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# Nutritional evaluation of passion fruit seed meal for meat quails

*Avaliação nutricional do farelo da semente de maracujá para codornas de corte (Coturnix coturnix japonica)*

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## SUMMARY

The objective of this study was to determine the chemical composition, apparent metabolizable energy (AME), apparent metabolizable energy corrected for nitrogen balance (AMEn) and the metabolizability of dry matter (DM), crude protein (CP), ether extract (EE) and neutral detergent fiber (NDF) of passion fruit seed meal (PFM) for quails. One hundred meat quails (*Coturnix coturnix japonica*), with 21 days old, allotted in a completely randomized design, with four treatments, five replicates and four animals per experimental unit. The treatments consisted of different levels PFM (4.0, 8.0, 12.0 and 16.0%) that replaced the basal diet (w/w). Metabolizable values were determined by fitting linear equations the PFM can be characterized as an alternative feedstuff for meat quails and the main chemical compounds are gross energy (5,569 kcal $kg^{-1}$), CP (11.34%), EE (18.84%) and NDF (50.22%), as fed basis. Linear equations were fitted as follow: AME = 2,976 x + 5.877 ($r^2$ = 0.94) and AMEn = 2,939 x + 4.864 ($r^2$ = 0.95), thus AME and AMEn were estimated at 2,976 and 2,939 kcal $kg^{-1}$, respectively. Additionaly, equations were adjusted for CP, EE, NFD and DM, respectively resulting in a metabolization of 6.35, 17.9, 12.48 and 45.66%. It is concluded that main components of the passion fruit seed meal are gross energy, crude protein, ether extract and neutral detergent fiber and its AME and AMEn for meat quails are 2,976 and 2,939 kcal $kg^{-1}$, respectively.

**Keywords:** alternative feedstuffs, chemical composition, metabolizability coefficient

## RESUMO

Objetivou-se com este estudo, determinar a composição química, a energia metabolizável aparente (EMA), energia metabolizável aparente corrigida para o nitrogênio (EMAn) e a metabolizabilidade da matéria seca (MS), proteína bruta (PB), extrato etéreo (EE) e fibra em detergente neutro (FDN) do farelo da semente de maracujá (FSM) para codornas. Foram utilizadas 100 codornas de corte (*Coturnix coturnix japonica*) com 21 dias de idade, distribuídos em um delineamento inteiramente casualizado, com quatro tratamentos, cinco repetições e quatro aves por unidade experimental. Os tratamentos constituíram de diferentes níveis de FSM (4,0; 8,0; 12,0; 16,0%) em substituição a ração referência. Valores metabolizáveis foram determinados por ajuste de equações lineares. O FSM pode ser caracterizado como um alimento alternativo para codornas de corte e seus principais compostos são a energia bruta (5.569 kcal $kg^{-1}$), PB (11,34%), EE (18,84%) e FDN (50,22%), na matéria natural. Foram ajustadas as equações EMA = 2.976 + 5,877 x ($r^2$ = 0,94) e EMAn = 2.939 + 4,864 x ($r^2$ = 0,95), assim, a EMA e EMAn foram estimadas em 2.976 e 2.939 kcal $kg^{-1}$, respectivamente. Adicionalmente, foram ajustadas equações para PB, EE, FDN e MS resultando em valores metabolizáveis de 6,35, 17,9, 12,48 e 45,66%, respectivamente. Conclui-se que os principais componentes do farelo da semente de maracujá são a energia bruta, proteína bruta, extrato etéreo e fibra em detergente neutro, e a EMA e

EMAn para codornas de corte é de 2.976 e 2.939 kcal $kg^{-1}$, respectivamente.

**Palavras-chave:** alimentos alternativos, coeficiente de metabolizabilidade, composição química

## INTRODUCTION

Has increased demand for products such as corn and soybean meal, the main ingredients used in feed formulations of poultry moreover, their prices greatly increased in recen year, increasing costs of production. An alternative has been studied in order to include agroindustrial by-products derived from the processing of fruit in the feed formulation, can reduce production costs without affect poultry performance (LOPES et al., 2011).

