ISSN 1819-1878

Asian Journal of Animal Sciences

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OPEN ACCESS Asian Journal of Animal Sciences

ISSN 1819-1878
DOI: 10.3923/ajas.2022.55.61

Research Article

Chemical and Hygienic Qualities of Stripped and Burnt Sheep Meat in Southern Benin

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Abstract

Background and Objective: Burning and stripping are the main methods of dressing sheep slaughtered in Benin's slaughterhouses. This study aims to compare the quality of sheep meat according to the type of dressing in Southern Benin. **Materials and Methods:** The hygienic quality was assessed through research on total vial counts (TVC), enterobacteria, *E. coli*, *Staphylococcus aureus* and *Salmonella* in 70 samples (35 from each dressing method). Chemical analyses were carried out on 40 samples of *Longissimus dorsi* (20 from each dressing method). **Results:** TVC, *Enterobacteriaceae* and *E. coli* count of burnt sheep carcasses (5.10 ± 1.37, 4.12 ± 0.59 and 2.06 ± 0.91 log CFU cm^{-2}, respectively) were significantly higher ($p<0.05$) than those of stripped sheep carcasses. *Salmonella* was only detected in 7 samples of burnt sheep meat. Meat chemical composition did not change except for the protein content which is higher in burnt sheep. **Conclusion:** This study shows that the hygienic quality of meat from sheep slaughtered in the south Benin slaughterhouse remains inadequate, regardless of the dressing method.

Key words: Quality, burnt, stripped, meat, sheep, microorganisms, *E. coli*, organoleptic

Citation: Salifou, C.F.A., G.G.A. Ahouanse, P.S. Kiki, I.O. Dotche, R. Agossa, M.T. Issifou and I.A.K. Youssao, 2022. Chemical and hygienic qualities of stripped and burnt sheep meat in Southern Benin. Asian J. Anim. Sci., 16: 55-61.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Meat and its derivatives have prominent importance in the human diet for both nutritional and organoleptic reasons. Its high protein content (19-35% depending on the type of meat) and the nature of these proteins makes it difficult to replace food[1]. In Benin, the national production of meat was estimated at 81,417 tons in 2018 and is mainly composed of beef (51%), poultry (18%) and small ruminants (12%)[2]. Although occupying third place in national meat production, small ruminants play a very important socio-economic role[3]. They are used for cultural and religious purposes, during festivals and for many sacrifices across in the country. They are accessible at any time of the year, so they are slaughtered daily in slaughterhouses, killings or slaughter areas in the country. Several different methods of dressing are used in the preparation of the small ruminant's carcasses. The common practice is to manually tear off the skin, thus exposing the carcass. However, others are burnt or scalded to remove the hair and are presented with the skin adhering to the carcass[4]. Consumers express their purchase preferences by choosing one or the other form of carcass presentation. This choice is usually related to hygienic or organoleptic quality or to the relatively long cooking time for carcasses presented with the skin. Furthermore, the consumer's preference for one or another type of meat can also be related to the culinary dishes that will be made from the meat obtained from these carcasses or to the consumer's dislike towards the skin[4]. There is thus a diversified demand for sheepmeat from Beninese consumers. The satisfaction of this demand, in terms of meat quality, is reflected at the research level by the need to identify, apart from pre-slaughter factors, slaughter and post-slaughter, practices that can influence the quality of meat. The safety and hygiene of slaughterhouses and slaughter areas, including the workers involved in the slaughter process, play a major role in meat quality[5]. The work of Salifou *et al.*[4] on ewes slaughtered at the Cotonou slaughterhouse showed that the slaughter process and, specifically, the burning of the animal's hair after slaughter, positively influences the tenderness of the meat compared to that of stripped sheep. However, the effects of dressing practices on the hygienic and nutritional quality of sheep meat slaughtered in Benin remain less documented.

The objective of this study is to access the hygienic and nutritional quality of sheep meat according to the type of dressing.

MATERIALS AND METHODS

Study area: The carcasses used in this study came from the Cotonou slaughterhouse in South Benin. Laboratory analyses were performed at the Laboratory of Animal Biotechnology and Meat Technology at the University of Abomey-Calavi (Republic of Benin) and the National Laboratory for Quality Testing of Metrology and Analysis, of the Nangui Abrogoua University (Côte d'Ivoire). The study was carried out from March-September, 2019.

