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# Productive performance, nutrient digestion and metabolism of Holstein (*Bos taurus*) and Nellore (*Bos taurus indicus*) cattle and Mediterranean Buffaloes (*Bubalis bubalis*) fed with corn-silage based diets

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ABSTRACT

The objective of this study was to evaluate the productive performance, nutrients digestion and metabolism of three different genetic groups fed with the same diet based on corn silage. 30 heifers in growth were used of three groups of cattle, the following: Nellore (*Bos taurus indicus*) (n = 10), Holstein (*Bos taurus taurus*) (n = 10), and Mediterranean buffaloes (*Bubalis bubalis*) (n = 10). The animals were fed in groups and received the same experimental diet composed of corn silage and concentrate for growing heifers. In the evaluation of animals the performance, consumption and total apparent digestibility of dry matter and nutrients with the aid of internal markers (chromic oxide) and external (iADF), rumen fermentation, excretion of purine derivatives, nitrogen balance and blood metabolites were measured.
No differences were observed in animal performance. There were differences in nutrient intake and apparent digestibility of dry matter and nutrients in different groups of cattle. The concentration of ammonia nitrogen (NH3-N) and short chain fatty acids (SCFA) in the rumen were higher and lower, respectively, for the group of buffaloes in relation to other experimental groups evaluated. When considering the excretion of total purine derivatives, buffaloes showed the lowest value compared to other genetic groups evaluated; about 61.76% of the total genetic group Nellore and 57.62% of the total genetic group Holstein with an average of 33.67 mmol/day. For the buffaloes, the excretion of xanthine and hypoxanthine observed was of 5.11% of total purine derivatives. There was a better nitrogen balance (g/day) for groups of Holstein heifers and Nellore in relation to the group of buffalo heifers. There were differences in the concentrations of urea and urea nitrogen in serum and liver enzymes where the buffaloes had higher values in relation at the bovines. There is a great metabolic diversity among the experimental groups evaluated and it was more exacerbated among buffaloes and bovines, when submitted to the same diet and same management conditions.


## 1. Introduction

Cattle and buffaloes are considered different for some characteristic, such as behavioral habits and their interactions with the environment; fermentation processes and anatomical rumen; physiology and capacity of the digestive system. The potential of cattle is best known, making it necessary to intensify comparative research, to know the productive skills of buffalo.

Several factors may be related to differences between cattle and buffaloes as the diets of lower quality. Buffaloes have greater rumen cellulolytic activity and better utilization of fibrous components (Tewatia and Bhatia, 1998); major

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number of ciliated protozoa, responsible for the fermentation of structural carbohydrates (Franzolin and Franzolin, 2000); higher rumen pH due to saliva secretion more intensive and higher buffering capacity of saliva flowing into the rumen (Sivkova et al., 1997); higher concentration of ammonia, reflecting better activity of intracellular deaminases and salivary recycling of urea (Tewatia and Bhatia, 1998) and maintenance of nitrogen balance positive due to the greater efficiency of utilization of ammonia nitrogen by use faster of the ammonia by ruminal bacteria (Trufchev et al., 1997).

Another difference about the metabolism between cattle and buffaloes is related with excretion of purine derivatives and calculation of protein synthesis, where Thanh and Ørskov (2005) reported that excretion of purine derivatives is low in buffalos due to two possibilities: glomerular filtration rate is lower in buffalo leaving more time in the blood, therefore, more time for recycling in the rumen and metabolism of bacteria, or that the permeability of the blood to the rumen is higher in buffalos.

Some comparative studies involving taurine, zebu cattle and buffaloes, aiming to detect differences in the intake capacity and use of food have been conducted (Velloso et al., 1994). In this research, buffaloes consumed an average less than Holstein cattle, 4.43 and 5.53 kg/DM/day, respectively and there was no difference in consumption between buffalo and Nellore. Pradhan et al. (1997) conclude that buffaloes digest more nutrients of the food than cattle, when fed with low quality forage; this difference did not persist when the forage was of good quality.

In literature there are few works that portray the diversity nutritional among heifers of different groups of cattle in traditional production conditions in Brazil, receiving roughage and concentrate of better quality.

Thus, the objective of this study was to evaluate the productive performance, nutrient digestion and metabolism of three different genetic groups, evaluating the animals in traditional conditions of Brazilian production of replacement heifers receiving corn silage as the main component of diet.

## 2. Materials and methods

### 2.1. Animals and treatments

The experiment was conducted at the Research Laboratory of Dairy Cattle, Faculty of Veterinary Medicine and Animal Science, University of São Paulo, Pirassununga, SP. 30 heifers in growth were used of three groups of cattle, the following: Nellore (*Bos taurus indicus*) (n = 10), with mean body weight (BW) of 407.50 kg; Holstein (*Bos taurus taurus*) (n = 10), with BW of 359.50 kg; and Mediterranean buffaloes (*Bubalis bubalis*) (n = 10), with BW of 515.50 kg.

This study was duly approved under the rules of the Commission of Bioethics, Faculty of Veterinary Medicine and Animal Science, University of São Paulo.

The experiment was conducted in a completely randomized design. The experimental period was composed of 77 days, where 56 days were used to trial of productive performance. The other 21 days were used to trial of digestion and metabolism, which were used 14 days for adaptation and 7 of sampling. The animals were fed in each respective group, and received the same experimental diet, composed of corn silage and concentrate for growing heifers (Tables 1 and 2), formulated according to (National Research Council, 2001).

