Chemical features of rejected taro tuber flour (*Colocasia esculenta* L. Schott) and its effect on productive performance in post-weaning pigs

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Abstract

This study evaluated the effect of the inclusion of rejected taro tuber flour (RTTF) on the productive performance in commercial hybrid pigs (Landrace × Duroc × Pietrain) during their post-weaning period. The experiment was established under a completely randomized design, comprising four treatments (0, 10, 20, and 30% inclusion of RTTF in the diet), using a total of 60 piglets with 15 repetitions each. The average daily feed intake (ADFI), average daily gain (ADG), feed conversion (FC), final body weight (BW), presence of diarrheas, mortality, and production cost, were determined. RTTF showed a high dry matter content, nitrogen-free extracts, gross energy, aspartic acid, glutamic acid, potassium, iron, polyphenols, and antioxidant activity. RTTF inclusion in the diet of pigs in the entire period (30-58 d) did not cause diarrhea or deaths and showed a quadratic effect on BW ($p < 0.001$) and ADFI ($p < 0.001$) and produced a linear effect on ADG ($p = 0.006$), FC ($p = 0.003$) and production cost ($p < 0.001$). In conclusion, the inclusion of RTTF in the diet of pigs after weaning (30-58 d) ranging between 0 and 30 % showed no effect on BW and ADFI, with a slight decrease in ADG and FC and a linear effect on production cost reduction.

Keywords: agricultural by-products, alternative feed, antioxidants, piglets, prebiotics

Características químicas de la harina de tubérculos de taro (Colocasia esculenta L. Schott) de rechazo y su efecto sobre el desempeño productivo de cerdos en posdestete

Resumen

Este estudio evaluó el efecto de inclusión de la harina de tubérculos de taro de rechazo (RTTF) sobre el desempeño productivo en cerdos híbridos comerciales (Landrace × Duroc × Pietrain) durante el período de posdestete. El experimento se estableció bajo un diseño completamente aleatorizado, conformando cuatro tratamientos (0, 10, 20 y 30 % de inclusión de RTTF en la dieta), empleando un total de 60 lechones con 15 repeticiones cada uno. Se determinó el consumo de materia seca diaria (CMSD), ganancia de peso diario (GPD), conversión alimentaria (CA), peso final (PF), presencia de diarreas, mortalidad y costo de producción. La RTTF presentó alto contenido de materia seca, extractos libres de nitrógeno, energía bruta, ácido aspártico, ácido glutámico, potasio, hierro, polifenoles y actividad antioxidante. La inclusión de RTTF en la dieta de los cerdos en el periodo completo (30-58 d) no ocasionó diarreas ni muertes y mostró un efecto cuadrático sobre el PF ($p < 0,001$), CMSD ($p < 0,001$), y produjo efecto lineal sobre la GPD ($p = 0,006$), CA ($p = 0,003$) y costo de producción ($p < 0,001$). En conclusión, la inclusión de RTTF en la dieta de los cerdos después del destete (30-58 d), entre 0 y 30 %, no mostró efecto sobre el PF y CMSD, con una ligera disminución en la GPD y CA, y con un efecto lineal en la reducción del costo de producción.

Palabras clave: alimento alternativo, antioxidantes, lechones, prebiótico, subproductos agrícolas

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Introduction

Taro, *Colocasia esculenta* L. Schott (Araceae) is an annual herbaceous plant that is cultivated in tropical and subtropical areas worldwide, guaranteeing the economy and food security in many countries (Ebert & Waqainabete, 2018; Ubalua et al., 2016). Taro tubers are an excellent source of carbohydrates, as taro contains 70-80% starch. In addition, due to the small size of its starch granules, taro is highly digestible (Ahmed & Khan, 2013). Unlike sweet potato and yam starches (28.3 and 251 µm), taro, with an average particle size of 1.067-64.19 microns, is more suitable when improved binding and a reduced rupture capacity for pharmaceutical applications are required (Aprianita et al., 2009).

Taro tubers possess a wide range of phytochemical compounds including flavonoids, condensed tannins, β-sitosterol, and vitamins B1, B3, and C, with a long history of medicinal uses in the treatment of asthma, arthritis, diarrhea, internal bleeding, neuronal and skin disorders, in addition to analgesic, anti-inflammatory, anti-cancer and hypolipidemic effects (Prajapati et al., 2011).

In intensive pig farming, weaning is carried out early (21 days of age), and subsequent to this process, important changes occur within the piglet’s gastrointestinal tract (GIT) due to the low digestion capacity of solid diets, with the consequent occurrence of diarrheas in these animals (Flores et al., 2015). Diarrhea is commonly associated with the proliferation of enterotoxigenic *Escherichia coli* in the pig’s intestine, and colistin, a cationic antibiotic for oral use, is widely used for its treatment. However, despite the effectiveness of this antibiotic in the treatment of diarrhea in pigs, many studies report high rates of *E. coli* resistant to colistin, and, currently, there are related concerns with the increase of bacterial strains, potentially tolerant to antibiotics (Clark et al., 2012; Rhouma et al., 2017).

Given this situation, intense work has recently been carried out to minimize the use of growth-promoting antibiotics, through the use of functional health feeds from plants containing phenolic compounds (Barszcz et al., 2020; Nguimbou et al., 2014), and, among them, roots and tubers (Chandrasekara & Kumar, 2016). Phenolic compounds constitute a heterogeneous group of natural antioxidants that exert beneficial and protective actions on human and animal health (Baião et al., 2017; Shang et al., 2020). The antioxidant activity of phenolic compounds is especially due to their redox properties, since they allow them to act as reducing agents, hydrogen donors and oxygen extinguishers, potentially chelating metals (Rice-Evans et al., 1995). Ferrous ions are the most effective pro-oxidants in the food system and the high chelating capacities of ferrous ions are beneficial for health (Yamaguchi et al., 1988).

In swine production, several effects are reported: antimicrobial action, maintenance of beneficial intestinal microbiota, antioxidant, anti-inflammatory and growth promoting, stimulation of the secretion of digestive enzymes, improved intestinal health, palatability and taste of the feed (Gheisar & Kim, 2018; Guevarra et al., 2019; Yang et al., 2015).

The objective of this research was to evaluate the effect of inclusion of rejected taro tuber flour (RTTF) on productive performance in commercial hybrid pigs (Landrace × Duroc × Pietrain) during the post-weaning period.

