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*Full Length Research Paper*

# Antibiotic resistance in food producing Animals in West Africa French speaking countries: A systematic review

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**This review aimed to make an inventory of the relevant work carried out on antibiotic resistance in the animal sector during the last two decades in French-speaking countries of the West African sub-region. English and French published articles from 2000 to 2019 indexed in PubMed, Google Scholar, and African Journals Online were reviewed in accordance with an adapted PRISMA guideline. Mean Resistance (MR) and interquartile ranges (IQR) of resistance were calculated for each antibiotic-bacterium combination for each country and globally. 28 articles were eligible for this qualitative review. One third of the countries did not have suitable data on antibiotic resistance in animals. Senegal (11/28) and Ivory Coast (8/28) are at the top of countries where more studies have been carried out. Poultry (17/28), cattle (10/28) and pigs (4/28) are the most investigated species. In poultry, resistance in *E. coli* strains was high to Tetracycline's (MR: 97%; IQR [80.65%- 98.5%]). Resistance in *Salmonella* spp. strains from poultry was high to Erythromycin (MR: 100%; IQR [99%-100%] and Amoxicillin-Clavulanic acid (47.76%; IQR [16.06%-52.52%]). In cattle, resistance of *Staphylococcus* spp. was low in general for all antibiotics with resistance of 16.25% IQR [11.75%-20.58%], 14.63% IQR [13.82%-31.32%], 10% IQR [8.55%-16%] respectively for Tetracycline's, Penicillin, and Gentamicin. More studies deserve to be done in West Africa French speaking countries in order to draw attention of decision-makers, lead to regulations on the correct use of antibiotics in the veterinary sector, and if possible set up a sub-regional network for the monitoring of antibiotic resistance.**

**Key words:** Antibiotic resistance, animals, West Africa, French countries.

## INTRODUCTION

Antimicrobial resistance (AMR) both in human and veterinary medicine has reached alarming levels in most parts of the world and has been recognized as a significant emerging threat to global public health and food security. West African countries face, like the rest of the world, this serious problem of the emergence of resistances to antibiotics (Ouédraogo and Sylvain, 2017). To fight against this threat, joint resolutions and actions are promoted by international organizations to combat AMR globally (Wall et al., 2016). Antimicrobial resistance affecting humans and animals is primarily influenced by an increase in using antimicrobials for a variety of

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purposes, including therapeutic and non-therapeutic uses in animal production. These practices contribute to the spread of drug-resistant pathogens in both livestock and humans (Van Boeckel et al., 2015). In low- and middle-income countries including African sub-Saharan countries, population growth and rising incomes have driven an unprecedented growth in demand for animal protein. As a result, efforts to meet rising demand are driving a shift in animal production from small holder, mixed crop, and livestock operations to increasingly intensive, large-scale, and specialized commercialization farms (Schar et al., 2018). These intensive production systems are known to employ more and more antimicrobial for therapeutic and non-nontherapeutic use, including mass administration for prevention and control of disease and as growth promoter. Unfortunately, in most African sub-Saharan countries, it is known that there is no or less control over the distribution of veterinary pharmaceuticals and phytosanitary products. Worse still, no appropriate legislation yet exists to guarantee the quality of the various antimicrobial products released onto the market. In West African French Speaking countries for example, there are massive shortcomings in the organization of the veterinary drug market. These include lack of specific legislation following the recent liberalization of veterinary drugs, lack of veterinary drug inspections before marketing drugs, lack of registration because of the existence of parallel channels alongside the official distribution channel of veterinary drugs (Mensah et al., 2014). The consequence of all these shortcomings is, in one side, the large scale of antimicrobial misuse in farms to combat low productivity and high mortality caused by infectious diseases and, in the other side, the development of resistances to antimicrobials. Unfortunately, there is limited data concerning anti-microbial use and antimicrobial resistance in these countries in comparison with English speaking countries of the West African Sub region due to the absence of systematic surveillance systems. Thus, conclusions must be drawn from point-prevalence assessments or research studies. Here, the available information are piece together to build a picture of the situation of resistance development in food producing animals in West African French speaking countries. Food producing animals are linked to humans via the food chain and shared environment (Oloso et al., 2018). Thus, they can play an important role in the dissemination of resistance pathogens or resistance genes to humans (Chantziaras et al., 2014). This review over his importance in animal health will have an importance in public health because it offers the opportunity to see the burden of Antibiotic resistance in the region.

## Research questions and objective

Some research questions guide this study, which aimed to establish the situation of ABR in food producing animals in 09 West African French speaking countries. These questions were: (i) what is the status of antibiotic resistance (ABR) in the food producing animals according to previous studies in the two last decades? (ii) what is the pattern of resistance in each state? (iii) what is the status of ABR among the common antibiotics that are used to control pathogens at animal's level?

## MATERIALS AND METHODS

### Data search design

Free databases (Pub Med, Google Scholar and African Journals Online) were searched using broad terms in English and French, "antimicrobial, resistance, and country name". Where necessary, search terms were stated as strings: Antimicrobial resistance OR Antimicrobial susceptibility AND country name AND animals; "animals" was substituted with different animal names (poultry, goat, sheep, cattle, camel, pig, etc.). References in the identified materials were also searched. Indeed, the reference lists of all included articles were used to carry out a supplementary literature search. Review articles in English were retrieved and assessed for potential relevant studies related to ABR in food producing animals in West Africa French speaking countries. The PRISMA-style flowchart was modified and used for this review (Figure1). Each publication was treated as a study, which contains single or multiple reports.

### Exclusion and inclusion criteria

Articles were assessed using predesigned eligibility forms and according to predefined eligibility criteria (Table 1). Briefly, studies on parasites, viruses, and fungi were excluded. Studies dealing with ABR in humans were excluded. Studies reporting data from outside West Africa French speaking countries were not further selected. The selection of French and English published articles was based on clearly defined populations involving food animals at farms and/or processed/freshly slaughtered animals at abattoirs/markets. To be included, studies must have performed antibiotic susceptibility testing with antibiotics using appropriate methods and results interpreted according to appropriate guidelines.

### Literature screening and data extraction

Mendeleyev (version 1.19.4) was used for literature management, and relevant data from included articles were extracted. The data were abstracted and analyzed using a framework on an Excel (Microsoft Office Excel 2013) spreadsheet. Each study included Country, first author details, year of publication, aims, study population (such as, pigs, poultry, cattle, sheep, goat), type of sample (such as, nasal swabs, rectal swabs, fecal samples, and meat products), sample size, clinical status (such as, apparently healthy, sick, and dead), study site (slaughterhouse, farm, and market), type of study (cross sectional, longitudinal), bacteria of interest (such as, *Staphylococcus aureus*, *Salmonella* spp., *Campylobacter* spp., *Escherichia coli*, and *Enterococcus* spp.), antibiotics tested, antimicrobial susceptibility testing (AST) methods (disk diffusion, micro-broth dilution, agar dilution, E-test, and automated methods), guidelines of interpretation of AST (such as, CA-SFM, EUCAST, CLSI, and NCCLS), ABR prevalence and molecular investigations.

