Chapter 14

Use of palm kernel cakes (*Elaeis guineensis* and *Orbignya phalerata*), co-products of the biofuel industry, in collared peccary (*Pecari tajacu*) feeds

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ABSTRACT

The oil palm (*Elaeis guineensis*) and the babassu (*Orbignya phalerata*) are palms of commercial interest in tropical countries and are found in the Brazilian Amazon. The oil from these palms has diverse uses, such as food, production of charcoal, soap and, most recently, biodiesel. The remainder of the plant, which is the bulk, is not normally commercialized, making it an ideal alternative source of low-cost energy for animal feed. The systems for breeding wild animals in captivity for commercialization and sustainability have an important role in conservation, because these species of game animals are under constant environmental pressure. For the collared peccary (*Pecari tajacu*) production system, the major part of the cost is feed. If alternative sources of low-cost animal feed could be used in the animal's diet, the production of the collared peccary could provide a new source of income for rural Brazilian producers. The use of co-products of oil palm and babassu has been found to be positive both for performance and for carcass characteristics of those animals bred in captivity. The replacement of 40 percent and 15 percent of the energy components of the traditional collared peccary diet with babassu and oil palm, respectively, showed the best improvement in the productive performance, demonstrating that they could reduce feeding costs while maintaining good animal development.

INTRODUCTION

Palms are plants typical to the tropics, and some are sufficiently prolific to be relevant to the subsistence of indigenous and traditional peoples (Clement, Lleras Peres and Van Leeuwen, 2005), providing an important contribution to the economies of several tropical countries (Lopes *et al.*, 2008). The oil palm and babassu are examples of species of commercial interest.

In recent years, production of the oil palm has expanded greatly on a large scale in many tropical countries (e.g. Brazil, Colombia, Ecuador, Indonesia, Malaysia and Thailand). The oil palm belongs to the monocotyledonous class, order Palmales, family Arecaceae and genus *Elaeis*. There are two species of commercial interest: *E. guineensis* Jacq, of African origin, known as oil palm, and *E. oleifera* Cortés, known as American oil palm or Caiaué. The palm of African origin is the principal species planted commercially, using varieties of the Tenera type. The American species is used in improvement programmes to obtain interspecific hybrids (*E. oleifera* × *E. guineensis*) especially for plantations in regions subject to fatal yellowing disorder. The ideal climatic conditions for its cultivation are: annual rainfall of more than 2000 mm that is well distributed, without a defined dry season, and a minimum of 100 mm per month; an average maximum temperature between 29 and 33 °C, with a minimum temperature between 22 and 24 °C; a daily insolation period of between 5 and 7 hours, and daily radiation of 15 MJ/m^2 (Corley and Tinker, 2003).

The oil palm, a perennial plant with continuous production throughout the year, has an economically productive life of around 25 years. This species is the most productive oleaginous palm and can produce from 6 to 10 tonne of oil per hectare per year. The oil palm produces at least 3 to 8 times more oil than most other oleaginous seeds. The oil

MAIN MESSAGES

- **Babassu cake substitution for maize as an energy source up to a level of 40 percent improved productive performance of collared peccaries, and good results were obtained with respect to dressing percentage of collared peccaries slaughtered at the terminal phase.**
- **Oil-palm cake can be used to replace 15 percent of the energy components of the traditional collared peccaries diets at the terminal phase.**
- **Babassu and oil-palm cakes could reduce feeding costs while maintaining good animal development.**

palm produces its fruit in clusters, varying in size from 10 to 40 kg per cluster. The individual fruit consists of an exterior layer (exocarp), pulp (mesocarp), endocarp and seed. The primary products produced from the fruit of the oil palm are oil and cake. The palm oil is extracted from the pulp of the fruit (mesocarp), and the palm kernel oil from the seed (endosperm). The ratio between the quantities produced by these types of oils is approximately 9:1 (palm oil:palm kernel oil). The cake results from the process of extracting oil from the seed and contains 17–19 percent protein and acceptable bromatological characteristics, particularly in ruminant diets due to its high proportion of fibre, and is rich in arginine and glutamic acid. The average composition of palm kernel cake is 48 percent carbohydrate, 19 percent protein, 13 percent fibre, 5 percent palm kernel oil, 11 percent water and 4 percent ash (Hartley, 1988). Oil palm oil production exceeds 35 million tonne per year, with marked growth in the last two decades, and has become the most produced and commercialized vegetable oil in the world (USDA, 2006; FEDEPALMA, no date; Oil World, 2008).

