

Full Length Research Paper

Traditional production and quality perception of grilled pork consumed in Benin

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Traditional grilled pork is a well appreciated ready-to-eat on the spot or takeaway food produced in Benin. This study, realized via field investigation, aimed to provide a better understanding of the traditional grilled pork production in Benin, for future improvement of the process and product quality for urban dwellers. The study showed most processors were men (85.6%), illustrating the particularity of this activity in the country where most street food vendors are women. They were also young (≤ 40 years - 63.9%), mainly from *Goun* and *Fon* sociocultural groups (59.5%), illiterate or primary school educated (72.3%). Indigenous pig breeds were preferred for processing (93.6%). Bristles elimination of the pig was carried out either by scalding or singeing. Among the eight grilling equipment recorded, vertical barrel grill was the most commonly used (46.8%) followed by locally made clay grills (28.7%). Wood (62.8%) and charcoal (37.2%) were the most used fuel for grilling. The diversity of equipment and methods used in traditional grilled pork production could be a source of quality variability of grilled pork in Benin. The texture was considered the suitable criteria to appreciate precooked (40.5%) and grilled pork (72.3%), while colour was used to appreciate fresh pork quality (53.2%).

Key words: Pig meat, traditional grill, fuel, singeing, quality.

INTRODUCTION

Pork is highly appreciated and consumed in West African countries due to its organoleptic characteristics and

nutritional quality (Fuller et al., 2004). The number of domesticated pigs increased by 44% from 2004 to 2014

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in Benin, with 5172 tons of pork produced (DE, 2014; FAOSTAT, 2016). As the third most-consumed meat after beef and poultry, pork consumption has increased in Benin despite religious prohibition for about 20% of the Beninese population (Youssao et al., 2008a). Meat such as pork is heat processed using traditional methods of grilling and smoking during which meat is directly laid on grid above the embers made from different fuels (Lee et al., 2016; Park et al., 2017; Assogba et al., 2020). Grilling is one of the most common methods of pork processing in Benin (Ayssiwede et al., 2009), being used to improve the meat's sensory characteristics including taste, appearance, colour, and aroma (Stolyhwo and Sikorski, 2005; Ciecierska and Obiedzinski, 2007; Igwegbe et al., 2014; Yusuf et al., 2015). Anihouvi et al. (2020) reported spoilage and pathogenic bacteria such as Enterobacteriaceae, *Escherichia coli* and *Clostridium perfringens* in grilled pork and explained their presence by different factors including the method and environment of processing. Several authors also reported that heat treatment of meat including grilling of pork results in production of toxic compounds like heterocyclic amines (Buła et al., 2019; Polak et al., 2020), oxidation products of cholesterol (Min et al., 2016) and aldehydes (Munasinghe et al., 2003). Iko Afé et al. (2020) also reported polycyclic aromatic hydrocarbons (PAHs) including benzo(a)pyrene, the carcinogenic compound, in grilled pork produced in cottage industry of Benin and showed that this contamination was due to traditional grilling. Even though, grilled pork produced in Benin has good nutritional quality, its consumption may result in public health issue due to the presence of both microbial and chemical hazards.

To our knowledge, there is no scientific data giving a good insight about the methods used to produce grilled pork in cottage industry. In addition, to improve the overall quality of grilled pork, the inventory of grilling processing is needed. Thus, the present study aimed to provide a better understanding of these processing practices and the perception of quality according to the processors of grilled pork in Benin.

MATERIALS AND METHODS

Choice of the survey areas

The field investigation was carried out in five cities located in four districts of Benin (Figure 1): Adjarra and Porto-Novo (Ouémé), Cotonou (Littoral), Abomey-Calavi (Atlantic), and Bohicon (Zou). High pork production and consumption levels were the main criteria justifying the choice of these districts (Youssao et al., 2008a; Ayssiwede et al., 2009; ANAT, 2014; PAFILAV, 2014).

Sample population

The number of randomly selected grilled pork producers was obtained according to Dagnelie (1998), using the following equation:

$$N = \frac{4p(1-p)}{d^2}$$

where N is the total number of stakeholders (processors) to be interviewed, d is the expected margin of error ($d = 0.05$), and p is the proportion of pork processors living in the survey areas.

A total of 188 processors were randomly selected and investigated at the production sites located in the following five municipalities of Benin: Adjarra ($n = 10$), Porto-Novo ($n = 42$), Cotonou ($n = 80$), Abomey-Calavi ($n = 46$) and Bohicon ($n = 10$).

Field data collection

A preliminary survey was conducted in order to identify the processing sites and to test the questionnaire design. The investigation was then carried out using the validated questionnaire designed in two parts based on processing and marketing. Processors (also sellers) were surveyed in the field at the processing sites. Individual interviews were used to collect data during the survey, with focus group discussions and observations of processors at work employed to collect complementary information for flow diagram description. The survey was conducted in French and five Beninese languages (*Goun*, *Fon*, *Mina*, *Torri*, and *Kotafon*). Data collected included demographic information, socio-cultural status of the processors, raw material and other ingredients used, as well as processing and storage. During the survey, questions related to their perception of quality criteria of pork products were also asked to the processors.

