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Nutritional properties of spectacled caiman (*Caiman yacare*) meat marketed as part of a wildlife management strategy in the Beni river basin

Propiedades nutricionales de la carne de yacare (*Caiman yacare*) comercializada en el marco de una estrategia de manejo de la fauna silvestre en la cuenca del río Beni

SHORT COMMUNICATION / NOTA CIENTÍFICA

Gustavo ALVAREZ[1*], Guido MIRANDA-CHUMACERO[1], José Luis MOLLERICONA[1], Rodolfo NALLAR[2], Robert B. WALLACE[1]

[1] Wildlife Conservation Society, Bolivia Program.
[2] Animalab, Santa Cruz de la Sierra, Bolivia.

*Corresponding author: galvarez@wcs.org

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ABSTRACT

We determined the nutritional quality of yacare meat (*Caiman yacare*) in the Beni river basin. Commercial cut samples were obtained from the tails of four males harvested as part of a management plan implemented in the Tacana Indigenous Territory. This plan guarantees long-term sustainability of caiman hunting. pH analysis, the Eber test, and the ammoniacal nitrogen test suggest that the meat was of good quality, processed properly, and free of contamination. Nutritional analyses suggest that yacare meat is a healthy alternative for human consumption, as it has a high protein value (23.02 g/100g) and low fat concentration (0.67g/100g). Yacare meat has a high concentration of minerals such as phosphorus (227.53 g) and calcium (11.84 g), both beneficial for memory and cardiovascular health. Caiman meat can be considered as a valuable nutritional supplement in human diets both in urban and rural areas

Keywords: Wildlife, sustainable management, proteins, minerals

RESUMEN

Para caracterizar las cualidades nutricionales de la carne de lagarto (*Caimán yacare*) en la cuenca del río Beni, se obtuvieron muestras de corte comercial de las colas de cuatro lagartos machos cosechados en el marco de un Plan de Manejo implementado por el Pueblo Indígena Tacana (TCO Tacana). El análisis de pH, la prueba de Eber y la prueba de nitrógeno amoniacal sugieren que la carne era de buena calidad para el consumo, procesada adecuadamente y libre de contaminación. Los análisis nutricionales nos permiten concluir que la carne de yacaré es una alternativa saludable para el consumo humano, ya que tiene un alto valor proteínico (23,02 g / 100 g), y una baja concentración de grasa (0,67 g / 100 g). La carne de yacaré tiene una alta concentración de minerales como el fósforo (227,53 g) y el calcio (11,84) que son beneficiosos para la memoria y la salud cardiovascular.

Palabras clave: Vida silvestre, manejo sostenible, proteínas, minerales

INTRODUCTION

The lives and traditional knowledge of Indigenous People are inextricably linked to nature and natural resources, reason why they are generally committed to the conservation of wildlife species (Townsend 1996a, Townsend 1996b, WCS/Gustu/AMA 2019). In Bolivia, indigenous people have the right to use sustainably the natural resources within their territories (Martinez 2000).

The yacare caiman is an important ecological component of the Bolivian tropical fauna and has a long history of exploitation by various indigenous communities, as it represents a natural resource of considerable economic value, mainly because of the quality of the leather and meat, and the extraction of products with medicinal properties (Oblitas 1971, Smith 1981, Ergueta & Pacheco 1990, Godshalk *et al.* 1997, Madhu & Mcgowan 2002, Aparicio & Ríos 2005, Tejada et al. 2006, Saadoun & Cabrera 2008, Miranda *et al*. 2010, Garcia & Rojas 2014, Reuter *et al*. 2018, WCS/Gustu/AMA 2019).

The hunting of the yacare (*Caiman yacare*) population became important from the 1970s onwards, after the population declines of black caiman (*Melanosuchus niger*) and Chaco caiman (*Caiman latirostris*) as a result of high hunting pressure (Aparicio 1997). A large percentage of yacare skins on the international market originated in Bolivia (Godshalk *et al*. 1997). However, in 1990, due to population crash of the species, the Bolivian government declared an Indefinite General Ban, prohibiting the commercial exploitation of all wildlife in the country (MDSP-VMARNDF-DGB 2002, Aparicio & Rios 2005).

In 1997, after the verification of population recovery of *Caiman yacare*, Supreme Decree 24774 was promulgated, regulating the exploitation of this species through the "National Program for the Conservation and Sustainable Use of the Yacaré" (PNCASL) (Aparicio 2001, MMAyA 2009), allowing the annual harvesting of approximately 40 000 individuals and the commercialization of their skin for the leather industry.

The implementation of the Program in Bolivia has proven to be feasible and beneficial for the conservation of the species and its habitat, generating economic benefits and the development of local capacities (Méndez *et al.* 2011, Garcia & Rojas 2014, WCS/Gustu/AMA 2019). Currently, most of yacare is exploited for meat, due the collapse of the leather value chain during the pandemics and the loss of markets for leather obtained from wild animals. Yacare is an excellent source of animal protein, and has high digestibility, with low cholesterol values (Romanelli *et al*. 2002).

The Tacana indigenous communities responsibly use their natural resources, including the yacare caiman. The Matusha Aidha Yacare Management Association developed a management plan which was approved and authorized (RM No 175/2007) by the Dirección General de Biodiversidad (DGB) of the Vice Ministry of Environment and Water. The yacare harvesting system is supported by solid monitoring data demonstrating that the wild populations under management are in a good state of conservation (Miranda *et al*. 2010, AMA 2020). This information is key for promoting the consumption of yacare meat among the broader Bolivian population.

To further disseminate to consumers about the benefits of consuming yacaré caiman, it is important to generate information about the nutritional value and composition of the meat. The present study aims to characterize the nutritional and physical-chemical properties of yacaré caiman meat exploited in a wildlife management program in the Tacana Indigenous Territory located in the Beni River basin, and compare the results with the meat of other crocodile species and livestock.

MATERIAL AND METHODS

The samples were collected during the harvest of yacare caiman for leather and meat by the Matusha Aidha Yacare Management Association within the TCO Tacana by the Tacana Indigenous People. Yacare caiman were shot during hunting, and then when retrieved to the boat, bled through a medullary cut at the atlanto-occipital joint at the base of the skull base. The hunted caiman were transferred from the lagoons to a mobile artisan slaughterhouse implemented on the shore of each lagoon. At the slaughterhouse, the yacare caiman meat (tail and loin) was extracted using hygiene and handling best practices established by SENASAG for the use of yacare meat (R.A. No. 0135/2018). Four meat samples of 300 g from tail cuts were taken at eight hours post-mortem, two from the southern management zone (San Buenaventura Municipality) and two from the northern management zone (Ixiamas Municipality) that belong to the Beni river basin. The samples were stored in airtight plastic bags for food use and kept at a temperature of-18 ºC. The caiman meat was transported from the harvesting site to the nearby urban population in a freezer at a temperature below 0 ºC, controlling the temperature with a Hanna puncture thermometer. The samples were then shipped to the city in a thermal box with ice inside at a ratio of 2 kg of ice/1kg of meat. The samples were transported by air (flight time of 35 min) and then taken to the laboratory for analysis.

To determine the physical, chemical and nutritional composition of yacare meat, the samples were taken to the National Institute of Health Laboratories (INLASA) to the Food Chemistry laboratory and to the Nutrition and Sensory Analysis laboratory of the Ministry of Health. The laboratories performed a proximal physical, chemical and nutritional analysis according to the methods of the American Association of Analytical Chemistry (AOAC). The analyses carried out were for pH, Ammoniacal Nitrogen (NB 311004-2001), Eber test "sulfidic gas" (NB 378-1997), Calcium (AOAC 944.03), Phosphorus (AOAC 995.11), Iron (AOAC 944.02), Fat (AOAC 963.15), Protein (AOAC 960.52), Vitamin A (AOAC 974.29), Moisture (AOAC 925.10), Ash (AOAC 923.03), Carbon H. (calculations), energy value (calculations).

RESULTS

Laboratory results showed that the pH varied between 5.92 and 6.83, with a mean of 6.07 (+/- 0.41). The ammoniacal nitrogen values were between 0.14 - 0.69 mg / 100 g, with a mean of 0.41 mg / 100g (+/- 0.25). For the Eber "sulfidic gas" test, the results for all four samples were zero.

The yacare meat showed the following nutritional composition: moisture content 71.5%, protein 23.02%, minerals 4.72% and fat 0.67% (Table 1, Figure 1). Moisture content varied between 68.5% and 76.8%, with an average of 71.5% (+/- 2.6). Protein values varied between 22.73 and 23.29 g, with a mean of 23.02 (+/- 0.23). Fat content varied between 0.25 and 1.64 g, with a mean of 0.67 (+/- 0.64) g.

Amongst the minerals (Table 1, Figures 1 and 2), phosphorus had values of between 216.1 and 233.8 mg, with a mean of 227.5 (+/- 7.83) mg. Calcium varied between 11.61 and 12.05 mg, with a mean of 11.84 (+/- 0.21) mg per 100 g.

TABLE 1. Nutritional composition per 100 g of yacare meat (*Caiman yacare*) and other meat types. a) TCO Tacana I (present study); b) Bolivian Food Composition Table (2005) Bolivian Ministry of Health and Sport; c) Carvajal (2001); d) Maldonado *et al*. (2009); e) Mamani-Linares (2014)

Composition	Type of meat	Yacare (a)	Cow (b)	Chicken (c)	Pig (c)	Pacú (d)	Pintado (d)	Sábalo (d)	Alpaca (e)	Flame (e)
Macrominerals	Calcium (mg)	11.8	5.4	4.1	8.0	37.1	18.1	33.4	------	------
	Phosphorus (mg)	227.5	183.4	161.2	210.0	169.5	------	220.0	------	------
Microminerals	Iron (mg)	1.4	3.7	0.7	1.1	8.5	3.1	7.6	------	------
Nutritional values	Fat (g)	0.7	2.6	7.8	2.3	4.5	2.1	1.5	2.1	1.6

Composition	Type of meat	Yacare (a)	Cow (b)	Chicken (c)	Pig (c)	Pacú (d)	Pintado (d)	Sábalo (d)	Alpaca (e)	Flame (e)
	Protein (g)	23.0	20.2	19.7	20.0	17.2	17.8	17.7	22.7	23.9
	Vitamin A (Ug)	5.3	------	------	------	------	------	------	------	------
	Humidity (%)	71.5	75.4	69.5	69.8	77.3	78.9	79.7	74.1	73.3
	Ash	1.3	------	1.2	0.9	1.4	1.2	1.3	1.2	11.2
	Carbon H	3.5	------	------	------	<0.1	------	<0.1	------	------
	Energy value (Kcal)	112.3	200.0	170.0	275.0	107.3	90.0	84.1	------	------

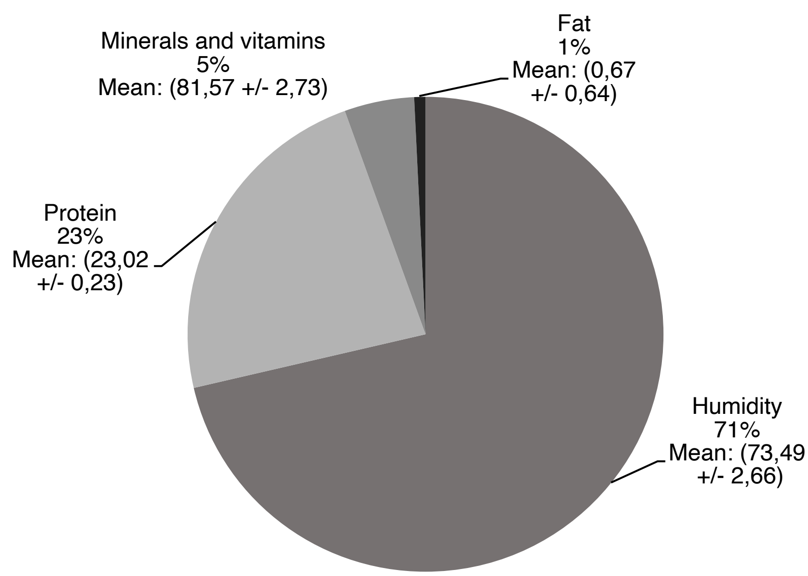

FIGURE 1. Nutritional composition of yacare (*Caiman yacare*) meat harvested from the Beni river basin.

DISCUSSION

The meat studied had a pH between 5.92 - 6.83, which is similar to the meat of *Caiman crocodilus yacare* (pH 5.8; Canto et al. 2015) and *Caiman latirostris* (pH 5.7; Simoncini 2020). This may be due to the concentration of muscle glycogen at the time of slaughter, which has a great influence on biochemical post mortem relationships, determining meat quality (Saadoun & Cabrera 2008). The amount of glycogen is related to the pH of the muscle, which is inversely related to the amount of lactic acid formed. The characteristics and properties of meat depend on the rate of decrease in pH over time (Saadoun & Cabrera 2008). Pre-slaughter stress causes a sudden drop in pH (Taboga *et al*. 2003).

The yacare meat harvested in the Tacana Indigenous Territory was processed within 8 hours after animal death, as defined in the Technical Regulation for the Use of Yacare Meat (SENASAG 2018). Therefore, pH values should not drop below 6.4 after 12 hours, 6.2 after 24 hours, and 5.8 after 36 hours (Taboga *et al*. 2003).

C. crocodrilus yacare (Canto *et al*. 2015) and *C. latirostris* (Simoncini 2020) samples were taken 24 hours after the animal was sacrificed (Varela *et al.* 2011).

Other factors that can influence pH values are stress prior to slaughter that causes a sudden drop in pH (Taboga *et al.* 2003), the time from when the animal was killed until the sample was taken (Aparicio & Rios 2005), and the cooling time of the meat. The characteristics and properties of meat depend on the rate of pH decrease over time (Saadoun & Cabrera 2008). If pH values are acidic, they delay the oxidation of meat, which helps maintain a fresh and rancid-free flavor for a longer time (Lawless 1991) The pH has a direct and indirect influence on flavor, tenderness and color (Honikel *et al*. 1980, Hoffman & Romanelli 1998).

The determination of ammoniacal nitrogen indicates the deterioration of the food product, and is a food safety indicator. The ammoniacal nitrogen values found in the present study are below permitted maximum parameters 125 mg/100g (IBNORCA 1997). Therefore, the harvested meat is free of contamination and of “good quality”, being optimal for human consumption. The Eber test allows the detection of ammonia due to putrefaction. Values of zero mean that the meat was processed properly and promptly, and was free of decomposition, and suitable for human consumption.

The results of the nutritional analyses of C. yacare meat highlight the low amount of fat, higher amount of protein, and concentration of phosphorus and calcium compared to other meats consumed in the traditional market (Table 1, Figures 1 and 2). The high concentration of these two minerals is necessary for the formation of bones and teeth (Carvajal 2001). It is also beneficial for memory, mood, digestion, kidneys, hormone production, heart rate normalization, protein production and enzyme activation (Lim & Kleisus 2000, Moreno *et al*. 2000, Valencia *et al.* 2013, De Smet & Vossen 2016). These mineral concentrations have an impact on meat quality, appearance, texture and stability (De Smet & Vossen 2016).

The amount of protein found in yacare meat in the present study (23.02 g) is higher than previously reported for *C. yacare* (21.8 g; Romanelli & Felicio 1999), *Melanosuchus niger* (19.23 g; Kluczkovski *et al*. 2015), *Alligator mississippiensis* (18.4 g; Thayer *et al*. 1996), and *C. latirostris* in captivity (16.9 g; Cossu *et al*. 2007). However, care should be paid when comparing the results of the present study with crocodilian species bred in captivity with controlled feeding and environmental conditions (Vicente *et al.* 2007). The protein content (23.02 g/100 g) in yacare meat is higher than beef, pork, chicken and three species of Amazonian fish: pintado (*Pseudoplatystoma fasciatum*), sábalo (*Prochilodus nigricans*) and pacú (*Piaractus brachypomus*).

The higher concentration of proteins in *C. yacare* meat compared to other meats may be due to different factors such as the sequences of essential amino acids present, the spatial configuration adopted by those sequences, the combination of complete or incomplete proteins, metabolism and biological value (Gonzales-Torrez *et al*. 2007, Diógenes 2013). The profile of amino acids in *C. yacare* meat from the Pantanal included the presence of aspartic acid, glutamic acid, serine, glycine, histidine, arginine, threonine, alanine, proline, tyrosine, valine, methionine, cystine, isoleucine, leucine, phenylalanine, taurine, lysine and tryptophan (Amorin *et al*. 2017).

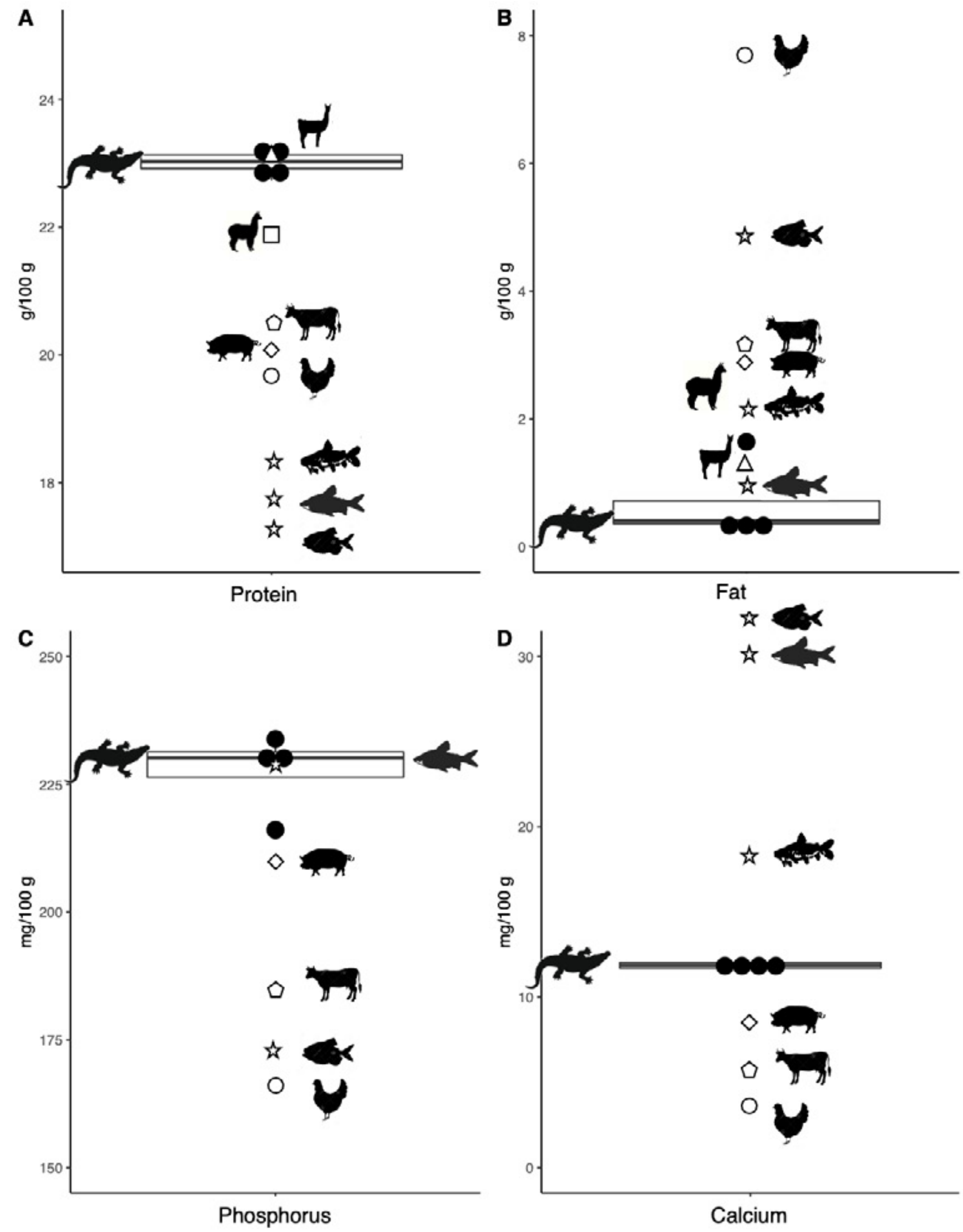

FIGURE 2. Comparison of the main nutritional values (protein, fat, phosphorus and calcium content) found in yacare meat and beef, chicken, pork and Amazonian fish. a) TCO Tacana I; b) Bolivian Food Composition Table (2005) Bolivian Ministry of Health and Sport; c) Carvajal (2001); d) Maldonado *et al*. (2009); e) Mamani-Linares (2014)

The *C. yacare* meat from the TCO Tacana had an average humidity value of 71.5%, which is less than the values reported in the Pantanal for *Caiman crocodilus yacare* (74.48%; Romanelli & Felicio 1999) and *C. yacare* (76.75%; Varela *et al*. 2011). It is also lower than the humidity percentage in other crocodile species, respectively, C. latirostris (77.4%; Simoncini *et al.* 2020), M. niger (78.17%; Kluczkovski *et al*. 2015), and Alligator mississippiensis (73.6%; Thayer *et al*. 1996). Moisture content in animals is related to age, since as animals develop and grow, their bodies generate a high concentration of protein and fat in their muscles (Forrest *et al.* 1979, Miller *et al*. 1986, Vicente-Neto *et al*. 2010), as found for *C. yacare* (Romanelli & Felicio 1995). The yacare meat evaluated in the present study was from wild adult males greater than 180 cm (= 7-10 years old), so these samples had a low amount of humidity, as compared to captive bred *C. yacare* juveniles (14 - 26 months old) (Vicente *et al*. 2007).

Comparing humidity values between traditionally consumed meats, the highest values are for Amazonian fish sábalo (*Prochilodus nigricans*), pintado (*Pseudoplatystoma fasciatum*) and pacú (*Piaractus brachypomus*) (Maldonado *et al*. 2009), followed by beef (Ministerio de Salud y Deportes de Bolivia 2005), C. yacare, and finally pork and poultry (Carvajal 2001).

Ash content is a measure of the total mineral present in a food (Carvajal 2001). The ash value for the yacare meat in the present study (1.25%) is similar to other traditionally consumed meats. In the Pantanal, the ash values found for C. yacare in two studies varied from 1.02 to 1.08% (Romanelli & Felicio 1995), and 0.95 to 1.17% (Vicente *et al.* 2007). For the American crocodile, averages of 1 to 1.5% are reported (Moody *et al*. 1980). Increases in the percentage ash value are observed in various animal species, and vary according to growth, as well as variations in exertions in their natural habitat, and consequently their metabolic requirement (Forrest *et al*. 1979).

In the present study, the fat content for C. yacare was lower than in other types of meat, such as beef and pork, and Amazonian river fish such as sábaló (Prochilodus nigricans), pintado (*Pseudoplatystoma fasciatum*) and pacú (*Piaractus brachypomus*). The meat with the highest fat content was chicken. Similar results were reported in Brasil (Vicente *et al*. 2006, Vicente *et al.* 2007) and Argentina (Martens 2010), with the quality of yacare meat superior to alternative meats.

The fat content of wildlife species is lower (< 2%) as compared to domestic species (Sinclair & Odea 1990). Fat is the most variable chemical component in the meat of most species (Williams *et al*. 1983). Fat deposition is determined by the balance of energy intake versus expenditure, metabolic requirements, and the types of muscle fiber (Eriksson & Pickova 2007, Vicente-Neto 2010).

Variations in the amount of water in meat are directly related to variations in the amount of fat. The higher the fat content, the lower the water content, because fat tissue has little or no moisture (Carvajal 2001). The amount of water varies between 68 and 73% and is related to juiciness and sensory attributes such as texture and color. The average content (by weight) of the meat was 71% water, 23% protein, 0.76% fat and 4.72% minerals. Further work is needed to evaluate nutritional parameters including essential amino acids and fatty acids.

We conclude that the yacare meat is a healthy alternative for human consumption due to its overall nutritional benefits, low-fat content which benefits cardiovascular health, and high protein value. The high phosphorus concentrations are also notable, as this mineral is essential in a balanced diet due mainly to its contribution to essential amino acids. It would be important to analyze in the future the fatty acid profile of the yacare meat harvested in the Beni river basin. Fatty acids are beneficial to human health, playing an important role in the prevention of cardiovascular diseases, colon cancer and immunological diseases, as well as being important for the development of the brain and retina (Castro-Gonzales 2002, Hoffman 2008).

We conclude that caiman meat can be considered a nutritional supplement in human diets, both in urban and rural areas. Moreover, the consumption of yacare meat under a responsible wildlife management regime, avoiding overharvesting, supports the conservation of the species and its habitat. The sustainable harvesting of yacare strengthens indigenous territorial management, generates economic benefits through the consolidation of a productive initiative and provides social benefits to Indigenous People.

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