A comparison of three highly fermentable carbohydrate sources (corn, cassava powder or cassava pulp) on in vitro digestion

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Abstract. Cassava powder and pulp contain high levels of carbohydrate and variable starch; thus, they have the potential as substitutes for corn grain in cattle rations. This study aims to determine whether cassava (powder and pulp) can replace corn as an energy source in rations. Using a completely randomized design, rations were formulated using three corn, cassava powder or cassava pulp; and palm kernel cake as a protein source with a ratio of 60:40 (carbohydrate:protein source). Cassava powder and cassava pulp in the diet increased (P<0.05) VFA concentration over that from corn (14.6 and 18.2 vs. 11.3 mM, respectively) and decreased NH₃-N (4.73 and 4.55 vs. 8.26 mg/100mL, respectively) in the rumen fluid compared to corn (P<0.05). pH did not change and ranged from 7.10-7.24. Rations containing cassava pulp showed the greatest microbial N concentration (P<0.05) compared to rations containing corn or cassava (5.85 vs. 4.52 and 1.43 mg/100mL, respectively). Dry matter digestibility of the ration with cassava powder is higher (P<0.05) than corn and cassava pulp (62.4 vs. 59.4 and 50.6%, respectively). It may be concluded that cassava powder and cassava pulp can substitute corn in ruminant rations with a positive effect on the characteristics of rumen fermentation.

1. Introduction
Carbohydrate and protein are needed for microbial synthesis and fermentation in rumen. Carbohydrate fermentation in the rumen produces volatile fatty acids (VFA) and adenosine triphosphate (ATP) which is used in rumen microbial synthesis. Feed protein is degraded to NH₃ which can be used as a N source in rumen microbial synthesis. Balanced diets of carbohydrate and protein can increase VFA and NH₃ production that contribute to rumen microbial population.

Cassava is a starch-containing feed that can be used as an energy source in diets. Cassava chips contains 90% dry matter, 4.2% crude protein, 2% ether extract, and 4.2% crude fiber. Cassava pulp is a by-product after starch extraction and contains variable levels of starch but its approximate composition is 90% dry matter, 2.8% crude protein, 3.1% ether extract, and 19.5% crude fiber [1]. Corn is another starch-based energy source feed and is used widely in north American feedlot rations. Corn contains 86% dry matter, 9.5% crude protein, 4.9% ether extract, 16.3% neutral detergent fiber, 4.6% acid detergent fiber and 69% starch [2]. Therefore, the objective of this study was to determine whether feedstuffs sourced from cassava (cassava powder and cassava pulp) can replace corn as an energy source in rations as assessed by in vitro fermentation characteristics.
2. Material and methods

2.1. Animal preparation
Two fistulated Ongole steers (approximately 8 years of age and 350kg live weight (W)) were used in this experiment to provide rumen fluid. The steers were adapted for 2 weeks before collecting rumen fluid. Elephant grass and commercial concentrate were given at a ratio of 70:30 offered at 35g DM/kgW/d. with the final ration containing 13% crude protein (CP) and 60% total digestible nutrients (TDN). Total digestible nutrients were calculated using Hartadi et al. (1980) [3] formula. Feed was given twice a day at 08.00 and 15.00. Drinking water was given throughout the day ad libitum. Rumen fluid was collected in the morning prior to feeding after at least 2 weeks on the ration.

2.2. In vitro fermentation
Three rations were formulated using three different types of carbohydrate sources (corn, cassava powder or cassava pulp) and palm kernel cake (PKC) as a protein source with a ratio of 60:40 (carbohydrate:protein source). Urea was added at 1% dry matter (DM) of carbohydrate source. Rice straw was added to each ration mixture at 20:80 (rice straw:carbohydrate and protein mixture). In vitro fermentation followed the method of Tilley and Terry [4] using a 48 hours fermentation and analysis of samples after fermentation only. Each treatment consisted of three replications. Two standard tubes and two blank tubes were also used to correct DM digestion. Standard tubes were filled with Pangola grass for which previous DM digestion data was available. After 48 hours fermentation, samples were filtered using crucible and glass wool. The fluid was used to analysed pH, VFA, NH₃ using Chaney and Marbach [5] method and rumen microbial protein using Lowry method. The residue was used to analysed dry matter digestibility (DMD).

**Table 1. Diet ingredients and chemical compositions**

| Item                  | Corn + PKC | Cassava powder + PKC | Cassava pulp + PKC |
|-----------------------|------------|-----------------------|---------------------|
| Ingredients (% of dry matter) |            |                       |                     |
| Corn                  | 47.5       | -                     | -                   |
| Cassava powder        | -          | 47.5                  | -                   |
| Cassava pulp          | -          | -                     | 47.5                |
| Palm kernel cake      | 32         | 32                    | 32                  |
| Rice straw            | 20         | 20                    | 20                  |
| Urea                  | 0.5        | 0.5                   | 0.5                 |
| Nutrient compositionₐ|            |                       |                     |
| DM (%)                | 95.3       | 95.7                  | 95.2                |
| OM (%) DM             | 91.5       | 91                    | 86.5                |
| CP (%)                | 11.6       | 9.2                   | 8.9                 |
| CF (%)                | 10.3       | 10.3                  | 17.0                |
| EE (%) DM             | 8.4        | 7.6                   | 7.7                 |

ₐ DM, dry matter; OM, organic matter; CP, crude protein; CF, crude fiber; EE, ether extract

ₐ Percentage of crude protein contains CP from urea.

