EFFECT OF DIETARY CARROT MEAL SUPPLEMENTATION ON PRODUCTIVITY AND CARCASS CHARACTERISTICS OF ARBOR ACRE BROILER CHICKENS AGED 22 TO 42 DAYS

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Abstract. This study determined the effect of carrot meal supplementation on productivity and carcass characteristics of Arbor acre broiler chickens aged 22 to 42 days in Limpopo province, South Africa. A total of 200 female Arbor acre broiler chickens were randomly allocated to five treatments with five replicates, each having 8 birds, in a completely randomized design. The supplementation levels were 0 (FA0), 20 (FA20), 50 (FA50), 75 (FA75) or 100 (FA100) g of carrot meal per kg DM feed. The results showed that dietary carrot meal supplementation had no ($P > 0.05$) effect on growth rate, live weight and carcass characteristics of female Arbor acre broiler chickens aged 22 to 42 days. Carrot meal supplementation improved feed intake, feed conversion ratio, metabolisable energy intake and nitrogen retention of Arbor acre broiler chickens aged 22 to 42 days. Dietary feed intake, feed conversion ratio, live weight, metabolisable energy intake and nitrogen retention were optimized at different dietary carrot meal supplementation levels of 52.8, 63.8, 38.0, 42.0 and 44.3 g/kg DM feed, respectively. It is concluded that carrot meal supplementation improved intake, feed conversion ratio, metabolisable energy and nitrogen retention of female Arbor acre broiler chickens aged 22 to 42 days.
Keywords: *metabolisable energy, meat sensory attributes, vitamin C, diets, performance*

Introduction

Poultry production is nutritionally, economically and socially important in Limpopo province and the world as a whole. Chicken production is an important source of income and employment, and it contributes substantially to food security among rural people in Africa (Ng'ambi et al., 2012). Much of the poultry meat comes from broiler chickens. Not only are broiler chickens heavier at an early age but they also have better feed conversion ratio (Havenstein, 2004). High mortality in broiler chickens leads to poor productivity and low income for rural people. Carcasses from broiler chickens have high fat content and, thus, reduced carcass quality and feed efficiency. High fat content meat is also not liked by consumers (Steenfeldt et al., 2007). Excessive fat is one of the main problems faced by the broiler chicken industry, since it does not just reduce carcass quality and feed efficiency but also causes consumer rejection and difficulties in meat processing (Macajova et al., 2003).

There is some evidence that carrot meal supplementation reduces chick mortality and improves carcass characteristics (Steenfeldt et al., 2007). Carrot (*Daucus carota)* is a commonly consumed vegetable species belonging to the family Apiacea, which grows in temperate regions of Europe, Asia and Africa (Hammam, 2014). It contains a lot of active ingredients such as steroids, tannins, flavonoids, and carotene (Jasicka-Misiak et al., 2005; Vasudevan et al., 2006). Aromatic plants such as carrots can increase feed intake, feed conversion ratio, weight gain and can improve the oxidative stability of tissues (Ürüşan and Bölükbaşı, 2017). Carrot meal has been tested for its potential as food in livestock industry

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(Rust and Buskirk, 2008; Steenfeldt et al., 2007); however, its prospect in Arbor acre broiler-based diets has not yet been fully exploited. Information generated in this study will help in formulating strategies aimed at improving productivity and carcass characteristics of Arbor acre broiler chickens. Improvement of productivity of broiler chickens may enhance the economic, nutritional and social status of broiler chicken farmers. Therefore, the aim of this study was to determine the effects of supplementing diets with carrot meal on feed intake, digestibility, live weight, growth, feed conversion ratio, mortality and carcass characteristics of Arbor acre broiler chickens.