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Materials and methods

Location of the experiment

The study was carried out in the pig area of the Caicedo Agricultural Farm, located in the Tarqui area, Pastaza canton, Pastaza province, Ecuador. The animals were kept in a half-closed unit with natural ventilation and photoperiod during the months of September and October 2018. During this period, the maximum average daily temperature was 29 \pm 1.6 \degree C and the minimum temperature 16.8 \pm 1.9 \degree C.

Elaboration of the RTTF

The flour was made following the procedure of the Ecuadorian Technical Standard, Norma Técnica Ecuatoriana (Instituto Ecuatoriano de Normalización [INEN], 2006) numeration NTE INEN 616-2006, corresponding to the preparation of vegetable flours. The rejected tubers were acquired in the rural area Teniente Hugo Ortiz, Allishungo community, and were conveyed to the premises of the “Granja Agropecuaria Caicedo”. Immediately, the tubers were washed with a 3 \% sodium hypochlorite solution in water for 10 minutes, rinsed, and cooked for 20 min in a Memert water bath at 120 \degree C. Then, the water was drained and the tubers cooled for 30 min and chopped in slices. Subsequently the drying was performed with hot air recirculation at 65 \degree C for 8 h, and the milling was performed in an industrial mill (Talsa, Model W22, Spain) with a 0.25 mm mesh. Finally, 0.05 g ascorbic acid per kg dry matter was applied, and the tubers were vacuum packed in hermetic packages and stored until their use (Escobar et al., 2016).

Chemical characterization of the RTTF

Three 1 kg flour samples were randomly taken to analyze their chemical composition: dry matter (DM), crude protein (CP), crude fiber (CF), ether extract (EE), ash and nitrogen-free extracts (NFE) according to the procedures of the Association of Official Agricultural Chemists Official Methods of Analysis (AOAC, 2005). The content of neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin were analyzed according to Van Soest et al. (1991). Hemicellulose was calculated as NDF-ADF and cellulose as ADF-lignin. Gross energy (GE), digestible energy (DE) and metabolizable energy (ME) were carried out in a Parr adiabatic calorimetric pump (model 1241, USA).

Amino acid composition was carried out by high performance liquid chromatography (HPLC); the samples were processed by the method recommended by Gratzfeld-Huesgen (1998). An internal Norvaline standard at 20 pmol/\mu L was used to avoid systematic errors in the sample during the hydrolysis process. Tryptophan was determined according to the methodology described by Spies (1967).

The determination of minerals: calcium (Ca), phosphorus (P), potassium (K), sodium (Na), magnesium (Mg), iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn) was carried out using atomic absorption spectrometry (Pérez et al., 2016).
Quantification of total phenols was performed by Folin-Ciocalteu’s spectrophotometric method (Magalhães et al., 2006). While for the total antioxidant capacity, the FRAP (Ferric Reducing Antioxidant Power) (Benzie and Strain 1996) and ABTS (2,2′-Azino-bis (3-ethylbenzothiazoline-6-sulfonic acid)) techniques were used (Re et al., 1999).

**Animal handling**

Sixty 30-day-old castrated male piglets from the commercial crossbreed (Landrace × Duroc × Pietrain) with an initial average live weight of 9.66 ± 0.29 kg were used. They were randomly housed in individual pens of 0.80 m x 1.0 m (0.80 m²) for 28 days. The pen was provided with a hopper-type feeder and a nipple waterer installed in a stable with 1.6 m high walls, a plastic floor and curtains to regulate the temperature of the unit. All procedures were approved by the Code of Ethics for research with domestic animals and wildlife of the Universidad Estatal Amazónica, under protocol 25-01/2017.

**Feed handling**

An alimentary scale was used according to the nutritional requirements of the pigs in the post-weaning stage. The treatments consisted of 0, 10, 20 and 30 % inclusion of RTTF in the diet, respectively. The diets were formulated according to the requirements and established by the National Research Council (NRC, 2012) for the post-weaning stage (table 1). All animals had ad libitum access to food and water throughout the experimental period.
### Table 1. Dietary composition of the basal diet (dry matter)

| Ingredient (%)                  | RTTF inclusion levels, % |
|---------------------------------|--------------------------|
|                                 | 0           | 10          | 20          | 30          |
| Pre-cooked maize                | 49.95       | 31.28       | 21.18       | 11.07       |
| Whole milk powder               | 2.00        | 2.00        | 2.00        | 2.00        |
| Micronized soybean meal         | 18.00       | 23.18       | 23.28       | 23.37       |
| Soybean oil                     | 1.53        | 2.44        | 2.32        | 2.21        |
| Taro tubers flour               | 0.00        | 10.00       | 20.00       | 30.00       |
| Wheat meal                      | 10.00       | 10.00       | 10.00       | 10.00       |
| Wheat germ                      | 10.00       | 10.00       | 10.00       | 10.00       |
| Calcium carbonate               | 0.45        | 0.48        | 0.51        | 0.53        |
| Monodicalcium phosphate         | 2.32        | 2.15        | 2.05        | 1.96        |
| Vitamin-trace mineral premix<sup>1</sup> | 0.50       | 0.50        | 0.50        | 0.50        |
| DL-Methionine 99%               | 0.28        | 0.34        | 0.37        | 0.40        |
| L-Lysine HCL 78%                | 0.66        | 0.67        | 0.65        | 0.63        |
| Antioxidant<sup>2</sup>         | 0.01        | 0.01        | 0.01        | 0.01        |
| Choline chloride 60%            | 0.20        | 0.20        | 0.20        | 0.20        |
| Antifungal                      | 0.05        | 0.05        | 0.05        | 0.05        |
| Lincomycin 1.1 %                | 0.05        | 0.05        | 0.05        | 0.05        |
| Sodium chloride                 | 0.35        | 0.35        | 0.35        | 0.35        |
| Starch                          | 3.65        | 6.30        | 6.48        | 6.67        |

**Calculated content<sup>3</sup>**

| Ingredient                      | Content, % |
|---------------------------------|------------|
| Dry matter, %                   | 91.7       |
| Metabolizable energy, MJ/kg     | 14.01      |
| Lactose, g/kg                   | 45         |
| Crude protein, %                | 19.24      |
| Crude fiber, %                  | 2.64       |
| Calcium, %                      | 0.70       |
| Available phosphorus, %         | 0.60       |
| Lysine, %                       | 1.53       |
| Methionine + cystine, %         | 0.87       |
| Threonine, %                    | 0.75       |
| Thrytophan, %                   | 0.22       |

Note: <sup>1</sup>Supplied per kilogram of complete diet: 2,300,000 IU vitamin A; 4,666.67 IU vitamin D3; 5,000 IU vitamin E; 667 mg vitamin K; 333 mg vitamin B1; 1,000 mg vitamin B2; 400 mg vitamin B6; 4,000 µg vitamin B12; 4,000 mg calcium pantothenate; 67 mg folic acid; 6,660 mg niacin; 17 mg biotin; 183 mg cobalt (cobalt sulfate heptahydrate); 41.67 mg copper (copper sulfate pentahydrate); 267 mg iodine (potassium iodine); 26.67 mg iron (ferrous sulfate); 16.67 mg manganese (oxide manganese); 67 mg selenium (sodium selenite) and 16.67 mg zinc (zinc oxide); <sup>2</sup>BHT; <sup>3</sup>Calculated according to NRC (2012).