**Table 1**
Composition of concentrate ingredients and experimental diets.

| Ingredient (% DM) | Concentrate | Diets |
|---|---|---|
| Corn silage | – | 75.63 |
| Ground corn | 54.20 | 13.15 |
| Soybean meal | 33.80 | 8.21 |
| Urea | 4.10 | 1.00 |
| Dicalcium phosphate | 2.70 | 0.65 |
| Mineral mix [a] | 1.30 | 0.31 |
| Limestone | 2.70 | 0.65 |
| Salt | 1.30 | 0.31 |

[a] Composition per kg of mineral mix: Ca — 180 g; P — 90 g; Mg — 20 g; S — 20 g; Na — 100 g; Zn — 3.000 mg; Cu — 1.000 mg; Mn — 1.250 mg; Fe — 2.000 mg; Co — 200 mg; I — 90 mg; Se — 36 mg; and F — 900 mg (max.).

### 2.2. Data and sample collection

During the period of 21 days referent to digestion and metabolism trial were collected samples of silage, concentrate and orts of each genetic group in question. The animals were fed according to the dry matter intake of the day before, to be kept orts percentage of the diets, daily, between 5 and 10% provided for not have restriction of consumption. Samples of food provided were collected and stored at −20 °C for further chemical bromatological analysis.

To estimate of the total fecal excretion was used as external marker chromic oxide (10 g/heifer/day) provided directly in the mouth, daily. The supply of the external indicator was started seven days before and maintained during the sampling, totalizing 10 days of supply of chromic oxide, always in the morning (Detmann et al., 2001). Feces were collected directly of the rectum, during 3 consecutive days of morning and afternoon before feeding. In determining

**Table 2**
Nutritional composition of the concentrate, silage and experimental diet.

| Nutrient | Concentrate | Corn silage | Diet |
|---|---|---|---|
| Dry matter (%NM) | 89.42 | 28.96 | 43.60 |
| Organic matter (%DM) | 89.98 | 94.47 | 93.29 |
| Crude protein (%DM) | 27.73 | 8.82 | 13.40 |
| NDIN (%TN) | 13.19 | 19.79 | 18.17 |
| ADIN (%TN) | 4.73 | 13.53 | 11.38 |
| Ether extract (%DM) | 2.90 | 2.91 | 2.90 |
| Total carbohydrate (%DM) NDT | 59.34 | 82.74 | 76.98 |
| Neutral detergent fiber (%DM) | 14.72 | 57.37 | 46.96 |
| $_{ap}$NDF (%DM) | 9.89 | 53.20 | 42.64 |
| Non-fiber carbohydrate (%DM) | 51.13 | 25.37 | 31.60 |
| $_{ap}$NFC (%DM) | 55.96 | 29.54 | 35.92 |
| Acid detergent fiber (%DM) | 7.94 | 37.46 | 30.26 |
| Lignin (%DM) | 1.07 | 5.44 | 4.37 |
| Mineral matter (%DM) | 10.02 | 5.53 | 6.61 |
| Total digestible nutrient [a] (%) | 82.48 | 62.73 | 67.26 |

NM = natural matter.
DM = dry matter.
TN = total nitrogen.
NDIN = neutral detergent insoluble nitrogen.
ADIN = acid detergent insoluble nitrogen.
$NDF_{ap}$ = NDF corrected for ash and protein.
$NFC_{ap}$ = NFC corrected for ash and protein.
[a] Estimated by National Research Council (2001).

of the consumption and apparent digestibility of nutrients, the total amount of fecal dry matter excretion was estimated by the concentration of chromic oxide in feces (Detmann et al., 2001).

In the food provided, in samples of orts and feces were analyzed the levels of dry matter (DM), organic matter (OM), mineral matter (MM), ether extract (EE), crude protein (CP), neutral detergent insoluble nitrogen (NDIN), acid detergent insoluble nitrogen (ADIN) and lignin according to the methods described by AOAC — Association of Official Analytical Chemists (2000). The crude protein (CP) was obtained by multiplying of the total nitrogen content by 6.25.

The total carbohydrate (TC) were calculated by Sniffen et al. (1992), where TC = 100 − (%CP + %EE + %MM). The levels of non-fiber carbohydrates (NFC) were estimated by Hall (1998) where: NFC = 100 − [(% CP − % CPurea + % UREA) + %EE + % MM + %NDF]. The total digestible nutrients were calculated according to National Research Council — NRC (2000), where: TDN = dNFC + dCP + (dFA 2.25) + dNDF − 7, where dCP, dNFC, dNDF and dFA represent the total of this digestible nutrients. The total digestible nutrients TDN = dCP + dNDF + (dEE 2.25) + dNFC were calculated according to Weiss et al. (1992).

The contents of neutral detergent fiber (NDF), ash and protein-free neutral detergent fiber (apNDF) and acid detergent fiber (ADF) were obtained according to a method described by Van Soest et al. (1991), using α-amylase and without addition of sodium sulfite in the NDF determination, at Ankon® System.

For evaluation of the indigestible acid detergent fiber (iADF) food samples, orts and feces were placed in bags non-woven fabric (NWF 100 g/m$^2$) with dimensions of 4 × 5 cm (Casali et al., 2008). The aliquots were placed in all the bags, as relation of 20 mg/cm$^2$ of surface (Nocek, 1988). The samples were incubated in the rumen of Nellore steers receiving the same diet used in the digestion and metabolism trial by 288 h (12 days), for the determination of iADF. Posteriorly, through of the fecal dry matter excretion and iADF concentrations in orts and food, were calculated the intake and total apparent digestibility of dry matter and nutrients.

