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EFFECT OF INCORPORATING FERMENTED COFFEE HUSKS INTO SWINE DIETS ON PRODUCTION PERFORMANCE AND FEED COST YIELDS

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ABSTRACT

Pig farming is an important component of the livestock sector at a global scale since pork is the most widely produced and consumed meat in the world. This study aimed to evaluate the effects of diets containing different levels of fermented coffee husk flour on the productive performance of pigs and economic viability in pig farming. Coffee husks were incorporated with probiotics based on *Moringa oleifera* Lam leaf extracts. Five gilts between 3 to 5 months of age, with an initial average weight of around 13.38 kg, were used. The experiment was conducted using a Latin Square Design, with 5 treatments and 5 replications. The treatments were a control treatment (T0) without coffee husks in the diet; and treatments T1, T2, T3, and T4 with coffee husks at 4%, 6%, 8%, and 10% in the diet, respectively. The statistical analysis showed that T1, which contained 4% fermented coffee husks in the diet, was the most efficient diet formulation with respect to the rest of the treatments. The animals that received T1 showed a high increase in average daily weight, with an average value of 867.70 g; and a better feed conversion rate, requiring only 3.57 kg to produce one kilogram of meat. The results of a descriptive yield analysis on feed cost showed that T1 could generate a higher yield of about $6.04 per kilogram of meat sold in the local market compared to the other treatments. Therefore, it is concluded that the incorporation of fermented coffee husks at 4% into pig diets can improve pig productive performance and reduce feed costs.

Keywords: Pigs, productivity, diet, coffee husk, fermentation, feed cost.

INTRODUCTION

Pig farming is an important component of the livestock sector at the global scale, pork being the most produced and consumed meat in the world. In fact, pigs have always been present in the lives of rural communities and these animals are still fed on crop residues and fodder, in turn providing noble foods to humans. With scientific and technological advances, animal feed began to be formulated with cereals that are also used as human foods. On the other hand, the growth of human population has generated much speculation about the need to restore the key role of pigs in waste management. In this sense, the scientific community has made efforts to propose alternatives for animal feed from waste. In countries with high swine production, many studies have evaluated the potential of agricultural by-products as feed ingredients. Due

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to economic reasons, pig producers might soon need to incorporate alternative ingredients into pig diets. Studies on the identification of potential agricultural by-products, such as coffee husks, as alternative feeds for animals, mainly pigs and poultry, are efforts towards the development of low-cost and ecologically appropriate animal production. This is important as environmental conditions pose a serious challenge to sustainable food production. In this sese, animal production can contribute to economic growth, but it can also cause environmental problems. To reduce competition for food, it is wise to seek for other food sources as breeding alternatives, such as waste and agricultural by-products (Bouafou et al., 2011).

Coffee husks (CHs) and coffee pulp are the solid residues obtained after dehulling coffee cherries during dry or wet processing, respectively (Oliveira and Franca, 2015). The use of CHs in animal feed is still limited because CHs contain antinutrients such as some forms of polyphenols, tannins, and caffeine, which hinder digestion and absorption of nutrients, affecting nutrition. It is important to note that the use of fibrous feeds for pigs and poultry does not only require considering the nutritional and physiological effects of the incorporation of fiber in the diet, but also its chemical and structural composition, as well as the way fiber is physically associated with other nutrients.

