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Consumption patterns of freshwater oyster *Etheria elliptica* (Lamarck, 1807) in the Surrounding Villages of Pendjari Biosphere Reserve: A Potential Substitute Protein source for Bushmeat

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Abstract

Hunting for bushmeat constitutes the main driver of wildlife decline in tropical Africa. Promotion of alternative protein source for forest people is nowadays a raising option for stakeholders to face decrease of wildlife population. This study aimed at assessing the consumption pattern of freshwater oyster Etheria elliptica among harvester groups and the potential of oyster meat as substitute protein source to bushmeat based on acceptability, availability, lower price and nutritious value criteria. Data were collected on oyster meals and consumption frequency during harvesting season using food frequency questionnaire, followed by a survey on comparative price and availability of oyster and bushmeat over the year. Literature information was also investigated on nutritious quality both of oyster and bushmeat. Six oyster traditional meals were reported in study area. The great majority of survey participants (78%) had consumed oyster meals on daily basis. About two oyster meals were eaten per day both by young (age < 40 years) and old people underlying acceptability across age groups among respondents. Outcomes indicated availability of oyster meat kept in ash over the year at lower price than bushmeat partly due to anti-poaching enforcement. Meat chemical composition of smoked oyster was similar to bushmeat. Consequently, oyster meat was likely a potential alternative protein source to bushmeat. Outcomes from this study are of great importance for Park managers for promoting alternative protein sources for forest people around protected areas in Benin and African countries.

Keywords: *Etheria elliptica*, consumption frequency, bushmeat, protein source, Benin.

Introduction

Illegal bushmeat hunting is regarded as a main driver of wildlife decline worldwide[1,2] and a main concern for biodiversity conservation within protected areas[2-4]. Indeed, poaching targets wildlife regardless species status (protected or endangered), sex and age group (young or adults) leading to species decline[5]. Protected areas in Africa, mostly in West Africa, were facing wildlife conservation concern owing to illegal hunting pressure of increasing poor forest people[6]. Thus, evidence of wild mammals decline under poaching pressure for bushmeat was provided in western and central Africa[2].

In West Africa, bushmeat consumption accounted for 25 % of protein needs required for forest dwellers[7]. Moreover, socio-economic drivers of wildlife hunting depend greatly on people purposes. Some populations, chiefly young men, hunt wildlife for income[5]. In some rural societies, bushmeat consumption depended on taste, delicacy of cultural preferences regardless alternative sources existence[8]. Other communities rely on bushmeat mainly for food when alternative available and cheaper protein sources were lacking[9]. Such communities accept substitutes in case of bushmeat shortage. The latter also consider provision of alternative protein as reliable approach to reduce not only bushmeat consumption but also hunting pressure on wildlife[10]. For instance, the effectiveness of promoting low-cost alternative protein sources to reduce bushmeat demand has been demonstrated in villages around the Serengeti National Park in Tanzania[11].

In Benin (West Africa), despite ongoing co-management approach between forest dwellers and Pendjari Biosphere Reserve staff[12], poaching remains of great concern for reserve wildlife[6,13]. Indeed, a recent survey carried out in surroundings of protected areas network W-Arly-Pendjari revealed that game meat for protein source, largely from illegal hunting, was the main resource used by forest dwellers from protected areas, targeting conservation concern[13]. Previously, population drops of mammals' species within Pendjari Biosphere Reserve were attributed to increasing poaching activities[3]. Consequently, promoting of alternative protein source for ever-increasing populace is an urgent priority for reserve managers to mitigate bushmeat demand and in turn wildlife poaching[13].

Past studies assessed characteristics required by a protein source to be a potential substitute for bushmeat and indicated four main criteria: i. acceptability by local consumers[11,14], ii. availability[2,8], iii. lower prices compared to game meat[2,11] and iv. better

nutritional value[14]. Besides, many research works documented various alternative protein sources to bushmeat including fish, mollusks, crustaceans or domestic livestock[15-17]. The studies exhibited credible and promising outcomes. However, whilst growing studies targeted fish and domestic livestock as substitutes of game meat[15], far less attention has been focused on other protein sources such as mollusks. Nevertheless, oyster species were widely consumed as main protein source, mineral and vitamins in many societies in Western Africa[18]. Furthermore, mangrove oysters supply cheap protein source to West African people[19]. Yet, no surveys examined oyster meat as potential substitute protein source for bushmeat.

