Effect of Level of Cassava Pulp in Fermented Total Mixed Ration on Feed intake, Nutrient digestibility, Ruminal fermentation and Chewing behavior in Goats

<table>
<thead>
<tr>
<th>Journal:</th>
<th>Songklanakarin Journal of Science and Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manuscript ID</td>
<td>SJST-2018-0202.R1</td>
</tr>
<tr>
<td>Manuscript Type:</td>
<td>Original Article</td>
</tr>
<tr>
<td>Date Submitted by the Author:</td>
<td>12-Oct-2018</td>
</tr>
<tr>
<td>Complete List of Authors:</td>
<td>Chumpawadee, Songsak; Mahasarakham University, Department of Agricultural Technology</td>
</tr>
<tr>
<td>Keyword:</td>
<td>Fermented total mixed ration, feed intake, nutrient digestibility, ruminal fermentation, goats, Agricultural and Biological Sciences</td>
</tr>
</tbody>
</table>
Effect of Level of Cassava Pulp in Fermented Total Mixed Ration on Feed intake, Nutrient digestibility, Ruminal fermentation and Chewing behavior in Goats

Songsak Chumpawadee1* and Sukanya Leetongdee2

1 Division of Animal Science, Department of Agricultural technology, Faculty of Technology, Mahasarakham University, Mahasarakham 44150, Thailand

2 Department of Bioprocessing, Faculty of Veterinary medicine, Mahasarakham University, Mahasarakham 44000, Thailand

* Corresponding author, Email address: songsak.c@msu.ac.th

Abstract

The objective of this study was to determine the effect of level of cassava pulp in fermented total mixed ration (FTMR) on feed intake, nutrient digestibility, chewing behavior and ruminal fermentation. Four native crossbred goats were randomly assigned in a 4x4 Latin Square Design. During each of four 21 d periods, the animals were fed four dietary treatment that varied in the levels of cassava pulp: 1) FTMR 0 % of cassava pulp, 2) FTMR 10 % of cassava pulp, 3) FTMR 20 % of cassava pulp and 4) FTMR 30 % of cassava pulp. The results showed that feed intake, nutrient digestibility, ruminal fermentation, and chewing behavior were not significant different among treatments (P>0.05). The results conclude that cassava pulp can be used in FTMR for goats about 10-30 %, which no affected on dry matter intake, nutrient digestibility, ruminal fermentation and chewing behavior.

Keywords: Fermented total mixed ration, feed intake, nutrient digestibility, ruminal fermentation, goats
1. Introduction

Cassava starch processing produces large amount of waste. The two major wastes of cassava starch processing are cassava peel and cassava pulp. Cassava peel and cassava pulp which accounts for 10-13% and 10-15% of tuber weight, respectively (Oladunjoye, Ojebiyi, & Amao, 2010; Khempaka, Molee, & Guillaume, 2009). In Thailand, approximately 1.5-2.0 million tones of cassava pulp are produced annually from the entire cassava starch industry (Chauynarong, Bhuiyan, Kanto, & Iji, 2015). Fresh cassava pulp contains approximately 60-75 % moisture (Chauynarong et al., 2015) and 69.89 % starch, 1.55 % crude protein, 27.75 % crude fiber 1.70 % ash on a dry matter basis (Sriroth, Chollakup, Chotineeranat, Piyachomkwan, & Oates, 2000). Additionally, cassava pulp price is always cheap, about 150 baht/tones. Therefore, cassava pulp have to is potential resources for reduce the cost of animal feed.

However, fresh cassava pulp contains high moisture content which not suitable for conventional feed, but there are strategies to use cassava pulp by making fermented total mixed ration. The fermented total mixed ration is a simple method to potentially nutrient utilization, extended the shelf life of feed (Wongnen et al., 2009) and can be used a high moisture ingredient. In addition, fermented total mixed ration can be increased feed intake and nutrient digestion (Yuangklang, Vasupen, Wittyakun, Srinanaun, & Sukho, 2004; Vasupen et al., 2006). However, cassava pulp is small particle size and less physical effective NDF that may affect chewing time in goats. There is currently insufficient information regarding fermented total mixed ration prepared by cassava pulp and its effects in goats. The objective of this study were to
determined the effect of level of cassava pulp in fermented total mixed ration on feed intake, nutrient digestibility, chewing behaviors and ruminal fermentation in goats.