The first references to coffee and its production in Timor-Leste date back to 1750 and 1800, respectively. According to Fragoso et al. (1972), a new regional trade based on coffee emerged in the mid-19th century, but its widespread production as a commodity occurred only in the late 19th and early 20th centuries when successive colonial governors compelled rural populations, especially those in mountainous areas, to plant, cultivate, and harvest coffee on their small family properties. Coffee grown on small family farms has always been the major source of Timorese coffee production, which relies on workers. Family farmers have produced coffee for the market as a supplement to their subsistence and provided large plantations with the labor required for their operations (Gonçalves and Mexia, 1975). Initially, the cultivated variety was typical of the Arabica species, but the emergence of rust led to the introduction of the Liberica species at the end of the 19th century, and the Robusta species at the beginning of the 20th century. A coffee bean is composed of a grain or endosperm (54%), the parchment or endocarp (12%), a mucilaginous layer or mesocarp (5%), the pulp or exocarp (29%), and the peel or epicarp, which is the external membrane that covers the entire fruit (Oliveira et al., 2016). In coffee production, CHs represent 40% of the mature fruit. In general, there are two types of CHs depending on the type of coffee bean harvested and processed, namely honeyed husk and dry husk (Oliveira, 2001). This material returns to coffee plantations as organic fertilizer or is lost because it is not utilized, resulting in large amounts of waste that are generally released into rivers, causing serious environmental damage.

The objective of the study was to evaluate the effects of diets containing different levels of fermented coffee husk flour on the productive performance of pigs and economic viability in pig farming. CHs were incorporated in the feed with probiotics based on *Moringa oleifera* Lam leaf extract, in search for sustainable animal production, and thus harmonize economic development with environmental preservation, and maintain good socio-environmental relations with ecological practices. An in-depth experimental study was carried out in order to identify the usefulness of the CHs fermented in the formulation of feed offered to pigs, especially gilts.

MATERIALS AND METHODS

Geographical location of the research site

The study was conducted in the Betano village, municipality of Manufahi, Timor-Leste. The municipality of Manufahi is located on the south coast of the island, at an altitude of 384 m.a.s.l. It borders the municipality of Manatuto to the north; the municipality of Aileu to the east; the municipality of Ainaro to the west; and the Timor Sea to the south. It has an area of 1325 km^2 **and the capital is the city of Same (Census, 201**5). It has partially cloudy skies, with temperature variations between 19 °C and 21°C and humidity variation between 87 and 94%.

Animal selection process

The pigs were selected based on reproductive history, age, sex, initial body weight and direct observations of morphological characteristics, according to criteria established to obtain the preferred type of pigs (individuals of the same breed, same sex, healthy and disease-free). The selected animals corresponded to female pigs, between 3 and 4 months of age, with an average initial weight of 12 kg.

Research method

The experiment was conducted between July and September 2023, using a Latin Square Design with 5 treatments and 5 replications. Each treatment was repeated 5 times to obtain 25 units of observations (5x5 = 25 units). The treatments corresponded to pig diets composed of yellow corn, rice bran, soybean, and fermented coffee husks (CHs) with probiotics based on *Moringa oleifera* Lam leaf extract. T0 (control treatment) was composed of 42% yellow corn, 38% rice bran, 20% soybean; whereas T1, T2, T3, and T4 also added fermented CHs at 4%, 6%, 8% and 10%, respectively. The nutritional composition of the foods is shown in Table 1. The nutritional composition of the pig diets is shown in Table 2.

Variables

The following variables were evaluated: average daily diet consumption; feed conversion rate; average daily body weight gain to measure the productive performance of pigs; and income over feed cost to obtain the treatment with the highest profit per kilogram of pork based on local market demand.

Data analysis

Data were tabulated and analyzed by using analysis of variance (ANOVA), while significant differences were analyzed using Duncan's test based on the recommendation of Gomes and Gomes (1984). In addition, a descriptive analysis was carried out to estimate the economic value of the diet and identify the treatment that yields the best results per kilogram of pork according to Sampurna and Nindhya (2008).

RESULTS AND DISCUSSION

The main results of the statistical analysis for average acceptable daily intake (ADI), feed conversion rate (FCR), average body weight gain (ABWG) and income over feed cost (IOFC) in the study are presented in Table 3 and Table 4. In general, the results of the statistical analysis of the variables described in Table 3 demonstrate that there was no significant difference (P>0.05) for average daily feed consumption and average daily weight gain of pigs. However, a clearly significant difference (P<0.05) was observed in terms of feed conversion rate. Duncan's comparison test showed that T1 (4% CHs) was the most efficient treatment as the animals only needed 3.57 kg of feed to produce a kilogram of pork. In addition, the results of the IOFC analysis revealed that the T1 has the highest yield (Table 4).

