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Influence of Sorbent Type on Drying Efficiency, Production Costs and Nutritional Values of Mango By-Products Feeds for Livestock

Kiendrébéogo Timbilfou[1,2,3], Koadia Marcelle Grâce[4], Sodre Etienne[1,2,3], Barry Drissa[5], Ouedraogo Zangbéwindin Isidor[3], Tarpaga Vianey[1,3]

[1]Laboratoire Centrale d'Horticulture (LCH, /Centre Régional d'Excellence en Fruits et Légumes (CRE-FL) Institut de l'Environnement et de Recherches Agricoles, Station de Farako-Bâ, Bobo-Dioulasso, Burkina Faso
[2]Laboratoire de Recherche et d'Etudes en Production et Santé Animales (LAREPSA), Département Productions Animales (DPA), l'Institut de l'Environnement et de Recherches Agricoles (INERA), Station de Farako-Bâ, Bobo-Dioulasso, Burkina Faso
[3]Laboratoire d'Etude des Ressources Naturelles et des Sciences de l'Environnement (LERNSE), Ecole Doctorale Sciences Naturelles et Agronomie (ED-SNA) /Université Nazi BONI, Bobo-Dioulasso, Burkina Faso
[4]Université Catholique de l'Afrique de l'Ouest (UCAO) section du Burkina Faso, Bobo-Dioulasso, Burkina Faso
[5]Direction Régionale de l'Agriculture, des Ressources Animales et Halieutiques de l'Est, Fada, Burkina Faso
Email: timbilfou@gmail.com

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Abstract

The aim of the study was to determine the best food absorbents between wheat, rice and maize bran and palm kernel cake, from a technical and economic point of view, in order to make a better recommandation for their use in the production process of food based on mango by-products (peels, peels + pulp). To this end, series of 18 kg of fresh feed were prepared and spread out in a stall for sun-drying using a randomized Fisher system. Preparations were made using either mango peels (75%) + absorbent (25%) or pulp + mango peels (67%) + sorbent (33%). The results show that mango Peel feed loses more water (WL) with lover production yields (PY), higher mango incorporation rates into dry feed (MRI), longer drying times (UDT) and lower production costs (CPkgPD) than mango peel + pulp. The average DM, MAT, ADF and NDF fiber contents were almost equal to those of mango peels + pulp feed. The average Crude Fiber (CF) (25.13%) and DEp (2839 kcal/kgDM) contents were higher for mango skin feed than for mango skin + pulp feed, at 8.59% and 2536 for MAT and DEp respectively. Mango peels + wheat bran (PSB25) and whole mango (MESB33) feeds recorded the highest and almost equal levels of TCP, NDF and MM. Production costs per kg of feed dry mater (CPkgDM) for feed produced at 25% were on average 33% higher than for whole mango (WM) feed. Excluding mango raw material, palm kernel meal (PK), rice bran (RB), maize bran (MB) and wheat bran (WB) can be ranked

1st, 2nd, 3rd and 4th in terms of cumulative performance of production parameters. Producers can then choose the type of sorbent they wish to use according to this ranking and the local availability of the sorbent. These feeds can be used for both ruminants and monogastrics, but are better suited to ruminant feeding due to their high fiber content.

Keywords

Mango Provends, Food Absorbent, Drying Efficiency, Nutritional Values, Animal Feed, Ivory Coast

1. Introduction

Among the constraints to the development of the livestock sector in West Africa, feed availability and its high costs are mainly cited [1] and [2]. Feed remains a permanent factor contributing to poor livestock performance [3]. For African countries south of the Sahara (SSA), particularly Sahelian countries, these factors are limiting for livestock development. The availability of food resources for animals, particularly pastoral animals, is and will be further challenged by the negative impact of climate change [4]. Livestock stakeholders are resorting to agricultural by-products (ABPs) and agro-industrial by-products (AIBPs) to mitigate the effects of low forage availability from pasture. However, we note that mango by-products are almost never used as livestock feed, while large quantities of these by-products are abandoned under orchards or discarded in nature after processing. This situation is also experienced by Burkina Faso and Côte d'Ivoire, two mango-producing countries in West Africa that share the same climate in the western and northern zones respectively. Despite this high production in these countries, post-harvest losses of mango in the sub-region oscillate between 40% and 50% without anything being done to create added value for these by-products. Indeed, processing, which could help limit these losses, is very uncommon and stands at around 6.8% in West Africa [5]. What's more, these by-products are a source of environmental pollution and reinfestation of orchards by escaping flies [6] and [7]. In Ivory Coast, as in Burkina Faso, mango drying units face difficulties in managing these mango by-products, which include mango peelings, downgraded mango and almonds [6]. In Burkina Faso, the search for solutions to the major constraint of low availability and high cost of food has directed research towards the valorization of non-conventional food resources, including mango food by-products [8]. This process makes it possible to reconcile two paradoxes, namely the high availability of unvalued mango by-products and the low availability coupled with the high cost of animal feed, a limiting factor for good farm productivity. The feed produced by the process was then used to feed growing and/or finishing pigs [9] [10], local breed chickens for meat [11], laying hens [12] and dairy cows [13]. The *Fond Interprofessionnel* *pour la Recherche et les Conseils Agricoles (FIRCA)* has signed an agreement with Burkina Faso's *Institut de l'Environnement et de Recherches Agricoles* (*INERA*) to transfer technologies to Ivory Coast's mango sector, with a view to supporting units in their management of by-products from the mango processing industry, by setting up a pilot feed production unit. In this context, a complementary study was carried out to assess the influence of sorbent type (rice bran, wheat bran, corn bran and palm kernel meal) on the drying efficiency, production costs and nutritional values of mango by-product feeds. The ultimate aim is to offer future users of the technology the possibility of making an informed choice of sorbents according to feed production objectives.