The Brazil has great potential for this market, as is third major fruit producer in the world (43 million tons) (SANTOS et al., 2014). Among the produced fruits, Brazil stands out as the largest producer and consumer of passion fruit, producing 776 thousand tons of passion fruit in 2012 (IBGE, 2013). The yellow or sour passion fruit (*Passiflora edulis Sims. F. Flavicarpa deg*) represents more than 95% of the Brazilian production, and its residue (seeds and hulls) of juice processing represents about 65-70% of the fruit weight (FERRARI et al., 2004), and may be a problem of agro-industrial residue.

Fruit byproducts contain nutrients that can be availed in animal production (ABUD & NARAIN, 2009). Passion fruit contains about 50.3% of hulls, 23.2% of juice and 26.2% of seeds (FERRARI et al., 2004). Cordova et al. (2005) reported that its hulls predominantly contains carbohydrates (55.96%), lipids (0.80%) and protein (1.50%). Seeds of this fruit contains about 55.45% of neutral detergent fiber (VALADARES FILHO et al., 2006), 1.34% of minerals (CHAU & HUANG, 2004), 25.7% of lipids and 15.62 % of protein (FERRARI et al., 2004).

Therefore, the byproduct generated by the passion fruit juice processing can be an alternative for animal feed. Ariki et al. (1977) evaluated hulls and seeds of passion fruit in broiler diets and obtained a metabolizable energy (ME) of 1,813 and 1,635kcal $kg^{-1}$, respectively. On the other hand, Romo & Nava (2007) obtained 1,950 kcal ME $kg^{-1}$ of passion fruit seed meal (PFM), for laying hens. However, no information is available about using this byproduct for meat quails.

In this way, an adequate knowledge about the nutritional value of the PFM is indispensable to be used in quail diets. This study aimed to determine the chemical composition, apparent metabolizable energy (AME) and apparent metabolizable energy corrected for nitrogen balance (AMEn) and the nutrients' metabolizability of PFM for meat quails.

## MATERIALS AND METHODS

All animal procedures were approved by the Committee for Ethics in Animal Experimentation (CEAE) of the university (protocol 3160180615). The experiment was carried out in the Fazenda Experimental de Iguatemi (FEI), belonging to Universidade Estadual de Maringá (UEM), located in Paraná State (23 ° 21'S, 52 ° 04'W, altitude 564m).

The passion fruit byproduct from variety *Passiflora edulis* (passion fruit yellow or sour) was obtained from the extraction of the pulp and hulls of the passion fruit, presenting about 60% of moisture. This byproduct was spread in layers of approximately seven inches thick, in a concrete floor, and naturally dried by the sun radiation. At least three times a day the by-product was revolved to avoid microorganisms proliferation. After that, the material was ground in a hammer mill (containing holes of 2.5mm of diameter), resulting in the PFM.

One hundred and meat quails (*Coturnix coturnix japonica*), with 21 days old, were allotted in a completely randomized design, with four treatments, five replicates and four animals per experimental unit. Treatments consisted in increasing levels of PFM (4.0, 8.0, 12.0 and 16.0%) that replaced the basal diet (w/w). This last was based on corn and soybean meal (Table 1), formulated according to the chemical composition of the feedstuffs proposed by Rostagno et al. (2011).

The experiment lasted 10 days, being five for adaptation to cages and diets and the other five for total excreta collection. Animals had free access to feed and water. In order to obtain the average feed intake of each experimental unit, feed was weighed at the beginning and end of the total collection period. Ferric oxide was used in order to determine the beginning and the end of the collection period.

Table 1. Composition of the basal diet

| Item | Amount (%) |
|---|---|
| Corn (8.55% PB) | 50.73 |
| Soybean meal (45.96% PB) | 41.82 |
| Soybean oil | 3.90 |
| Limestone | 0.30 |
| Dicalcium phosphate | 1.55 |
| Salt | 0.46 |
| DL-Methionine 99% | 0.43 |
| L-Lysine HCl | 0.35 |
| L-Threonine | 0.04 |
| Premix Vit./Min.[1] | 0.40 |
| Antioxidant[2] | 0.02 |
| Calculated composition | |
| Metabolizable energy (kcal/kg$^{-1}$) | 3.036 |
| Crude protein (%) | 23.50 |
| Calcium (%) | 0.610 |
| Available phosphorus (%) | 0.410 |
| Sodium (%) | 0.200 |
| Potassium (%) | 0.914 |
| Chlorine (%) | 0.324 |
| SID Lysine (%) | 1.450 |
| SID Threonine (%) | 0.943 |
| SID Methionine + Cystine (%) | 1.044 |
| SID Tryptophan (%) | 0.294 |
| DEB (mEq kg$^{-1}$)[3] | 229.33 |

