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Impact of bushmeat consumption on health risk management in Southern Benin

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The consumption of bushmeat has been linked to several socioeconomic factors. This study examines bushmeat consumers in southern Benin, including their motivations, health risks, and groups. In the Littoral, Atlantique, and Zou districts, 373 people were surveyed. The data were analyzed with R 4.0.2 and SAS 2013 software, and as a result, 74.3% reported consuming bushmeat. Few hunters and transformers were in Group 1, but many were in Group 2. Group 1 consisted of hunters, processors, and restaurant owners, whereas Group 2 was mostly illiterate. Bushmeat is eaten for its taste, nutritional value, and economic and cultural reasons, with many believing it is healthier than domestic meat. Group 1 and Group 2 consume bushmeat frequently and live in peri-urban and rural locations near woods for easy access to bush animals. Group 3, which eats bushmeat rarely, is less involved in the supply chain of bushmeat. Due to poor transit and processing conditions, bushmeat hunting, processing, and consumption in these places expose people to pathogens and increase the risk of food poisoning and zoonotic diseases. Education of local residents is necessary to improve food safety and reduce health concerns. Diversifying income, promoting safer, more sustainable practices, and encouraging rural youth education require supportive policies. To improve Benin's food security and public health, this study stresses bushmeat consumers' motivations.

Key words: Bushmeat, food security, consumption, zoonoses, Benin.

INTRODUCTION

Bushmeat hunting, trade, and consumption are growing biodiversity and food security concerns (van Velden et al., 2018). Bushmeat is consumed for a variety of reasons, despite the risks involved. Bushmeat trade and consumption have been reported in Africa (Bannor et al., 2022; Ahouanse et al., 2023; Sackey et al., 2023; Gaubert et al., 2024). The consumption of bushmeat has been associated with socioeconomic factors, including increased food insecurity, demographic changes, low cost in rural areas (compared with other meat products), cultural practices, taste preferences, perceived medicinal value, and prestige (Katani et al., 2019; Dell et al., 2020). A significant decline in bushmeat consumption has been observed in recent years, and this trend has been attributed to zoonotic crises, biodiversity degradation, urbanization, and cultural changes (Djagoun et al., 2018;

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Foya et al., 2023; Gaubert et al., 2024). However, the preference for bushmeat has not truly shifted, and it continues to be consumed in rural areas and by certain social classes (Wilkie et al., 2016; Ordaz-Németh et al., 2017; Codjia et al., 2021; Funk et al., 2022; Amponsah et al., 2024).

In Benin, bushmeat is consumed throughout the country. In southern Benin, the main source of bushmeat is the Lama classified forest, which abounds in a wide variety of flora and fauna and crosses two major districts in southern Benin: Atlantique and Zou (Codjia and Assogbadjo, 2004; Djagoun et al., 2018). Most of the people living near the forest are farmers, but they also hunt to meet their needs. Despite the various restrictions on the harvesting of certain species in this forest, hunting is still a daily activity for these populations because of the cultural weight and the high demand for bushmeat from major towns (Djagoun et al., 2018; Chabi-Boni et al., 2019; Vodouhe et al., 2024). These populations consume hunted meats, which they also sell in surrounding towns. This situation of prohibited hunting is at the root of the degradation of the Lama classified forest, but this degradation is also linked to the uncontrolled exploitation of floral resources (Agbahoungba et al., 2019; Djagoun et al., 2022).

On the other hand, wildlife and bushmeat are frequently linked to the transmission of zoonotic illnesses such as COVID-19, Ebola, monkeypox, and Lassa (Funk et al., 2022; Izah et al., 2022; Suraka et al., 2024). Hunting and the preparation of bushmeat have been associated with a high risk of spreading pathogens (Foya et al., 2023; Jagadesh et al., 2023). Indeed, the methods of catching bush animals, processing meat, and consuming meat are implicated in food health risks because they are unregulated and carried out under unsuitable conditions, exposing those who handle bushmeat to various difficult-to-control public health problems (Degla et al., 2017; Ahmadi et al., 2019; Ahouanse et al., 2024). In Benin, zoonotic crises such as Lassa fever and COVID-19 have led to the organization of awareness campaigns and restrictions on the consumption of bushmeat, although these efforts ceased after critical periods (Attinsounon et al., 2018; Yessinou et al., 2020; Maccaro et al., 2022; Gaubert et al., 2024). However, few studies have examined the link between the consumption of these meats and zoonotic risk in the country (Nago et al., 2021; Djagoun et al., 2023; Vodouhe et al., 2024). Understanding the behaviors and perceptions of populations regarding bushmeat and zoonotic diseases is essential for anticipating and better managing these crises. Although these issues are of growing importance, there is a significant gap in knowledge concerning bushmeat consumption and processing practices in local communities, and in-depth studies are needed to shed light on the health and environmental implications.

Sustainable regulation of wildlife hunting and the promotion of safer processing and consumption practices are imperative to protect public health and biodiversity. Wildlife management policies must strike a balance between the need to preserve natural resources and the food security and livelihood needs of local communities.

This study aims to provide an in-depth analysis of the behaviors and perceptions of bushmeat consumers in southern Benin, identifying consumer groups, their motivations, and perceived health risks. Understanding these dynamics is crucial for developing effective interventions aimed at improving health safety and promoting more sustainable and safer bushmeat consumption. By highlighting differences between consumer groups, this study will help implement targeted strategies to reduce health risks and preserve biodiversity while taking into account local socioeconomic realities.

MATERIALS AND METHODS

Study area

The Republic of Benin is located in West Africa. Benin has 12 districts and 77 municipalities. Alibori and Atakora districts are in the north, Borgou and Donga districts are in the north-central area, and Collines district is in the south-central area. Zou, Mono, Plateau, Couffo, Atlantique, Littoral, and Ouémé districts are in the south. The northern and central regions have a tropical climate, with a dry season from October to April and a rainy season from May to September. The climate in southern Benin is equatorial, with two dry seasons (November-March and mid-July-mid-September) followed by two rainy seasons (April-mid-July and mid-September-October).

