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Use of pulp and husk of coffee in animal feed

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ABSTRACT

Objective: To review the literature related to the use of husk and pulp of coffee in the feeding of ruminant and non-ruminant animals.
Approximation: The husk and pulp of coffee are by-products that remain after cleaning the bean. These are a potential source of pollution; however, they can also be used for animal feed, reducing costs for the producer.
Study limitations/implications: Coffee by-products have been used in animal feed globally, especially in those countries that are the highest producers of this bean. Therefore, it is important to know the results obtained there when those by-products are supplied as fed to animals in different conditions.
Conclusions: The results obtained vary when these coffee by-products are included in animal diets, depending on the species and the amount offered.

Keywords: coffee husk, coffee pulp, ruminants, non-ruminants, feeding.

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INTRODUCTION

In the last decade in the world, up to a third of the total production of cereals has been used for livestock feed (Makkar, 2016). Due to this, there is research focused on replace them with agricultural and industrial by-products, such as those of coffee.

Coffee is for long the most traded food product and one of the most widely consumed, as varied beverages in the world (Farah, 2009); it is the most important crop plant for trading and the second most valuable international product after petroleum (Esquivel and Jiménez, 2012; Skibba, 2016; Alves *et al.*, 2017).

Brazil is the largest global producer, contributing a third of world production; followed by Vietnam, Colombia, Indonesia, Ethiopia, Honduras, India, Mexico, Peru and Guatemala, among others. In 2020, world production of green coffee exceeded 9.9 million Mg (Megagrams, *i.e.* tons) (ICO, 2020). In Mexico, coffee cultivation is an activity with economic, social and ecological relevance (Hernández and Nava, 2018).

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There are two methods of processing cherry coffee to obtain the beans (Figure 1); the wet benefit and the dry or natural benefit. The wet benefit consists of pulping the harvested cherry coffee, followed by a fermentation and washing process to remove mucilage (exocarp and mesocarp), leaving together the coffee parchment and grain. Whereas, in the dry method once the fruits are dehydrated, the grain is separated from the husk (also called hull when dried), which is then composed of the pulp, mucilage and parchment (exocarp, mesocarp and endocarp remain together) (Berecha *et al.*, 2011).

Both methods generate great amounts of both solid and liquid waste (Kebede *et al.*, 2010). For every two Megagrams of fresh cherry coffee that are processed, one Megagram of coffee pulp and 0.5 Mg of husk is produced. Such by-products are mainly rich in carbohydrates, proteins, pectin and bioactive compounds, such as polyphenols.

The coffee husk has a high content of carbohydrates, as well as other organic compounds such as protein and lipids. In addition to bioactive compounds and phytochemicals, which allows its use in animal feed, compost production, used directly as fuel, biogas production and edible mushrooms production (Franca and Oliveira, 2009).

Of the total polysaccharides present in coffee husk, the most abundant are cellulose up to 35%, followed by hemicellulose (35%). It also has soluble carbohydrates such as fructose, glucose, galactose and arabinose; raffinose and sucrose (Hejna, 2021).

The protein content ranges from 6.6-11%, which are mainly made up of glutamic acid (7.7%) and aspartic acid (7.1%); as well as leucine (4.7%), glycine (4.2%), proline and valine (3.7%), alanine (3.5%), lysine (3.4%), serine (3.3%), threonine (3.1%) and phenylalanine (3%) (Hoseini *et al.*, 2021).

This by-product of coffee is also rich in minerals, especially potassium, calcium and magnesium. In addition, it contains polyphenols such as chlorogenic acid, which is considered a soluble polyphenol derived from the esterification of caffeic acid with quinic acid (Hoseini *et al.*, 2021), with antioxidant properties (Moraczewski *et al.*, 2018), which when ingested by animals can reduce the damage of reactive oxygen species [di oxygen

