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Chemical and structural evaluation of pellets made from mango pit biomass

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Abstract

The generation of agro-industrial waste represents an environmental problem; its efficient utilization can offer new options for use. This work aimed to utilize agro-industrial waste from mango industrialization through the production of pellets for animal feed. Pellets were made from mango pits from Escuinapa, Sinaloa. The contents of moisture (M), ashes (ASH), crude protein (CP), crude fat (CFa), crude fiber (CF), nitrogen-free extract (NFE), neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose (CEL), hemicellulose (HE), and lignin (L), as well as *in vitro* digestibility of dry matter (IVDDM), total digestible nutrients (TDNs), and gross energy (GE) were determined for biomass and pellets. The data obtained were tested for normality, homogeneity, and comparison of means using the Shapiro-Wilk, Levene, and T-student tests (α=0.05), respectively. Statistical differences ($P \leq 0.05$) were found in some variables of both chemical composition and structural components. The chemical composition of the biomass underwent modifications after the pelletizing process. Favorable changes are key to determining the nutritional value of a feed, which positively impacted its quality.

Keywords: Pellet; Mango pit; Nutritional value

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Biomass can be obtained from a wide variety of sources, such as forest residues, energy crops, and agro-industrial waste[1], the latter being generated from the collection and processing of agricultural crops[2]. Agro-industrial waste can be used in various processes; nevertheless, producing new products would provide added value to the original sources and would promote the recovery of altered environmental conditions. Knowledge of its chemical composition can determine potential use alternatives[3].

Mango (*Mangifera indica* L.) is one of the most important tropical fruits in the world due to its production, cultivated area, and popularity[4]. This fruit produces a large amount of agro- industrial waste, including mango pits, which generate around 69 to 103.5 million tonnes annually. The lack of adequate storage practices can cause negative environmental and social impacts[5]. Mango pits are a lignocellulolytic residue that can be discarded or used in animal feeding[6].

The increase in input prices for ruminant feeding intensifies the need to use feed alternatives for livestock, where agro-industrial waste plays a key role[7]. This waste constitutes a viable alternative to feed scarcity during the dry season of the year, making it possible to use it as a source of fiber[8].

Although mango pits have high potential to be used as livestock feed due to their high nutritional value[9], their conservation, storage, and transport may limit their use, so their transformation into pellets may be a viable alternative. Pellets are the result of the densification of biomass, thereby improving many of its characteristics[10,11]. In addition, pellets increase feed conversion thanks to their greater palatability, waste reduction, and greater nutrient availability, which is achieved through heat treatment[12].

A fundamental aspect of animal nutrition is the nutritional value of the feeds used, which depends on the contents of protein, fiber, fats, ashes, structural components, and digestibility[13,14,15]. The values of these factors can change when specific treatments are applied to biomass, such as densification. Therefore, this work aimed to evaluate and compare the nutritional quality of biomass and pellets made from mango pits as an alternative for animal feed.

Keitt mango pits were collected from a company that produces *orejones de mango* (dried mango slices) located in the municipality of Escuinapa, Sinaloa. The pits were spread on a flat surface at a room temperature of 32 to 38 °C for 60 d in the same municipality to reduce their moisture to a value of 40 %, then in the laboratory, they were subjected to a grinding process on a hammer mill (TFS 420) that is equipped with a 3.1 mm diameter sieve. The ground and screened mango pits (biomass) were spread again on a flat surface to continue moisture reduction for 30 d at a room temperature of 18 to 22 °C until a moisture of approximately 20 % was reached; later, they were deposited in sacks to be later used in the characterization and in the elaboration of pellets. Laboratory analyses of the biomass were performed on a subsample sifted through a No. 60 mesh (250 μm opening), yielding a particle size of 0.85 mm, whose moisture content was normalized in a drying oven at 40 ºC.

Before making the pellets, the biomass was conditioned again until it reached a moisture content of 12 %. The pellets were produced in a ZSLP-R300 industrial flat die equipment with a capacity of 250-300 kg h^{-1}; the channels of the plate where the rollers by extrusion force the passage of the biomass are 8 mm long and 6 mm in diameter[16]; the pressure exerted by the rollers is 150 bar and generates a friction temperature of 90 to 100 ºC; the biomass flow is 5 kg/min. The pellets were left to cool at room temperature for a day and then stored in plastic bags for later analysis.