Slaughter process: The slaughter process was approved by the Animal Health Production of the Polytechnic School of Abomey-Calavi (University of Abomey-Calavi, Benin). The slaughter process for sheep at the Cotonou slaughterhouse was previously described by Salifou *et al.*[4]. The animals to be slaughtered are inspected antemortem the day before slaughter by a veterinary inspector. On slaughter day, the animals are sent to the slaughter hall in groups of 5 or 10. Once there, they are individually weighed. To keep them under control, the posterior and anterior limbs are joined together and attached with a rope provided for that purpose. The animals are then placed on the ground to direct the jugular vein towards the cutthroat and then they are slaughtered using a very sharp and clean knife. They are then dressed. Some are burnt with a high-burning wood fire and then scraped and turned over at every moment. At the end of the burning process, which lasts longer than the stripping process, they are washed with a steel sponge before being eviscerated on the ground. For others, the skin is completely detached from the muscles, so they are stripped before being eviscerated. The rumen and intestines are taken to the drainage areas to be emptied and undergo the first cleaning. They are then taken back to the gut room where they are properly cleaned before being sold. The legs and head are burnt to remove hooves and hair. The leather is sold directly for use as carpets or leather goods.

Evaluation of the hygienic quality of burnt and stripped sheep carcasses: The hygienic quality of burnt and stripped sheep meat was assessed through microbiological analysis performed on meat samples taken from the carcasses. These analysis involved in the research and enumeration of total vial count (TVC), *Enterobacteriaceae*, *Salmonella*, which are indicators of process hygiene and *E. coli*, which is an indicator of faecal contamination[6].

Table 1: ISO standard method detail

Purpose	ISO numbers	Standard year (original/modified)	ISO title	URL link
Sample collection	ISO 17604:2015	2015 (modified)	Microbiology of food and animal feeding stuffs-carcass sampling for microbiological analysis	https://www.iso.org/standard/33146.html
TVC calculation	ISO 4833-1:2013	2013 (modified)	Horizontal method for the enumeration of microorganisms	https://www.iso.org/standard/53728.html
Salmonella calculation	ISO 6579-1:2017	2017 (modified)	Horizontal method for the detection, enumeration and serotyping of *Salmonella*	https://www.iso.org/standard/56712.html
Enterobacteriaceae	ISO 6888-3:2003	2003 (original)	Horizontal method for the enumeration of coagulase-positive staphylococci (*Staphylococcus aureus* and other species)	https://www.iso.org/standard/33147.html
Escherichia coli	ISO 7251:2005	2005 (original)	Horizontal method for the detection and enumeration of presumptive *Escherichia coli*	https://www.iso.org/standard/34568.html

Sampling: Microbiological analysis was carried out on meat samples from 70 carcasses (35 from stripped sheep and 35 from burnt sheep). Samples were taken 1 day per week for 7 weeks and under ISO 17604:2015 (Table 1). The day of sampling varied each week to ensure that the results were representative of the entire week. For each day of sampling, 10 samples were taken, 5 from stripped sheep and the other 5 from burnt sheep.

Following Decision 2001/471/EC of June 8, 2001, of the European Commission, four samples of at least 5 cm^{-2} and a maximum thickness of 5 mm each were taken from each carcass and on five carcasses. The sampling sites were the neck, thigh, shoulder and flank. Using a 2.5 cm diameter punch, forceps and a disposable blade mounted on a scalpel handle, the samples were taken after dressing by the excision method (destructive method). The 4 samples were aseptically placed in a pre-identified stomacher bag, sealed and placed in a cooler and then transported under cool conditions (4°C) to the laboratory for analysis on the same day.

Germ determination technique: The preparation of the stock solution and the different dilutions, the inoculation of the culture media and the bacterial enumeration was carried out according to the method described previously by Salifou *et al.*[7].

Each germ was searched following its specific ISO standard. Thus, TVC was sought according to ISO:4833-1:2013 (Table 1), *Salmonella* according to ISO 6579-1:2017 (Table 1) and *Enterobacteriaceae* according to ISO 6888-3:2003 (Table 1). *E. coli* was determined according to ISO 7251:2005 (Table 1).

The results were expressed in log CFU cm^{-2} of meat sampled for quantitative investigations and in absence or presence for *Salmonella*. The results in log daily average were assigned to one of the following three categories: Satisfactory (result below minimum), acceptable (result between the minimum and maximum) and unsatisfactory (result above maximum) according to the European Union Commission Regulation (http://data.europa.eu/eli/reg/2005/2073/oj). The minimum concentration for the TVC is 3.5 log CFU cm^{-2} and the maximum is 5 log CFU cm^{-2}. For *Enterobacteriaceae*, the minimum concentration is 1.5 log CFU cm^{-2} and the maximum is 2.5 log CFU cm^{-2}. For *Salmonella*, the result is satisfactory if at most 2 out of 50 tests are positive and unsatisfactory if more than 2 out of 50 tests are positive.

Nutritional quality of burnt and stripped sheep meat: Chemical analysis were carried out on meat samples from 40 female Sahelian sheep selected among the animals and declared healthy by the inspection service of the Cotonou slaughterhouses. The animals were all slaughtered at the Cotonou slaughterhouse and were all between 2 and 3 years old. The age of the animals was determined from their date of birth or, if not available, from the dental table. Twenty were burnt and presented with the skin and 20 were stripped and therefore presented without the skin. The study focused on Sahelian ewes because they are mostly slaughtered in abattoirs and killings. They come from the Alibori and Borgou departments where they are grass-fed (*Panicum maximum*) and monitored daily.

Chemical analysis (dry matter, ash, lipid and crude protein content) were carried out on samples of *Longissimus dorsi* from each slaughtered animal. They were taken after slaughter and kept at -20°C until chemical analysis at the National Laboratory for Quality Testing of Metrology and Analysis (Cote d'Ivoire). The dry matter content of the meat samples was determined by AOAC[8] procedures. A 10 g sample of each sample (cut into small pieces) was dried at 105°C in a ventilated oven till constant weight. The crude ash was determined by burning the previously dried samples in a muffle furnace at 550°C for 24 hrs[8]. Lipids were determined by direct extraction with Soxhlet petroleum ether for 7 hrs at 60°C according to the AOAC[8] method. Crude protein was determined by the Kjeldahl method from the nitrogen content ($N \times 6.25$)[8].

Statistical analysis: Statistical Analysis System (https://support.sas.com/documentation.htlm) software was used for the statistical analysis. Various means were calculated by the Proc means procedure and compared two by two by the student t-test. The type of dressing and the sampling day were considered as factors of variation for the microbiological analysis and for the nutritional quality, only the type of dressing was used. The significance of each factor was determined by the F test performed by the Proc GLM procedure.

RESULTS

Hygiene of sheep slaughter processes: The Colony Forming Units (CFU) counted per sampled carcass are presented by dressing type in Table 2-4. From Monday to Sunday, the TVC varied per day from 3.97-5.65 log CFU cm^{-2} for stripped sheep and from 2.93-6.28 log CFU cm^{-2} for burnt sheep. On Wednesday, it was higher ($p<0.001$) for burnt sheep carcasses while on Sunday, the opposite trend was observed in favour of stripped sheep carcasses ($p<0.01$). In general, the TVC of burnt sheep carcasses (5.10 log CFU cm^{-2}) was significantly higher ($p<0.05$) than that of stripped sheep carcasses (4.64 log CFU cm^{-2}) (Table 2). For *Enterobacteriaceae*, daily loads ranged from 2.37-4.49 log CFU cm^{-2} for stripped sheep carcasses and from 3.30-4.54 log CFU cm^{-2} for burnt sheep carcasses. This gives an average total load of 4.12±0.59 log CFU cm^{-2} for burnt sheep carcasses. This load is significantly higher ($p<0.001$) than that of stripped sheep (3.41 log CFU cm^{-2}). Daily *Enterobacteriaceae* loads were significantly higher for sheep carcasses burnt on Wednesdays ($p<0.05$), Fridays and Sunday ($p<0.001$) (Table 3).

Based on the total vial count (TVC) and following the EU (2005) grid for the interpretation of microbiological test results in ruminant meat, the slaughter process of skinned sheep is unsatisfactory hygiene on Monday (TVC concentration higher than the maximum (5 log CFU cm^{-2}) required). On the other hand, the TVC concentrations obtained from Tuesday to Sunday for the carcass of stripped sheep is between the minimum (3.5 log CFU cm^{-2}) and the maximum from Tuesday to Sunday. Process hygiene is therefore acceptable these days. As for burnt sheep, the hygiene of the slaughter process is only acceptable on Thursday and Sunday. For the other days, it is unsatisfactory. On the other hand, for *Enterobacteriaceae*, all concentrations obtained from Monday to Sunday for both burnt and stripped sheep carcasses are above the maximum required (2.5 log CFU cm^{-2}).

For *E. coli*, loads ranged from 0.64-2.48 log CFU cm^{-2} for the stripped and from 1.53-2.75 log CFU cm^{-2} for the burnt.

Table 2: Bacterial load in log CFU cm^{-2} of TVC counted per sampling day and per dressing type

	Stripping		Burning		
Days	Mean±SD	Interpretation$^{\beta}$	Mean±SD	Interpretation$^{\beta}$	Significance test
Monday	5.65±0.69^{a}	Unsatisfactory	5.26±1.30^{a}	Unsatisfactory	NS
Tuesday	4.91±0.19^{a}	Acceptable	5.71±0.68^{a}	Unsatisfactory	NS
Wednesday	3.97±0.10^{b}	Acceptable	6.28±0.42^{a}	Unsatisfactory	***
Thursday	4.46±0.54^{a}	Acceptable	4.98±1.26^{a}	Acceptable	NS
Friday	4.35±0.30^{a}	Acceptable	5.32±0.68^{a}	Unsatisfactory	NS
Saturday	4.92±0.93^{a}	Acceptable	5.26±1.85^{a}	Unsatisfactory	NS
Sunday	4.20±0.66^{a}	Acceptable	2.93±0.15^{b}	Acceptable	*
Overall mean	4.64±1.37^{a}	-	5.10±0.74^{b}	-	*

NS: Not significant, ***p<0.001, *p<0.05, Mean±SD: Mean±standard deviation, means of the same line followed by the same letter, do not differ significantly at the 5% threshold and β: According to EU regulation 2073

Table 3: Enterobacterial load in log CFU cm^{-2} of counted per sampling day and by type of dressing

	Stripping		Burning		
Days	Mean±SD	Interpretation$^{\beta}$	Mean±SD	Interpretation$^{\beta}$	Significance test
Monday	4.30±0.14^{a}	Unsatisfactory	4.15±0.24^{a}	Unsatisfactory	NS
Tuesday	2.98±0.11^{a}	Unsatisfactory	3.30±0.50^{a}	Unsatisfactory	NS
Wednesday	3.53±0.46^{b}	Unsatisfactory	4.30±0.41^{a}	Unsatisfactory	*
Thursday	3.46±0.88^{a}	Unsatisfactory	4.37±0.79^{a}	Unsatisfactory	NS
Friday	2.77±0.48^{b}	Unsatisfactory	4.54±0.62^{a}	Unsatisfactory	***
Saturday	4.49±0.70^{a}	Unsatisfactory	3.96±0.47^{a}	Unsatisfactory	NS
Sunday	2.37±1.06^{b}	Satisfactory	4.19±0.40^{a}	Unsatisfactory	***
Overall mean	3.41±0.59^{a}	-	4.12±0.92^{b}	-	***

NS: Not significant, ***p<0.001, *p<0.05, Mean±SD: Mean±standard deviation, means of the same line followed by the same letter, do not differ significantly at the 5% threshold and β: According to EU regulation 2073

Table 4: *E. coli* count in log CFU/cm^2/day and dressing type, by collection day and dressing type