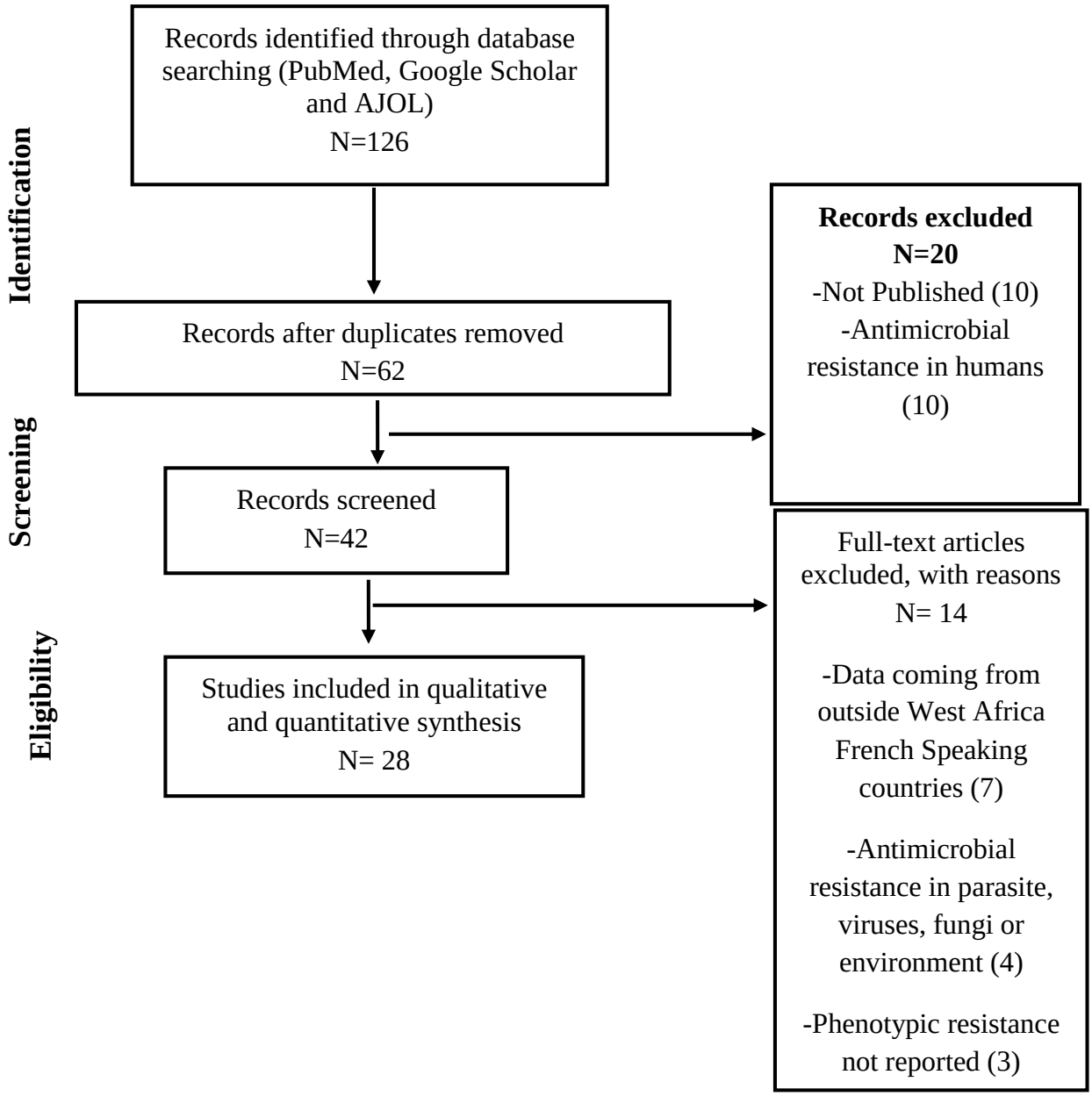


**Figure 1.** Adapted PRISMA method for data research.

**Quality assessment**

Preexisting scales were not used to assess study quality. Appraisal tool was used to assess the quality of included studies. So the researcher checked if:

(1) the basic data including: sample type, bacteria of interest, and study site, was provided; (2) samples of the study were collected in an appropriate way; (3) sample size was representative of the target population; (4) the number of strains representative; (5) the Antimicrobial Susceptibility Test perform with a valid method and interpreted according to a valid guideline; (6) all important sub-groups (Animal population or sample) identified and accounted for when reporting resistance rate. If all the criteria were met, the study was ranged according to the quality. If one or more criteria were not fulfilled, the study was ranged as moderate quality.

**Data analysis**

Microsoft Excel (2013 for Windows) was used to analyze the data following an initial extraction. Prevalence was calculated, median resistance (MR) and interquartile range (IQR) of resistance for each bacterium-antibiotic combination in each specific animal population (poultry, cattle…). Meta-analysis was not conducted because of the small number of articles available. All reports reporting ABR for an antibiotic were categories as no resistance (when resistance was <1%); very low resistance (1-24%); low resistance (25-49%); high resistance (50-74%) and very high resistance (75-100%) (Figure 1).

**Table 1.** Criteria for inclusion and exclusion.

| **Inclusion criteria** |
|---|
| Studies reporting prevalence and molecular epidemiology of bacterial resistance in livestock animals |
| ABR in food animals and food products (meat, carcasses, egg, chicken, ready-to-eat meat/chicken, cheese, and sausage at supermarket) |
| ABR in food animals, exposed workers, and food products |
| Antimicrobial susceptibility testing by either disk diffusion or broth micro dilution, E-test |
| AST conducted using CLSI/EUCAST/CASFM/other relevant committee guidelines |
| Articles published in French and English. |
| |
| **Exclusion criteria** |
| Data coming from outside West Africa French Speaking countries |
| Antimicrobial resistance in parasite, viruses, and fungi |
| Antimicrobial resistance in humans, wildlife and pets |
| Reports published in languages other than French and English |

## RESULTS

### Number of studies per country and per year

A total of 28 studies from 6 countries were included in the review (Vounba et al., 2018, 2019**;** Cardinale et al., 2003; Bada-Alambedji et al., 2006; Fall-Niang et al., 2019; Fall et al., 2012; Shyaka et al., 2010; Stevens et al., 2006; Dione, 2009; Kadja et al, 2013; Mama et al., 2019; Sidibé et al., 2019; Coulibaly et al., 2010; Rene et al., 2014; Attien et al., 2013; Gblossi et al., 2012; Abdoulkarim et al., 2013, 2014; Caroline et al., 2019; Kagambèga et al., 2013; Somda et al., 2018; Deguenon et al., 2019; Boko et al., 2013; Ahouandjinou et al., 2016; Yao et al., 2018, 2017; Coulibaly et al., 2018; Guessennd et al., 2012. Three out of nine countries had no suitable report on antimicrobial resistance in animals as shown in Figure 2. The country in the considered region having the higher number of reports is Senegal followed by Ivory Coast. The majority of published articles are from the last decade as shown in Figure 3. The mean of published papers per year is less than 2 with 2019 being the year with a record number of published papers.

