ABSTRACT: The aim of this study was to evaluate the chemical composition of jatobá-do-cerrado flour and its effects on rat’s growth. The chemical composition of the flour was determined according to AOAC. The PER, NPR, food efficiency ratio (FER), food conversion ratio (FCR), dry matter digestibility (DMD) and fecal output were evaluated by an assay in which animals were fed according the AIN-93 diet: casein (CAS) diet and another having 50% of its protein source from jatobá flour (JAT). Chemical analysis showed significant amounts of crude fibre and minerals (potassium, magnesium, calcium and zinc) in the flour. The CAS group ate more and gained more weight than JAT group (p<0.05). JAT was less efficient on converting diet in body weight. PER was lower for JAT (p<0.05), but no significant difference was observed for NPR values (p>0.05). Faeces moisture and dried weight for JAT were higher, which corroborated its lower DMD (p<0.05). Although JAT group had to intake more diet to promote weight gain, the protein utilization was acceptable. Therefore, further studies are necessary for better understand nutrient and phytochemical composition, their bioavailability, and metabolic effects of jatobá-do-cerrado flour.

KEYWORDS: Jatobá-do-cerrado; Hymenaea stigonocarpa Mart.; growth; protein quality.

INTRODUCTION

Native fruits are present in Brazilian cerrado’s community diets since earliest times. However, today their use is occasional and it occurs according to seasonality. The species belonging to the Fabaceae (Leguminosae) family are well distributed across the cerrado extension and jatoba-do-cerrado (Hymenaea stigonocarpa Mart.) is one of them. This species belongs to the subfamily Caesalpinioideae, and it can be easily found in regions of cerrado, such as Piauí, Bahia, Goiás, Minas Gerais, Mato Grosso do Sul and São Paulo states as well as in Bolivia. Their ripe fruits are collected from April to November. They have rounded pods that surround the yellow pulps which are mealy, sweet, edible, taste and aromatic. This pulp surrounds the seeds.

In general, the jatobá-do-cerrado pulp is consumed in natura, but it can also be used as ingredient in cakes, breads, fritters, porridges, jams, liqueurs, biscuits and cookies. Recently, chemical and technological aspects of the jatobá flour have been studied for the development of products for industrial use. Therefore, considering that jatobá-do-cerrado pulp is a natural resource for rural communities, it can be used as an ingredient for food industry or for consumption, contributing to improved their economy and quality of life.

Indeed, despite the culinary use of this fruit in the cerrado regions, knowledge about its chemical, biological and sensory properties is poor. Moreover, urban populations are unaware of cerrado plants. Therefore, it is important to accomplish studies that clarify these issues, since this fruit can be a potential source of nutrients and photochemical or a useful ingredient for food industry.

Thus, since jatobá-do-cerrado is a Leguminosae, we hypothesized that its flour is a good source of vegetable protein and it doesn’t affect, negatively, the growing in rats. This study therefore was done to determine the chemical composition of the jatobá-do-cerrado flour. We also evaluated the effect of a diet added this flour, as a partial source of protein, on the growing parameters of rats.

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MATERIALS AND METHODS

Jatobá Flour Preparation and Chemical Composition

Fruits of *jatobá-do-cerrado* were collected by June 2008 at Fazenda Experimental do Moura, which belongs to Federal University of Vales do Jequitinhonha e Mucuri – UFVJM, at latitude of 18º45’S and longitude of 45º25’W, in Minas Gerais State - Brazil. The fruits were cleaned and the pulp was removed manually using a hammer and spoons for domestic use. After extraction, the pulp was oven-dried (DeLeo® mark, A.8.C. model), at 60°C for 48h. Then it was homogenized into an industrial mixer (G.P ANIZ mark, BP 12S model), for 10 minutes to obtain the flour. After, it was wrapped in plastic bags, cooled at -18°C and kept so until the analysis. It was determined the content of moisture, ash, protein, total lipids, fibre, 5 phosphorus, potassium, calcium, iron, zinc and magnesium. Carbohydrates were obtained by difference and total energy value (TEV) was estimated using the Atwater factors for kcal.13