[1]Guaranteed levels per kg of product: Vit.A - 4.500,000 UI; Vit.D3 - 1.250,000 UI; Vit.E - 4,000 mg; Vit.B1 - 278 mg; Vit.B2 - 2,000 mg; Vit.B6 - 525 mg; Vit.B12 - 5,000 mcg; Vit.K3 - 1.007 mg; Calcium Pantothenate - 4,000 mg; Niacin - 10,000 mg; Choline - 140,000 mg; Antioxidant - 5,000 mg; Zinc - 31,500 mg; Iron - 24,500 mg; Manganeese - 38,750 mg; Copper - 7,656 mg; Cobalt - 100 mg; Iodine - 484 mg; Selenium - 127 mg.[2] BHT (Butylated hydroxytoluene); [3] Diet Eletrolitic Balance.

Animals were housed in wired cages (20 cm wide x 33 cm deep x 25 cm tall), of with 165,6cm²/quails, respecting the desity recommended for this stage. equipped with nipple drinkers and self-feeders. The temperature and humidity measurements at the facility were recorded by means of maximum and minimum thermometers and bulb throughout experimental period prescribed, recording variation of the temperature range 25.6 to 17.34ºC and moisture 85.37 to 57.64%, the experiment was realized out in the autumn period.

The trays for excreta collection were covered with plastic bags, identified, and removed at each excreta collection, held every 12h00. The collected material, after the removal of feather waste and peeling skin, it was heavy and packed in plastic bags and stored in a freezer until the end of the total collection period. The excreta were thawed, homogenized, weighed and dried for 72h00 at 55°C. Then we proceeded to laboratory analysis.

Chemical composition of the PFM, excretas and experimental diets were determined in the Animal Nutrition Laboratory (UEM). Analyzes of dry matter (DM), organic matter, mineral matter (MM), gross energy (GE), crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose, cellulose and lignin were performed according to the methodologies described by Silva & Queiroz (2009). Pectin content was determined according to the technique described by Bucher (1984) cited by Van Soest (1991). The determination of total polyphenol was by the Folin Ciocalteu method with spectrophotometer of reading.

Gross energy of PFM, excretas and experimental diets were determined in the COMCAP-UEM by means of an adiabatic calorimeter (Parr®, Model 6200). At each level of PFM inclusion was determined the AME and metabolizable values of DM, GE, CP, EE and NDF by using the equations proposed by Matterson et al. (1965). AMEn was adjusted according to the equation cited by Albino (1991).

Metabolizable values of DM, CP, EE and NDF of PFM, as well as AME and AMEn, were determined by fitting linear equations, in which the slope of the linear regression equation represents the mentioned parameters (ADEOLA & ILELEJI, 2009).

Apparent metabolizability coefficients (AMC) of PFM compounds were estimated after fitting linear equation for each compound, corresponding to the ratio between the angular coefficient and the respective compound determined in the laboratory.

Data of apparent metabolizability of nutrients were subjected to statistical analysis using the Sistema de Análises Estatísticas - SAEG Versão 9.1 (UFV, 2007), and the significance was established until 5.0%. As statistical procedures, the degrees of freedom relating to PFM levels were deployed in polynomials of first and second degrees.

## RESULTS AND DISCUSSION

The PFM presented 92.2% of DM, resembling the DM contents (83.3 and 92.31%) obtained in studies performed with processing by-products of the passion fruit (LOUSADA JUNIOR et al., 2006; ROMO & NAVA, 2007). DM of PFM may differ depending on the exposure time for drying and its storage conditions, because it shows a hygroscopic capacity during processing, being able to absorb large amounts of water.