IOFC is defined as the portion of the income from pork sold that remains after paying for the feed purchased, raised, and used to produce each kilogram of meat. The IOFC formula is the yield of each kilogram of meat minus the cost of feed

Table 1. Nutritional composition of the foods used in the study.

Type of Nutrition	*Yellow corn	*Rice bran	**Soybean	*Coffee husk	*Coffee husk fermented
DM (%)	89.73	91.17	89.60	94.59	90.53
OM (%)	97.53	80.19	-	75.92	75.16
Crude protein (%)	9.24	14.34	37.00	11.89	12.39
Crude fiber (%)	4.54	10.10	4.82	30.83	29.99
Crude lipid (%)	6.98	12.99	18.00	2.81	2.25
ME (Kcal/kg)	3157.00	3113.00	3510.00	1956.01	1955.54

Source: *Gomes (2020); **Parra et al. (2008); Obs: DM: Dry matter; OM: Organic matter.

Table 2. Nutritional composition of the different diets evaluated.

Type of nutrition	Treatment				
	T0	T1	T2	T3	T4
EM (Kcal/kg)	3211.00	3154.80	3105.60	3130.20	3085.00
Crude protein (%)	16.93	17.30	16.72	16.76	16.89
Crude lipid (%)	6.58	6.39	6.52	6.56	6.36
Crude fiber (%)	5.75	5.85	7.87	7.36	8.27
Calcium (%)	0.10	0.11	0.12	0.12	0.12
Phosphorus (%)	0.18	0.17	0.17	0.17	0.17

Source: Elaboration adapted to the Trial & Error standard method.

Table 3. Results of the statistical analysis of pig production performance data.

Treatment	N Observed	Variable		
		ADI (g)	FCR	ABWG (g)
T0 (0% CHs)	5	751.40	3.63a	228.97
T1 (4%CHs)	5	867.70	3.57a	253.26
T2 (6%CHs)	5	770.60	4.84ab	188.95
T3 (8%CHs)	5	952.96	6.70bc	208.34
T4 (10%CHs)	5	642.83	8.99d	100.09
Probability		>0.05	<0.01	>0.05
$\bar{X}$±SEM		797.09±62.50	5.54±0.63	195.92±26.11
CV (%)		7.84	11.37	13.33

Obs.: SEM: Standard error of the mean; CV: Coefficient of variation; CHs: Coffee husk; different letters in the same column indicate significant differences between treatments at the 5% level (P<0.05).

Table 4. Results of descriptive analysis of the Income Over Feed Cost.

Evaluated components	Treatment				
	T0	T1	T2	T3	T4
Average daily consumption (g)	751.40	867.70	770.60	952.96	642.83
Feed conversion rate (kg)	3.63	3.57	4.84	6.70	8.99
Average body weight gain (g)	228.97	253.26	188.95	208.34	100.09
Cost of diet ($/kg)	0.61	0.55	0.55	0.64	0.43
Total diet/Treatment (kg)	45.84	53.8	47.78	59.08	39.86
Total cost of diet/Treatment (USD$)	27.96	29.59	26.28	37.81	17.14
Total cost /kg pork ($)	2.21	1.96	2.66	4.29	3.87
Total body weight gain/pig (kg*70%)	14.20	15.70	11.71	12.92	6.21
Price of pork (USD$/kg)	8.00	8.00	8.00	8.00	8.00
Income (USD$ /kg of pork)	5.97	6.04	5.34	3.71	4.13
Loss (USD$ /kg of pork)	0.00	0.00	0.00	0.00	0.00
Gross income (USD$/pig)	84.77	94.83	62.53	47.93	25.65
Gross income (USD$ / 5 pigs /treatment	423.85	474.14	312.65	239.67	128.24
Net Profit (USD$)	395.90	444.55	286.37	201.86	111.10

Obs: T0: control treatment (no CHs added); T1: treatment with 4% CHs in the diet; T2: treatment with 6% CHs in the diet; T3: treatment with 8% CHs in the diet; T4: treatment with 10% CHs in the diet.

required to produce each kilogram of meat based on the price of pork obtained on the local market in the last period of the study. Accordingly, IOFC is an efficiency index that measures income over feed costs (Menegat et al., 2019). The result of the IOFC analysis (Table 4) shows that the treatment with the highest yield per kilogram of pork was T1 (treatment with 4% fermented CHs).