2. Materials and Methods

Preparation of Fermented Total mixed Ration (FTMR)

The feed stuffs such as cassava pulp, soybean meal, chopped rice straw (1 centimeter), cassava chip, rice bran, salt, limestone and mineral mixed were used as ingredient in ration of FTMR. The rations of FTMR were formulated followed as Table 1. The ingredients were mixed together and added fresh water into ration at 50, 15, 10, and 5 liter respectively. The rations were contained in plastic bag and suction by vacuum pump. The FTMR were place in shed about 21 day before start experiment.

Animals and feeding

Four male Thai native goats an initial body weight of 15.75±2.39 kg were used. The animals were dewormed using Ivermectin and injected with AD₃E vitamin-complex prior to beginning of the experiment. They were housed individuals pen and fed ad libitum at 7.00 h and 19.00 h. Drinking water were offered and available at all time. Animals were randomly allocated to one of five treatments in 4x4 Latin Square Design with 21 day periods. The dietary treatments were control group (0% of cassava pulp), FTMR composed of 10 % cassava pulp, FTMR composed 20% cassava pulp and FTMR composed 30% cassava pulp. The experimental was carried out at the Division of Animal Science, Faculty of Technology, Mahasarakham University, Thailand. The animals were weighed at the beginning and end of each period.

Sample collection and preparation
The FTMRs were randomly collected and compositized prior to analyses. Composites samples were ground to pass through a 1 mm screen and analyzed for DM, Ash and CP (AOAC, 1990) NDF, ADF, ADL (Van Soest, Robertson, & Lewis, 1991) and acid insoluble ash (AIA) (Van Keulen & Young, 1977).

Fecal samples were collected by gap sampling at 10.00 h for three consecutive days and composites; the feces were placed into an oven at 65 °C for 72 h, weighed and ground to pass through a 1 mm screen and the analyzed for DM, Ash CP, NDF, ADF and AIA. The chemical composition of feed and feces were estimated for nutrient digestibility using AIA as internal marker (Schneider & Flatt, 1975).

Rumen fluid (15 ml) was collected at the end of each sampling period at 4 h post feeding by stomach tube connected with a vacuum pump. Ruminal pH was measured immediately after sampling using pH meter (Handy Lab 1, CG842 Schott). Rumen fluid samples were then filtered through four layers of cheesecloth. Fifteen milliliter of rumen fluid was acidified with 1.5 mL of 6 N HCl and centrifuged at 16000g for 15 minute and the clear supernatant was stored in plastic tubes at -20 °C until analyzed for rumen ammonia nitrogen using the micro Kjeldahl methods.

On day 19 and 20 of each period, chewing behaviors and activities after rumination chew were monitored visually at all time. Total chewing time was calculated by the sum of eating time and ruminating time. Eating chew and ruminating chew were measured by counting according to Chumpawadee & Pimpa (2009).

Statistical analysis

A 4x4 Latin Square Design (four animals; four periods) was carried out in this experiment. Each period consisted of 21 days (14 days for adaptation and 7 days for sample collection). All data obtained from the experiment were subjected to the analysis of variance.
procedure of statistical analysis system (SAS, 1996). Means were separated by Duncan New’s multiple range tests. Significance was determined at P<0.05.

3. Results and Discussion

Chemical composition of dietary treatment

The chemical compositions of dietary treatments are presented in Table 1. All diets had similar chemical composition, but differences in NDF and ADF. Increasing levels of cassava pulp in fermented total mixed ration resulted in higher NDF and ADF content, because cassava pulp had high content of NDF and ADF (Pilajun & Wanapat, 2016). Crude protein content in fermented total mixed ration was similar to calculated value and met the requirement of goat. Collectively, these observations indicated that the nutritional aspect and fermentation characteristic of fermented total mixed ration used in this study were within the normal ranges.