### Situation of ABR in food producing animals in all countries

#### *Animal population and bacteria of interest in studies*

Investigations were mainly done in poultry (60.71%; 17/28) and cattle (35.71; 10/28) followed by Pigs (14.28%; 4/28) Sheep's (7.14%; 2/28), Goats (3.57%; 1/28) and Guinea fowl (3.57%; 1/28). Some studies investigated two or more species at the same time. The investigated bacteria were *Salmonella* spp. (50%; 14/28); *Staphylococcus* spp. (25%; 7/28); *Escherichia coli* (10.7; 3/28) and *Campylobacter* spp. (7.14%; 2/28). These bacteria were tested against 54 antibiotics belonging to 14 classes (Table 2). The most tested ATB were Tetracyclines (23 reports) followed by Gentamicin and association Sulfoxide-Trimethoprim (22 reports each). High to very high resistances were frequently reported for Tetracyclines (8 reports) followed by Sulfoxide-Trimethoprim, Streptomycin and Amoxicillin-clavulanic acid with 05 reports each (Table 3).

#### *Samples tested and their origin*

Studies included in this review investigated mainly in healthy animals (75%). Studies in diseased animals were performed in animals with mastitis (14.29%), Colibacillosis (7.14%) or Salmonellosis (7.14%). The majority of the studies were performed in samples collected in slaughterhouses or vendors in markets (60.71%; 17/28) and farms (46.42%; 13/28). Only one study was undertaken in samples from veterinary clinic and three studies investigated samples from both farm and slaughterhouse. Samples investigated were mainly carcasses (39.29% of the studies) and feces (39.29%). Two studies investigated carcass and feces at the same time. Milk was investigated