Days	Burnt sheep meat Mean±SE	Stripped sheep meat Mean±SE	Significance test
Monday	2.48±0.31^a	2.31±0.74^a	NS
Tuesday	0.64±0.34^a	1.53±0.80^a	NS
Wednesday	1.53±0.69^a	2.07±1.09^a	NS
Thursday	1.60±1.01^a	1.54±1.20^a	NS
Friday	0.69±0.40^b	2.68±0.19^a	***
Saturday	1.20±0.55^a	1.53±1.00^a	NS
Sunday	1.94±0.61^a	2.75±0.22^a	NS
Overall mean	1.44±0.57^b	2.06±0.91^a	***

NS: Not significant, ***p<0.001, *p<0.05, Mean±SD: Mean±standard deviation and means of the same line followed by the same letter do not differ significantly at the 5% threshold

Table 5: Chemical characteristics of *Longissimus dorsi* of sheep by dressing type

Variables	Burnt sheep meat	Stripped sheep meat	Significance test
Dry matter (%)	22.89±2.13	23.81±2.84	NS
Ash (%)	0.83±0.03	0.952±0.07	NS
Protein (%)	20.14±1.37	17.16±1.08	***
Fat (%)	2.81±0.86	1.91±0.78	NS

NS: Not significant, ***p<0.001, Mean±SE: Mean±standard error and means of the same line followed by the same letter, do not differ significantly at the 5% threshold

From one type of dressing to another, *E. coli* count only varied significantly on Friday in the benefit of burnt sheep carcasses (p<0.001) (Table 4).

Salmonella was identified in only one sample out of the 35 samples analyzed for stripped sheep and in 7 samples out of the 35 analyzed for burnt sheep. For the duration of the study, slaughter hygiene was unsatisfactory for both stripped and burnt sheep. In addition, *Staphylococcus aureus* was identified in 3 of the 35 samples analyzed for stripped sheep and in 5 of the 35 samples analyzed for burnt sheep. The average bacterial load of samples containing *Staphylococcus aureus* did not vary from one dressing type to another (p>0.05). However, there was an increasing trend in favour of burnt sheep carcasses (3.99 log CFU cm^{-2} versus 3.26 log CFU cm^{-2} for stripped).

Nutritional quality of burnt and stripped sheep meat: The chemical characteristics of the meat of burnt and stripped sheep are presented in Table 5.

No significant difference was obtained in the dry matter, ash and lipid contents of *Longissimus dorsi* from burnt and stripped sheep. However, the protein content was significantly higher in *Longissimus dorsi* from burnt sheep (20.14%) than in *Longissimus dorsi* from stripped sheep (17.16%) (p<0.001).

DISCUSSION

The average TVC load of 4.67 and 5.10 log CFU cm^{-2} obtained in the present study, respectively for stripped and burnt sheep are above those reported by Ncoko *et al.*[9] on stripped sheep carcasses in South Africa (2.48-4.38 log CFU cm^{-2}) and Ali *et al.*[10] in Sudan (2.9 log CFU cm^{-2}) on stripped sheep carcasses. However, the overall AFM average obtained in this study for stripped sheep carcasses is close to that obtained by Magdaa *et al.*[11] on stripped sheep carcasses in Sudan (4.8 log CFU cm^{-2}). But, higher TVC loads were reported by Al-Hasan *et al.*[12], who obtained an average load ranging from 8.39 and 8.58 log CFU cm^{-2} on sheep and goat carcasses in Sudan. This author worked on stripped sheep carcasses. In addition, Adetunji and Odetokun[13] obtained a TVC load of 14 log CFU cm^{-2} on burnt goat carcasses in Nigeria. The average *Enterobacteriaceae* load obtained in this study for stripped carcasses (3.41 log CFU cm^{-2}) is in the range of 2.48-3.45 log CFU cm^{-2} reported by Ncoko *et al.*[9] and obtained on stripped sheep carcasses. However, these values are well below those obtained from burnt sheep carcasses (3.30-4.54 log CFU cm^{-2}) in the present study. The average *Enterobacteriaceae* load obtained on burnt carcasses is, nevertheless, similar to that obtained by Saad *et al.*[5] on sheep carcasses in Egypt with no specification of the dressing method. For *E. coli* counts, the loads obtained in the present studies ranged from 0.64-2.48 log CFU cm^{-2} and 1.53-2.63 log CFU cm^{-2} on burnt and stripped sheep carcasses, respectively. In general, the high bacterial loads obtained on any working day indicate a lack of hygiene in the slaughter process already reported by Salifou *et al.*[14] at the Cotonou slaughterhouse. These high levels of microbial contamination may be due to poor evisceration, poor hygienic management of both the work environment and the workforce handling the carcass. This contamination of carcasses occurs mainly during slaughter and dressing. It could be from various sources such as skin, intestinal contents, contact surfaces and handling by workers[15].