This study was carried out in three districts. These districts were the districts of Atlantique and Littoral in southern Benin and Zou in central Benin. These three districts were chosen because two of them (Zou and Atlantique) are crossed by one of the largest forests in southern Benin, and the third district has one of the largest urbanized towns in southern Benin, which often receives products from Zou and Atlantique. People in six municipalities and 10 localities were surveyed in the three chosen districts. The districts concerned are Littoral, where only one commune, the town of Cotonou, was covered; it is bounded to the west by the commune of Abomey-Calavi, to the east by the commune of Sémè-Kpodji, to the north by Lake Nokoué, and to the south by the Atlantic Ocean. Atlantique comprises eight municipalities, two of which, Abomey-Calavi and Allada, were visited. The Atlantic Ocean forms the southern boundary of the district. The Atlantique district is bordered to the north by the Zou district and to the east by the Ouémé district. Zou comprises nine municipalities, and the survey took place in the municipalities of Djidja, Abomey, and Zogbodomey. It is bordered to the north by the Collines district, to the south by the Atlantique and Ouémé districts, to the east by the Plateau district, and to the west by Couffo and the Republic of Togo.

Sample size

The study involved questioning 38 people per locality about bushmeat consumption. The sample size was obtained as described by Fisher et al. (1991) via the following formula:

$N = z^2 pq / d^2$

where N= the desired sample size; z = the standard normal deviation, usually set at 1.96, which corresponds to the 95%

confidence level; p = proportion in the target population estimated to have a particular characteristic (which will be approximated to be 0.5, corresponding to the worst case, the largest dispersion); q = 1.0-p; d= degree of accuracy desired set at 0.05.

$N = (1.96)^2 (0.5) (0.5) / 0.05^2 = 384$.

To determine the sample size per city, the sample size (N) was divided into 10 localities (villages or cities), resulting in 38 individuals surveyed per locality. The questionnaire was administered after consent was obtained. Those who gave their consent were asked about their identity, whether they consumed bushmeat, their perception of zoonoses, and their preference for bushmeat.

Inclusion and exclusion criteria

The participants were chosen randomly from localities near Lama Forest and other small forests, localities with bushmeat markets, and cities where most bushmeat is sent for sale at restaurants. In addition, processors and hunters were included in our study population. Villages and towns where bushmeat is not sold or where there are no bushmeat restaurants were excluded.

Ethical considerations

The director of the Department of Food Science and Agro-processing, as well as the director of postgraduate studies at Sokoine University of Agriculture, granted approval for the conduct of the study. Additionally, the Vice Chancellor of Sokoine University of Agriculture issued a clearance letter to introduce the authors to the authorities in Benin to facilitate the research. The researchers informed the participants that all information collected during the study would be treated as confidential. The participants were also informed of the study's objectives and were explicitly made aware that their participation was voluntary, with the option to withdraw from the study at any time. During the fieldwork, the participants were asked to consent to their participation in the study.

Procedure

The study was conducted in the towns and villages surrounding the Lama Forest and other classified forests in southern Benin using purposive sampling methods. The Lama Forest and several smaller classified forests extend across the Zou and Atlantique districts, which together encompass a total of 1,141 villages. We selected villages that surround the Lama Forest and other classified forests, where hunting is prevalent. According to Djagoun et al. (2018), the villages Tègon, Sèhouè, and Massi are located near the Lama Forest. Additionally, Abomey, Agbadagba, and Djidja are also close to the Lama classified forest as well as to smaller classified forests in southern Benin, such as those of Dan and Atchérigbé. Peri-urban localities such as Allada and Zinvié were also included in our research, along with two urban districts, namely, the 11th and the 5th boroughs.

A total of 380 individuals were randomly selected from 10 villages and towns. Thus, in each village and/or town, 38 individuals were interviewed, resulting in a total of 380 respondents. Out of the entire sample size surveyed, 373 were considered for data analysis. Indeed, out of the 380 survey questionnaires, 7 were set aside after decoding due to missing information that participants refused to provide. Therefore, we excluded these seven questionnaires and retained the remaining 373 for analysis. The questionnaire was first used to gather sociodemographic data (ethnic origin, age, and occupation). A food frequency questionnaire (FFQ) was used to collect data on bushmeat consumption over 12 months. The questionnaire provided information on the price of bushmeat, place of purchase, method of meat preservation at the time of purchase, time elapsed between purchase and consumption, methods of meat preservation between purchase and preparation, method of preparation before consumption, perception of zoonoses, and preference for bushmeat.

Statistical analysis

The data collected were analyzed using SAS 2013 software (SAS Institute Inc., Cary, NC, USA) and R version 4.0.2. For the typology of bushmeat consumers, the MCA (Multiple Correspondence Analysis) function in R's FactoMineR library was used for multiple correspondence analysis (MCA) (Husson et al., 2016). The variables considered in the correspondence analysis included education level, marital status, respondents' religions, respondents' profiles (simple consumer, hunter, processor), reasons for bushmeat consumption, species consumed, preferred forms of preparation, knowledge of zoonoses, consumption habits in relation to deadly zoonoses (Lassa, Ebola, COVID-19, etc.), and preferred species. The MCA was then followed by hierarchical ascending classification via R's hierarchical clustering on principal components (HCPC) function, which was based on respondents' characteristics from the most important MCA components. Three groups of consumers were identified. These groups were then characterized by testing frequency differences between the three groups with the Chi² test using the SAS PROC FREQ procedure (SAS, 2013) for categorical variables. Two-tailed Z tests were used to compare relative frequencies between groups. For each relative frequency, a 95% confidence interval (CI) was calculated using the following formula:

$$IC = 1,96\sqrt{\frac{[P(1-P)]}{N}}$$

where P is the relative frequency and N is the sample size.

RESULTS AND DISCUSSION

Demographic characteristics of the respondents and Typology of bushmeat consumers

The demographic characteristics of the respondents in the three groups are presented in Table 1. These groups of respondents are referred to as Cluster 1: Group 1 consumers; Cluster 2: Group 2 consumers; and Cluster 3: Group 3 consumers. The demographic characteristics of the respondents are presented in the table in different groups, such as clusters. The majority of respondents were men (61.93%), with no significant difference between the groups. These respondents were from various religious denominations, but the majority were Christians (65.05%) or animists (18.5%), with a significant difference between the groups. Compared with the other groups, Islam was significantly more common (13.59%) among Group 3 consumers, as was animism (9.71%). The vast majority of respondents were married (61.39%), followed by single individuals (33.24%). Compared with those in the other groups, married respondents in Group 3 (41.75%) were in the minority, while singles in Group 3 (50.49%) outnumbered those in

Table 1. Characteristics of survey respondents.