Data analysis

Sphinx Survey Plus 2 (version 4.5) was used to record the collected data and Microsoft Excel 2010 for descriptive statistics. The Statistical Analysis System (SAS Institute, Cary, NC) was used for data treatment. The Logistic Regression Model (LRM) method was used to assess the effect of the selected independent variables (survey area; academic qualifications, religion and socio-cultural groups of processors; pig breed; grilled pork form; type of fuels) on the dependent variables (bristle removal practises and precooking). The Chi-squared (χ^2) test and Fisher's Exact Test were employed to test the qualitative variables.

RESULTS

Socio-demographic characteristics of processors

The socio-demographic characteristics of processors are summarized in Table 1. The results revealed that pork processing in the study areas is mainly carried out by men (85.6%), with most female processors starting this activity via a relative or spouse. Processors interviewed belonged to various age ranges, with most (63.9%) aged less than 40 years old. Those questioned had an average length of grilling experience of twelve years, and belonged to various socio-cultural groups including *Goun* (30.8%), *Fon* (28.7%), and *Torri* (18.1%). The majority of the processors (58.5%) received explicit schooling (primary, secondary, university). Most were married (89.4%) and Christian (88.8%).

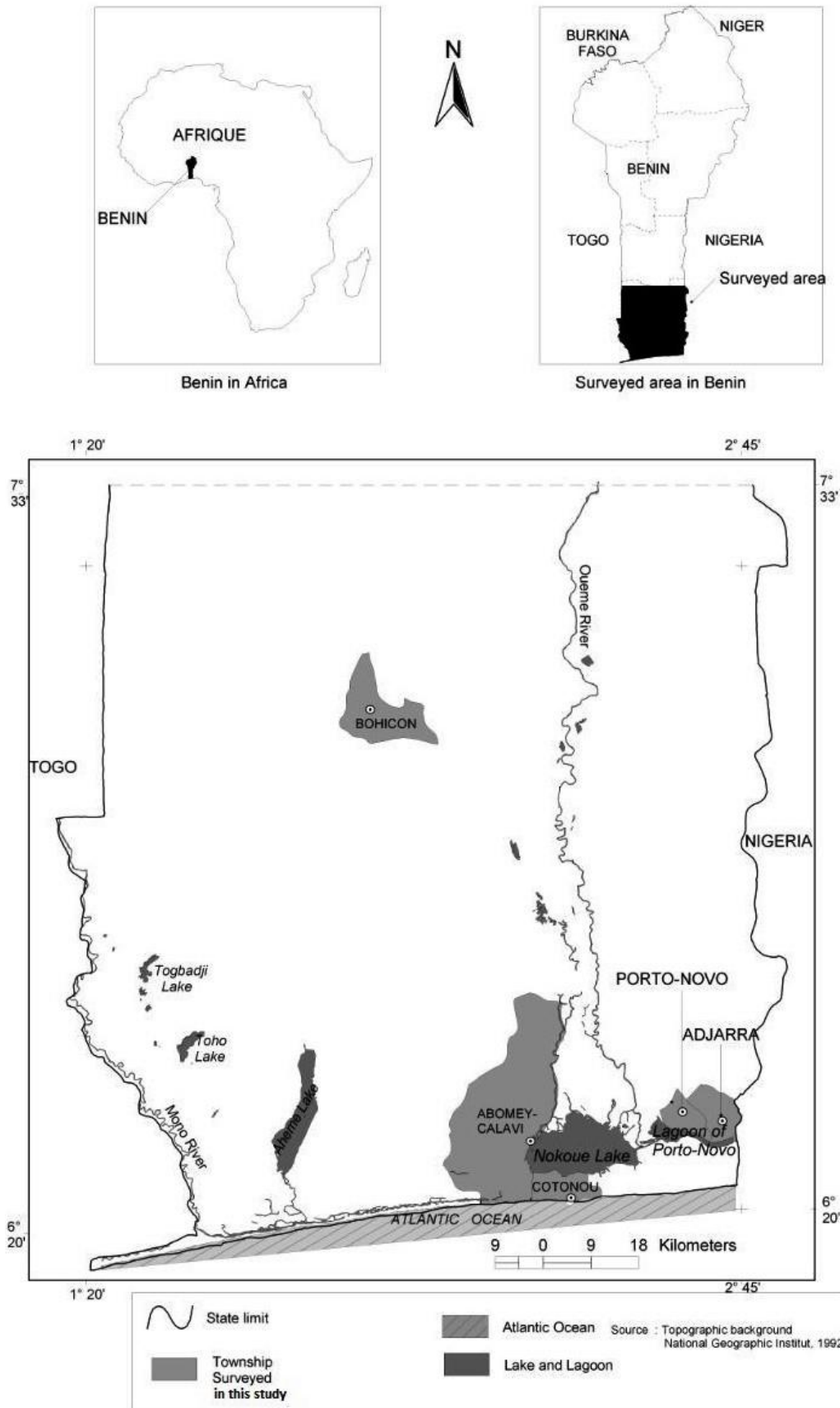


Figure 1. Map of Benin showing the surveyed areas.

