An Acad Bras Cienc (2023) 95(Suppl. 1): e20200495 DOI 10.1590/0001-3765202320200495
Anais da Academia Brasileira de Ciências | *Annals of the Brazilian Academy of Sciences*
Printed ISSN 0001-3765 I Online ISSN 1678-2690
www.scielo.br/aabc | www.fb.com/aabcjournal

ANIMAL SCIENCE

Development of broiler chickens fed with different percentages of cassava meal

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Abstract: The objective was to determine the zootechnical performance of broiler chickens fed different diets containing cassava meal. A total of 450 male broiler chickens of the Cobb lineage was used. The experimental design was completely randomized with five treatments (0, 25, 50, 75, and 100% inclusion of cassava meal) and five replications, composed of 18 birds per experimental unit. Morphometric characteristics of broiler chickens were evaluated: live weight, and weights of full and empty carcasses, livers, hearts, full and empty gizzards, abdominal fat, wings, thighs, drumsticks, breasts, and dorse. Data were tested using an analysis of variance, regression model, and cluster and discriminant analyses. There was a difference in the weight of the heart, full gizzard, wing, thigh, drumstick, and breast in relation to the different diets. The inclusion of 8.2%, 57.57%, and 25.38% cassava meal maximized thighs at 323.96 g, drumsticks at 385.04 g, and breasts at 921.12 g, respectively. The formation of two groups of birds was verified, and the classification rate was 92%. Inclusion of up to 50% cassava meal in the broiler diet did not alter its zootechnical performance, implying a lower cost of production.

Key words: carcass quality, discriminant analysis, weight development, zootechnical performance.

INTRODUCTION

Poultry farming is one of the most developed animal production sectors in recent years, especially in the chicken meat production sector (Nogueira et al. 2019). Maximum feed efficiency and cost reduction in poultry are critical points to be considered in commercial farms because a properly balanced and nutritionally complete food will reduce stress, minimize deficiencies, improve immune competence, and produce quality carcasses with better performance and greater profitability (Pires et al. 2019). The increasing selection for high carcass and parts yields provides the industry with increasingly specific birds, which obtaining better use for specific cuts, reducing leftovers and flaps, and implying better carcass quality and chicken meat (Moreira et al. 2003).

The broiler chicken diet consists of vegetable ingredients, which are deficient in some minerals, especially Na^+; therefore, supplementation with products that provide this mineral is necessary (Rosa et al. 2010). The cost of feeding the animals could be approximately 70% of the total amount spent on production and is affected by the price of grains and ingredients, such as soybeans, causing the production sector to use alternative food sources with lower costs (Berwanger et al. 2017).

The price of maize grain has fluctuated considerably, causing poultry producers to search for alternative foods for use in poultry diets (Swain et al. 2006, Ashour et al. 2015, Niamat 2017). Cassava root meal which has been used as good alternative energy source in poultry and pig diets (Diarra & Devi 2015, Kyawt et al. 2014, Zanu et al. 2017). In this context, the use of cassava stands out as an ingredient rich in carbohydrates, dietary fiber, starch, proteins, lipids, and ash (Holanda et al. 2015), being capable of composing diets providing optimum weight gain and contributing to the reduction of the production cost of broiler chickens (Diarra & Devi 2015, Zanu et al. 2017).

Therefore, the objective of this study was to evaluate the zootechnical performance of broiler chickens fed diets containing different amounts of cassava meal.

MATERIALS AND METHODS

Study area

The research was conducted from November 29, 2019, to January 10, 2020, in the aviary of Fazenda São João, located in the district of Santa Rita, municipality of Serra Talhada-PE, in the micro-region of the Sertão do Pajeú, mesoregion of the Sertão de Pernambuco, under license number 127/2019 of the Ethics Committee on the Use of Animals of the Federal Rural University of Pernambuco.

Experimental design

A total of 450 male broiler chickens of the Cobb lineage, 1 d old, with a starting weight of 42 g. They were vaccinated while still in the hatchery, against Mareck, Newcastle, and Gumboro, and revaccinated at 14 d against Newcastle and Gumboro.

The birds were housed in an aviary built in masonry, with ceramic tiles and concrete floors, lined with a bed of inert material (rice husks) at a depth of 15 cm, padded with galvanized wire screen, and curtained to prevent drafts and control the environmental temperature. During the first 14 d of life, a 150-watt incandescent lamp was used as the heat source for broiler chickens. The aviary was divided into 25 experimental plots, each measuring 2 m², with a density of 9 birds/m².