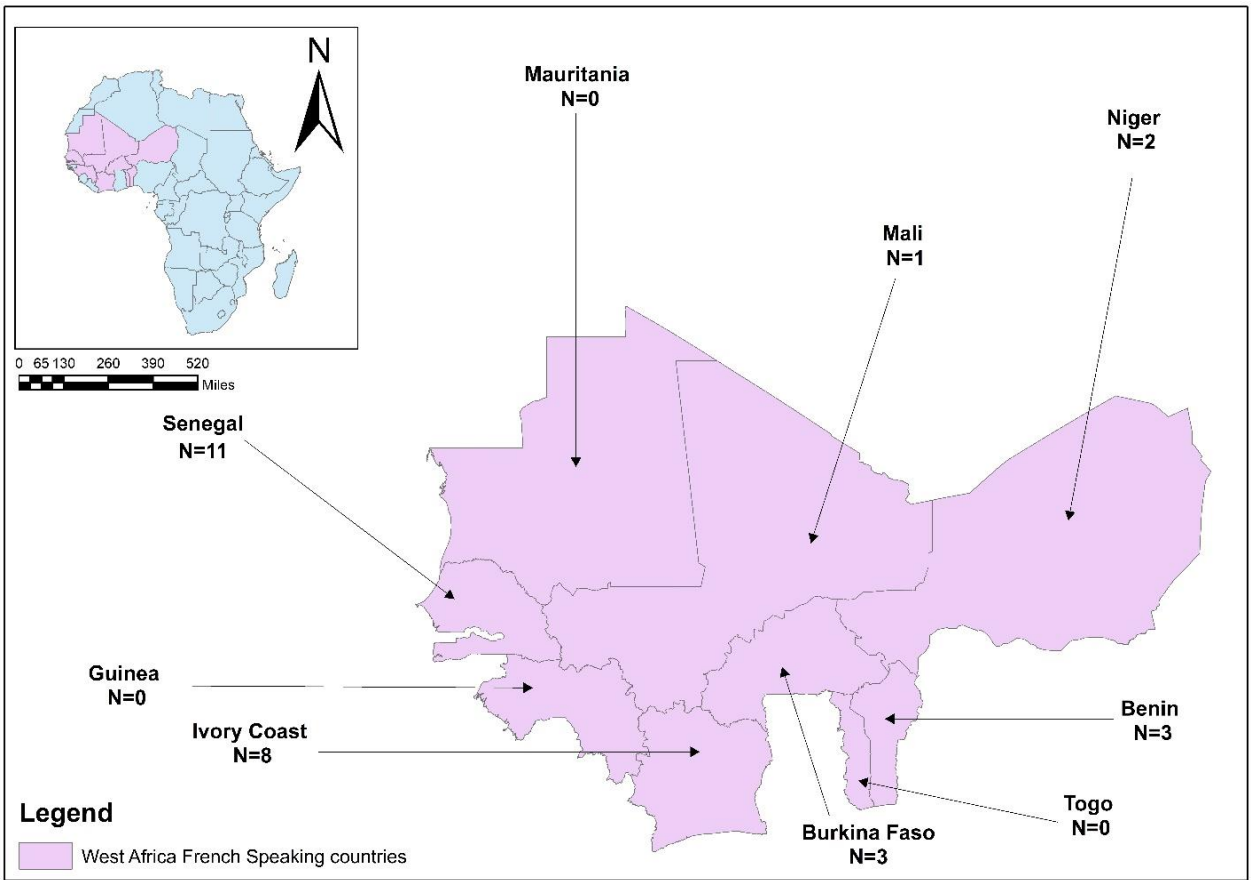


**Figure 2.** West Africa French speaking countries with number of included studies in each country.

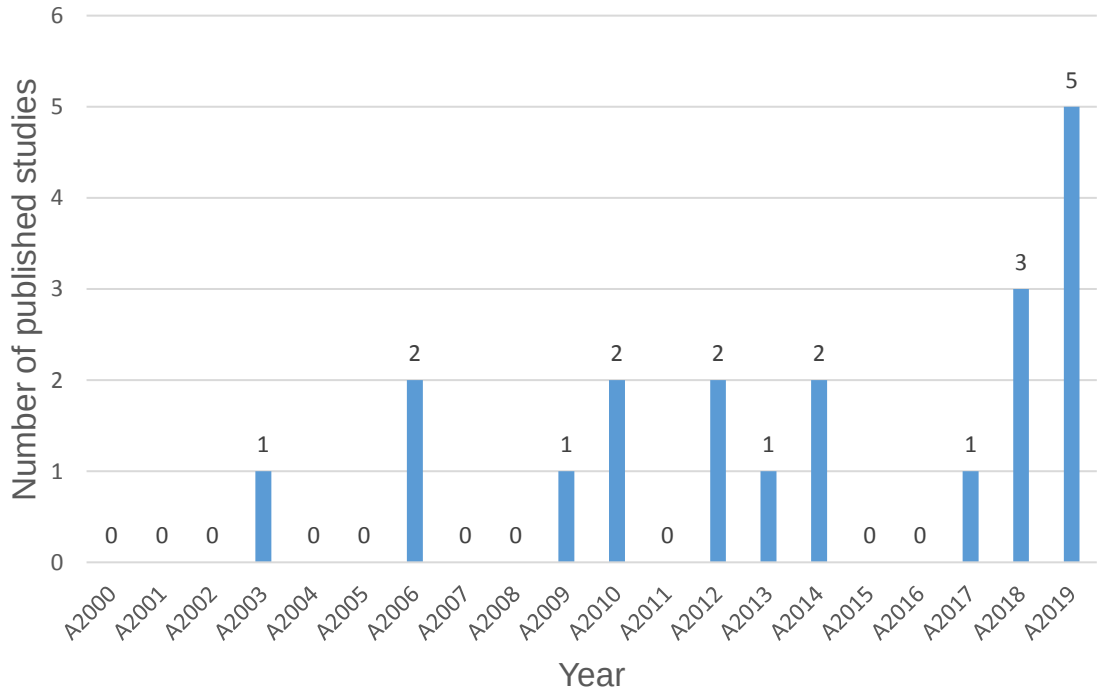


**Figure 3.** Number of publication over years.

**Table 2.** Antibiotics tested and their respective classes.

| Class (Generation) | Antibiotic tested (Number of studies) |
|---|---|
| β-lactam+ | Amoxicillin-Clavulanic Acid (14) |
| β-lactam(1) | Penicillin (4); Aztreonam (3); Cefalotin (7) |
| β-lactam(2) | Cefalexine (3); Cefoxitin (8); Cefuroxim(2) ; Methicillin(1); Oxacillin(3); |
| β-lactam(3) | Amoxicillin (7); Ampicillin(8); Cefixim(1); Cefotaxim(8); Ceftazidim (4); Ceftiofur(2); Ceftriaxone(8); Cephoperazone (1) ; Piperacillin (1) |
| β-lactam(4) | Ticarcilline (6) ; Cefepim (1) |
| β-lactam(NGC) | Imipenem(5); Mecilinam(1); |
| Quinolone(1) | Nalidixic Acid (11); Flumequine(3) |
| Quinolone(2) | Ciprofloxacine(14); Enrofloxacin(3); Norfloxacin(6); Ofloxacin(1); Pefloxacin(3) |
| Aminoglycoside | Amikacin(5); Gentamicin(19); Kanamicin(4); Neomycine(3); Sisomicin(1); Spectinomycine(2); Streptomycine(8); Tobramycine(4); |
| Phenicolé | Chloramphenicol (11) |
| Macrolide | Clindamycin(2); Erythromycin(5); Lyncomycin(1); Pristinamycin(1); Spiramycin(1) |
| Polypeptide | Colistin(5) |
| Tetracyclines | Doxycycline(5); Tetracyclin(18) ; Minocycline (3) |
| Organophosphate | Fosfomycine (2) |
| Furanes | Nitrofurane (3) |
| Ansamycin | Rifampicin (1) |
| Sulfonamides | Sulfoxides (7) |
| Sulfonamides + | Sulfoxide-Trimethoprim (19) |
| Diaminopyrimidine inhibitor. | Trimethoprim (5) |
| Glycopeptide | Vancomycin (1) |

in 4 studies (14.28%) and only two studies (7%) investigated animal organs. Nasal and cloacal swabs were used as samples in one study each. Table 4 resumes the characteristics of included studies.

### *Resistance in poultry*

Resistance was analyzed in *E. coli*, *Staphylococcus* spp*.* And *Salmonella spp.* subgroup. Resistance in *E. coli* strains from poultry was high to Tetracycline (MR: 97%; IQR [80.65- 98.5%]); Sulfoxide (MR: 81.4%; IQR [81.1-81.7%]); Sulfoxide-Trimethoprim (MR: 61%; IQR [46.57-68.85]) and Ampicillin (42.68%; IQR [40.58-60.43%]). Reported resistance in Salmonella strains from poultry was high to: Erythromycin (MR: 100%; IQR [99%-100%]; Amoxicillin-Clavulanic acid (47.76%; IQR [16.06-52.52%]); and Tetracyclines (46.04%; IQR [38.06-60.75]). Resistance of *Campylobacter* spp. to ciprofloxacin was 60% (IQR [55.25-65.75%])

### *Resistance in cattle*

*E. coli* strains isolated from cattle's show very high resistances with resistance of 98.8% (IQR [98.2-99.4%]) for Tetracycline's; 97.65% (IQR [96.48-98.43%]) for Aztreonam and 96.45% (IQR [94.68-98.23]) for Ampicillin. Resistance of *Salmonella* spp. strains to Streptomycin was high, 58.58% (IQR [40.04-77.11%]), and resistance of *Staphylococcus* spp*.* was low in general for all antibiotics with resistance of 16.25% IQR [11.75-20.58%], 14.63% [13.82-31.32%], 10% [8.55-16%] respectively for Tetracycline's, Penicillin and Gentamicin.

## Molecular investigations

### *Resistance and virulence genes in E. coli*

Three studies investigated AMR and or virulence

**Table 3.** Antibiotics tested and the level of resistance reported.

| ATB | Generation | No resistance (0%) | Very low resistance (1-24%) | Low resistance (25-49%) | High resistance (50-74%) | Very high resistance (75-100%) | Total reports* |
|---|---|---|---|---|---|---|---|
| Acid Nalidixic | 1 | 5 | 5 | 4 | 0 | 1 | 15 |
| Amoxicillin | 3 | 1 | 3 | 1 | 1 | 1 | 7 |
| Amoxicillin+Clavulinic Acid | 4 | 3 | 4 | 2 | 4 | 1 | 14 |
| Ampicillin | 3 | 1 | 2 | 5 | 0 | 2 | 10 |
| Amikacin | NGC* | 1 | 3 | 0 | 0 | 1 | 5 |
| Aztreonam | 1 | 1 | 1 | 1 | 0 | 0 | 3 |
| Cefalexin | 2 | 2 | 0 | 1 | 0 | 0 | 3 |
| Cefalotin | 1 | 1 | 2 | 3 | 0 | 1 | 7 |
| Cefixim | 3 | 0 | 0 | 1 | 0 | 0 | 1 |
| Cefotaxime | 3 | 5 | 2 | 3 | 0 | 1 | 11 |
| Cefoxitine | 2 | 2 | 5 | 0 | 0 | 1 | 8 |
| Ceftazidime | 3 | 2 | 2 | 0 | 0 | 0 | 4 |
| Ceftiofur | 3 | 0 | 2 | 0 | 0 | 0 | 2 |
| Ceftriaxone | 3 | 0 | 5 | 0 | 0 | 3 | 8 |
| Cefuroxime | 2 | 0 | 1 | 0 | 1 | 0 | 2 |
| Cephoperazone | 3 | 0 | 0 | 1 | 0 | 0 | 1 |
| Chloramphenicol | NGC | 6 | 7 | 1 | 0 | 0 | 14 |
| Ciprofloxacine | 2 | 5 | 9 | 1 | 2 | 0 | 17 |
| Clindamycin | NGC | 0 | 2 | 0 | 0 | 0 | 2 |
| Colistin | 1 | 1 | 3 | 0 | 1 | 1 | 6 |
| Doxycycline | NGC | 0 | 4 | 1 | 0 | 0 | 5 |
| Enrofloxacine | 2 | 2 | 1 | 0 | 0 | 0 | 3 |
| Erythromycine | NGC | 1 | 3 | 0 | 0 | 4 | 8 |
| Flumequine | 1 | 0 | 2 | 0 | 1 | 0 | 3 |
| Fosfomycine | 1 | 1 |  | 0 | 0 | 0 | 2 |
| Gentamicin | NGC | 9 | 11 | 1 | 0 | 1 | 22 |
| Imipenem | NGC | 5 | 2 | 0 | 0 | 0 | 7 |
| Kanamycin | NGC | 0 | 3 | 0 | 1 | 0 | 4 |
| Lincomycin | NGC | 0 | 0 | 0 | 1 | 0 | 1 |
| Mecillinam | NGC | 1 | 2 | 0 | 0 | 0 | 3 |
| Methicillin | 2 | 0 | 1 | 0 | 0 | 0 | 1 |
| Neomycin | NGC | 1 | 2 | 0 | 0 | 0 | 3 |
| Nitrofuran | NGC | 0 | 1 | 1 | 1 | 0 | 3 |
| Norfloxacin | 2 | 3 | 2 | 1 | 0 | 0 | 6 |