Experimental diets

We prepared a diet of casein (CAS), a diet containing 50% of its protein from *jatobá* flour (JAT) and a non-protein diet (NPT), based on The American Institute of Nutrition for Growing Animals (AIN-93G), according to Reeves et al. We modified protein from 9 to 10%. The composition of all diets was adjusted according to the composition of *jatobá* flour, in order to keep them isoproteic and isocaloric (Table 1). The diets were homogenized into an industrial mixer (G.P ANIZ mark, BP 12S model), for 10 minutes, packed in polyethylene bags, labeled and stored in refrigerator (4°C). The proximate composition of all diets was determined according to Association of Official Analytical Chemists.5

Rat study

The bioassay was conducted in a completely randomized design with 24 *Wistar* male rats with approximately 30 days of life (Center for Biological and Health Sciences, Federal University of Viçosa – UFV, Brazil) with 107.16±5.17g, in a light (12h light) and temperature (24°C) controlled room. The animals were randomly assigned into three groups of eight animals, according the experimental diets (CAS, JAT and NPT). The rats were placed in separated cages and they received food and water *ad libitum* for 14 days with weight gain and feed intake monitored throughout the experimental period. Feces were collected for a 72h period during the final week of the study to obtain the wet weight. After, they were oven-dried (Tecnal® mark, TE-394/3 model), at 105°C for 3h, to obtain the dry weight and % of moisture. Food Efficiency Ratio (FER = body weight gain/total food intake) and Food Conversion Ratio (FCR = total food intake/body weight gain) were used to evaluate the effect of consumption of diets on weight gain and vice versa.31 The Protein Efficiency Ratio (PER = weight gain/protein intake),3 and the Net Protein Ratio (NPR = Weight gain of test group – weight loss of non-protein group / protein intake by test group)9 were evaluated to access protein quality related to promote growing. The relative ratios – RFER, RFCR, RPER and RNPR - were calculated according to casein values.48 Considering the values of dry matter consumed and excreted in the faeces collected for a 72h period during the final week of the study, we calculated the apparent dry matter digestibility – DMD according to Monteiro (DMD = dry matter intake - fecal dry matter / dry matter intake x 100).

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>CAS</th>
<th>JAT</th>
<th>APT</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Jatobá</em> flour</td>
<td>0.00</td>
<td>54.05*</td>
<td>0.00</td>
</tr>
<tr>
<td>Casein**</td>
<td>11.77</td>
<td>5.88</td>
<td>0.00</td>
</tr>
<tr>
<td>Corn starch</td>
<td>53.44</td>
<td>18.62</td>
<td>63.45</td>
</tr>
<tr>
<td>Sucrose</td>
<td>10.00</td>
<td>10.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Cellulose</td>
<td>14.80</td>
<td>00.00</td>
<td>16.50</td>
</tr>
<tr>
<td>Soybean oil</td>
<td>5.00</td>
<td>6.40</td>
<td>5.00</td>
</tr>
<tr>
<td>Mineral Mix</td>
<td>3.50</td>
<td>3.50</td>
<td>3.50</td>
</tr>
<tr>
<td>Vitamin mix</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>L-cystine</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>Choline bitartrate</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
</tbody>
</table>

*The amount of *jatobá* flour corresponded to 5g of protein per 100g of diet. **Commercial casein: 85% of protein.

Table 1 – The composition (g.100g⁻¹) of experimental diets.
NPR, DMD) as well as food intake, weight gain, wet and dry weights and nitrogen from faeces of JAT and CAS diets were evaluated by analysis of variance (ANOVA). For all statistical analysis, we used the software Statistica® version 6.0 and it was adopted as the significance level p<0.05.

RESULTS

The jatobá-do-cerrado flour is carbohydrate-rich and it seems to be a significant source of crude fibre (Table 2). The profile of minerals indicates that this flour has expressive amounts of potassium, magnesium, zinc, and calcium.

The JAT diet showed higher ash content (Table 3) compared to CAS (p<0.05), but there was no significant difference (p>0.05) between them on protein or calorie content. Both diets were isocaloric (p>0.05). However, the mean weight of the feeders completely fulfilled with both diets was 146.32±7.51g and 133.95±3.09g for CAS and JAT respectively, so JAT diet had higher volume.

Animals fed with CAS ate more and were heavier than JAT group (p<0.05). Additionally, JAT rats were less efficient in converting diet consumed in body weight, which reflected a significant lower of FER compared to the CAS group (p<0.05). Furthermore, the FCR was higher for JAT (p<0.05), indicating that these animals had to intake more diet to promote weigh gain. PER showed a lower protein efficiency for JAT group compared to CAS (p<0.05).