In the evaluation of rumen fermentation, the samples of rumen fluid were collected with use of esophageal gavage 3 h after the morning feeding. Immediately after collection were determined rumen pH values using potentiometer. The samples were stored in a thermal box and sent to the measurements of ammonia nitrogen (NH3-N) and short chain fatty acids (acids acetic, propionic and butyric). The collected rumen fluid was centrifuged at 2000 *g* during 15 min, and 2 mL of the supernatant was pipetted and stored in trial tubes containing 1 mL of 1 N sulfuric acid for later determination of ammonia nitrogen (NH3-N) concentration, and 1 mL in tubes containing 0.4 mL of formic acid for determination of short chain fatty acids. The analyses of the ammonia nitrogen (NH3-N) concentration were determined by the method with salicylic acid. The ruminal concentration of short chain fatty acids was analyzed using gas chromatography and glass column of 2 m length of 1/8″, packaged with 80/120 Carbopack B-DA/4% Carbowax 20 M.

In the measurement of nitrogen balance was realized the determination of the creatine concentration in urine according to Valadares et al. (1999) and Rennó et al. (2008). The spot urine samples were collected from all heifers on day 20° of experimental period of the digestibility trial and metabolism, 4 h after the morning feeding, during urination stimulated by massage of the vulva. The urine was filtered and aliquots were stored at −20 °C for later analysis of total nitrogen and creatinine. Creatinine concentrations were determined by commercial kits (Laborlab®). The total daily urine volume was estimated by dividing the daily urinary excretion of creatinine by the observed values of creatinine concentration in urine of the spot samples, according to Valadares et al. (1999). The daily urinary excretion of creatinine was estimated based on the proposition of 24.05 mg/kg body weight. Thus, with the average daily excretion of creatinine and creatinine concentration (mg/dL) in spot urine sample, was estimated the total daily urine volume, in liters per animal/day, for the calculation of nitrogen balance (Chizzotti et al., 2007).

The concentration of allantoin and uric acid, xanthine and hypoxanthine in urine were determined by colorimetry method, according to methodology described by Chen and Gomes (1992). Total excretion of purine derivatives, in mmol/day, for groups Nellore and Holstein was calculated for the sum of quantities of allantoin and uric acid and for group of buffaloes were also considered the concentrations of xanthine and hypoxanthine excreted in urine (Chen et al., 1996).

The total nitrogen of the urine samples was determined according to the methods described by AOAC — Association of Official Analytical Chemists (2000), where the amount in grams of nitrogen per 100 mL of urine was obtained by dividing the crude protein value of the samples by factor 6.25 for urine samples. Nitrogen balance was obtained by subtracting the total nitrogen in grams consumed by the values of nitrogen in urine and feces obtaining in the values of retained nitrogen in grams and in percentage of total nitrogen.

Blood collections were realized on the 19° day of the experimental period by venipuncture and/or coccygeal artery, previously to the supply of rations in the morning. The samples were collected in tubes vacuolated (*vacutainer*) of 10 mL for dosage of the blood parameters in serum, glucose, triglycerides, total cholesterol, HDL cholesterol, total protein, albumin, urea, and the enzymes aspartate aminotransferase (AST), gamma glutamyl transferase (GTA) and alkaline phosphatase (ALP) in serum.

Analyses of concentrations of blood parameters were performed using commercial kits (LABORLAB® and CELM®) using an enzymatic colorimetric method of end point or kinetic, and reading realized in automatic blood chemistry analyzer (ABS-200 automatic biochemistry system — CELM®). The concentration of HDL-C was determined by the concentration of cholesterol molecules through enzymatic colorimetric system with the commercial kit CELM-1755. The concentrations of LDL-cholesterol and VLDL cholesterol were determined indirectly through of formulas, where: VLDL cholesterol (mg/dL) = (triglycerides concentration/5) and LDL cholesterol (mg/dL) = total cholesterol − (HDL cholesterol + VLDL cholesterol). (Friedewald et al., 1972).

### 2.3. Statistical analysis

The data obtained were submitted to SAS (Version 9.1.3, SAS Institute, 2004), verifying the normality of residuals and homogeneity of variance by PROC UNIVARIATE.

Data were analyzed using PROC MIXED according to the following model:

$Yi = \mu + Gi + ei$.

Where: Yi = dependent variable; μ = overall mean, Gi = fixed effect of genetic group; ei = random error. The random effect used Aj(Gi) = animal within group, where: Aj = fixed effect of the animal. The degrees of freedom calculated were performed according to the Satterthwaite method (ddfm = satterth).

Posteriorly the LSMEANS were submitted at the test of TUKEY adjusted of PROC MIXED.

## 3. Results

### 3.1. Productive performance

The data obtained in relation at the initial and final weight of animals were not subjected to statistical analysis, due to the morphological discrepancy among the genetic groups evaluated. However by analyzing the weight gain is not observed differences (P>0.05) among genetic groups (Table 3).

### 3.2. Intake and total apparent digestibility

Lower intake of dry matter and organic, crude protein, non-fibrous carbohydrates and total (P<0.05) was observed for the Nellore group compared to the Holstein (Table 4). Difference was observed (P<0.05) only between Nellore and Buffaloes group for the consumption of non-fiber carbohydrates and total. For all consumption variables evaluated there was no observed difference (P>0.05) between Holstein and Buffaloes groups.