**Table 3**. Contd.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ofloxacin | 2 | 0 | 1 | 0 | 0 | 0 | 1 |
| Oxacillin | 2 | 1 | 1 | 0 | 1 | 1 | 4 |
| Pefloxacin | 2 | 2 | 1 | 0 | 0 | 0 | 3 |
| Penicillin | 1 | 0 | 3 | 2 | 0 | 1 | 6 |
| Pristinamycin | NGC | 0 | 1 | 0 | 0 | 0 | 1 |
| Rifampicin | NGC | 0 | 1 | 0 | 0 | 0 | 1 |
| Sisomicin | 0 | 1 | | 0 | 0 | 0 | 1 |
| Spectinomycin | NGC | 0 | 2 | 0 | 0 | 0 | 2 |
| Spiramycine | NGC | 0 | 0 | 0 | 0 | 0 | 0 |
| Streptomycin | NGC | 2 | 2 | 2 | 3 | 2 | 11 |
| Sulfoxide | NGC | 2 | 1 | 2 | 1 | 3 | 9 |
| Sulfoxide-Trimethoprim | NGC | 4 | 8 | 5 | 3 | 2 | 22 |
| Tetracyclin | NGC | 2 | 7 | 6 | 3 | 5 | 23 |
| Ticarcillin | 4 | 1 | 2 | 2 | 1 | 0 | 6 |
| Tobramycine | NGC | 2 | 2 | 0 | 0 | 0 | 4 |
| Trimethoprim | NGC | 2 | 2 | 1 | 0 | 2 | 7 |
| Vancomycin | NGC | 0 | 0 | 1 | 0 | 0 | 1 |

*Report: level of resistance reported for a combination of animal space and bacterium. *NGC: Non Generation Classification.

**Table 4.** Characteristics of included studies.

| | Study Name | Study Population | Type of samples | Clinical Status | Setting | Organismes | Guidelines | AMR gene investigated | Virulence gene investigated | Study quality appraisal |
|---|---|---|---|---|---|---|---|---|---|---|
| Senegal | Bada-Alambedji et al. (2006) | Poultry | Carcass | Healthy | Vendors | *Salmonella* spp. | CASFM | NO | NO | H |
| | Cardinale et al. (2003) | Poultry | Carcass | Healthy | Abattoir/Vendor | *Compylobacter* spp. | CLSI | NO | NO | H |
| | Fall et al. (2012) | Pig | Carcass/Feces | Healthy | Farm/Abattoir | *Staphylococcus* spp. | NS | NO | NO | M |
| | Dione et al. (2009) | Poultry | Carcass/Feces | Healthy | Farm/Abattoirs | *Salmonella* spp. | CASFM | NO | NO | H |
| | Fall-Niang et al. (2019) | Poultry | Carcass | Healthy | Abattoir/Vendor | *Salmonella* spp. | CASFM | NO | NO | H |
| | M. KADJA et al (2013) | Goat/Sheep | Milk | Mastitis | Clinic | *Staphylococcus* spp | CASFM | NO | NO | M |
| | Mama et al. (2019) | Poultry | Nasal Sample | Healthy | Abattoir | *Staphylococcus* spp. | NS | NO | YES | M |
| | | Cattle | Nasal Sample | Healthy | Abattoir | *Staphylococcus* spp. | NS | NO | YES | M |
| | Vounba et al. (2018) | Poultry | Feces | Healthy | Farm | *E.coli* | CLSI | YES | YES | H |
| | Vounba et al. (2019) | Poultry | Organs (liver, heart, intestines, and spleen) | Collibacillosis | Farm | *E.coli* | EUCAST | YES | YES | H |
| | Shyaka et al. (2010) | Cattle | Milk | Mastitis | Farm | *Staphylococcus* spp. | CASFM | NO | NO | M |
| | Stevens et al. (2006) | Cattle | Carcass | Healthy | Abattoir | *Salmonella* spp. | NS | NO | NO | M |

**Table 4**. Contd.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ivory Coast | Attien et al. (2013) | Beef, pig and Poultry | Carcass | Healthy | Vendors | *Staphylococcus* spp. | CASFM | NO | NO | M |
| | Coulibaly et al. (2010) | Poultry | Carcass | Healthy | Abattoir/Vendors | *Salmonella* spp. | NS | NO | NO | H |
| | Gblossi Bernadette et al. (2012) | Poultry | Organs/caeca | Healthy | Abattoir | *Camplylobacter* spp. | CLSI | NO | NO | H |
| | Rene et al. (2014) | Poultry | Carcass | Healthy | Abattoir/Vendors | *Salmonella* spp. | CASFM | NO | NO | H |
| | Yao et al. (2018) | Cattle | Feces | Healthy | farm | *E.coli* | CASFM | YES | NO | H |
| | Yao et al. (2017) | Cattle | Feces | Healthy | farm | *Salmonella* spp. | CASFM | NO | NO | H |
| | Coulibaly et al. (2018) | Cattle | Feces | Healthy | Abattoir | *E.coli/Salmonella* spp. | CASFM/EUCAST | NO | NO | H |
| | Guessennd et al. (2012) | Pig | Feces | Colibacillosis | farm | *E.coli* | CASFM | NO | NO | M |
| Mali | Sidibé et al. (2019) | Poultry | Cloacal Swab | Salmonellos diseas | Farm | *Salmonella* spp. | CASFM | NO | NO | H |
| Niger | Abdoulkarim et al. (2014) | Cattle | Milk | Mastitis | Farm | *Staphylococcus* spp. | CASFM | YES | NO | H |
| | Abdoulkarim et al. (2013) | Cattle | Milk | Mastitis | Farm | *Staphylococcus* spp. | CASFM | NO | YES | H |
| Burkina Faso | Kagambèga et al. (2013) | Cattle | Feces | Healthy | Abattoir | *Salmonella* spp. | NS | NO | NO | M |
| | | Poultry | Feces | Healthy | Abattoir | *Salmonella* spp. | NS | NO | NO | M |
| | | Pig | Feces | Healthy | Abattoir | *Salmonella* spp. | NS | NO | NO | M |
| | Caroline Bouda et al. (2019) | Poultry | Eggs | Healthy | Vendors | *Salmonella* spp. | EUCAST | NO | NO | H |
| | | Poultry | Feces | Healthy | Farm | *Salmonella* spp. | EUCAST | NO | NO | H |
| | Somda et al. (2018) | Poultry | Carcass | Healthy | Abattoir/Vendors | *E.coli* | EUCAST | NO | YES | H |
| Benin | Boko et al. (2013) | Guinea fowl(pintades) | Feces | Mixte (Healthy/diseas) | farm | *Salmonella* spp. | CASFM | NO | YES | H |
| | Deguenon et al. (2019) | Poultry/sheep/pig | Feces | Healthy | farm | *Salmonella* spp. | NS | NO | YES | M |
| | Ahouandjinou et al. (2016) | Cattle | Carcass | Healthy | Abattoir | *Salmonella* spp. | CASFM | YES | NO | H |

genes in *E. coli* strains. Somda et al. (2018) in BF investigated the presence of STEC, EPEC, ETEC, EIEC, and EAEC genes on grilled chicken meat samples by 16- plex PCR for the genes *uid*A, *pic*, *bfp*, *inv*E, *hly*A, *elt*, *ent*, *esc*V, *eae*A, *ipa*H, *agg*R, *stx*1, *stx*2, *est*Ia, *est*Ib, and *ast*. Only *st*Ia, *stx*2A, *inv*E, *ast*A, and *agg*R virulence genes were detected. Six diarrheagenic *E. coli* were detected as follows: EAEC and ETEC (in two samples each) and STEC and EIEC (in one sample each). No EPEC gene was detected.