Biofuel demand might greatly exceed that for edible use, and the interchangeability of the major oils, for edible and biofuel uses, means that this demand will drive oil palm expansion, whether or not palm oil is actually used for biodiesel (Corley, 2009).

Although the oil palm plantations are, in some situations, world-challenged by presenting some environmental risks (e.g. Friends of the Earth, 2005; Rosenthal, 2007; Fitzherbert *et al.*, 2008; Koh and Wilcove, 2008; Butler and Laurence, 2009), these risks can be considerably reduced through sustainable development practices, with proper management (Basiron, 2007; Corley, 2009; Boyfield, 2010; Nelson *et al.*, 2010).

The palm oil industry could supply sufficient vegetable oil to meet the growing food requirements for the global population in 2050, and there is sufficient land available for necessary expansion without the need for deforestation (Corley, 2009). Due to the fact that Malaysia does not have physical space to increase its plantation area (Thoenes, 2006), it is necessary to increase cultivation of oil palm elsewhere. Various countries could emerge as major producers of palm oil (East and West Africa, other Asian countries, and Central and South America). Brazil, in spite of currently having little market penetration in terms of global production of palm oil, has a great potential for expansion and has recently expanded production in this sector. To control expansion of oil palm plantations in the Brazilian Amazon and minimize possible negative environmental impacts, the Brazilian government has requested the implementation of agri-ecological zoning for the culture. This zoning is a technico-scientific basis for achieving sustainability by defining lands suitable for oil palm culture (Ramalho Filho and Motta, 2010). The focus area, set in the Amazonian biome (5 million km^2), refers to areas already deforested, with the exception of strictly protected areas (state and national parks, and indigenous reserves). The areas already deforested and considered suitable for the cultivation of oil palm total 30 million ha (300 000 km^2), being some 5.9 percent of the Brazilian legally-defined Amazon (Ramalho Filho *et al.*, 2010).

The babassu (*Orbignya phalerata* Mart.) is a palmaceous plant of the Arecaceae family, found in abundance in the Brazilian Amazon region, especially in the States of Maranhão, Tocantins, Pará and Piauí, and possesses a high energy potential. Maranhão State has around 65 percent of the national occurrence of the palm, which represents 30 percent of the State surface (Ferreira, 1999). Babassu is a native of the transition zone between the savannah and open forests of the southern Amazon, and is in areas anthopogenically altered (Clement, Lleras Peres and Van Leeuwen, 2005), often appearing in spontaneous homogeneous groupings. This species covers extensive regions in Brazil, Bolivia and Suriname (Zylbersztajn *et al.*, 2000).

The babassu produces drupe type fruits with oleaginous and edible seeds from which the oil is extracted in sufficient quantities for local needs. Fundamental aspects for the exploitation of the babassu are the harvesting and the gathering system. There are no commercial plantations of these palms in the world, and the fruits are collected from natural forests by native populations. It is a natural resource whose economic importance has been recognized. Its exploitation is characterized by the collection of fruits from natural stands of native vegetation with no additional management action.

Natural babassu density in the forest varies from 1 to 4000 plants per hectare, with an average of 1111 plants per hectare (Ferreira, 1999), but not all these plants can be utilized. Each adult plant produces approximately

2000 fruits per year (Lorenzi *et al.*, 1996). Each fruit can weigh between 40 and 400 g dry weight (Revilla, 2002). Each 17.6 kg of fruit provides 2.6 kg of epicarp, 3.5 kg of mesocarp, 10.4 kg of endocarp and 1.1 kg of kernels (Wisniewski and Melo, 1981).

The seed is the principal product extracted from the fruit, and represents the greatest commercial and industrial value. One fruit contains from 3 to 5 seeds, which are extracted manually by traditional cottier families, being the most important source of income for the landless population in the interior regions where babassu is found. In the state of Maranhão, seed extraction involves more than 300 000 families, especially women (called "breakers").

The food products from the babassu and oil palm production could significantly contribute to food security in the Amazon forest region, and currently provide a large variety of foods and an adequate health standard for the population (Alencar *et al.*, 2007). These palms could be used for numerous purposes, such as the production of starch, charcoal, soap, margarine, oil tar, alcohol, palmetto and, more recently, biodiesel. Nevertheless, the remainder of the plant, which constitutes the bulk of the plant, is not normally commercialized, and could be considered as an alternative source of low-cost energy for animal feed.

USE OF BABASSU (*ORBIGNYA PHALERATA*) IN THE FEED OF COLLARED PECCARIES RAISED IN CAPTIVITY

Very few studies have been carried out regarding sustainable production systems for native wild animals maintained in captivity for commercial purposes. These systems may play an important role in conservation because these species are under constant human pressure due to subsistence and commercial hunting, fragmentation of the habitat and deforestation.