Variable	Total (N=373)		Cluster 1(N=210)		Cluster 2 (N=60)		Cluster 3 (N=103)		Chi² test
	%	CI	%	CI	%	CI	%	CI	
Sex									
Male	61.93[a]	4.93	63.33[a]	6.52	68.33[a]	11.77	55.34[a]	9.60	NS
Female	38.07[b]	4.93	36.67[a]	6.52	31.67[a]	11.77	44.66[a]	9.60	NS
Religion									
Christian	65.05[a]	4.84	65.71[a]	6.42	61.67[a]	12.30	66.02[a]	9.15	NS
Muslim	5.63c	2.34	2.38[b]	2.06	3.33[b]	4.54	13.59[a]	6.62	***
Animist	18.5[b]	3.94	21.43[a]	5.55	23.33[a]	10.70	9.71[b]	5.72	*
Any religion	10.72[b]	3.14	10.48[a]	4.14	11.67[a]	8.12	10.68[a]	5.96	NS
Marital status									
Single	33.24[b]	4.78	30[b]	6.20	15c	9.04	50.49[a]	9.66	***
Maried	61.39[a]	4.94	66.19[a]	6.40	78.33[a]	10.42	41.75[b]	9.52	**
Widow	2.95c	1.72	1.9[a]	1.85	3.33[a]	4.54	4.85[a]	4.15	NS
Cohabitation	1.88cd	1.38	1.43[a]	1.61	3.33[a]	4.54	1.94[a]	2.66	NS
Divorced	0.54d	0.74	0.48[a]	0.93	0[a]	0	0.97[a]	1.89	NS
Education level									
No level	30.56[a]	4.68	31.43[b]	6.28	46.67[a]	12.62	19.42c	7.64	**
Primary	24.4[b]	4.36	26.19[a]	5.95	23.33[a]	10.70	21.36[a]	7.92	NS
Secondary	29.49[ab]	4.63	33.33[a]	6.38	18.33[b]	9.79	28.16[ab]	8.69	*
University	14.21c	3.54	7.62[b]	3.59	10[b]	7.59	30.1[a]	8.86	*
Other	1.34d	1.17	1.43[a]	1.61	1.67[a]	3.24	0.97[a]	1.89	NS
Type of Person									
Consumer	100[a]	0.00	100[a]	0	100[a]	0	100[a]	0	NS
Hunter	6.17[b]	2.45	0.95[b]	1.31	31.67[a]	11.77	1.94[b]	2.66	***
Processor	4.83[b]	2.18	4.29[b]	2.74	13.33[a]	8.60	0.97[b]	1.89	**

N: Respondents; Cluster 1: Group 1 consumers; Cluster 2: Group 2 consumers; Cluster 3: Group 3 consumers; CI: index of confidence; NS: not significant; NS: p>0.01; *, ** and ***: p<0.1, p<0.01 and p<0.001, respectively.

Group 1 (30%), who outnumbered those in Group 2 (15%). The majority of the respondents were uneducated (30.56%), followed by those with secondary education (29.49%) and university education (14.21%). The vast majority of those with no education were Group 2 consumers (46.67%), and the majority of those with secondary education (28.16%) were Group 3 consumers, as were those with university education (30.1%). The respondents were all bushmeat consumers, but a large majority of Group 2 consumers were also hunters compared with the other groups. A large majority of Group 1 consumers were also bushmeat processors (Table 1).

For the typology of bushmeat consumers, three axes were used to interpret the MCA. The three axes represent the variability of the data. The proportion of inertia accounted for by the three axes is 37.47%, with 25.38% attributed to the first axis, 6.68% to the second axis, and 5.41% to the third axis. Each axis was used to describe the type of bushmeat consumed in southern Benin. Figure 2 shows the three groups of consumers (indicated as clusters) formed in space in the two-dimensional plane. Group 1 consumers were described as medium-frequency bushmeat consumers, Group 2 consumers were described as high-frequency bushmeat consumers, and Group 3 consumers were described as rare-frequency bushmeat consumers (Figure 1).

Group 1 consumers: This group consists of bushmeat consumers and a minority of bushmeat processors, the majority of whom consume bushmeat at least once a week but infrequently. Most of them (53.9%) find bushmeat to be of very good quality and buy it in all available forms. They limit their consumption in the event of zoonotic diseases. Compared with the other groups, they have an average level of education and are located in rural and peri-urban areas (Table 2).

Group 2 consumers: This group consists of bushmeat consumers, some of whom are also hunters and processors. The majority (64%) find bushmeat to be of very good quality but generally do not need to buy it

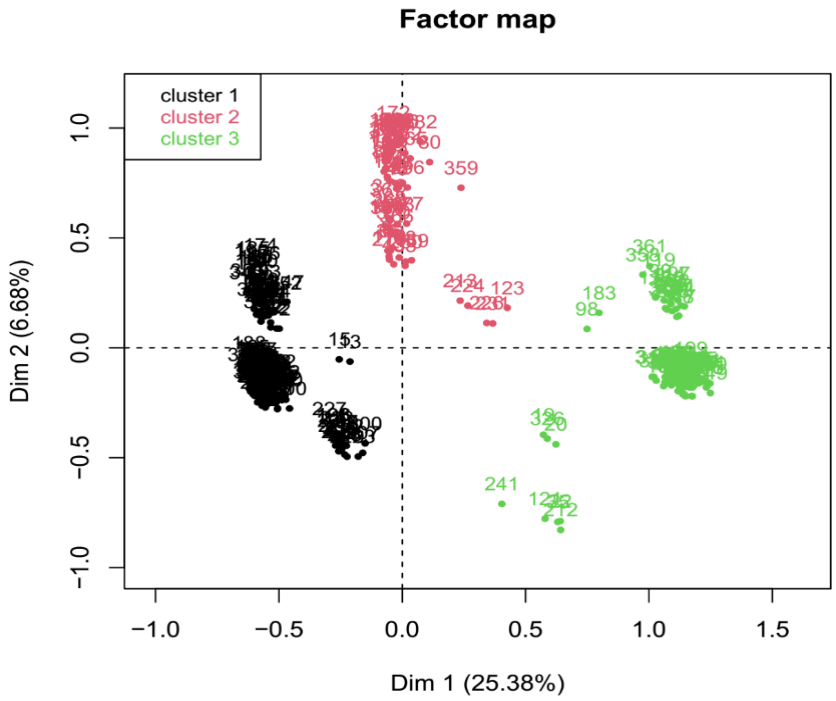

Figure 1. MCA of bushmeat consumer groups in southern Benin.