In Senegal, Vounba et al. (2018) investigated Antimicrobial Resistance (AMR) genes in *E. coli* isolated from diseased chicken. Many AMR genes were detected, including variants of $bla_{CTX\text{-}M}$ encoding resistance to third-generation cephalosporins. Most fluoroquinolone-nonsusceptible isolates were carriers of mutations in *gyrA (Ser83Leu, Asp87Asn, and/or Asp87Tyr)* and/or *parC (Ser80Ile)* genes*. A total of 84.5%* isolates exhibited at least one of the virulence markers of Avian Pathogenic *Escherichia Coli* (APEC), among which 39.7% were defined as potential virulent APEC. The same author investigated *E. coli* from healthy chicken in Senegal (Vounba et al., 2019) and reported the presence of AMR genes. According to this report, 95% of tested farms harbored isolates carrying mutations in *gyrA* (*Ser83*Ile and *Asp*87Asn) and *par*C (*Ser*80Ile). 3GC resistance was mediated by b$la_{CMY\text{-}2}$ or $bla_{CTX}$-M genes, $bla_{CTX}$-M bein Stevens g of genotypes $bla_{CTX\text{-}M\text{-}1}$, $bla_{CTX\text{-}M\text{-}8}$ and the genotype $bla_{CTX\text{-}M\text{-}15}$. The most prevalent AMR genes were those encoding resistance against tetracycline (tet genes) and trimethoprim-sulfamethoxazole (*dfr*A genes). Genes encoding

resistance against streptomycin (*aadA*1) or ciprofloxacine (*qnr*B) were also detected.

### *Resistance and virulence genes in Salmonella strains*

Boko et al. (2013) screened all confirmed Salmonella isolates in Guinea fowl by polymerase chain reaction (PCR) for the presence of several virulence-associated genes located on Salmonella Pathogenicity Islands (SPI) 1 to 5: *prg*H, *inv*A, *sit*C, *spa*I, *inv*E (SPI-I); *spi*C, ssaU, *ttr*B (SPI-2); *mgc*T, *mis*L (*SPI*-3); *orf*L (*SPI*-4); *pip*D (SPI-5). All isolates belonging to five serotypes tested positive by PCR for most of the target genes (Deguenon et al., 2019). The genes of virulence that were targeted for amplification by PCR were *inv*A, spvR, *spv*C, *fimA* and *stn*. All Salmonella isolates were positive for the presence of *inv*A genes, *fim*A and *stn*. The *spv*C gene was present in 10% and *spv*R gene in 20% of the isolates.

### *Resistance and virulence genes in Staphylococcus strains*

Mama et al., 2019 in Senegal tested six S. aureus isolates of cow origin. All the isolates showed resistance for penicillin (with *bla*Z gene) and two of them to tetracycline (with ***tet*** **(**K) gene). All the isolates hosted hemolysin-encoding genes. The following genotypes were observed for non *S. aureus* strains: tetracycline [*tet*(K), *tet*(L)], trimethoprim/sulfamethoxazole (SXT) (*dfr*G, *dfrK*), penicillin (***bla***Z), erythromycin [*msr*(A)/ *msr*(B)].

In Niger, Abdoulkarim et al., 2014 tested all the isolates resistant to Amoxicillin in his study for the presence of *bla*Z gene (coding for β-lactamase) by polymerase chain reaction (PCR). 90% of the isolates tested positive for the blaZ gene suggesting that the blaZ gene encodes the production of β-lactamase by most penicillin-resistant S. aureus of this study. Previously, the same author (Abdoulkarim et al., 2013) virulotyped *S. aureus* strains by PCR for the presence of genes coding for Microbial Surface Components Recognizing Adhesive Matrix Molecules (MSCRAMM) to colonize the host epithelia and extracellular matrix components (*clf*A, *clfB*, fnbA, cna, ebpS and *sdr*C). This was done for capsular and other surface antigens conferring resistance to phagocytosis (*cap*5H, *cap*8H, *spa* and *ica*A); exfoliative toxins active on extracellular matrix components (*et*A, *et*B and *et*D); haemolysins and leukocidins counteracting the cells of the host's innate immune response (*hla, hlb, hld, hlgAC, lukD, lukM, lukF-PV* and *luk*S-PV); and for enterotoxins causing diarrhoea by action on the host enterocytes (*sea, seb, sec, sed, seg, seh, sei, sej and sen*). All or most of the *S. aureus* isolates gave amplified fragments with most for the genes coding for surface antigens: *clfA* (91%), *clf*B (100%), *fnbA* (100%), *cna* (100%), *ebpS* (100%), sdrC (87%), *cap*5H (83%), *spa* (96%), *ica*A (96%); and with several for the toxin-encoding genes: *et*D (74%), *hla* (96%), *hlb* (100%), *hld* (96%), *hlgA*C (74%), *luk*D (96%), *luk*M (96%). Conversely, a minority of isolates tested positive for the following genes: *cap*8H (4%), *lukF-PV* (17%), *lukS*-PV (9%); only one isolate (4%) tested positive for 2 of the 9 enterotoxin-encoding genes (*sej* and *seg*);

## Situation of ABR per country

### *Senegal*

Eleven studies from Senegal are included in this qualitative review. 39 different antibiotics were tested in these studies namely : Methicillin ; Penicillin; Ampicillin; Amoxicillin; Amoxicillin+ Clavulanic Acid; Nalidixic Acid; Cefotaxime; Ceftazidime; Ticarcilline; Imipenem; Cefoxitine; Cephalexin; Cephoperazone; Cefalotin; Cefoxitin; Ceftiofur; Ceftriaxone; Flumequine; Gentamicin; Spectinomycine; Streptomycin; Spiramycine; Kanamycin; Amikacin; Pefloxacin; Norfloxacin; Ciprofloxacin; Neomycin; Erythromycin; Tetracycline; Doxycycline; Chloramphenicol; Nitrofurane; Sulfoxide; Sulfoxide-Trimethoprim; Tobramycin; Trimethoprim; Colistin; Rifampicin; Tetracyclines were the most frequently tested antibiotics in the studies (90.9%) followed by the association Sulfoxide-Trimethoprim (81.81) and Gentamicin tested in 72.72% of the studies.

Most of the studies in Senegal were performed in poultry (63.63%; 7/11). Four studies out of the 7 in poultry was performed in carcass sampled in slaughterhouses or vendors and 2 studies performed on feces sampled in farms, one (1/7) on animal's organs and one on nasal samples. Salmonella (3/7), *E. coli* (2/7), Campylobacter (1/7) and *Staphylococcus* spp. (1/7) were the studied bacteria in poultry. The ABR in Campylobacter was 75% to Ciprofloxacin; in *Staphylococcus* spp., resistance was 83.33% for Tetracycline and 50% for Sulfoxide-Trimethoprim.