Feed intake and nutrient digestibility

Feed intake in term of kg/d, %BW and g/kg BW^{0.75} are presented in Table 1. Many dietary factors may influence dry matter intake in ruminant such as physical characteristics, ingredient and nutrient composition. In this study, dry matter intake was not influenced by levels of cassava pulp in fermented total mixed ration. Dry matter intake of animal fed fermented total mixed ration which difference levels of cassava pulp were similarly. This is due to cassava pulp had palatability and good physical characteristics. Additionally, the fermented total mixed ration had sour taste, which preferred by ruminant. Therefore, cassava pulp levels in fermented total mixed ration were not affected on feed intake.
Nutrient digestibilities are shown in Table 2. Digestibility of DM, OM, NDF and ADF were not significantly different (P>0.05) between treatments. This results show that cassava pulp levels were not affected in nutrient digestibility in fermented total mixed ration. The result implies that the animal have similar nutrient uptake when fed fermented total mixed ration which different of cassava pulp levels. It is noticeable nutrient digestibility of all treatment were high. The result agree with Yuangklang et al. (2004) who suggested fermented total mixed ration can be increased feed intake and nutrient digestion. Many factors may influences nutrient digestibility such as protein levels, protein sources, and protein fraction (Kawashima et al., 2003; Milis & Licmalis, 2007). Moreover RUP:RDP ratio, animal condition, breed, sex, nonstructural carbohydrate (Chantiratikul et al., 2009) and proportion of lignified cell walls (Chumpawadee & Pimpa, 2008) also affected nutrient digestibility. Due to this experiment was balance all ration to similar nutrient composition, but different in levels of cassava pulp. Therefore, this experiment emphasize on levels of cassava pulp in fermented total mixed ration was not affected on nutrient digestibility.

**Ruminal fermentation**

Concentrations of NH$_3$-N, and pH in rumen fluid were used to monitor the ruminal fermentation pattern. Ruminal pH at 4 h post feeding is presented in Table 2. Means value of ruminal pH did not differ significantly (P>0.05) at any level of cassava pulp in fermented total mixed ration. Ruminal pH values were relatively within the normal value range from 6.30 to 6.70 and all treatment means were within the normal range that has been reported as optimal pH (6.0-7.0) for microbial digestion of protein (Hoover, 1986) and fiber digestion (Theodorou & France, 1993). Rumen pH decreases when diets contain abundant of soluble carbohydrates (Sutter & Beever, 2000). Generally, rate and extent of carbohydrates degradation are influenced
ruminal pH (Nocek & Russell, 1988). The large amount of soluble carbohydrate may reduce the pH of rumen fluid and this can affect the rate of fermentation of structural carbohydrate (Sutton & Alderman, 2000). In addition, ruminal pH was partly regulated by the NH$_3$-N concentration (Chanjula, Wanapat, Wachirapakorn, & Rowlinson, 2004) and VFA concentration in the rumen (Stokes, Hoover, Miller, & Blauweikel, 1991). However, all treatment in this experiment was similarly in chemical composition (Table 1). Therefore ruminal pH was similar in all treatment. Moreover, all treatment have rice straw as roughage source about 15%. The rice straw had property to effective fiber. It was expected that they positively affect chewing activity and leading to normal rumen condition and digestion.

Ruminal ammonia nitrogen (NH$_3$-N) at 4h post feeding is presented in Table 2. The result show that level of cassava pulp in fermented total mixed ration did not alter ruminal NH$_3$-N concentration. The ruminal NH$_3$-N derived from protein degradation in the rumen. Rumen microorganisms degraded feed protein in the rumen to NH$_3$-N, peptides and amino acids. This experiment was calculated diet to iso-nitrogenous. Therefore NH$_3$-N concentrations were similar in all treatment. Ammonia nitrogen is the major end product of protein degradation and used by majority of rumen bacteria to synthesize bacterial protein (Bava, Rapetti, Crovetto, & Tamburini, 2001). Ammonia nitrogen is the preferred nitrogen source for fiber digesting bacteria and also required starch, sugar, and secondary rumen fermentation for protein synthesis (Song & Kennelly, 1990). Inadequate N supplies for rumen microbial activity has negative effect on the degradation of the other dietary component, particularly in diets rich in cellulose. The optimum ammonia concentration for microbial growth was suggested in the range 5-8 mg% (Satter & Slyter, 1974). In this study ranges of NH$_3$-N were 9.0-9.90 mg%. Therefore, NH$_3$-N was optimum levels for microbial protein synthesis, rumen ecology and microbial activity (Wanapat & Pimpa, 1999).