The biomass and pellets were characterized by proximate chemical analysis[17], which includes the determination of moisture (M) content using an oven at 105 ºC; the ashes (ASH)

were determined by incineration in a muffle at 600 ºC; the determination of total nitrogen was performed in a Micro Kjeldahl equipment; the value obtained was multiplied by 6.25 to obtain the percentage of crude protein (CP); ethereal extract (EE) was determined in a Soxhlet equipment; and non-fibrous carbohydrates (NFCs) were determined by difference.

The contents of neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin (L) were determined according to the method proposed by ANKOM[18]. Cellulose (CEL) was calculated by the difference of ADF minus L, and hemicellulose (HE) was calculated by the difference of NDF minus ADF.

Samples of both biomass and pellets were subjected to anaerobic fermentation for the determination of the true *in vitro* digestibility of dry matter (IVDDM). Fermentation was carried out with rumen liquid obtained from two fistulated male cattle, weighing 700 kg, that were fed with alfalfa hay (50 %) and commercial concentrate (50 %) with 12 % protein. The fermentation process was performed in a DaisyII incubator (ANKOM Technology Corp., Macedon, NY) for 48 h following the protocol suggested by the manufacturer[19]. Gross energy (GE) was determined on a LECO AC 600 calorimeter, and total digestible nutrients (TDNs)[20] were calculated according to the following equations:

$$\text{TDNs total} = \text{TDNs CP} + \text{TDNs EE} + \text{TDNs CF} + \text{TDNs NFE}$$

Where: TDNs CP= total digestible nutrients of crude protein; TDNs EE= total digestible nutrients of ethereal extract; TDNs CF= total digestible nutrients of crude fiber; TDNs NFE= total digestible nutrients of nitrogen-free extract.

$$\text{TDNs CP}(\text{CP})(0.8)$$

$$\text{TDNs EE}(\text{EE})(2.25)(0.9)$$

$$\text{TDNs CF}(\text{CF})(0.5)$$

$$\text{TDNs NFE}(\text{NFE})(0.75)$$

The values of three replications of the variables of chemical composition, structural components, and IVDDM were subjected to normality and homogeneity of means tests, as well as mean comparisons using the Shapiro-Wilk, Levene, and t-student tests (α=0.05), respectively; all analyses were performed using the RStudio[21] statistical program.

The normality tests of the data from all the evaluated variables, both biomass and pellets, except for cellulose, showed normal distributions (P>0.05). The t-test comparison of means

indicates that 8 of 13 variables showed a significant modification (P<0.05), whereas 5 variables were statistically similar (P>0.05).

Statistical differences were found between biomass and pellets for chemical composition in most of the variables evaluated. CF and NFE presented highly significant differences; H, EE, and NFCs showed significant differences; by contrast, ASH and CP were statistically the same. For structural components, statistically significant differences were found for NDF, HE, and TDNs; the rest were statistically the same.

It is observed that the pelletizing process modifies certain variables in the chemical composition of the biomass; in the pellets, H and CF decreased, and EE, NFCs, and TDNs increased after the process (Table 1).

Table 1. Average values and standard deviations of the chemical composition of mango pits, before (biomass) and after pelletizing

DM component (%)	Biomass	Pellet
Moisture	4.50 (0.07) [a]	4.03 (0.19) [b]
Ashes	3.41 (0.33) [a]	3.31 (0.06) [a]
Crude protein	5.21 (0.19) [a]	5.45 (0.10) [a]
Ethereal extract	2.44 (0.45) [b]	4.35 (0.08) [a]
Non-fibrous carbohydrates	36.47 (2.57) [b]	49.13 (4.78) [a]
Neutral detergent fiber, %	52.48 (2.28) [a]	37.76 (4.88) [b]
Acid detergent fiber, %	38.05 (2.53) [a]	29.67 (5.76) [a]
Cellulose, %	29.42 (0.002) [a]	22.04 (5.76) [a]
Hemicellulose, %	14.43 (1.27) [a]	8.09 (2.11) [b]
Lignin, %	8.69 (2.53) [a]	7.62 (0.012) [a]
IVDDM, %	56.26 (3.33) [a]	62.06 (2.76) [a]
TDNs, %	68.63 (1.00) [b]	72.47 (2.22) [a]
Gross energy, MJ/kg	18.68 (0.01) [a]	18.65 (0.06) [a]

IVDDM= *in vitro* digestibility of dry matter; TDNs= total digestible nutrients.
[ab] Different letters in the same row indicate statistical differences.