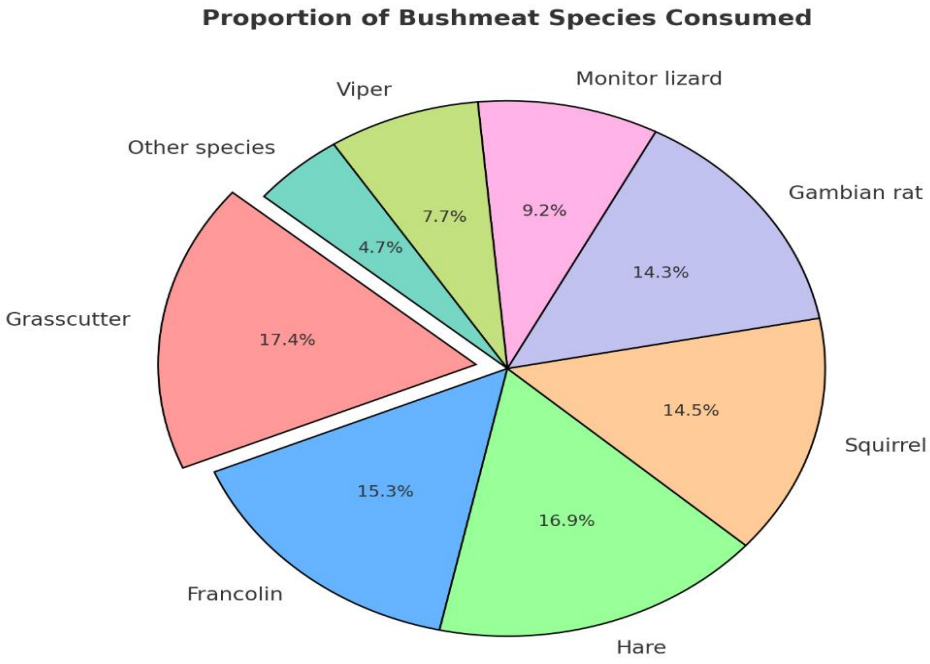

Figure 2. Distribution of bushmeat species consumption among respondents.

before eating it. The majority (50.9%) consume it very often, at least once a week. For them, bushmeat is of very good quality and is also a source of income. These consumers generally have a low level of education, with

Table 2. Consumption Information.

Variable	Total		Cluster 1		Cluster 2		Cluster 3		Chi² test
	%	CI	%	CI	%	CI	%	CI	
Bushmeat consumption									
N	373		210		60		103		
Yes	74.3[a]	4.4	100[a]	0	100[a]	0	6.8b	4.9	***
No	25.7[b]	4.4	0[b]	0	0[b]	0	93.2a	4.9	***
Justification									
N	351		208		56		88		
Best Quality	42.3	5.2	53.9[a]	6.8	64.3[a]	12.1	1.14b	2.2	***
Habits Eating	10.8	3.2	13.9[a]	4.7	16.1[a]	9.6	0b	0.0	***
Bad Quality	3.1	1.8	0[b]	0.0	0[b]	0.0	12.5a	6.9	***
Other reason	46.5	5.2	36.7[b]	6.6	23.21[b]	13.1	86.4a	7.2	***
Eaten 1									
N	373		210		60		103		
Never Eaten	14.8[b]	3.6	0[b]	0	0[b]	0	53.4a	9.6	***
Eaten1	85.3[a]	3.6	100[a]	0	100[a]	0	46.6b	9.6	**
Frequency									
N	269		208		59		2		
By week	34.9[a]	5.7	30.3[b]	6.2	50.9[a]	12.8	50	69.3	**
By month	13.0[b]	4.0	14.4[a]	4.8	8.5[a]	7.1	0	0.0	NS
By year	13.4[b]	4.1	13.9[a]	4.7	11.9[a]	8.3	0	0.0	NS
Rarely	38.7[a]	5.8	41.4	6.7	28.8	11.6	50	69.3	NS
Species Consumed[1]									
N	270		210		60		1		
Blue duiker	35.9[c]	5.7	36.7[a]	6.5	33.3[a]	11.9	0	0	NS
Grasscutter	77.0[a]	5.0	79.1[a]	5.5	70.0[a]	11.6	0	0	NS
Cephalophe	13.3 g	4.1	14.3[a]	4.7	10.0[a]	7.6	0	0	NS
Monitor lizard	40.7[c]	5.9	42.9[a]	6.7	33.3[a]	11.9	0	0	NS
Boa	19.3f	4.7	18.6[a]	5.3	21.7[a]	10.4	0	0	NS
Antilope	28.2[e]	5.4	30.0[a]	6.2	21.7[a]	10.4	0	0	NS
Guib anarché	11.1 g	3.7	12.4[a]	4.5	6.7[a]	6.3	0	0	NS
Francolin	67.4[b]	5.6	69.1[a]	6.3	61.7[a]	12.3	0	0	NS
Viper	34.1[c]	5.7	33.3[a]	6.4	36.7[a]	12.2	0	0	NS
Gambian rat	63.0[b]	5.8	66.2[a]	6.4	51.7[a]	12.6	0	0	NS
Hare	74.8[a]	5.2	77.1[a]	5.7	66.7[a]	11.9	0	0	NS
Genetta	23.3[e]	5.0	24.3[a]	5.8	20.0[a]	10.1	0	0	NS
Cilvette	18.9f	4.7	19.5[a]	5.4	16.7[a]	9.4	0	0	NS
Squirrel	64.1[b]	5.7	65.2[a]	6.4	60.0[a]	12.4	0	0	NS
Cobra	12.6 g	4.0	14.3[a]	4.7	6.7[a]	6.3	0	0	NS
Guinea fowl	28.4d	5.4	31.9[a]	6.3	16.7[a]	9.4	0	0	NS
Other species	20.7f	4.8	19.5[a]	5.4	23.3[a]	10.7	100	0	NS
Paid Form[1]									
N	246		190		54		1		
Fresh	9.8d	3.7	12.1[a]	4.6	1.9[c]	3.6		0	**
Smoked	16.3[c]	4.6	17.4[a]	5.4	13.0[c]	9.0		0	NS
Smoked and dried	8.9d	3.6	9.5[a]	4.2	7.4[c]	7.0		0	NS
Rosted	4.1f	2.5	3.2[a]	2.5	7.4[c]	7.0		0	NS
Boil in soup	4.1f	2.5	4.2[a]	2.9	3.7[c]	5.0		0	NS

Table 2. Contd.