2. Materials and Methods

2.1. Presentation of the Study Area

The study was initiated during the implementation of a pilot mango by-product feed production unit for a mango drying cooperative in Tengréla in the far north of Ivory Coast on 2019. Tengréla is located 108 km north of Boundiali, the capital of the region to which it belongs. Its geographic coordinates are 10˚28'55.056" north latitude and 6˚24'47.016" west longitude. Tengréla enjoys a relatively dry, warm Sudanian climate. Vegetation is dominated by wooded savannah. The area produces mangoes and is ideal for livestock farming [14]. The study was conducted near the mango drying unit of the Koto Wobin cooperative in Tengréla.

2.2. Biological Materials

The biological material consists of the following:

- Effluent by-products from the processing of mangoes into dried mangoes. There are two types of effluent: 1) whole mangoes (WM) from the sorting holes before the start of the peeling operation to obtain slices of mango pulp for drying. These discarded mangoes are either injured during harvesting, or bitten by fruit flies, making them unsuitable for processing into dried mango, and 2) mango peelings (MP), waste from mango peeling, consisting of mango peelings or skin and pits.

- Agro-industrial by-products used as feed sorbents: wheat, rice and maize bran and palm kernel cake were the feed sorbents tested in the animal feed production process. They were acquired locally in Tengréla (rice bran and maize bran) or purchased in Abidjan, the capital of Ivory Coast (wheat bran and palm kernel cake) and transported to Tengréla. Sorbents are dehydrated products that are preserved and sold to feed mills in Côte d'Ivoire.

2.3. Production Equipment

Production equipment consists of:

- ***01 mango crusher-sorter***: this is a machine that crushes the whole mango while sorting the pits so as to separate the peels + pulp on the one hand and the pits on the other, to enable separate processing of the 2 products. The crushed peel + pulp is then used for the drying test;

- ***01 mixer***: this is a machine used to mix products with a high water content. In the present test, it was used to mix the fresh feed obtained after blending the peel + pulp and the chosen sorbent.

- ***01 drying table*** (experimental setup): As shown in **Figure 1**, it's a rectangular table made of planks, rafters and spikes, 3.85 m long and 2.62 m wide, with four (04) supports 20 cm high. The table is made up of ten (10) boxes of 1 m^2 each, of which nine (9) were used. Each box is rectangular, 1.31 m long, 0.77 m wide and four (04 cm) cm deep. Each box has a surface area of 1 m^2 and a volume of 0.05 m^3. At the bottom of each box is a tarpaulin on which the food is placed for drying. At the bottom of each box is a tarpaulin on which the food is placed for drying. The quantity of fresh food to be dried in each box is 18 kg. The process used to produce the feed was that of [9]. Following this process the feeds are dried to a moisture content of 14%, which ensures good food preservation in the tropics according to [15]. Two rates of sorbent incorporation were used in the experiment: 25% of the expected fresh weight of the feed for preparations using only mango peel, and 33% in the case of the grind composed of peel + pulp. The fresh feed obtained is then carefully mixed and spread out in the boxes of the drying table.

2.4. Experimental Setup

Food preparations are carried out in series of three treatments, each differentiated by the ingredients used. For each serie, 03 sorbents are used and 03 preparations of each type of sorbent are made, 09 preparations per series. The preparations, each weighing a uniform 18 kg, are then spread out in a box (plot) on the **Table 1**, as shown in **Figure 1**. Exposure to the sun takes place between 8 am and 6 pm. The drying feed is stirred 3 times a day at 8 a.m., 12 p.m. and 3 p.m. At night, the table is covered with tarpaulins to prevent the food from getting wet with surprise rainwater.

