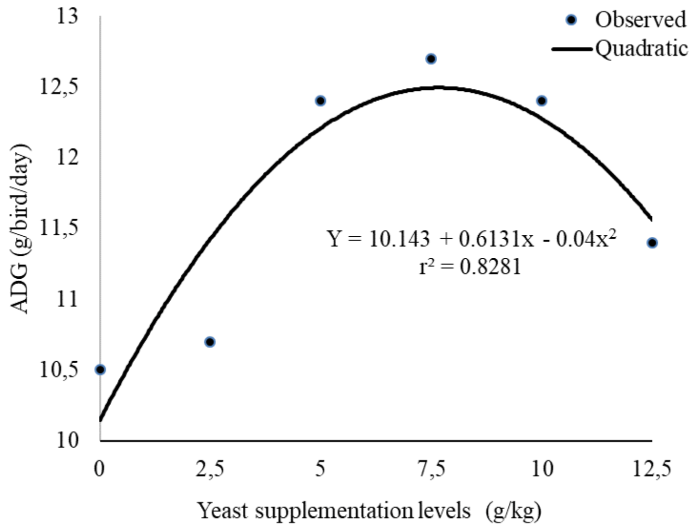

Figure 3. *Effect of probiotic-yeast on ADG in Boschveld chickens aged 1 to 49 days*

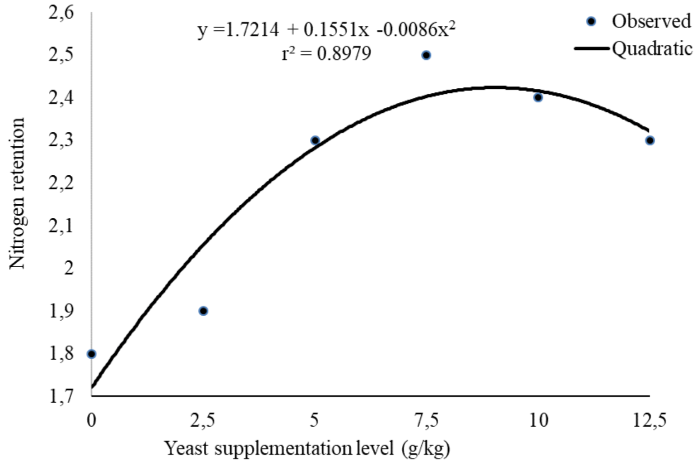

Figure 4. *Effect of probiotic-yeast on nitrogen retention in Boschveld chickens aged 1 to 49 days*

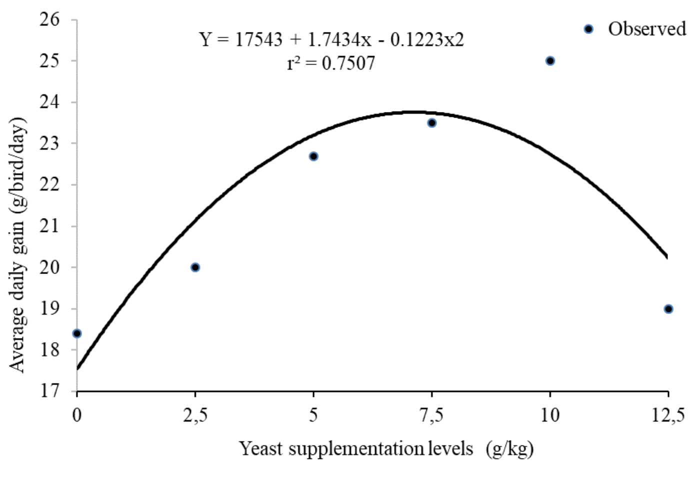

Figure 5. *Effect of yeast on ADG of Boschveld chickens from one 50 to 91 days of age*