Fried	8.9d	3.6	10.0[a]	4.3	5.6[c]	6.1	0	NS
Unprocessed	48.8[a]	6.2	53.7[a]	7.1	29.6[b]	12.2	100	*
Live (Unslaughted animal)	6.2[e]	3.0	7.9[a]	3.8	0[c]	0	0	*
Not Buy	33.3[b]	5.9	27.4[b]	6.3	55.6[a]	13.3	0	***

N: Respondents; Cluster 1: Group 1 consumers; Cluster 2: Group 2 consumers; Cluster 3: Group 3 consumers; CI: Index of confidence; NS: Not significant; NS: p>0.01; *, ** and ***: p<0.1, p<0.01 and p<0.001 respectively.

the majority being uneducated. They are located in rural and forest environments (Table 2).

Group 3 consumers: A minority (6.8%) of these consumers eat bushmeat, but the vast majority (93.2%) do not. They do not eat bushmeat because of its poor quality and other reasons, such as disease or fear of the Ebola and COVID-19 crises. They are the best educated of the three groups, with higher levels of education. They are located in urban areas (Table 2).

Consumption of bushmeat and reasons for consumption

The results in Table 2 show that bushmeat is consumed by all the respondents in Groups 1 and 2 (100%), but only a small minority of Group 3 consumers (6.8%). The reasons for consuming or not consuming bushmeat vary from one group to another. The vast majority consume bushmeat because of its better quality: Group 1 consumers (53.9%) and Group 2 consumers (64.3%). In contrast, only a minority in Group 3 consumes it (1.14%). Group 3 consumers do not eat much of this meat due to its poor quality (12.5%), whereas the other groups find no disadvantage in eating bushmeat (0%). Group 3 consumers avoid bushmeat for several other reasons, including fear related to the COVID-19 and Ebola crises, availability issues, its high price, and a lack of knowledge about bushmeat. Only respondents in Group 1 (13.9%) and Group 2 (16.1%) consumed bushmeat as a habit. The vast majority of respondents (85.3%) have eaten bushmeat at least once in their lives, with those who have never eaten bushmeat primarily belonging to Group 3 consumers (53.4%).

The frequency of bushmeat consumption varies across the groups. Most respondents consumed bushmeat either weekly (34.9%) or rarely (38.7%), with a smaller percentage consuming it monthly (13%) or annually (13.4%). The majority of weekly consumers are Group 2 consumers (50.9%), while those who consume it rarely are mostly Group 1 consumers (41.4%). Overall, most respondents purchased unprocessed bushmeat (48.8%), followed by those who did not purchase bushmeat (33%), and a smaller group that bought processed bushmeat or live animals (6.2%). The majority of individuals who do not purchase bushmeat belong to Group 2 consumers (55.6%). Conversely, the majority of individuals who buy unprocessed bushmeat belong to Group 1 consumers (53.7%).

The motivations for consuming bushmeat in Groups 1 and 2 include not only perceived organoleptic qualities (such as taste and nutritional value) but also economic and cultural factors. The very few consumers in Group 3 also consume it for its good taste and cultural reasons. The perception of bushmeat's superior quality, both in terms of taste and health, compared with domestic meat, is prevalent, which aligns with findings from Bachand et al. (2015) and Kibenga et al. (2021). However, behind these preferences lie socioeconomic realities such as poverty and the search for additional income, particularly for Groups 1 and 2 consumers. Individuals in these groups often engage in hunting and bushmeat processing, which provides a significant source of income. These consumers in Group 1 live primarily in rural and peri-urban areas, while those in Group 2 live close to the Lama classified forest and smaller forests, thus facilitating access to bush animals and influencing consumption frequency.

Bushmeat consumption frequencies vary considerably across groups: Groups 1 and 2 consume bushmeat frequently, on average once a week and once a month, with many Group 2 consumers eating it even daily. In contrast, Group 3 consumers eat bushmeat infrequently. This suggests that bushmeat consumption is less frequent than domestic meat in urban and peri-urban areas, likely due to its limited availability, purchasing capacity, and education level. Group 3 consumers have a higher level of education and are predominantly younger. Education level and urbanization influence not only consumption frequency but also food choices, as demonstrated in studies by Nielsen et al. (2018) and Luiselli et al. (2020).

Notably, the practice of eating bushmeat varies greatly across continents. For instance, in Asia and South America, bushmeat consumption is often motivated by similar tastes, cultural traditions, and poverty, but the economic implications and legal frameworks differ (Zhou et al., 2021; Nguyen and Jones, 2022; Zhao et al., 2023). Furthermore, highly developed countries in Europe and North America have more modern eating habits and consume little or no bushmeat compared to developing countries in Africa, Asia, and South America. These findings highlight the significant role urbanization plays in

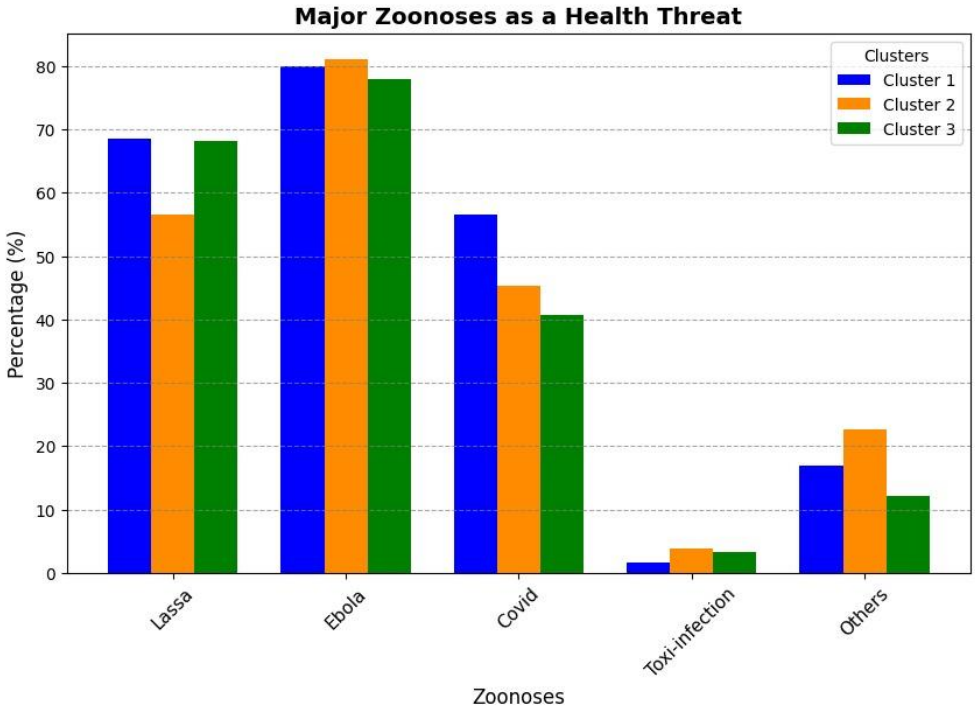

Figure 3. Awareness of major zoonotic diseases among consumer.

consumption, therefore, varies from one environment to another, depending on the level of development and social, economic, and cultural realities (Zhou et al., 2021).