Figure 1. Feed drying table.

Table 1. Layout of a serie of feed préparations on the drying table.

Plot1	Plot2	Plot3	Plot4	Plot5
Provende mango skin + rice bran	Provende mango skin + Weat bran	Provende mango skin + maize bran	Provende mango skin + Weat bran	Provende mango skin + rice bran
Provende mango skin + maize bran	Provende mango skin + rice bran	Provende mango skin + Weat bran	Provende mango skin + maize bran	
P6	P7	P8	P9	P10

2.5. Data Collection and Analysis

The parameters studied to determine the best sorbent are:

- Water loss through dehydration in the sun: this is calculated as the difference between the weights of fresh spread material (FMs) and sun-dried material (DMs) (Weight of fresh material—Weight of dry material).

- The production yield (PY) is given by the following formula DMs/FMs * 100

- Mango incorporation rate: MIR (%) = (PROD—sorbent weight)/PROD) * 100

- Production cost per kilogram of feed: given by the following formula:

CPkgPD (FCFA) = Total Production cost (FCFA)/quantity of feed obtained (kg)

- Number of days required for sun drying: UDT (days) = UDT (hours)/24 (hours) × 01 days.

3. Results

3.1. Effects of Sorbent and Incorporation Rates on Feed Production Characteristics

Results concerning feed drying characteristics are presented in Table 2. Feed quantities (PROD) and yields (PY) were significantly higher and lower for feed groups PCWM33, RBWM33 and MBWM33, which were homogeneous with each other, and for feed groups MBMP25, WBMP25, PCMP25 and WBWM33, which were also homogeneous with each other ($p = 0.000$). Conversely, feed water losses were significantly higher and decreased between feed groups MBMP25, WBMP25, PCMP25 and RBWM33, MBWM33, and feed group PCWM33 ($p = 0.000$). Feed drying time and number of days were significantly lower for feed groups RBWM33, MBWM33, WBWM33, PCWM33 compared with MBMP25, WBMP25, RBMP25 and PCMP25 ($p = 0.000$). Production costs per 01 kg of Provende (CPkgPVD) were significantly higher and decreased from the WBWM33 and RBWM33,

3.2. Dietetic and Energy Values of Some Mango Provends

Bromatological analyses were carried out on foods produced with hides incorporating various sorbents. Table 3 shows the results relating to the dietary values of these foods. Water contents were almost equal, and all below 10%. TCP contents were highest for WBMP25 and PCMP25, then MBMP25 and finally RBMP25. Crude Fiber (CF) contents were higher for PCMP25 and WBMP25 than for WBMP25 and MBMP25. Gross energy was higher and lower between PCMP25, WBMP25, MBMP25 and RBMP25 respectively. Energy digestibility for pigs was higher and decreased between MBMP25 (93.25%), WBMP25 (91.94%), RBMP25 (87.16%) and PCMP25 (83.65%).

Table 2. Technical and economic characteristics of feed produced.

PROV	PROD (kgDM)	WL (kg)	PY (%)	MIR (%)	UDT (H)		CPkgPVD (XOF)
					Hours	Days	
MBMP25	5.738 c	12.929 ab	30.710 e	61.147 a	65.50 a	8.000 b	70.500 bc
WBMP25	5.727 c	13.273 a	30.163 e	62.234 a	61.95 a	7.167 bc	76.000 b
RBMP25	6.337 bc	12.663 abc	33.289 cde	56.464 b	64.11 a	7.333 bc	58.250 c
PCMP25	5.597 c	12.403 bcd	31.093 de	60.556 ab	65.56 a	9.333 a	58.250 c
RBWM33	6.730 b	11.270 de	37.389 bc	41.026 c	46.45 b	6.000 cd	86.200 b
MBWM33	7.033 b	10.967 e	39.074 b	38.128 cd	45.56 b	5.667 d	88.167 b
WBWM33	6.380 bc	11.620 cde	35.444 bcd	41.619 c	47.31 b	6.000 cd	121.000 a
PCWM33	8.273 a	9.727 f	45.963 a	33.649 d	42.11 b	5.333 d	86.200 b
Pr > F	0.000	0.000	0.000	0.000	0.000	0.0000	0.000
Sig.	Oui	Oui	Oui	Oui	Oui	Oui	Oui

- Means bearing the same letter in the same column are not significantly different at the 5% level; - **MBMP25** = Mango skin provende + maize bran at 25% incorporation in the fresh mater; **WBMP25** = Mango skin provende + wheat bran at 25% incorporation of absorbent in the fresh mater; **RBMP25** = Mango skin provende + rice bran at 25% incorporation in the fresh mater; **PCMP25** = Mango skin provende + palm kernel cake at 25% incorporation of palm kernel cake in the fresh mater; **RBWM33** = Whole mango provende + rice bran incorporated at 33% in the fresh mater; **MBWM33** = Whole mango provende + corn bran at 33% incorporation in the fresh mater; **WBWM33** = Whole mango provende + wheat bran at 33% incorporation of wheat bran in the fresh mater; **PCWM33** = Whole mango provende + palm kernel cake incorporated at 33% in the fresh mater; **PROD (KgDM)** = dry feed obtained by sun-drying; **WL** (kg) = water loss due to sun-drying; **PY** (%): feed yield obtained by sun-drying, MIR (%) = mango by-products incorporation rate in dry feed; **UDTs (hours or days)** = useful sun-drying time of feed; **CPkgPVD** (XOF) = production cost of 01 kg of dry feed.

Table 3. Chemical composition of mango feed.

NUTRIENTS	PROVENDS						
	PCMP25	MBWM33	RBWM33	WBWM33	WBMP25	WBMP25	MBMP25
DM (%)	91.95	92.63	93.25	92.46	92.90	92.12	92.23
TNM (%)	11.34	11.79	7.23	14.59	6.98	14.77	11.54
CF (%)	43.64	8.59	8.59	8.59	31.53	15.01	10.32
NDF (%)	-	36.33	50.94	43.82	51.45	44.98	35.44
ADF (%)	-	11.07	34.42	14.66	34.87	16.35	10.04
MM (%)	5.66	5.91	10.71	6.58	10.18	5.88	4.92
CE (kcal/kg)	4380	4448	4178	4464	4232	4424	4615
DEp (kcal/kg)	3664	2870	2155	2584	2164	2515	3014

MBMP25 = Mango skin provende + maize bran at 25% incorporation in the fresh mater; **WBMP25** = Mango skin provende + wheat bran at 25% incorporation of absorbent in the fresh mater; **RBMP25** = Mango skin provende + rice bran at 25% incorporation in the fresh mater; **PCMP25** = Mango skin provende + palm kernel cake at 25% incorporation of palm kernel cake in the fresh mater; **RBWM33** = Whole mango provende + rice bran incorporated at 33% in the fresh mater; **MBWM33** = Whole mango provende + corn bran at 33% incorporation in the fresh mater; **WBWM33** = Whole mango provende + wheat bran at 33% incorporation of wheat bran in the fresh mater; **PCWM33** = Whole mango provende + palm kernel cake incorporated at 33% in the fresh mater;

4. Discussion

4.1. Effects of Sorbent and Incorporation Rates on Feed Characteristics

The drying efficiency of palm kernel meal (PK) feeds is controversial, depending on the mango by-product (skin, skin + pulp) used. In fact, the results show that palm kernel flour-based foods lose less water over a shorter period of time than all other foods, and in particular those based on mango skin. If we consider the dietary values of the foods analyzed, we see that the Crude Fiber (CF) content of palm kernel flour + skin (PCMP25) is almost three and four times higher than that of wheat bran + mango skin (25%) (WBMP25) and corn bran (25%) + mango skin **(MBMP25)**. On the other hand, it is only 12% higher than the Crude Fiber content of rice bran (25%) + mango skin **(RBMP25)**. Closer examination of the chemical constituents of palm kernel flour reveals a higher starch content in these sorbents than in palm kernel flour. This is due to the presence of residual granules following the milling of the bran of these cereals. Starch has a very high water absorption capacity, but a slower release rate. In contrast, the abundant walls of palm kernel swell in a humid environment and release water more rapidly under the effect of heat. It has been reported that higher water absorption capacities are obtained from the gelatinized starch contained in bran, after gentle mechanical processing [16], which is similar to grain processing in traditional mills, where extraction leaves residual grains in the bran. Wheat, on the other hand, which undergoes more extensive industrial processing to extract the maximum amount of grain, contains little or no residual grain and, consequently, lower starch contents. The longer dehydration time of foods made from corn bran and rice combined with mango skin is certainly due to the combined effect of residual grains and the slow release of water from mango skin. It should be noted that foods using whole mangoes dehydrate faster and release less water than those using mango skin. In addition, whole mangoes are subjected to the crushing process, which has the advantage of greater fragmentation of the skin, allowing water to be released earlier during crushing and drying. All these factors explain the higher yields and incorporation rates of mango by-products in the foods produced, with peel than with peel + pulp.

4.2. Effects of Absorption and Incorporation Rates on Feed Characteristics

The lowest production costs were recorded for feed produced with mango skin + rice bran **(RBMP25)** and mango skin + palm kernel cake (**PCMP25)**, followed by feed batches of skin + maize bran (MBMP25), skin + wheat bran (WBMP25), whole mango + rice bran (RBWM33), whole mango + maize bran (MBWM33) and whole mango + palm kernel cake (PCWM33). The various costs obtained at Tengréla are lower than the production costs reported at Bobo-Dioulasso in Burkina Faso, which average 147.25 FCFA for WBWM33 and 100.93 FCFA for

MBWM33 feed [9]. This is a consequence of the cost of sorbents (corn bran and wheat bran), which are higher in Burkina Faso than in Tengréla in Ivory Coast. Whole mango + wheat bran (WBWM33) was the most expensive feed produced, due to the high cost of wheat bran (6000 XOF per 50 kg bag) in both Burkina Faso and Ivory Coast. The results of the analysis of the chemical composition of the few feeds obtained show that these feeds have waters contents of less than 10%. Similar results have been reported by other authors [9] [17]. This indicates that under Tengréla conditions, food can be dried as well as in Burkina Faso, with water contents below 14%, which is favorable for good preservation according to recommendations for drying agricultural products [15]. We can imagine that the water content of the feed made from whole mango is similar to that reported by [9], which was below 10%. In terms of total nitrogenous matter (TNM), with the exception of rice bran feed (RBMP25) whose content is more than 2 times lower than that of palm kernel flour feed (PCMP25) and wheat bran feed (WBMP25), and 2 times higher than that of maize bran feed (MBMP25), the contents of other feeds prepared with skin and different types of bran at 25% incorporation in fresh feed are appreciable. They are slightly higher than those of certain sorghum grains [18]. Our results show that mango-based feeds are rich in crude energy (3910 to 4380 kcal/kg DM) and digestible energy for pigs (3408 to 3847 kcal/kg DM). However, the digestibility of these feeds is influenced by their fiber content. The higher the fiber content, the lower the digestibility, especially in monogastic animals. The high energy composition of feeds means that they could be used as basic ingredients in the diets of monogastric animals, including pigs and poultry, where microbial digestibility is low and fiber degradation very limited. The gross energy composition of mango-based feeds is comparable to that of maize (4571 kcal/kgMS) [19], which is used in pig feed. Its digestible energy content is sufficient to cover the energy requirements of a pig weighing between 15 and 20 kg live weight [20]. In the formulation of pig rations, the recommended energy content is 3000 - 3200 kcal Digestible Energy (DE)/kg of dry matter (DM) and less than 12% of crude fiber (CF) for good pig growth [21]. Given these requirements, MBWM33, WBWM33, MBMP25 and WBWM33 feeds, in descending order of importance (**Table 3**), would easily achieve the required energy level and acceptable crude fiber level, and ensure rapid pig growth. It can also be used to prepare pullets for laying [12]. It should be noted that feed production reduces crude fiber content, making it more digestible in rations for monogastric animals. The high crude fiber content of palm kernel flour and rice bran feeds is due to the high crude fiber content of palm kernel flour, rice bran and mango skin. These two foods could be used in ruminant feed [13], as ruminants are able to valorize fibers through digestion, which is mainly microbial in these species. Putting together technical drying efficiency factors, production costs and feed values, we arrive at several possible choices of sorbents and combinations to use. Those aiming to produce low-cost feeds with low feed values will probably opt for combinations using mango skins. Those looking for good feed values regardless of production cost will be more inclined to use combinations based on wheat bran and whole mango (mango skin and pulp).

5. Conclusion

The aim of this study was to evaluate the technical and economic efficiency of sorbents used in the feed production process, with a view to making better recommendations to technology users and breeders. It evaluated mango feed production parameters using four sorbents, namely corn bran, rice, wheat and palm kernel meal. The lowest production costs were recorded for feeds produced with mango skin + rice bran (25%) and mango skin + palm kernel flour, followed by feeds produced with skin + maize bran (25%), skin + wheat bran (25%), whole mango + rice bran (33%), whole mango + maize bran (33%) and whole mango + palm kernel flour (33%). In addition, chemical analyses show that the feeds produced have a very high energy content, enabling them to be used as a substitute for maize in monogastric feeds. The Crude Fiber content of the palm kernel meal and rice bran feeds was high, making them ideal for ruminants.

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Conflicts of Interest

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

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