In the Amazon region, subsistence hunting of game animals provides a significant proportion of the protein component of the diet of rural families (Robinson and Bodmer, 1999; Peres, 2000, 2001). In certain regions, the trade in bushmeat and other co-products of game animals is a great source of income (Bodmer, 2000; Baia Junior, Guimarães and Le Pendu, 2010.).

The collared peccary (*Pecari tajacu*) is a wild species which is frequently hunted. Its diet in its natural environment is basically fruit, leaves and roots, and in captivity can easily adapt to different types of feed, including grain, fruits, potherbs, roots and fodder, and accepts porcine commercial feed (Albuquerque and Hühn, 2001; Albuquerque *et al.*, 2004)

The collared peccary belongs to the Suiformes suborder and the Tayassuidae family. The animals belonging to his family possess a stomach subdivided into compartments, and some authors suggest that its digestive physiology could be similar to that of ruminants. Due to its low requirements for protein and its high digestive performance, these animals are able to adapt to green foods such as fodder (Comizzoli *et al.*, 1997; Cavalcante Filho *et al.*, 1998; Mendes, 2008), and the wild collared peccary resort to this type of diet when there is a scarcity of fruits.

Captive breeding of collared peccary has been proposed by Nogueira-Filho (1999), Albuquerque *et al.* (2004) and Garcia *et al.* (2005). This could be a new source of income for rural Brazilian producers, supported by supplementing the animal's diet with alternative sources of low-cost feed.

Albuquerque (2006) studied the use of babassu cake as an alternative energy source in the captive collared peccary's diet. In the experiment, babassu cake substituted maize at varying levels in feed formulated for animals in the termination phase, and animal performance was evaluated using daily weight gain and daily feed consumption. After the experimental phase the animals were slaughtered to analyse the carcasses.

Table 1 shows the chemical characteristics of the experimental feed, and Table 2 shows the average composition of the ingredients used in the experiment. The experimental feed was based on maize and soy bran, replaced with varying levels of babassu cake.

At the end of the experimental phase, when the experimental animals reached slaughter weight (average of 16.25 kg and 7 months old), they were weighed. After this, the animals were fasted for 24 hours, re-weighed and

TABLE 1
Average chemical characteristics of the ingredients of the experimental feed

Ingredient	DM	MM	P	CF	CP	Ca	EE	NDF	ADF	Sodium
Soy bran[(1)]	88.1	6.6	0.6	5.9	45.5	0.3	1.4	14.1	7.8	0.1
Maize[(1)]	87.1	1.3	0.2	2.0	8.6	<0.1	3.5	11.4	3.4	<0.1
Babassu (cake)[(2)]	90.2	4.6	0.7	26.0	17.3	0.1	3.1	–	–	–
Soy oil	99.3	–	–	–	–	–	99.0	–	–	–
Dicalcium phosphate	–	–	18.5	–	–	24.8	–	–	–	–
Calcitic lime	–	–	<0.1	–	–	31.9	–	–	–	–
Salt	–	–	–	–	–	–	–	–	–	39.7
Lysine-HCl	–	–	–	–	79.1	–	–	–	–	–

Notes: DM = dry matter; MM = mineral material; P = phosphorus; CF = crude fibre; CP = crude protein, Ca = Calcium; EE = ether extract; NDF = neutral-detergent fibre; ADF = acid-detergent fibre.
Sources: (1) Rostagno *et al.*, 2000. (2) Embrapa, 1991.

TABLE 2
Average composition of experimental feeds

Ingredient	Inclusion levels of babassu cake in the feed TA	TB	TC	TD
Babassu (cake)	0.0	15.7	31.3	47.0
Maize	78.3	62.7	47.0	31.3
Soy bran	14.6	14.6	14.6	14.6
Soy oil	1.0	3.5	3.5	3.5
Dicalcium phosphate	1.25	1.25	1.25	1.25
Calcitic lime	0.78	0.78	0.78	0.78
Salt	0.40	0.40	0.40	0.40
Lysine-HCl	0.15	0.00	0.00	0.00
Vitamin supplement(1)	0.40	0.40	0.40	0.40
Mineral supplement(2)	0.10	0.10	0.10	0.10
Inert	3.00	0.65	0.65	0.65
Total	100.00	100.00	100.00	100.00
Calculated Values				
Digestible energy (Kcal)	3304	3304	3304	3304
Gross protein	13.5	13.5	13.5	13.5
Calcium	1.19	1.19	1.19	1.19
Total phosphorus	0.78	0.78	0.78	0.78
Available phosphorus	0.53	0.53	0.53	0.53
Lysine	0.49	0.49	0.49	0.49
Methionine+cystine	0.41	0.41	0.41	0.41
Threonine	0.41	0.41	0.41	0.41
Tryptophan	0.11	0.11	0.11	0.11
Sodium	0.19	0.19	0.19	0.19