NDF and ADF (Table 2) were higher than feedstuffs conventionally used in quail diets. Increased fiber in quail diets is an undesiderable factor, once these animals doesn't secrete enzymes that are able to hydrolize β linkages and may also affect the digesta's time flux in the gut.

However, fiber fractions showed a different profile compared to other alternative feedstuffs. Lignin (5.77%) and hemicellulose (6.51%) were low, but cellulose content (37.05%) and pectin (18.34%) were high compared to residues of acerola and guava (LOUSADA JUNIOR et al., 2006). These byproducts also show high contents of lignin and hemicellulose, as low pectin content, differing of our findings for the PFM. The fiber fractions of PFM (Table 2) are in agreement with those reported by Chau & Huang (2004), which characterized the seeds of passion fruit as fiber sources mainly consisting of cellulose, hemicellulose and pectic substances.

Table 2. Chemical composition of passion fruit seed meal, as-feed basis

| Nutrient | Passion fruit seed meal |
|---|---|
| Dry matter (%) | 92.23 |
| Organic matter (%) | 88.70 |
| Crude protein (%) | 11.34 |
| Gross energy kcal / kg | 5,569 |
| Calcium (%) | 0.08 |
| Total phosphorus (%) | 0.43 |
| Mineral matter (%) | 3.52 |
| Ether extract (%) | 18.84 |
| Neutral detergent fiber (%) | 50.22 |
| Acid detergent fiber (%) | 43.71 |
| Cellulose (%) | 37.05 |
| Hemicellulose (%) | 6.51 |
| Lignin (%) | 5.77 |
| Pectin (%) | 18.34 |
| Total carbohydrates (%) | 58.53 |
| Non fibrous carbohydrates (%) | 8.31 |
| Polyphenols mgeq/g | 4.01 |

The obtained CP (11.34%) is within the range (10.48 to 13.94%) observed by Romo & Nava (2007). The GE content (5.569 kcal / kg) is partially related to the high EE content (18.84%). The obtained EE is higher than the observed in conventional feedstuffs, but is lower than those reported by Chau & Huang (2004) and Malacrida & George (2012), which obtained 24.50% and 30.39%, respectively. Differences in EE values, observed in this study and reported in other research, can be due to differences in the variety of passion fruit, harvest time and processing methods.

MM, Ca and P (Table 2) were higher than those reported by Romo & Nava (2007), and may be due to different soil characteristics and fertilization procedures, because mineral nutrition of the plant is very important for passion fruit quality (MENDONÇA, 2006). According to Freitas et al. (2006), Ca and P deficience reduces the number of fruits per plant and only P deficiency increases the hulls thickness of the fruits.

Phenolic substances are also found in passion fruit or its seeds, mostly presenting bioactive properties, such as flavonoids, phenolic acids and polyphenols, representing the major compound of these phenolic substances. In this study we found 4.01 mgEq of polyphenols/g of PFM (Table 2). Many of these compounds exhibit a wide range of biological and pharmacological effects, like antioxidants, antibacterial, antiviral, anti-inflammatory, anti-allergic and vasodilatory (ZERAIK et al., 2010). However, the maximum inclusion of PFM in the experimental diets (16%) provided a relatively low concentration of these compounds (0.65 mgEq) not expressing the mentioned effects (ROMO & NAVA, 2007).

Apparent metabolizability of NDF linearly decreased (P=0.014) according to the increased levels of PFM in the experimental diets (Table 3). A quadratic effect was observed for AME (P=0.037) and AMEn (P=0.022), estimating the better PFM inclusion when using respectively 6.56 and 7.72% in the diets, according to the fitted equations AME = 3,168 + 111.100x - 8.469x² ($R^2$ = 0.59) and AMEn = 2,821 + 156.756x - 10.150x² ($R^2$ = 0.50). These results are mainly related to the high fiber content of the PFM (Table 2) compared to others feedstuffs used in the basal diet. It is important to recognize the regression method to determine the AME, AMEn and others metabolizable compounds of an unknown feedstuff, once its values can change according to the substitution levels in basal diet, and also emphasize the additive effect of the inclusions levels of the studied feedstuff.