Materials and methods

Study site and experimental design

This study was conducted as part of the Pahlomoje Poultry Project, Shikwane village in Maruleng Municipality, South Africa. The project site is 64 km north-west of Tzaneen. The chickens were raised on commercial starter mash up to 21 days old before the experiment commenced. Prior to the start of the experiment the chickens were fed a 22% crude protein (CP) diet that would satisfy their nutritional requirements according to NRC (1994). A total of 200 female Arbor acre broiler chickens (Females were used because there were not enough males), weighing 650 ± 4 g per chicken were randomly assigned to five treatments with five replicates, each replicate having 8 Arbor acre female chickens in a completely randomized design. Thus, chickens were raised on 25 floor pens in an environmentally controlled house and temperature maintained at 30 to 33 °C and 23 to 25 °C during the starter and grower phase, respectively. Lighting was provided continuously (*Fig. 1*). The chicks were vaccinated against Newcastle virus disease and infectious bronchitis. A grower diet was offered from day 22-42 days with different carrot supplementation levels (*Table 1*). The nutrient composition of the treatments is presented in *Table 2*. The diets contained similar nutrients but different carrot meal levels ranging from zero to 100 g per kg DM. The carrot meal contained 12% crude protein, 17.1 MJ of gross energy/kg DM, 18% ash, 13.3% neutral detergent fibre (NDF), 8.8% acid detergent fibre (ADF) and 300-700 mg/kg dry matter (DM) of vitamin C. The grower diet was formulated and produced by a commercial feed company, Meadow Feeds, South Africa. Feed and water were offered ad libitum throughout the experiment.

Figure 1. *Ross 308 broiler chickens feeding on treatment diet*

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Table 1. *Diet composition of grower feed for Arbor acre chickens*

Ingredient	Quantity (%)
Yellow maize	567
Sunflower meat	100
Full fat soya meal	290
Fish meal	10
Monocalcium phosphate	13.6
Limestone	13.6
Iodised salt	0.5
DL Methionine	0.3
L Threonine	0.0
Vitamin/mineral premix	5.0
Total	1000
CP (%)	20
Energy (MJ/kg DM)	16.9

Table 2. *Nutrient composition of the diets for Arbor acre broiler chickens (units are in g/kg DM except energy as MJ/kg DM feed and dry matter as g/kg feed)*

Diet code	Nutrient			
	Dry matter	Energy	Protein	Carrot meal supplement
UA_0	930	16.9	200	0
UA_{20}	930	16.9	200	20
UA_{50}	930	16.9	200	50
UA_{75}	930	16.9	200	75
UA_{100}	930	16.9	200	100

Data collection

The initial live weights of the chickens were taken at the beginning of the experiment and weekly weights were taken thereafter using the electronic weighing scale (RADWAG AS 220/C/2). Weekly feed intakes were determined. Daily mean growth rates and feed conversion ratios were calculated. Digestibility was done when the chickens were between 35 and 42 days. Digestibility was conducted in specially designed metabolic cages with separate watering and feeding troughs. Four birds were randomly selected from each replicate and transferred to metabolic cages to measure apparent digestibility. A three-day acclimatization period was allowed prior to a three-day collection period. Droppings voided by each bird were collected daily at 09h00. Care was taken to avoid contamination from feathers, scales, debris and feeds. Dry matter and nitrogen contents of the diets, refusals and faeces were determined. At 42 d of age, 3 chickens per pen were slaughtered according to the rules and regulations of University of Limpopo Animal Research Ethics Committee. After slaughtering, carcass weight of each chicken was measured. Dressing percentage was determined by dividing carcass weight by live weight and then multiplying by 100. Breast, fat pad, thigh, wing, drumstick, gizzard and liver weights were measured using an electronic scale. Breast

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meat samples were further analysed for meat sensory attributes. Breast meat was prepared and the skin was left on the meat samples. Nothing was added to the meat samples to add taste. An oven set at 105 °C was allowed to preheat prior to cooking. The meat samples were put in trays and they were covered with aluminium foil to prevent water loss. Thereafter, the trays with meat were put in an oven for approximately 60 min and the meat samples were turned after every 10 min. Samples were cut into small 5 cm cubic pieces and served immediately after cooking to a total of 30 panel composed of students and staff members of the University of Limpopo that were from the Sepedi, Setswana, Tshivenda and Tsitsonga tribes. The panel was shown how to infer and record scores for each parameter. The waiting period between meats samples tastings was 10 min. Distilled water with lemon was given to panel to clean their palate between sub-sample measurements to avoid crossover effects. Breast meat was evaluated for tenderness, juiciness and flavour using a 5-point ranking scale (AMSA, 1995) (*Table 3*).