Notes: TA = Control feed based on maize and soy bran; TB = Feed containing 20% babassu cake and 80% maize; TC = Feed containing 40% babassu cake and 60% maize; TD= Feed containing 60% babassu cake and 40% maize.
(1) Vitamin supplementation per kg of feed: vitamin A = 625 000 IU; vitamin D3 = 125 000 IU; vitamin E = 3375 IU; folic acid + 875 mg; biotin = 27.56 mg; choline chloride = 2475 mg; niacin = 4000 mg; pantothenic acid = 2000 mg; thiamine = 175 mg; riboflavin = 550 mg; pyridoxine = 175 mg; vitamin B_{12} = 2800 mg; antioxidant = 200 mg.
(2) Mineral supplementation per kg of feed: Iron = 22 000 mg; copper = 5000 mg; zinc = 18 750 mg; manganese = 12 500 mg; iodine = 238 mg; selenium = 56.3 mg; cobalt = 116 mg.
Values calculated in accordance with the nutritional demands in basal feed for swine of low genetic potential.
Source: Rostagno *et al.*, 2000.

TABLE 3
Average daily weight gain (DWG) and daily feed intake (DFI) of the collared peccary in the terminal phase

Parameter	Inclusion levels of babassu cake in the feed (%) 0	20	40	60	SE
DWG (g)	32.7	38.0	44.7	37.0	4.6
DFI (g)	355.5	359.1	356.1	362.2	11.4

Notes: SE = Standard error. *Source*: Albuquerque, 2006.

then sent to the abattoir. The characteristics of the animal carcasses included in this study were dressing percentage, corporal composition, carcass measurements, organs and glands, and commercial cuts. Table 3 shows the daily weight gain and daily feed intake in the terminal phase.

In this experiment, no significant (P >0.05) relationships were observed between the levels of babassu cake and DWG and DFI. The DWG at the 40 percent babassu cake inclusion level showed an increase of 36.74 percent compared with the basal diet. No significant effects were observed in DFI.

Evaluation of the carcass

Tables 4, 5, 6 and 7 show the variables studied in the carcass evaluation of the experimental collared peccaries. The levels of babassu cake did not affect the variables of live weight, fasting weight, hot carcass, cold carcass, length, hide, hind and front feet, as shown in Table 4.

Albuquerque (1993) evaluated the carcasses of male, female and castrated male capybaras (*Hydrochoerus hydrochaeris*) slaughtered after the terminal phase, and found no significant differences (P >0.05) in carcass components among different experimental groups.

Silva *et al.* (2002) studied the effects on the animal carcass of different levels of CP in the diet of collared peccaries slaughtered after the terminal phase, but they found no significant differences. The carcass length was between 55.25 and 57.63 cm, and was greater than reported by Albuquerque (2006). The authors did not report the age of the animals studied, but it is thought that they were older, due to the differences in body length.

Albuquerque (2006) observed no significant differences (P >0.05) in hot or cold dressing percentages related to varying levels of babassu cake (Table 5), and ribs, gammon, shoulder blades and percentage of gammon in relation to the cold, left half-carcass (Table 6). There was an increase over basal feed of 7.1 percent for ribs, 8.9 percent for gammon, 6.4 percent for shoulder blades, and 21.6 percent for percentage of gammon relative to the cold, left half-

TABLE 4
Measurements of the carcass components of slaughtered collared peccaries after the terminal phase

Parameter	Levels of babassu cake in the feed (%) 0	20	40	60	SE
Live weight (g)	16533	15633	16600	16233	834.8
Fasting weight (g)	16467	15700	16400	16000	746.8
Hot carcass (g)	9233	8267	9500	9500	407.5
Cold carcass (g)	9141	8184	9405	9405	403.4
Carcass length (cm)	23	21	21	21	0.8
Blood (g)	148	212	217	204	27.0
Hide (g)	2088	1892	1998	1980	103.5
Hind feet (g)	123	122	130	117	4.7
Front feet (g)	122	122	120	120	2.7

Notes: SE = Standard error. *Source*: Albuquerque, 2006.