Table 1. Socio-demographic characteristics of the surveyed Beninese grilled pork processors.

Characteristics	Processors (%) (n=188)
Age (years)	
<20	8.0
20-30	17.1
31-40	38.8
41-50	22.3
51-60	8.5
>60	5.3
Gender	
Male	85.6
Female	14.4
Sign. Test	***
Socio-cultural groups	
<i>Goun</i>	30.8
<i>Fon</i>	28.7
<i>Torri</i>	18.1
<i>Aizo</i>	6.4
<i>Mina</i>	3.2
<i>Xlwa</i>	3.2
Sign. Test	***
Academic qualification	
Primary school	35.1
Secondary school	18.6
University	4.8
Illiterate (no schooling)	37.2
Local language education	4.3
Sign. Test	***
Marital status	
Unmarried	10.1
Married	89.4
Divorcee	0.5
Widowed	0.0
Sign. Test	***
Religion	
Animism	11.2
Christianity	88.8
Islam	0.0
Sign. Test	***

Sign. Test: Significance tests among proportions. ***: significant difference ($p < 0.001$).

Production of grilled pork

The various processing methods employed during the production of the three forms of grilled pork sold in Benin

are summarized in the flow diagram in Figure 2. Raw pork is firstly boned, followed by optional fat removal, and then cut into sliver or skewer form using a knife and wooden cutting table. The pork is then seasoned in a