Source: Elaborated by the authors
Evaluation of the productive index and the production cost

The animals were weighed individually every 7 days on a 100 kg capacity Cardinal brand scale. We surveyed their average daily feed intake (ADFI), average daily gain (ADG), feed conversion (FC), body weight (BW), presence of diarrheas and mortality (Halas et al., 2010). To estimate the production cost, we took into account the direct (piglets, feed, materials, sanitary control, labor) and indirect costs (depreciation of the sheds, equipment, tools), administrative expenses (2% of the 10,000 dollars’ investment) and financial expenses (8% of 10,000 dollars in investment) (Brito et al., 2017).

Statistical analysis

The experiment was carried out using a completely randomized design with four treatments, 15 repetitions and an animal that constitutes the experimental unit. The assumptions of normality and variance homogeneity were examined using the Shapiro-Wilk and Levene tests, respectively. The results were statistically analyzed by ANOVA of repeated measures for related samples. For all the data, the linear and quadratic effects of the RTTF inclusion levels were studied using polynomial contrasts. A Chi square test was used for the statistical analysis of the diarrhea and mortality incidence values. The responses were considered significantly different when \( p < 0.05 \), and the results presented as mean ± standard error (SD). All statistical analyses were performed using R software (R Core Team, 2019).

Results

Chemical composition

The chemical composition of the RTTF can be seen in table 2. High levels of DM, NFE, GE, DE, ME, and moderate values of CP, CF, EE, ash, NDF, ADF, lignin, cellulose and hemicellulose were obtained. The contents of aspartic acid and glutamic acid were high; there were moderate levels of lysine, threonine, serine, proline, alanine, phenylalanine, glycine, leucine, isoleucine, valine, tyrosine and histidine; and low levels of methionine and tryptophan; there was no presence of cystine. A significant content of potassium, iron, zinc, calcium, phosphorus, magnesium, sodium, manganese and copper was obtained.
### Table 2. Analyzed content of rejected taro tubers flour (RTTF) (dry matter)

| Item                      | Mean  | SD    |
|---------------------------|-------|-------|
| **Nutrients**             |       |       |
| Dry matter, %             | 89.51 | 0.04  |
| Crude protein, %          | 8.51  | 0.03  |
| Crude fiber, %            | 3.37  | 0.02  |
| Ether extract, %          | 4.97  | 0.02  |
| Ash, %                    | 4.23  | 0.02  |
| Nitrogen-free extract, %  | 78.57 | 0.31  |
| Neutral detergent fiber, %| 22.87 | 0.05  |
| Acid detergent fiber, %   | 5.36  | 0.05  |
| Lignins, %                | 1.25  | 0.01  |
| Cellulose, %              | 4.10  | 0.06  |
| Hemicelluloses, %         | 17.50 | 0.01  |
| Crude energy, MJ/kg       | 18.50 | 5.03  |
| Digestible energy, MJ/kg  | 13.21 | 1.53  |
| Metabolizable energy, MJ/kg| 10.83 | 1.00  |
| **Total amino acids**     |       |       |
| Lysine, %                 | 0.38  | 0.01  |
| Methionine, %             | 0.06  | 0.01  |
| Cystine, %                | ND    | -     |
| Treonine, %               | 0.34  | 0.01  |
| Tryptophan, %             | 0.08  | 0.01  |
| Aspartic acid, %          | 1.90  | 0.02  |
| Serine, %                 | 0.49  | 0.02  |
| Proline, %                | 0.17  | 0.02  |
| Alanine, %                | 0.37  | 0.02  |
| Phenylalanine, %          | 0.32  | 0.02  |
| Glycine, %                | 0.47  | 0.02  |
| Glutamic acid, %          | 0.84  | 0.01  |
| Leucine, %                | 0.67  | 0.02  |
| Isoleucine, %             | 0.25  | 0.02  |
| Valine, %                 | 0.38  | 0.01  |
| Tyrosine, %               | 0.37  | 0.02  |
| Histidine, %              | 0.19  | 0.02  |
| **Mineral concentration** |       |       |
| Ca, %                     | 0.10  | 0.01  |
| P, %                      | 0.28  | 0.01  |
| K, %                      | 2.27  | 0.03  |
| Mg, %                     | 0.08  | 0.01  |
| Na, %                     | 0.39  | 0.02  |
| Fe, ppm                   | 166.67| 2.08  |
| Zn, ppm                   | 37.33 | 1.53  |

ND: Not detected  
Source: Elaborated by the authors
RTTF showed a considerable content of total phenols; a moderate FRAP antioxidant activity; and a low ABTS antioxidant activity (figure 1).

**Figure 1.** Total phenol content and antioxidant activity of rejected taro tubers flour (RTTF). Source: Elaborated by the authors

