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Bacteriological, physicochemical, and sensory characteristics of collared peccary sausages (*Pecari tajacu*) with added dietary fibers

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Abstract

Collared peccary (*Pecari tajacu*) is a wild animal, which the meat presents high levels of proteins and unsaturated fatty acids that enable the development of innovative healthier food products. In this study, fresh sausages of collared peccary meat were developed with claimed functional appeal due to the addition of dietary fibers. The fresh sausages were prepared using a standard formulation (SF) without the addition of dietary fibers, and four other formulations containing oat (OF), wheat (WF), cassava (CF), and a mixture of the three fibers (OWCF). Both the collared peccary meats and the sausages were in accordance with the bacteriological limits established by the Brazilian law. The palette and ham meat presented around 6.7-7.0% of total lipids and 20.96% of total proteins, while in the sausages these values varied from 19.7-24.1% of total lipids and ≈15.5% of total proteins. SF and OWCF sausages were the most accepted among consumers, with acceptance index of 87% for both sausages, and purchase intention above 4 (scale from 1 to 5). Therefore, the use of collared peccary meat, to prepare fresh sausages with dietary fiber addition, can be seen as a promising innovative alternative to provide a healthier protein-containing food with pleasing sensory characteristics.

Keywords: wild meat; fresh sausage; oat fiber; wheat fiber; cassava fiber.

Practical Application: Sausages of collared peccary meat with added dietary fibers can be seen as innovative and promising healthy food products for both the subsistence consumption and gastronomic markets.

1 Introduction

The demand for protein-containing foods is increasing due to human population growth, economic improvement, and urbanization. Offering meat from various sources provides consumers with affordable meat products, generates revenue for the industry, and reduces wastes during processing (Warren et al., 2020).

In this context, wild meat is an essential nutritional source in human evolutionary history and across cultures (Saadoun & Cabrera, 2008; Cawthorn & Hoffman, 2016) and makes up 20–70% of all protein intake in the diet of millions of people around the world where domestic meat is scarce, particularly in isolated tropical forest regions (Fa et al., 2015). Brazil has several wild species that are bred for commercial purposes, including capybara (*Hydrochoerus hydrochaeris*) (Nogueira-Filho et al., 2013) and paca (*Cuniculus paca*) (Correia et al., 2016). In central Amazonia (Amazonas State, Brazil), most wild meat was reported as bought in local markets (80%) or hunted by a family member (≈15%), which the annual consumption was estimated in 10,691 t (equivalent of 6.49 kg per person per year) (El Bizri et al., 2020). The biology and zootechnical aspects of these animals (i.e., reproduction, behavior, health, and nutrition) are being studied, and some of them have satisfactory production rates, including the collared peccary (*Pecari tajacu*) (Albuquerque et al., 2016).

Collared peccary is a widely distributed species in a variety of habitats from the southern USA through the Amazon basin and currently listed as "Least Concern" in the International Union for Conservation of Nature and Natural Resources (IUCN) (Gongora et al., 2011). In Northern Brazil (Amazonia biome), collared peccary are often hunt for subsistence consumption, but in other regions of Brazil, such as São Paulo (Southeast), its meat is sold as exotic meat for gastronomic preparations.

Although very few data are available regarding the chemical composition of collared peccary, its meat has technological potential based on its noted levels of total proteins (21%) and low total lipids (1%), which are composed by oleic (28–37%), linoleic (13–22%), linolenic (0.2-0.6%) and palmitic (21–24%) acids (ω-6/ ω-3 = 37.9–60.0), as well as lower cholesterol levels (48.8%) than meats from other ruminants (Freire et al., 2000; Lopes et al., 2007; Saadoun & Cabrera, 2008). Ham meat from collared peccaries fed diets with different levels of babassu meal (*Orbignya phalerata*) have high content of unsaturated fatty acids, especially polyunsaturated (22–26%), which reduce cholesterol levels when added to human foods (Albuquerque et al., 2009).

Concerning to this issue, food technologies are being used to develop new and innovative products. One strategy for encouraging meat consumption, including from wild animals

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(Chakanya et al., 2018), is the production of fresh sausages, one of the most commonly manufactured meat products in Brazil (Santos et al., 2015), which was not approached yet for the meat of collared peccary. In this case, the addition of dietary fibers is expected to improve the nutritional value of these type of meat products (Deuri et al., 2016). Therefore, the main objective of this innovative study was to propose the enhancement of fresh sausages of collared peccary, adding selected dietary fibers, oat (*Avena sativa*), wheat (*Triticum spp.*), and cassava (*Manihot esculenta*), as a technological alternative to stimulate consumption. In specific, we focused on: 1) bacteriological quality, 2) physicochemical characteristics, and 3) sensory evaluations of collared peccary meat.