Implications of bushmeat consumption for food security beyond southern Benin

Contributing to local food security

The species consumed as bushmeat were largely consistent across the three groups, with Grasscutter (77%) and Hare (74.8%) being the most commonly consumed, followed by Francolin (67.4%) and Squirrel (64.1%), as shown in Figure 3. Bushmeat is an important source of protein and is highly valued by many people in both rural and urban areas. Group 2 consumers, who consume bushmeat daily and weekly, underscore the nutritional importance of bushmeat, especially in terms of its protein content and other nutrients. This finding is consistent with research from other African countries, including Nigeria, the Congo, and Tanzania (Babalola and Oladipupo, 2018; Lucas et al., 2022; Foya et al., 2023).

The presence of bushmeat hunters and processors in Group 2, along with processors in Group 1, also highlights the economic importance of bushmeat. The local populations living near the classified forests and smaller forests are actively involved in the bushmeat value chain, finding it profitable. These findings align with those of Vodouhe et al. (2024) in southern Benin. Bushmeat is sold both in processed and unprocessed forms, and the inedible parts are often sold to traditional therapists, which provides a significant additional source of income to meet household needs (Nielsen et al., 2017; Evans et al., 2019; McNamara et al., 2019).

In general, all three groups of consumers spoke highly of the exceptional quality and taste of bushmeat, describing it as a source of well-being and an important element of food security. Consumers claim that these meats are very tasty, with exceptional nutritional quality, often being very low in fat. These results align with findings from other studies in Africa (Hoffman 2008; Jama'a et al., 2022).

Regarding the species consumed as bushmeat, there were no significant differences in preferences across the three consumer groups, although smaller species were more popular. Rodents, particularly Grasscutters, were the most consumed species due to their availability. This is consistent with the findings of Duda et al. (2018) in Cameroon. Grasscutter meat is the most commonly consumed bushmeat in the rodent family, which aligns with studies conducted in Benin and other African countries such as Ghana, Nigeria, and Côte d'Ivoire (McNamara et al., 2019; KouadioYéboué et al., 2020; Nago et al., 2021; Amponsah et al., 2024; Umaru et al., 2024).

However, in the Congo, particularly near natural resource extraction companies (gold and timber), the most consumed species are *Cephalophus* and *Atherurus*,

which contrasts with the findings from southern Benin (Kibenga et al., 2021). This highlights the regional variation in bushmeat consumption patterns depending on the local availability of species and cultural preferences.

Overall, this study emphasizes the nutritional and economic value of bushmeat, its role in food security, and its importance in local economies, particularly in rural and peri-urban areas near forests. The species consumed also underscore the cultural and ecological diversity in bushmeat consumption across different regions.

Vulnerability and security risks

Hunting is a significant factor contributing to the destruction of biodiversity, particularly in areas like the Lama Forest in southern Benin, which is one of the most important reserves of flora and fauna in the region. However, anthropogenic activities and uncontrolled hunting are increasingly threatening the sustainability of these vital resources (Nago et al., 2021). The intensive exploitation of these resources by local populations, driven by high demands from urban areas, is a major concern, as discussed by hunters and bushmeat processors in Groups 1 and 2.

The Lama Forest and smaller classified forests in southern Benin are easily accessible to major towns, which exacerbates the pressure on these resources. This situation aligns with the findings of Ikeh et al. (2021), who emphasized that hunting is often most intensive in forest environments close to large cities, where there is a high demand for bushmeat. In this context, consumers from all groups reported the scarcity of meat from large animals such as antelopes, warthogs, and duikers, signaling the overexploitation of these species in the forests of southern Benin. As a result of this heavy hunting pressure in accessible areas, many of these species are retreating to protected areas, like the Lama Classified Forest, to escape hunting. This trend was noted by Djagoun et al. (2018), who revealed that large mammals are increasingly found in protected areas due to the threats posed by unsustainable hunting practices.

The situation suggests a clear need for promoting rational logging practices alongside moderate hunting to ensure the long-term sustainability of both wildlife resources and biodiversity. While it may seem somewhat reassuring that the most commonly consumed bushmeat species are small mammals like rodents (grasscutters, hares, squirrels, giant rats) and small, fast-reproducing birds like francolins, this is not without its ecological implications. These small species are being exploited due to their availability, which points to an underlying degradation of biodiversity. The absence of larger mammals in the forests, where their populations have drastically declined, serves as a stark indicator of the broader environmental issues at play.

Thus, the preference for small animals, although not necessarily linked to endangered species, underscores the unsustainable pressures placed on biodiversity in the region. This situation mirrors findings from Côte d'Ivoire, where similar patterns of hunting small animals due to their availability have been observed (Sikpo et al., 2023). The depletion of large mammal populations and the shift towards small, more abundant species point to the unsustainable exploitation of wildlife in southern Benin, further contributing to the decline in biodiversity in the region.

Consumers' perceptions of zoonotic diseases and food safety

The majority of surveyed respondents (87.9%) were aware of zoonotic diseases. Most had heard of Ebola (79.6%), Lassa (66.5%), or COVID-19 (50.5%). However, only a small minority (2.4%) were aware of the risk of toxiinfections caused by consuming bushmeat (Table 3). Beliefs about the existence of these diseases and the risk of contamination from meat consumption varied among different groups. Notably, individuals with a high level of education (Group 3 consumers) predominantly believed in the risk of contamination through meat consumption. In contrast, Group 1 consumers (46.5%) and Group 2 consumers (40%) primarily did not believe in this risk.

Most respondents had experienced the recent COVID-19 crisis (93.6%). During this period, there was no significant difference between those who stopped consuming bushmeat (48%) and those who continued to consume it despite the risk of COVID-19 (50.4%), with only a small proportion limiting their consumption (Table 3). Reasons for stopping or limiting consumption during the COVID-19 pandemic varied among user groups. Fear was the primary motivator for those who stopped consumption, with most of these individuals belonging to Group 3 consumers (87.7%).

Conversely, those who continued consuming bushmeat cited reasons such as finding it very healthy and seeing no connection between it and COVID-19. Moreover, certain individuals relied solely on bushmeat as their primary source of protein, compelling them to persist in its consumption. The predominant proportion of individuals with this reasoning originated from Group 1 consumers (79.3%) and Group 2 consumers (15.4%). Bushmeat is often described as poor quality, as it is often associated with zoonotic diseases in both humans and domestic animals (Katani et al., 2019). Nevertheless, the majority of consumers in this study found bushmeat much healthier than meat from domestic animals. This finding was also made by Lucas et al. (2022) in Democratic Republic of Congo, and even in cases of illness from wild animals, symptoms were attributed to witchcraft. A study by Amponsah et al. (2024) identified the presence of *Staphylococcus* species, *Arthrobacter*, *Macrococcus*, and

Table 3. Zoonosis perception by consumers.

Variable	Total		Cluster1		Cluster2		Cluster3		Chi² test
	%	CI	%	CI	%	CI	%	CI	
Known Zoonosis									
N	373		210		60		103		
Yes	87.9^{a}	3.3	87.6^{a}	4.5	88.3^{a}	8.1	88.4^{a}	6.2	NS
No	12.1^{b}	3.3	12.4^{a}	4.5	11.7^{a}	8.1	11.7^{a}	6.2	NS
Which do you know?									
N	328		184		53		91		
Lassa	66.5^{b}	5.1	68.5^{a}	6.7	56.6^{a}	13.3	68.1^{a}	9.6	NS
Ebola	79.6^{a}	4.4	79.9^{a}	5.8	81.1^{a}	10.5	78.0^{a}	8.5	NS
Covid	50.3^{c}	5.4	56.5^{a}	7.2	45.3^{ab}	13.4	40.7^{b}	10.1	NS
Toxi-infection	2.4^{c}	1.7	1.6^{a}	1.8	3.8^{a}	5.1	3.3^{a}	3.7	NS
Others	16.5^{a}	4.0	16.9^{a}	5.4	22.6^{a}	11.3	12.1^{a}	6.7	NS
What do you think?									
N	333		187		55		91		
Believe	36.3^{a}	5.2	27.8^{b}	6.4	36.4^{b}	12.7	53.9^{a}	10.2	**
Do not Believe	37.2^{a}	5.2	46.5^{a}	7.1	40.0^{a}	12.9	16.5^{b}	7.6	**
I do not know	26.4^{b}	4.7	25.7^{a}	6.3	23.6^{a}	11.2	29.7^{a}	9.4	NS
Known Covid									
N	373		210		60		103		
Yes	93.6^{a}	2.5	93.8^{a}	3.3	90.0^{a}	7.6	95.1^{a}	4.1	NS
No	6.4^{b}	2.5	6.2^{a}	3.3	10.0^{a}	7.6	4.9^{a}	4.1	NS
Stop Bushmeat									
N	373		210		60		103		
Yes	48.0^{a}	5.1	33.8^{b}	6.4	64.3^{a}	12.1	1.9^{c}	2.6	***
No	50.4^{a}	5.1	21.7^{b}	5.6	75.0^{a}	11.0	3.3^{c}	3.5	***
Limited	1.6^{b}	1.3	92.2^{a}	3.6	7.8^{b}	6.8	0.0^{c}	0.0	***
Justification									
N	274		167		26		81		
I stopped eating	38.0^{a}	5.7	16.2^{b}	5.6	23.1^{b}	16.2	87.7^{a}	7.2	***
No relation to covid	16.4^{c}	4.4	19.8^{a}	6.0	15.4^{ab}	13.9	9.9^{b}	6.5	*
Bushmeat is healthy	25.6^{b}	5.2	34.1^{a}	7.2	34.6^{a}	18.3	4.9^{b}	4.7	**
Consumption was limited by fear	8.0d	3.2	10.8^{a}	4.7	11.5^{a}	12.3	1.2^{b}	2.4	**
rarely eat. as meat is becoming scarce	3.3^{e}	2.1	5.4^{a}	3.4	0.0^{ab}	0.0	0.0^{b}	0.0	*
what we find as protein	10.6d	3.6	79.3^{a}	6.1	15.4^{b}	13.9	2.5^{c}	3.4	*

N: Respondents; Cluster 1: Group 1 consumers; Cluster 2: Group 2 consumers; Cluster 3: Group 3 consumers; CI: Index of confidence; NS: Not significant; NS: p>0.01; *, ** and ***: p<0.1, p<0.01 and p<0.001, respectively.

Proteus in smoked and fermented bushmeat from four species. Javier-Oñate et al. (2024) conducted a study in Orellana province, Amazonia, which identified infections like *Staphylococcus aureus*, *Salmonella* species, and *Escherichia coli* in bushmeat from eight species. The prevalence of these microorganisms was linked to the unsanitary procedures of the meat producers. Several studies have indicated that the behavior and habits of consumers during the processing and preparation of wild animals are at the root of zoonotic diseases (Oghenekome and Rose, 2020, Ikeh et al., 2021). Consumers also said that they prepare bushmeat themselves, which is a beneficial thing. However, Group 2 consumers, which also include hunters and processors, say that they consume viscera and other parts that are not widely marketed (head, tail, liver, heart, certain viscera, etc). The consumption of these parts is quite dangerous, especially the viscera, as animals that are slaughtered and not eaten immediately after death can begin to putrefy, especially the viscera, which are rich in

enterobacteria such as *Salmonella* and *E. coli*, already found in freshly prepared bushmeat (Kayode and Kolawole, 2010; Haindongo et al., 2019; Ikeh et al., 2021).