TABLE 5
Averages of the dressing percentage of slaughtered collared peccaries after the termination phase

Parameter	Levels of babassu cake in the feed (%) 0	20	40	60	SE
HDP (%)	56.1	53.2	57.8	59.4	2.62
CDP (%)	55.5	52.6	57.2	58.8	2.59

Notes: SE = Standard error; HDP = Hot dressing percentage; CDP = Cold dressing percentage. *Source*: Albuquerque, 2006

TABLE 6

Average features of the commercial cuts removed from the cold, left half-carcass of the collared peccaries slaughtered after the termination phase

Parameter	Levels of babassu cake in the feed (%)				
	0	20	40	60	SE
Ribs (g)	1320	1147	1147	1413	186.6
Gammon (g)	1428	1420	1468	1555	80.2
Shoulder blade (g)	967	953	943	1028	67.7
% Gammon[(1)]	30.6	32.4	35.3	37.2	3.4

Notes: SE = Standard error. (1) % of gammon in relation to the left side cold half carcass. *Source*: Albuquerque, 2006.

TABLE 7

Average percentages of organs and glands in relation to the carcass of the collared peccaries slaughtered after the terminal phase

Parameter	Inclusion levels of babassu cake in the feed (%)				
	0	20	40	60	SE
Stomach (%)	5.0	4.7	5.2	4.0	0.65
Heart (%)	0.7	0.8	0.7	0.6	0.08
Lung (%)	1.3	1.8	1.5	1.2	0.11
Liver (%)	2.1	2.7	2.5	2.2	0.19
Spleen (%)	1.1	0.8	0.7	0.5	0.24
Kidneys (%)	0.5	0.6	0.6	0.6	0.07
Intestines (%)	5.9	8.2	7.3	6.5	0.93
Total (%)	16.6	19.7	18.3	15.3	1.73

Notes: SE = Standard error. *Source*: Albuquerque, 2006.

carcass. In the diet with an inclusion level of 40 percent babassu cake, the increase was 2.8 percent for gammon and 15.4 percent for percentage of gammon in relation to the cold, left half-carcass.

Silva *et al.* (2002) studied the effect of different inclusion levels of CP in the feed on carcass and meat of collared peccaries slaughtered after the terminal phase, and found no significant differences ($P > 0.05$) for the carcass parameters studied. Similar to observations of Albuquerque (2006), the average dressing percentage was between 56.88 and 59.47 percent. The percentage of gammon in relation to the carcass was between 35.0 and 38.2 percent, showing slightly higher values than reported in Albuquerque (2006).

Some bovine data for dressing percentage were poorer when compared with that of collared peccaries reported by Albuquerque (2006), such as the data found by Schwarz *et al.* (1993), who found average dressing percentages of between 57.7 and 58.4 percent, and Holzer *et al.*, (1999), who reported an average dressing percentage between 55.4 and 57.4 percent. The inclusion of different levels of babassu cake showed no significant differences ($P > 0.05$) in the values for organs and glands (Table 7).

Meat properties and fatty acids profile in the collared peccary gammon

Albuquerque *et al.* (2009) studied the organoleptic properties (cooking losses, shearing force, pH and water holding capacity) of gammon from 12 collared peccaries, and the fatty acid (FA) profile of the oil extracted from the meat. No significant differences ($P > 0.05$) were observed in meat properties, and unsaturated FA (mono- and polyunsaturates) were more frequent than saturated fatty acids in the collared peccary gammon meat. When comparing the meat from collared peccaries, bovines, ovines and swine, the collared peccary had more unsaturated FA (mono- and polyunsaturates) than saturated FA. The FA polyunsaturates are responsible for a reduction in cholesterol blood levels (Monteiro, Mondini and Costa, 2000), suggesting that the meat from the collared peccary is a healthy source of animal protein (Albuquerque *et al.*, 2009).

PALM KERNEL CAKE (*ELAEIS GUINEENSIS*) USE IN THE FEED OF COLLARED PECCARIES RAISED IN CAPTIVITY

The use of oil palm cake in the diet has been studied in various animal species: fish – *Pieractus mesopotamicus* and *Oreochromis niloticus* (Oliveira et *al.*, 1997, 2008; Pascoal, Miranda and Silva-Filho, 2006.); chicken (Onwudike, 1986, 1988; Farias-Filho *et al.*, 2006); and in swine (Rhule, 1996; Gómez, Benavides and Diaz, 2007.).

Embrapa Amazônia Oriental, in partnership with the Universidade Federal do Pará, embarked on a research project (PROFAMA, 2008) that evaluated the performance of collared peccaries bred in captivity on diets of oil palm kernel cake as an alternative feed source. Animal performances (daily weight gain and daily feed intake), the characteristics of the carcass and the non-carcass components were observed, and the bacterial microbiota in the gastro-intestinal tract of these animals was studied.