Conversely, there were no significant differences on NPR values between these groups (p>0.05) (Table 4). The moisture found in the faeces was approximately 3 times higher for JAT group (p<0.05). The highest production of faeces (p<0.05) for JAT corroborated the lowest DMS for this group (p<0.05) (Table 5).

DISCUSSION

The chemical composition of the jatobá-do-cerrado flour is markedly differed from other legumes, with emphasis on its high fibre and sugar and low lipids and protein contents. Silva et al. justified that these differences can be based on the fact that the edible part of jatobá refers to the fruit pulp, while in other legumes, refers to the seeds.

Almeida et al. analyzed the wet pulp of jatobá from the Brazil’s Midwest region. They found 4.20% of ash, 6.41% of protein, 2.12% of lipids, and 13.07% of crude fibre. Silva et al. found 4.60% of ash and 7.60% of protein in the dry pulp. Similarly, Silva et al. found a lower protein content (6.20%) in jatobá. So, our dried samples were slightly higher in protein, maybe due to differences of geographic origin, since our samples were obtained from north central region of Minas Gerais state, Brazil.

According our data, one hundred grams of jatobá-do-cerrado flour can supply 12.57% of the energy requirement for an adult with a 2000 Kcal diet, and

Table 2 – Proximate composition (g.100g⁻¹), energy density (Kjoules.100g⁻¹) and mineral composition (mg.100g⁻¹) of jatobá-do-cerrado flour.

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Mean ± Standard Deviation</th>
<th>Constituents</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter</td>
<td>83.12 ± 0.03</td>
<td>Potassium</td>
<td>4,275.0</td>
</tr>
<tr>
<td>Ashes</td>
<td>4.03 ± 0.03</td>
<td>Calcium</td>
<td>249.0</td>
</tr>
<tr>
<td>Protein (Nx 6,25)</td>
<td>8.07 ± 0.10</td>
<td>Magnesium</td>
<td>135.0</td>
</tr>
<tr>
<td>Lipid</td>
<td>2.41 ± 0.48</td>
<td>Phosphorus</td>
<td>104.7</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>19.24 ± 0.61</td>
<td>Zinc</td>
<td>1.7</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>49.37 ± 0.54</td>
<td>Iron</td>
<td>0.7</td>
</tr>
<tr>
<td>Energy</td>
<td>251.45 ± 4.15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 – Proximate composition (g.100g⁻¹) of the experimental diets.*

<table>
<thead>
<tr>
<th>Constituents</th>
<th>CAS</th>
<th>JAT</th>
<th>NPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter</td>
<td>95.02 ± 0.48</td>
<td>93.59 ± 0.35</td>
<td>95.08 ± 0.38</td>
</tr>
<tr>
<td>Ashes</td>
<td>2.06 ± 0.25</td>
<td>4.59 ± 0.56</td>
<td>1.69 ± 0.05</td>
</tr>
<tr>
<td>Protein</td>
<td>9.82 ± 0.12</td>
<td>9.94 ± 0.17</td>
<td>0.87 ± 0.01</td>
</tr>
<tr>
<td>Lipid</td>
<td>4.42 ± 0.42</td>
<td>8.30 ± 1.60</td>
<td>6.57 ± 2.14</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>9.67 ± 1.42</td>
<td>11.11 ± 1.06</td>
<td>10.80 ± 0.76</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>69.05 ± 1.55</td>
<td>59.65 ± 1.25</td>
<td>75.15 ± 2.68</td>
</tr>
<tr>
<td>Energy (Kcal.100g⁻¹)</td>
<td>355.21 ± 3.29</td>
<td>353.08 ± 10.60</td>
<td>363.23 ± 10.36</td>
</tr>
</tbody>
</table>

*Values expressed as mean ± standard deviation. Means followed by different letters (line) are statistically different by Tukey test (p<0.05).
contributes approximately with 76.96% of dietary fibre requirement. This fact points out that the consumption of jatobá flour may benefit population’s health, since regular fibre intake is associated with reduced risk of several diseases.

For a child aged between 9 and 13 years, protein requirement is 0.95g/kg/day, so the intake of 100g of jatobá flour could provide 24.27% of the recommended daily intake. However, it is important to access the protein quality of this flour.