Average acceptable daily intake

There were no differences in acceptable daily intake between the treatments. However, regarding quantity, 4% fermented CHs in feed is still a good percentage for growing pigs if a comprehensive assessment is made based on the average feed intake, feed conversion rate, and average body weight gain of pigs (Table 4). This agrees with Oliveira et al. (2016), who conducted a study with pigs in the growing and finishing phases, and reported that CHs can replace only 5% of corn in isoenergetic rations. However, a previous study using CHs in feed for finishing pigs determined that CHs has low digestibility and energy balance values when compared to corn, thus reducing the performance of finishing pigs (Oliveira, 2001). In this sense, it has been described that the high level of crude fiber in the diet causes a reduction in the ability of the animal's digestive system to absorb nutrients (Barcelos et al., 1997). Unfortunately, due to the inability of the stomach enzymes of pigs to digest crude fiber content, the food consumed simply passes through and is excreted without maximum utilization to promote production. According to Bressani and Braham (1980), CHs contain carbohydrate (63.2%), total protein (10.1%), reduced sugar (12.4%), ash (8.3%), and caffein (1.3%). The content of caffeine and tannins makes CHs toxic and slow degradation in nature, which can cause environmental damage (Dzung Nguyen et al., 2013. However, CHs are rich in lignocelluloses materials, being an ideal substrate for microbial processes.

Feed conversion rate

Feed Conversion measures animal productivity defined by total feed consumption, divided by average weight gain. In animal production, particularly in pig farming, the efficiency of animal feed conversion is extremely important in order to guarantee the proper use of the food used in the formulation of the feed provided. The two direct indices that have the greatest influence on pig production costs are average weight gain and feed conversion rate. In the presents study, the results revealed that the incorporation of 4% of CHs (T1) in the diet can improve the feed conversion of pigs, reaching the best rate compared to the rest of the treatments; to produce a kilogram of pork only 3.57 kg of food is needed. These results are similar to those of Gomes et al. (2022), who reported that to produce one kilogram of pork normally requires 2.5 to 3.5 kg of food. In general, pigs do not have sufficient capacity to digest foods rich in fiber. Therefore, when formulating feed for pigs, crude fiber content should not exceed the recommended standard of 5% to 6% in the diet, and also consider the effect of other factors, including antinutrient substances. According to Mehansho et al. (1987), the use of coffee crop residues is restricted by the content of anti-nutritional factors, such as polyphenols, tannins and caffeine as these anti-nutritional factors interfere with the acceptance of food and the absorption of nutrients. The crude fiber in coffee pulp includes 25.88% of cellulose, 3.6% of hemicelluloses, and 20.07% of lignin. The content of cellulose in coffee pulp was similar to that in rice husk (24.3%) (Zhang et al., 2009), but lower than that in wheat straw (38.2%) (Wiselogel et al., 2018) and bagasse (38%) (Goyal et al., 2008). However, there was also a similar proportion between the cellulose content in the coffee pulp (equivalent to 52.23%, g cellulose/100g crude fiber) and the typical proportion of lignocellulose (40-60%) (Gnansounou, 2008). Therefore, coffee pulp is also considered a source of lignocellulose biomass, which can be used in the production of bioethanol (second generation ethanol production).