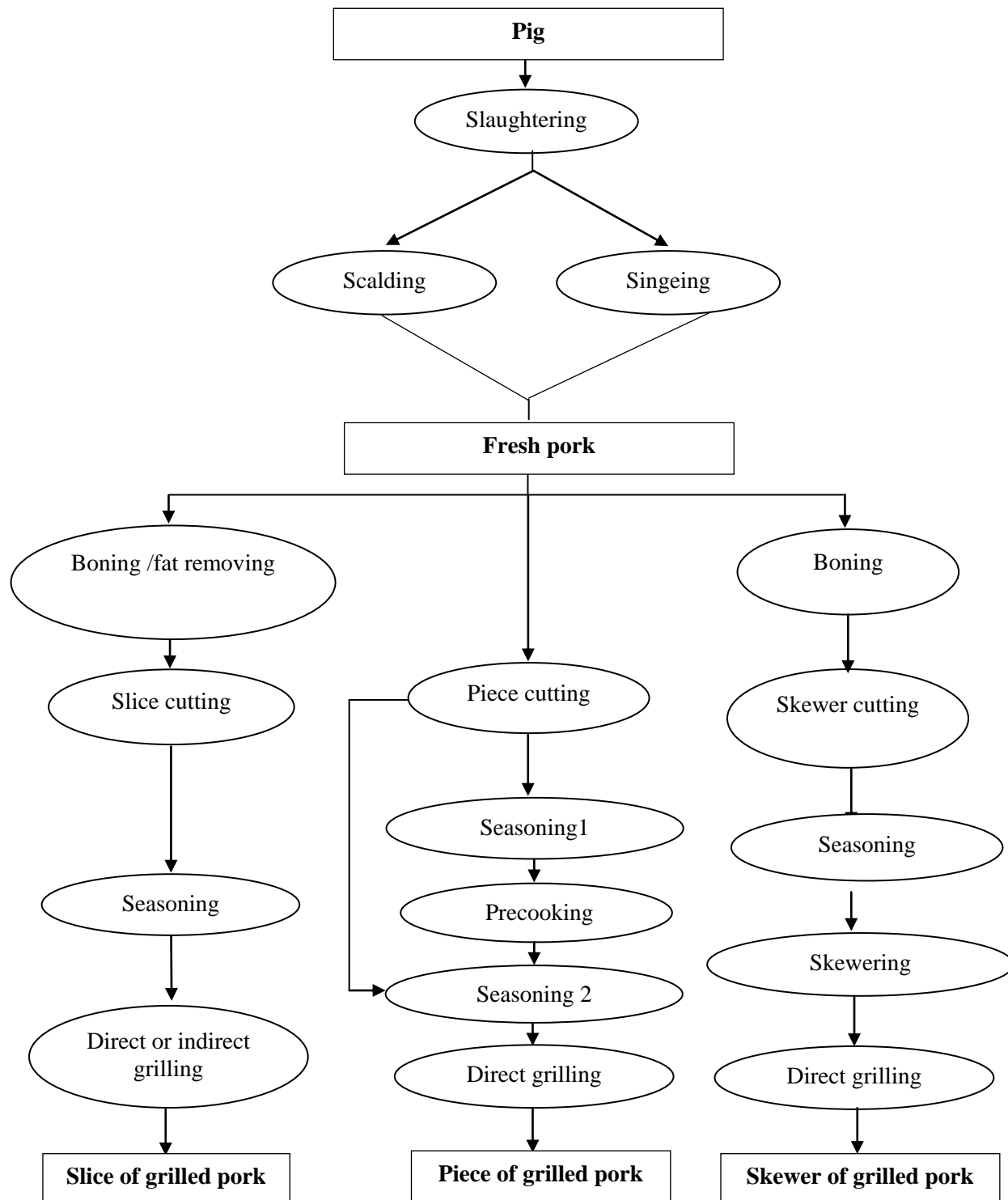


Figure 2. Flow diagram of fresh pork processing into grilled pork in Benin.

bowl and grilled. Precooking in boiling water and complementary seasoning are the main operations differentiating piece-form grilled pork from the other two options.

Three breeds of pig are non-exclusively used by the

processors: indigenous (93.6%), crossbred (Large White × Indigenous, 71.8%), and exotic (Large White, 38.3%). Pigs are purchased in national markets (90.4%) including Adjarra and Azovè, breeding farms and small cattle breeders (43.6%), or are imported from neighbouring

Table 2. Proportions of processors using different methods of processing and types of fuels.

Variable and modalities	Proportion (%)
Processing	
Processing including precooking	22.9
Processing excluding precooking	77.1
Significance test	***
Bristle removal by scalding	52.1
Bristle removal by singeing	47.9
Significance test	***
Types of fuels	
Charcoal	37.2
Wood	62.8
Significance test	***

***p<0.001

countries (36.7%), namely Burkina Faso, Nigeria and Togo. Most processors (88.8%) preferred castrated pigs. Pig choice is based mainly on health status and fat content, regardless of breed (Supplementary data 1).

Most processors claimed to check the pigs before purchasing, to ensure quality. About 64.3% of processors control pig health status by checking for the presence of tongue cysts, with 10.1% checking eye colour. About 46.8% of processors felt pig neck to state if the animal is fat or lean; if the neck is too developed, the pig is considered too fat and therefore inappropriate for processing due to lower profitability. Pigs are also inspected by a veterinary officer both prior to slaughter (ante-mortem inspection, 47.9% of processors) and more often after slaughter (post-mortem inspection, 98.9% of processors). The surveyed processors slaughter the pigs in their residence (42.6%), on the processing site (42%), in a slaughterhouse (20.2%) or in slaughtering areas (6.4%). Pig bristles are eliminated either by scalding (52.1%) or singeing (47.9%) (Table 2). The scalding is carried out by immersion of the slaughtered pig in hot water for a few seconds and then removing the bristles from the skin using a knife. In the second case named singeing, pig is firstly exposed to flames and then bristles are eliminated with a knife. The pig is then gutted, cleaned and the carcass packed and transported to the processing site, mainly in bowls (45.7%), polyester bags (26.1%), burlap (12.8%), baskets (3.7%) or iceboxes (0.5%). Transportation is carried out mostly via motorbikes (55.9%), although some interviewees reported transport on foot (20.2%) or car (3.7%).

The cleaned pork is deboned and sometimes defatted before being cut into either small pieces for skewers or thin slices, which are seasoned and grilled (Figure 2). Ingredients such as garlic (*Allium sativum*), pepper (*Piper nigrum* and *Capsicum* species), onion (*Allium cepa*), ginger (*Zingiber officinalis*), laurel leaves (*Laurus nobilis*) and glutamate concentrate may be mixed and used for

seasoning of the pork before grilling. The grilling of the pork in piece form is carried out either by precooking in hot water (22.9%) or without precooking (77.1%) before grilling (Table 2). Significant difference ($p < 0.001$) was found among processors in terms of the three main variables (processing, main fuel, and bristle removal). Whereas those located in Cotonou and Abomey-Calavi tend to precook pork, grilling of pork without precooking is exclusively undertaken by processors in Adjarra and Bohicon, and by almost all the processors in Porto-Novo. Bristle removal via singeing is carried out by almost all processors in Adjarra, Bohicon and Porto-Novo.

Types of grills and fuels used for processing

Eight different types of grills were recorded during the field investigation (Table 3), the most common being vertical barrel grills (46.8%) and locally made clay grills (28.7%). Two variants of locally made clay grill have been identified: the first comprises two chambers, one for combustion and one for grilling, which communicate through an opening (indirect grilling technique used by 21.8% of processors), while the second variant comprises only one chamber for both combustion and grilling (direct grilling technique used by 6.9% of processors).