Table 3. Apparent metabolizability of nutrients of passion fruit seed meal (PFM) for meat quails

| Metabolizable nutrient | PFM inclusion (%) | | | | SE[1] | P values | |
|---|---|---|---|---|---|---|---|
| | 4 | 8 | 12 | 16 | | Lin[2] | Qua[3] |
| Dry matter (%) | 48.99 | 50.04 | 48.33 | 43.87 | 1.35 | NS | NS |
| AME (kcal kg$^{-1}$) | 3,367 | 3,845 | 2,951 | 2,887 | 221.24 | 0.0005[4] | 0.0369[5] |
| AMEn(kcal kg$^{-1}$) | 3,167 | 3,781 | 2,885 | 2,849 | 215.45 | 0.0053[6] | 0.0222[7] |
| Crude protein (%) | 7.21 | 7.04 | 6.80 | 6.01 | 0.26 | NS | NS |
| Ether extract (%) | 15.02 | 15.73 | 16.48 | 16.36 | 0.33 | 0.0410[8] | NS |
| Neutral detergent fiber (%) | 19.00 | 14.94 | 13.77 | 11.65 | 1.54 | 0.0144[9] | NS |

[1]Standard error, [2]Linear effect of PFM levels, [3]Quadratic effect of PFM levels, [4] AME= 3,845 – 58.279x ($r^2$ 0.46), [5]AME = 3,168 + 111.100x - 8.469x² ($r^2$ 0.59), [6]AMEn= 3,633 – 46.247x ($r^2$ 0.31), [7]AMEn= 2,821 + 156.756x - 10.150x² ($r^2$ 0.50), [8]EE= 14.704 + 0.119x ($r^2$ 0.84), [9]FDN= 20.646 – 0.580x ($r^2$ 0.94). NS – Not significative (P>0.05).

The EE of PFM is mainly constituted of polyunsaturated fatty acids, especially linoleic acid (MALACRIDA & GEORGE, 2012), and poultry uses unsaturated fat acids more efficiently than the saturated ones (FERRARI et al., 2004), partially explaining the high metabolizability coefficient of EE (Table 4) and its increased metabolizable values (P=0,041) according to increased PFM levels (Table 3). The high EE metabolizability is also observed in other alternative feedstuffs for meat quails with a predominance of polyunsaturated fatty acids, like coconut meal (95.96%) and cashew nuts meal (98.60%) (SILVA et al., 2008).

The obtained results (Table 3) were used to fit linear equations to determine the metabolizable compounds of PFM. For AME and AMEn were fitted the equations AME= 2,976x + 5.877 ($r^2$ = 0.94) and AMEn = 2,939x + 4.864 ($r^2$ = 0.95) (Figures 1. A and B), and the values of AME and AMEn were 2,976 kcal $kg^{-1}$ and 2,939 kcal $kg^{-1}$, respectively, represented by the angular coefficients of the equations. Evaluating separately the hulls and seeds of passion fruit for broilers Ariki et al. (1977) observed an AME of 1,813 and 1,635 kcal $kg^{-1}$, respectively. On the other hand, Romo & Nava (2007) obtained an AME of 1,950 kcal $kg^{-1}$ of PFM for laying hens. These differences, between the obtained AME and that reported in the literature, can be due to differences in chemical composition which can be influenced by plant maturation stage, which increases the content total solids with the fruit maturation, período de colheita and the variety of passion fruit used to obtain the PFM, leading to different proportions of its chemical compounds, affecting the gross energy metabolization. Furthermore, the passage time of digesta through quail's gut ranges from 1.0 to 1.5 hours while for hens ranges from 3.0 to 5.0 hours, and quails are able to a better energy utilization from fibrous feedstuffs, what can be due to the greater relative size of cecum, resulting in improved fiber digestibility (SAKAMOTO et al., 2006) and contributing to greater AME values of fibrous feedstuffs for quail (OLIVEIRA et al., 2007). Additionaly, equations were adjusted for the other studied compounds, wherein CP= 6.35x + 0.008 ($r^2$ = 0.75), EE= 17.9x – 0.013 ($r^2$ = 0.99), FDN= 12.48x + 0.087 ($r^2$ = 0.71), (Figure 1. C, D and E), respectively resulting in a metabolization of 6.35, 17.9 and 12.48%. For DM was adjusted the equation DM = 45.66x + 0.076 ($r^2$ = 0.91), wherein the angular coefficient (45.66%) represents the metabolizable DM.