**Chewing behavior**

Chewing behaviors variables are shown in Table 3. Chewing time (min/d) at eating and ruminating, eating rate (gDM/min) and Rumination efficiency (gDM/min) were not significant different (P>0.05) among treatment. However, chewing time in term of min/kgNDF were significant different among treatment (P<0.05). The goats consumed control group (0% cassava pulp in fermented total mixed ration) had highest chewing time. In contrast, goat consumed 10%, 20% and 30% cassava pulp in fermented total mixed ration had low chewing time in term of min/kgNDF. The incidences, probably due to cassava pulp are small particle size and less physical effective NDF that may affect chewing time. This result agree with Grant et al. (1990) who reported that chewing time decreases as dietary particle size decreases. Although, chewing time in term of min/kgNDF decreases but did not affected on feed intake nutrient digestibility and ruminal fermentation (Table 2). Moreover, goats kept on individual housing had frequency of eating and ruminating time lower than goat kept on colony housing (Panjone & Agus, 2014). Additionally, Hooper & Welch (1993) who suggested that body size was affected on chewing efficiency. Jang et al. (2017) who reported that chewing time of Korean native goats ranged from 248.7-297.2 mind/day, but in this experiment chewing time of Thai native goats ranged from 318.7-410.5 mind/d. The chewing times are different due to breed, body size, dietary particle size and housing condition.

Number of chews/d of eating and rumination, number of chews per kg NDF intake of rumination, number of chews per min eating time, number of chews per min ruminantion time, ruminated boli, number of chews per bolus and number boli per rumination time were not significantly (P>0.05) affected by level of cassava pulp in fermented total mixed ration (Table 4),
except for number of chews per min eating time and ruminated boli in term of no./kgNDF intake. The number of chewing had highest when goats fed 0% cassava pulp in fermented total mixed ration. However, chewing time and number of chewing are in the normal range. The result suggested that cassava pulp was not negatively affect chewing activity, when use about 10-30% in fermented total mixed ration. Generally, chewing activity was affected by effective fiber in the ration (NRC, 1989). In this experiment used rice straw as roughage which high in effective fiber. Therefore all treatments remained normal chewing and ruminating activity.

4. Conclusions

Based on this study, it can be conclude that cassava pulp can be used in fermented total mixed ration for goats about 10-30 %, which not affected in dry matter intake, nutrient digestibility, ruminal fermentation and chewing behavior.

Acknowledgments

The authors would like to express their gratitude to all staff and my student for their invaluable help on the farm and laboratory. We are grateful to the Division of Animal Science, Faculty of Technology, Mahasarakham University for supporting experiment facilities. Financial support was provided by Faculty of Technology.

References


Oladunjoye, I.O., Ojebiyi, O., & Amao, O.M. (2010). Effect of feeding processed cassava (Manihatesculentacrentz) peel meal based diet on the performance characteristics, egg


Table 1. Feed formulation and chemical composition of dietary treatments.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Level of Cassava Pulp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>Cassava pulp</td>
<td>0.00</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>15.00</td>
</tr>
<tr>
<td>Rice straw</td>
<td>15.00</td>
</tr>
<tr>
<td>Cassava chip</td>
<td>45.00</td>
</tr>
<tr>
<td>Cane molasses</td>
<td>5.50</td>
</tr>
<tr>
<td>Rice bran</td>
<td>18.00</td>
</tr>
<tr>
<td>Salt</td>
<td>0.50</td>
</tr>
<tr>
<td>Lime stone</td>
<td>0.50</td>
</tr>
<tr>
<td>Mineral mixed</td>
<td>0.50</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Chemical composition