2.3. Statistical analysis
The results were analysed using a completely randomized design by analysis of variance (ANOVA) procedure of SPSS Statistics 25.

3. Results and discussion

3.1. Rumen pH level
The influence of varying the 60% carbohydrate source (corn, cassava powder, or cassava pulp) with 40% palm kernel cake on 48 hours rumen fermentation characteristics are presented in Table 2.
Rumen pH was not different between treatments varying from 7.10 – 7.24. There may have been an effect of the high lipid level on digestion and pH. However, the values are normal but on the on the high end of expectation. Rumen pH is a result of microbial fermentation and VFA absorption in the rumen [6] and ruminants’ diets are usually less than 5% ether extract content. Low microbial activity in the rumen tends to decrease VFA production and increase rumen pH level [7].

### Table 2. The effect of varying the 60% carbohydrate source (corn, cassava powder, or cassava pulp) with 40% palm kernel cake on 48 hours rumen fermentation characteristics

| Item                        | Corn      | Cassava powder | Cassava pulp |
|-----------------------------|-----------|----------------|--------------|
| pH                          | 7.10±0.05 | 7.18±0.07      | 7.24±0.13    |
| VFA total (mM)              | 11.3±0.83a| 14.6±1.30a     | 18.2±2.51b   |
| Acetate (mM)                | 8.30±0.15a| 8.47±0.22a     | 12.9±1.66b   |
| Propionate (mM)             | 2.26±0.22a| 3.40±0.20a     | 3.39±0.47b   |
| Butyrate (mM)               | 1.08±0.55a| 1.49±0.41ab    | 1.94±0.39b   |
| Acetate:Propionate          | 3.69±0.18a| 2.49±0.21b     | 3.81±0.65a   |
| NH₃-N (mg N/100mL)          | 8.26±0.03a| 4.73±0.29b     | 4.55±1.84b   |
| Microbial protein (mg CP/100mL) | 4.52±0.02b | 1.43±0.07a    | 5.85±0.51c   |
| Dry matter digestibility (%)| 59.4±0.84b| 62.4±0.96a     | 50.6±1.92c   |

*a,b,c* Different superscripts denote a significant difference P<0.05.

#### 3.2. Volatile fatty acid

The cassava pulp-based energy source resulted in the highest concentration of VFA (P<0.05), whereas corn and cassava powder were not significantly different (18.2, 11.3 and 14.6 mM, respectively). Levels of VFA were low as concentration of VFA generally ranges from 70 – 150 mM. This may be a consequence of the high lipid level.

Cassava pulp produced the highest acetate (P<0.05). Cassava powder and cassava pulp produced higher propionate than corn (P<0.05). Butyrate productions from cassava pulp-based energy source is higher than corn (P<0.05), but not significantly different with cassava powder (P>0.05). The ration with cassava powder produced lower acetate:propionate ratio than corn and cassava pulp (P>0.05). Addition of concentrate increased production of propionate, whereas butyrate is less affected by diet than acetate and propionate [7]. Generally, a high starch diet increases propionate and reduces acetate concentration [8] and increases the amylolytic microbial population. This situation increases production of propionate if the pH level is low [2]. Cassava powder appears to be a good source of starch to replace corn [9].

#### 3.3. Rumen ammonia

Highest concentration of ammonia (P<0.05) was produced by the ration with corn whereas cassava powder and cassava pulp were not significantly different (8.26, 4.73 and 4.55 mg/100mL, respectively). The concentration of NH₃ is a result of the CP of the diet and microbial protein production. The corn-based ration had the highest concentration of CP in the diet. Ammonia is an important nutrient in the process of fermentation and rumen microbial synthesis. A high concentration of NH₃ is needed to increase the rate of fermentation in the rumen [10]. Concentration of NH₃ in rumen fluid varied from 4.55 to 8.26 and it is generally accepted that a minimum NH₃ concentration of 5 mg/100mL is required for optimal digestion [11]. Orskov has suggested that a higher NH₃ concentrations needed for high starch diets [12] as used here. This seems to suggest that CP levels need to be higher in the ration and that PKC alone is not suitable as any increase would further increase lipid levels with detrimental effects on DM digestion.

#### 3.4. Rumen microbial protein

Microbial protein levels in the ration with cassava powder was lower than corn and cassava pulp (P<0.05) and the levels are classified as low. This was associated with low concentrations of NH₃ and
VFA further suggesting that rumen microbial synthesis was inhibited. Low concentration of NH$_3$ inhibit rumen microbial synthesis [7] and the results suggest that both low concentrations of NH$_3$ and higher than expected lipid levels reduced microbial synthesis.

3.5. Dry matter digestibility
Cassava powder increased DMD whereas cassava pulp decreased DMD compared to corn (P<0.05). This was related to low acetate:propionate ratio suggesting that cassava powder has higher starch content than corn and cassava pulp. Low acetate:propionate ratio indicates high energy availability for nutrient utilization and ruminal fermentation efficiency for microbes’ activities. Van Soest reported that cell content is highly degradable and lignin content may be a limiting factor in feed digestibility [13]. High starch diet decreases acetate:propionate ratio and increases efficiency of rumen fermentation [14].

4. Conclusion
Cassava powder and cassava pulp can substitute corn in ruminant rations with a positive effect on the characteristics of rumen fermentation.

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