**Productive performance**

The effects of the inclusion of RTTF on ADFI, ADG, FC, BW and production cost are shown in table 3. There was no presence of diarrhea or mortality during the study.
Table 3. Live body weight (BW), average daily gain (ADG), average daily feed intake (ADFI), feed conversion ratio (FC), diarrhea occurrences, mortality and production cost in post-weaning piglets supplemented with rejected taro tuber flour (RTTF)

| Item                        | RTTF Levels, % | SEM | Contrast |
|-----------------------------|----------------|-----|----------|
| Day 30-37                   |                |     |          |
| Initial BW, kg              | 9.65           | 9.76| 9.56     | 9.66 | 0.038 | 0.641 | 0.959 |          |
| Day 37 BW, kg               | 12.10          | 12.66| 12.61   | 13.03 | 0.081 | <0.001 | 0.624 |          |
| ADFI, kg                    | 0.51           | 0.52 | 0.53    | 0.54  | 0.003 | <0.001 | 0.979 |          |
| ADG, kg                     | 0.35           | 0.41 | 0.43    | 0.48  | 0.010 | <0.001 | 0.578 |          |
| FC, kg/kg                   | 1.48           | 1.30 | 1.22    | 1.15  | 0.028 | <0.001 | 0.248 |          |
| Day 37-44                   |                |     |          |
| Day 44 BW, kg               | 14.76          | 17.03| 16.28   | 16.36 | 0.171 | 0.003 | <0.001 |          |
| ADFI, kg                    | 0.86           | 0.87 | 0.87    | 0.87  | 0.001 | 0.037 | 0.004 |          |
| ADG, kg                     | 0.38           | 0.62 | 0.52    | 0.48  | 0.017 | 0.155 | <0.001 |          |
| FC, kg/kg                   | 2.30           | 1.56 | 1.66    | 1.85  | 0.058 | 0.005 | <0.001 |          |
| Day 44-51                   |                |     |          |
| Day 51 BW, kg               | 18.23          | 20.16| 19.54   | 19.02 | 0.166 | 0.192 | <0.001 |          |
| ADFI, kg                    | 0.96           | 0.93 | 0.97    | 0.93  | 0.003 | 0.347 | 0.287 |          |
| ADG, kg                     | 0.50           | 0.45 | 0.47    | 0.38  | 0.008 | <0.001 | 0.132 |          |
| FC, kg/kg                   | 1.96           | 2.08 | 2.11    | 2.48  | 0.039 | <0.001 | 0.049 |          |
| Day 30-58                   |                |     |          |
| BW 58d, kg                  | 23.69          | 24.22| 25.05   | 23.08 | 0.193 | 0.535 | <0.001 |          |
| ADFI, kg                    | 0.88           | 0.88 | 0.89    | 0.88  | 0.001 | 0.628 | <0.001 |          |
| ADG, kg                     | 0.50           | 0.52 | 0.55    | 0.48  | 0.016 | 0.006 | 0.924 |          |
| FC, kg/kg                   | 1.82           | 1.75 | 1.63    | 1.91  | 0.051 | 0.003 | 0.593 |          |
| Production cost, dollars     | 24.61          | 24.10| 23.94   | 23.21 | 0.069 | <0.001 | 0.046 |          |

SEM: standard error mean.
Source: Elaborated by the authors

In this study there was no presence of diarrhea or animal deaths during the study. In the first period (30-37 d) the inclusion of RTTF produced a linear effect of the BW ($p < 0.001$), ADFI ($p < 0.001$), ADG ($p < 0.001$) and FC ($p < 0.001$). For the second period (37-44 d), a quadratic effect of the BW ($p < 0.001$), ADFI ($p = 0.04$), ADG ($p < 0.001$) and FC ($p < 0.001$) was obtained. In the third period (44-51 d), a quadratic effect was verified for the BW ($p < 0.001$) and linear effect for ADG ($p < 0.001$) and FC ($p < 0.001$), there were no significant differences for the ADFI for which the groups had an mean consumption of 0.96, 0.93, 0.97 and 0.93 kg/d. For the complete period (30-58 d), a quadratic effect was obtained on BW ($p < 0.001$), ADFI ($p < 0.001$), and a linear one on ADG ($p = 0.006$), FC ($p = 0.003$) and production cost ($p < 0.001$).
Discussion

Chemical composition

RTTF showed high content of DM (89.56 %), NFE (78.57 %), GE (18.50 MJ/kg), DE (13.21 MJ/kg) and ME (10.83 MJ/kg), as can be seen in table 2. The high DM content is appropriate to preserve the product for prolonged periods (Caicedo et al., 2018). Moreover, levels higher than 12 % could induce moisture damage during storage of the flours, since it can cause growth of putrefactive microorganisms such as molds (Alternaria, Aspergillus, Cladosporium, Fusarium) and bacteria (coliforms, enterococci, E. coli) (Kaur et al., 2013; Salgado & Jiménez, 2012). These microorganisms cause deterioration of the product, and produce changes in its appearance and losses in its nutritional value, due to the degradation of proteins, lipids and carbohydrates; contamination with microbial toxins may also cause damage to human and animal health (Organización Panamericana de la Salud [OPS], 2020).

The high levels of NFE, GE, DE and ME in the RTTF allow us to classify this feed as a good alternative energy source, which can compete with traditional grains such as corn and wheat. For this reason, taro tubers are a staple in many developing countries due to their high energy inputs for food and feeds (Huang et al., 2007; Ogunlakin et al., 2012).

The RTTF showed moderate content of CP (8.51 %), ash (4.23 %), EE (4.97 %), CF (3.37 %), FDN (22.87 %), FDA (5.36 %), lignin (1.25 %), cellulose (4.10 %) and hemicellulose (17.50 %), respectively (table 2). These results are similar to those reported for taro varieties grown in Africa (Aboubakar et al., 2008; Ndabikunze et al., 2011; Nguimbou et al., 2014), Colombia (Púa et al., 2019), and Mexico (Madrigal-Ambriz et al., 2018). Moreover, it has to be noted that taro fiber is considered dietetic and is very advantageous for its active role in regulating the intestinal transit, increasing the diet’s volume and stool consistency due to its ability to absorb water (Temesgen & Ratta, 2015).

Regarding the amino acid composition of the RTTF (table 2), high contents of non-essential amino acids were determined; aspartic acid (1.90 %), glutamic acid (0.84 %) and low levels of sulfur amino acids; methionine (0.06 %) and absence of cystine. In African taro flour varieties, Njintang et al. (2014) and Temesgen et al. (2017) reported high values of nonessential amino acids (aspartic acid and glutamic acid) and low levels of methionine and absence of cystine, results similar to the ones obtained in this study. In this sense, Yeoh and Chew (1997) and Shewry (2003) report that the roots and tubers are deficient in sulfur amino acids.

The RTTF showed a high content of K (2.27 %), Fe (166.67 ppm), Zn (37.33 ppm), Ca (0.10 %), P (0.28 %), Mg (0.08 %), Na (0.39 %), Mn (18 ppm) and Cu (9.33 ppm) (table 2). The results obtained from this research are consistent with other studies that have reported that taro tubers have significant contents of K, P, Mg, Zn, Fe, Cu and Ca (Madrigal-Ambriz et al., 2018; Mergedus et al., 2015). Among the macro-minerals, K and P stand out, while Fe and Zn predominate among the micro-minerals.