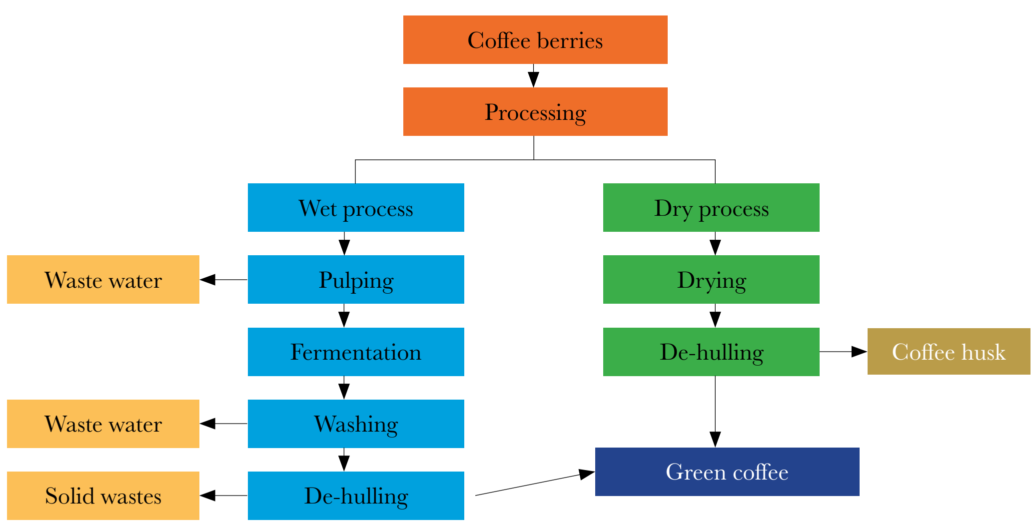

Figure 1. Coffee processing.

(O_2), superoxide anion $\left(O_2^-\right)$, hydroxyl (OH), peroxide (ROO), alkoxy (RO) and nitric oxide (NO)] (Chaves-Ulate and Esquivel-Rodríguez, 2019).

The pulp is the fraction of the mesocarp that is removed during the wet processing of ripe cherry coffee (Albes *et al.*, 2017) and is the most abundant by-product constituting approximately 40% of the fresh weight of the cherry coffee (Hejna, 2021). Pulp is mainly composed of carbohydrates such as glucose, fructose and pectin, has characteristics similar to husk (Pereira *et al.*, 2020). It has been used as a substrate for microorganisms in the synthesis of amino acids, for the production of bioethanol, as an ingredient in the diet of animals and as a source of antioxidants. It contains bioactive compounds, such as flavonoids and phenolic compounds that are of great interest not only for their high antioxidant power, but also for their anti-inflammatory, antimicrobial, antiallergic and anticancer activities (Murthy and Madhava, 2012).

Coffee pulp is characterized by a high level of moisture compared to husk, as well as a higher percentage of protein, tannins and caffeine. This coffee byproduct is a natural source of antioxidants. Of these compounds, caffeine and tannins are found in greater proportion. The antioxidant effect of caffeine is the result of the increase in the production of glutathione, in addition, it activates the enzymes glutathione reductase and superoxide dismutase (Dorsey and Jones, 2017). It is rich in potassium, followed by phosphorus, magnesium, calcium and sulfur (Martínez *et al.*, 2019).

Use of the husk and pulp of coffee in ruminant feeding

Use of coffee husk in bovines

Souza *et al.* (2006a) tested different levels of inclusion of coffee husk (0.0, 8.75, 17.5 and 26.25%) as substitute for maize in Holstein × Zebu heifer diets; they found that digestibility, consumption and weight gain were not affected when using up to 17.5% husk in the diet. However, in another study, Souza *et al.* (2010) noted that increased levels of husk in the diet would alter microbial protein synthesis by promoting N excretion.

The substitution of corn for coffee husk in the diet of Holstein × Zebu breeding heifers in lactation in a percentage of up to 10.5% did not affect either the production, quality of milk (Souza *et al.*, 2005), nor the balance of N (Souza *et al.*, 2006b). On the other hand, Oliveira *et al.* (2007a) observed that a level of up to 25% of coffee husk in diets with 60% fodder and 40% concentrate for lactating Holstein breeding heifers, did not affect milk production or microbial protein synthesis in those heifers that reached a production of 20 kg of milk per day (Oliveira *et al.*, 2007(b). Cyprian *et al.* (2006a), mentioned that it was possible to use up to 12% coffee husk to replace maize silage in lactating Holstein heifers whose diet consisted of 60% fodder and 40% concentrate. In another study Cipriano *et al.* (2006) noted that it was possible to replace up to 15% maize corn with coffee husk without affecting milk production in lactating Holstein heifers with a diet consisting of 60% maize silage and 40% concentrate.