Table 3. *Evaluation scores used by the sensory panel*

Score	Sensory attributes		
	Tenderness	**Juiciness**	**Flavour**
1	Too tough	Much too dry	Very bad flavor
2	Tough	Dry	Poor flavor
3	Neither tough nor tender	Neither dry nor juicy	Neither bad nor good flavor
4	Tender	Juicy	Good flavor
5	Too tender	Too juicy	Very good flavor

Chemical analysis

Dry matter and nitrogen contents of the diets, refusals, faeces and meat samples were determined as described by AOAC (2008). Neutral and acid detergent fibre contents were analysed by AOAC (2008) methods. The energy of the diets, excreta samples and meat were determined using an adiabatic bomb calorimeter IKA® C5003 Control.

Statistical analysis

Data on feed intake, feed conversion ratio, growth rate, live weight and carcass characteristics of Arbor acre broiler chickens were analyzed using the general linear model procedures of the statistical analysis of variance (SAS, 2008). Where there was a significant difference, the Duncan test for multiple comparisons was used to test the significance of differences between treatment means (SAS, 2008). The dose - responses in feed intake, live weight, growth rate, feed conversion ratio, metabolisable energy, nitrogen retention and carcass characteristics of the chickens were models using the following quadratic equation:

$$Y = a + b_1x + b_2x^2 \quad \text{(Eq.1)}$$

where y = feed intake, digestibility, live weight, growth rate, feed conversion ratio, metabolisable energy, nitrogen retention and carcass characteristics; a = intercept; b_1 and b_2 = coefficients of the quadratic equation; x = dietary carrot meal supplementation level and $-b_1/2b_2 = x$ value for optimum response. The quadratic model was fitted to

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experimental data by means of the NLIN procedure of SAS (SAS, 2008). The quadratic model was used because it gave the best fit.

The relationships between carrot meal supplementation and optimal responses in meat tenderness, flavour and juiciness were models using a linear regression equation (SAS, 2008) of the form:

$$Y = a + bx \quad \text{(Eq.2)}$$

where Y = optimal tenderness, juiciness and flavour; a = intercept; b = coefficient of the linear equation and x = dietary carrot meal supplementation level.

Results

Results of the effect of carrot meal supplementation on feed intake, growth rate, feed conversion ratio, live weight, metabolisable energy intake and nitrogen retention of female Arbor acre broiler chickens aged 22 to 42 days are presented in *Table 4*. Carrot meal supplementation had no effect ($P > 0.05$) on growth rate of female Arbor acre broiler chickens aged 22 to 42 days. Broiler chickens on a diet supplemented with 50 g of carrot meal per kg DM had higher ($P < 0.05$) feed intakes than those on a diet not supplemented with carrot meal, and those on diets supplemented with 20 or 100 g of carrot meal per kg DM feed. Feed intakes of female Arbor acre broiler chickens aged 22 to 42 days were optimized at dietary carrot meal levels of 52.8 ($r^2 = 0.888$) (*Table 5*).

Carrot meal supplementation improved dietary intake of female Arbor acre broiler chickens aged 22 to 42 days. However, these improvements did not have any impact on growth rates of the chickens. Similarly, improvements in dietary intake, feed conversion ratio, metabolisable energy intake and nitrogen retention did not result in any improvement of live weights of the chickens. Female broiler chickens on a diet supplemented with 50 g of carrot meal per kg DM had higher ($P < 0.05$) live weights than those on diets supplemented with 20 or 100 g of carrot meal per kg DM feed. Broiler chickens on a diet supplemented with 20 g of carrot meal per kg DM feed had higher ($P < 0.05$) live weights than those on a diet supplemented with 100 g of carrot meal per kg DM. Live weights of female Arbor acre broiler chickens aged 22 to 42 days were optimized at dietary carrot meal levels of 63.8 ($r^2 = 0.780$) (*Table 5*). Supplementation with 50 g of carrot meal per kg DM feed improved ($P < 0.05$) feed conversion ratio. Feed conversion ratios of female Arbor acre broiler chickens aged 22 to 42 days were optimized at dietary carrot meal levels of 38.0 ($r^2 = 0.673$) (*Table 5*).