The fuels used for the grilling of pork were wood (62.8%) and charcoal (37.2%). Processors recognized about fifteen tree species as sources of fuel wood (Table 4), predominantly *Acacia auriculiformis* (38.3%), *Tectona grandis* (36.2%), *Manguifera indica* (17.6%), and *Anogeissus leiocarpa* (13.3%). To light their charcoal or wood fires, processors use secondary fuels such as petroleum (6.4%), cake of palm nuts (5.3%), coconut husks (4.3%), palm nut shells (3.2%), and plastic bags (0.5%). A variety of factors were provided with respect to the choice of a fuel source, as illustrated in Figure 3.

Among these, 'it burns well' was the main reason

Table 3. Frequency of use of different types of grills for pork grilling in Benin.

Types of grill	Fuel	Features	Frequency of use (%)	Total (%)
Locally made clay grill	Wood	With two chambers	21.8	28.7
		With one chamber	6.9	
Metallic and parallelepiped	Wood	Without chimney	8.5	10.6
		With chimney	2.1	
Brick and parallelepiped	Wood	NA	5.9	5.9
Vertical barrel	Wood	NA	37.8	46.8
	Charcoal	NA	9.0	
Horizontal barrel	Charcoal	Without cover and chimney	10.6	12.8
		With cover and chimney	1.1	
		With moving grid	1.1	
Gas grill	Gas	NA	0.5	0.5
Metallic with wheel rim	Charcoal	NA	3.7	3.7
Metallic and rectangular	Charcoal	NA	3.7	3.7

NA: Not applicable.

Table 4. Proportions of processors using different tree species as wood fuel for grilled pork production in Benin.

Scientific name	Local name of tree species	Processors (%)
<i>Acacia auriculiformis</i>	Cassia	38.3
<i>Tectona grandis</i>	Tekitin	36.2
<i>Mangifera indica</i>	Amanaguatin	17.6
<i>Anogeissus leiocarpa</i>	Agni/Kétoutin	13.3
<i>Azadirachta indica</i>	Kininoutin	4.8
<i>Anacardium occidentale</i>	Acajoutin	4.8
<i>Garcinia kola</i>	Ahowétin	4.2
<i>Casuarina equisetifolia</i>	Filaotin	8.5
<i>Psidium guajava</i>	Kinkountin	0.5
<i>Zanthoxylum zanthoxyloides</i>	Hêtin	1.1
<i>Khaya senegalensis</i>	Caïlcédratin	3.2
<i>Pterocarpus erinaceus</i>	Kossoétin	3.7
<i>Eucalyptus camaldulensis</i>	Eucalyptustin	4.3
<i>Citrus</i> sp.	Yovozintin	0.5
<i>Elaeis guineensis</i>	Dékpa	1.1

provided by 21.8, 20.7, 9 and 10.1% of processors using *A. auriculiformis*, *T. grandis*, *M. indica* and *A. leiocarpa*, respectively (Figure 3).

Effect of socio-demographic characteristics, technological parameters and survey area on precooking and bristle removal practices

The results (Table 5) showed that both bristle removal and pork precooking significantly ($p < 0.001$) varied with the production areas. Moreover, bristle removal ($p < 0.05$)

and precooking ($p < 0.01$) also significantly varied with the type of fuel while only bristle removal significantly ($p < 0.05$) varied with the socio-cultural groups. Regarding the other independent variables, no significant change was recorded.