In relation to the dry matter intake at percentage of body weight (%BW) was observed a greater value for the Holstein group and smaller for the Buffaloes. But there was no difference (P<0.05) compared to the Nellore group, with the same results observed for neutral detergent fiber intake at %BW. The observed results are justified by the greater body weight presented by genetic group of buffaloes in relation to other experimental groups, which alters the result at comparison with consumption measured only in kg/day. It was observed, therefore, strong effect of genetic group on consumption.

Considering the total apparent digestibility was not observed (P>0.05) difference among the groups evaluated in the total apparent digestibility of ether extract, neutral detergent fiber, non-fiber carbohydrates and total (Table 4). In relation to dry matter digestibility was observed lower value (P<0.05) for the group Buffaloes in relation to the Holstein, however, there was no difference (P>0.05) in relation to the Nellore group, and the same result observed for the organic matter digestibility.

**Table 3**
Productive performance according to three groups of cattle evaluated.

| Parameters | Genetic group | | | Means | SEM |
|---|---|---|---|---|---|
| | Buffaloes | Nellore | Holstein | | |
| *kg* | | | | | |
| Initial weight | 515.50 | 407.50 | 359.50 | 427.50 | 46.13 |
| Final weight | 659.11 | 552.50 | 484.10 | 565.24 | 163.32 |
| Weight gain | 143.61[a] | 145.00[a] | 124.60[a] | 137.74 | 136.06 |
| *kg/day* | | | | | |
| Weight gain | 0.96[a] | 0.97[a] | 0.83[a] | 0.92 | 0.04 |
| *Percentage* | | | | | |
| Relative weight gain | 27.85[a] | 35.58[a] | 34.65[a] | 32.69 | 0.01 |

Means within a row with different superscripts differ (P<0.05).
SEM = standard error of the mean.

**Table 4**
Intake and digestibility of dry matter and nutrients according to three groups of cattle evaluated.

| Variables | Cattle group | | | Means | SEM |
|---|---|---|---|---|---|
| | Buffaloes | Nellore | Holstein | | |
| *Intake (kg/day)* | | | | | |
| Dry matter | 8.32[ab] | 7.56[b] | 9.07[a] | 8.31 | 0.36 |
| Organic matter | 7.23[ab] | 6.81[b] | 7.85[a] | 7.29 | 0.33 |
| Crude protein | 1.37[ab] | 1.20[b] | 1.50[a] | 1.21 | 0.05 |
| Ether extract | 0.26[ab] | 0.22[b] | 0.28[a] | 0.26 | 0.01 |
| NDF | 4.06[ab] | 3.31[b] | 4.28[a] | 3.88 | 0.17 |
| NFC | 2.30[a] | 1.64[b] | 2.60[a] | 2.18 | 0.11 |
| Total carbohydrate | 5.93[a] | 4.24[b] | 6.03[a] | 5.40 | 0.26 |
| *Intake (%BW)* | | | | | |
| Dry matter | 1.29[b] | 1.54[ab] | 1.65[a] | 1.49 | 0.36 |
| NDF | 0.62[b] | 0.68[ab] | 0.78[a] | 0.69 | 0.17 |
| *Apparent digestibility coefficient (%)* | | | | | |
| Dry matter | 63.69[b] | 65.94[ab] | 66.55[a] | 65.40 | 0.82 |
| Organic matter | 66.15[b] | 68.56[ab] | 69.75[a] | 67.13 | 0.80 |
| Crude protein | 71.37[ab] | 68.00[b] | 75.43[a] | 68.10 | 1.39 |
| Ether extract | 82.97[a] | 84.98[a] | 82.78[a] | 83.58 | 0.64 |
| NDF | 57.73[a] | 62.60[a] | 59.27[a] | 58.87 | 1.10 |
| NFC | 74.81[a] | 75.76[a] | 77.98[a] | 76.18 | 1.01 |
| Total carbohydrate | 59.85[a] | 62.23[a] | 60.23[a] | 59.99 | 0.97 |
| Feces (kg/day) | 3.18[a] | 2.56[b] | 3.46[a] | 2.93 | 0.07 |

Means within a row with different superscripts differ (P<0.05).
SEM = standard error of the mean.

### 3.3. Rumen fermentation

There was no difference (P>0.05) for rumen pH values between cattle groups evaluated (Table 5). The concentration

**Table 5**
Rumen fermentation according to three groups of cattle evaluated.

| Parameters | Cattle group | | | Means | SEM |
|---|---|---|---|---|---|
| | Buffaloes | Nellore | Holstein | | |
| pH | 6.34[a] | 6.48[a] | 6.28[a] | 6.36 | 0.05 |
| NH3-N(mg/dL) | 22.36[a] | 16.52[b] | 18.98[b] | 19.29 | 0.80 |
| *mmol* | | | | | |
| Acetic | 38.42[b] | 51.17[a] | 46.68[a] | 45.42 | 1.15 |
| Propionic | 7.80[b] | 11.02[a] | 10.22[a] | 9.68 | 0.30 |
| Butyric | 5.55[b] | 8.14[a] | 6.14[b] | 6.61 | 0.25 |
| Total SCFA | 51.83[b] | 70.85[a] | 63.34[a] | 62.01 | 1.67 |
| A/P | 4.98[a] | 4.71[ab] | 4.47[b] | 4.72 | 0.07 |
| *Percentage* | | | | | |
| Acetic | 74.32[a] | 73.02[a] | 73.62[a] | 73.65 | 0.21 |
| Propionic | 15.16[a] | 15.59[a] | 16.06[a] | 15.60 | 0.16 |
| Butyric | 10.65[ab] | 11.43[a] | 10.25[b] | 10.78 | 0.17 |

Means within a row with different superscripts differ (P<0.05).
SEM = standard error of the mean.
SCFA = short chain fatty acid.

of NH3-N in the rumen was higher (P<0.05) for the Buffaloes group in relation to other groups evaluated.