The RTTF exhibited a significant content of total phenols (220 mg gallic acid/100 g DM); antioxidant activity moderated by FRAP (25 mg TROLOX/100 g DM); and low antioxidant activity with ABTS (11 mg TROLOX/100 g DM) (figure 1). Regarding phenolic compounds in taro flour, Arcé et al. (2016) reported 120 mg gallic acid/100 g DM; Madrigal-Ambriz et al. (2018) obtained 113 gallic acid.

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mg/100 g DM; and Purwandari et al. (2018) attained (79 mg gallic acid/100 g DM), lower figures than those found in this research. Regarding antioxidant activity, a better value was obtained with the FRAP technique; this is probably due to the fact that this foodstuff has an appreciable iron content (Mergedus et al., 2015) and therefore the affinity for ferric ions of the FRAP method.

Simsek and El (2015) studied the total phenolic and flavonoid composition of taro corm, and determined that flavonoids were present in about a quarter of the total phenolic content. The main flavonoids found in taro corm were quercetin and antocyanins (Awa & Eleazu, 2007). In another study with liquid chromatography mass spectrometry, Kumar and Sharma (2017) determined that caffeic acid, gallic acid, chlorogenic acid, catechin, epicatechin 3, 5 DiCQ acid and flavanol were the main compounds present in taro flour extract.

The bioactive compounds of taro have antitumor, antimutagenic, immunomodulatory, anti-inflammatory, antioxidant, antihyperglycemic and antihyperlipidemic activities. Ribeiro et al. (2021) reported that the bioactivity of taro tuber is attributed to the combination of tarin, taro polysaccharide-4,1, taro polysaccharides 1 and 2 (TPS-1 and TPS-2), A-1/B-2 α-amylase inhibitors, monogalactosyldiacylglycerols (MGDGs), digalactosyldiacylglycerols (DGDGs), polyphenols and non-phenolic antioxidants and provide anticancer and immunomodulatory benefits.

**Productive performance**

The literature on the evaluation and use of RTTF in post-weaning pigs’ diets is scarce. This study was carried out in adequate sanitary conditions, and the RTTF inclusion between 0 and 30% presented high production levels for the BW (23.69-23.08 kg) and ADFI (1.19-1.19 kg/d), although a slight effect in ADG (0.78-0.58 kg/d) and FC (1.53-2.15 kg/kg) was verified. Nonetheless, with the increasing inclusion of RTTF there was a linear reduction in the feeding cost (24.61-23.21 dollars) for the entire period (30-58 d), as can be seen in table 3. In this regard, Aragadvay et al. (2016) found that the inclusion of taro meal for human consumption in the diet of post-weaning pigs up to 30% did not affect the BW (23.44-22.87 kg), with a slight detriment in the FC (1.39-1.48 kg/kg). Variation in ADG and FC for the full period (30-58 d) with the inclusion of RTTF in the diet could be explained largely by substituting ingredients of high nutritional value – such as corn and soybean meal (Satessa et al., 2020). These raw materials are irreplaceable in the diet of pigs due to their high energy and protein content of high biological value and digestibility (Florou-Paneri et al. 2014; Liu et al., 2019).

The linear reduction found for the production cost can be related to the use of a product of rejection that does not compete with conventional raw materials which are frequently used for human consumption. This element was demonstrated by Bauza et al. (2005) and Caicedo and Flores (2020) who used alternative ingredients in pigs after weaning and managed to reduce the production cost without negative effects on productive indicators or the animals’ health.

The optimal use of starch from RTTF is due to its structural form, amylose has a linear structure, whilst amylpectin is ramified (Vargas & Hernández, 2013). This favors the entry of water into intermolecular spaces, improving the solubility of the polymers (Araujo et al., 2004). In summary, when the starch granules hydrate, they cause increase in its size and its structure changes from a semi-crystalline to an amorphous one – this process is known as gelatinization (Torres et al., 2013). This change of structure favors the use of starch due to the action of amylases generated in the salivary

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and pancreatic glands of pigs (Lapis et al., 2017). On the other hand, the combination of small granules and low content of highly soluble dietary fiber makes taro tubers an excellent source of carbohydrates (Vargas & Hernández, 2013).

Conclusions

Inclusion of RTTF in the diet of pigs after weaning (30-58 d), between 0 and 30%, showed no effect on the BW and ADFI, with a slight decrease in ADG and FC, and with a linear effect on the reduction of the production cost.

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Disclaimers

All the authors made significant contributions to the document and agree with its publication; further, they all declare that there are no conflicts of interest in this study.

References

Aboubakar, Y., Njintang, Y., Scher, J., & Mbfung, C. (2008). Physicochemical, thermal properties and microstructure of six varieties of taro (Colocasia esculenta L. Schott) flour and starches. Journal of Food Engineering, 86(2), 294-305. https://doi.org/10.1016/j.jfoodeng.2007.10.006

Ahmed, A., & Khan, F. (2013). Extraction of starch from taro (Colocasia esculenta) and evaluating it and further using taro starch as disintegrating agent in tablet formulation with overall evaluation. Inventi Rapid: Novel Excipients, 2, 1-5.

Association of Official Agricultural Chemists [AOAC]. (2005). Official Methods of Analysis (18th ed.).

Aprianita, A., Purwandari, U., Watson, B., & Vasiljevic, T. (2009). Physico-chemical properties of flours and starches from selected commercial tubers available in Australia. International Food Research Journal, 16, 507-520. http://www.ifrj.upm.edu.my/16%20(4)%202009/07%20IFRJ-2008-158%20Todor%20Australia%202nd%20proof.pdf

Aragadvay, R., Núñez, O., Velástegui, G., Villacís, L., & Guerrero, J. (2016). Uso de harina de Colocasia esculenta L., en la alimentación de cerdos y su efecto sobre parámetros productivos. Journal Selva Andina Animal Science, 3(2), 98-104. http://www.scielo.org.bo/pdf/jsaas/v3n2/v3n2_a04.pdf

Araujo, V., Rincón, C., & Padilla, A. (2004). Caracterización del almidón nativo de Dioscorea bulbifera L. Archivos Latinoamericanos de Nutrición, 54(2), 241-245. https://www.alanrevista.org/ediciones/2004/2/art-16/
Arani, M., Yıldırım, R. M., Özülkü, G., Yaşar, B., & Toker, O. S. (2016). Physicochemical and nutritional properties of taro (Colocasia esculenta L. Schott) flour as affected by drying temperature and air velocity. LWT - Food Science and Technology, 74, 434-440. https://doi.org/10.1016/j.lwt.2016.08.006