In the present study, dietary intake and feed conversion ratio and live weight of female Arbor acre broiler chickens aged 22 to 42 days were optimized at different dietary carrot meal supplementation levels of 52.8 and 63.8 g/kg DM feed, respectively. Female broiler chickens on a diet supplemented with 20 g of carrot meal per kg DM had higher ($P < 0.05$) metabolisable energy intakes than those on a diet not supplemented with carrot meal and those on diets supplemented with 50, 75 or 100 g of carrot meal per kg DM. Broiler chickens on diets supplemented with 50 or 75 g of carrot meal per kg DM had higher ($P < 0.05$) metabolisable energy intakes than those on a diet not supplemented with carrot meal. Metabolisable energy intakes of female Arbor acre broiler chickens aged 22 to 42 days were optimized at dietary carrot meal levels of 42.0 ($r^2 = 0.385$) g/kg DM (*Table 5*). Female broiler chickens on diets supplemented with 20 or 50 g of carrot meal per kg DM had higher ($P < 0.05$) nitrogen retention values than

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those on a diet not supplemented with carrot meal and those on diets supplemented with 75 or 100 g of carrot meal per kg DM. Nitrogen retention of female Arbor acre broiler chickens aged 22 to 42 days were optimized at dietary carrot meal levels of 44.3 ($r^2 = 0.603$) g/kg DM (*Table 5*). Carrot meal supplementation improved dietary metabolisable energy intakes of female Arbor acre broiler chickens aged 22 to 42 days. In the present study, metabolisable energy intake and nitrogen retention of female Arbor acre broiler chickens were optimized at different carrot meal supplementation levels of 42.0 and 44.3 g/kg DM feed, respectively. This means carrot meal levels for optimal metabolisable intake and nitrogen retention intake will depend on the variable of interest.

Table 4. *Effect of carrot meal supplementation on feed intake (g DM/bird/day), growth rate (g/bird/day), feed conversion ratio (FCR) (g DM feed/g live weight gain), live weight (g/bird aged 42 days), metabolisable energy (MJ/kg DM) and nitrogen retention (g/bird/day) of female Arbor acre broiler chickens aged 22 to 42 days*

Variables	Treatment					SE
	FA_0	FA_{20}	FA_{50}	FA_{75}	FA_{100}	
DM intake	140.0^{b}	150.5^{b}	172.0^{a}	160.3^{ab}	147.5^{b}	3.80
Growth rate	33.3	29.5	27.8	31.8	28.0	1.13
FCR	5.3^{a}	4.5^{ab}	3.3^{b}	4.2^{ab}	4.0^{ab}	0.22
Live weight	1834^{ab}	1755^{b}	1891^{a}	1835^{ab}	1609^{c}	36.84
ME intake	9.4^{c}	13.8^{a}	11.4^{b}	11.4^{b}	10.4^{bc}	0.388
N retention	2.0^{b}	2.8^{a}	3.0^{a}	2.0^{b}	2.0^{b}	0.115

^{a,b,c}Means in the same row not sharing a common superscript are significantly different ($P < 0.05$)
SE: Standard error

Table 5. *Carrot meal supplementation levels for optimal feed intake (g/bird/day), feed conversion ratio (g DM feed/g live weight gain), live weight (g/bird aged 42 days), metabolisable energy (ME) (MJ/kg DM) and nitrogen retention (g/bird/day) of female Arbor acre broiler chickens aged 22 to 42 days*

Trait	Formula	r^2	Carrot meal	Optimal Y-value
Feed intake	$Y = 137.884 + 1.0559x + -0.0094x^2$	0.888	52.8	166.8
FCR	$Y = 5.2775 + -0.0510x + 0.0004x^2$	0.780	63.8	3.65
Live weight	$Y = 1781.939 + 4.7089x + -0.0615x^2$	0.673	38.0	1872
Apparent ME	$Y = 10.427 + 0.0841x + -0.0008x^2$	0.385	42.0	12.4
N retention	$Y = 2.15894 + 0.2811x + -0.0003x^2$	0.603	44.3	2.78

r^2: regression coefficient. Carrot meal: carrot meal supplementation level for optimal variable

Results of the effect of carrot meal supplementation on carcass characteristics of female Arbor acre broiler chickens aged 42 days are presented in *Table 6*. Carrot meal supplementation had no effect ($P > 0.05$) on carcass, breast, drumstick, thigh, liver, gizzard and fat pad weights of female Arbor acre broiler chickens aged 42 days. Results of the effect of carrot meal supplementation on tenderness, juiciness and flavour of meat of female Arbor acre broiler chickens aged 42 days are presented in *Table 7*. Carrot

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meal supplementation did not improve ($P > 0.05$) meat tenderness and flavour of female Arbor acre broiler chickens aged 42 days. Female broiler chickens supplemented with 20, 50 or 100 g of carrot meal per kg DM feed produced meat with higher ($P < 0.05$) juiciness than those of meat from a diet not supplemented with carrot meal and those on a diet supplemented with 75 g of carrot meal per kg DM. A positive relationship was observed between carrot meal supplementation to the diets of female Arbor acre broiler chickens and meat juiciness ($r^2 = 0.085$). Carrot meal supplementation did not affect tenderness and flavour of female Arbor acre broiler chicken meat. However, carrot meal supplementation improved the juiciness of female Arbor acre broiler chicken meat. Thus, there was a weak but positive relationship between carrot meal supplementation and juiciness of female Arbor acre broiler chicken meat.

Table 6. *Effect of carrot meal supplementation on carcass characteristics (g) of female Arbor acre broiler chickens aged 42 days*

Variable	Treatment					SE
	FA_0	FA_{20}	FA_{50}	FA_{75}	FA_{100}	
Carcass	1569	1434	1534	1461	1526	26.03
Breast	205	221	207	214	202	8.42
D/stick	102	99	88	89	96	2.15
Thigh	108	112	104	76	107	5.75
Liver	68	62	62	55	54	3.01
Gizzard	41	34	32	37	33	1.65
Fat pad	39	43	44	31	42	2.62

SE: standard error

Table 7. *Effect of carrot meal supplementation level on tenderness, juiciness and flavour of meat of female Arbor acre broiler chickens aged 42 days*

Sensory attributes	Treatment					SE
	FA_0	FA_{20}	FA_{50}	FA_{75}	FA_{100}	
Juiciness	2.50^b	3.50^a	3.70^a	2.50^b	3.60^a	0.153
Tenderness	3.30	3.30	3.00	3.00	3.30	0.131
Flavour	3.00	3.10	3.00	3.00	3.20	0.131

^{a,b}Means in the same row not sharing a common superscript are significantly different ($P < 0.05$)
SE: standard error

Discussion

In the present study, carrot meal supplementation had no effect on growth rate of female Arbor acre broiler chickens aged 22 to 42 days. Carrot meal supplementation improved dietary intake of female Arbor acre broiler chickens aged 22 to 42 days. However, these improvements did not have any impact on growth rates of the chickens. Similarly, improvements in dietary intake, feed conversion ratio, metabolisable energy intake and nitrogen retention did not result in any improvement of live weights of the chickens. These results are similar to those of Erhan and Bölükbaşı (2017) who found out that supporting the diet with citrus peel oil did not change the weight of the broilers. According to Yu et al. (2005), the obtained results in this study may be attributed to

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antioxidant and antimicrobial properties of carrot meal. However, the present results are contrary to those of Ürüşanet al. (2018) who observed improvements in live weights of chickens supplemented with carrot meal. Similarly, Abdu et al. (2012) reported improvements in live weights of rabbits with carrot meal supplementation. This might also be because large amounts of easily-fermented components as sugars and soluble non-starch polysaccharides contribute some energy to the chickens Steenfeldts et al. (2007).

Supplementation with 50 g of carrot meal per kg DM feed improved feed conversion ratio. Rizal et al. (2010) reported an improvement in feed conversion ratio of broiler chickens supplemented with carrot meal. Improvements in dietary feed conversion ratio observed in the present study are similar to those observed by Hammershøj et al. (2005) and Hammershøj et al. (2010) reported improvements in feed conversion ratio of laying hens when they were supplemented with carrot meals. However, Khan (2019) reported no improvements in feed conversion ratio of broiler chickens fed carrot pulp. In the present study, dietary intake and feed conversion ratio and live weight of female Arbor acre broiler chickens aged 22 to 42 days were optimized at different dietary carrot meal supplementation levels of 52.8 and 63.8 g/kg DM feed, respectively. This means that carrot meal levels for optimal productivity will depend on the particular variable of interest. This has implications on ration formulation where carrot meal is included.

Carrot meal supplementation improved dietary metabolisable energy intakes of female Arbor acre broiler chickens aged 22 to 42 days. These results are similar to those of Magouze et al. (1998) who observed that carrot meal supplementation in growing rabbits improved their metabolisable energy intakes. However, El-Kerdawy et al. (1992) found that carrot meal supplementation to the diets of growing rabbits decreased their metabolisable energy intakes. Similarly, Steenfeldts et al. (2007) observed a decrease in metabolisable energy intakes of laying hens supplemented with carrot meal. The results of the present study indicate that carrot meal supplementation increased nitrogen retention in female Arbor acre broiler chickens aged 22 to 42 days. Their findings may imply that an alteration of tissues takes place, particularly muscle and fat deposits, which may differ in nutrient digestion (Moran and Bilgili, 1990). However, these results contradict with those of El-Kerdawy et al. (1992), which indicated that carrot meal supplementation to the diets of growing rabbits decreased nitrogen retention. Similarly, Steenfeldts et al. (2007) found that nitrogen retention in laying hens supplemented with carrot meal was increasing. In the present study, metabolisable energy intake and nitrogen retention of female Arbor acre broiler chickens were optimized at different carrot meal supplementation levels of 42.0 and 44.3 g/kg DM feed, respectively. This means carrot meal levels for optimal metabolisable intake and nitrogen retention intake will depend on the variable of interest.

Carrot meal supplementation had no effect on carcass, breast, drumstick, thigh, liver, gizzard and fat pad weights of female Arbor acre broiler chickens aged 42 days. Ürüşanet al. (2018) reported increase in hot carcass weight and carcass yield of broiler chickens feed carrot seed oil authors indicated that increase carcass weights which were observed in many studies, occurred because of the appetizer properties of plant extracts by increasing the gastric digestion liquor. Carrot meal supplementation did not affect tenderness and flavour of female Arbor acre broiler chicken meat. Meat sensory attribute values of tenderness and flavour were similar across the dietary treatments. It is not clear how carrot meal supplementation affect the sensory attributes of broiler chickens and this may require further studies. However, carrot meal supplementation

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improved the juiciness of female Arbor acre broiler chicken meat. Thus, there was positive relationship between carrot meal supplementation and juiciness of female Arbor acre broiler chicken meat. No such information was found for either indigenous or broiler chicken breeds. Further research is needed to deepen the knowledge in this area.

Conclusion

Carrot meal supplementation did not have any effect on growth rate, live weight, carcass weight, meat tenderness and flavour of Arbor acre broiler chickens aged 22 to 42 days. However, carrot meal supplementation improved intake, feed conversion ratio, metabolisable energy intake, nitrogen retention and meat juiciness of female Arbor acre broiler chickens aged 22 to 42 days. As a result, carrot meal can be added in the diet of broilers as a beneficial dietary supplement which contains natural antioxidants. Optimal improvements of feed intake, FCR, live weight, metabolisable energy intake and nitrogen retention were achieved at different carrot meal supplementation levels. Thus, carrot meal levels for optimal productivity will depend on the parameter in question. This has a lot of implications in diet formulations where carrot meal is included. Further studies are recommended to repeat and confirm results of this study.

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