The experimental design was completely randomized with five treatments and five replications, where each experimental unit was composed of 18 birds. The treatments consisted of a control diet based on corn and soybean meal, and four test diets containing a 25, 50, 75, and 100% inclusion of integral meal of cassava roots supplemented with endogenous enzymes, at the quantity of 500 g/t of feed.

Cassava roots were acquired in the municipality of Araripina-PE, and the roots were processed and dehydrated in the sun for 5 d until they lost the maximum amount of moisture to obtain dry meal. A sample was collected and taken to the laboratory for chemical analysis and the following results were obtained: 88.56% dry matter, 2.54% crude protein, 0.62% lipids, 5.32% crude fiber, 10.84% neutral detergent fiber (NDF), 3.96% fiber acid detergent (FDA), 84.92% organic matter, 3.52% ash, 0.18% calcium, and 0.09% phosphorus. The gross energy of 4,123 kcal/kg was determined using an IKA 200 calorimeter.

The results of the chemical composition were used to formulate the experimental diets with metabolizable energy of 2,986 Kcal/kg (determined in a metabolism experiment previously conducted with chicks). The multi-enzyme complex was composed of galactosidase (35 U/g), galactomannanase (110 U/g), xylanase (1,500 U/g), and β-glucanase (1,100 U/g). This was mixed with the premix in a Y-type mixer for the low-level dietary ingredients.

From the first day of life, the birds received experimental diets according to the treatments, following the nutritional recommendations of Rostagno et al. (2017) (Tables I, II, III, and IV). At the end of the experiment, the following morphometric characteristics of broiler chickens were evaluated: live weight (LW), and weights of the full carcass (FC), empty carcass (EC), liver (L), heart (H), full gizzard (FG), empty gizzard (EG), abdominal fat (AF), wing (W), thigh (T), drumsticks (DST), breast (B) and dorse (D).

Table I. Chemical composition and calculated of the experimental diets for broiler chickens from 1 to 7 days of age as a function of the levels cassava meal.

Ingredients	**Levels of cassava inclusion (%)**				
	0	**25**	**50**	**75**	**100**
Corn (kg)	46.543	34.907	23.271	11.635	0.000
Soybean meal (45%)	46.129	47.743	49.360	50.977	52.594
Cassava meal (kg)	0.000	8.888	17.777	26.665	35.554
Dicalcium phosphate	1.930	2.239	2.549	2.859	3.169
Calcitic Limestone	0.941	0.705	0.470	0.235	0.000
Vegetable oil	3.330	4.390	5.451	6.512	7.573
NaCl	0.456	0.450	0.445	0.439	0.434
L-lysine HCl (78%)	0.133	0.111	0.088	0.066	0.044
DL-methionine (99%)	0.328	0.348	0.368	0.388	0.408
L-threonine (98%)	0.010	0.017	0.025	0.032	0.040
Multienzyme complex	0.000	0.012	0.025	0.037	0.050
Choline chloride (60%)	0.100	0.100	0.100	0.100	0.100
[1]Premix mineral/vitamin	0.100	0.100	0.100	0.100	0.100
Calculated Composition (%)					
Crude protein (%)	25.31	25.31	25.31	25.31	25.31
Metabolizable energy (kcal/kg)	3.000	3.000	3.000	3.000	3.000
Calcium (%)	1.011	1.011	1.011	1.011	1.011
Phosphorus available (%)	0.482	0.535	0.589	0.642	0.696
Digestible lysine (%)	1.364	1.364	1.364	1.364	1.364
Digestible methionine (%)	0.669	0.680	0.692	0.703	0.715
Digestible met+cys (%)	0.989	0.989	0.989	0.989	0.989
Digestible threonine (%)	0.773	0.773	0.773	0.773	0.773
Digestible tryptophan (%)	0.296	0.304	0.312	0.320	0.328
Sodium (%)	0.227	0.227	0.227	0.227	0.227
Fat (%)	5.642	5.781	5.921	6.060	6.200

[1]Premix mineral/vitamin/kg: Folic Acid 106.00 mg; Pantothenic 2,490 mg; Antifungal 5,000 mg; Antioxidant 200 mg; Biotin 21mg; Coccidiostatic 15,000 mg; Choline 118,750 mg; Vitamin K3 525.20 mg; niacin 7,840 mg; Pyridoxine 210 mg; Riboflavina 1,660 mg; Thiamine 360 mg; Vitamin A 2,090,000 UI; Vitamin B12 123,750 mcg; Vitamin D3 525,000 UI; Vitamin E 4,175 mg. Cu 2,000 mg; I 190 mg; Mn 18,750 mg; Se 75 mg; Zn 12,500 mg.