Forty male animals were used, aged between 8 and 10 months, in their final growth phase and weighing an average of 13.20 kg. During the experiment, the animals received varying levels of oil palm cake (T1 = 0% cake; T2 = 7.5% cake; T3 = 15% cake; and T4 = 22.5% cake). The proximate analysis of the feed is shown in Table 8, and the nutritional analysis in Table 9.

At the end of each experimental phase, the animals were slaughtered to evaluate the effects of the feed utilized on the carcass and non-carcass characteristics (gammon and carcass dressing percentage, head, hide, blood, feet, carcass length, organs and glands, and commercial cuts) and live weight and fasting weight.

The results observed in the feed with the inclusion of oil palm cake demonstrated that its use in the diet of the collared peccary in an intensive breeding system could be a regional low-cost nutritional component.

Rhule (1996) studied the effect of breed on the growth of swine with varying levels of oil palm cake in the feed, and observed more weight gain in swine than in collared

TABLE 8

Chemical characteristics (percentage basis) of the experimental feed

Ingredient	DM	MM	P	CF	CP	Ca	EE	NDF	ADF	Na
Soy bran[1]	88.1	6.6	0.6	5.92	45.54	0.3	1.4	14.1	7.8	0.1
Maize[1]	87.1	1.3	0.2	1.95	8.57	<0.1	3.5	11.4	3.4	<0.1
Oil palm (cake)[2]	94.9	3.1	–	–	15.70	–	–	83.2	80.3	–
Wheat bran[3]	88.0	5.6	1	9.52	50.63	0.2	3.5	44.3	13.5	<0.1
Meat/bone flour[3]	93.4	25.0	5.0	1.61	59.9	8.6	12.4	–	–	–
Dicalcium phosphate	–	–	18.5	–	–	24.8	–	–	–	–
Calcitic lime	–	–	<0.1	–	–	31.7	–	–	–	–
Salt	–	–	–	–	–	–	–	–	–	39.7

Notes: DM = dry matter; MM = mineral material; P = phosphorus; CF = crude fibre; CP = crude protein, Ca = Calcium; EE = ether extract; NDF = neutral-detergent fibre; ADF = acid-detergent fibre; Na = sodium.

Sources: (1) Rostagno *et al.*, 2000. (2) Unpublished data from Animal Nutrition Laboratory, CENA-USP. (3) Valdares Filho *et al.*, 2006.

TABLE 9

Composition of experimental feeds (on a percentage basis)

Ingredient	Oil palm cake inclusion level			
	0% (control)	7.5%	15%	22.5%
Maize grain	60.2	60.2	60.2	60.2
Palm oil cake	0.0	7.5	15.0	22.5
Wheat bran	31.0	23.5	16.0	8.5
Soy bran 45%	2.5	2.5	2.5	2.5
Meat and bone flour 55%	5.0	5.0	5.0	5.0
Lime	0.5	0.5	0.5	0.5
Vitamin supplement	0.4	0.4	0.4	0.4
Common salt	0.3	0.3	0.3	0.3
Mineral supplement	0.1	0.1	0.1	0.1
Total	100	100	100	100
Calculated values				
SDE (Mcal/kg)	3.05	3.06	3.07	3.07
Crude protein (%)	14.2	14.1	14.0	13.8
NDF (%)	5.7	10.9	16.1	21.3
ADF (%)	19.8	23.0	26.2	29.4
Ca (%)	0.68	0.67	0.66	0.65
Na (%)	0.18	0.18	0.18	0.18
Available P (%)	0.35	0.33	0.31	0.29
Total P (%)	0.66	0.59	0.52	0.45
Total lysine (%)	0.55	0.51	0.46	0.41
Total Methionine+cystine (%)	0.48	0.44	0.40	0.36
Total methionine (%)	0.22	0.21	0.19	0.17
Total threonine (%)	0.48	0.44	0.41	0.37
Total tryptophan (%)	0.13	0.11	0.10	0.08
Fat (%)	3.68	3.43	3.186	2.92

Notes: Values are calculated in accordance with the nutritional demands in basal feed for swine of low genetic potential (Rostagno *et al.*, 2000). SDE = Swine Digestible Energy; NDF = neutral-detergent fibre; ADF = acid-detergent fibre; Ca = calcium; Na = sodium. Vitamin supplementation was (per kg of feed): vitamin A = 625 000 IU; vitamin D_3 = 125 000 IU; vitamin E = 3375 IU; folic acid = 875 mg; biotin = 27.56 mg; choline chloride = 2475 mg; niacin = 4000 mg; pantothenic acid = 2000 mg; thiamine = 175 mg; riboflavin = 550 mg; pyridoxine = 175 mg; vitamin B_{12} = 2800 mg; antioxidant = 200 mg. Mineral supplementation was (per kg of feed): Iron = 22 000 mg; copper = 5000 mg; zinc = 18 750 mg; manganese = 12 500 mg; iodine = 238 mg; selenium = 56.3 mg and cobalt = 116 mg.