Awa, E., & Eleazu, C. (2015). Bioactive constituents and antioxidant activities of raw and processed cocoyam (Colocasia esculenta). Nutrafoods, 14, 133-140. https://doi.org/10.1007/s13749-015-0033-x

Baião, D., De Freitas, C., Gomes, L., Da Silva, D., Correa, A. C., Pereira, P., Del Aguila, E., & Paschoalín, V. M. (2017). Polyphenols from root, tubercles and grains cropped in Brazil: Chemical and nutritional characterization and their effects on human health and diseases. Nutrients, 9(1044), 1-29. https://doi.org/10.3390/nu9091044

Barszcz, M., Taciak, M., Tuśnio, A., Święch, E., & Skomiał, J. (2020). Dose-dependent effects of two inulin types differing in chain length on the small intestinal morphology, contractility and proinflammatory cytokine gene expression in piglets. Archives of Animal Nutrition, 74(2), 107-120. https://doi.org/10.1080/1745039X.2019.1697140

Bauza, R., González, A., Panissa, G., Petrocelli, H., & Miller, V. R. (2005). Evaluación de dietas para cerdos en recría incluyendo forraje y suero de queso. Revista Argentina de Producción Animal, 25, 11-18. https://www.produccion-animal.com.ar/produccion_porcina/00-produccion_porcina_general/80-Bauzadx

Benzie, I. F., & Strain, J. J. (1996). The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the FRAP assay. Analytical Biochemistry, 239(1), 70-76. https://doi.org/10.1006/abio.1996.0292

Brito, M., Sánchez, D., Aucanela, M., & Carrión, H. (2017). Estandarización de los costos de producción agropecuaria en el Ecuador. Revista Observatorio Economía Latinoamericana, 232, 1-26. http://www.eumed.net/cursecon/ecolat/ec/2017/costos-produccion-agropecuaria.html

Caicedo, W., Sanchez, J., Tapuy, A., Vargas, J.C., Samaniego, E., Valle, S., Moyano, J., & Puupapat, D. (2018). Apparent digestibility of nutrients in fattening pigs (Largewhite × Duroc × Pietrain), fed with taro (Colocasia esculenta (L.) Schott) meal. Technical note. Cuban Journal of Agricultural Science, 52(2), 1-6. https://www.cjascience.com/index.php/CJAS/article/view/795

Caicedo, W., & Flores, A. (2020). Características nutritivas de un ensilado líquido de banano orito (Musa acuminata AA) con tubérculos de taro (Colocasia esculenta (L.) Schott) y su efecto en cerdos de post-destete. Revista de Investigaciones Veterinarias del Perú, 31(1), Article e17545. http://dx.doi.org/10.15381/rivep.v31i1.17545

Chandrasekara, A., & Kumar, T. J. (2016). Roots and tuber crops as functional foods: A review on phytochemical constituents and their potential health benefits. International Journal of Food Science, 2016, Article 3631647. https://doi.org/10.1155/2016/3631647

Clark, S., Daly, R., Jordán, E., Lee, J., Mathew, A., & Ebner, P. (2012). Extension Education Symposium: The future of biosecurity and antimicrobial use in livestock production in the United States and the role of extension. Journal of Animal Science, 90(8), 2861-2872. https://doi.org/10.2527/jas.2011-4739

Ebert, A., & Waqainabete, L. (2018). Conserving and sharing taro genetic resources for the benefit of global taro cultivation: A core contribution of the Centre for Pacific Crops and Trees. Biodiversity and Biobanking, 16(5), 361-367. https://doi.org/10.1089/bio.2018.0017

Escobar, J., Asanza, M., Herrera, B., & González, J. (2016). Caracterización físico-química de harinas de especies vegetales para la agroindustria ecuatoriana. Revista Amazónica Ciencia y Tecnología, 5(2), 159-168. https://dialnet.unirioja.es/servlet/articulo?codigo=5761085
Flores, L., Elías, A., Proaño, F., Granizo, G., Medina, Y., López, S., Herrera, F., & Caicedo, W. (2015). Effects of a microbial preparation, a probiotic and commercial antibiotic on the productive performance and pig’s health in post-weaning period. *Cuban Journal of Agricultural Science*, 49(3), 357-365. https://www.redalyc.org/pdf/1930/193042629013.pdf

Florou-Paneri, P., Christaki, E., Giannenas, I., Bonos, E., Skoufos, I., Tsinas, A., Tzora, A., & Peng, J. (2014). Alternative protein sources to soybean meal in pig diets. *Journal of Food, Agriculture & Environment*, 12(2), 655-660. https://www.cabdirect.org/cabdirect/abstract/20143310441

Gheisar, M. M., & Kim, I. H. (2018). Phytobiotics in poultry and swine nutrition – a review. *Italian Journal of Animal Science*, 17(1), 92-99. https://doi.org/10.1080/1828051X.2017.1350120

Gratzfeld-Huesgen, A. (1998). *Sensitive and reliable amino acid analysis in protein hydrolysates using the HP 1100 Series HPLC* [Technical Note, publication No. 5968-5658E]. Agilent Technologies. https://www.yumpu.com/en/document/read/6655152/sensitive-and-reliable-amino-acid-analysis-in-protein-hydrolysates.

Guevarra, R. B., Lee, J. H., Lee, S. H., Min-Jae, S., Kim, D. W., Kang, B. N., Johnson, T. J., Isaacson, R. E., & Kim, H. B. (2019). Piglet gut microbial shifts early in life: Causes and effects. *Journal of Animal Science and Biotechnology*, 10(1), 1-10. https://doi.org/10.1186/s40104-018-0308-3

Halas, A., Hansen, C. F., Hampson, D. J., Mullan, B. P., Kim, J. C., Wilson, R. H., & Pluske, J. R. (2010). Dietary supplementation with benzoic acid improves apparent ileal digestibility of total nitrogen and increases villous height and caecal microbial diversity in weaner pigs. *Animal Feed Science and Technology*, 160(3-4), 137-147. https://doi.org/10.1016/j.anifeedsci.2010.07.001

Huang, C. C., Chen, W. C., & Wang, C. C. (2007). Comparison of Taiwan paddy- and upland-cultivated taro (*Colocasia esculenta* L.) cultivars for nutritive values. *Food Chemistry*, 102(1), 250-256. https://doi.org/10.1016/j.foodchem.2006.04.044