Some significant differences obtained for the various germs searched for and from one dressing type to another are in favour of burnt sheep. However, logically, the heat brought by the fire during the hair burning should normally partially disinfect the animal's leather, which initially contains a certain load of microorganisms. This unexpected result is probably due to the poor hygienic production practices of the burnt sheep. Indeed, sanitary and hygienic conditions in slaughterhouses can have a direct influence on the microbial load, including TVC, *Enterobacteriaceae* and *E. coli* loads of the resulting carcasses[11,13,16].

At the slaughterhouse in Cotonou, placing the carcasses of sheep on the ground after slaughter and after burning and washing them certainly causes further contamination. As for striped sheep, even if evisceration is occasionally carried out on the ground, the stripped animal is placed on its skin, which serves as a barrier against soil contamination. The presence of *E. coli* in the samples confirms the poor hygienic conditions and particularly faecal contamination. Hygiene defects certainly occurred during evisceration. To consider burning as a decontamination practice for the carcasses of small ruminants, preventive measures will have to be taken so that post-burning operations do not cause new contamination. The hygiene of the slaughter process should be reviewed for both burnt sheep and stripped cattle.

Chemical analysis of *Longissimus dorsi* generally reveals a tendency for higher lipid contents and higher protein content in favour of meat from burnt sheep. The opposite observation was made for dry matter and ash contents, which tend to be higher for stripped sheep meat. These findings are similar to those of Putra *et al.*[17] on samples of meat from burnt or stripped goats. These results can be explained by the fact that the burning would have caused a start of cooking, which would have resulted in a slight loss of water from the burnt animals' carcass. The loss of water probably carried away with it some soluble minerals and as a result, there is a concentration of nutrients in the meat. A similar finding was made by Sainsbury *et al.*[18] based on chemical analysis of raw and cooked samples of *Longissimus dorsi* from sheep. Indeed, the results obtained by these authors reveal that uncooked sheep meat had lower protein and lipid contents (20.2 and 4.86%, respectively) compared to cooked meat (26.3 and 8.58%, respectively). Hafid and Meziane[19] obtained higher contents (dry matter: 27.26%, ash: 1.07%, protein: 19.93% and fat: 4.12%) in *Longissimus dorsi* from local sheep in Algeria than those obtained in this study. Protein contents of 19.7% and lipid contents of 5% were obtained in raw sheep meat[20]. The lipid contents obtained in this study are low. They are because the sheep studied was raised on natural grazing land and fed only on grass.

CONCLUSION

A study on the hygienic quality of sheep meat showed that sheep slaughter practices at the Cotonou slaughterhouse result in high bacterial contamination of the carcasses. The hygiene of each slaughter process is unsatisfactory. The carcasses of slaughtered and burnt sheep are more contaminated than those of slaughtered and stripped sheep. The burning process causes cooking to begin, resulting in water loss and an increase in meat protein. The hygiene of each slaughtering process must be revised and regular process control must be instituted. To this end, operators must be trained on good practices in the meat industry to limit contamination risks caused by the introduction and handling of raw material.

SIGNIFICANCE STATEMENT

This study discovers the positive effect of dressing slaughtered sheep by burning on the protein content of the meat. This could be beneficial to consumers. The study will help researchers to explore the impact of the dressing method on the preservation of sheep meat over time. Furthermore, it will help the authors to propose ways to improve the dressing process of sheep in Benin to guarantee to the consumers satisfactory hygienic quality of the meat.

ACKNOWLEDGMENT

The authors would like to thank the National Laboratory for Quality Testing of Metrology and Analysis of the Nangui Abrogoua University (Côte d'Ivoire) for the analysis of sheep meat nutritional quality.

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