In peri-urban and urban areas, several respondents also reported consuming smoked bushmeat without any particular preparation or fried bushmeat. The preparation of these meats, which are often performed in the open space and sometimes sold in the open space, exposes consumers to the risk of zoonotic bacterial diseases caused by *E. coli*, *Salmonella* spp., *S. aureus* and many others, like (Bachand, 2012; Ikeh et al., 2021). Hunters and processors, as well as other consumers, handle bush animals with little application of hygiene measures, which also exposes them to zoonotic risks, such as inhalation of viral or microbial particles present on the animals' skin or hair, contamination through wounds to the hands or other parts of the body, and unprotected contact with the carcass. A large proportion of the bush animals sold and consumed are small animals, such as rodents, which harbor the arenavirus responsible for Lassa fever (Olayemi and Fichet-Calvet, 2020), especially certain wild rodents. Benin experienced a Lassa virus epidemic in 2018, so bushmeat consumers are at risk of contracting the disease when they handle the meat of these rodents without adequate hygiene measures (Attinsounon et al., 2018). As Lassa virus is a highly contagious and fatal disease, it can also spread rapidly through the population, increasing the risk of being taken very seriously. Consuming contaminated meat without proper hygiene during and after preparation can have serious repercussions, as many zoonoses are unknown to doctors. Similarly, in rural areas where bushmeat is widely consumed, there is often a lack of appropriate health centers to treat sick people and make proper diagnoses. Furthermore, Nigeria, a country bordering Benin, has experienced several zoonotic epidemics in recent decades, such as Ebola, Lassa, and Monkeypox, which are highly contagious diseases that spread from wild animals to humans, and from humans to humans (Ayegbusi et al., 2016; Alakunle et al., 2020; Izah et al., 2022). It is therefore vital to increase surveillance for these zoonoses and to educate the population about proper hygiene measures when handling wild animals and wild meats, as well as the habits to adopt when eating them.

Perceptions of zoonoses and health risks

Recent epidemic crises, such as Ebola and COVID-19, have significantly influenced eating habits, with varying impacts across different groups. Individuals in Group 3, who possess higher levels of education, have demonstrated increased awareness of health risks by completely ceasing their consumption of bushmeat, similar to observations in the Congo (Ordaz-Németh et al., 2017; Mialoundama et al., 2020). In contrast, Group 1 and 2 consumers, despite their roles in the bushmeat value chain, did not exhibit the same level of responsiveness. Although they temporarily suspended bushmeat consumption and wildlife-related activities during these crises, they quickly resumed once the perceived threat diminished, consistent with findings by Ayegbusi et al. (2016).

This ongoing insensitivity to health risks can be attributed to lower education levels, nutritional reliance on bushmeat, and the economic necessity of hunting and processing bushmeat in these groups (Luiselli et al., 2020). Notably, Group 3 comprised the youngest group of people, reflecting the new eating habits of young people who, although influenced by culture, are also influenced by current events. A study in China found that the younger generation, although inclined towards organic food, did not accept the consumption of bushmeat, unlike the older generation (Xie et al., 2020). In rural and remote areas, a significant lack of awareness of health risks heightens vulnerability. Although recent disease outbreaks, such as Lassa, Ebola, and COVID-19, have been acknowledged by consumers across all groups due to widespread awareness campaigns, many consumers remain largely unaware of other pathogenic microbes that can cause diseases and toxiinfections, such as *Salmonella* spp., *S. aureus*, *E. coli*, and *Listeria*. These regions, which consume the most bushmeat and include key players in their value chain, suffer from inadequate information that hinders adherence to preventive measures essential for ensuring meat quality and reducing the risk of epidemics and other zoonotic diseases.

Poverty and limited access to information further complicate efforts to regulate the uncontrolled harvesting of wild animals. Thus, in southern Benin, the perception of zoonotic diseases is heavily marked by skepticism, particularly due to the absence of significant outbreaks aside from the recent COVID-19 crisis. For many rural people, bushmeat consumption is seen as a natural practice, with wild animals considered nontransmissible carriers of disease. This belief is bolstered by accounts from previous generations who consumed bushmeat without evident health issues. In contrast, concerns about the consumption of domesticated animals are growing, with some claiming that it is linked to rising mortality rates. Consequently, for a large segment of rural people, the health risks associated with bushmeat consumption are often regarded as myths rather than realities.

Zoonotic implications

Bushmeat consumers, particularly in remote areas of southern Benin, face significant public health concerns. Individuals involved in the bushmeat value chain, including hunters and processors, are exposed to zoonotic diseases. These diseases can be caused by

viruses, such as hemorrhagic fever viruses, and bacteria responsible for foodborne illnesses. Zoonotic diseases affecting domestic animals also pose a considerable additional risk. The process of capturing, transporting, and consuming bushmeat carries numerous zoonotic risks. Hunters confirmed in interviews that they often transport captured animals under unsanitary conditions, exposing individuals to blood, hair, urine, and other secretions from wild animals, which can transmit viruses and other dangerous microbes. Furthermore, bushmeat processing practices, such as smoking or frying, are frequently carried out under unhygienic conditions, as reported by consumer-processors. Processors often lack access to drinking water or sufficient quantities, resulting in inadequate washing of meat carcasses to remove harmful elements. Moreover, during animal processing, workers use the same utensils, cutters, pans, and basins without washing them, exposing people to health risks, such as toxic infections, due to poor processing, conservation, and exposure to the open air of bushmeat (Ahouanse et al., 2024; Kibenga et al., 2021).

Consumers who purchase fresh bushmeat are also at risk of consuming rotting animals or animals caught using poisoned bait. Improper handling of these meats exposes consumers to harmful microbes and other pathogens. Additionally, hunters, processors, and livestock farmers may bring their domestic animals into contact with the viscera and other fluids of wild animals, increasing the risk of transmission of zoonotic diseases to domestic animals (Craft, 2015; Kukielka et al., 2016; Dell et al., 2020).

Conclusion

This study provides an in-depth perspective on the behaviors and perceptions of bushmeat consumers in southern Benin. Notable differences between consumer groups in terms of frequency of consumption and perception of health risks highlight the complexity of bushmeat consumption practices. These insights are essential for developing effective interventions to improve health security and reduce the risk of zoonotic disease transmission. Future efforts should focus on improving education and health information and promoting alternative sources of income for key players in the bushmeat value chain. Encouraging ecotourism and sustainable hunting, as well as promoting and supporting farming and craft initiatives, allows local players to diversify their income. Public health campaigns in rural areas are necessary, particularly workshops that inform communities about safe handling practices for bushmeat and the risks associated with certain pathogens. Effective health education programs must respect and integrate traditional beliefs regarding bushmeat, potentially involving local leaders or health agents who understand the cultural context of the community. Implementing sustainable regulations for wildlife hunting is also crucial.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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