Instituto Ecuatoriano de Normalización [INEN]. (2006). *Norma Técnica Ecuatoriana NTE INEN 616-2006. Tercera revisión. Harina de trigo: Requisitos*. Instituto Ecuatoriano de Normalización. https://www.normalizacion.gob.ec/buzon/normas/616.pdf

Kaur, M., Kaushal, P., & Sandhu, K. S. (2013). Studies on physicochemical and pasting properties of Taro (*Colocasia esculenta* L.) flour in comparison with a cereal, tuber and legume flour. *Journal of Food Science and Technology*, 50, 94-100. https://doi.org/10.1007/s13197-010-0227-6

Kumar, V., & Sharma, H. K. (2017). Process optimization for extraction of bioactive compounds from taro (*Colocasia esculenta*), using RSM and ANFIS modeling. *Food Measure*, 11, 704-718. https://doi.org/10.1007/s11694-016-9440-y

Lapis, T. J., Penner, M. H., Balto, A. S., & Lim, J. (2017). Oral digestion and perception of starch: Effects of cooking, tasting time, and salivary α-Amylase activity. *Chemical Senses*, 42(8), 635-645. https://doi.org/10.1093/chemse/bjx042

Liu, D., Liu, H., Li, D., & Wang, F. (2019). Determination of nutrient digestibility in corn and soybean meal using the direct and substitution methods as well as different basal diets fed to growing pigs. *Journal of Applied Animal Research*, 47(1), 184-188. https://doi.org/10.1080/09712119.2019.1597725

Madrigal-Ambriz, L., Hernández-Madrígil, J., Carranco-Jauregui, M., Calvo-Carrillo, M., & Casas-Rosado, R. (2018). Caracterización física y nutricional de harina del tubérculo de “Malanga” (*Colocasia esculenta* L. Schott) de Actopan, Veracruz, México. *Archivos Latinoamericanos de Nutrición*, 68(2), 175-183. https://www.alanrevista.org/ediciones/2018/2/art-8/

Magalhães, L. M., Segundo, M. A., Reis, S., Lima, J. L., & Rangel, A. O. (2006). Automatic method for the determination of Folin-Ciocalteu reducing capacity in food products. *Journal of Agricultural and Food Chemistry*, 54(15), 5241-5246. https://doi.org/10.1021/jf060324s

Cien. Tecnol. Agropecuaria, 22(3): e2345
DOI: https://doi.org/10.21930/rcta.vol22_num3_art:2345
Mergedus, A., Kristl, J., Ivancic, A., Sober, A., Sustar, V., Krizan, T., & Lebot, V. (2015). Variation of mineral composition in different parts of taro (Colocasia esculenta) corms. Food Chemistry, 170, 37-46. https://doi.org/10.1016/j.foodchem.2014.08.025

Ndahikunze, B. K., Talavera, H. A., Mongi, R. J., Isa-Zacharia, A., Serem, A. K., Palapala, V., & Nandi, J. O. (2011). Proximate and mineral composition of cocoyam (Colocasia esculenta L. and Xanthosoma sagittifolium L.) grown along the Lake Victoria Basin in Tanzania and Uganda. African Journal of Food Science, 5(4), 248-254. http://erepo.usiu.ac.ke/bitstream/handle/11732/4515/Proximate%20and%20Mineral%20Composition%20of%20Cocoyam.pdf?sequence=1&isAllowed=y

Nguimbou, R. M., Boudjeko, T., Njintang, N. Y., Himeda, M., Scher, J., & Mbofung, C. M. F. (2014). Muclilage chemical profile and antioxidant properties of giant swamp taro tubers. Journal of Food Science and Technology, 51(12), 3559-3567. https://doi.org/10.1007/s13197-012-0906-6

Njintang, N. Y., Boudjeko, T., Tatsadjieu, L. N., Nguema-Ona, E., Scher, J., & Mbofung, C. M. F. (2014). Compositional, spectroscopic and rheological analyses of mucilage isolated from taro (Colocasia esculenta L. Schott) corms. Journal of Food Science and Technology, 51, 900-907. https://doi.org/10.1007/s13197-011-0580-0

National Research Council [NRC]. (2012). Nutrient Requirements of Swine (11th ed.). National Academies Press.

Ogunlakin, G. O., Oke, M. O., Babarinde, G. O., & Olutunbosun, D. G. (2012). Effect of drying methods on proximate composition and physic-chemical properties of cocoyam flour. American Journal of Food Technology, 7(4), 245-250. https://doi.org/10.3923/ajft.2012.245.250

Organización Panamericana de la Salud [OPS]. (2020). Peligros biológicos. Organización Panamericana de la Salud. https://www.paho.org/hq/index.php?option=com_content&view=article&id=10838:2015-peligros-biolgicos&Itemid=41432&lang=es

Pérez, D. M., Soto, L. R., Granadillo, V. A., & Peña, J. L. (2016). Determinación de minerales y caracterización físico-química de la pulpa de lima Tahití (Citrus x latifolia (Yu.Tanaka) Yu.Tanaka). Revista de la Facultad de Agronomía, 33(4), 482-506. https://produccioncientificahuzu/index.php/agronomia/article/view/27211

Prajapati, R., Kalariya, M., Umbarkar, R., Parmar, S., & Sheth, N. (2011). Colocasia esculenta. A potent indigenous plant. International Journal on Nutrition, Pharmacology, Neurological Diseases, 1(2), 90-96. https://www.ijnpmnd.com/text.asp?2011/1/2/90/84188

Púa, A. A., Barreto, G. E., Zuleta, J. L., & Herrera, O. D. (2019). Análisis de nutrientes de la raíz de la Malanga (Colocasia esculenta Schott) en el trópico seco de Colombia. Información Tecnológica, 30(4), 69-76. http://dx.doi.org/10.4067/S0718-07642019000400069

Purwandari, U., Farida, U., Dianing, V. P. P., Sari, L. Y., Kurniawati, A. G., Warnianti, A., & Fauziyah, E. (2018). Texture, sensory, antioxidant, and blood glucose profile of gluten-free taro and banana noodles using gathotan flour as texturing agent. International Food Research Journal, 25(6), 2459-2466. http://www.myjournal.my/filebank/published_article/83078/30.pdf

R Core Team. (2019). R: A language and environment for statistical computing. Vienna (Austria): R Foundation for Statistical Computing.

Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M., & Rice-Evans, C. (1999). Antioxidant activity applying an improved ABTS radical cation decolorization assay. Free Radical Biology and Medicine, 26(9-10), 1231-1237. https://doi.org/10.1016/S0891-5849(98)00315-3

Rhouma, M., Fairbrother, J. M., Beaudry, F., & Letellier, A. (2017). Post weaning diarrhea in pigs: risk factors and non-colistin-based control strategies. Acta Veterinaria Scandinavica, 59(1), 1-19. https://doi.org/10.1186/s13028-017-0299-7

Cient. Tecnol. Agropecuaria, 22(3): e2345
DOI: https://doi.org/10.21930/rcta.vol22_num3_art:2345
Ribeiro, P., Bertozzide, É., Nitzsche, A. C., Afonso, M., & Margaret, V. (2021). Anticancer and Immunomodulatory Benefits of Taro (Colocasia esculenta) Corms, an underexploited tuber crop. *International Journal of Molecular Science, 22*, 265. [https://doi.org/10.3390/ijms22010265](https://doi.org/10.3390/ijms22010265)

Rice-Evans, C. A., Miller, N. J., Bolwell, P. G., Bramley, P. M., & Pridham, J. B. (1995). The relative antioxidant activities of plant-derived polyphenolic flavonoids. *Free Radical Research, 22*(4), 375-383. [https://doi.org/10.1080/10715769509145649](https://doi.org/10.1080/10715769509145649)

Salgado, A. A., & Jiménez, M. T. (2012). Métodos de control de crecimiento microbiano en el pan. *Temas Seleccionados de Ingeniería de Alimentación, 6*(2), 160-172. [https://tsia.udlap.mx/metodos-de-control-de-crecimiento-microbiano-en-el-pan/](https://tsia.udlap.mx/metodos-de-control-de-crecimiento-microbiano-en-el-pan/)

Satessa, G. D., Tamez-Hidalgo, P., Hui, Y., Cieplak, T., Krych, L., Kjerulff, S., Brunsgaard, G., Nielsen, D. S., & Nielsen, M. O. (2020). Impact of dietary supplementation of lactic acid bacteria fermented rapeseed with or without macroalgae on performance and health of piglets following omission of medicinal zinc from weaner diets. *Animals, 10*(1), 1-20. [https://doi.org/10.3390/ani10010137](https://doi.org/10.3390/ani10010137)

Shang, Q., Ma, X., Liu, H., Liu, S., & Piao, X. (2020). Effect of fibre sources on performance, serum parameters, intestinal morphology, digestive enzyme activities and microbiota in weaned pigs. *Archives of Animal Nutrition, 74*(2), 121-137. [https://doi.org/10.1080/1745039X.2019.1684148](https://doi.org/10.1080/1745039X.2019.1684148)

Shewry, P. R. (2003). Tuber Storage Proteins. *Annals of Botany, 91*(7), 755-769.

Simsek, S., & El, S. N. (2015). *In vitro* starch digestibility, estimated glycemic index and antioxidant potential of taro (Colocasia esculenta L. Schott) corm. *Food Chemistry, 168*, 257-261. [https://doi.org/10.1016/j.foodchem.2014.07.052](https://doi.org/10.1016/j.foodchem.2014.07.052)

Spies, J. R. (1967). Determination of tryptophan in proteins. *Analytical Chemistry, 39*(12), 1412-1416. [https://doi.org/10.1021/ac60256a004](https://doi.org/10.1021/ac60256a004)

Temesgen, M., & Ratta, N. (2015). Nutritional potential, health and food security benefits of taro Colocasia esculenta (L.): A Review. *Food Science and Quality Management, 36*, 23-30. [https://www.iiste.org/Journals/index.php/FSQM/article/view/19775/20137](https://www.iiste.org/Journals/index.php/FSQM/article/view/19775/20137)

Temesgen, M., Retta, N., & Tesfaye, E. (2017). Amino acid and fatty acid composition of Ethiopian taro. *American Journal of Food Sciences and Nutrition, 1*(1), 1-13. [https://ajpojournals.org/journals/index.php/AJFSN/article/view/217](https://ajpojournals.org/journals/index.php/AJFSN/article/view/217)

Terasawa, N., Saotome, A., Tachimura, Y., Mochizuki, A., Ono, H., Takenaka, M., & Murata, M. (2007). Identification and some properties of anthocyanin isolated from Zuiki, stalk of Colocasia esculenta. *Journal of Agricultural and Food Chemistry, 55*(10), 4154-4159. [https://doi.org/10.1021/jf063204t](https://doi.org/10.1021/jf063204t)

Torres, A., Durán, M., & Montero, P. (2013). Evaluación de las propiedades funcionales del almidón obtenido a partir de malanga (Colocasia esculenta). *Revista Ciencias e Ingeniería en el Día, 8*(2), 29-38. [http://hdl.handle.net/11227/5195](http://hdl.handle.net/11227/5195)

Ubalua, A., Ewa, F., & Okeagu, O. (2016). Potentials and challenges of sustainable taro (Colocasia esculenta) production in Nigeria. *Journal of Applied Biology & Biotechnology, 4*(1), 053-059. [https://doi.org/10.7324/JABB.2016.40110](https://doi.org/10.7324/JABB.2016.40110)

Van Soest, P. J., Robertson, J. B., & Lewis, B. A. (1991). Methods for dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science, 74*(10), 3583-3597. [https://doi.org/10.3168/jds.S0022-0302(91)78551-2](https://doi.org/10.3168/jds.S0022-0302(91)78551-2)

Vargas, P., & Hernández, D. (2013). Harinas y almidones de yuca, ñame, cayote y ñamápi: propiedades funcionales y posibles aplicaciones en la industria alimentaria. *Tecnología en Marcha, 26*(1), 37-45. [https://doi.org/10.18845/trm.v26i1.1120](https://doi.org/10.18845/trm.v26i1.1120)
Yamaguchi, R., Tatsumi, M. A., Karo, K., & Yoshimitsu, U. (1988). Effect of metal salt and fructose on the antioxidation of methyl linoleate in emulsions. *Agricultural and Biological Chemistry, 52*(3), 849-850. https://doi.org/10.1271/bbb1961.52.849

Yang, C., Chowdhury, M. A., Hou, Y., & Gong, J. (2015). Phytogenic compounds as alternatives to in-feed antibiotics: potentials and challenges in application. *Pathogens, 4*(1), 137-156. https://doi.org/10.3390/pathogens4010137

Yeoh, H. H., & Chew, M. Y. (1977). Protein content and acid composition of cassava seed and tuber. *Malaysian Agricultural Journal, 51*(1), 1-6.