2 Materials and methods

Four carcasses of collared peccary (*P. tajacu*) were donated from the experimental breeding farm (LO 10054/2016-SEMAS) of EMBRAPA Easter Amazon (Belém, Pará, Brazil). Two females and two males between 18 and 21 months old, showed an average weight of 14.8 kg, yielding a total of 7.9 kg of palette and 14.9 kg of ham. The animals were maintained in a collective paddock of 36 m^2, at ambient temperatures, humidity, and light-dark cycles. Water was offered *ad libitum*, and the diet was based on elephant grass (*Pennisetum purpureum*) and swine ration (2500 kcal and 14% crude protein/animal/day) (Albuquerque et al., 2016).

Slaughter processing was carried out in accordance with most procedures adopted for small animals, according to (Albuquerque et al., 2016), within the norms of the Ministry of the Environment and the Ministry of Agriculture.

This project was carried out according to the National Council for the Control of Animal Experimentation, and was approved for the use of collared peccary carcasses by the Ethics Committee on the Use of Animals of the Federal University of Pará (Process No. 21159.000808/2018-09).

2.1 Formulation and preparation of fresh sausages

In the formulation of fresh sausages, a 1:1 mixture of palette:ham (w/w) of collared peccary was used. In this study, five types of fresh sausage were elaborated: a standard formulation without the addition of fibers (SF); four different formulations containing 3% oat (OF), wheat (WF), or cassava (CF) fiber, or a mixture of the three fibers: oat + wheat + cassava (OWCF) (Table 1). Fibers and other ingredients were purchased from the local market in Belém, Pará, Brazil. The formulations elaborated in this study were adapted from the literature based on fresh swine sausages (Teixeira et al., 2012), and the fiber percentage was adjusted to 3% such that the sausage portion was considered a "food source of fiber," according to current Brazilian legislation (Brasil, 2012).

For the production of fresh sausages, the meat samples were ground in a meat grinder (PRD-0856, MALTAMIX, Caxias do Sul, RS, Brazil) until reaching a diameter of approximately 5 mm, before adding water and ice for complete homogenization. Then, all other ingredients were mixed and added to the previously homogenized meat for further maturation of the fresh sausage for 30 min at 5 °C for flavor enhancement. The products were embedded individually in an electric sausage stuffer (VF80/165-1, Handtmann, Biberach, Germany), in edible collagen casings (19 gauge), and tied in 10 cm segments with final weights of 50 g.

2.2 Bacteriological analysis of collared peccary meat and fresh sausages

The bacteriological characterization was performed on the ham, palettes, and fresh sausages. Each sample was analyzed in triplicate and compared with the standards required by current legislation (Brasil, 2001). The following bacteria were investigated, according to Downes & Ito (2001): coliform counts at 35 °C and 45 °C, coagulase-positive *Staphylococci*, mesophilic bacteria, and *Salmonella*.

Table 1. Formulations of collared peccary (*Pecari tajacu*) fresh sausages, with and without the addition of dietary fibers.

Ingredients (%)	SF	OF	WF	CF	OWCF
Collared collared peccary meat	73.96	75.96	75.96	75.96	75.96
Swine bacon	18	8	8	8	8
Cold water/ice	3	8	8	8	8
Refined salt	1	1	1	1	1
Herbs and spices	0.305	0.305	0.305	0.305	0.305
Brown sugar	0.5	0.5	0.5	0.5	0.5
Sodium monoglutamate	0.085	0.085	0.085	0.085	0.085
Sausage condiment	2.8	2.8	2.8	2.8	2.8
Sodium erythorbate	0.05	0.05	0.05	0.05	0.05
Sodium tripolyphosphate	0.3	0.3	0.3	0.3	0.3
Oat fiber	0	3	0	0	1.0
Wheat fiber	0	0	3	0	1.0
Cassava fiber	0	0	0	3	1.0
Total	100	100	100	100	100

SF = Standard formulation; OF = formulation with oat fiber; WT = formulation with wheat fiber; CF = formulation with cassava fiber; OWCF = formulation with oat, wheat and cassava fibers. Formulations adapted from Teixeira et al. (2012).