These values were probably affected by the high contents of NDF (50.22%) and ADF (43.71%) of the PFM compared with conventional feedstuffs, promoting an increase in passage rate and then a reduced time remaining of digesta in the gastrointestinal tract of quails, increasing excretions of these compounds, once high fiber levels turns digestion more difficult (BEDFORD, 1995). Most studies carried out with poultry considers dietary fiber as a diluent with negative impacts on voluntary feed intake and nutrients digestibility (ROUGIERE & CARRE, 2010).

The fiber effects in quail diets depends on the physical chemical characteristics, including particle size, solubility and degree of lignification, affecting in different ways the pH and the passage rate in different segments of the gastrointestinal tract (MORENO et al., 2010). Evaluating the inclusion (3.0%) of rice hull in quail diets Rezaei et al. (2014) reported improvements on performance, intestinal morphology and litter moisture. Similarly, Moreno et al. (2011) reported that including up to 5.0% of pea hulls in the diet improved the apparent digestibility of nutrients, but damaging effects were observed at 7.5% inclusion.

The dry matter showed a low AMC (Table 4) compared with conventional feedstuffs used in quail diets, reflecting the coefficients of the other studied compounds. However, the AMC obtained for CP (Table 4) was higher than other products, such as sunflower meal (24.72%) and sunflower seed (38.51%) (MANTOVANI et al., 2000), and EE coefficient was too high, and may be due to the fatty acid profile of the PFM, mainly consisting of unsaturated fatty acids, as mentioned above.