The Buffaloes group showed the lowest molar concentration (P<0.05) of acetic, propionic, butyric acids and total SCFA in relation to the Nellore and Holstein groups. However, there was no difference for molar ratios (P>0.05) of acetic, propionic, butyric acids among genetic groups, except the Holstein group, which presented lower molar ratio (P>0.05) of butyric acid compared to the Nellore group. The Buffaloes group presented a higher ratio of acetate/propionate (A/P) (P<0.05) when compared to the Holstein group, without differ, however, of the Nellore group.

### 3.4. Purine derivative excretion

Among the genetic groups evaluated, the Holstein heifers presented higher (P<0.05) total excretion of urine in liters per day (Table 6). The Buffaloes group presented less (P<0.05) excretion of allantoin, uric acid and total purine derivatives, which the cattle groups. Comparing the Nellore and Holstein groups difference (P<0.05) only in uric acid concentration was observed, where the Nellore group presented a higher value. When considering the excretion of total purine derivatives (PD/day at mmol/day), buffaloes showed the lowest value compared to other genetic groups evaluated; about 61.00% of the Nellore genetic group and 62.14% of the Holstein genetic group, with an average of 33.68 mmol/day.

For the buffaloes, the xanthine and hypoxanthine excretions observed were of 4.92% of the total purine derivatives (Table 6). In this study the allantoin proportion in purine derivatives did not differ between the cattle groups, and was at average 88.59%. The proportion of uric acid in purine derivatives was lower for buffaloes (P<0.05); 5.49% in relation to the two groups of cattle, which did not differ, showing at average 10.39%.

When analyzing the concentration of uric acid (mmol/L) a greater value (P<0.05) for the Nellore group compared to the other experimental groups was observed (Table 6). When comparing the Holstein group and the Buffaloes group difference (P>0.05) in allantoin concentration (%PD) was not observed, but the Buffaloes group presented lower concentration (P<0.05) of uric acid.

**Table 6**
Urinary excretion of purine derivatives according to three cattle groups evaluated.

| Item | Cattle group | | | Means | SEM |
|---|---|---|---|---|---|
| | Buffaloes | Nellore | Holstein | | |
| Urine (L/day) | 7.68[b] | 7.55[b] | 11.96[a] | 9.06 | 0.43 |
| *mmol/day* | | | | | |
| Allantoin | 30.17[b] | 48.66[a] | 49.31[a] | 42.71 | 2.60 |
| XH | 1.66 | – | – | 1.72 | 2.05 |
| Uric acid | 1.85[c] | 6.49[a] | 4.89[b] | 4.40 | 0.39 |
| PD/day | 33.68[b] | 55.15[a] | 54.20[a] | 47.67 | 1.48 |
| *%PD* | | | | | |
| Allantoin | 89.57[a] | 88.23[a] | 90.97[a] | 88.59 | 0.20 |
| XH | 4.92 | – | – | 4.92 | 1.90 |
| Uric acid | 5.49[b] | 11.76[a] | 9.02[a] | 8.75 | 1.62 |

Means within a row with different superscripts differ (P<0.05).
SEM = standard error of the mean.
Xanthine and hypoxanthine.
Total purine derivatives.

### 3.5. Nitrogen balance

There was difference (P<0.05) in nitrogen intake (g/day) among the experimental groups, where the Nellore group presented lower intake in relation to the Holstein group, but not differing from the Buffaloes group (Table 7). In relation to nitrogen excretion in feces was observed (P<0.05) lower value for Holstein group in relation to the Nellore, however no difference was observed in relation to the Buffaloes. In relation to nitrogen excretion in urine (g/day), the Buffaloes group presented a value 2.1 and 1.9 times higher (P<0.05) than the group of Nellore and Holstein respectively. When analyzing the nitrogen balance (g/day) a better balance (P<0.05) for the Holstein group in relation to the Buffaloes was observed, but there was no difference (P>0.05) between Nellore and Holstein.

Regarding the excretion of fecal nitrogen (% total nitrogen) a greater (P<0.05) value for the Nellore group compared to the Holstein group was observed, but there was no observed difference (P>0.05) for Buffaloes group. The Buffaloes group showed excretion of 30.41% of the nitrogen consumed in urine and higher (P<0.05) than the Nellore and Holstein groups. Analyzing the nitrogen balance (% total nitrogen) better balance (P<0.05) for Holstein group compared to Buffaloes was observed, but the Nellore group did not differ (P>0.05) for Holstein and Buffaloes group.

### 3.6. Blood metabolites

No differences were observed (P>0.05) among experimental groups in relation to serum glucose concentrations, triglycerides and VLDL cholesterol. Regarding the concentrations of total cholesterol and LDL-cholesterol lower value (P<0.05) for Buffaloes group when compared to other groups was observed, but the Nellore group had higher concentration (P<0.05) than the Holstein group (Table 8). The Nellore group also presented higher concentration (P<0.05) of HDL-cholesterol, when compared to the others, however there was no difference (P>0.05) between the Holstein group and Buffaloes.