<table>
<thead>
<tr>
<th></th>
<th>DM, %</th>
<th>Ash, %</th>
<th>CP, %</th>
<th>NDF, %</th>
<th>ADF, %</th>
<th>ADL, %</th>
<th>Total digestible nutrient* (TDN), %</th>
<th>Calcium (Ca)*, %</th>
<th>Phosphorus (P)*, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>94.88</td>
<td>7.91</td>
<td>10.45</td>
<td>18.88</td>
<td>15.91</td>
<td>5.45</td>
<td>74.34</td>
<td>0.43</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>95.75</td>
<td>8.18</td>
<td>11.76</td>
<td>21.45</td>
<td>19.69</td>
<td>3.82</td>
<td>72.94</td>
<td>0.47</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>95.13</td>
<td>8.00</td>
<td>9.17</td>
<td>26.77</td>
<td>22.64</td>
<td>4.43</td>
<td>71.54</td>
<td>0.51</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>94.23</td>
<td>6.57</td>
<td>9.33</td>
<td>27.48</td>
<td>24.67</td>
<td>4.73</td>
<td>70.14</td>
<td>0.56</td>
<td>0.32</td>
</tr>
</tbody>
</table>

*Calculated value

Table 2. Effect of level of cassava pulp in fermented total mixed ration on voluntary feed intake, nutrient digestibility and ruminal fermentation in goats.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Level of Cassava Pulp</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter intake</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kg/d</td>
<td>0%</td>
<td>0.59</td>
</tr>
<tr>
<td>%BW</td>
<td>3.44</td>
<td>3.56</td>
</tr>
<tr>
<td>g/kgBW^{0.75}</td>
<td>70.18</td>
<td>73.42</td>
</tr>
<tr>
<td>Nutrient digestibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMD</td>
<td>62.53</td>
<td>67.95</td>
</tr>
<tr>
<td>OMD</td>
<td>67.60</td>
<td>72.65</td>
</tr>
<tr>
<td>CPD</td>
<td>55.46</td>
<td>64.55</td>
</tr>
<tr>
<td>NDFD</td>
<td>48.26</td>
<td>49.27</td>
</tr>
<tr>
<td>ADFD</td>
<td>43.23</td>
<td>45.57</td>
</tr>
<tr>
<td>Ruminal fermentation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>6.30</td>
<td>6.47</td>
</tr>
<tr>
<td>NH₃-N, mg%</td>
<td>9.43</td>
<td>9.72</td>
</tr>
</tbody>
</table>
Table 3. Eating and ruminating behavior, ruminated boli and boli characteristics in goat fed difference fermented TMRs.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Level of Cassava</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
<td>10%</td>
</tr>
<tr>
<td><strong>Chewing time, min/d</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating</td>
<td>261.20</td>
<td>176.63</td>
</tr>
<tr>
<td>Rumination</td>
<td>149.33</td>
<td>142.08</td>
</tr>
<tr>
<td>Total</td>
<td>410.53</td>
<td>318.70</td>
</tr>
<tr>
<td><strong>Chewing time, min/kg NDF intake</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating</td>
<td>2497.80</td>
<td>1261.00</td>
</tr>
<tr>
<td>Rumination</td>
<td>1397.30</td>
<td>1042.50</td>
</tr>
<tr>
<td>Total</td>
<td>3895.10</td>
<td>2303.60</td>
</tr>
<tr>
<td><strong>Eating rate, g DM/min</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating</td>
<td>23382.00</td>
<td>15799.00</td>
</tr>
<tr>
<td>Rumination</td>
<td>10398.70</td>
<td>9542.80</td>
</tr>
<tr>
<td>Total</td>
<td>33773.7</td>
<td>25341.80</td>
</tr>
<tr>
<td><strong>Rumination efficiency, gDM/min</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating</td>
<td>4.40</td>
<td>4.92</td>
</tr>
<tr>
<td>Rumination</td>
<td>3</td>
<td>4.40</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>4.92</td>
</tr>
<tr>
<td><strong>No. of chews/d</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating</td>
<td>224518.00</td>
<td>113337.0</td>
</tr>
<tr>
<td>Rumination</td>
<td>63594.00</td>
<td>69964.00</td>
</tr>
<tr>
<td>Total</td>
<td>321466.00</td>
<td>183301.00</td>
</tr>
<tr>
<td><strong>No. of chews/kg NDF intake</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating</td>
<td>90.57</td>
<td>89.20</td>
</tr>
<tr>
<td>Rumination</td>
<td>71.23</td>
<td>66.37</td>
</tr>
<tr>
<td>Total</td>
<td>161.80</td>
<td>155.57</td>
</tr>
<tr>
<td><strong>Ruminated boli, no/d</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating</td>
<td>181.00</td>
<td>162.75</td>
</tr>
<tr>
<td>Rumination</td>
<td>1693.70</td>
<td>1187.70</td>
</tr>
<tr>
<td>Total</td>
<td>1874.70</td>
<td>1347.45</td>
</tr>
<tr>
<td><strong>No. of chews/bolus</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating</td>
<td>57.66</td>
<td>61.90</td>
</tr>
<tr>
<td>Rumination</td>
<td>1.23</td>
<td>1.17</td>
</tr>
</tbody>
</table>