The moisture content of the pellets produced in this study is below the limit allowed for feeds for animal consumption[22], which should not have more than 12 % to prevent the growth of fungi that affect the nutritional quality of the pellets. The decrease in moisture content in pellets is due to an increase in temperature during the pelletizing process caused by the friction that occurs during the process[23].

Pelletizing did not affect the percentage of ash content, as no statistical differences were found before and after the process. EE increased after the process, even without the addition of pelletizing fat; this increase is attributed to the fact that, after the thermal process (pelletizing), there is an extraction of lipids[24]; these reduce the friction and pressure exerted during pelletizing at high temperatures (80 to 110 ºC)[25].

In CP, there was no change after the pelletizing process; the values obtained in this work are lower than those reported by Granados *et al*[26] for forage corn in La Laguna (7.67 %), which is a traditional feed in cattle diets. A previous study[27] that evaluated the chemical composition of alfalfa pellets found values of 18.7 % for CP, 6.4 % for EE, and 7.0 % for ASH; these values are higher than those obtained in the present study, which may be mainly due to the species evaluated.

Similarly, in the structural components, there was a change after pelletizing; in biomass, values of 52.48 % for NDF and 8.09 % for HE were obtained; in pellets, NDF decreased to 37.76 % and HE to 8.09 %.

For the remaining variables (ADF, CEL, L, and IVDDM), although statistically the same, a tendency to decrease after pelletizing was observed (Table 1).

The results obtained in this study for both mango pit biomass and pellets were superior to those reported for mangoes from Nayarit[28] (ASH 2.13 %, CP 1.20 %, NDF 56.7 %, ADF 24.1 %, and HE 32.5 %) and were similar to those reported for mango pits[29] (HE 18 %, CEL 27.7 %, and L 9.3 %). ADF values can be related to the level of digestibility of the feed, and NDF values are directly related to feed intake and the time the animal remains full[9]. Based on the above, it can be said that after pelletizing, the quality of the mango pit improved and can be considered as cattle feed, since these levels decrease; in addition, they are within the values required to be considered good quality feed (NDF= 52 % and ADF= 32 %)[30]. ADF is related to digestibility and energy intake; feeds with ADF values close to 30 % have higher consumption and high energy intake[31], which is consistent with the results obtained in this study.

Lignin did not show statistical differences before and after the pelletizing process because it exhibits thermosetting properties starting at 140 ºC[32], a temperature that was not reached during this process. It is observed that lignin, despite not presenting statistical differences, decreases after the pelletizing process, and this in turn contributes to the increase of IVDDM, since lignin is a poorly digestible compound that brings with it a decrease in quality[33].

A good quality forage has approximately 70 % of IVDDM, less than 50 % of NDF, and more than 15 % of CP[34]; the pellet made from mango pits made in this work complies with the percentage of IVDDM, which is 62.06 %, and NDF; however, the percentage of CP is lower than what is required, and it would be necessary to use of a protein concentrate, which is recommended to be 13 %[35].

NFCs increased after the pelletizing process. The consumption of diets high in NFCs can cause rumen acidosis, which results in decreased feed intake and reduced digestibility[36].

The IVDDM obtained in this study was within the range reported for sweet sorghum varieties across different environments in the state of Durango, which ranged from 60 to 80 %[37].

TDN values are associated with the fibrous fraction of feed, which includes components such as cellulose, hemicellulose, and lignin, and indicates the digestibility of nutrients that are available to animals, which are related to ADF[38]; in addition, TDNs express the energy of feed. In the present work, TDNs increased after pelletizing; although GE remained the same before and after the process, the increase in TDNs is due to the increase in NFCs, since, during the process, the temperature reached causes the solubilization of the fiber (cellulose, hemicellulose, and lignin)[25].

The value of GE is not an indicator of quality; nevertheless, it is necessary to know it[39] because it will help balance rations to meet the animals' energy requirements[40]. The values obtained for GE in this study are higher than those reported by Serna and Torres[41] for mango peels, who obtained an average of 15.319 MJ/kg.

The chemical composition of the mango pit pellets is not affected with respect to the original biomass, and there is a positive effect on the components. Mango pit pellets can be used as an ingredient in cattle diets; they comply with the values of IVDDM and NDF that a forage must have to be considered of good quality; however, they do not meet the required percentage of crude protein; therefore, other ingredients must be included to meet the necessary requirements.

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