**Table 7**
Nitrogen balance according to three cattle groups evaluated.

| Parameters | Cattle group | | | Means | SEM |
|---|---|---|---|---|---|
| | Buffaloes | Nellore | Holstein | | |
| *Nitrogen g/d* | | | | | |
| Intake | 219.00[ab] | 192.36[b] | 240.07[a] | 217.14 | 8.92 |
| Feces | 62.28[ab] | 60.15[a] | 51.44[b] | 57.95 | 2.25 |
| Urine | 62.94[a] | 30.00[b] | 32.30[b] | 41.74 | 3.85 |
| Balance | 93.76[b] | 102.20[ab] | 150.45[a] | 115.47 | 9.78 |
| *%Total nitrogen* | | | | | |
| Feces | 28.64[ab] | 32.00[a] | 24.52[b] | 28.38 | 1.25 |
| Urine | 30.41[a] | 16.49[b] | 14.58[b] | 20.49 | 2.26 |
| Balance | 40.94[b] | 51.50[ab] | 60.90[a] | 51.11 | 2.92 |
| Feces (kg/day) | 3.18[a] | 2.56[b] | 3.46[a] | 3.06 | 0.12 |

Means within a row with different superscripts differ (P<0.05).
SEM = standard error of the mean.

**Table 8**
Blood metabolites according to three cattle groups evaluated.

| Parameters | Genetic groups | | | Means | SEM |
|---|---|---|---|---|---|
| | Buffaloes | Nellore | Holstein | | |
| *mg/dL* | | | | | |
| Glucose | 82.90[a] | 79.40[a] | 80.40[a] | 80.90 | 2.20 |
| Cholesterol | 102.30[c] | 196.80[a] | 123.50[b] | 140.86 | 7.96 |
| Triglycerides | 32.80[a] | 35.90[a] | 27.50[a] | 32.06 | 2.27 |
| HDL-C | 33.70[b] | 69.00[a] | 35.30[b] | 46.00 | 3.32 |
| LDL-C | 60.04[c] | 118.70[a] | 82.70[b] | 87.14 | 5.33 |
| VLDL-C | 6.56[a] | 7.18[a] | 5.50[a] | 6.41 | 0.45 |
| Urea | 50.30[a] | 39.00[b] | 25.20[c] | 38.16 | 2.21 |
| SUN | 23.50[a] | 18.22[b] | 11.77[c] | 17.83 | 1.03 |
| *g/L* | | | | | |
| Total protein | 8.24[b] | 7.85[b] | 9.08[a] | 8.39 | 0.13 |
| Albumin | 3.30[a] | 3.00[b] | 2.91[b] | 3.07 | 0.04 |
| *U/L* | | | | | |
| AST | 131.5[a] | 50.70[b] | 59.80[b] | 80.66 | 7.09 |
| GGT | 8.95[a] | 5.74[c] | 7.36[b] | 7.35 | 0.35 |
| ALP | 164.00[a] | 143.40[ab] | 124.60[b] | 144.00 | 6.90 |

Means within a row with different superscripts differ ($P<0.05$).
SEM = standard error of the mean.
HDL-C = HDL-cholesterol.
LDL-C = LDL-cholesterol.
VLDL-C = VLDL-cholesterol.
SUN = serum urea nitrogen.
AST = aspartate aminotransferase.
GGT = γ-glutamyl transferase.
ALP = alkaline phosphatase.

In Buffaloes group higher concentration ($P<0.05$) of urea and serum urea nitrogen when compared to the cattle groups was observed, however, among the cattle the Nellore group presented higher concentrations ($P<0.05$) compared to the Holstein. The buffaloes showed concentrations of urea and serum urea nitrogen 1.29 and 2.00 times higher than the Nellore and Holstein group, respectively.

The Holstein heifers presented higher concentration ($P<0.05$) of total protein when compared to other groups of heifers, but no differences were observed ($P>0.05$) between Nellore heifers and Buffaloes. Regarding the concentrations of albumin higher concentration ($P<0.05$) for the Buffaloes group in relation to the cattle groups was observed, but no difference ($P>0.05$) among cattle.

In evaluation of the concentration of liver enzymes aspartate aminotransferase and γ-glutamyl transferase, the buffaloes presented higher concentration ($P<0.05$) compared to the cattle, but only γ-glutamyl transferase were different among cattle, where the Nellore group had lower value ($P<0.05$) to the Holstein. Regarding the concentrations of alkaline phosphatase there was no difference ($P>0.05$) from the Nellore group for others, but the buffaloes had higher concentration ($P<0.05$) than Holstein heifers.

## 4. Discussion

### 4.1. Productive performance

Analyzing the average values of daily weight gain of the three genetic groups were obtained values that are within the recommended for the performance of heifers in this stage of development. The equality presented in relation to the weight gain is related with the diet given to the animals that despite to be the same for each genetic group, differences were observed in dry matter intake among the groups and as there was no difference in weight gain, this result can be explained by metabolic differences among groups of heifers evaluated.

The results obtained in relation to weight gain of animals are in agreement with Jorge et al. (1997), who observed the same gain weight for Nellore, Holstein and Murrah Buffaloes in feedlot receiving similar diets.

### 4.2. Intake and total apparent digestibility

The Holstein group showed higher nutrient intake in relation to the Nellore group. This result can possibly be attributed to differences in physiology, metabolism and behavior among both groups. The Holstein animals tend to have higher energy requirements, with a dry matter intake and nutrient higher (National Research Council, 2001). Rennó et al. (2005) observed that zebu animals have lower dry matter intake than taurine animals when fed with high quality forage. However, in diets with low quality forage, zebu cattle, generally presents higher dry matter intake.