Average daily weight of pigs

No significant differences were found in terms of average daily weight gain between the treatments, indicating that the incorporation of fermented CHs in the diet did not meet the nutritional requirements of pigs to stimulate better growth. This can also be explained by the high content of crude fiber and other antinutrients in CHs, which may affect poor digestion and absorption of food. According to Sinaga and Martini (2011), growth and growth rate of animals are influenced by factors, namely dietary factors such as the content and digestibility of these ingredients, and also genetic factors. The increase in animal weight reflects how nutrition and balance of amino acids contained in a given diet positively impact the animal (Akhouri et al., 2013). CHs have been used as a component of food for animal species, including laying hens (Souza et al., 2019), pigs (Parra et al., 2008), sheep (Souza et al. 2004), and calves (Souza et al., 2006). Related factors such as management, nutrition, health, genetics, and environment can affect the growth performance of pigs (Heck, 2009). Therefore, it is important to allow adjustments by producers.

Income over feed cost (IOFC)

Income over feed cost is a margin of profit calculated by subtracting feed cost from the revenue, commonly on a per pig basis. Revenue per pig is often estimated by multiplying hot carcass weight by hot carcass weight price, or by multiplying total weight gain by live weight price (Menegat et al., 2019). The result of the IOFC obtained in the study (Table 4) shows that the treatment that could bring the highest yield per kilogram of pork and thus the highest yield per treatment was treatment T1, using 4% fermented CHs in the diet. The use of fermented CHs at up to 4% in the diet can improve feed conversion and increase the average weight gain of animals compared to other treatments, including the reference or control treatment. The T1 treatment showed that to produce one kilogram of meat, only US$ 1.96 would be needed to obtain an income of US$ 6.04 per kilogram of meat sold, with the total income from all carcasses obtained being around US$ 444.55 (Table 4) during the research period. However, the use of 10% fermented CHs in the diet worsened feed conversion, requiring US$3.87 to produce one kilogram of meat and resulting in an income of US$4.13, with a total income total of US$111.10 during the research period. In pig farming, the efficiency of animal feed conversion is extremely important in order to guarantee the efficient use of the food used in the formulation of the feed provided. When it comes to for-profit activities, one of the greatest challenges is related to producing efficiently, i.e., at lower costs, and how to run off the production (Stoffel and Rambo, 2022). Feed cost only considers the cost of diets for comparison between one nutritional program and another. This method is the simplest and most applicable when there is no expected change in pig performance associated with the nutritional program (Menegat et al., 2019). Changes in ingredients or nutrient levels often alter pig performance and should rarely be used as the primary assessment of the economic competitiveness of a feeding program. Feed cost per kilogram of gain is calculated by multiplying feed efficiency by feed cost per kilogram (Gomes, 2020). The best application of this method is for comparison between nutritional programs when there is an expected change in feed efficiency in relation to a change in growth rate. Consumption efficiency and better feed conversion are considered determining factors in reducing the cost of food and could contribute to improving producers' income (Gomes et al., 2021). Furthermore, it is stated that, in general, pigs only need 2.5 to 3.4 kg of nutritious feed to produce one kilogram of meat. The feed formulated with agricultural by-products fermented with a probiotic based on Moringa oleifera Lam leaf was able to improve the physical and chemical quality of the feed through superficiality, aroma, and texture, which can stimulate the palatability of animals and facilitate digestion and absorption (Gomes et al., 2022). According to Vranken and Berckman (2017), producers can achieve economically, environmentally, and socially sustainable farming through observation, interpretation, and on-farm control. As a result, farmers have adopted a variety of feed ingredients perceived to be cheaper regardless of their influence on the body systems of the animals (Etim et al., 2014)

CONCLUSION

The incorporation of fermented coffee husks in the diet did not significantly affect average daily feed ration consumption or increased average daily weight of pigs. However, there were significant differences in feed conversion. The average feed conversion comparison test showed that the treatment that included 4% coffee husks in the diet outperformed the control treatment (T0, without coffee husk flour) and the rest of the treatments with the addition of 6% (T2), 8% (T3), and 10% (T4) fermented coffee husk in the diets. Therefore, the incorporation of 4% coffee husks can provide higher returns for income over feed cost.

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Conflicts of interest declaration

The authors declare that no conflicts of interest regarding the publication of this article.

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