Use of coffee pulp in livestock

The consumption and preference of Swiss-zebu bullocks for silage with different levels of coffee pulp (25, 50, 75 and 100%) in substitution for *Pennisetum purpureum* were evaluated by Pinto *et al.* (2017), who reported that by increasing coffee pulp levels in silage, the percentage of crude protein increased, and the percentage of fiber decreased.

Pedraza *et al.* (2012) evaluated the effect of supplementing concentrates with three levels of coffee pulp (10, 15 and 20%) in diets for Holstein × Swiss-zebu dairy cows in grazing, on milk production and forage intake. Those authors did not observe a negative effect on those variables; thus, coffee pulp can be used as an alternative ingredient with the ability to reduce feed costs.

Use of coffee husk in sheep

Chemical treatment of coffee husk to improve digestibility was tested by García *et al.* (2000), who used 15.2% of coffee husk (hulls), untreated or treated with 4% urea, to replace maize in diets for lambs, without observing differences in DM intake, daily weight gain, feed conversion, weight of the carcass, nor in the cuts or composition of leg, shoulder or loin (García *et al.*, 2003b). However, they did find differences in the size of the reticulum-rumen of animals fed diets with coffee husks (García *et al.*, 2003a), associated with the husk fiber. However, by using calcium oxide (5%) to treat coffee husk, it is possible to include up to 16% of this as a substitute for maize silage in lamb diets, composed of 50% silage and 50% concentrate, without affecting DM intake, nutrient digestibility, weight gain, carcass yield or meat quality (Nunes *et al.*, 2020).

On the other hand, Pires *et al.* (2009) observed that by adding 15% coffee hulls to elephant grass silage in diets for lambs composed of 60% forage and 40% concentrate, lambs feeding behavior was modified increasing DM intake; while substituting up to 22.5% of coffee hulls for oat hay in diets for lambs composed of 30% forage and 70% concentrate, did not affect the digestibility of nutrients and became an alternative to reduce production costs (Rego *et al.*, 2019).

Souza *et al.* (2004) mentioned that the use of up to 25% of coffee husks in substitution of maize in the diet of adult sheep did not affect DM intake or nutrient digestibility and resulted in an alternative feed.

Use of coffee pulp in sheep

Nurfeta (2010) evaluated the effect of feeding castrated rams with diets containing two levels of coffee pulp 16.6% or 12.7% plus poultry manure (12.9%), without finding a difference in DM intake or weight gain; tough the digestibility of DM decreased in the diet with coffee pulp and poultry manure, while the N balance was also affected by that diet.

Salinas *et al.* (2014) evaluated the effect of including 0, 8 and 16% coffee pulp (ensiled for two months) in the diet of housed Blackbelly lambs, on carcass characteristics and meat antioxidant capacity; observed that the carcass yield improved compared to the control. In addition, rumen and intestine fat decreased in proportion to the increase in coffee pulp in the diet; however, the antioxidant capacity of meat was not affected. The inclusion of 0, 8 and 16% of ensiled coffee pulp did not affect feed intake, daily weight gain or feed conversion in the study carried out by Salinas *et al.* (2015); although the water consumption increased when the percentage of coffee pulp in the diet increased, the digestibility of FAD was reduced in the treatments with 8 and 16 % of pulp; while the rumen concentration of acetic, propionic and butyric acids, as well as ammoniacal N, increased with the inclusion of 16% of coffee pulp.

Hernandez *et al.* (2018) evaluated the productivity and health of Pelibuey lambs housed for fattening, fed with different levels of inclusion of coffee pulp in the diet, 0, 7, 14, 21 and 28%; without finding differences in DM intake, weight gain or feed conversion, nor were they observed in cholesterol, glucose, protein, urea, or creatinine levels in the blood. In the hematological analysis, no changes were observed in the hematocrit or in the number of leukocytes.

The inclusion of 25% coffee pulp in the diets of multiparous Dorset × Suffolk ewes 14 d before the application of the progestogen until 25 d after the service, had no effect on the duration of estrus; although it may affect the percentage of gestation at 30 d, also increasing the antioxidant capacity of blood plasma at the time of applying the progestogen (Salinas *et al.*, 2016).

In another study, Gutiérrez *et al.* (2019) reported that when using 0.5 and 10% of coffee pulp in the diet of Dorset × Suffolk primiparous ewes 16 d before mating, it did not affect the duration of estrus, nor the gestation percentage, nor the weight of the offspring. In addition, the antioxidant capacity of sheep blood plasma was increased by including coffee pulp in the diet, while plasma lipid oxidation decreased by including 10% coffee pulp.

Use of coffee husks in goats

The use of 15% coffee hulls as an additive in elephant grass silage in diets for Saanen dairy goats, composed of 60% silage and 40% concentrate, did not affect DM intake, digestibility or milk production (Oliveira *et al.*, 2010).

Use of husk and pulp of coffee in the feeding of non-ruminants

Fishes

Aquaculture plays a very important role in providing high-quality protein to the population. In addition, it is characterized as a sector with rapid growth in food production (Yue and Shen, 2021). Nutrition is an important factor, since meeting the nutritional requirements of the fish ensures production and reduces the incidence of diseases (Yu *et al.*, 2021), but when formulating a diet, the availability and cost of feed must be considered as well as ingredients or alternative ingredients (Celada and Fuertes, 2016).

Coffee pulp has been used up to 30% in the diet of tilapia (*Tilapia aurea*) for 5 months, without presenting differences in weight gain compared to diets without coffee pulp (Brahan, 1979). Christensen (1981) used 10 and 30% coffee pulp in the diet of common carp (*Cyprinus carpio* L.) and catfish (*Clarias mossambicus* Peters). In both species, the daily weight gain was reduced from 1.65 g to 0.34 g when using 30%, extending the growth time, although production costs decreased.

In another study carried out by Fagbenro and Arowosoge (1991) to evaluate the feeding of catfish (*Clarias isheriensis*) in ponds for 150 d, with the use of coffee pulp at 10, 20 and 30% inclusion in the diet in substitution for yellow maize corn, they found that by increasing the inclusion level of coffee pulp, daily weight gain was reduced, although when using up to

20% of coffee pulp, no differences were found in the final weight compared to the control diet, thus it is possible to reduce the production costs.

When using different levels of inclusion of dehydrated coffee pulp (10, 20 and 30%) in diets of red tilapia fingerlings (*Oreochromis aureus* × *Oreochromis niloticus*), no differences in weight gain were reported between the control diet and the diet with 10% coffee pulp; however, the economic feasibility was better in the diets with 20 and 30% coffee pulp compared to the control diet (Castillo *et al.*, 2002).

Moreau *et al.* (2003) evaluated the feeding of fresh and ensiled coffee pulp protein by Nile tilapia fingerlings (*Oreochromis niloticus*), by testing a control diet with 100% protein and diets with 80% protein, plus a contribution of 20% protein from fresh and ensiled coffee pulp. When feeding the fingerlings for 28 d, no toxicity was observed, although growth was negatively affected when using fresh coffee pulp as well as silage.

Ulloa and Verreth (2003) reported that by including 13, 26 and 39% dehydrated coffee pulp in diets for tilapia (*Oreochromis aureus*) housed in ponds, no difference was found in the final weight when using 13% coffee pulp in comparison to control treatment.

Bautista *et al.* (2005) fed fingerlings of the hybrid cachamay (*Colossoma* × *Piaractus*) for 84 d with diets composed of ensiled coffee pulp with 5% molasses and without molasses, with three levels of pulp inclusion: 10, 15 and 18% and a control treatment without pulp. The best weight gain was found in the individuals that were fed with a level of 18% coffee pulp silage without molasses, although the highest survival rate of the fish was associated with the treatments with added molasses.

Poultry

The production of chicken meat in 2019 was more than 118 million Mg in the world. Among the countries with the highest production, the United States stands out in first place with more than 20 million Mg, followed by China with 15.1 million Mg and Brazil with 13.5 million Mg. Mexico is positioned in the ninth place with a production of 3 476 622 Mg (FAO, 2019).

The large production of chicken meat demands a large amount of inputs and raw materials, so it is essential to search for alternative inputs that avoid direct competition with food for humans and that reduce the pressure on the environment (Govoni *et al.*, 2021). The use of by-products can partially replace traditional ingredients such as maize and soy flour, reducing costs and avoiding competition for food (Pires Filho *et al.*, 2021). Coffee by-products have a considerable amount of carbohydrates, although they are also high in fiber (dos Santos *et al.*, 2021); however, it has been used in the diet of chickens (Funes *et al.* 1986; Donkoh *et al.*, 1988; Molina *et al.*, 1990; Zelaya *et al.*, 1994; Acosta *et al.*, 1997).

Funes *et al.* (1986) tested the inclusion of 0, 10, 20 and 30% of dehydrated coffee pulp in diets of Indian River hybrid male chickens, in the starter and fattening stage. They evaluated feed intake, daily weight gain, and feed conversion. In the initiation stage, feed intake and weight gain decreased in relation to the increase in coffee pulp in the diet, also feed conversion was negatively affected. While in the fattening stage, consumption, weight gain and feed conversion were only affected with levels equal to or greater than 20% of coffee pulp.

The use of coffee pulp in chicken diets was also evaluated by Donkoh *et al.* (1988), who added 0, 2.5, 5, 7.5 and 10% of coffee pulp in diets for chickens, fed for 8 weeks; demonstrating that by increasing the levels of coffee pulp, weight gain tends to decrease; therefore, an acceptable level of this by-product in the diet is 2.5%.

Molina *et al.* (1990) reported that the use of coffee pulp subjected to solid fermentation, inoculated with *Aspergillus niger*, in addition to adding urea (2.5%) and dicalcium phosphate (2%), improved the composition of the pulp by reducing the levels of polyphenols, caffeine and fiber. In addition, they tested different levels (0, 5, 10 and 15%) of fermented and unfermented coffee pulp in broiler diets, where feed intake was increased by using fermented and unfermented pulp, while gain of weight and feed conversion were not affected when using up to 15% of fermented coffee pulp. In contrast, a level greater than 10% of unfermented pulp negatively affected these variables.

Zelaya *et al.* (1994) evaluated the effect of the use of 0, 6, 9 and 12% of dehydrated coffee pulp in Single Comb White Leghorn hybrid chicks in the initiation and development stage. In the first stage, feed intake was not affected, while weight gain decreased by increasing the levels of pulp in the diet, in the same way feed conversion was negatively affected, during this first stage there was a high mortality of individuals especially in the treatments with 9 and 12% of coffee pulp. Whereas in the development stage, the feed intake and daily weight gain of the pullets were not affected, although the feed conversion increased when using 12% of coffee pulp in the diet.

Acosta *et al.* (1997) evaluated the digestibility of DM, N and metabolizable energy of corn-based rations with different levels of ensiled coffee pulp with 5% molasses and without molasses (0, 5, 10, 15, 20, 25, 30 and 35%) in Hy Line roosters of 32 weeks; finding that by increasing the ensiled coffee pulp with or without molasses to more than 5%, digestibility of DM, N and metabolizable energy decreased.

Pigs

The use of coffee pulp in pigs was evaluated by Parra *et al.* (2008), who measured the digestibility of diets with levels of 25% fresh coffee pulp with different particle sizes, in growing male pigs weighing 45.7±4.12 kg and 15 finishing pigs weighing 77.5±6.28 kg. Those authors observed that the particle size did not influence the digestibility of the DM, although the fresh pulp presented greater digestibility compared to the dry pulp; they also found that the pigs in the growth stage presented a better digestibility coefficient compared to the growing-finishing pigs.

Carvalo *et al.* (2011) also evaluated the digestibility of a diet with a level of 25% ensiled and not-ensiled coffee pulp, in a group of 15 castrated male pigs with an initial average weight of 43.06±4.12 kg, without finding differences in digestibility. of the coffee pulp when subjected to the silage process. Those authors also evaluated the productive performance of 30 castrated male pigs and 30 females with an average weight of 35.52±3.21 kg, in the growth phase, and 55 pigs in the finishing phase with an average weight of 61.7±3.56 kg. The evaluated diets contained 0, 2, 8, 12 and 16% of ensiled coffee pulp, in both phases feed intake, weight gain, feed conversion and carcass yield were not affected.

CONCLUSIONS

Due to the characteristics of the digestive system of ruminants and their greater capacity to digest fiber, these species may have a greater use of these by-products compared to non-ruminant animals, although the results of providing them are variable.

Both in the case of ruminant and non-ruminant animals, if the husk or pulp is subjected to a chemical treatment or the silage process, its digestibility and use may increase.

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