Quality criteria for fresh pork, intermediary products, and end product

The quality criteria used by processors to judge fresh

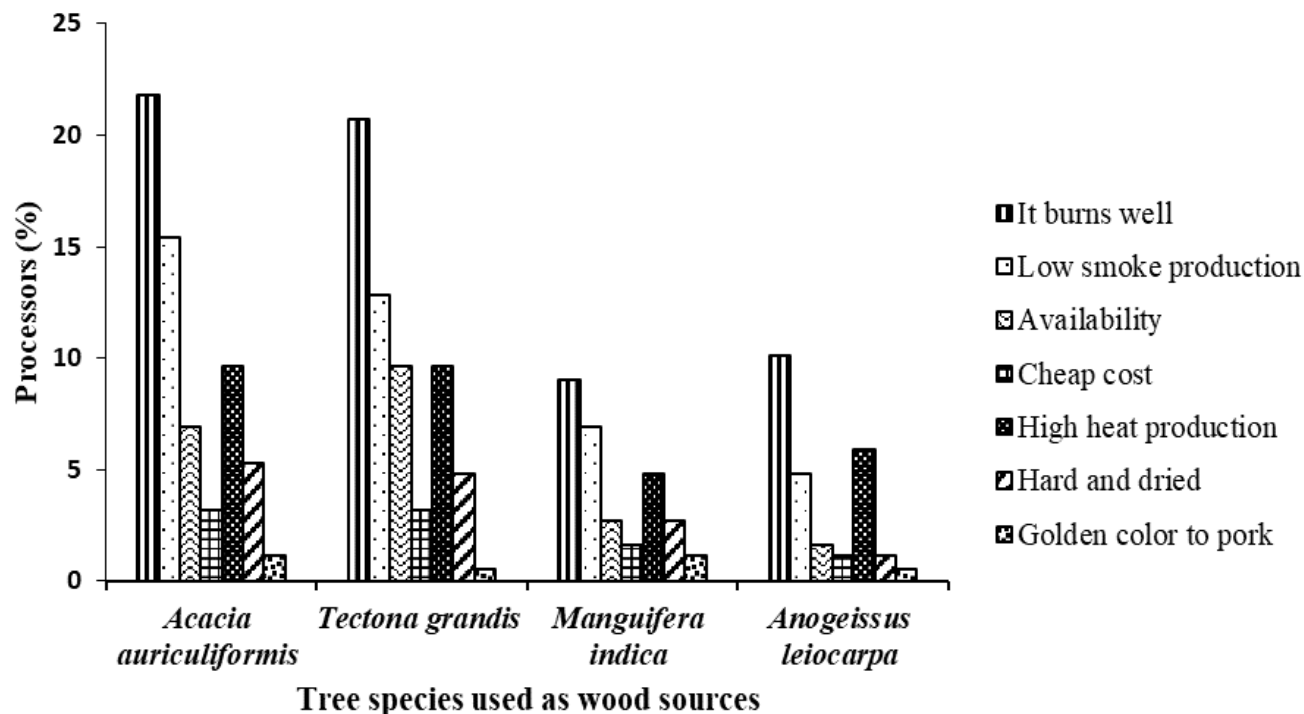


Figure 3. Proportions of processors giving the reasons regarding the choice of the four main tree species used for fuel in pork grilling in Benin.

Table 5. Effect of survey areas, socio-demographic characteristics and technological parameters on precooking and bristle removal practices.

Variable	Survey areas	Socio-cultural groups	Religion	Academic qualification	Pig breed	Grilled pork form	Type of fuels
Bristle removal (scalding or singeing)	***	*	NS	NS	NS	NS	*
Precooking (yes or no)	***	NS	NS	NS	NS	NS	**

NS: Non-significant; *p<0.05; ***p<0.001.

pork, the intermediary product and end product (grilled pork) included texture, colour, aroma, taste and low fat content. However, texture was considered the most suitable to appreciate precooked (40.5%) and grilled pork (72.3%), while colour was used to appreciate fresh pork quality (53.2%) (Supplementary Data 2).

Quality issues for fresh pork and processed products

Several quality issues were listed by processors during the investigation (Supplementary Data 3). Quality issues related to fresh pork included malodour emission (claimed by 23.7% of processors), presence of cysts (21%), and the presence of blood (13.2%). For precooked pork, a less soft texture and malodour emission were listed as main quality issues by 31.2 and 25% of processors, respectively. Carbonization of pork during grilling and malodour emission was the two main

quality issues selected by 30.5 and 21.8% of processors interviewed, respectively, with respect to grilled pork. Surprisingly, 36.8, 37.5 and 17.4% of processors were not aware of any quality issues regarding fresh, precooked and grilled pork, respectively.

Preservation of grilled pork and treatment of unsold grilled pork

The survey showed that not all grilled pork may be sold during the day of processing, with the remaining products kept at ambient temperature (41%), in the fridge (45.2%) or under ice (13.8%) for selling the next day. Various techniques for selling unsold products were described by the processors (Supplementary Data 4), including grilling again the next day (46.3%), flavouring and grilling (23.9%), frying (9.6%) or cooking in a sauce commonly known as *kpètè* (2.1%) in *Goun* language.

Factors influencing the selling price of grilled pork

Processors sell grilled pork directly at processing sites. Selling price was found to depend on three main factors: production cost, influenced by the purchase price of the pig (77% of processors); quality of grilled pork (5.7% of processors); and yield of grilled pork (17.4% of processors).

DISCUSSION

Socio-demographic characteristics of processors

The socio-cultural groups of processors recorded in this study are in agreement with those reported by Ayssiwede et al. (2009), who found a preponderance of the *Goun* and *Fon* sociocultural groups among pork butchers in Benin. The high proportion of these sociocultural groups is due to the fact that most of them are originally from these municipalities and the production of grilled pork is family activity transmitted from father to son or relatives. The high proportion of men undertaking pork grilling illustrates the particularity of this activity, as in Benin, most street food stalls and traditional restaurants are run by women (Nago et al., 1994; FAO, 1997). Moreover, the fact that processors averaged around twelve years of experience and most of them were aged less than 40 years old demonstrates that many processors likely started at a young age in recent decades, illustrating the vitality of this activity among the younger generation.