The freshwater oyster *Etheria elliptica* (Mollusca: bivalvia) was currently harvested for food and income source by riparian inhabitants of Pendjari Biosphere Reserve in North of Benin (West Africa). Oyster *E. elliptica* was the second resource collected in Pendjari Biosphere Reserve after fish species. The core objective of this survey was to demonstrate whether oyster meat met required criteria (acceptability, availability, lower price and better nutritional value) to serve as potential alternative protein source to bushmeat. This research work focused on two main objectives: i. to examine oyster meals consumption patterns among oyster collectors and ii. to investigate oyster meat as potential alternative protein source to bushmeat across acceptability, availability, lower cost and nutritional qualities.

Material and Methods

Study area: Pendjari Biosphere Reserve (PBR) is a protected area located in Northern part of Benin (West Africa).The reserve is encompassed between 10° 30'-11°30' N, and 0° 50'-2° 00'E (figure-1). The PBR belongs to West African protected areas network namely W-Arli-Pendjari. PBR`s area accounted for 4 661.4 km^2 [12]. The PBR is surrounded by about 20 small villages with 30 000 inhabitants. Population density accounted for 13 inhabitants per km^2, and is relatively lower than other regions of the country[12]. Three main ethnic groups were encountered amongst local population: Berba (65%), Gourmantche (23%), Waama (7%) and other (5%). Agriculture is the main activity of riparian people; followed by cattle rearing by Fulani ethnic group. Berba tribe dominates along the Tanguiéta-Porga road whereas Gourmantche and Waama populate villages encountered along Tanguiéta-Batia road[12]. Since 1993, local population was involved in PBR management owing to ongoing participatory approach. Therefore, local residents were involved in the reserve management through the Village Association of Wildlife Management (AVIGREF). Each village was asked to set up its AVIGREF structure to benefit from reserves opportunities such as anti-poaching agents and tourist guide. Moreover, AVIGREF members were granted permit to access natural resources within the reserve such as medicinal plants, straw, fish and oyster species in Pendjari River. The Pendjari River originates in the Atakora Mountains in Northern Benin. It flows along the border of Burkina Faso and Benin, passes through Northern Togo highlands and joins Ghana as Oti River. Thus, the river is main tributary of Volta basin[20]. Pendjari River has a tropical hydrological regime with a low water season between December and June and a flood season from September to October[3]. Pendjari River hosts wild stocks of freshwater oyster *Etheria elliptica* harvested for food and income by local people[12]. *E. elliptica* (Lamarck, 1807) is the only one freshwater species occurring in West African rivers[21].

Survey sampling: Prior to data collection, the number of harvesting groups' actively collecting oyster within the protected area was recorded from reserve managers. Data available covered the four recent harvesting seasons namely 2009 to 2012. Over this period, 90 oyster collectors distributed in five harvesting groups originated from following AVIGREF villages: Daga (10 collectors), Porga 6 (18 collectors), Porga 7 (19 collectors), Pouri (15 collectors) and Setchendinga (28 collectors) were active within the PBR. Oyster harvesting within the PBR was carried out in groups under permit delivered by managers. AVIGREF membership status of collectors group is required to obtain harvesting license. Harvesting groups were often set up per village. Unlike occasional collectors operating outside the reserve, people collecting oysters within the reserve were devoted annually to harvesting as main activity during dry season. Owing to the specific objectives, the current survey targeted mainly oyster collectors' members of AVIGREF and harvesting within the reserve. Such collectors were assumed to be more knowledgeable about oyster consumption rate, local market price and oyster availability along the year as they consume and sell oysters. Collectors were selected based on their willingness to participate to the survey. Out of 90 collectors recorded, 60 respondents were chosen for the survey based of two-third rate per village. Respondents were sampled randomly per group.)

