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Short communication

Performance, carcass yield, and meat quality of buffalo (*Bubalus bubalis*) fed on diets with different levels of concentrate

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Abstract

The objective of this study was to evaluate the influence of diets with increasing concentrate levels on performance, carcass characteristics, and meat quality of Murrah buffaloes in feedlot. Twenty-four animals, with an initial body weight of 240 ± 50.5 kg and mean age of 9 months, were distributed to four treatments: 20%, 40%, 60% and 80% concentrate. After 114 days, the animals were weighed, slaughtered, and meat quality and performance data were submitted to analysis of variance and regression. The dry matter intake and average daily gain increased linearly. The final body, hot carcass, and cold carcass weights responded linearly to increases in concentrate level. The subcutaneous fat thickness, protein, and ether extract of meat increased linearly with an increase in concentrate level. The colour parameters, cooking losses, and shear force of the meat were not affected by increasing the concentrate. The inclusion of concentrate in feedlot diets increases performance, characteristics of carcass, and meat quality of Murrah buffalo in a feedlot.

Keywords: average daily gain, feedlot buffalo, fat thickness, meat colour
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Introduction

Buffalo are usually farmed extensively based on native pasture. Due to the seasonality of forage production in some regions, producers may need to use concentrated feeds to supplement their herds (Contò *et al*., 2022). There is a need to encourage the slaughter of young animals and the characterization of their meat to standardise and create a product identity, such that buffalo meat commercialization can be improved (Li *et al*., 2018; Ulutaş *et al*., 2021).

The quality and quantity of buffalo meat depends upon several factors, such as breed, age, feeding intensity, management system, and environmental conditions (Awan *et al*., 2014; Naveena & Kiran, 2014). Andrighetto *et al*. (2008) noted that as the level of concentrate in the diet increased, the degree of fat in the carcass increased due to the high level of energy available, leading to higher fat deposition. There is therefore a need to find an optimum level of concentrate and to seek feed that favours productive gains (Masucci *et al*., 2016), is less expensive, meets the needs of the buffalo, and generates carcasses and quality meat (Kandeepan *et al*., 2009), both during the period of the greatest forage production and during the dry season. There has been a wide discussion about the

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ideal level and quality of the concentrate to be used in the diets (Azmi *et al*., 2021). However, data related to buffalo, especially the Murrah breed, are scarce. The objective of this study was therefore to evaluate the performance, carcass characteristics, and meat quality of Murrah buffalo fed different levels of concentrate.

Materials and Methods

This research was approved by the Animal Use Ethics Committee in Research (CEUA-UFRPE), technical report Nº 075/2015, following the recommendations of the National Council for Animal Experimentation Control (CONCEA) for the protection of animals used for scientific purposes.

The research was carried out in the Bubalinoculture Sector of the Animal Science Department of the Federal Rural University of Pernambuco (UFRPE), located in the city of Recife, Pernambuco (geographical coordinates of 8º04'03' 'S and 34º55'00'' W). Twenty-four non-castrated Murrah bulls, with a mean age of 9 months and an average body weight of 240± 50.5 kg, were randomly distributed in four treatments with six replicates.

The animals were housed in individual stalls in a covered confinement shed, with free access to a feeder and drinking fountain. Before the start of the experiment, the buffaloes were identified, vaccinated against foot-and-mouth disease and rabies, and treated against endo- and ectoparasites.

The experimental period lasted 114 days and was divided into a 30-day adaptation period (when the animals were treated against ecto- and endoparasites and received supplementation of A, D and E vitamins), and an 84-day period of the feeding trial (for data and sample collection).

To estimate voluntary feed intake, refusals were saved and weighed before each feeding; the feed intake was estimated by the difference between the offer and refusal (up to 15%). The diets were formulated to be isonitrogenous and composed of sugarcane forage (variety RB92579), maize/ corn meal, wheat bran, and soybean meal. Animals were fed with 20, 40, 60, and 80% inclusion of concentrate in the dry matter of the diet (Table 1), and formulated to meet the nutritional requirements of buffalo for a weight gain of 800 g/day (Paul, 2011).

Table 1. Ingredients and chemical compositions of the experimental diets.