Production of grilled pork

The three pig breeds used for processing are derived from both national markets and neighbouring countries (Burkina Faso, Nigeria, and Togo), all of which have a land border with Benin, facilitating the pig trade. These results are in agreement with observations made by several authors (Ayssiwede et al., 2009; Goussanou et al., 2013) listing the same countries as the main exporters of pigs to Beninese butchers. The use of castrated pigs by processors for pork grilling might be due to the fact that castration improves pig zootechnical performance, as well as the sensorial and technological properties of pig meat (Youssao et al., 2008b). The use of singeing and scalding as bristle removal methods may affect the carcass and raw pork quality. Indeed, Monin et al. (1995) recorded higher carcass yield when singeing was used rather than scalding. Moreover, the fact that singeing is carried out using organic matter including wood could be a potential pathway for the contamination of raw pork with PAHs.

Grilled pork is sold in three different forms (skewer, slice and piece) whose production differs based on specific unit operations. Whereas grilled pork slices are

made via both indirect and direct grilling operations, grilled pork pieces differ from the other two forms due to the practice of precooking. Precooking before grilling was found to be widespread in the Cotonou and Abomey-Calavi municipalities and was not a common practice in the other production zones under study.

Types of grills and fuels used for processing

During direct grilling, the pork is simply laid above the combustion/grilling chamber and is exposed to smoke and heat, enabling pork fat to drop through the grill into the embers below. This is significant, as Viegas et al. (2012) reported the contribution of fat combustion during meat grilling to PAH production. Iko Afé et al. (2020) reported contamination with PAHs of traditional grilled pork produced with barrel grill using *A. auriculiformis*. Kpoclou et al. (2014) reported that the use of *A. auriculiformis* as fuel resulted in a higher PAH concentration compared to *M. indica*, with both tree species recorded during the present investigation. We also recorded the use of coconut husks as a secondary fuel. The Codex Alimentarius Commission reported that the use of coconut husks in food grilling/smoking can lead to high PAH contamination due to its high lignin content (CAC, 2009). Moreover, because of the temperatures of cooking applied to pork during traditional grilling, the digestibility of grilled pork proteins could be affected. According to Bax (2012) and Djekic et al. (2020), the impact of meat cooking on proteins results in a progressive combination of denaturation, oxidation and aggregation of proteins, what can improve or slow down the digestibility of proteins according to the temperatures of cooking. A heat treatment led to a denaturation of protein, which results in an externalization of the hydrophobic amino acids, thus offering hydrophobic sites attainable to the proteases (Bax, 2012; Santé-Lhoutellier et al., 2017).

The traditional grilling could also affect the quality of fatty acids (Janiszewski et al., 2016) and contribute to the formation of oxidation products like aldehydes (Munasinghe et al., 2003). These traditional practices of grilling showed that improvement of the grilling process and product quality for urban dwellers are needed to reduce consumer's exposure to toxic compounds.

Effect of socio-demographic characteristics, technological parameters and survey area on precooking and bristle removal practices

The significant variation recorded among these parameters showed that for future improvement, particular attention should be paid to bristle removal practices and precooking to reduce their effect on grilled pork production.

Quality criteria for fresh pork, intermediary products and end product

The quality criteria mentioned by processors will be useful in future studies to assess the change in sensory characteristics of grilled pork after traditional process improvement.

Quality issues for fresh pork and processed products

The malodour emission described by processors for fresh pork, precooked pork and grilled pork is a consequence of poor preservation practices (at ambient tropical temperature), which lead to produce spoilage. In addition to malodour, the presence of cysts in fresh pork reported as a quality issue by processors indicates that pig from which the pork derived was ill and probably unsafe for consumption. The presence of cysts in pork has previously been reported as responsible for several seizures in veterinary inspectors during inspection (Goussanou et al., 2013). The carbonization of grilled pork described by 30.5% of processors involves the blackening of grilled pork and/or the emission of a strong smoked odour.

Preservation of grilled pork and treatment of unsold grilled pork

The heat treatments applied to unsold grilled pork as preservation practices could result in modification of nutritional (protein and lipid oxidation) and sensory quality of pork.

Factors influencing the selling price of grilled pork

The purchase price of the pig is the biggest factor influencing the selling price of grilled pork since it affects greatly the production cost. In that condition, the only factor under the control of the processors is the quality of pigs in term of healthiness, low fatness and ability to provide high yield of grilled pork.

Conclusion

This investigation contributes to improving the understanding of grilled pork production and marketing in the South Benin. Processors of grilled pork in the region are mainly men from different socio-cultural groups, the most important of which are *Goun* and *Fon*. Three forms of grilled pork are produced (slice, skewer, and pieces), made from three pig breeds including indigenous, exotic and cross-breed. Precooking is a key unit operation differentiating the production processes of these forms.