It is known that several mineral elements have fundamental importance for growth and development, being involved in various physiological and metabolic processes. The jatobá flour showed expressive amounts of potassium, magnesium, zinc, and calcium. Almeida et al. also highlighted the amount of magnesium (194.8mg), zinc (1.2mg) and calcium (245.3mg) in the jatobá pulp. According to our findings and considering the daily requirements for children aged between 9 to 13 years, 100g of jatobá flour would supply 94.44% of potassium, 21.25% of zinc, and 19.15% of magnesium and calcium, respectively.

The addition of jatobá pulp to the JAT diet increased its content of ash. According to Silva et al., the inclusion of 10% of jatobá for making cookies, also provided a significant increase in ash content in the final product.

The JAT animals ate less and were lighter than CAS ones. The scientific literature associate food intake and weight gain to several factors such as food volume, biological quality of protein, water retention, production of lipids in the body, insoluble fibre content, presence of antinutrients, diet palatability, among others.

<table>
<thead>
<tr>
<th>Variables</th>
<th>CAS</th>
<th>JAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total weight gain (g)</td>
<td>59.33 ± 15.50a</td>
<td>38.13 ± 4.15b</td>
</tr>
<tr>
<td>Food intake (g)</td>
<td>243.25 ± 42.13a</td>
<td>204.57 ± 21.56b</td>
</tr>
<tr>
<td>Food Efficiency Ratio (FER)</td>
<td>0.24 ± 0.03a</td>
<td>0.19 ± 0.02b</td>
</tr>
<tr>
<td>Relative FER (%)</td>
<td>100</td>
<td>77.88 ± 9.95</td>
</tr>
<tr>
<td>Food conversion Ratio (FCR)</td>
<td>4.23 ± 0.66a</td>
<td>5.41 ± 0.73b</td>
</tr>
<tr>
<td>Relative FCR (%)</td>
<td>100</td>
<td>127.93 ± 17.36</td>
</tr>
<tr>
<td>Protein Efficiency Ratio (PER)</td>
<td>2.46 ± 0.34a</td>
<td>1.89 ± 0.24b</td>
</tr>
<tr>
<td>Relative PER (%)</td>
<td>100</td>
<td>76.94 ± 9.83</td>
</tr>
<tr>
<td>Net Protein Ratio (NPR)</td>
<td>3.61 ± 0.32a</td>
<td>3.24 ± 0.37b</td>
</tr>
<tr>
<td>Relative NPR (%)</td>
<td>100</td>
<td>89.74 ± 10.16</td>
</tr>
</tbody>
</table>

*Indexes related to CAS. Means followed by different letters (line) are statistically different by One way-ANOVA (p<0.05).
or preventing their absorption, which contributes for less weight gain. Paula et al. observed that weight gain of or preventing their absorption, which contributes for less weight gain. Paula et al. observed that weight gain of or preventing their absorption, which contributes for less weight gain. Paula et al. observed that weight gain of or preventing their absorption, which contributes for less weight gain. Paula et al. observed that weight gain of JAT group also showed lower FER and higher FCR. According to Lima et al., the ratios generated from the relationship between weight gain and food intake exhibit better the nutritional quality of a diet. These ratios can be used as parameters for evaluating the performance, functionality, digestion and absorption of nutrients. So, in addition to high fibre content, the jatobá flour could have some phytochemical, such as protease inhibitors, lectins, tannins, oxalates and phytates, which may promote nutritional imbalance to the diet. The data of Matuda & Maria Netto, point out a 17.1UTI/mg of jatobá seeds, which is below the average found in raw soybean (39.62 UTI/mg) and raw pigeon pea (7.42UTI/mg). Almeida et al. found 0.33g.100g⁻¹ of tannins in jatobá pulp, being higher than pequi (0.17g.100g⁻¹), and araticum (0.25g.100g⁻¹), and lower than baru (0.45g.100g⁻¹) and buriti (1.11g.100g⁻¹), another common Brazilian Savannah’s fruits. It has been postulated that the high phytate, tannin, lectin and protease inhibitor content of vegetable diets can promote adverse effects on growing by reducing nutrient bioavailability, so animals gain less weight.

There is no data in the literature about the evaluation of protein quality of jatobá flour. However it is known that animal proteins have higher nutritional value than vegetal proteins. Adding jatobá flour to the AIN93G diet reduced the PER. This can denote a lower quality of jatobá protein, which could have brought impairment to the animal protein in some extent. Besides, to turn all diets isocaloric, it was necessary adjust their lipid content, so JAT diet had its lipid content over 8%, which is considered another reason to reduce PER. It is relevant to observe that we also found a relative low PER for CAS diet. Several studies have shown that the casein PER is around 4. Still, Miura et al. found a PER of 2.23 after 28 days of experiment, which was close to our value. According Sgarbieri, initial animal age over 25 days can be a factor that determine lower PER for casein diets. It can be inferred that this result may be due the initial animal age, which was around 30 days. However, when analyzing NPR results, we can infer that inclusion of jatobá-do-cerrado in the diet did not expressively impair the nutritional quality of the animal protein, since they were similar (p>0.05). According Sgarbieri, NPR index is considered an index less sensitive to variations of protein concentration in experimental diets and, therefore, more reliable parameter than PER. In addition, a RNPR above 80% shows a good protein quality, as it is compared to vegetable proteins considered with high biological value, like beans and rice (RNPR= 86%).

Raupp et al. and Freitas et al. state that the defecation frequency, the wet and the dry weight of faeces and the volume of dry faeces are higher in rats fed with diets containing different sources of fibre than in rats fed with control. Soluble fibres are highly fermentable and responsible for increasing of viscosity of intestinal contents. Moreover, insoluble fibres increase volume and softening of faeces and the defecation frequency, reducing the intestinal transit time. A suitable proportion of soluble and insoluble fractions of dietary fibre are associated with functional effects in the body, such as, cholesterol-lowering effects and glycemic control, which contribute for reducing the risk of chronic diseases. As stated previously, Silva et al. found higher amounts of insoluble fibres in jatobá flour. So, this explains the higher amounts of faeces in the JAT group. Conversely, the presence of soluble fibres contributed to the higher humidity on faeces from these animals. In addition, soluble fibres are capable to complex other dietary constituents through various mechanisms, which may drag them in larger amounts in fecal excretion. Therefore it may be inferred that the inclusion of jatobá in the diet may have influenced the absorption of nutrients, leading to an increase of dry matter excretion and consequently lower DMD. In addition, Braga et al. found DMD values between 80.64 to 85.99% in a trial with AIN-93 diets based in corn, which were close to JAT. Therefore, we can infer the JAT promoted an acceptable DMD.

Thereby, the chemical composition of the jatobá-do-cerrado flour points out this fruit as a potential source of energy, crude fibres and minerals such as potassium, magnesium, calcium and zinc. It also can inferred that the inclusion of jatobá-do-cerrado flour into the diet did not impair extensively the bioavailability of casein, although promoted less gain of weight in these animals. Factors such as the palatability and volume of the diet, fibre content and their fractions, as well as the presence of certain phytochemical may have influenced these results. Therefore, considering the nutritional potential of jatobá-do-cerrado flour, it is relevant to elucidate and better understand its nutrients and phytochemical composition, as well as their bioavailability, and its metabolic effects to assure de safety of its intake by the population.


RESUMO: O objetivo deste estudo foi avaliar a composição química da farinha de jatobá-do-cerrado e os seus efeitos sobre o crescimento de ratos. A composição química da...
farinha foi determinada segundo a AOAC. Os índices PER, NPR, Quocientes de Eficiência Alimentar (CEA) e Conversão Alimentar (CCA), digestibilidade da matéria seca (DMD) e a excréção fecal foram avaliados por ensaio em que os animais foram alimentados com dietas baseadas na AIN-93G: caseína (CAS) e outra com 50% da fonte de proteína oriunda da farinha de jatobá (JAT). A análise química mostrou quantidades significativas de fibra bruta e minerais (potássio, magnésio, cálcio e zinco) na farinha. O grupo CAS obteve maior ingestão e ganho de peso com relação ao JAT (p<0,05). JAT foi menos eficiente em converter a dieta em peso corporal. O PER foi menor no grupo JAT (p<0,05), mas não foi observada diferença significativa para valores de NPR (p>0,05). A umidade e peso seco das fezes do grupo JAT foram maiores, o que corroborou sua menor DMD (p<0,05). O grupo JAT precisou ingerir mais dieta para ganhar peso, mas a utilização protéica foi satisfatória. Assim, são necessários estudos adicionais para compreender melhor a composição nutricional, os fitoquímicos, a biodisponibilidade de nutrientes e efeitos metabólicos advindos da ingestão da farinha de jatobá-do-cerrado.

PALAVRAS-CHAVE: Jatobá-do-cerrado; Hymenaea stigonocarpa Mart.; crescimento; qualidade proteica.

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