International Journal of Biomedical Materials Research
2022; 10(2): 31-38
http://www.sciencepublishinggroup.com/j/ijbmr
doi: 10.11648/j.ijbmr.20221002.11
ISSN: 2330-7560 (Print); ISSN: 2330-7579 (Online)

Review Article

A Review on the Status of *Staphylococcus aureus* in Ethiopia: A Ten Years Trend Analysis

Gebrerufael Girmay*, Gadisa Muleta

Ethiopian Institute of Agricultural Research, National Agricultural Biotechnology Research Center, Holeta, Ethiopia

Email address:
rufel2000@yahoo.com (G. Girmay)
*Corresponding author

To cite this article:
Gebrerufael Girmay, Gadisa Muleta. A Review on the Status of *Staphylococcus aureus* in Ethiopia: A Ten Years Trend Analysis. *International Journal of Biomedical Materials Research.* Vol. 10, No. 2, 2022, pp. 31-38. doi: 10.11648/j.ijbmr.20221002.11

Received: July 8, 2022; **Accepted**: August 3, 2022; **Published**: August 9, 2022

Abstract: As *Staphylococcus aureus (S. aureus)* gave the opportunity for the penicillin discovery, it also has been challenging the health of both humans and their livestock due to its drug resistance property. In spite of the fact that fragmented studies on the apparent prevalence of *S. aureus* in milk and meat have been conducted in Ethiopia, a well-organized national review on this pathogen remained scarce. A review on *S. aureus* was conducted to overview the pooled apparent prevalence and its trend in Ethiopia in a ten-year period from 2011 to 2020. PubMed and Google Scholar databases were used to search for research articles published in reputable journals. Eventually, 29 research articles were selected for the analysis. Regression models and Odds Ratio were employed to determine the association and degree of associations of risk factors with the pooled apparent prevalence (PAP) of *S. aureus*, respectively. The PAP of *S. aureus* was 22.2% (95% CI: 21.0-23.4). The apparent prevalence of *S. aureus* was found twice in milk samples than in meat. A statistically significant difference in the apparent prevalence of *S. aureus* was found among the Ethiopian regions in which, more than half (57.2%) of it was found in SNNP and Oromia. Trend analysis indicated that the apparent prevalence of *S. aureus* was decreasing by 2.9 every single year.

Keywords: Ethiopia, *Staphylococcus aureus*, Ten-Year Review

1. Introduction

Nowadays, the world is experiencing different challenges from which, including climate change, fast transportation facilities, and active population growth are found among others. One of the predisposing factors that impose different micro-organisms to adapt to their environment is climate change, leaving the common preventive methods from threats. From the time of Alexander Fleming in 1940, the first drug invention, the world has been using different antibiotics to treat both humans and animals [1]. However, as time goes on, the commonly used drugs have created drug-resistance, for some of them as multi-drug resistance [2].

One of the common bacteria that cause health problems to humans and their animals is *Staphylococcus aureus* [3]. As critically reviewed by Kumar and his colleagues [4], the drug-resistant *S. aureus*, especially the methicillin-resistant *S. aureus* (MRSA) has gotten special attention. However, the drug-susceptible *S. aureus* has been creating health threatening to humans and their livestock.

The actual status of drug-resistant and drug-susceptible *S. aureus* in developed countries, especially in America, Europe and Australia has been widely studied [4]. As a result, the proportion of MRSA surpass the proportion of MSSA from 20 to 80% demanding alternative drugs to treat infections caused by this agent. In developing countries, the effect of both the MRSA and MSSA could be beyond the studies reported in the developed countries due to the inappropriate and none proportional use of drugs both in the medical and veterinary scenarios. Ethiopia is one of the developing countries where drugs are sold in open markets as any shopping goods which lead to a wide distribution of drug-resistant bacteria. A meta-analysis on methicillin-resistant *S. aureus* from 2004 to 2015 in Ethiopia indicated a high prevalence of the disease [5].

However, the general trend of *S. aureus* (both susceptible and resistant) in the last ten years in Ethiopia is not well analyzed. Therefore, the aim of this review is to summarize the available data of *S. aureus* and show the trend of the disease in the ten years period (2011-2020).

2. Materials and Methods

2.1. Study Selection

A literature search was conducted in the PubMed and Google Scholar databases and articles potentially relevant to our study were identified. The search was performed by using the following terms as keywords (and combinations thereof) "*Staphylococcus aureus*", "*S. aureus*", "prevalence" and "Ethiopia". Among the citations extracted, abstracts were reviewed in an attempt to retrieve the prevalence studies on *S. aureus*. Articles that were relevant, by title and abstract, were accessed in full text to determine those that provided sufficient information to be included in our review analysis. Finally, the references cited by each eligible study were scrutinized to identify additional articles.

2.2. Inclusion and Exclusion Criteria

Studies were included in the review if they reported extractable data on the prevalence of *S. aureus* in Ethiopian cattle meat, cattle and camel milk and milk products, and only articles written in English language were considered. On the other hand, studies that did not report on a study of *S. aureus* and failed to comply with the Ethiopian setting were excluded from the study. Articles believed to be published in non-reputable journals were not included in this review. This was conducted using the article published by Elmore and Weston which states "Predatory Journals: What they are and how to avoid them" [6]. According to this article, the like of 'The Directory of Open Access Journals (DOAJ)', 'The Committee on Publication Ethics (COPE)', 'SCImago Journal Rank', 'National Library of Medicine (NLM) Catalog' and 'Stop Predatory Journals' were used to check where the article to be included in this review was relevant or not.

2.3. Outcome of Interest

The major outcome of interest was the prevalence of *S. aureus* isolated from cattle, camel and their products. The apparent prevalence was calculated by dividing the numbers of samples that have *S. aureus* isolates to the total number of samples taken from cattle, camel and their products.

2.4. Data Extraction

Data from eligible studies were extracted and summarized into an excel spreadsheet. For each of the included studies, the following information was extracted; name of regions, study area/city, study names, year of the study, study design, types of specimens, numbers of study participants, total numbers of *S. aureus* and references. If an article has different study areas (Region, zone and district) and if the sample size in each study area were enough to stand alone (enough sample size), additional data/ article was extracted from the original article.

2.5. Quality Control

The quality of eligible studies was checked using a set of predetermined criteria such as research design, quality of paper and employed methods for *S. aureus* isolation.

2.6. Data Analysis

Data extracted and prepared an in excel spreadsheet was ready for analysis. Data of each study area was set to have presence or absence with its weight as dependent variable and study areas (regions), years and source of sample were considered as independent variables/ risk factors. Logistic regression was conducted to determine the association of these risk factors/ independent variables with the pooled apparent prevalence of *S. aureus*. The strength of association was addressed using Odds Ratio. The data of pooled apparent prevalence in excel was also converted to a csv file and overlaid to the regions of Ethiopia to observe the geographic distribution of the *S. aureus* isolates. All statistical analysis was performed using the Stata Version-16 software.

3. Results

Using the electronic database search, a total of 114 articles (71 from Pub Med and 43 from Google scholar) were retrieved. Among the 114 articles, 93 of them were excluded due to the inclusion/exclusion criteria mentioned in the methodology. Four articles were also excluded due to duplication in PubMed and Google scholar remaining 14 from PubMed and 3 from Google Scholar. In addition, 12 articles/ data were extracted from existing articles (articles that have different study areas) that fulfill the inclusion criteria mentioned in the methodology. Overall, 29 articles were subjected to be reviewed. All the articles included here were laboratory-based cross-sectional studies. Based on the source of the specimen, twenty-six articles were based on milk samples, of which, one article was from camel milk. Three of the studies were on beef from abattoir (Table 1 and Figure 1).

Table 1. *Summary of Staphylococcus aureus apparent prevalence studies in different parts of Ethiopia, 2011-2020.*

Author and year	Region	District	Sample used	Detection method	S. size	Proportion
[7] Kalayu et al. 2020	Tigray	Mekelle	Cow milk	Molecular	385	12.5
[8] Berhe et al. 2020	Tigray	Mekelle, Wuk., Adig.	Cow milk	Bacterial culture	315	11.4
[9] Girmay et al. 2020	Tigray	Shire	Cow milk	Bacterial culture	220	9.5
[10] Amenu ea al. 2019	Oromia	Yabello	Cow milk	Bacterial culture	126	11.1
[10] Amenu et al. 2019	Oromia	Yabello	Camel milk	Bacterial culture	44	11.4

Author and year	Region	District	Sample used	Detection method	S. size	Proportion
[11] Regasa et al. 2019	Oromia	Mukaturi	Cow milk	Bacterial culture	78	21.8
[11] Regasa et al. 2019	Oromia	Sululta	Cow milk	Bacterial culture	105	10.5
[12] Bihon et al. 2018	Amhara	Gondor	Cow milk	Bacterial culture	334	5.1
[13] Adugna et al.2018	A. Ababa	Addis Ababa	Beef from abattoir	Bacterial culture	384	9.4
[13] Adugna et al.2018	A. Ababa	Addis Ababa	Beef from butcher	Bacterial culture	384	19.8
[14] Birhanu ea al.2017	Oromia	Bishoftu	Subclinic. mastitic cow	Bacterial culture	262	45.0
[15] Beyene et al. 2017	A. Ababa	Addis Ababa	Cow pooled milk	B. culture & bioch.	48	20.8
[15] Beyene et al. 2017	A. Ababa	Addis Ababa	Meat from abattoir	B. culture & bioch.	103	11.7
[16] Ayele et al. 2017	Oromia	Sebeta	Cow milk	B. culture & bioch.	209	19.6
[17] Seyoum et al. 2017	Oromia	Asella town	Mastitic cow milk	Bacterial culture	230	46.5
[18] Tolosa et al. 2016	Oromia	Jimma	Cow milk from cows	B. culture & bioch.	32	37.5
[18] Tolosa et al. 2016	Oromia	Jimma	Retail & col. center's cow milk	B. culture & bioch.	42	35.7
[19] Tarekgne et al. 2016	Tigray	Mekelle	Cow milk & m.products	B. culture & bioch.	147	31.3
[19] Tarekgne et al. 2016	Tigray	Shirendasilasie	Cow milk &milk products	B. culture & bioch.	139	43.2
[19] Tarekgne et al. 2016	Tigray	Addigudem	Cow milk & m.products	B. culture & bioch.	52	30.8
[19] Tarekgne et al. 2016	Tigray	Adigrat	Cow milk & m.products	B. culture & bioch.	43	20.9
[19] Tarekgne et al. 2016	Tigray	Wukro	Cow milk & m.products	B. culture & bioch.	60	25.0
[19] Tarekgne et al. 2016	Tigray	Abi-Adi	Cow milk & m.products	B. culture & bioch.	34	8.8
[19] Tarekgne et al. 2016	Tigray	Maichew	Cow milk & m.products	B. culture & bioch.	53	15.1
[20] Abebe et al. 2016	SNNPR	Awasa milk shade	Cow milk	B. culture & bioch.	172	51.2
[21] Makita et al. 2012	Oromia	Bishoftu	Bulk cow milk	B. culture & bioch.	170	43.5
[22] Daka et al. 2012	SNNPR	Awasa	Cow milk	B. culture & bioch.	160	48.8
[23] Abera et al. 2012	SNNPR	Awasa	Cow milk	B. culture & bioch.	201	16.9
[24] Haftu et al. 2012	Tigray	Mekelle	Cow milk	B. culture & bioch.	305	15.1

Source: Compiled by authors.

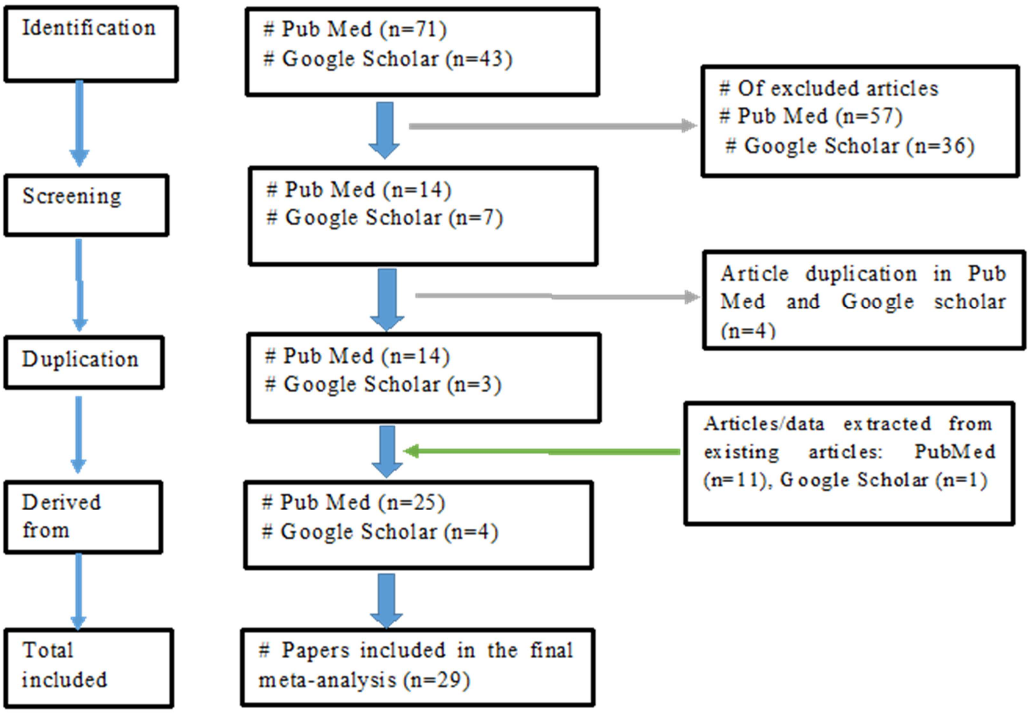

Figure 1. *Flowchart of literature search and inclusion/exclusion process.*

Pooled Apparent Prevalence and Geographic Distribution:

Overall, 4837 samples were retrieved from the twenty-nine study articles. Pooled apparent prevalence of the study was 22.2% (95% CI: 21.03-23.38). The pooled apparent prevalence of *S. aureus* was found almost about twice in milk samples than in meant with a statistically significant difference (X^2 - 42.2, p<0.001). According to this review, there was a statistically significant difference in the apparent prevalence of *S. aureus* among the Ethiopian Regional states. The highest apparent prevalence was found in SNNP, which is about eleven times that of the Amhara Regional states. More than half (57.2%) apparent prevalence of *S. aureus* was found in SNNP and Oromia (Table 2).

Table 2. *Effect of different factors on the pooled apparent prevalence of Staphylococcus aureus in Ethiopia over ten years (2011-2020).*

Variables		Samples taken	No. of positive	P. A, Prevalence	95% CI	OR	X^2	p-value
Sample source	Milk	3966	949	23.93	22.6-25.2	1.89	42.2	P<0.001
	Meat	871	124	14.24	11.9-16.6	1		
Region	Tigray	1753	308	17.57 [a]	15.8-19.4	4.0	261.6	P<0.001
	Oromia	1298	414	31.90 [b]	29.4-34.4	8.7		
	SNNP	533	200	37.52 [c]	33.4-41.6	11.2		
	A/Ababa	919	134	14.58 [d]	12.3-16.9	3.2		
	Amhara	334	17	5.09 [e]	2.7-7.5	1		
Years	2012	836	232	27.75 [A]	24.7-30.8	3.0	312.5	P<0.001
	2016	774	272	35.14 [B]	31.8-38.5	4.2		
	2017	852	288	33.80 [B]	30.6-37.0	4.0		
	2018	1102	129	11.71 [C]	9.8 -13.6	1.0		
	2019	353	47	13.31 [C]	9.8 -16.9	1.2		
	2020	920	105	11.41 [C]	9.4 -13.5	1.1		
Over all P. A prevalence		4837	1074	22.2	22.0-23.4			

Note: P. A- Pooled apparent, CI- Confidence Interval, OR- Odds ratio, Results sharing the same letters are not statistically significant, and capital letters will not be compared with small letters.

As showed in Figure 2, the geographical distribution of the pooled apparent prevalence of S. aureus had clear difference among the regions of Ethiopia; hence SNNP ranked first (37.52%), followed by Oromia (31.9%), Tigray (17.57%) and Addis Ababa (14.58%). Whereas relatively low magnitude of S. aureus was demonstrated in Amhara regional state (5.09). On the other hand, there was not even a single valid article from Somali, Afar, Gambela and Benishangul-Gumuz in the study time-bound (Figure 2).

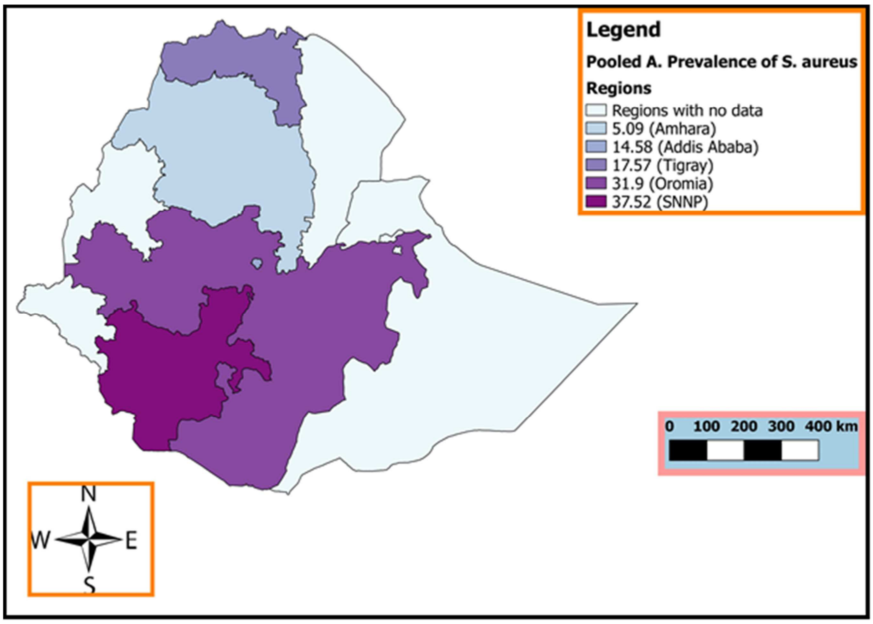

Figure 2. *Map illustrating the proportion of pooled Staphylococcus aureus in different regions of Ethiopia over time (2011–2020).*

This review also indicated that, the apparent prevalence of *S. aureus* was decreasing with a statistically significant difference. The apparent prevalence in 2016 and 2017 decreased by almost twenty-five percent in 2020 (Table 2). The linear regression model constructed on the pooled apparent prevalence of *S. aureus* to the period of time (2011 - 2020) indicated a decrement of 2.88 every year (Figure 4). The model was constructed as:

$$Yi = A + BXi + \text{Error term}$$

Where:
Yi = the pooled apparent prevalence at year Xi,
A = the constant term,
B = the regression coefficient.

Even though the linear regression model is statistically significant (F=7.68 and p=0.01), the model is explained by only 22.1% (R-squared = 0.2214).

Box plot analysis indicated that there were higher variations within years. The highest variation was observed in studies conducted in 2016 ranged from 8.8% to 51.2%. At the same time, highest variation within the 50% (2^{nd} and 3^{rd} quartiles) was observed in 2016 followed by 2012 (Figure 5). The apparent prevalence of *S. aureus* had a very huge variation from 5.1% in Gondar, Amhara to 51.2% in Awasa milk shade (Figure 3).

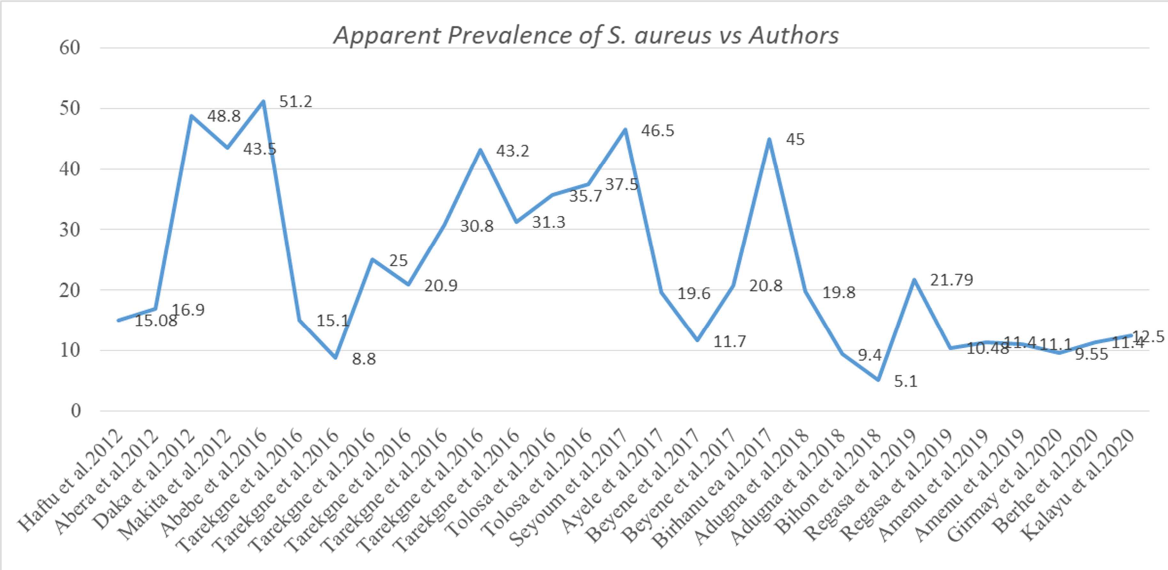

Figure 1. *The apparent prevalence of S. aureus over ten years reported by the authors, that ranging from 5.1 to 51.2.*

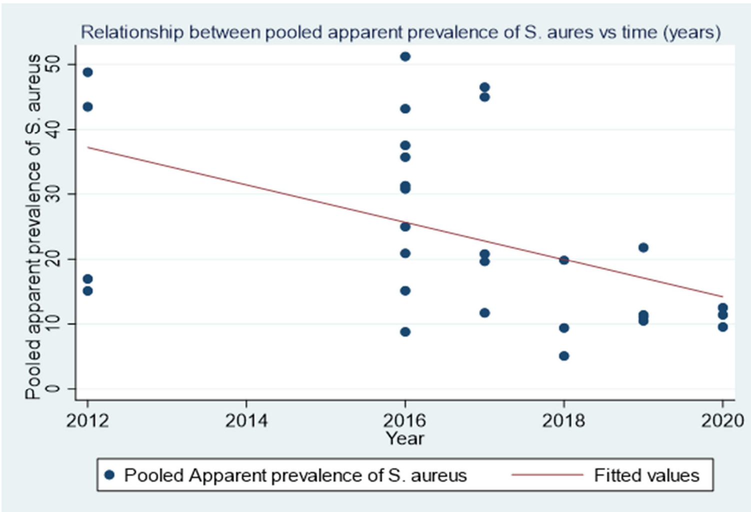

Figure 4. *The linear regression plot illustrating the decrement of pooled apparent prevalence of S. aureus over ten years.*

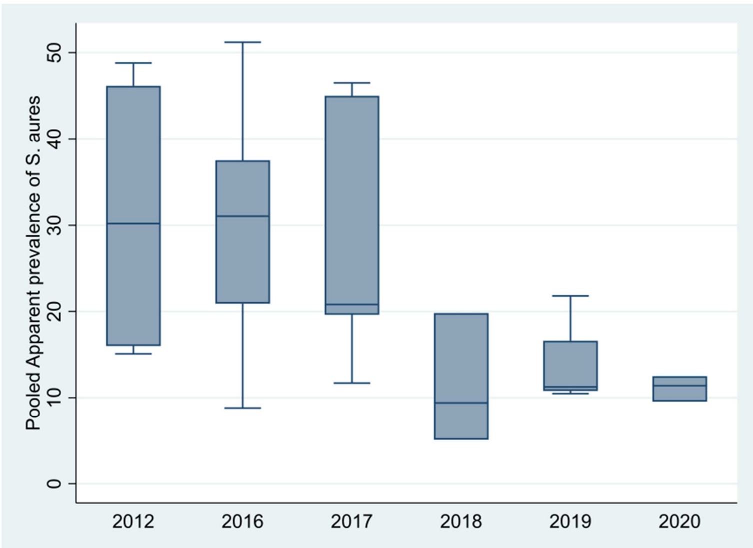

Figure 5. *The mean prevalence of twenty-nine studies pooled in ten years (2011 to 2020).*

4. Discussion

Staphylococcus aureus is one of the worst mastitis casing pathogens in dairy animals [25]. It is also among the public health important zoonotic diseases across the globe due to creating fast drug resistant properties [26]. Most importantly, the causative agent attracts the attention of the world as it is one of the six pathogens associated to death due to its drug resistance in 2019 [27]. There has been some systematic review and meta-analysis on the drug resistant *S. aureus* in Ethiopia. However, to the best level of our understanding, this is the first review article of *S. aureus* in milk and meat products in Ethiopia.

The overall pooled apparent of *S. aureus* from milk and meat in Ethiopia in the period of 2011 to 2020 was found to be 22.2% (CI: 22.0-23.4). The pooled apparent prevalence of *S. aureus* in our study was more or less similar with a finding of 25% (CI: 21-29) from 137 number of studies in milk [28]. Another study from Ethiopia revealed with the pooled estimate of *Staphylococcus spp*. isolated from meat samples of 21% (95% CI: 12, 30) out of 27 relevant articles [29]. On the other hand, higher pooled prevalence of *S. aureus* contamination in beef was reported (29.7%, 95% CI, 18.4-42.3%) from a world -wide review [30]. Similarly, higher pooled apparent prevalence of *S. aureus* (35.8%, 95% CI: 30.4- 41.5) was found in a study conducted in seven African and Asian countries from ready to eat foods [31]. These variations in the pooled apparent prevalence could be due to difference in level of understanding about the risk and contamination mechanism of *S. aureus* [16]. Dairy and meat activities managed by workers who have the awareness of *S. aureus* can lower the risk of contamination to the products than those without.

One interesting finding of our review is that the pooled apparent prevalence of *S. aureus* in Ethiopia was decreased by 2.88 times every year from 2011 to 2020 (Figure 3). Similar finding was observed in chicken meat contamination in that, the pooled apparent prevalence of *S. aureus* was decreased from 46% in 2000 - 2011 to 24% by the years 2011 - 2016 [30]. The possible reason for this scenario is that, while the drug susceptible *S. aureus* are decreasing, drug resistant once are increasing from time to time. In spite of the fact that the overall apparent prevalence of *S. auresu* (drug resistant and drug susceptible) seems decreasing, the drug resistant strains have been increasing. This implies that the drug resistant strain population is taking over the drug susceptible strain population. A drug resistance systematic review and meta-analysis conducted world-wide from 1969 to 2020 revealed that the prevalence of drug resistance was increasing through time, more apparently from 2009 onwards [32]. Hundreds of thousands of death has been rising each year [33]. This will be the most dangerous situation in the near future, especially in the developing countries in that, over 10 million yearly deaths will be triggered by antimicrobial-resistant pathogens by the year 2050 [34].

The pooled apparent prevalence in milk (23.93%, 95% CI: 22.6-25.2) was about twice (1.89) as compare to meat (14.24%, 95% CI: 11.9-16.6). Similar to our finding, higher antimicrobial resistance in milk than in meat was observed in Ethiopia [35]. The possible reason or this could be the longer life span of the diary animals compared with the meat animals. The more the animal stays, the higher the probability of the pathogens stayed in the mammary glands.

5. Conclusion

From this review, we conclude that the overall apparent prevalence of *S. aureus* seems decreasing from time to time. However, this decline in apparent prevalence could be due to the excessive use of drugs that affect the susceptible strains while increasing the drug-resistant ones. In fact, this scenario will be extremely devastating if fast solution will not be imminent. We also conclude that the apparent prevalence of the *S. aureus* extremely varies from place to place and from time to time.

Acknowledgements

The authors would like to acknowledge Dr. Desiye Tesfaye and Dr. Gebremeskel Mamu for reviewing this article before sending to publication.

References

[1] Tan, S. Y., & Tatsumura, Y. (2015). *Alexander Fleming (1881–1955): Discoverer of penicillin*. *56* (7), 366–367. https://doi.org/10.11622/smedj.2015105

[2] Kehrenberg, C., Schwarz, S., Jacobsen, L., Hansen, L. H., & Vester, B. (2005). *A new mechanism for chloramphenicol, florfenicol and clindamycin resistance : methylation of 23S ribosomal RNA at A2503*. *57*, 1064–1073. https://doi.org/10.1111/j.1365-2958.2005.04754.x

[3] Haag, A. F., Fitzgerald, J. R., & Penadés, J. R. (2019). *Staphylococcus aureus in Animals*. *May*. https://doi.org/10.1128/microbiolspec.GPP3-0060-2019

[4] Kumar, S., Anwer, R., Yadav, M., Sehrawat, N., Singh, M., & Kumar, V. (2021). Molecular Typing and Global Epidemiology of *Staphylococcus aureu*s. *Current Pharmacology Reports*, *0123456789*. https://doi.org/10.1007/s40495-021-00264-7

[5] Eshetie, S., Tarekegn, F., Moges, F., Amsalu, A., Birhan, W., & Huruy, K. (2016). Methicillin resistant *Staphylococcus aureu*s in Ethiopia : a meta-analysis. *BMC Infectious Diseases*. https://doi.org/10.1186/s12879-016-2014-0

[6] Elmore, S. A., & Weston, E. H. (2020). *Predatory Journals : What They Are and How to Avoid Them*. *48* (4), 607–610. https://doi.org/10.1177/0192623320920209.Predatory

[7] Kalayu, A. A., Woldetsadik, D. A., Woldeamanuel, Y., Wang, S., Gebreyes, W. A., & Teferi, T. (2020). *Burden and antimicrobial resistance of S . aureus in dairy farms in Mekelle, Northern Ethiopia*. 1–8.

[8] Berhe, G., Wasihun, A. G., Kassaye, E., & Gebreselasie, K. (2020). Milk-borne bacterial health hazards in milk produced for commercial purpose in. 1–8.

[9] Girmay, W., Gugsa, G., Taddele, H., Tsegaye, Y., Awol, N., Ahmed, M., & Feleke, A. (2020). Isolation and Identification of Methicillin-Resistant *Staphylococcus aureu*s (MRSA) from Milk in Shire Dairy Farms, Tigray, Ethiopia. 2020.

[10] Amenu, K. (2019). