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Original Research Article

Consumption and nutritional quality of grilled pork purchased from open road-side restaurants of Benin

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ABSTRACT

This study focused on the determination of consumption habits and nutritional composition of ready-to-eat grilled pork from Benin. A face-to-face survey of 372 grilled pork consumers using a semi-structured questionnaire was carried out in the same municipalities where 24 samples of grilled pork were collected for physico-chemical characterisation. Three hundred out of 372 (80.6 %) consumers eating grilled pork at least once per month were selected to estimate the daily intake of protein, lipid and fatty acids. Grilled pork consumption ranged between 0.7 g/day and 342.9 g/day with a median of 28.6 g/day. Protein and lipid contents ranged between 19.5 % and 69.5 % of dry weight and between 27.9 % and 82.1 % of dry weight, respectively. Fatty acid profile showed that linoleic acid was the most abundant omega 6-PUFA (Polyunsaturated fatty acid). The consumption of high quantity of grilled pork (342.9 g/day) enables to cover 25 % (for women) and 31 % (for men) of adult requirement of PUFA (11 – 22 g/day for women and 14 – 28 g/day for men). The omega 6 daily intake from high grilled pork consumption contributed to satisfy about 15 % of adult requirement of omega 6 fatty acids for both genders while the omega 3 daily intake from high grilled pork consumption was over 80 % for both genders.

1. Introduction

Meat products are valuable sources of nutrients including proteins and polyunsaturated fatty acids (PUFA) in the human diet. Raw pork is composed of 26 % of dry matter, 85 % of protein (dry matter basis), 2 % of fat in muscle, 70 % of total lipid in fat tissue (Youssao et al., 2004). Several papers reported the fatty acid profile of raw and processed pork, including omega 3 and omega 6 (Janiszewski et al., 2016; Olsen et al., 2007; Visessanguan et al., 2006). Raw pork like other meat can be processed using traditional methods like grilling and smoking (Guerrero-Legarreta and García-Barrientos, 2012; Poligné et al., 2005, 2002). During grilling and smoking of meat, including pork, moisture content is reduced and microbial development is inhibited (Broncano et al., 2009; Ranken, 2000). In African countries like Benin, traditional grilling is applied to different meat products (Anihouvi et al., 2013) including pork (Ayssiwede et al., 2009). In Benin, where pork production increased by about 45 % between 2004 and 2014 (DE/MAEP, 2014; Faostat 3, 2016), grilled pork is a popular ready-to-eat food sold as street food. Ayssiwede et al. (2009) estimated the average level of pork consumption in Benin at 1.2 kg per week. Most of the various studies carried out on pork quality were focused on its fatty acid composition. Fat composition of pork may be affected by gender, breed, diet and other parameters (Alonso et al., 2009; Teye et al., 2006; Youssao et al., 2004, 2002). In Benin, three pig breeds are used to process pork: indigenous, exotic (Large White) and crossbreed (exotic × indigenous) (Ayssiwede et al., 2008). Changes in nutritional quality of pork can occur when thermal processing is applied. It is the case of roasting, responsible of the increase of saturated fatty acids (SFA) and the decrease in PUFA of pork muscles (Janiszewski et al., 2016). On the other hand, no significant changes were observed in the content of SFA, PUFA or monounsaturated fatty acids (MUFA) when pork was cooked in the oven and in the pan (Douny et al., 2015). Even if several studies were realised on pork (Swanepoel et al., 2016; Visessanguan et al., 2006; Youssao et al., 2004, 2002), to our knowledge very few data

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showing nutritional characteristics of grilled pork are available. This study aims to determine the consumption habits and nutritional quality of grilled pork as marketed in Benin to estimate their contribution to recommended intake.

2. Material and methods

2.1. Survey area and consumption data collection

A survey of adult (≥18 years old) consumers of grilled pork was conducted in five municipalities of southern Benin (Cotonou, Abomey-Calavi, Porto-Novo, Adjarra and Bohicon). The total number of consumers was determined according to Dagnelie (1998) and the number of consumers per municipality was calculated on the basis of sampling rate applied to demographic data of the concerned municipalities using the census data of Benin (INSAE, 2015). The sampling rate formula is as followed:

$T_j = \frac{n_j}{N}$ where T_j = sampling rate; n_j = number of inhabitants in the municipality j (which is one the five municipalities listed above) and N = Total number of inhabitants in the five municipalities.

A semi-structured questionnaire divided into two main parts composed each of approximately 12 questions (subdivided in 1–3 other questions) was administrated face to face to 372 grilled pork consumers randomly selected in the five municipalities. The first part of the questionnaire was about socio-demographic profile of grilled pork consumers (name, age, weight, gender, socio-cultural group, educational level, religion…). The second part was composed of questions related to the different methods of cooking pork meat as consumed, forms of grilled pork consumed, preference of consuming fatty or lean part of grilled pork, ingredients and accompaniments of grilled pork, other grilled and smoked products consumed, frequency and quantity, time of day when grilled pork was consumed (breakfast, lunch, diner), places where grilled pork was consumed. Grilled pork consumers were interviewed when coming into or leaving open road-side restaurants (n = 188) randomly visited in the 5 municipalities mentioned above, during ten days. Interviews were conducted in French or local languages of Benin (*Goun, Fon, Mina, Tori* and *Kotafon*).

For the estimation of the quantity of grilled pork individually consumed, each interviewed consumer was asked how much he spent for his consumption of grilled pork at the time of the interview. A quantity of grilled pork corresponding to the cost mentioned by the interviewed consumer was then purchased in the same restaurant and weighed to estimate the quantity of grilled pork consumed per person. During the survey, the consumer's body weight was also measured using calibrated scales (Seca LK N° 5158, Germany).

2.2. Sampling of grilled pork and laboratory analysis

2.2.1. Sample collection

A total of 24 samples of grilled pork was randomly purchased according to the four presentation forms (skewer, slice, piece and wrapped) available in 24 open road-side restaurants. Samples were collected in individual plastic bags, which were packed in icebox filled with dry ice and transported to laboratory for analysis.

2.2.2. Chemical composition and Fatty acid profile determination

Moisture content was calculated from the difference between fresh weight of ground sample and its dry matter which was determined by drying (103 °C ± 2) until constant weight using an oven (Heraeus T5042, Geprufte Sicherheit), according to ISO-1442 (1973). The pH of the samples was measured using a digital pH meter (Inolab pH 7110 WTW 82,362 Wellheim, Germany) according to the method described by Anihouvi et al. (2006). After adding 80 mL of distilled water to 20 g of ground sample, the mixture was rotary homogenised before pH measurements.

Protein content was determined according to the Kjeldahl method (NF V04-407, 2002) composed of a mineralisation step using a digester (DK8 Heating Digester Velp Scientifica), a distillation step using a BÜCHI Distillation Unit (K-350), followed by titration before protein content calculation by multiplying the nitrogen content by a factor of 6.25. Lipid content was determined according to the method described by Folch et al. (1957). All solvents used were from analytical grade.

The determination of fatty acid profile was carried out according to the method previously described by Douny et al. (2015) and modified as followed. Firstly, a saponification and methylation of fatty acids was initiated. Fat sample of 50 mg was dissolved in a test tube with 5 mL of hexane. After vortexing, 10 μL of this mixture were taken into Pyrex glass screwed tubes to which 75 μL of internal standard solution (0.05 mg/mL hexane, nonadecanoic acid C19:0) were added. Then, 1 mL of toluene was added, followed by 2 mL of sulfuric acid (H_2SO_4, 2 % V/V in MeOH). The obtained solution was vortexed, then heated in boiling water (100 °C, 1 h) with vigorous stirring. The tubes were then cooled at room temperature and 3 mL of sodium chloride (NaCl, 5%) and 2 mL of hexane were added before centrifugation (3700 *g*, 5 min). Hexane phase thus obtained was taken from a test tube and then washed with 3 mL of K_2CO_3 (2% W/V), vortexed and centrifuged (3700 *g*, 5 min). After this phase, 1 mL of hexane phase was taken from a test tube and then evaporated to dryness and 400 μL of hexane were added. This extract was vortexed and 100 μL were then taken into an injection vial. The second step of the method consisted of an injection and quantification of fatty acids. A bulk of 1 μL of the final extract was injected into a GC–MS (Thermo Fisher scientific) using a CP-Sil88 column (100 m × 0.25 mm × 0.2 μm) (Varian; Agilent Technologies, Santa Clara, CA) coupled with a mass spectrometer (Polaris Q; Thermo Fisher Scientific). The peaks were identified by comparing the retention times and masses detected on the mass spectrum with those of the corresponding standards. The results were expressed in % of total fatty acids. The limit of quantification (LOQ) of total fatty acids corresponded to the first point of the calibration curve and represented 0.1 % of the total fatty acids. For the calibration curve, the same protocol was applied to hexane solutions containing a pool of 23 fatty acids, at seven different concentration levels (from 0.1 ng/μL to 25.4 ng/μL depending on the compound). The method was validated according to Douny et al. (2015). In addition to individual standards, a certified reference material (CRM) consisting of a mixture of pork and beef fat (BCR163, IRMM) having seven fatty acids assigned values was used for quality control of the analytical procedure. The values (expressed in % of the fatty acids) recorded for myristic acid, palmitic acid, stearic acid, palmitoleic acid, oleic acid, linoleic acid and alpha-linolenic were 1.8; 26.6; 19.1; 1.7; 38.8; 7.5 and 1.3 respectively while the assigned values (expressed in % of the fatty acids) were 2.3; 26.0; 18.3; 2.6; 38.3; 7.1 and 0.9 respectively.

2.3. Estimation of daily intake of macronutrients

Daily intake of macronutrients (proteins, lipids and fatty acids) through grilled pork consumption was calculated for 300 consumers (out of the 372 people interviewed) eating grilled pork at least once per month. For each consumer, the daily intake of protein (g/kg of body weight) was calculated from the daily consumption of grilled pork, the mean protein content (%) in the 24 samples (wet weight) and the body weight (kg) of the consumer. For the other nutrients (lipid and fatty acids) the daily intakes were expressed in g/day. Each daily intake was then compared to a dietary reference value recommended by international organisations (EFSA, 2012, 2010; FAO, 2010; WHO, 2007).

2.4. Data analysis

The Sphinx plus[2] (SphinxSurvey Plus2, Eureka, version 4.5) software was used to record survey data. Chi square test was performed on survey data to test quality variables using R (version 3.5.1, R Core Team) software. Multiple comparisons of grilled pork consumers'

Table 1
Socio-demographic characteristics of grilled pork consumers in the study area.

Variables and modalities	Surveyed consumers number (n = 372)	Proportion ± CI (%)
Age (years)		
< 20	24	6.5 ± 2.5A
20 – 30	168	45.1 ± 5.1B
31 – 40	100	26.9 ± 4.5C
41 – 50	58	15.6 ± 3.7D
51 – 60	14	3.7 ± 1.9E
> 60	8	2.2 ± 1.5E
Gender		
Male	293	78.8 ± 4.2A
Female	79	21.2 ± 4.2 B
Socio-cultural groups		
Goun	81	21.8 ± 4.2A
Fon	139	37.4 ± 4.9B
Torri	20	5.4 ± 2.3C
Aïzo	22	5.9 ± 2.4C
Mina	23	6.2 ± 2.4C
Xlwa	9	2.4 ± 1.6D
Others*	78	20.9 ± 4.1A
Educational level		
Primary school	74	19.9 ± 4.1A
Secondary school	95	25.5 ± 4.4B
University	148	39.8 ± 5.0C
No school	48	12.9 ± 3.4D
Local languages education	7	1.9 ± 1.4E
Marital status		
Unmarried	155	41.7 ± 5.0A
Married	214	57.5 ± 5.0B
Divorcee	2	0.5 ± 0.7C
Widow	1	0.3 ± 0.5C
Religion		
Animism	29	7.8 ± 2.7A
Christianism	340	91.4 ± 2.8B
Islam	3	0.8 ± 0.9C

CI: confidence interval at.95 %
Percentages of modalities of each variable with different capital letters according to column of proportion are significantly different.
* This percentage regroups sociocultural groups which proportion is below 2%.

proportions were realised based on 95 % confidence interval (CI) using the following formula:

$$CI = 1{,}96 \times \sqrt{\frac{p(1-p)}{n}}$$

With p = proportion of grilled pork consumers and n = total number in sampled population.

Analysis of variance (ANOVA) one way was carried out to compare means of physico-chemical characteristics of different forms of grilled pork using Statistica 7 (Version 7.1, StatSoft France, 2006). Significant differences were reported when the probability was below 0.05 ($p < 0.05$).

3. Results and discussion

3.1. Characteristics of consumers and factors determining grilled pork consumption

3.1.1. Socio-demographic profile of grilled pork consumers

Socio-demographic characteristics of surveyed consumers are summarized in Table 1. Data showed that most (94.1 %) of the 372 interviewed grilled pork consumers were ≤ 50 years old with the majority (51.6 %) ≤ 30 years old representing young people. They belonged mainly to socio-cultural groups of *Fon* (37.4 %) and *Goun* (21.8 %). Interviewed consumers were mostly male (78.8 %) ($p < 0.001$). Most of them (85.2 %) had formal education with 39.8 % ($p < 0.001$) with university level. The marital status of grilled pork consumers revealed that 57.5 % ($p < 0.001$) of them were married. Moreover, 91.4 % ($p < 0.001$) were Christians and the others were animists (7.8 %) and Muslims (0.8 %).

3.1.2. Consumption habits

Three differently cooked pork, namely grilled pork, fried pork and cooked pork in *kpètè* (pork blood-based sauce) were claimed by 98.2, 56.2 and 48.1 % of interviewed consumers respectively (data not shown). The three most consumed forms of grilled pork were piece (73 %), slice (57.5 %) and skewer (39.3 %) (Supplementary data 1). The difference between piece and skewer is that a piece can be used to have 1–2 skewers. The last form of cooked pork is a wrapped form made from sliced and grilled pork which is seasoned again, wrapped in paper and grilled a second time. None of the consumers mentioned wrapped form which is produced only on special demand.

Most consumers (90.1 %) disliked fatty part of pork ($p < 0.001$) because "it could make them sick", contrary to 9.9 % of them (Supplementary data 2) who appreciated fatty part of pork for its taste and flavour.

Grilled pork was often eaten with "*akassa*", a cooked fermented maize dough (88.8 % of consumers) and "*Eba*", a cooked dough from *gari* (granules of roasted fermented cassava flour) (68.5 % of consumers) (Supplementary data 2). Grilled pork was eaten with other foods such as dough from maize flour, rice, bread, *"lio"* (another cooked fermented maize dough), "*telibo"* (dried yam dough), pounded yam (4.3 %, 3 %, 1.1 %, 0.8 %, 0.5 % and 0.5 % of consumers, respectively), or wheat product (semolina, macaroni) (Supplementary data 2). Consumers added other ingredients such as a mixture of crushed onion and pepper (64 %), crushed pepper (32 %) or *kpètè* (pork blood-based sauce) (59.1 %) (Supplementary data 2), to grilled pork before eating. Grilled pork was usually consumed at lunch (91.7 % of consumers). However, some consumers ate it also for breakfast (13.2 %) or dinner (16.7 %). Most consumers ate grilled pork either in the restaurants (66 %) or at home (34 %) (Supplementary data 2).

The majority (95.7 %) of consumers ate several other grilled or smoked products (Supplementary data 3), namely grilled peanuts (58.3 %), roasted chicken (52.2 %), grilled maize (48.9 %), *kpanman*, a smoked cattle meat skin (48.9 %), roasted turkey wing (36 %), grilled banana (26.3 %), *tchachanga*, a roasted sheep meat (74.2%), roasted cattle meat (19.1 %), smoked fish (15.6 %) and roasted gizzard (12.9 %). Other smoked products were mentioned as consumed (once per month) by less than 5% of surveyed consumers.

3.1.3. Frequency and consumption level of grilled pork

The frequency and the quantity of grilled pork individually consumed in the study area are presented in Table 2. The daily consumers (once or twice per day) represented 6.5 % of total consumers of grilled pork. Most consumers (74.2 %) ate grilled pork at least once per month while 19.4 % of them consumed this meat occasionally (funeral

Table 2
Frequency and quantity of grilled pork consumed individually in the municipalities of study.

Consumption factors	Consumer's proportion (%)
Frequency of grilled pork consumption	
Occasional (less than 1/month)	19.4
1 – 10/month	52.4
11 – 24/month	21.8
Daily	6.5
Quantity of consumed grilled pork (g/day)	
≤ 50	67.2
] 50 – 100]	21.0
] 100 – 150]	5.6
] 150 – 200]	1.6
] 200 – 250]	3.5
] 250 – 350]	1.1

Table 3
Physico-chemical characteristics of the collected samples of grilled pork (n = 24). Mean ± standard deviation; n = 24.

Parameters	Moisture (%)	pH	% of dry weight	
			Protein	Lipid
Minimum	33.0	5.8	19.5	27.9
Median	47.1	6.2	43.7	49.3
Mean ± sd	47.3 ± 5.7	6.3 ± 0.2	45.4 ± 11.2	50.8 ± 12.3
Maximum	56.7	7.0	69.5	82.1

ceremony and other types of festivity).

About 67.2 % of consumers had a daily consumption of grilled pork ≤ 50 g (Table 2). The other consumers (28.2 %) had a daily consumption of grilled pork ranging from 50 to 200 g and the rest (4.6 %) had a daily consumption of grilled pork ranging from 200 to 350 g.

3.1.4. Physico-chemical characteristics of grilled pork

The pH of the grilled pork ranged between 5.8 and 7.0 with an average of 6.3 ± 0.2. The median pH (6.2) is similar to the pH recorded by Atanassova et al. (2001) for smoked ham which was 6.04. No significant differences ($p > 0.05$) on pH, moisture, protein and lipid content were found among the 4 grilled pork forms investigated (Supplementary data 4). The moisture content of the grilled pork samples ranged between 33.0 % and 56.7 % (Table 3), which agrees with the results reported by Solomon et al. (1994) who found moisture content between 33.4 % and 56.0 % in samples of *unam inung*, a cured Nigerian pork product. The variability in moisture content in this study could be due to the grilling practices of processors which changed from a restaurant to another. Protein content was between 19.5 and 69.5 % whereas lipid content ranged between 27.9 and 82.1 % (dry weight basis). The average protein content (45.4 ± 11.2 %) recorded is lower than the average (59.4 ± 0.6 %) recorded by Ogunsola and Omojola (2008) in *kilishi* made from pig meat but higher than the average protein content (30.8 ± 3.2 %) recorded by Solomon et al. (1994) in *unam inung*. Janiszewski et al. (2016) also recorded similar average (46 %) of protein in grilled pork processed in Poland. Lipids are important in human diet as they are the main source of energy and improve absorption of liposoluble vitamins (SHC, 2016). The high variation recorded in the lipid content and protein content could be related to pig's breed, its diet, the sex and the system of breeding (Petron et al., 2004; Teye et al., 2006; Youssao et al., 2004). Moreover, the variation recorded in the lipid content could be due either to fat removal during meat preparation before grilling by some processors, or to the melting and exudation of lipid during grilling process.

3.1.5. Fatty acid profile of grilled pork

The fatty acid profile of the 24 grilled pork samples is presented in Supplementary data 5. The main SFA were palmitic acid (C16:0), which ranged between 17.3 % and 55.4 % of the total fatty acids, and stearic acid (C18:0), which ranged between 8.8 % and 20.9 % of total fatty acids, while in the group of MUFA, oleic acid (C18:1 (w9)) was the most abundant and ranged between 24.4 % and 48.8 % of total fatty acids (Supplementary data 5). Concerning PUFA, the predominant omega 6-PUFA was linoleic acid (C18:2 (omega 6)), which ranged between 0.5 % and 3.6 % of total fatty acids while the most abundant omega 3-PUFA were stearidonic acid (C18:4), which ranged between < 0.1 % and 4.2 % of total fatty acids, and docosahexaenoic acid (DHA, C22:6) which ranged between 0.5 % and 1.4 % of total fatty acids (Supplementary data 5). In all samples, the proportion of gamma linolenic acid (C18:3 (omega 6)), di-homo-γ-linolenic acid (C20:3 (omega 3)) and eicosapentaenoic acid (EPA, C20:5 (omega 3)) was below 1% of total fatty acids. The high stearidonic acid content recorded in this study could be attributed to the feeding of pig from which pork derived from. Otten et al. (1993) reported the presence of stearidonic acid in different part of pork (heart, liver, kidney, *Longissimus dorsi*, adipose tissue…) with maximum concentration of 0.5 % of total fatty acids. Only pig fed with diet containing fish oil had such stearidonic acid content (Otten et al., 1993). D'arrigo et al. (2002) also reported stearidonic acid in pork liver (about 0.3 % of total fatty acids) with content changing according to pig feeding.

The presence of DHA in pork at such high concentration in total fatty acids (0.5–1.4 %) is unusual because DHA and EPA were more associated to fish (Kaya et al., 2008; SHC, 2009). However, DHA was also found at a lower percentage (0.1 % of the total fatty acids) in dry-cured pork from Spain (Veiga et al., 2003). Janiszewski et al. (2016) and Nuernberg et al. (2006) also reported DHA concentration in total fatty acids of grilled pork processed in Germany and Poland with concentration till 0.2 % of the total fatty acids. In the study reported by Nuernberg et al. (2006), DHA was found in the feeding of pig and in the pork before and after grilling. Moreover, in Benin, pork from indigenous pig breed had important DHA content (0.4 % of the total fatty acids) which mainly came from its diet (Youssao et al., 2004).

The variation of fatty acid composition between samples may be attributed to feeding, sex and pig breeds as reported by Petron et al. (2004) and Youssao et al. (2004).

SFA ranged between 40.9 and 69.3 % of total fatty acids, MUFA ranged between 25.5 % and 52.6 % of total fatty acids while PUFA ranged between 3.4 % and 9.2 % of total fatty acids (Table 4). Fernández-Cabanás et al. (2011) recorded MUFA levels ranging between 46.8 % and 56.8 % of total fatty acids in commercial Spanish dry-cured sausage based on pork. The PUFA concentration in the total fatty acids (3.4–9.2 %) found in this study were lower than the PUFA levels (14.2–15.8 %) recorded in roasted pork as reported by Guillevic et al. (2007). Janiszewski et al. (2016) reported SFA (38.2 %), MUFA (41.5 %) of roasted pork from Poland, which were in the range found in this study. However, the PUFA concentration in the total fatty acids (19.6

Table 4
Fatty acid composition (% of total fatty acids) of individual samples of grilled pork (n = 24).

Form	SFA	MUFA	PUFA	Omega 6	Omega 3	Omega 6/Omega 3
Piece	59.5	35.2	5.3	1.2	4.1	0.3
	52.5	41.7	5.8	1.3	4.6	0.3
	58.3	32.9	8.8	3.1	5.8	0.5
	59.0	36.4	4.6	1.9	2.7	0.7
	60.6	33.2	6.2	2.4	3.8	0.6
	44.6	49.8	5.6	2.7	2.9	0.9
Skewer	43.7	49.9	6.4	1.6	4.7	0.4
	54.0	41.8	4.1	1.6	2.5	0.6
	65.1	31.0	3.9	1.6	2.3	0.7
	50.7	44.6	4.7	2.2	2.5	0.9
	47.8	45.3	6.9	2.6	4.3	0.6
	50.7	40.1	9.2	3.2	6.0	0.5
Slice	40.9	52.6	6.5	3.4	3.1	1.1
	50.8	42.1	7.1	1.9	5.2	0.4
	52.2	44.0	3.8	0.5	3.3	0.2
	69.3	25.5	5.2	0.5	4.7	0.1
	63.8	32.3	3.9	1.3	2.6	0.5
	65.9	28.4	5.7	2.2	3.5	0.6
Wrapped	62.2	34.4	3.4	0.6	2.8	0.2
	59.8	35.1	5.1	2.3	2.8	0.8
	59.8	35.2	4.9	1.9	3.0	0.6
	53.7	41.4	4.9	1.5	3.5	0.4
	43.3	51.9	4.7	4.2	0.5	7.8
	56.6	36.5	6.9	3.2	3.6	0.9
Minimum	40.9	25.5	3.4	0.5	0.5	0.1
Mean	55.2	39.2	5.6	2.0	3.5	0.9
Median	55.3	38.3	5.3	1.9	3.4	0.6
P75	60.0	44.2	6.4	2.6	4.4	0.7
P97.5	67.3	52.2	9.0	3.7	5.9	3.9
Maximum	69.3	52.6	9.2	4.2	6	7.8

SFA: Saturated fatty acid; **MUFA:** Monounsaturated fatty acid; **PUFA:** Polyunsaturated fatty acid.

Table 5
Comparison between fatty acids of grilled pork from Benin and fatty acids of roasted pork from US.

Fatty acids (g/100 g of product)	Grilled pork from Benin	Roasted pork (USDA, 2019)
SFA	12.9	5.3
MUFA	8.2	6.5
PUFA	1.2	1.2

SFA: Saturated fatty acid; **MUFA:** Monounsaturated fatty acid; **PUFA:** Polyunsaturated fatty acid.

%) of roasted pork from Poland were two times higher than the PUFA concentration in the total fatty acids recorded in this study. On the other hand, the SFA and MUFA contents (g/100 g of product) recorded in grilled pork in Benin exceeded 2.4 and 1.2 times respectively the SFA and MUFA contents recorded in roasted pork from the United States (USDA, 2019) (Table 5). However, PUFA content of grilled pork from Benin is similar to the PUFA content of roasted pork from US. The ratio between omega 6 and omega 3 fatty acids contents ranged between 0.1 and 7.8, with only 2 samples out of the 24 displaying a ratio above 1 (Table 4). According to Simopoulos (2008), omega 6/omega 3 ratio should be kept lower or equal to 1 in human diet for chronic disease risk reduction.

Alpha linolenic acid (C18:3 (omega 3)) and linoleic acid (C18:2 (omega 6)) are two essential fatty acids which are not synthetized by humans (FAO, 2010). All grilled pork samples contained linoleic acid in the range of 0.5–3.6 % of total fatty acids while alpha linolenic acid was detected only in four samples (data not shown). As the grilled pork samples analysed were collected from different processing sites, the results of fatty acids might be affected by pig breed used to produce grilled pork (Youssao et al., 2004) and grilling practices (Janiszewski et al., 2016). High PUFA content food such as grilled pork can be subjected to oxidation which results firstly in loss of nutritional value and secondly in formation of volatile components responsible of loss of colour, rancid taste and odour which make food unfit for consumption (Nout et al., 2003).

3.1.6. Macronutrients intake from grilled pork consumption

Consumption data collected from the 300 consumers ranged between 0.7 g/day and 342.9 g/day with a median of 28.6 g/day. Average contents of protein (23.7 %, wet weight) and lipid (27.03 %, wet weight) determined in the 24 collected grilled pork samples were used to estimate the nutrient daily intake. The average contents (expressed in g/100 g of product) of SFA, MUFA, PUFA, omega 6 fatty acids, omega 3 fatty acids and eicosapentaenoic acid (EPA) + docosahexaenoic acid (DHA) were 12.8, 9.1, 1.3, 0.5, 0.8, and 0.2 respectively (Supplementary data 6). According to minimum and maximum daily consumptions of grilled pork (0.7 g/day and 342.9 g/day), male consumers had a daily protein intake through grilled pork consumption ranging between 0.01 g/kg.bw/day and 1.04 g/kg.bw/day while protein intake of female consumers ranged between 0.003 g/kg.bw/day and 0.9 g/kg.bw/day (Table 6). The median protein daily intake from grilled pork of male and female consumers was 0.12 g/kg.bw/day and 0.08 g/kg.bw/day, respectively. The 75 % (third quartile) of male and female consumers selected for this estimation had a protein intake from grilled pork consumption below or equal to 0.2 g/kg.bw/day. According to WHO (2007), the recommended protein intake is 0.75 g/kg.bw/day while EFSA (2012) recommended 0.8 g/kg.bw/day. These results revealed that the only consumption of grilled pork is not sufficient to cover adult protein requirements in the study area. However, the consumption of grilled pork highly contributes to daily protein intake, as it corresponds to about 25 % of adult protein requirement.

Male and female consumers had a lipid daily intake through grilled pork consumption ranging between 0.8 and 92.7 g/day and between 0.2 and 57.9 g/day, respectively. The median lipid intake for male and female consumers was 11.6 and 6.8 g/day respectively. The 75th percentile of male and female consumers selected for this estimation had a daily lipid intake from grilled pork consumption of 19.3 g/day and 15.4 g/day, respectively. According to the Belgian Superior Health Council (SHC, 2016), lipid intake for adults should range between 55 and 83 g/day for men, and between 44 and 66 g/day for women. In the case of fatty acids, the daily intake of SFA from grilled pork ranged between 0.4 g/day and 44.0 g/day, for men, and between 0.1 g/day and 27.5 g/day, for women. The daily intake of SFA met the recommendation of < 22 g/day for women and < 28 g/day for men, with a maximum of 97.5 percentile of grilled pork consumption for men and 96 percentile for women (SHC, 2016). The daily intake of MUFA ranged between 0.3 and 31.3 g/day for men and 0.1 and 19.6 g/day for women. Consumption of high quantity of grilled pork (342.9 g/day) enabled to cover 89 %, for women, and more than 100 %, for men, of adult requirements of MUFA (which range between 28 − 55 g/day for men and 22 − 44 g/day for women) (SHC, 2016).

The daily intake of PUFA through grilled pork consumption ranged between 0.04 g/day and 4.4 g/day, for men, and between 0.009 g/day and 2.8 g/day for women, while adult recommended intake range of PUFA is 14 − 28 g/day for men and 11 − 22 g/day for women (SHC, 2016). The consumption of the highest recorded quantity of grilled pork (342.9 g/day) enabled to cover 31 % of adult PUFA requirements for men and 25 % for women.

The daily intake of omega 6 fatty acids from grilled pork ranged between 0.01–1.6 g/day for men and 0.003–1.0 g/day for women. The highest level of grilled pork consumption recorded in this study covered 14 % (men) and 11 % (women) of omega 6 fatty acid requirements. The omega 3 fatty acids daily intake from grilled pork ranged between 0.02 g/day and 2.9 g/day for men, and between 0.006 g/day and 1.8 g/day for women, while the recommended intake is 2.8–5.6 g/day for men and 2.2–4.4 g/day for women (SHC, 2016). Finally, the long chain PUFA EPA and DHA daily intake through grilled pork consumption ranged between 6.0 mg/day and 723.9 mg/day for men, and between 1.5 mg/day and 452.4 mg/day for women. According to EFSA (2010) and FAO (2010), the recommended intake of EPA + DHA is 250 mg/day. Even though this study showed the nutritional importance of grilled pork in Benin, its consumption can present health concerns for consumers (Iko Afé et al., 2020). Indeed, grilled pork can be contaminated with carcinogenic compounds such as polycyclic aromatic hydrocarbons (PAHs) during traditional grilling (Duedahl-Olesen et al., 2015; Iko Afé et al., 2020).

4. Conclusion

This paper highlights that grilled pork is a good source of proteins and lipids in Benin, mostly for the young generation (less than 30 years old) representing 51.6 % of grilled pork consumers. Linoleic acid and stearidonic acid were respectively the most abundant omega 6-PUFA and omega 3-PUFA found in grilled pork samples. Grilled pork consumption enabled to cover 25 % of adult protein requirement for about 75 % of interviewed consumers. The findings also pointed out that female and male consumers had similar daily protein intake. Regarding the fatty acids, it was noticed an important contribution of grilled pork consumption to the intake of EPA and DHA, till three times the recommended value of 250 mg/day. For the same level of grilled pork consumption, the daily intake of omega 3 fatty acids was more important than the daily intake of omega 6 fatty acids. Despite the significant contribution of grilled pork to daily nutritional needs among the young generation in Benin, more attention should be paid to the health concerns related to its consumption.

Author Statement

This work was carried out in collaboration between all authors who approved the final manuscript.

Table 6
Protein, lipid and fatty acids daily intake through grilled pork consumption in Benin.

Descriptive statistics	Daily intake of nutrient from grilled pork consumption															
	Protein (g/kg bw/day)[1]		Lipid (g/day)[2]		SFA (g/day)[3]		MUFA (g/day)[4]		PUFA (g/day)[5]		Omega 6 fatty acids (g/day)[6]		Omega 3 fatty acids (g/day)[7]		EPA + DHA (mg/day)[8]	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Minimum	0.01	0.003	0.8	0.2	0.4	0.1	0.3	0.1	0.04	0.009	0.01	0.003	0.02	0.006	6.0	1.5
Median	0.1	0.1	11.6	6.8	5.5	3.2	3.9	2.3	0.6	0.3	0.2	0.1	0.4	0.2	90.5	52.8
P75	0.2	0.2	19.3	15.4	9.2	7.3	6.5	5.2	0.9	0.7	0.3	0.3	0.6	0.5	150.8	120.6
P97.5	0.8	0.7	57.9	54.7	27.5	26.0	19.6	18.5	2.8	2.6	1.0	0.9	1.8	1.7	452.4	427.5
Maximum	1.0	0.9	92.7	57.9	44.0	27.5	31.3	19.6	4.4	2.8	1.6	1.0	2.9	1.8	723.9	452.4

[1] Dietary reference value, (DRV) = 0.83 g/kg.bw/day for both genders (SHC, 2016; EFSA, 2012) and DRV = 0.75 g/kg.bw/day (WHO, 2007).
[2] DRV = $> 55 < 83-97$ g/day for men and $> 44 < 66-77$ g/day for women (SHC, 2016).
[3] DRV = < 28 g/day for men and < 22 g/day for women (SHC, 2016).
[4] DRV = 28 − 55 g/day for men and 22 − 44 g/day for women (SHC, 2016).
[5] DRV = 14 − 28 g/day for men and 11 − 22 g/day for women (SHC, 2016).
[6] DRV = 11 − 22 g/day for men and 8.8 − 18 g/day for women (SHC, 2016).
[7] DRV = 2.8–5.6 g/day for men and 2.2–4.4 g/day for women (SHC, 2016).
[8] DRV = 250 − 500 mg/day for both genders (SHC, 2016) and DRV = 250 mg/day for both genders (EFSA, 2010; FAO, 2010).

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Declaration of Competing Interest

No potential conflict of interest was reported by the authors.

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Appendix A. Supplementary data

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