Table II. **Chemical composition and calculated of the experimental diets for broiler chickens from 8 to 21 days of age as a function of the levels cassava meal.**

Ingredients	Levels of cassava inclusion (%)				
	0	25	50	75	100
Corn (kg)	48.080	36.060	24.040	12.020	0.000
Soybean meal (45%)	43.600	45.235	46.870	48.505	50.141
Cassava meal (kg)	0.000	9.355	18.710	28.065	37.420
Dicalcium phosphate	1.679	1.699	1.719	1.739	1.760
Calcitic Limestone	1.017	0.967	0.918	0.869	0.820
Vegetable oil	4.510	5.547	6.585	7.622	8.660
NaCl	0.444	0.438	0.432	0.426	0.420
L-lysine HCl (78%)	0.136	0.113	0.091	0.069	0.047
DL-methionine (99%)	0.327	0.348	0.369	0.390	0.412
L-threonine (98%)	0.012	0.041	0.071	0.100	0.130
Multienzyme complex	0.000	0.012	0.025	0.037	0.050
Choline chloride (60%)	0.100	0.100	0.100	0.100	0.100
[1]Premix mineral/vitamin	0.100	0.100	0.100	0.100	0.100
Calculated Composition (%)					
Crude protein (%)	24.30	24.30	24.30	24.30	24.30
Metabolizable energy (kcal/kg)	3.100	3.100	3.100	3.100	3.100
Calcium (%)	0.970	0.970	0.970	0.970	0.970
Phosphorus available (%)	0.432	0.432	0.432	0.432	0.432
Digestible lysine (%)	1.306	1.306	1.306	1.306	1.306
Digestible methionine (%)	0.657	0.669	0.681	0.693	0.705
Digestible met+cys (%)	0.966	0.966	0.966	0.966	0.966
Digestible threonine (%)	0.816	0.805	0.794	0.783	0.773
Digestible tryptophan (%)	0.282	0.269	0.257	0.244	0.232
Sodium (%)	0.221	0.221	0.221	0.221	0.221
Fat (%)	6.820	6.990	7.160	7.330	7.500

[1]Premix mineral/vitamin /kg: Folic Acid 106.00 mg; Pantothenic 2,490 mg; Antifungal 5,000 mg; Antioxidant 200 mg; Biotin 21mg; Coccidiostatic 15,000 mg; Choline 118,750 mg; Vitamin K3 525.20 mg; niacin 7,840 mg; Pyridoxine 210 mg; Riboflavina 1,660 mg; Thiamine 360 mg; Vitamin A 2,090,000 UI; Vitamin B12 123,750 mcg; Vitamin D3 525,000 UI; Vitamin E 4,175 mg. Cu 2,000 mg; I 190 mg; Mn 18,750 mg; Se 75 mg; Zn 12,500 mg.

Table III. **Chemical composition and calculated of the experimental diets for broiler chickens from 22 to 35 days of age as a function of the levels cassava meal.**

Ingredients	**Levels of cassava inclusion (%)**				
	0	**25**	**50**	**75**	**100**
Corn (kg)	60.880	45.660	30.440	15.220	0.000
Soybean meal (45%)	32.814	34.825	36.837	38.848	40.860
Cassava meal (kg)	0.000	12.560	25.135	37.702	50.270
Dicalcium phosphate	1.420	1.445	1.470	1.495	1.520
Calcitic Limestone	0.718	0.655	0.589	0.524	0.460
Vegetable oil	3.084	3.721	4.358	4.995	5.663
NaCl	0.422	0.413	0.405	0.396	0.388
L-lysine HCl (78%)	0.220	0.194	0.168	0.142	0.116
DL-methionine (99%)	0.272	0.299	0.327	0.364	0.394
L-threonine (98%)	0.000	0.027	0.055	0.082	0.110
Multienzyme complex	0.00	0.012	0.025	0.037	0.050
Choline chloride (60%)	0.100	0.100	0.100	0.100	0.100
[1]Premix mineral/vitamin	0.100	0.100	0.100	0.100	0.100
Calculated Composition (%)					
Crude protein (%)	20.58	20.58	20.58	20.58	20.58
Metabolizable energy (kcal/kg)	3.150	3.150	3.150	3.150	3.150
Calcium (%)	0.758	0.758	0.758	0.758	0.758
Phosphorus available (%)	0.374	0.374	0.374	0.374	0.374
Digestible lysine (%)	1.124	1.124	1.124	1.124	1.124
Digestible methionine (%)	0.557	0.572	0.588	0.603	0.619
Digestible met+cys (%)	0.832	0.832	0.832	0.832	0.832
Digestible threonine (%)	0.773	0.773	0.773	0.773	0.773
Digestible tryptophan (%)	0.225	0.229	0.233	0.237	0.241
Sodium (%)	0.224	0.224	0.224	0.224	0.224
Fat (%)	5.680	6.285	6.890	7.495	8.100

[1]Premix mineral/vitamin/kg: Folic Acid 106.00 mg; Pantothenic 2,490 mg; Antifungal 5,000 mg; Antioxidant 200 mg; Biotin 21mg; Coccidiostatic 15,000 mg; Choline 118,750 mg; Vitamin K3 525.20 mg; niacin 7,840 mg; Pyridoxine 210 mg; Riboflavina 1,660 mg; Thiamine 360 mg; Vitamin A 2,090,000 UI; Vitamin B12 123,750 mcg; Vitamin D3 525,000 UI; Vitamin E 4,175 mg. Cu 2,000 mg; I 190 mg; Mn 18,750 mg; Se 75 mg; Zn 12,500 mg.

Table IV. Chemical composition and calculated of the experimental diets for broiler chickens from 36 to 42 days of age as a function of the levels cassava meal.

Ingredients	Levels of cassava inclusion (%)				
	0	25	50	75	100
Corn (kg)	62.722	46.976	31.321	15.675	0.000
Soybean meal (45%)	30.217	32.282	34.348	36.414	38.500
Cassava meal (kg)	0.000	12.973	25.946	38.919	51.892
Dicalcium phosphate	1.089	1.114	1.139	1.164	1.190
Calcitic Limestone	0.701	0.634	0.568	0.501	0.435
Vegetable oil	4.218	4.856	5.494	6.132	6.770
NaCl	0.407	0.398	0.390	0.381	0.373
L-lysine HCl (78%)	0.226	0.199	0.173	0.146	0.120
DL-methionine (99%)	0.253	0.281	0.309	0.337	0.366
L-threonine (98%)	0.064	0.075	0.087	0.098	0.110
Multienzyme complex	0.000	0.012	0.025	0.037	0.050
Choline chloride (60%)	0.100	0.100	0.100	0.100	0.100
[1]Premix mineral/vitamin	0.100	0.100	0.100	0.100	0.100
Calculated composition (%)					
Crude protein (%)	19.54	19.54	19.54	19.54	19.54
Metabolizable energy (kcal/kg)	3.250	3.250	3.250	3.250	3.250
Calcium (%)	0.661	0.661	0.661	0.661	0.661
Phosphorus available (%)	0.309	0.309	0.309	0.309	0.309
Digestible lysine (%)	1.067	1.067	1.067	1.067	1.067
Digestible methionine (%)	0.525	0.541	0.557	0.573	0.589
Digestible met+cys (%)	0.790	0.790	0.790	0.790	0.790
Sodium (%)	0.201	0.201	0.201	0.201	0.201
Digestible threonine (%)	0.704	0.704	0.704	0.704	0.704
Fat (%)	6.760	6.922	7.085	7.247	7.410

[1]Premix mineral/vitamin/kg: Folic Acid 106.00 mg; Pantothenic 2,490 mg; Antifungal 5,000 mg; Antioxidant 200 mg; Biotin 21mg; Coccidiostatic 15,000 mg; Choline 118,750 mg; Vitamin K3 525.20 mg; niacin 7,840 mg; Pyridoxine 210 mg; Riboflavina 1,660 mg; Thiamine 360 mg; Vitamin A 2,090,000 UI; Vitamin B12 123,750 mcg; Vitamin D3 525,000 UI; Vitamin E 4,175 mg. Cu 2,000 mg; I 190 mg; Mn 18,750 mg; Se 75 mg; Zn 12,500 mg.

Statistical analysis

An analysis of variance was used to compare the components of broiler chicken carcasses with different levels of cassava meal inclusion in the diet after which pairwise differences were detected with the Tukey test at the 5% level. For the carcass components that showed differences in relation to the diet, a quadratic regression model was adjusted and defined by:

$$Y = aX + bX^2 + c + \varepsilon$$

where Y is the dependent variable (carcass component of broiler chickens), X is the independent variable (level of inclusion of cassava meal in the diet), ε is the random error that presents a normal distribution with a mean of zero and constant variance $\sigma^2 > 0$; a, b, and c were the model parameters to be estimated.

Ward cluster analysis (Lucena et al. 2019) was used to evaluate the difference between the carcass components of broiler chickens that showed statistical differences in relation to the different diets. To evaluate the quality of the grouping method, the cophenetic correlation coefficient (CCC) was used (Farris 1969).

The CCC measures the degree of fit between the dissimilarity matrix (phenetic matrix F) and the resulting matrix of simplification provided by the grouping method (cophenetic matrix C).

$$r_{cof} = \frac{\sum_{j=1}^{n-1}\sum_{j'=j+1}^{n}\left(c_{jj'} - \bar{c}\right)\left(f_{jj'} - \bar{f}\right)}{\sqrt{\sum_{j=1}^{n-1}\sum_{j'=j+1}^{n}\left(c_{jj'} - \bar{c}\right)^2}\sqrt{\sum_{j=1}^{n-1}\sum_{j'=j+1}^{n}\left(f_{jj'} - \bar{f}\right)^2}}$$

where,

$$\bar{c} = \frac{2}{n(n-1)}\sum_{j=1}^{n-1}\sum_{j'=j+1}^{n}c_{jj'} \quad \text{and} \quad \bar{f} = \frac{2}{n(n-1)}\sum_{j=1}^{n-1}\sum_{j'=j+1}^{n}f_{jj'}$$

The higher the value obtained for r_{cof} the less distortion was caused by the grouping of individuals. Rohlf (1970) evaluated the inadequacy of the grouping method when $r_{cof} < 0.7$.

Discriminant analysis (Lucena & Lessa 2019) was used to identify the functions of observed variables that explained the observed differences among diet groups and classify the broiler chickens. Fisher's linear discriminant function is a linear combination of the original characteristics, which is characterized by producing maximum separation between two populations. Fisher's discriminant function is defined as follows:

$$D(X) = \left[\mu_1 - \mu_2\right]'\Sigma^{-1}X$$

where $X = \left[X_1, X_2, \ldots, X_p\right]$ is the vector of carcass components of broiler chickens that showed differences in relation to the diet; μ_1 and μ_2 are the mean vectors of the carcass components of broiler chickens of the two groups of diets (group I–diets with the inclusion of 0%, 25%, and 50% cassava meal, and group II–diets with the inclusion of 75% and 100% cassava meal), and Σ is the covariance matrix of the carcass components of broiler chickens.

The value of Fisher's discriminant function for a given set of carcass components of the respective broiler chickens is

$$D(x_0) = \left[\mu_1 - \mu_2\right]'\Sigma^{-1}x_0$$

The midpoint between the two mean vectors of the carcass components of broiler chickens was defined by:

$$m = \frac{D(\mu_1) + D(\mu_2)}{2}$$

The classification rule based on Fisher's discriminant function allocated x_0 to the carcass components of broiler chickens group I if $D(x_0) \geq m$ otherwise it allocated x_0 to the carcass components of broiler chickens group II.

RESULTS

No differences were found in LW, or weight of full and empty carcasses, full and empty gizzards, abdominal fat, and dorse of the broiler chickens in relation to the different diets (Table V).

The birds fed 25% cassava meal presented higher values for the weight of the hearts

Table V. **Comparison of carcass components of broiler chickens in relation to different diets.**

	Percentage of inclusion of cassava meal (Mean±SD)					p-value
	0%	25%	50%	75%	100%	
Live weight (LW)	3290±54.8	3340±51.7	3386±49.8	3340±81.7	3300±70.5	0.703
Full carcass (FC)	3047±69.9	3092±20.1	3137±77.4	3131±15.4	3013±87.3	0.611
Empty carcass (EC)	2730±76.1	2784±93.4	2845±84.0	2824±79.7	2730±76.1	0.462
Liver (L)	52±5.7	46±6.5	45±6.8	49±8.2	51±7.4	0.538
Heart (H)	12±2.7b	18±7.6a	11±2.3b	12±2.7b	12±2.7b	0.036
Full gizzard (FG)	62±18.2a	50±13.2b	56±5.5ab	36±10.4c	41±10.8c	0.035
Empty gizzard (EG)	34±13.9	33±4.5	33±2.7	31±8.2	28±4.5	0.762
Abdominal fat (AF)	33±6.1	30±3.5	30±6.9	30±6.1	19±6.5	0.363
Wing (W)	244±13.4a	209±9.6b	236±15.6a	200±7.9bc	183±20.8c	0.001
Thigh (T)	317±7.6ab	340±26.5a	295±33.9b	287±8.4bc	269±27.5c	0.001
Drumsticks (DST)	408±50.8ab	443±72.9a	372±52.9b	361±21.9b	350±24.3b	0.038
Breast (B)	905±50.2a	915±70.8a	912±42.2a	850±90.5b	768±21.4c	0.009
Dorse (D)	417±56.9	438±52.2	400±42.3	383±45.5	388±18.2	0.322

p-value <0.05 difference in ANOVA; different letters in the lines indicate difference between treatments.

compared to the birds that received the other diets (p-value = 0.036) (Table V). There was a difference in the weight of the full gizzard (p-value = 0.035). The birds that received the control diet presented the highest weight of full gizzards, whereas birds that received diets with 75% or 100% inclusion of cassava meal presented the lowest weights (Table V).

The mean wing weight of birds fed a control diet and 50% of cassava meal did not differ, but they were higher than those of birds fed other diets (p-value = 0.001) (Table V). The highest weights of the thighs and drumsticks were related to birds that were fed diets with up to 25% inclusion of cassava meal, whereas the lowest weights occurred for birds that fed on diets with 75% and 100% inclusion of cassava meal (p-value = 0.001 and 0.038, respectively) (Table V). Birds fed diets with up to 50% cassava meal inclusion presented the highest breast weight, whereas the lowest breast weight was related to birds that received 100% cassava bran inclusion in their diet (p-value = 0.009) (Table V).

Regression models were adjusted for the thigh, drumstick, and breast cuts because these cuts presented a statistically significant difference in relation to the different diets. The carcass components, weights of the heart, full gizzard, and wing, were not in adjusted regression models. They presented cubic behavior that did not generate biological information.

Thigh weights presented a quadratic behavior as a function of the different diets. The adjusted model presented a coefficient of determination (R^2) of 78.01%, the inclusion of cassava meal of 8.2% maximized the weight of the thighs at 323.96 g (Figure 1). Drumsticks presented the same behavior as the broiler chickens thighs, and the adjusted model presented a coefficient of determination of 78.30%. The percentage of the inclusion of cassava meal of 57.57% maximized the weight

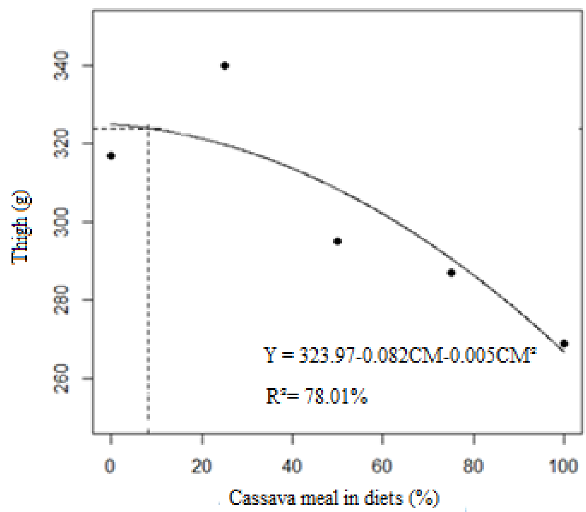

Figure 1. **Regression model adjustment to explain the behavior of the broiler chicken thighs as a function of the different levels of inclusion of cassava meal.**

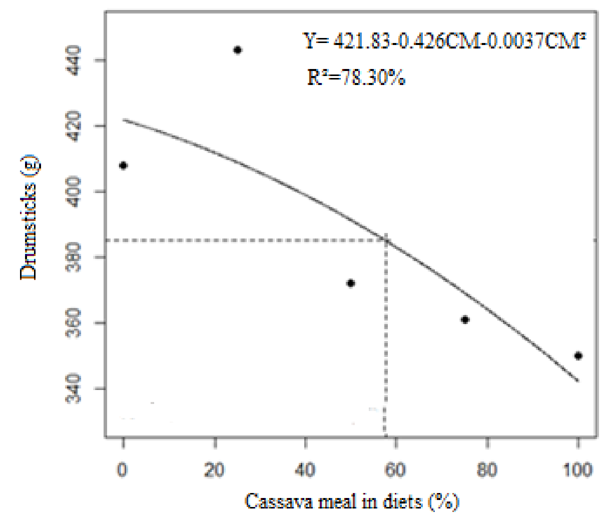

Figure 2. **Regression model adjustment to explain the behavior of the broiler chicken drumsticks as a function to the different levels of inclusion of cassava meal.**

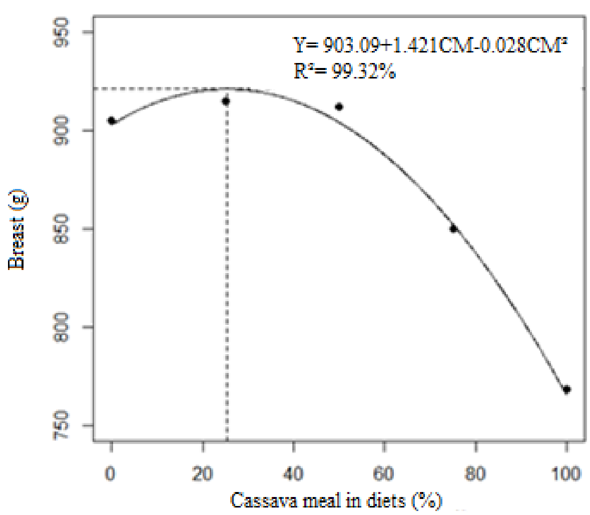

Figure 3. **Regression model adjustment to explain the behavior of the broiler chicken breast as a function to the different levels of inclusion of cassava meal.**

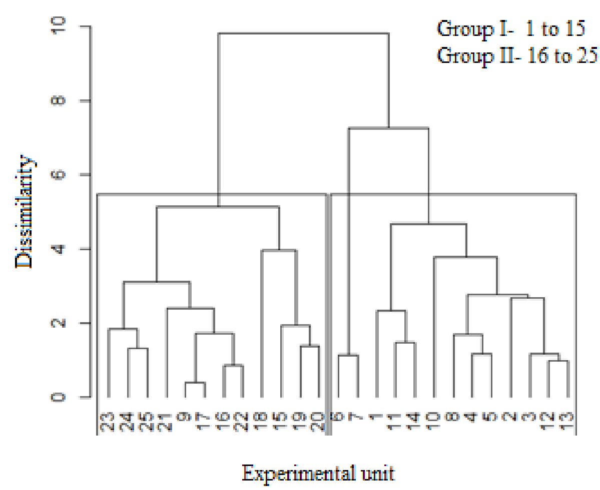

Figure 4. **Cluster of carcass components that showed differences in weight in relation to different diets using the Ward method.**

of the drumsticks at 385.04 g (Figure 2). Broiler chicken breasts presented quadratic behavior as a function of the different levels of inclusion of cassava meal in their diet. The adjusted model presented a high coefficient of determination (R^2= 99.32%), with the percentage of inclusion of 25.38% cassava meal maximized the broiler chicken breast at 921.12 g (Figure 3).

Using broiler chicken carcass components (weights of heart, full gizzard, wing, thigh, drumstick, and breast) that showed differences in weight in relation to the different diets, Figure 4 shows the formation of two groups (group I, birds that received the control diets, and diets with 25% and 50% inclusion of cassava meal; group II, birds that received diets with

75% and 100% inclusion of cassava meal). Two experimental units (9 and 15) of group I were classified in group II, generating a classification rate in the cluster method of 92% and a cophenetic correlation of 0.83, indicating good quality of the cluster method.

The analysis of comparison of means and clusters suggests the formation of two groups, one formed by broiler chickens fed with control diets, and diets with 25% and 50% inclusion of cassava meal, and the other formed by broiler chickens fed diets with 75% and 100% inclusion of cassava meal. In this scenario, the discriminant analysis was performed with these two groups, generating a Fisher discriminant function defined by:

$$D(x) = -0.077H-0.033FG-0.039W-0.021T+0.002DST-0.006B$$

Table VI shows the mean characteristics of the carcass components of the two groups under the test, as well as the value of the discriminant function for each group. Fischer's discriminant function generated a 92% hit rate (23/25), with the hit rate in group I being 86.67% (13/15) and in group II 100% (10/10).

Using the values of the Fisher discriminant functions of both groups, we have a midpoint value of m = (-23.15-19.57)/2 = -21.36; thus, the rule for allocation of broiler chickens that presented a Fischer discriminant function value greater than or equal to -21.36 was allocation to the group of birds that received diets with 0%, 25%, and 50% cassava meal; otherwise, they were allocated to the group of birds fed diets with 75% and 100% inclusion of cassava meal.

Table VI. Means of carcass components of broilers chickens in relation to diet groups (Group I- diets containing 0%, 25% and 50% cassava meal; Group II- diets containing 75% and 100% cassava meal).

Characteristics of the carcass components	Means	
	Group I	Group II
Heart	13.67	11.00
Full gizzard	56.00	38.50
Wing	229.67	191.50
Thigh	317.33	278.00
Drumstick	407.67	355.50
Breast	907.67	809.00
D(x)	-23.15	-19.57

DISCUSSION

The zootechnical performance of the broiler chickens was not altered by the inclusion of cassava meal in their diet, because few carcass components showed a difference in the weight of the cuts according to the diets. LW and weights of the liver, abdominal fat, and dorse of the broiler chickens did not change with the inclusion of cassava meal up to 100%. Because of the different selection goals applied by geneticists in the last few decades, growth parameters of broiler genotypes can differ in several characteristics, including those that affect potential growth curves using weight and maturation rates (Sakomura et al. 2011).

Geron et al. (2015) verified that the inclusion of up to 10% of cassava meal did not compromise the zootechnical performance of broiler chickens; however, there was a decreasing linear behavior for the LW of birds (R^2= 59%) and weight of the breast (R^2= 54%), wing (R^2= 86%), and dorse (R^2= 70%). Sousa et al. (2012) verified a difference in the weight gain of broiler chickens fed up to 20% of cassava meal in the initial phase (1–21 d), whereas during the final phase (22–40 d), there was no difference in weight gain.

Bhuiyan & Iji (2015) suggests that cassava could be used to replace maize in broiler diets at up to 50% with enzyme supplementation of such diets, without compromising the zootechnical performance of the broiler chickens. Replacing maize with cassava root flour at 100% of inclusion rate in broiler chicken's decreased the weight gain and FCR, as well as carcass weight and dressing percentage. But haematological indices were not affected by dietary inclusion of cassava flour (Zanu et al. 2017).

Gottardi et al. (2019) verified that the broiler chickens at 42 d of age presented a mean LW of 2,804 g, and weight of breast of 806 g, thigh 274 g, drumstick 323 g, wing 103 g, liver 40 g, heart 9 g, and abdominal fat at 23 g. Henrique et al. (2017) verified that the zootechnical performance of birds of the Cobb lineage did not change when housed up to 14 birds/m². The same authors reported that the LW (2,350 g) and the weight of the leg yield (645.55 g) and the breast (888.06 g) of the birds did not differ housing up to 16 birds/m². Mendes et al. (2004) used metabolizable energy of 3,020 kcal/kg, and verified a LW of 2,390 g for broiler chickens, with wings weighing 228.96 g, dorse 433.79 g, abdominal fat 68.35 g, breast 647.93 g, and legs 670.63 g.

Cassava meal diet did not have significant dietary effects on the egg quality parameters, the results demonstrated that, up to 40% of maize could be repleace with cassava meal for improving laying performance and egg quality and lowering yolk cholesterol contentes (Kyawt et al. 2014). Holanda et al. (2015) verified differences in LW, and weight of the drumstick, abdominal fat, and liver with the inclusion of up to 48% cassava meal, without compromising the zootechnical performance of free-range broiler chickens. Carrijo et al. (2010) verified that the inclusion of up to 45% cassava meal did not affect the zootechnical performance of free-range female broiler chickens, whereas Souza et al. (2011) verified that the inclusion of up to 60% cassava meal did not affect the zootechnical performance of free-range broiler chickens.

These results corroborated the findings of this study because using 9 birds/m², with metabolizable energy of 2,986 Kcal/kg and inclusion of up to 50% of cassava meal, broiler chickens presented zootechnical performance much higher than that reported by the aforementioned authors. As an example, the LW of birds had a mean of 1,000 g higher than those reported, whereas the broiler chicken breast was 500 g larger, the cuts of the wing, thigh, drumstick, and dorse presented values that were greater by 100 g or more.

Cassava meal in the dietary supplementation of broiler chickens, in addition to promoting better zootechnical performance, decreased production costs. For diets without the inclusion of cassava meal, the production cost was higher because more corn was used ($0.27 per kg of feed for 0%; $0.26 per kg of feed for 25%; $0.24 per kg of feed for 50%; $0.23 per kg of feed for 75%; $0.21 per kg of feed for 100%) (Lucena et al. 2020), whereas the cost using 50% and 100% inclusion of cassava meal was lower because half of the corn was used relative to the control diet (Lucena et al. 2020). Efficient use of cassava by-products will reduce feed cost of poultry production and provide additional source of income to cassava farmers and processors (Diarra & Devi 2015, Zanu et al. 2017).

Inclusion of up to 50% of cassava meal in the broiler diet did not alter its zootechnical performance, implying a lower cost for poultry production.

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How to cite
LUCENA LRR, DE HOLANDA MAC & DE HOLANDA MCR. 2023. Development of broiler chickens fed with different percentages of cassava meal. An Acad Bras Cienc 95: e20200495. DOI 10.1590/0001-3765202320200495.

Manuscript received on April 7, 2020;
accepted for publication on December 7, 2020

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Leandro Ricardo Rodrigues de Lucena – participation in the experimental design, conduct of the experiment, statistical analysis and writing of the manuscript. Marco Aurélio Carneiro de Holanda – participation in obtaining the birds, such as conducting the experiment, formulating the ration and writing the manuscript. Mônica Calixto Ribeiro de Holanda-participation in the experimental design, writing of the manuscript and conducting the experiment.