In *Salmonella* spp. the resistance was mainly observed to Tetracyclines (66%; [56.34-70.5]), Trimethoprim (59.1%; [50.55%-67.65%); sulfoxides (56.55%; [48.83-64.28%]) Streptomycin (50.86%, IQR: [39.33-62.44]) and association Sulfoxide-Trimethoprim (47% [43.5-63.5]). The highest resistance in *E. coli* was observed for the same antibiotics: Tetracycline (98.50%; [97.75-99.25%]), Sulfoxide (81.04% [81.1-81.7%]) Sulfoxide-Trimethoprim (68.85%; [64.93-72.78]) and Ampicillin (58.15%; [48,23%-68,08%]). Two studies focus on cattle (2/11; 18.18%) and bacteria of interest was *Staphylococcus* spp. (milk samples) for one study and *Salmonella* spp. (carcass samples) for the other study. Only one study on ABR was performed in pigs (Carcass and feces samples) and one on small ruminants (Sheep and goat with milk as sample matrix). *Staphylococcus* spp. as bacteria of interest was

investigated in these two studies.

**Ivory coast**

Twenty eight different antibiotics were tested in a total of 8 studies included in this qualitative review: Pristinamycin; Oxacillin; Ofloxacin; Amoxicillin; Amoxicillin+Clavulinic Acid; Nalidixic Acid; Cefotaxime; Cefuroxime; Imipenem; Cefalotin; Ceftriaxone; Gentamicin; Kanamycin; Rifampicin; Vancomycin; Lyncomycine; pefloxacin; Ciprofloxacin; Erythromycin; Tetracycline; Doxycycline; Chloramphenicol; Sulfoxide-Trimethoprim; Sixomicin; Tobramycin; Piperacillin; Cefepime; Minocycline. The association Amoxicillin-Acid Clavulanic was tested in all the studies followed by Association Sulfoxide-Trimethoprim tested in seven of the eight studies.

Studies were mainly conducted in poultry (4/8) and cattle (3/8) and Salmonella was the bacteria of interest in four studies followed by *E. coli* in three studies. Globally, the highest prevalence of resistance in Salmonella in poultry was observed with Amoxicillin (50.47% IQR [49.55-51.37]); Amoxicillin-Acid Clavulanic (MR=47.76% [44.50-50,01]) and Cefalotin (MR=42.99%; IQR[41.77%-44.22%]). In cattle, Salmonella was most frequently resistant to Tetracycline's (MR=42.99%; IQR [41.77%-44.22%]). One of the three studies in poultry investigated resistance of *Campylobacter* spp. to antibiotics and reported resistances to these bacteria. Indeed, interesting resistances were reported to: Nalidixic Acid (78%) Ciprofloxacin (50%) ; Erythromycin (13,5%) and Amoxicillin + Clavulanic Acid (11.8%) (Gblossi et al., 2012).

Another study investigated the resistance of *Staphylococcus* spp*.* in three species (beef pork and chicken) but did not report resistance per specie (Attien et al., 2013). According to this study, resistance to staphylococcus in food producing animals in Ivory Coast was 100% to erythromycin, 62% to Amoxicillin-acid-clavulanic and 58% to Oxacillin. To finish, Guessennd et al. (2012) investigated *E.coli* resistance to antibiotics in pigs and reported notable resistance of 76.7, 66.7 and 56.7% respectively for Tetracycline, Cefotaxime and Sulfoxide-Trimethoprim.

**Benin**

Three studies were identified from Benin and antibiotic susceptibility was performed against 24 antibiotics namely: Oxacillin; Ampicillin; Amoxicillin; Amoxicillin-Clavulanic; Nalidixic Acid; Cefotaxime; Cefuroxime; Imipenem; Cefoxitine; Cefalotin; Ceftriaxone; Flumequine; Gentamycin; Amikacin; Ciprofloxacin; Neomycin; Tetracycline; Chloramphenicol; fosfomycine; Sulfoxide; Sulfoxide-Trimethoprim; Trimethoprim; Colistin; gentamicin.

Studies in Benin were done on poultry/sheep/pigs for one study, guinea fowl for another study and cattle. Two studies were performed in feces samples and one on carcass from cattle. *Salmonella* spp*.* strains were investigated in the three studies. Salmonella isolates from poultry/sheep/pigs were resistant to Amoxicillin (100%), Amoxicillin-Acid clavulanic (100%) Cefotaxime (100%) Cefoxitin (100%) Cefalotin (100%) Gentamycin (100%) Amikacin (100%) Trimethoprim (100%); Ceftriaxone (85%). Those from Guinea flow were resistant to Oxacillin (100%), Sulfoxide (100%) and Colistin (100%). In cattle, High resistance was reported from Ampicillin (87.77), Ceftriaxone (88.49), Sulfoxide-Trimethoprim.

**Burkina Faso**

In BF, three published studies reported ABR in food producing animals. The three studies tested a total of 21 antibiotics: Ampicillin; Amoxicillin-Clavulanic acid; Nalidixic Acid; Aztreonam; Cefotaxime; Mecilinam; Ticarcilline; Imipenem; Cephalexin; Ceftriaxone; Gentamycin; Streptomycin; Ciprofloxacin; Norfloxacin; Erythromycin; Tetracycline; Chloramphenicol; Sulfoxide; Sulfoxide-Trimethoprim; Trimethoprim; Colistin.

Common antibiotics in the studies were: Imipenem; Gentamycin; Streptomycin; Ciprofloxacin; Tetracycline and Chloramphenicol. Disc diffusion method was used in all studies. Salmonella and *E. coli* were the bacteria studied. Salmonella resistance was reported in two studies and *E. coli* in One study. Resistance of *E. coli* to Tetracycline in chicken meat was 64.3%. Salmonella from food producing animals in BF was resistant to Erythromycin (MR=100%); Amoxicillin-Clavulanic (MR=55.85%; [54.23-57.48%]); Ticarcillin (MR=49%; [45.78-53.13%]) and Tetracycline (MR=42.1%; IQR [34.05-43.75%]).

**Mali-Niger**

Three published studies were found for these countries. In Mali, the only published paper reported resistance to salmonella in poultry while in Niger the two included studies reported resistance of *Staphylococcus* spp. in Cattle milk. The three studies used disc diffusion method and followed the CASFM guidelines. Resistance of salmonella in Mali was high for Erythromycin (98%); Colistin (94%); Streptomycin (90%); Kanamycin (67%); Flumequine (65%) and Tetracycline (59%). In Niger, moderate to low resistance of *S. aureus* was observed to penicillin (30.5% [21.75-39.25]); Gentamycin (16% [13-19]); and Tetracycline (10.5% [9.25-11.75]).

**DISCUSSION**

As a threat to a century of gains made since the discovery

of antibiotics and the contribution of these drugs to improvements in animal and human health and wellbeing, antibiotic resistance has become a global concern. Sub-Saharan Africa has a high incidence of invasive bacterial infections in humans and this condition increase demand for both preventive and therapeutic antimicrobials. However, antibiotics are widely used in domestic and commercial animal husbandry and this can contribute to the annihilation of the therapeutic arsenal used in human medicine and on which the continent's and the world relies to overcome these infections. Indeed, the development of resistances in animals can threat human health through dissemination of resistance bacteria or resistance genes from animal to human through food chain or direct contact.