Among the various grill types recorded for pork grilling, locally made clay grills and vertical barrel grills are the most common, with wood and charcoal as the main fuels. In terms of quality perception, processors predominantly use texture and colour as main quality criteria to appreciate grilled pork. The malodour emission is the main quality issue raised by grilled pork processors. However, further investigation is required to better characterize the chemical and microbial hazards associated with grilled pork.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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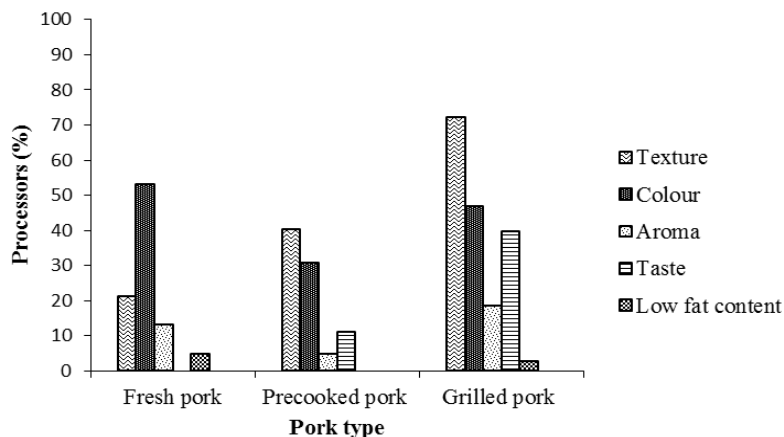
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Supplementary Data

Supplementary data 1. Criteria used by grilled pork processors in choosing pig breeds

Pig breed	Processor percentage (%) (n = 188)			
	Age (year)	Health status	Fat content	Weight
Indigenous	0.5	80.9	36.7	18.1
Crossbreed	1.1	59.2	31.9	11.7
Exotic breed (Large White)	1.1	25.5	19.7	11.2

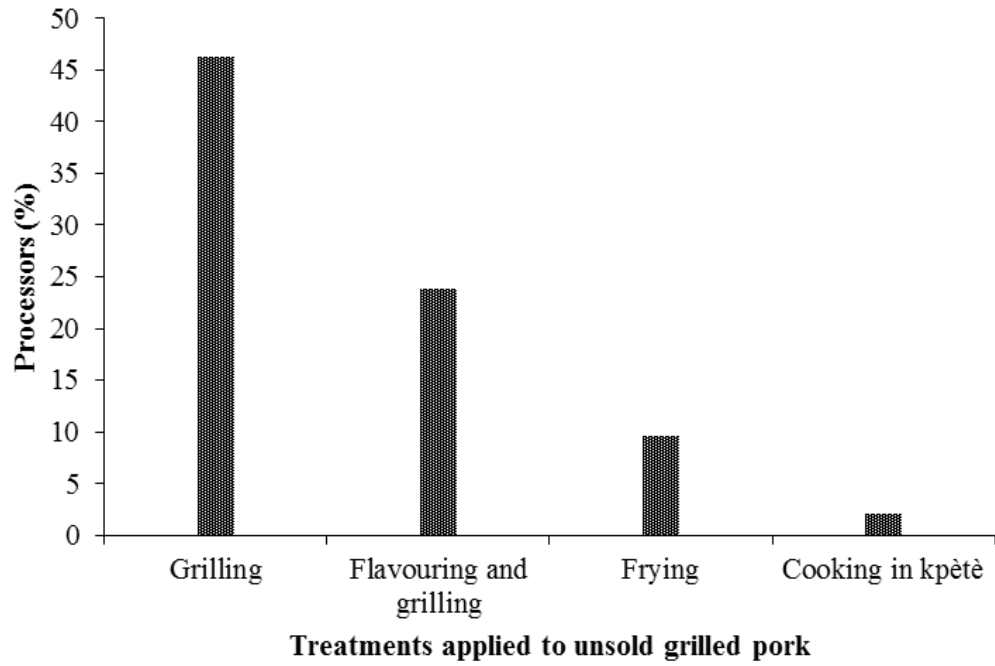


Supplementary data 2. Quality criteria used for fresh pork, precooked pork and grilled pork as selected by the sampled grilled pork processors

Supplementary data 3. Quality issues for fresh, precooked and grilled pork, and proportion of processors

Quality issues	Proportion of processors (%)
Fresh pork	
Malodour emission	23.7
Presence of cysts	21
Presence of blood	13.2
Pork fat status	2.6
Greenish colouring	2.6
Others	36.8
Precooked pork	
Less soft texture	31.2
Malodour emission	25
Bad precooking of pork	6.3
Others	37.5
Grilled pork	
Carbonization of pork	30.5
Malodour emission	21.8
Less soft texture	17.4
Presence of blood	4.3
Bad flavour	4.3
Bad cooking of pork during grilling	4.3
Others*	17.4

*Others: processors with no opinion about the quality



Supplementary data 4. Proportion of processors employing each treatment applied to grilled pork before selling to consumers