Source: Rostagno *et al.*, 2000.

peccaries. The differences observed in the weight gain between the collared peccary and the swine may be related to the physiological metabolism of each species, and genetic improvements.

TABLE 10

Daily weight gain (DWG) and daily feed intake (DFI) of collared peccaries fed with varying inclusion levels of oil palm cake

	Oil palm cake inclusion level			
	0%	7.5%	15%	22%
DWG (g)	38	54	70	28
DFI (g)	452	429	425	455

Source: Projeto PROFAMA 109/2008 FAPESPA/SEDECT/UFPA/Embrapa.

TABLE 11

Characteristics of the carcass and non-carcass components of collared peccaries fed with varying levels of oil palm cake

Parameter	Oil palm cake inclusion percentage			
	0%	7.5%	15%	22.5%
Live weight (kg)	15.05	14.25	16.00	15.3
Fasting weight (kg)	14.45	12.75	15.00	14.65
Dressing percentage (%)	58.4	58.4	56.8	60.4
Gammon dressing percentage (%)	29.7	32.1	31.2	29.8
Carcass length (cm)	56.3	57.0	57.5	61.8
Head (kg)	1.37	1.24	1.45	1.35
Hide (kg)	1.79	1.55	1.83	1.73
Organs and glands (kg)	1.65	1.43	1.36	1.35
Front and hind feet (g)	141	134	138	168
Blood (g)	197	206	205	200
Gammon (kg)	1.35	1.37	1.32	1.46
Ribs (kg)	1.17	1.12	1.34	1.31
Shoulder blade (g)	740	692	813	832

Source: Projeto PROFAMA 109/2008 FAPESPA/SEDECT/UFPA/Embrapa.

The characteristics of the carcass and of the non-carcass components in collared peccaries fed with varying levels of oil palm cake are shown in Table 11. Dressing percentage variations from 56.8 to 60.4 percent were observed. These values are close to those of Silva *et al.* (2002), who observed dressing percentages from 56.9 percent to 59.5 percent when evaluating different levels of diet crude protein, and slightly higher than those reported by Albuquerque (2006), who tested increasing levels of babassu cake (20, 40 and 60 percent) giving dressing percentages of 53.2, 57.8 and 59.4 percent, respectively.

In the captive white-lipped peccary fed with fodder and feed (13 percent of crude protein and 2800 kcal/kg), the average dressing value was 53.8 percent, slightly below that observed in collared peccaries (Ramos *et al.*, 2009), probably related to the different nutritional composition in the diet offered. This fact can be verified in domesticated swine breeds fed with different diets containing oil palm cake and which present distinct dressing percentages (Rhule, 1996; Gómez, Benavides, Diaz, 2007; Oluwafemi and Akpodiete, 2010).

In javelinas (*Sus scrofa*) fed with sugar cane, vegetables and commercial swine feed, dressing percentages were observed similar to those of domestic swine fed with diets containing oil palm cake (Marchiori, 2001), suggesting that this diet supports good animal performance.

The dressing percentages of collared peccaries are similar or better than other free-ranging artiodactyl wild animals, such as: *Lama glama* (Pérez *et al.*, 2000), *Lama guanicoe* (Gonzalez *et al.*, 2004), *Aepyceros melampus* (Hoffman, 2000), *Tragelaphus strepsiceros* (Hoffman *et al.*, 2009), and *Damaliscus dorcas philipsi* (Hoffman, Smith and Muller, 2008).

The gammon dressing percentage (29.7 to 32.1 percent) observed in the collared peccary (Table 11) was close to the values observed by Silva *et al.* (2002) (36.1 percent) and Albuquerque (2006) in the same species. These observations suggest that the inclusion of oil palm cake in the diet does not appear to prejudice collared peccary performance.

The weight of the shoulder blade was similar to that encountered by Albuquerque (2006) feeding varying levels of babassu cake in the diet of the collared peccary (953.3 g with 20 percent; 943.3 g with 40 percent; and 1028.3 g with a level less than 60 percent). These results were higher than those in the capybara, which did not exceed 800 g (Albuquerque, 1993).

The weight of the ribs was lower than that observed by Albuquerque in the same species and similar to those observed in capybara (Albuquerque, 1993).

Study of the bacterial microbiota from the gastro-intestinal tract

The project PROFAMA (2008) evaluated the bacterial population in the gastro-intestinal tract of collared peccaries and studied the adaptation of the bacterial populations with respect to different feed treatments. Microbiological evaluations were carried out on different components of the gastro-intestinal tract of 26 slaughtered collared peccaries.

In the 27 bacterial microbiota isolated, only Gram-negative bacteria were observed, including *Escherichia coli* (85.2 percent), *Shigella* spp. (7.4 percent), *Salmonella* spp. (3.7 percent) and *Klebsiella oxytoca* (3.7 percent). These results are similar to those reported in literature based on isolations of faecal micro-organisms from both domestic and wild animals (Adesiyun *et al.*, 1998; Melville *et al.*, 2004; Marinho, Meireles and Souza, 2004; Oliveira *et al.*, 2009).

TABLE 12
Gram-positive and Gram-negative bacteria (percentage) isolated post-slaughter from the gastro-intestinal tract of 26 collared peccaries

Bacterial species	Pre-stomach	Stomach	Intestine
Corynebacterium spp.	10	6.2	9.0
Escherichia coli	40	71.4	58.8
Klebsiella oxytoca	20	9.5	11
Klebsiella pneumoniae	10	0	0
Micrococcus spp.	90	56.2	63.6
Salmonella spp.	10	4.7	5.8
Serratia spp.	0	0	11.7
Shigella spp.	10	0	0
Staphylococcus spp.	0	25	18.8
Streptococcus spp.	0	12.5	9.0
Yersinia enterocolitica	10	14.2	11.7

Source: Projeto PROFAMA 109/2008 FAPESPA/SEDECT/UFPA/Embrapa

Eighty-five isolated bacterial microbiota were obtained, including 20 samples (23.5 percent) from the pre-stomach, 37 samples (43.5 percent) from the stomach, and 28 samples (32.9 percent) from the intestine.

Some of the genera and bacterial species identified are similar to those reported in swine (Jensen, 2001). Of these, *Lactobacillus* spp., *Streptococcus* spp., *Clostridium* spp., *Eubacterium* spp., *Fusobacterium* spp., *Bacterioides* spp. and *Peptostreptococcus* spp. are those most frequently isolated.

Some bacteria, namely *Clostridium perfringens*, *Salmonella* spp., *E. coli*, *Klebsiella* spp., *Campylobacter* spp. and *Pseudomonas aeruginosa* are etiologic agents responsible for enteritis in various animal species, including humans. Despite finding these highly pathogenic micro-organisms, the experimental animals did not present symptoms suggestive of gastro-enteritis.

Irrespective of the treatments the animals received, the results demonstrate that this does not affect the presence or frequency of the bacteria isolated from the gastro-intestinal tract of the collared peccary in captivity, with the majority of isolations having *E. coli* as part of the normal microbiota. It has become necessary to institute strict feed handling procedures to maintain the integrity of the gastrointestinal system in order to prevent diseases and to reinforce food safety measures.

KNOWLEDGE GAPS AND FUTURE RESEARCH NEEDS

In addition to the collared peccary, it is important to develop further studies on the captive management of other non-domestic neo-tropical animals of commercial interest, such as white-lipped peccary (*Tayassu pecari*), capybaras

(*Hydrochoerus hydrochaeris*), paca (*Cuniculus paca*), agouti (*Dasyprocta* spp.), broad-snouted caiman (*Cayman latirostris*), yacare caiman (*Caiman yacare*) and greater rhea (*Rhea americana*).

In order to make intensive neo-tropical animal production systems viable for those wild species that may be of economic importance, and for their sustainability and conservation, it will be necessary to study alternative feed resources, such as those already studied with the domestic species. This should be done with feed resources deriving from the agro-processing co-products of cassava, fruits and oil palms. To this could be added sugar cane forage, as suggested by Archimede and Garcia (2010), as this could provide a sustainable feed supply.

CONCLUSIONS

- Babassu cake substitution for maize as an energy source up to a level of 40 percent was a success in feed for collared peccaries in the terminal phase.
- Babassu cake, used to replace up to 40 percent of maize, obtained good results with respect to dressing percentage and commercial cuts of collared peccaries slaughtered at the terminal phase.
- Oil palm cake can be used to replace wheat bran as an energy source in feed for collared peccaries at the terminal phase.
- Oil palm cake used to replace wheat bran gave satisfactory results with respect to dressing percentage and commercial cuts of collared peccaries slaughtered at the terminal phase.

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