Being in human health or veterinary medicine, sub-Saharan Africa has the least antimicrobial surveillance strategies of all world regions. Only six (15%) of the 41 WHO Africa region member states carry out surveillance for bacterial antimicrobial resistance in human health (Williams et al., 2018). In animal health, surveillance of antibacterial resistance in animals is almost nonexistent in Africa countries. Then, the lack of consistency in the measurement and reporting of antibiotic susceptibility data in animals makes it difficult to know the situation in food producing animals in different countries. To address this issue, scientists are making efforts in research to yield data that can draw attention of decision makers to set up surveillance network. Unfortunately, these efforts although useful are often rare and scattered that they do not allow the visibility of the magnitude of the situation. That is why a synthesis of the scientific data generated here and there over a long period is often useful to give visibility of the situation and draw attention. This summary of the situation of antibiotic resistance in food producing animal in West Africa French-speaking countries from 2000 to 2019 (20 years) trailed this objective.

In a recent systematic review and meta-analysis, some published papers tried to report the situation of ABR in food producing animals in all African countries (Founou et al., 2018). However, it failed sometime to include some interesting studies from French countries in west Africa may be because some are published in French or are not index in high databases as PubMed or simply did not met authors inclusion criteria. The present review has the advantage of zooming on the situation of antibiotic resistance in French-speaking countries, where interesting scientific work is often not very visible because of language limitations. Indeed, this study proved that antibiotic-resistant is globally under investigation in West Africa French speaking countries with only 28 studies included from 6 countries out of the 9 countries in the study area. This is similar to the situation previously reported by Founou et al. (2018) who reported data from 12 countries out of 54 in Africa. However, unlike this study, which includes only one study from Senegal, many data were reported from Senegal and data from other French speaking countries, giving the real situation in this geographic area.

Our systematic review has demonstrated widespread prevalence of antibiotic resistance in food producing animals in West Africa French speaking countries. Poultry and cattle were the most studied species with *Salmonella* spp. and *Staphylococcus* spp. as bacteria's of interest in most investigations. The fact that poultry is the specie most concerned by studies is not surprising and is rather interesting because poultry farming is the sector that uses antibiotics the most, often in modern farms constituted by semi-intensive or intensive systems unlike other livestock sectors which for the most part still extensive (Schneider et al., 2010). Salmonella as bacteria of interest in studies would be linked to the role of salmonellosis in food poisoning and to the interest of this bacterium in several monitoring programs (Jajere, 2019).

Many studies investigated ABR on samples from healthy animals and this is a good indicator according to WHO advisory group on integrative surveillance who estimated that samples from both healthy animals and sick animals are useful for surveillance but samples from healthy animals should be the primary focus for surveillance because such samples can provide an unbiased measure of antimicrobial resistance in animals source of human food supply (WHO, 2017).

Studied bacteria were Salmonella, *Staphylococcus* spp., *E. coli* and *Campylobacter* spp. . These bacteria are important bacteria commonly investigated and monitored for resistance in many monitoring systems. According to WHO advisory group worldwide, Salmonella is the first priority for inclusion in a program of integrated surveillance of antimicrobial resistance in foodborne bacteria. Campylobacter spp. is also an important foodborne pathogen and should be included in program of integrated surveillance of antimicrobial resistance in foodborne bacteria. Because Escherichia coli are common and some strain variants may cause disease, E. coli is used as a sentinel organism for antimicrobial resistance. *E. coli* also serve as reservoirs of resistance genes that can be transferred to human pathogens transiting the intestinal tract; as such, it provides information on the flow of Gram-negative resistance trend in the food chain (WHO, 2017).

The majority of studies included used the disk diffusion method and CASFM guidelines. This reduces the impact of the variation in AMR methodology on the pooled estimation. Resistance was found to be high in *E. coli* strains from poultry to Tetracycline (MR: 97%; IQR [80.65-98.5%]); Sulfoxide (MR: 81.4%; IQR [81.1-81.7%]); Sulfoxide-Trimethoprim (MR: 61%; IQR [46.57-68.85]) and Ampicillin (42.68%; IQR [40.58-60.43%]). Similar high rates of resistance in *E.coli* have been reported for tetracycline (10.6- 95%), ampicillin (6.02- 95.7%) and trimethoprim/sulfamethoxazole (4.49-80%) in a previous

review (Alonso et al., 2016).

In Salmonella strains, high resistance were found to: Erythromycin (MR: 100%; IQR [99-100%]; Amoxicillin-Clavulanic (47.76%; IQR [16.06-52.52%]); and tetracycline (46.04%; IQR [38.06-60.75]). Full resistance to Erythromycin (100%) is not surprising as Salmonella is known to have natural resistance to this antibiotic (Braoudaki and Hilton, 2005). The findings are comparable with previous review in the African region by Founou et al. (2018) who identified similar resistance of Salmonella. Indeed, these authors' reported a high level of resistance of Salmonella (80.9% [95% CIs; 54-93.8%) in a Meta-analysis of all reported resistance to all antibiotics. This findings highlights serious concerns relating to the use of these antibiotics in animals and corroborate similar findings in Cameroun where Moctar et al. (2019) reported high levels of resistance of *E. coli* and Salmonella spp. to all classes of antibiotics tested who are usually antibiotics of critical importance for humans and animals according to WHO and OIE classifications. Very few publications associated molecular investigation of resistance to phenotypic resistance. This is because the most important in these countries remain the inventory of the situation of antibiotic resistance before any thorough investigation.

Given the findings of this review, harmonization efforts are urgently needed in West Africa French speaking countries. Standardizing bacteria of interest, antibiotic to be tested (to avoid testing bacteria against antibiotics for which they have a natural resistance such as salmonella against erythromycin which has been reported a lot in studies when this is not really of interest to public health), AMR methods, interpretation guidelines, report format and prioritizing animal population of interest, could allow better comparability of results and situation from all countries. Also in this sense, technical and financial support of laboratories in these countries is a necessity to support the monitoring of the situation in human and food producing animals in a one health approach as recommended by WHO (2017) so as not to undermine the efforts undertaken around the world to combat resistances to antibiotics. The limitations of the current review include the exclusion of English language countries as Nigeria and Ghana biasing this view of the situation in the wall West Africa Sub region. For example, only in Nigeria, with similar inclusion and exclusion criteria, the review of (Oloso et al., 2018) reported 77 studies from animal sector. This shows that the inclusion of the situation in English-speaking countries would provide a better view of the situation in West Africa. A further limitation is combining AMR results from different species across different countries to have median resistance for a bacterium. However, given the observed trends, it is believed that the resolution of the obtained data was sufficient to show general trend of AMR in livestock in French Speaking countries. Moreover, since no monitoring system exist, this review can draw attention of sub regional institutions as ECOWAS to further support the establishment of One Health monitoring networks for the wall countries as it is done in many part of the word especially in Europe with EUCAST monitoring network (Silley et al., 2011).

## Conclusion

Tackling the public health threat posed by antimicrobial resistance requires effective antimicrobial resistance surveillance programs. The essential need for robust antimicrobial resistance surveillance systems is emphasized in the Global Action Plan on Antimicrobial Resistance (WHO, 2017). Based on this study, antibiotic resistance is high in food producing animals in West Africa French speaking countries. It is necessary to design a carefully planned, multi-sectoral, surveillance plan, which can be used for research and monitoring of resistances in all countries and sectors in a one health approach. The relevant ministries and governments should enforce registration and monitoring of veterinary drugs use, promote good practices in antimicrobial use by trained professionals.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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