a, b, c, d Means within a row different superscripts differ (p<0.05* DM intake (g/d)/ eating time (min/d).  

* = DM intake (g/d)/rumination time (min/d)
Table 1. Feed formulation and chemical composition of dietary treatments.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>0%</th>
<th>10 %</th>
<th>20 %</th>
<th>30 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassava pulp</td>
<td>0.00</td>
<td>10.00</td>
<td>20.00</td>
<td>30.00</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
</tr>
<tr>
<td>Rice straw</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
</tr>
<tr>
<td>Cassava chip</td>
<td>45.00</td>
<td>35.00</td>
<td>25.00</td>
<td>15.00</td>
</tr>
<tr>
<td>Cane molasses</td>
<td>5.50</td>
<td>5.50</td>
<td>5.50</td>
<td>5.50</td>
</tr>
<tr>
<td>Rice bran</td>
<td>18.00</td>
<td>18.00</td>
<td>18.00</td>
<td>18.00</td>
</tr>
<tr>
<td>Salt</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Lime stone</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Mineral mixed</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Chemical composition**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>0%</th>
<th>10 %</th>
<th>20 %</th>
<th>30 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM, %</td>
<td>94.88</td>
<td>95.75</td>
<td>95.13</td>
<td>94.23</td>
</tr>
<tr>
<td>Ash, %</td>
<td>7.91</td>
<td>8.18</td>
<td>8.00</td>
<td>6.57</td>
</tr>
<tr>
<td>CP, %</td>
<td>10.45</td>
<td>11.76</td>
<td>9.17</td>
<td>9.33</td>
</tr>
<tr>
<td>NDF, %</td>
<td>18.88</td>
<td>21.45</td>
<td>26.77</td>
<td>27.48</td>
</tr>
<tr>
<td>ADF, %</td>
<td>15.91</td>
<td>19.69</td>
<td>22.64</td>
<td>24.67</td>
</tr>
<tr>
<td>ADL, %</td>
<td>5.45</td>
<td>3.82</td>
<td>4.43</td>
<td>4.73</td>
</tr>
<tr>
<td>Total digestible nutrient* (TDN), %</td>
<td>74.34</td>
<td>72.94</td>
<td>71.54</td>
<td>70.14</td>
</tr>
<tr>
<td>Calcium (Ca)*, %</td>
<td>0.43</td>
<td>0.47</td>
<td>0.51</td>
<td>0.56</td>
</tr>
<tr>
<td>Phosphorus (P)*, %</td>
<td>0.34</td>
<td>0.33</td>
<td>0.33</td>
<td>0.32</td>
</tr>
</tbody>
</table>

*Calculated value

Table 2. Effect of level of cassava pulp in fermented total mixed ration on voluntary feed intake, nutrient digestibility and ruminal fermentation in goats.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>0%</th>
<th>10 %</th>
<th>20 %</th>
<th>30 %</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter intake</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kg/d</td>
<td>0.59</td>
<td>0.64</td>
<td>0.69</td>
<td>0.53</td>
<td>0.03</td>
</tr>
<tr>
<td>%BW</td>
<td>3.44</td>
<td>3.56</td>
<td>3.09</td>
<td>3.07</td>
<td>0.11</td>
</tr>
<tr>
<td>g/kgBW0.75</td>
<td>70.18</td>
<td>73.42</td>
<td>63.94</td>
<td>62.70</td>
<td>2.28</td>
</tr>
<tr>
<td>Nutrient digestibility</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMD</td>
<td>62.53</td>
<td>67.95</td>
<td>67.86</td>
<td>61.10</td>
<td>3.03</td>
</tr>
<tr>
<td>OMD</td>
<td>67.60</td>
<td>72.65</td>
<td>71.46</td>
<td>64.67</td>
<td>2.77</td>
</tr>
<tr>
<td>CPD</td>
<td>55.46</td>
<td>64.55</td>
<td>55.86</td>
<td>60.75</td>
<td>3.47</td>
</tr>
<tr>
<td>NDFD</td>
<td>48.26</td>
<td>49.27</td>
<td>52.03</td>
<td>55.85</td>
<td>2.15</td>
</tr>
<tr>
<td>ADFD</td>
<td>43.23</td>
<td>45.57</td>
<td>46.46</td>
<td>43.20</td>
<td>2.68</td>
</tr>
<tr>
<td>Ruminal fermentation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>6.30</td>
<td>6.47</td>
<td>6.60</td>
<td>6.70</td>
<td>0.15</td>
</tr>
<tr>
<td>NH3-N, mg%</td>
<td>9.43</td>
<td>9.72</td>
<td>9.00</td>
<td>9.90</td>
<td>0.76</td>
</tr>
</tbody>
</table>

*Calculated value
Table 3. Eating and ruminating behavior, ruminated boli and boli characteristics in goat fed difference fermented TMRs.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Level of Cassava</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
<td>10%</td>
</tr>
<tr>
<td>Chewing time, min/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating</td>
<td>261.20</td>
<td>176.63</td>
</tr>
<tr>
<td>Ruminated</td>
<td>149.33</td>
<td>142.08</td>
</tr>
<tr>
<td>Total</td>
<td>410.53</td>
<td>318.70</td>
</tr>
<tr>
<td>Chewing time, min/kg NDF intake</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating</td>
<td>2497.80</td>
<td>1261.00</td>
</tr>
<tr>
<td>Ruminated</td>
<td>1397.30</td>
<td>1042.50</td>
</tr>
<tr>
<td>Total</td>
<td>3895.10</td>
<td>2303.60</td>
</tr>
<tr>
<td>Eating rate, g DM/min²</td>
<td>2.83</td>
<td>3.72</td>
</tr>
<tr>
<td>Ruminated efficiency, gDM/min³</td>
<td>4.40</td>
<td>4.92</td>
</tr>
<tr>
<td>No. of chews/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating</td>
<td>23382.00</td>
<td>15799.00</td>
</tr>
<tr>
<td>Ruminated</td>
<td>10398.70</td>
<td>9542.80</td>
</tr>
<tr>
<td>Total</td>
<td>33773.7</td>
<td>25341.80</td>
</tr>
<tr>
<td>No. of chews/kg NDF intake</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating</td>
<td>224518.0a</td>
<td>113337.0ab</td>
</tr>
<tr>
<td>Ruminated</td>
<td>63594.00</td>
<td>69964.00</td>
</tr>
<tr>
<td>Total</td>
<td>321446.00</td>
<td>183301.00</td>
</tr>
<tr>
<td>No. of chews/min eating time</td>
<td>90.57</td>
<td>89.20</td>
</tr>
<tr>
<td>No. of chews/min rumination time</td>
<td>71.23</td>
<td>66.37</td>
</tr>
<tr>
<td>Ruminated boli, no/d</td>
<td>181.00</td>
<td>162.75</td>
</tr>
<tr>
<td>Ruminated boli, no./kg NDF intake</td>
<td>1693.70a</td>
<td>1187.70ab</td>
</tr>
<tr>
<td>No. of chews/bolus</td>
<td>57.66</td>
<td>61.90</td>
</tr>
<tr>
<td>No. of boli/ min rumination time</td>
<td>1.23</td>
<td>1.17</td>
</tr>
</tbody>
</table>

a, b, c, d Means within a row different superscripts differ (p<0.05) = DM intake (g/d)/ eating time (min/d). ² = DM intake (g/d)/rumination time (min/d)