Data collection: The survey was performed in villages bordering Pendjari Biosphere Reserve along the Tanguiéta-Porga axis where Berba people dominated. The research followed three steps: i. an oyster consumption survey on different oyster meals and consumption patterns, ii. a survey of oyster and bushmeat price and availability over the year and iii. a literature investigation on comparative chemical composition (ash, moisture, proteins, fat and carbohydrates) of oyster meat and bushmeat.

Oyster consumption pattern was assessed by means of questionnaires in March-April 2013 during the harvesting season where oyster meat was abundant and likely to be consumed at high level. Information was elicited in native language by selected local guide trained both to ensure data reliability and warrant interviewees' confidence. Data were collected on respondents' socio-economic characteristics (age, sex, ethnic group and occupation), oyster consumption frequency and oyster meals consumed during the last month [22]. Prior to individual interview, a focus group was carried out with 15 respondents (12 females and 3 males) to report different oyster meals using free-listing technique. Participants were asked to list all dishes including oyster. Oyster consumption patterns were assessed administering a food frequency questionnaire.

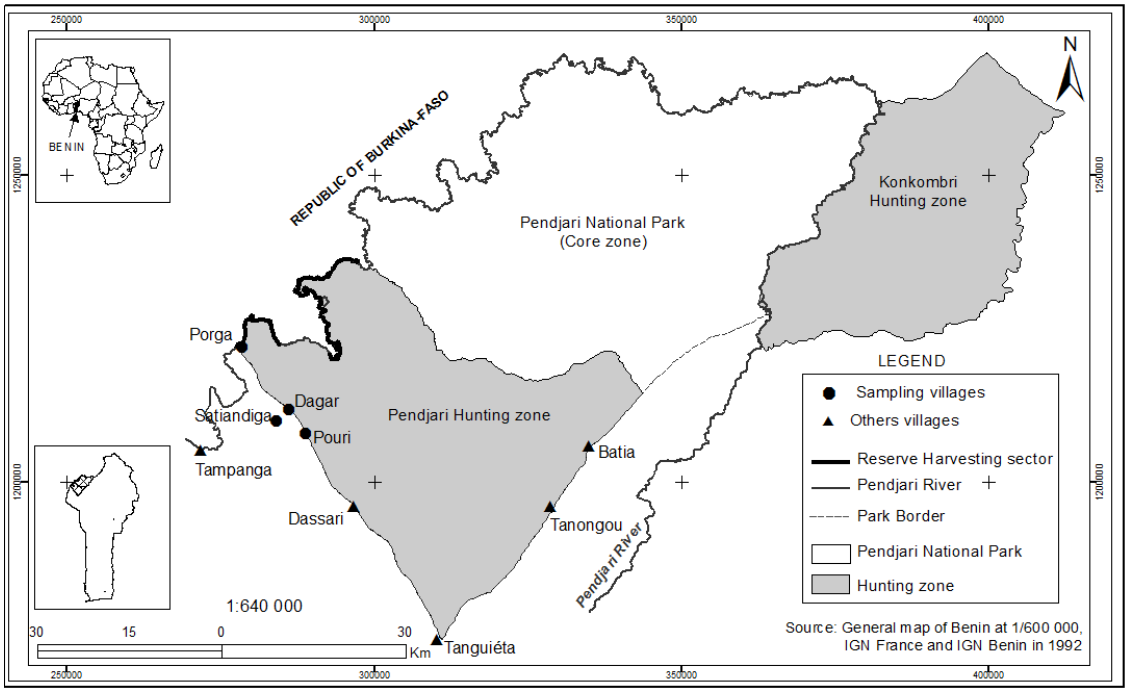

Figure-1
Pendjari Biosphere Reserve and survey villages

Oyster price and availability data over the year were collected through semi-structured interviews with harvesters. Additional data collection included local market survey and discussion with oyster vendors. Bushmeat price and availability along the seasons were collected through informal discussions as it is illegal good. Information was also gathered both from reserve safe guards in charge of anti-poaching fight and local population especially saleswomen involved in game meat trade.