The characteristic of dual purpose (milk and meat) inferred to the Buffaloes may be related with the consumption of this animals group obtained in this study, since there was no difference of Buffaloes when compared Nellore and Holstein heifers.

Rodrigues et al. (2001) working with crossbred Jaffarabadi Buffalo and Canchim cattle (5/8 Charolais × 3/8 Zebu) fed with forage consisting of silage (70% elephant grass and 30% sorghum) more concentrated, at a ratio of 60:40 (forage: concentrate), observed no difference ($P>0.05$) among species in results of dry matter intake. Abdullah et al. (1992) and Kennedy et al. (1992) observed no difference ($P>0.05$) for dry matter intake when comparing the performance of buffaloes and cattle.

The results obtained in relation to total apparent digestibility of dry matter and nutrients among the genetic groups evaluated are related to own characteristic of the diet provided to the animals, since there were no differences in digestibility coefficients of the most nutrients, despite the physiological differences among species. Pradhan et al. (1997) concluded that the Buffaloes used better the nutrients from food than cattle when fed with low quality forage, this difference did not persist when the forage was of high quality.

Rodriguez et al. (1997) compared the digestibility coefficients of dry matter and nutrients in Nellore, Holstein and Buffaloes fed with diets containing different levels of concentrate in DM. These authors observed no difference among the genetic groups as the digestibility of crude protein, neutral detergent fiber and acid detergent fiber, independently of the level of concentrate in diets. The Holstein showed digestibility coefficients of dry matter and organic matter larger than Nellore and Buffaloes, however there was no difference between these two genetic groups, similar results to this study.

### 4.3. Rumen fermentation

The pH values observed for genetic groups evaluated showed no differences, being bellow of the average value of

6.7 recommended by Moran et al. (1983), for have no decrease in rate of fiber degradation. The results obtained can be explained by own characteristic of the diets offered to animals where there was a predominance of corn silage with a high level of neutral detergent fiber in the diet, since there were no major problems in total apparent digestibility coefficient of NDF.

The measures of ruminal pH executed by Sousa et al. (2000) in buffaloes and cattle fed with diets containing different proportions of neutral detergent fiber, showed that the pH was higher ($P<0.01$) in buffaloes (pH = 6.78) than in cattle (pH = 6, 58), contradicting the present experiment. However, Franzolin et al. (2010) observed no difference ($P>0.05$) for the average pH in buffaloes and cattle, in a period of 8 h, with sampling every 2 h after feeding.

The average concentration of ammonia nitrogen among the genetic groups was of 19.29 mg/dL, where the animals of Buffaloes group had higher concentration compared to the cattle. Mean values of ammonia were higher than those recommended by Satter and Slyter (1974), Preston and Leng (1987) and Pisulewski et al. (1981), corresponding to 5.00, 8.00, and 9.60 mg/dL, respectively, for the least microbial growth, but bellow of the 24.00 mg/dL recommended by Mehres et al. (1977) for maximum disappearance of the substrate, although these authors have proposed not be necessary maintain, consistently, high concentrations of ammonia in the rumen fluid.

The higher concentration of ammonia nitrogen presented by buffaloes indicates higher proteolytic activity in the rumen of buffaloes than in the rumen of cattle, fact proposed by Paliwal and Sagar (1990) and confirmed by Bhatia et al. (1992). Zanetti et al. (1995) using a diet composed of *Coastcross* hay, ground corn and cottonseed meal with 9.91% CP in DM, collected rumen fluid from 2 at 2 h after feeding in the morning and verified that the Buffaloes had higher values of ammonia nitrogen (17.18 mg/dL) compared to the cattle (11.93 mg/dL). However, Raj Kumar et al. (1993) and Franzolin et al. (2010) did not observe the same result when comparing the ammonia nitrogen between buffaloes and cattle.

In relation to the molar concentration of short chain fatty acids acetate, propionate and butyrate and total SCFA were observed lower values for Buffaloes heifers when compared to others, but were no observed differences between the two groups of cattle. These results can be attributed to the higher passage of short chain fatty acids (SCFA) in rumen fluid to the omasum and also by higher absorption of SCFA by the walls of the rumen of buffaloes. Similar results were reported by Moran et al. (1983) and Franzolin et al. (2010).

The Buffaloes group presented higher acetate:propionate ratio compared to other genetic groups, results consistent with the individual concentrations of acetate and propionate observed for this experimental group. When evaluated the individual concentrations of short chain fatty acids at percentage of the total SCFA were not observed differences among buffaloes and other groups, there was only difference between the groups of Holstein and Nellore heifers to butyrate concentration. These results are consistent with Valadares Filho et al. (1990), that working with Holstein, Nellore and buffaloes steers observed effect in ruminal concentration of butyrate among the genetic groups.

### 4.4. Purine derivatives excretion

The Buffaloes group presented lower concentrations of purine derivatives in urine, in relation to the cattle groups, probably because there was little entrance of exogenous purines from the rumen microbial biomass in the level of dry matter intake presented by Buffaloes. The results of this study are consistent with studies by Vercoe (1976), Liang et al. (1993) and Chen et al. (1996), which indicated that the uric acid excretion (the main component of purine derivatives) per unit of digestible DM intake was lower in buffaloes than in cattle.

The presence of purine derivatives xanthine and hypoxanthine in the urine of buffaloes was detected which represents an increase in the total purine derivatives. These results contradict the results obtained by Chen et al. (1996), where measured the excretion of purine derivatives in buffaloes and did not detect the presence of xanthine and hypoxanthine in the urine of these animals, justified by the authors due to high concentrations of xanthine oxidase present in the buffaloes.