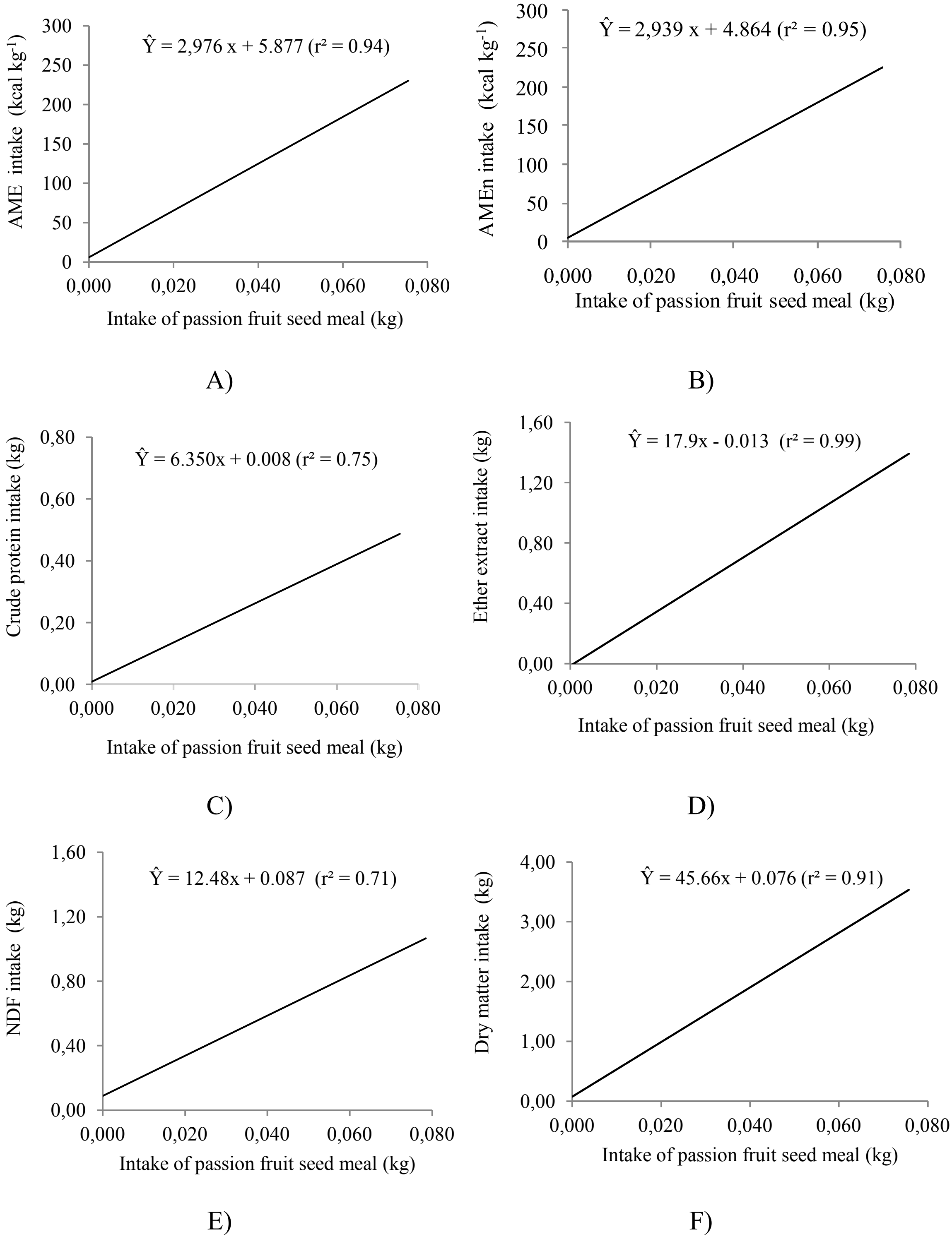


Figure 1. Graphical representation of A) Apparent Metabolizable Energy (AME), B) AME corrected for nitrogen balance (AMEn) and metabolizable values of C) Crude Protein (CP), D) Ether Extract (EE), E)Neutral detergent fiber (NFD) and F) Dry matter (DM) of passion fruit seed meal (PFM).

Insoluble fiber of passion fruit (5.77% lignin, 6.51% hemicellulose and 37.05% cellulose) included in appropriate levels in diets tends to increase the retention time of digesta in the upper gastrointestinal tract, stimulates the development of the gizzard and the production of endogenous enzymes, improves the digestibility of starch, lipids, and other compounds (HETLAND et al., 2005). It is difficult to assure that these effects occurred or not in our study, because the AMC of NDF was lower than the other ones (Table 4) and can't be considered a low coefficient, once quails don't have enzymes able to act in β linkages. By the other side, these mentioned effects were not expected once the soluble fibers rich in pectins of the passion fruit increases the intestinal viscosity decreasing the passage rate of digesta in the gut (MATEOS et al., 2012). These fibers forms a superficial layer along the small gut mucosa and acts as a barrier to the absorption of some nutrients (WASCHECK et al., 2008) what could decrease the feed intake and performance (MORENO et al., 2010) due to a lower metabolizability of nutrients.

Table 4. Apparent metabolizability coefficients (AMC) of passion fruit seed meal for meat quails

| AMC | % |
|---|---|
| Dry matter | 49.51 |
| Apparent metabolizable energy | 53.44 |
| Apparent metabolizable energy corrected for nitrogen | 52.77 |
| Crude protein | 56.00 |
| Ether extract | 95.00 |
| Neutral detergent fiber | 24.85 |

These fiber's effects possibly influenced the coefficients (Table 4) of AME (53.44%) and AMEn (52.77%) that are considerably lower than the corn coefficients reported by Silva et al. (2003), that presented coefficients of 74.27% and 74.58% for AME and AMEn, respectively, indicating that quails do not efficiently metabolize the gross energy of this feedstuffs, possibly due to the lack of pectinase and the hygroscopic effect of pectin in the gastrointestinal tract (OLIVEIRA et al., 2007) because the PFM has a high pectin content (18.34%), and also due to the high fiber content of this feedstuff.

It is concluded that main components of the passion fruit seed meal are gross energy (5,567 kcal $kg^{-1}$), crude protein (11.34%), ether extract (18.84%) and neutral detergent fiber (50.22%) and its AME and AMEn for meat quails are 2,976 and 2,939 kcal $kg^{-1}$, respectively. This research shows the passion fruit seed meal as a potent alternative food for meat quails.

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