Sample preparation

Two representative portions of the sample were aseptically weighed, one homogenized portion of sterile buffered peptone for pre-enrichment of *Salmonella sp* and the other portion homogenized with saline solution, from which decimal dilutions were carried out, which were also used in the other analyses. Analyzes were performed in triplicate.

Determination of the most probable number (MPN) of Coliforms at 45 °C and 35 °C

The multiple tube technique was used. Lauryl Sulfate Tryptose broth was used as a presumptive medium with incubation at 35 °C – 37 °C for 48 h. After reading, the positive tubes were subcultured into *Escherichia coli* broth (EC) for confirmatory testing, and incubated at 45 °C in a water bath for 24 hours. For analysis of coliforms at 35 °C, after reading, the positive tubes were subcultured to the green broth (VB), for confirmatory test, and incubated at 35 °C. The determination of NMP, of coliforms at 45 °C and coliforms at 35 °C, was carried out with the aid of the Hoskins table.

Coagulase Positive Staphylococcus Count

The surface seeding technique was used on the surface of Baird-Park Agar in triplicate. After inoculation at 36 °C for 48 h, the characteristic *Staphylococcus* colonies were enumerated and submitted to the coagulase test. Results were expressed in colony forming units (CFU/g).

Search for Salmonella sp.

For this analysis, the sample was pre-enriched in sterile Buffered Peptone and transferred to Rappaport-Vassiliadis Broth and Tetrathionate Broth, being incubated at 43 °C for 24 h. The isolation of typical colonies was performed by seeding them on a surface on Xylose Lysine Deoxycholate Agar (XLD) and Bright Green Agar (BGA), with incubation at 36 °C for 24 h. Typical colonies were confirmed by biochemical tests using Three Sugars Iron Agar (TSI), Lysine-Iron Agar (LIA), Urea Broth and Simmons Citrate Agar and serological test (polyvalent O and H serum).

Mesophilic bacteria count

The diluted sample was transferred to plates containing Plate Count Agar, where they were incubated in an oven at 36 °C for 48 h. Analyzes were carried out in triplicate and the results were expressed in CFU/mL.

2.3 Physicochemical analysis of collared peccary meat and fresh sausages

Proximate composition and total energy value

The proximate composition of the meat and fresh sausages was determined using moisture analysis (method 952.08), crude protein (conversion factor of 6.25 total nitrogen to total protein), ash (muffle incineration at 550 °C, method 938.08), and total lipids (Soxhlet method, using petroleum ether as solvent), according to Association of Official Analytical Chemists (2000). The methodology described in Brasil (2003) was used for the values of total carbohydrates, which determines the calculation by the difference between 100% and the sum of the percentages of moisture, ash, lipids, and proteins. The total energy value (kcal/100 g) was calculated according to the Atwater coefficients (carbohydrates: 4 kcal/g, protein: 4 kcal/g, and fat: 9 kcal/g) (Brasil, 2003). Determinations were performed in triplicate, and the results (g/100 g or %) were expressed as means and standard deviations.

Color

Instrumental color determination was performed using the CIELAB system with a portable colorimeter (Model CR-300, Konica Minolta, Sensing, Inc. Osaka, Japan), according to the following parameters: diffuse illumination, included specular, 2° observer angle, and illuminant D65. The color parameters were obtained using the CIELAB system: L^* (brightness), the color coordinates a^* (red to green) and b^* (yellow to blue), chroma (C^*_{ab}) (Equation 1), and the chromatic hue angle ($h°_{ab}$) (Equation 2):

$$C^*_{ab} = \sqrt{\left(a^*\right)^2 + \left(b^*\right)^2} \quad (1)$$

$$h^{\circ}_{ab} = \arctan\left(\frac{b^*}{a^*}\right), \text{ when } +a^* \text{ and } +b^* \text{ (first quadrant)} \quad (2)$$

pH determination

The pH values were obtained directly using a Hanna Instruments digital potentiometer (model HI9321), previously calibrated with buffer solutions of pH 7.0 and 4.0, according to the method 981.12 of Association of Official Analytical Chemists (2000).

Water activity (A_w)

The determination of A_w was carried out through direct reading in a digital thermo-hygrometer (Decagon, Aqualab, 3TE Series, model TE 8063), with internal temperature control (~25 °C).

Water retention capacity (WRC)

WRC was determined according to the methodology adapted from Hamm (1961). Each 2.5 g sample was placed between two circular filter papers of 5.5 cm in diameter, 200 μm thick, and 80 g/m^2. The samples and filter papers were placed between two square polyurethane plates, and a 5 kg weight was placed on this system for five minutes. The pressure exerted on the sample was uniform throughout its area. Subsequently, the sample and papers were weighed, and the results were expressed as percentages.

2.4 Sensory evaluation of the sausages

The sensory evaluation of the developed sausages was carried out with the approval of the Research Ethics Committee of the Federal University of Pará (CAAE 99005018.8.0000.0018) and all participants provided written informed consent. The fresh sausages were roasted at 180 °C in a preheated oven (Gourmet Grill, Fisher, Santa Catarina, Brazil) for 10 min and the samples were cut into pieces of 1 x 2 x 2 cm^2 (height, width, and length).

Two affective tests were applied: acceptance test on a nine-point hedonic scale structured (ranging from "liked very much" – score 9 to "disliked very much" – score 1) and a purchase intention test with a five-point structured scale (ranging from "definitely would buy" – score 5 and "definitely would not buy" – score 1) (Associação Brasileira de Normas Técnicas, 2016).

We randomly recruited 112 untrained participants of both genders, with no age restriction, who were potential sausage consumers; they received coded samples of the roasted sausages, at 65 °C, in an individual cabin equipped with white light (Sensory Analysis Laboratory). Because both affective tests were applied to rate the overall impression of each type of sausage, the acceptability index (AI) was calculated using Equation 3, as suggested by Minim (2013).

$$AI\,(\%) = \frac{A_m \times 100}{B} \quad (3)$$

where Am = mean score obtained for the sausages and B = maximum score that the product may be rated (score 9 in the acceptance test and score 5 in the purchase intention test).

2.5 Statistical analysis

All analyses were performed in triplicate, the results were expressed as mean and standard deviation, and the analysis of variance was performed using the Statistica Kernel Release 7.1 software (StatSoft Inc. 2006, Tulsa, USA). The comparison of means was performed using the Tukey test ($p < 0.05$), and a probability value lower than 0.05 was considered significant ($p < 0.05$).

For the sensory analysis data, the least significant difference was calculated for the differences between means. When this difference is greater than or equal to the least significant difference value, the means differed statistically from each other (Dutcosky, 2013).

3 Results and discussion

3.1 Bacteriological characterization of collared peccary meat and fresh sausages

The results of the bacteriological characterization performed on fresh meat (palette and ham) and collared peccary sausage formulations are shown in Table 2. All samples were according to current legislation (Brasil, 2001). The microorganisms found at the highest concentrations were mesophiles. The absence of *Salmonella* was found in 25 g samples. For coagulase-positive *Staphylococci*, all values were below the limit (10^2 colony-forming units [CFU]/g). Results for coliforms at 35 °C and 45 °C were below 10^2 most probable number [MPN]/g. The mesophilic count showed a value of 1.3 x 10^2 CFU/g in all samples. Thus, the results are as established standards by RDC Nº 12 of January 12, 2001 (Brasil, 2001).

The International Commission on Microbiological Specification for Foods (International Commission on Microbiological Specification for Foods, 2005) sets the limit of 7.0 x 10^2 log CFU/g for standard counting on aerobic microorganism plates. Therefore, results of the present work showed that the values were below the limit. Although, Brazilian legislation does not set limits for mesophilic microorganisms, high populations can reduce shelf life and causes health risks (Kirschnik & Viegas, 2004). In this sense, low values for these microorganisms are acceptable. It should be mentioned that, the values for mesophiles observed in this work are below that those reported for Tuscan sausages (5 x 10^1; Silva et al., 2014).

Grammenos et al. (2020) stated that pathogenic microorganisms could be found when there is a deficiency in handling, such as inadequate temperatures and lack of hygiene, which was not found in the present study. As observed in the literature, Sarkis, (2002) evaluated the bacteriological conditions of fresh meat from wild animals in the city of São Paulo-Brazil. These authors found in collared peccary commercial meat higher values of mesophilic (3.60 x 10^3 to 1.51 x 10^6) and *Staphylococcus aureus* (6.67 x 10^1 to 4.30 x 10^3), than those observed in the present study. This finding can be explained by a deficiency in adopting good practices when handling the carcass in the pre-slaughter, slaughter, and post-slaughter stages.

Table 2. Bacteriological evaluation of the palette, ham meat, and fresh sausage of collared peccary (*Pecari tajacu*).

Samples	*Salmonella spp.*	*Estafilococos coagulase positiva* (CFU/g)	Coliforms at 35 °C (MPN/g)	Coliforms at 45 °C (MPN/g)	Mesophiles count (CFU/g)
Palette	Absence/25 g	< 1.3 x 10^1	2.1 x 10^1	2.3 x 10^1	1.3 x 10^2
Ham	Absence /25 g	< 1.3 x 10^1	2.3 x 10^1	2.3 x 10^1	1.3 x 10^2
SF	Absence /25 g	< 1.3 x 10^1	2.2 x 10^1	2.0 x 10^1	1.3 x 10^2
OF	Absence /25 g	< 1.1 x 10^1	2.3 x 10^1	2.3 x 10^1	1.3 x 10^2
WF	Absence /25 g	< 1.3 x 10^1	2.1 x 10^1	1.9 x 10^1	1.3 x 10^2
CF	Absence /25 g	< 1.1 x 10^1	2.0 x 10^1	2.3 x 10^1	1.3 x 10^2
OWCF	Absence /25 g	< 1.2 x 10^1	2.0 x 10^1	2.1 x 10^1	1.3 x 10^2
Legislation limits*	Absence /25 g	3 x 10^3	5.0 x 10^2	10^4	Not established

CFU = Colony-Forming Unit. MPN = Most Probable Number. SF = Standard formulation; OF = formulation with oat fiber; WT = formulation with wheat fiber; CF = formulation with cassava fiber; OWCF = formulation with oat, wheat and cassava fibers. *Brasil (2001).

3.2 Physicochemical analysis and instrumental color

Table 3 shows the results of the physicochemical analyses and instrumental color for fresh meat (palette and ham) and collared peccary sausages. A significant difference was observed between fresh meat (palette and ham) and all sausage formulations in moisture, total protein, and water activity. However, no significant difference was observed for the same analyses between the fiber-added formulations.

Regarding the moisture value of the palette (70.02%) and ham (70.83%), the results were close to those documented by the current legislation that determines a maximum moisture of 70% for fresh meats (Brasil, 2001). In contrast, the moisture contents for all sausage formulations ranging from 56.02% to 58.19%. The high index established for the moisture content in animal proteins is related to the sensory attributes of the meat such as juiciness, texture, color, and flavor. In addition, to the conservation and eventual processes that the meat undergoes, such as maturation, freezing, among others (Pitombo et al., 2013; Cruz et al., 2016).

Lipid contents of 6.73% and 7.01% were found for the palette and ham cuts, respectively. Lopes et al. (2007) affirmed that collared peccary meat has an excellent lipid profile due to the presence of unsaturated fatty acids, making this source compelling for consumers who seek healthier alternatives compared to others beef, without losing its excellent sensory characteristics. In comparison with another wild animal, Lui et al. (2007) determined a value of 2.80% of lipids for wild boar meat (*Sus scrofa*). Bragagnolo & Rodriguez-Amaya (2002) found a lipid content of 5% for the swine palette and ham, and Lopes et al. (2012) found content of 2.10% of lipids in the palette of lambs.

Factors such as animal feeding conditions, liver metabolism, and intestinal absorption directly influence the quantity and quality of lipids stored in tissues (Berchielli et al., 2011). Age and sex also influence the lipid profile, as concluded by Menezes et al. (2009), and the females are more predisposed to fat accumulation. In addition, very young animals may have more tender, succulent, and flavorful meat, because they have not yet completed the intramuscular fat deposition.

The present work results showed that the lipid observed in the SF sausages range from 19.74% to 24.12%, and are according to the standard values for fresh sausage (30%) (Brasil, 2000). We found mean values of total protein of 20.96% for fresh meat (palette and ham) and 15.51% for the sausage formulations. This high protein content increases the emulsifying power and WRC, making the sausage more succulent (Choe et al., 2013).

There was no significant difference in the ash contents for the palette (0.91%) and the ham (0.89%), and the various formulations (2.12% to 4.12%). These results were lower than that found by Jardim et al. (2003), i.e., 1.18% in the palette and ham of the capybara. These differences can be explained by the animal handling, as diet influences the composition and quality of the meat.

The content of total carbohydrates observed in the palette (0.86%) and ham (0.95%) comply with the standards of legislation (1%) (Brasil, 2001). The carbohydrate content in meat is directly related to the glycogen reserve, which is primarily influenced by the animal stress at the time of slaughter, causing a reduction in the sugar content (Damodaran et al., 2007). The standard sausage formulation (SF) had a lower carbohydrate content (1.53%) than those added with fiber, because oats, wheat, and cassava have substantial carbohydrate content.

The ham and palette cuts had pHs of 6.01% and 6.16%, respectively, following the Regulation of Industrial and Sanitary Inspection of Animal Products (Brasil, 2017). This regulation determines that the average of pH meat rage 6.0 to 6.4 are considered suitable for consumption, as it suggests that there was an appropriate rigor mortis process, promoting the transformation of muscle into the meat.

Table 3. Physicochemical parameters and instrumental color for palette, ham meat and the fresh sausage formulations.

Parameters	Palette	Ham	SF	OF	WF	CF	OWCF
Moisture (%)	70.02 ± 0.68^{a}	70.83 ± 0.42^{a}	56.02 ± 0.41^{b}	57.16 ± 0.71^{b}	58.19 ± 1.20^{b}	57.18 ± 0.37^{b}	57.02 ± 0.86^{b}
Total proteins (%)	21.79 ± 0.30^{a}	20.13 ± 0.52^{a}	16.21 ± 1.12^{b}	16.02 ± 0.81^{b}	15.43 ± 0.98^{b}	15.10 ± 0.11^{b}	16.98 ± 0.32^{b}
Total lipids (%)	6.73 ± 0.69^{d}	7.01 ± 0.87^{d}	24.12 ± 0.91^{a}	21.12 ± 0.76^{bc}	20.31 ± 1.04^{bc}	21.98 ± 0.45^{b}	19.74 ± 0.66^{c}
Ashes (%)	0.91 ± 0.22^{b}	0.89 ± 0.04^{b}	2.12 ± 0.11^{a}	2.81 ± 0.55^{a}	3.71 ± 0.91^{a}	3.74 ± 1.01^{a}	4.12 ± 0.93^{a}
Total carbohydrates (%)	0.86 ± 0.45^{c}	0.95 ± 0.63^{c}	1.53 ± 0.52^{b}	2.89 ± 0.04^{a}	2.36 ± 0.61^{ab}	2.00 ± 0.31^{ab}	2.14 ± 0.24^{ab}
TEV (kcal/100g)	151	147	284.6	265.72	253.95	265.5	254.14
pH	6.16 ± 0.91^{a}	6.01 ± 0.85^{a}	6.13 ± 0.83^{a}	6.17 ± 0.17^{a}	6.19 ± 0.43^{a}	6.29 ± 0.51^{a}	6.13 ± 0.70^{a}
Water activity (A_w)	0.97 ± 0.01^{a}	0.99 ± 0.01^{a}	0.919 ± 0.12^{b}	0.899 ± 1.07^{b}	0.881 ± 0.49^{b}	0.902 ± 0.57^{b}	0.907 ± 1.02^{b}
WRC (%)	79.12 ± 0.61^{c}	78.49 ± 0.92^{c}	82.32 ± 1.28^{b}	89.43 ± 2.02^{a}	87.33 ± 1.35^{a}	90.32 ± 0.83^{a}	88.02 ± 1.11^{a}
Instrumental color							
L^*	48.12 ± 0.03^{b}	51.81 ± 0.43^{a}	45.54 ± 0.24^{c}	48.73 ± 0.12^{b}	50.11 ± 0.73^{a}	49.77 ± 0.76^{b}	52.12 ± 0.91^{a}
a^*	12.75 ± 0.98^{a}	11.95 ± 0.38^{a}	13.32 ± 0.72^{a}	12.45 ± 0.55^{a}	12.99 ± 0.09^{a}	12.01 ± 0.64^{a}	12.77 ± 0.92^{a}
b^*	9.95 ± 0.21^{a}	8.95 ± 0.65^{a}	9.33 ± 0.76^{a}	9.70 ± 0.99^{a}	10.02 ± 0.74^{a}	9.39 ± 1.12^{a}	9.32 ± 0.37^{a}
C^*_{ab}	16.17 ±0.01^{b}	14.93 ±0.01^{c}	16.26 ±0.03^{a}	15.78 ±0.07^{b}	16.41 ±0.05^{a}	15.25 ±0.05^{b}	15.81 ±0.05^{b}
h°_{ab}	52.03 ±0.02^{b}	53.17 ±0.02^{b}	54.99 ±0.05^{a}	52.08 ±0.07^{b}	52.35 ±0.05^{b}	51.98 ±0.05^{c}	53.88 ±0.05^{b}

Results expressed as mean ± standard deviation (wet basis). TEV = total energy value (kcal/100 g). WRC = water retention capacity (%). SF = Standard formulation; OF = formulation with oat fiber; WT = formulation with wheat fiber; CF = formulation with cassava fiber; OWCF = formulation with oat, wheat and cassava fibers. Superscript letters on the same line showed no significant difference ($p < 0.05$).

The pH also is an important parameter for the sensory characteristics and WRC after slaughter because the meat continues a biochemical process. Among other transformations, the pH of the meat decreases due to the formation of lactic acid. After slaughtered animal has a pH between 6.9 and 7.2. The rate of decline is very rapid, and can compromise the final characteristics of the meat in terms of water retention, leaving the meat with a soft, pale, and exudative aspect (Pearce et al., 2011; Guerrero et al., 2013).

Water activity (A_w) is an essential indicator in assessing the growth of microorganisms, as it represents the amount of water available for microbial reactions, making food susceptible to deterioration. We found values of 0.97% and 0.99% for the palette and ham, respectively, similar to those documented by Fernandes et al. (2015) for the same species (0.96% and 0.98%, respectively). These high values show that meat products are susceptible to microbial activity, even when exposed suitable conditions; therefore, handling with controlled steps of sanitization, storage, packaging, and transport, is required.

The WRC of the palette (79.12%) and ham (78.49%) observed in this study were similar to that was reported by Fernandes et al. (2015) for the fresh meat (79.10%) of collared peccary. Albuquerque et al. (2009) analyzed the meat properties and fatty acid profile of the ham of collared peccaries fed with babassu (*Orbignya phalerata*) and found lower WRC values (59–63%). These authors related this result to the diet offer the collared peccary (with a high lipid content), that directly influenced the proximate composition of the meat of these animals. The fat present in meat is a determining characteristic for the yield of the product at the time of consumption, and can be influenced by several factors, including sex, weight, age, race, nutrition, and pre- and post-slaughter conditions, among others (Silva et al., 2008).

Concerning sausages with added fibers (OF, WF, CF, and OWCF), these presented higher WRC than the standard formulation (SF). This fact is probably due to the greater WRC of these components, which influences the reduction of syneresis and dehydration of foods with added fiber, improving sensory aspects such as texture.

Color is an essential attribute in evaluating meat quality and decision-making at the time of purchase by consumers (Guerrero et al., 2013). This aspect may be associated with muscle fibers, the oxidation state of myoglobin, and hemoglobin pigments in the animal's blood. Feeding, pH, and amount of intramuscular fat also exert influences on color (Gao et al., 2014; Sañudo et al., 2013).

We found significant differences in the value of L^* (brightness) for the palette (48.12%) and ham (51.81%) of the collared peccary, values higher than those found by Fernandes et al. (2015), 42.08%. Higher L^* values indicate paler meats; however, even the consumer assumes that more colored and shiny meats are associated with young animals and softer meat, the color is also a cultural issue according to the region (Mancini & Hunt, 2005; Realini et al., 2013). It should also be emphasized that other characteristics influence the meat color, including the glycogen reserve at the time of slaughter, making it difficult to obtain low pH values to produce typical colors (Jacob & Pethick, 2014).

Regarding the parameter a^*, which indicates the tendency to the reddish coloration, a value of 12.75% and 11.95% was found for the palette and ham, respectively. Meats with high a^* values, when associated with lower luminosity values, have more reddish colors (Page et al., 2001). In contrast, the b^* parameter indicates the tendency to yellow coloration, which may be related to fat in the meat, and the values found were 9.95% for palette and 8.85% for ham. Possibly, the low values of the parameter b^* in collared peccary represent the low-fat content observed in wild meat. Concerning sausages, there was a significant difference for the formulations only in the L^* parameter, the OF, WF and CF showed the highest lightness value (52.12%).

The color intensity (C^*_{ab}) and the chromatic hue angle ($h°_{ab}$) were similar for fresh meat and sausages. These values are directly related to the concentration and structure of myoglobin, which, in turn, are influenced by *ante mortem* factors, such as the species, sex, and age of the animal. Furthermore, it is necessary to consider *post mortem* factors, such as temperature and pH (Mancini & Hunt, 2005; Cruz et al., 2016). As mentioned earlier, pre-slaughter stress causes a reduction in muscle glycogen and pH, and increases the concentration of deoxygenated myoglobin, resulting in darker meat (Cruz et al., 2016).

3.3 Effect of formulation on acceptability and purchase intention of sausages

The acceptability and purchase intention test for fresh sausages can be seen in Table 4.

Regarding the aroma, the notes were similar to the matured collared meat (Fernandes, 2012). Concerning color, only the formulation with CF had less acceptance, even though it did not show a significant difference concerning instrumental color (Table 3). Regarding flavor, the tasters attributed a higher score to the formulation with OF due to affective memory and declaring that they were regular consumers of oat. The scores of the SF and FT were identical, reinforcing the findings of Borrajo et al. (2016), who reported wheat as a "neutral" flavor, causing no significant difference for sausage formulations. The tasters reported that sausages with fiber from oat, wheat, and cassava increased the texture hardness, reducing the scores.

In general, the sausages had good sensory acceptance, considering the results attributed to the sensory parameters of aroma, color, flavor, and texture for all samples (mostly above 7). A similar result was observed by Demartini et al. (2018), who studied consumer preferences for red deer meat (*Cervus elaphus*), using a scale from 1 to 6, and in order of importance, participants signaled that the meat was tasty (4.70), had good nutritional properties (4.61), and safe for consumption (4.51).

All formulations had a high overall impression index (77–87%). However, the OWCF sausage had the highest average of the attributes analyzed (85.42%) and the highest purchase intention (4.35; scale from 1 to 5). In contrast, the formulation prepared with oats (OF) had the lowest purchase intention (2.79; scale from 1 to 5).

Table 4. Acceptability and purchase intention tests of collared peccary (*Pecari tajacu*) fresh sausages.

	Sensory attributes*					
	Aroma	Color	Taste	Texture	Global impression	Purchase intention
SF	**7.75^{A}**	**7.65^{A}**	**7.24^{B}**	**7.68^{A}**	**7.84^{A}**	**4.19^{A}**
AI (%)	86.11	85.00	80.44	85.33	87.11	
OF	**7.68^{A}**	**7.39^{A}**	**7.91^{A}**	**7.13^{B}**	**7.41^{B}**	**2.79^{C}**
AI (%)	85.33	82.11	87.89	79.22	82.33	
WF	**7.06^{B}**	**7.61^{A}**	**7.24^{B}**	**6.95^{B}**	**7.22^{B}**	**2.88^{C}**
AI (%)	78.44	84.56	80.44	77.22	80.22	
CF	**6.89^{B}**	**7.13^{B}**	**7.04^{B}**	**7.22^{B}**	**6.98^{B}**	**3.62^{B}**
AI (%)	76.56	79.22	78.22	80.22	77.56	
OWCF	**7.87^{A}**	**7.69^{A}**	**7.43^{B}**	**7.62^{A}**	**7.83^{A}**	**4.35^{A}**
AI (%)	87.44	85.44	82.56	84.67	87.00	

*Analysis of Variance (ANOVA) and Minimum Significant Difference test (MSD), where the same letters in the same column do not show significant MSD ($p < 0.05$). SF= Standard formulation; OF = formulation with oat fiber; WT = formulation with wheat fiber; CF = formulation with cassava fiber; OWCF = formulation with oat, wheat and cassava fibers; AI = Acceptance Index.

4 Conclusion

This is the first study that evaluated the technological potential of collared peccary meat to produce fresh sausage, and the entire process were carried out according to good manufacturing practices to ensure the microbiological safety. In addition, this product has high added value and healthy appeal, and the possibility of application in the food industry, as present an excellent sensory characteristics and good consumer acceptance.

The sausage containing 1% oat, wheat, and cassava flour (OWCF) obtained acceptance equivalent to the sausage without added fiber (SF), for the attributes of flavor, texture, and overall impression. Thus, we suggest using this percentage of oat, wheat, and cassava flour to prepare fresh sausage. It should be emphasized that these results are important due to the potential use of cassava in the State of Pará, one of Brazil's largest producers. Especially to traditional agriculture, which can generate income for rural communities.

The results obtained showed favorable characteristics to produce fresh sausages from wild meat. This work also serves as a basis for future studies of fresh sausages, testing new ingredients and formulations, allied to the potential market research of the product.

Conflict of interest

The authors declare no conflicts of interest.

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