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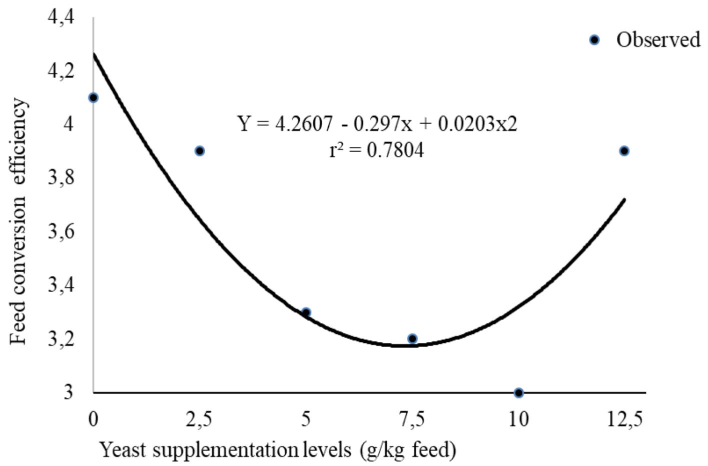

Figure 6. *Effect of yeast on FCE of Boschveld chickens from one 50 to 91 days of age*

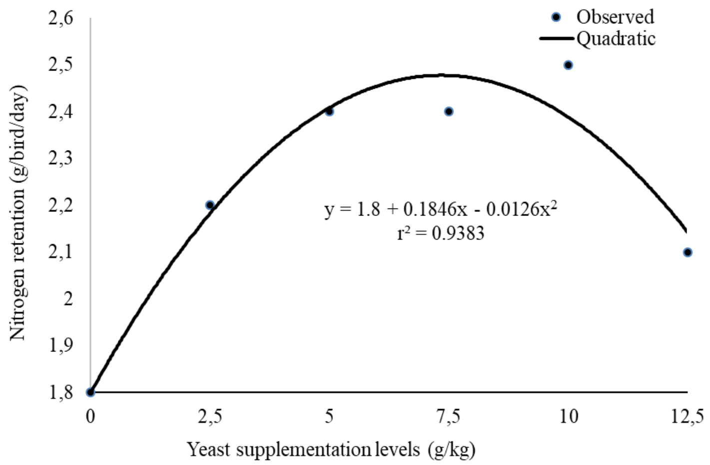

Figure 7. *Effect of yeast on nitrogen retention of Boschveld chickens from 50 to 91 days of age*

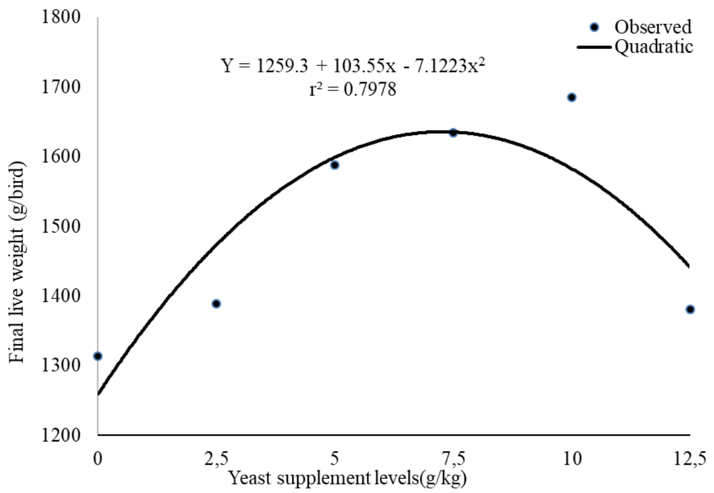

Figure 8. *Effect of yeast on live weight of Boschveld chickens aged day-old up to 91 days*

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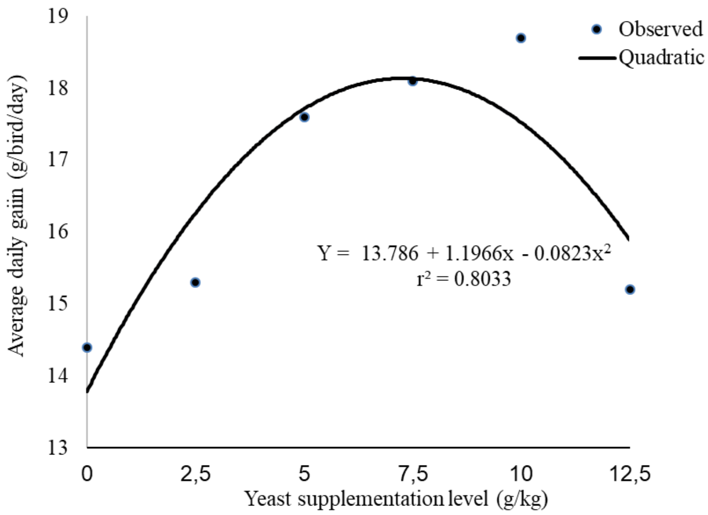

Figure 9. *Effect of yeast on ADG of Boschveld chickens aged day-old up to 91 days*

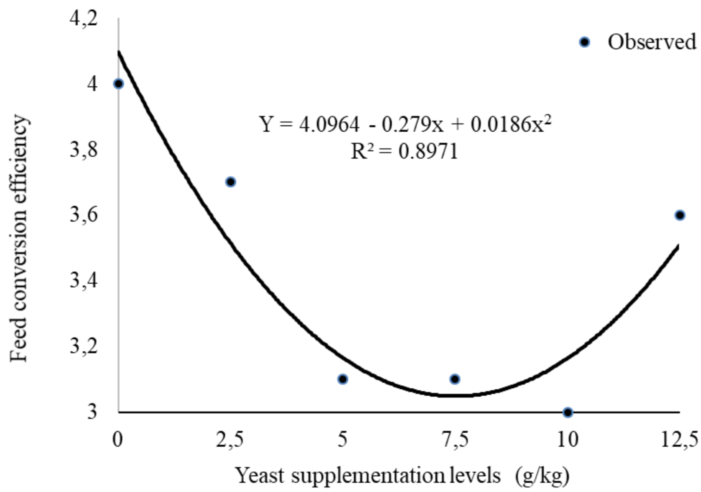

Figure 10. *Effect of yeast on FCE of Boschveld chickens aged day-old up to 91 days*

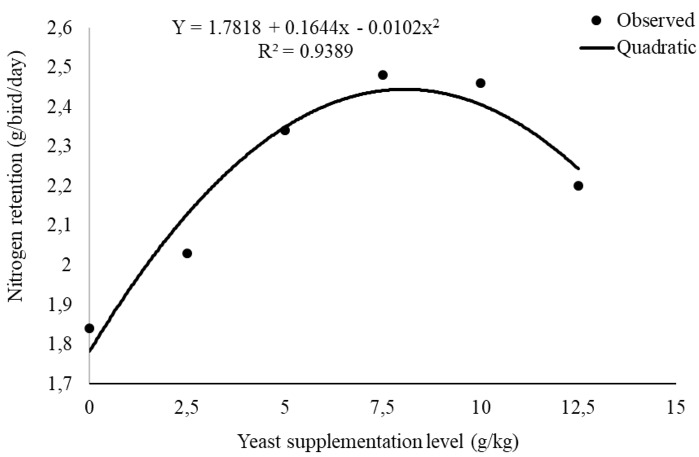

Figure 11. *Effect of yeast on nitrogen retention of Boschveld chickens aged 1 to 91 days*

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Discussion

There is little or no information in the literature on ideal dietary yeast levels for optimal production responses in Boschveld chickens. Probiotic-yeast supplementation levels had a quadratic effect on productive traits of Boschveld chickens aged 1 - 49 days. These findings supported Mbajiorgu et al. (2011) who reported that the amount of nutrients needed to optimise different production parameters in indigenous chickens is dynamic. The single yeast level of 7.7 g/kg feed that optimised FLW and ADG in Boschveld chickens aged 1-49 days in the present study is expected given that the two parameters are positively correlated (Mbajiorgu et al., 2011). The yeast levels of 7.4 and 7.7 g/kg feed that supported optimum FCE (2.9) and ADG (12.4 g/bird/d), respectively were higher than the levels of 2.5 and 4.5 g/kg feed calculated from the data of Ahmed et al. (2015) that optimised the same parameters in broiler chickens aged 1 - 21 days. This result is envisaged as indigenous Boschveld chickens are slow-growing chicken breed when compared to broiler chickens which are selected for high growth efficiency. The r^2 values for Boschveld chickens aged 1-49 days were ranged from 82 to 90% and were considered high. That implied that there is a very high strength of determination of the various production indices using the quadratic equation and that FLW, FCE, ADG and nitrogen retention could be predicted based on a given amount of yeast added to the diet.

Dietary yeast had a quadratic effect on ADG, FCE and nitrogen retention in Boschveld chickens aged 50-91 days and was optimised at yeast levels of 7.1, 7.3 and 7.3 g/kg feed, respectively. Quadratic effect was observed for ADG and nitrogen retention in response to yeast levels up to 7.5 g/kg feed and thereafter it started to decline. However, the reverse pattern was the case for FCE. The ADG and FCE were optimised at different yeast supplementation levels in Boschveld chickens aged 50-91 days, indicating that yeast level for optimal productivity in Boschveld chickens is dynamic and dependent on the production variable under consideration. Data estimated from the results of Gao et al. (2008) found that yeast levels of 2.3 and 2.5 g/kg feed supported optimum ADG and FCE, respectively in Arbor Acres broiler chickens aged 1 - 42 days of age fed yeast culture at the levels of 0, 2.5, 5.0, and 7.5 g/kg as similarly observed by Mulatu et al. (2019). The genetics of a chicken influences its digestibility; feed efficiency and growth rate in poultry (Rondelli et al., 2003). However, the yeast levels for optimum ADG and FCE in this study were higher than the levels of 2.3 and 2.5 g/kg feed estimated from the data of Gao et al. (2008) for optimal value (ADG and FCE, respectively) in broiler chickens. This indicates that yeast inclusion for optimal productivity in Boschveld chickens aged 50 – 91 days is higher than that of broiler chickens aged 1 - 42 days and this response could be ascribed to variation in genetics. The optimal yeast value of 1.2 g/kg feed (FCE) and 2.3 g/kg feed (ADG) estimated from the data of Ding et al. (2019) in Chinese native chickens fed yeast derivatives at levels between 0.5 and 2.0 g/kg feed for 42 days was lower than the values recorded in the current study. The observed discrepancies in animal response could be attributed to variations in yeast type, diet composition as well as the age of chickens in studies under consideration.

The results of the present study showed that a single yeast level of 7.3 g/kg feed optimised both FCE and nitrogen retention in Boschveld chickens aged 50 to 91 days. The yeast level of 7.3 g/kg feed recorded in the present was higher than the estimated value of 1.9 g/kg feed from the data of Oyedeji et al. (2008) that optimised nitrogen retention in broiler chickens. Results also support the view that Boschveld chicken is a slow-growing chicken strain when compared to broiler chickens. In contrast, the value of 7.3 g/kg feed that optimised nitrogen retention in Boschveld chickens aged 50 to 91 days

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was 19% lower than the value of 9.0 g/kg recorded in Boschveld chickens aged 1 to 49 days old. The observed difference is expected since the starter diet was high in protein (20.0%) than the grower diet (18.0%), thus the birds on the starter phase will tend to consume less diet to meet their daily protein requirements when fed diets supplemented with yeast that is high in crude protein (45%) as stated by Reed and Naodawithana (1999). The r^2 values of 75 to 94% recorded for production parameters in Boschveld chickens aged 50 to 91 days were high, meaning that there is a very high strength of determination of the response parameters using a quadratic model.

Our results indicated that as the dietary yeast level was increased, FLW, FCE, N-retention and ADG of Boschveld chicken aged 1 to 91 days also increased until they were optimized at different dietary yeast levels. A single yeast level of 7.3 g/kg feed supported optimum FLW and ADG. This level is higher than the single yeast level of 2.2 g/kg feed reported for FLW and ADG by Manal (2012) in broiler chickens aged 1 to 42 days. Indigenous chicken breeds are slow-growing chickens and, thus, may require higher yeast levels as their feed conversion efficiency are usually higher than that of broiler chickens (Mbajiorgu et al., 2011). This has implications in diet formulations for indigenous chickens. Our quadratic results also showed that yeast level of 7.5 g/kg feed supported optimum FCE, which was higher than the value of 0.23 g/kg feed (Manal, 2012) and 2.5 g/kg feed (Gao et al., 2008) recorded in broiler chickens aged 1 - 42 days. This is also higher than the level of 0.77 g/kg feed recorded for broiler chickens aged 1 - 42 days by Ahmed et al. (2015). This suggests that Boschveld chickens have poor feed conversion efficiency; as a result, broiler chickens were expected to outperform locally developed Boschveld chicken breeds (Padhi, 2016). Daily yeast supplementation level of 8.1 g/kg feed supported optimum nitrogen retention in Boschveld chickens which were lower than the levels of 9.0 g/kg that optimised the same parameter in Boschveld chickens aged 1 to 49 days. The yeast level of 8.1 g/kg feed that optimised nitrogen retention in the current study was higher than the value of 1.9 g/kg feed reported in fast-growing chickens (Oyedeji et al., 2008). The lower value estimated for broiler chickens from the data of Oyedeji et al. (2008) may be a genotypic factor achieved via selection and breeding for higher performance in broiler chickens. The r^2 values for FLW, FCE, ADG and nitrogen retention in the present study were regarded as being high (r^2 = 80 - 94%). This means that there is a very high strength of determination of these production variables using a quadratic equation. The r^2 indicated that yeast supplementation had a 94% influence on nitrogen retention of indigenous Boschveld chickens reared in a confined environment from day-old up to 91 days of age. This means that yeast had a greater influence on nitrogen retention and lesser influence on FLW, FCE and ADG of indigenous Boschveld chickens reared from day-old up to 91 days of age.

Conclusion

Daily supplementation with 7.7, 7.4, 7.7 and 9.0 g/kg feed probiotic-yeast level, respectively, supported optimum live weight, feed conversion efficiency, average daily gain and nitrogen retention in Boschveld chickens reared from 1 to 49 days of age. In addition, daily probiotic-yeast supplementation levels of 7.3, 7.1 and 7.3 g/kg feed optimised feed conversion efficiency, average daily gain and nitrogen retention, respectively in Boschveld chickens aged 50 to 91 days. Daily yeast levels of 7.3, 7.5, 7.3 and 8.1 g/kg feed, respectively optimised live weight, feed conversion efficiency, average daily gain and nitrogen retention in Boschveld chickens from 1 – 91 days of age.

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However, a single yeast value of 7.7 and 7.3 g/kg feed optimised live weight and average daily gain, respectively in Boschveld chickens aged 1 to 49 days and 1 to 91 days, while a single value of 7.3 g/kg feed optimised feed conversion efficiency and nitrogen retention in Boschveld chickens from 50 to 91 days of age. The results of this study also suggest that the optimum probiotic-yeast level necessary to maximize performance in terms of average daily gain and nitrogen retention decreases as the bird ages. It is, therefore, recommended that effect of dietary probiotic-yeast supplement on productive indices of male and female Boschveld chickens reared from 1 to 91 days of age be determined.

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