Protein contents of oyster and bushmeat were analyzed using secondary data from existent literature. Data on nutritional composition were collected from a study on freshwater oyster *E. elliptica* in Ghana. The study was carried out with freshwater oyster *E. elliptica* specimens collected from Oti River in Ghana, a tributary of Volta basin[21]. The river Oti is the continuum of Pendjari River leading to so called Pendjari-Oti River[20]. Therefore, nutritional composition of oyster specimens sampled in Oti River is likely similar to their counterparts in Pendjari river. Chemical composition of bushmeat was collected from study of Abulude[23] in Nigeria. Research was carried out in forest reserve of Federal College of Agriculture, Akure Campus, Nigeria and targeted ten species of rats, snakes and birds. Additional data were collected from protein contents of bushmeat especially the African ungulates.

Data processing: Frequency counts, percentages were performed to analyze socio-demographic backgrounds of respondents, oyster meals frequency whereas cross-tabulation was used to assess oyster meals consumption patterns. An univariate ANOVA test was performed to compare mean consumption frequency among respondents' age categories with Statistica 6 software.

Results and Discussion

Oyster meals and consumption patterns: The age of study population ranged from 22 to 76 years old with a mean of 48 years old. About 75% of respondents were older people (age > 40 years). Female dominated the survey participants with 57 out of 60 respondents (95%). Likewise, Berba tribe people (93%) were mostly encountered as oyster harvesting was a traditional Berba women activity. Kankamba tribe people (7%) were less represented. Collectors were mostly farmers (96.7%) during rainy season and were devoted to oyster harvesting in dry season.

Overall, six meals consumed with oyster were reported in study area: cowpea (*Vigna unguiculata*) sauce, baobab (*Adansonia digitata*) leaves, Okra (*Hibiscus esculentus*) sauce, mustard sauce, fried sauce and a mixed small fish-oyster sauce. Mustard arose from African locust (*Parkia biglobosa*) processing. Cowpea sauce was the most consumed oyster meal (70%) followed by baobab leaves sauce (35%) (figure-2). The majority of respondents (78%) displayed oyster meals daily consumption patterns (average of 2 oyster meals per day) whereas less than the quarter (21.7%) ate oyster weekly (on average once a week). More than half (55%) of interviewees consumed oyster meals twice or three times per day (table-1). Although the dominance (76%) of older people (age > 40 years) among respondents, the frequency of oyster meals consumption revealed no significant difference among age groups (ANOVA test, $p > 0.05$).

Of the six oyster meals, cowpea sauce and baobab leaves sauce were eaten by 56 out of 60 respondents (93%) (table-2). Among

interviewees eating cowpea and baobab leaves sauces, the daily consumption frequency varied from one to three times for 53% of respondents. Fried sauce and mixed small fish-oyster were less consumed by collectors (20%).

In the study area**,** all the survey participants consumed oyster meat during the study period (a month) probably because the research took place in the peak of harvesting period, on one hand and respondents were oyster collectors, on the other hand. Moreover, oyster appeared to be more eaten (77 %) by older people (age > 40%) than younger people (23 % of 22-40 years). The same trend of oyster consumption was reported in communities of Rivers State (Nigeria) where oyster meat was more acceptable among old people[18]. However, in this study, this trend should be attributed to dominance of older people among survey participants; since hard harvesting conditions (staying many days away from home, fear of wild animals in reserve) pertaining to oyster collection in the protected area mostly limited young people involvement. This results in less implication of younger people.

Consumption frequency accounted for one to three times per day for a great majority of consumers (78%) where as the others ate oyster weekly (22%). Among people eating oyster on a daily basis, the average daily consumption frequency was not only estimated to two (2) oyster meals per day but was also similar both in younger (age < 40 years) and older people (age > 40 years). Consequently, oyster was accepted across age categories in our rural study area. Our findings were in conflict with previous studies conducted in urban area which outlined that oyster meals were more acceptable among old people than young[18]. The source of difference could arise from the difference of eating behaviour between rural and urban areas. In most African rural areas, family meals were served to all households members especially the traditional dishes leading to a similar food consumption frequency among family members[24,25.] Unlike urban areas, young people in rural areas have less possibilities to consume food outdoors[26]. Furthermore, in rural Africa, three (3) routine daily meals namely breakfast, lunch, and dinner were often eaten in family[26]. Thus, oyster meals were likely consumed during the two out of three daily family meals consumed in households in Africa[24].

Oyster meat was consumed with traditional sauces mostly based on legumes and vegetables (Cowpea sauce, baobab sauce, Okra sauce and mustard sauce). In West Africa, many studies reported the consumption of sauces based on cowpea baobab leaves Okra and mustard sauces[27-29]. In Northern Benin, Vodouhê et al.[29] outlined the use of baobab leaves as sauce condiment by Berba people whilst Assogbadjo et al.[28] reported the daily consumption frequency of baobab based meals. The traditional knowledge of local population on those plants could explain their frequent use in traditional food[29]. In the current study, our outcomes pointed out the consumption of oyster meat in traditional food based on legumes and leafy vegetables and were in accordance with previous reports. However, Lykke et al.[27] pointed out in rural Burkina Faso that higher frequency intake of legumes and vegetables meals was an indicator of poverty in local communities. Therefore, households mostly eating legumes foods were poor and could not afford expensive protein sources[27]. Previous studies stressed the poverty among population living around Pendjari Biosphere Reserve with low purchasing power[12]. Likewise, fishes caught in Pendjari River were mainly exported to neighboring country (Burkina Faso) owing to their high cost. Thus, fish protein source was not available for local people. Given that, it is of a great priority to promote cheaper protein source for local dwellers.

As potential alternative protein source for bushmeat, oyster meat should meet four main criteria: acceptability, availability, lower price and better nutritional value.

Oyster meat acceptability: Oyster met the acceptability feature as a traditional protein source of Berba ethnic group communities. Indeed, high oyster meals consumption frequency corroborates traditional use of oyster meat as animal protein source. Oyster meat was widely eaten by survey participants (78% with oyster meals intake per day) as main protein source in traditional menus. Respondents ate oyster meals mostly during two main foods per day and similarly among age categories. Based on the favourable disposition towards oyster consumption (80.5%) and the higher proportion of consumers (95%), the acceptability of oyster was demonstrated among consumers of Rivers State in Niger delta (Nigeria)[18]. Likewise, In Nigeria, Oduntan et al.[14] reported acceptability of edible frog as substitute to bushmeat by great majority of local populace (87% of respondents) as cheaper a nutritious protein source.

In the current study, survey participants were dominated by Berba people especially by women as oyster harvesting was a traditional Berba woman activity. In our study area as in many African families, women are kitchen-head and meals are taken together by all household members[24]. Therefore, consumption patterns reported for respondents are likely similar to their whole family members[24]. Furthermore, evidence of oyster acceptability in study population was the dominance of Berba people between consumers interviewed. Indeed, Berba ethnic group (65%) represented more than half the population living around the reserve[12], the others tribes accounted respectively for 23% (Gourmantche) and 7% (Waama). It appears that oyster meat is included in dietary habits of the principal tribe which populates the PBR surroundings. Acceptability by dominant ethnic group is likely an advantage for promoting oyster meat like alternative protein source for bushmeat. Furthermore, the high frequency of oyster consumption with traditional dishes in all age groups indicated the oyster meat acceptability among participants dominated by Berba. Consequently, this suggests oyster acceptability by the Berba, the dominant ethnic group in communities surrounding the PBR[23]. Further actions of promoting alternative protein sources to bushmeat should take into account the feeding practices of local people.

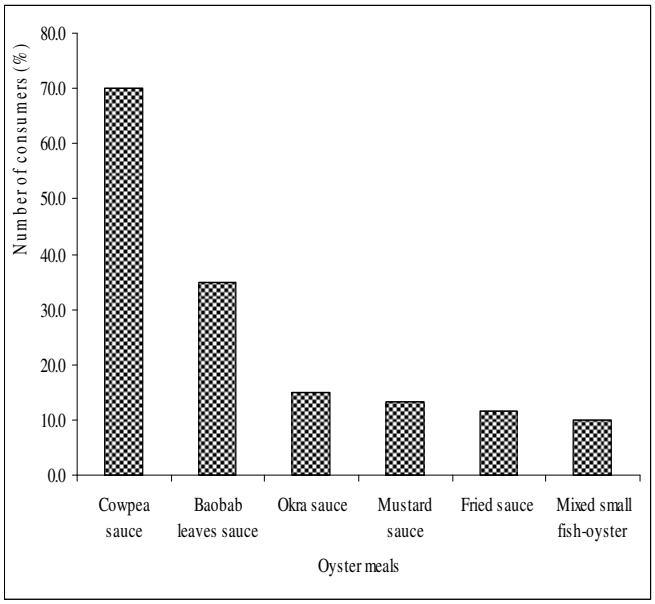

Figure-2
Oyster meals consumption frequency among respondents

Table-1
Oyster consumption pattern among respondents

	Number of consumers	Percent
Number of oyster meals per week		
1-3	13	21.7
Number of oyster meals per day		
1	14	23.3
2	17	28.3
3	16	26.7
Total	60	100

Table-2
Cross-tabulation of oyster consumption frequency and different types of oyster meals

Oyster meals	Consumption frequency				
	Per day			Per week	Never
	Once	Twice	Thrice	once to thrice	
Cowpea sauce	10	15	9	8	0
Baobab leaves sauce	6	4	4	7	0
Okra sauce	0	2	5	2	0
Mustard sauce	2	3	2	1	0
Fried sauce	0	2	5	0	0
Mixed small fish-oyster	3	1	0	2	0

Table-4
Proximate composition comparison between smoked oyster meat and bushmeat

Parameters	*Etheria elliptica* Smoked oyster meat (Ghana)	*Crassostrea gasar* (smoked oyster meat) (Nigeria)	Bushmeat (Nigeria)
Moisture (%)	9.1	14.9	12.65
Ash (%)	14.2	6.88	13.10
Fat (%)	8.6	10.19	5.18
Protein (%)	40.7	45.21	49.16
Carbohydrate (%)	27.4	29.70	17.36
Energy (Kcal/100g)	350	374.60	-
Iron (mg/100g)	19.3	-	6.64
Calcium (mg/100g)	365.9	-	477.3
Phosphorus (mg/100g)	221.0	-	-
Source	Ampofo-Yeboah [21]	Alfred-Ockiya [36]	Abulude [23]

Price and availability of oyster meat and bushmeat: Oyster meat was sundried after harvesting and conserved in ash all the year round. Oyster was sold based on local unit measure of 1.5 kg. Oyster meat price varied along the season. It was lower during harvesting period during dry season (1 300 FCFA/Kg) (1 USD = 450 FCFA) and increased slightly (1 600 FCFA) in rainy season. Conversely, bushmeat price accounted for 2 000 FCFA/kg in dry season and decreased in rainy season (1 200 FCFA). Although, oyster meat was declared to be available all the year, the quantity was higher in dry season decreasing towards the rainy season. Bushmeat availability showed an inverse trend (table-3).

Table-3
Price and availability of oyster meat and bushmeat in villages surrounding the Reserve

	Price (F CFA/Kg)		Availability	
Seasons	Oyster meat	Bush meat	Oyster meat	Bush meat
Dry season (November-May)	1 300	2 000	High	low
Rainy season (June-October)	1 600	1 250	low	high