	Concentrate level (%)			
	20	**40**	**60**	**80**
Ingredients (g/kg of DM)				
Sugarcane#	800.0	600.0	400.0	200.0
Corn	92.5	190.0	287.5	385.0
Soybean meal	5.0	10.0	15.0	20.0
Wheat bran	92.5	190.0	287.5	385.0
Mineral mix	10.0	10.0	10.0	10.0
Chemical composition (g/kg of DM)				
Dry matter (g/kg of FM$)	461.7	566.5	671.4	776.3
Organic matter	958.8	954.1	949.4	944.7
Crude protein	132.8	134.8	136.8	138.8
Ether extract	16.8	21.5	26.3	31.0
Neutral detergent fibre	471.7	425.1	378.4	331.8
Indigestible neutral detergent fibre	169.5	134.9	100.2	65.6
Non-fibre carbohydrates	337.6	372.8	408.0	443.2

#Sugarcane forage corrected with urea/ammonium sulphate (96.0% sugarcane and 4.0% urea/as); $g/kg of fresh matter

Weekly feed samples were collected and dried in an oven with forced ventilation at 55 °C to perform the chemical composition analysis. The contents i.e., dry matter (DM), organic matter (OM), and crude protein (CP) analyses were performed according to the AOAC (2012), method numbers 934.01, 930.05, and 981.10, respectively. Ether extract (EE) was analysed using Soxhlet extraction with petroleum ether, according to method number 920.39 of the AOAC (2012). The concentration of neutral detergent fibre (NDF) was assayed with heat-stable amylase and corrected for ash and nitrogen compounds [$aNDF_{OM}(n)$] by using techniques described by Mertens (2002), with corrections for protein according to Licitra *et al*. (1996), with added thermostable alpha-amylase. Non-fibre carbohydrates (NFC) were calculated according to the method of Hall (2000):

$$NFC\ (g/kg) = 1000 - [(CP - \text{urea-derived } CP + \text{urea}) + NDF_{ap} + EE + \text{ash}],$$

where CP = crude protein; NDF_{ap} = neutral detergent fibre corrected for ash and protein; and EE = ether extract.

To determine indigestible neutral detergent fibre (NDF_i), samples of all foods were incubated in the rumen of a buffalo for 288 hours, as suggested by Detmann *et al*. (2012).

At the start and end of the experiment, the animals were weighed after a 16-h solid fast to determine average daily weight gain (ADG). At the end of the experiment, after 16 hours of fasting, the animals were weighed and then slaughtered according to RIISPOA standards (Brazil, 2000) and standard slaughterhouse procedures.

After slaughter, the carcass of each animal was divided into two half-carcasses, which were identified and weighed to obtain the weight of the hot carcass. Measurements were then made on the left half of the carcass, estimating carcass length, chest depth, leg length, leg thickness, and leg perimeter (Gomes *et al*., 2021). The carcasses were taken to the cold chamber at 4 ºC and after 24 h, the cold carcass weight, losses from cooling, pH, and temperature were measured by means of a digital meter (Testo SE & CO, Lenzkirch, GER).

Carcass compactness index was calculated as:

CCI (kg/cm) = cold carcass weight/internal carcass length

To obtain the longissimus thoracis et lumborum muscle area in the left half carcass, an incision was performed between the 12th and 13th ribs to expose the muscle, the area of which was hatched on transparent plastic sheet and later obtained by means of a digital planimeter (HAFF ®, Digiplan model). At the same position, the subcutaneous fat thickness was measured with the aid of callipers. Samples were collected from the longissimus muscle, which were identified, vacuum-packed, and immediately frozen (-20 °C) for further analysis.

Samples of the longissimus muscle collected from the 10th and 13th rib areas were used for the physico–chemical analysis of the meat. The chromatic characterization was performed according to the method of Ramos & Gomide (2017) using Minolta colourimeter (model Chroma Meter CR-400), operating in the CIE system (L *, a *, b *). To evaluate cooking losses (CL), the samples were previously thawed for 24 h under refrigeration (4°C) and cut into 2.5-cm thick steaks. Then, the steaks were roasted in a preheated oven at a temperature of 200 °C, until reaching 70 °C in the geometric centre; the temperature was monitored using a specialized thermometer. The losses during cooking were calculated from the weight difference of the samples before and after cooking and expressed as a percentage, according to the procedure cited by Duckett *et al*. (1998). Following the methodology of Ramos & Gomide (2017), three cylindrical/cores samples were taken in the longitudinal direction of the fibres from the remaining cooked samples, with the aid of a 1.27-cm diameter borer. The force required to cut each cylinder was measured using the Warner–Bratzler Shear Force (Model 3000).

Samples of the longissimus muscle (ground in a ball mill, placed in 90 × 15 mm Petri dishes, weighed, and frozen at -20 °C), were used for the composition analyses. After freezing, the samples were lyophilised to obtain dry matter (DM) and humidity according to protocol no. 925.09 (AOAC, 2012). The levels of minerals were evaluated in a muffle furnace (942.05), crude protein (CB) was assessed using the micro-Kjeldahl method (954.01), and ether extract was assessed using the Soxhlet method (EE) (920.39) (AOAC, 2012).

Data were submitted to analysis of variance and regression using the GLM procedure of SAS (Statistical Analysis System), considering a level of significance of 5% for data analysis. The experimental model used was completely randomized with four groups and six replicates per groups, according to the model:

$$Y_{ijk} = \mu + T_i + e_{ij},$$

where Y_{ij} = dependent variable observed; μ = overall mean; T_i = effect of groups i (i = 1 to 4); and e_{ij} = experimental error.

Results and Discussion

An increase in concentrate levels resulted in an increase (P <0.05) in the dry matter intake and average daily gain (ADG). Body weight at slaughter (BWS) showed a linear increase (P <0.05) as the levels of concentrate in the diet increased, ranging from 275.25 to 342.06 kg. Hot carcass weight (HCW) and cold carcass weight (CCW) showed the same pattern (P <0.05) for BWS (Table 2).

Table 2. Performance and carcass characteristics of buffalo fed on diets with different levels of concentrate

	Levels of concentrate (%DM)				SEM#	*P*-value$	
	20	40	60	80		L	Q
Dry matter intake (kg)	5.38	6.62	7.16	7.29	0.27	<.001	0.081
Average daily gain (kg)	0.66	0.92	1.20	1.38	0.07	<.001	0.588
Initial body weight (kg)	220.1	216.2	214.1	226.2	10.31	-	-
Body weight at slaughter (kg)	275.2	293.7	315.0	342.0	13.02	0.032	0.514
Hot carcass weight, kg	128.3	138.4	150.9	165.0	6.83	0.004	0.525
Cold carcass weight, kg	124.0	134.3	145.8	159.4	6.72	0.003	0.597
Hot carcass yield, %	46.2	46.9	47.8	48.1	0.35	0.010	0.744
Cold carcass yield, %	44.6	45.5	46.1	46.5	0.36	0.024	0.647
Leg length, cm	63.0	61.9	63.3	64.6	0.85	0.279	0.302
Leg perimeter, cm	92.5	92.3	97.1	99.1	1.54	0.047	0.478
Carcass length, cm	115.0	115.2	116.3	117.8	1.54	0.157	0.678
Carcass width, cm	38.0	37.6	37.2	37.8	0.62	0.748	0.534
CCI, kg cm^{-1}	1.0	1.1	1.2	1.3	0.05	0.034	0.825
Fat thickness, mm	4.6	6.5	6.5	8.6	0.47	0.023	0.827
Longissimus muscle area, cm^2	43.9	44.8	48.1	51.0	1.55	0.031	0.673
pH	5.4	5.4	5.4	5.4	0.01	0.984	0.065

#standard error of the mean; $L linear effect, Q quadratic effect

There was a linear effect (*P* <0.05) for protein and ether extract in buffalo meat due to the increasing inclusion of concentrate (Table 3). There was no influence (*P* >0.05) of the increasing inclusion of concentrate on the colour parameters, cooking losses, and shear force of the meat. An increase in concentrate levels resulted in an increase (*P* <0.05) in the carcass compactness index (CCI), subcutaneous fat thickness (EGS) and longissimus muscle area (LMA).

Table 3. Chemical composition and physicochemical parameters of meat (longissimus thoracis et lumborum) from buffalo fed on diets with increasing levels of concentrate

	Levels of concentrate (%DM)				SEM#	*P*-value$	
	20	40	60	80		L	Q
Moisture (%)	75.4	73.9	73.1	73.3	0.32	0.021	0.111
Mineral matter (%)	1.0	1.0	1.0	1.0	0.02	0.091	0.222
Crude protein (%)	21.1	22.9	23.3	22.5	0.21	0.031	0.011
Ether extract (%)	0.5	0.6	0.9	1.2	0.11	0.021	0.491
L*	31.4	32.0	32.9	31.0	0.67	0.972	0.405
a*	15.8	15.1	15.5	14.4	0.41	0.342	0.833
b*	7.0	6.7	6.8	6.7	0.15	0.604	0.766
Cook losses (%)	22.8	21.3	22.9	22.2	0.65	0.712	0.208
Shear force (N)	15.9	16.6	15.9	15.9	1.18	0.977	0.886

#standard error of the mean; $L linear effect, Q quadratic effect

A higher inclusion of concentrate (80%) generated a total weight gain of 115.86 kg, which was twice as high as that obtained from animals fed a diet containing less concentrate (55.15 kg). The highest weight gain was observed in the animals fed with 80% concentrate; this was due to the fact that the feed had a higher energy content than the other diets (Paul, 2011; Lambertz *et al*., 2014).

The carcass weights in the present study can be justified by the linear growth of the slaughter weight of the animals (Ulutaş *et al*., 2021). In the present study, the cold carcass weight ranged from 124 kg to 159 kg, a value close to that reported by Masucci *et al*. (2016) when evaluating dietary levels of silage in Mediterranean buffalo. The weight of the animal carcass is important because, besides demonstrating the gains obtained with the provided diet, it has a direct relation with the commercial value of the animal.

The carcass yield indicates the relationship (percentage) between the carcass weight and the body weight at slaughter, in addition to representing the edible fraction (meat) of the carcass. Diets that have a lower proportion of concentrate (i.e., higher content of neutral detergent fibre) result in a longer retention of the digesta in the gastrointestinal tract of the animal, causing a high rumen content to be present at the time of weighing, negatively interfering with the carcass yield (Cifuni *et al*., 2014). In addition, buffalo slaughtered with higher body weights have higher hot and cold carcass yields (Rashad *et al*., 2019). The averages obtained in this study for carcass yields were lower than that observed by Cabral Neto *et al*. (2013), which were 48.3 and 47% for hot and cold carcass yields, respectively, for Mediterranean buffalo in a feedlot.

Carcass length, carcass width, and leg length are related to the animal's bone development. In the present study, averages of 149.00, 37.68, and 72.80 cm, respectively, indicated no influence of the level of concentrate on bone development. Ulutaş *et al*. (2021) reported an average carcass length and carcass width of Turkish Anatolian buffaloes close to that found in the present study.

Thickness of subcutaneous fat (TSF) is related to the amount of adipose tissue found in the carcass. The average TSF in the present study was within the expected minimum of 3 mm required in cattle carcasses (Gomes *et al*., 2021). Andrighetto *et al*. (2008) and Mello *et al*. (2018), when evaluating crossbred buffalo finished in confinement, observed average subcutaneous fat thicknesses of 6.2 and 8.1 mm, values close to those found in the current study.

As the level of concentrate increased in the diets, the slaughter weight gain and the hot carcass weight increased and, consequently, the longissimus muscle area (LMA) increased linearly. According to Rashad *et al*. (2019), the LMA is positively correlated to the HCW, such that an increase in the values observed in this work can be attributed to the increase in carcass weight.

The mean pH value of the meat in the present study was similar to that found by Mello *et al*. (2018), who found a pH of 5.68 in crossbred buffalo in a finishing system. After 24 hours, the pH of buffalo meat, according to Marrone *et al*. (2020) reaches between 5.71 and 5.75.

The inclusion of concentrate influenced the moisture, protein and fat of the meat linearly. The fat content is negatively correlated with moisture in the buffalo meat (Li *et al*., 2018). Buffalo fed a higher inclusion of concentrate produce meat that is richer in protein and fat, influenced by the higher energy intake (Naveena & Kiran, 2014). This suggests that buffalo meat is potentially more beneficial from a nutritional or human health standpoint than bovine beef from a feedlot (Giuffrida-Mendoza *et al*., 2015).

Regarding the physico–chemical characteristics, the similarity observed for the values of L*, a*, b*, and the cooking losses of buffalo meat may be related to the proximity in the final pH values of meat of the buffalo fed with increasing concentrate inclusions. Buffalo fed increased concentrate produced light-coloured (31.8 L* and 15.2 a*) and tender (16.0 N) buffalo meat. These results indicate a high-quality meat, of the standard of a young animal (Turan *et al*., 2021).

Conclusion

The addition of up to 80% concentrate increases dry matter intake, improves performance, carcass yields, and meat quality of buffalo in a feedlot.

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Authors' Contributions

SAFM, DOL, GHPV, and MLMWN participated in designing the study, laboratory analysis, and manuscript writing; RASP, ALRM, AASM, and FFRC: involvement in drafting and revising the manuscript for important intellectual content; SAFM, RASP, and DMLJ: data analysis and interpretation, involvement in the preparation and revision of the manuscript; FFRC, DOL, DMLJ: contributions to the acquisition, analysis, and interpretation of data.

Conflict of interest

The authors declare that they have no conflict of interest.

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