Data of excretion of purine derivatives comparing cattle and buffaloes are scarce in the literature, and more studies are necessary to improve the techniques of measurement of purine derivatives, which could generate more information on purine metabolism, especially in buffaloes.

### 4.5. Nitrogen balance

The nitrogen balance was positive for all species, indicating that there was retention of protein in the animal organism, creating conditions for that would not occurred weight loss of the experimental animals.

The diversity presented in relation to nitrogen balance between cattle and buffaloes, where lower nitrogen retention for buffalo heifers occurred mainly due to higher nitrogen excretion in urine for the buffaloes was observed. Despite some differences in the excretion of fecal nitrogen and nitrogen intake, these variables were not preponderant for influence the nitrogen balance as the nitrogen excretion in urine. The buffaloes group excreted 2.1 and 1.94 times more nitrogen in relation to the group of the Nellore and Holstein heifers, respectively.

The results observed in this study to nitrogen excretion in urine between buffaloes and cattle are according to Pereira et al. (2007), which evaluated the nitrogen compounds balance and estimated protein requirements for maintenance by equations recommended by systems (National Research Council — NRC, 2000) and (Agricultural Research Council — ARC, 1980), in four cattle and four buffaloes. The results obtained can be explained, according to Kearl (1982) due to nutritional requirement of protein of the buffaloes are smaller than that of cattle.

The information obtained indicates that buffaloes have a greater ability to utilize protein more efficiently than cattle and therefore, their digestible protein requirements for maintenance are lower (Kearl, 1982).

The higher nitrogen excretion in urine of buffaloes is related with the higher concentration of ammonia nitrogen in the rumen (Table 5) and with the larger concentration of serum urea nitrogen (Table 8) presented by this group of animals, since the main route of excretion of excess nitrogen is by urine. Similar results were obtained by Verma et al.

(1998), Ajmal Khan et al. (2008) and Sultan et al. (2009), working with growing buffaloes fed with diets of low quality roughage and variables levels of crude protein.

### 4.6. Blood metabolites

Data relatives to glucose levels obtained in this study showed higher values than those mentioned by Tiwari et al. (2001) and similar to Oliveira et al. (2005), which observed glucose levels of 51 to 64 mg/dL for growing buffaloes and from 74 to 76 mg/dL for Holstein cattle, respectively.

According to Kaneko et al. (1997), values normal of serum triglycerides to cattle are between 0 and 14 mg/dL. Based on these values can be verified that the mean of triglyceride obtained in this study were above this interval of variation.

The lower concentration of lipidogram parameters (total cholesterol, HDL-cholesterol, LDL-cholesterol), presented by buffalo heifers in relation to cattle may be associated with the genetic and physiological characteristics in relation to milk yield of this group of animals that secrete about 2 to 3 times more fat in milk in relation to cattle. The ability dairy also may explain the lower concentration in the lipidogram of the Holstein heifers compared to Nellore heifers. The groups of animals with ability dairy regulate lipid metabolism for the formation of the mammary gland and later for milk yield, thus circulating plasma lipids were higher for the group with ability of meat production, where the lipidogram constituents will be deposited in the carcass and not secreted in the milk.

The results obtained in relation to lipidogram for buffaloes are according to Anand and Prakash (2008) that worked with non-lactating buffaloes in different seasons of the year featuring the lipid profile of this group of animals in summer and winter. For the group of Holstein animals the results are in agreement with Gandra et al. (2009) and Freitas Júnior et al. (2010), who worked with Holstein dairy cows. However Miguel et al. (2010), when dosed total cholesterol in Nellore heifers observed mean values of 167.80 mg/dL, results lower to this study.

In literature there are few studies that compared the plasma lipid profile between buffaloes and cattle. Therefore is necessary to realization of further studies that more conclusive results might be enlightened about this subject.

Franzolin et al. (2001), working with feedlot steers Buffaloes observed mean values of blood urea nitrogen of 17.82 mg/dL, below of the value obtained in this work and similar to that reported by Tiwari et al. (2001), working with growing buffalo calves. The result of urea nitrogen and urea in the blood of animals in this study can also be related to lower crude protein requirement of the buffaloes compared to cattle. The concentrations of urea nitrogen and plasma urea of the cattle groups are according to Mendes et al. (2005), who worked with cattle in the feedlot at phase of growth.

The values found in this study are similar to those described by Rebhun and Guard (2000), which are 7.00 to 8.50 g/dL for total protein and 3.03 to 3.55 g/dL for albumin. The higher concentration of plasma protein to the Holstein animals when compared to other groups, is related to better nitrogen balance presented by this group of animals. The concentrations of plasma protein of buffaloes, Holstein and Nellore heifers are according to Tiwari et al. (2001), Canesin et al. (2010) and Mendes et al. (2005), respectively.

The group of buffalo heifers showed a higher concentration of liver enzymes aspartate aminotransferase, γ-glutamyl transferase and alkaline phosphatase in relation to cattle. These results may be related to high hepatic metabolism by the buffaloes, because of high concentration of plasma urea that may be related with a lower protein requirement, as demonstrated by the nitrogen balance (Table 7) and by the rumen ammonia nitrogen concentration for this group of animals (Table 5).

## 5. Conclusions

There is a great metabolic diversity among the experimental groups evaluated and it is more exacerbated between buffaloes and cattle, when fed with the same diet and same management conditions. Studies evaluating other phases of development and other animals categories should be performed with the objective of characterize potential differences in the metabolism of cattle and buffaloes.

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