Oyster meat annual mean price accounted for 1450 FCFA/kg (1300 FCFA/kg -1600 FCFA/kg) and was slightly lower than bushmeat cost (1625 FCFA/kg). Oyster price estimated in this study was almost close to value (2000 FCFA/kg) reported for mangrove oyster (*Crassostrea gasar*) in Senegal[30]. Bushmeat price was higher than value estimated to 1360 FCFA/kg (US$ 3) in Takoradi Ghana[31] and lower than kilogram cost of bushmeat (Grass cutter) estimated to 2400 FCFA in Nigeria [23]. Our findings were in conflict with previous studies which stated that bushmeat was cheaper than domestic or alternative

protein sources[32]. Those studies were carried out in countries such as Cameroon, Democratic Republic of Congo (DRC) and Central African Republic where bushmeat remains an open access resource[32]. Conversely, in Pendjari Biosphere Reserve, bushmeat species were protected leading likely to the increase of game meat price as illegal good. Furthermore, in our study area, anti-poaching enforcement during a long dry season period over the year (seven months) limited illegal hunting and bushmeat off-take[12]. Information gathered from safe-guards and saleswomen asserted that poachers were more likely active during rainy season as surveillance was less intense. Similar behavior was reported in Zimbabwe where some poachers had better hunted during rainy season presumably to avoid being apprehended[33]. Consequently, bushmeat was cheaper in rainy period. In this respect, Rentsch and Damon[34] outlined the link between bushmeat availability along season and its prices. Strategies to raise surveillance activities during the rainy season were likely to lower poaching and increase bushmeat price. Consequently, some poor consumers would rely on alternative protein sources due to their limited purchasing power.

Availability of oyster meat year-long was eased by traditional conservation technique in ash after being sundried or smoked. In Senegal, Cormier-Salem[35] reported the availability of mangrove oyster meat smoked or sundried and kept in ash over the year. Moreover, in Nigeria, smoke-dried mangrove oyster (*Crassostrea gasar*) still contains high values of protein and nutrients[36]. In the study area, oyster was harvested in dry season (almost seven months) in Pendjari River both outside and within the Pendjari Biosphere Reserve. Important stocks existing in River inside the Reserve were collected under permit for food and sale. Indeed, long harvesting period and traditional conservation methods both enabled oyster meat availability year-long with increased abundance towards the end of dry season (May-June). Conversely, bushmeat hunting activities faced anti-poaching and tourism activities during dry season. Consequently bushmeat was less available and more expensive. Bushmeat was likely more available during rainy season. However, coercion and arrests even in poachers or saleswomen`s households by forest guards hampered consumers access to bushmeat in the study area.

Overall, in the survey area oyster meat was slightly cheaper than bushmeat and accessible over the year compared to bushmeat. Therefore, it could represent an alternative protein source to bushmeat. Moreover previous studies reported that availability and cheaper price of a substitute to bushmeat increased its consumption and supported our findings. In Tanzania, for instance, Moro et al.[11] demonstrated that availability and cheaper price of fish and chicken, two substitutes to bushmeat, had effectively increased their consumption in households surrounding Serengheti Reserve and in turn decrease hunting activities. In Ghana, evidence was provided that supplies of fish results in decrease of bushmeat off-take[15]. Moreover, in Latin America people replace game meat by domestic protein when it becomes available[8]. In the study area, fish caught in Pendjari River was mainly exported to Burkina Faso. Thus, oyster meat appeared to be more affordable for local poor residents living around Pendjari Biosphere Reserve than bushmeat. Finally, aquaculture promotion is likely a right way to increase oyster production in Pendjari River as occurred for mangrove oyster *Crassostrea gasar* in Senegal[35].

Nutritional value of freshwater oyster meat and bushmeat*:* Protein content of oyster *Etheria elliptica* meat (40.7%) recorded in Pendjari-Oti River (Ghana) [21] is slightly lower than both the mean value of mangrove oyster *Crassostrea gasar* (45.21%)[36] and that of bushmeat (49.16%)[23] (table-4). Conversely oyster content in ash, fat and carbohydrate is higher than bushmeat. Many others studies reported that African bushmeat protein contents ranged from 16 - 55%[37]. Moreover, Hoffman and Wiklund[1] reviewed proximate composition of many African ungulate species and indicated desirable protein (17.4 to 25.7%) in the meat.

Table-4
Proximate composition comparison between smoked oyster meat and bushmeat

Parameters	***Etheria elliptica* Smoked oyster meat (Ghana)**	***Crassostrea gasar* (smoked oyster meat) (Nigeria)**	**Bushmeat (Nigeria)**
Moisture (%)	9.1	14.9	12.65
Ash (%)	14.2	6.88	13.10
Fat (%)	8.6	10.19	5.18
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Energy (Kcal/100g)	350	374.60	-
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Calcium (mg/100g)	365.9	-	477.3
Phosphorus (mg/100g)	221.0	-	-
Source	Ampofo-Yeboah [21]	Alfred-Ockiya [36]	Abulude [23]

Protein content of oyster meat was almost similar to bushmeat[21, 23]. Moreover, oyster meat protein content not only belongs to range of protein estimated for bushmeat (16-55%) but is also higher than the values (17.4 to 25.7%) reported for ungulates[1]. In tropical Africa, mammals especially ungulates make up the most hunted bushmeat species[2,38]. In Pendjari Biosphere Reserve, ungulates such as African buffalo (*Syncerus caffer brachyceros*), Roan antelope (*Hippopotragus equinus),* Hartebeest (*Alcelaphus buselaphus* and Kob (*Kobus kob)* were the bushmeat species frequently hunted 3. Evidence was also provided by meats seized from poachers caught by Reserve guards or from saleswomen. Furthermore, Abulude [23]

reported 49.16 % of protein in game meat in Nigeria (table-4). This indicates higher protein content in bushmeat than the estimated values reported for both freshwater oyster *E. elliptica* (40%) [21] and mangrove oyster (45%)[36] (table-4). In contrast, Ntiamoa- Baidu[37] reported a lower mean protein value averaging 30 g of protein per 100 g (30%) for game meat taking into account a larger range of bushmeat species than Abulude[23]. Ntiamoa- Baidu[37] focused on ungulates, the frequently hunted bushmeat species in the study area. Consequently, freshwater oyster meat probably contains higher protein value than mostly eaten bushmeat in the study area. Given that, oyster meat would likely be accepted by local people as more nutritious protein source[14]. In the study area, oyster meat was certainly more abundant at the end of oyster harvesting period coinciding with shortage period (May-June). Therefore, oyster meat potentially filled in consumers protein needs as available, cheaper and nutritious protein source particularly during shortage period in dry season[29]. An increase in oyster meat intake may reduce protein deficiency for forest dwellers by providing energy supply for local residents.

Oyster meat supplies essential minerals for human organism. According to Akinrotimi et al.[18] oyster is known not only as an important source of protein, but also provides mineral and vitamins required for human livelihood. Presence of great amount of calcium (365.9 mg/100g) would likely strengthen bone and teeth for people in need such as young children, old men and women[14]. Iron content of oyster (19.6 mg/100g) was not only three times higher than bushmeat value (6.68 mg/100g) reported by Abulude[23] (table-4) but also met the adult daily requirement (10 mg/day) for this mineral [39]. Iron amount would prevent consumers form iron deficiency anemia[38]. Teeth and bone development require useful phosphorus and calcium amount[38]. Furthermore, it was demonstrated that oyster meat increase libido and showed aphrodisiac effects owing to presence of zinc[40].

Conclusion

Overall, oyster met the main criteria to be a potential alternative protein source to bushmeat in villages surrounding the Pendjari Biosphere Reserve. Indeed, the bivalve meat is available yearlong, accepted and frequently consumed in communities especially by the dominant Berba ethnic group. It costs slightly cheaper and probably contains more protein than ungulates bushmeat species often hunted within the reserve. Advantages of oyster eating in improving livelihoods were to be highlighted to stimulate local populations to consume more oyster meat and in turn, reduce household bushmeat demand. Therefore, popularization of this survey outcomes towards all riverine communities by park managers; followed by effective survey of dwellers willingness to substitute bushmeat by oyster meat was required. This could reveal the real potential of oyster meat to contribute to poaching reduction. Future study should be designed to investigate oyster consumption patterns among other ethnic groups, on one hand and assess the potential of domestic protein sources to substitute bushmeat and reduce illegal off-take of wildlife.

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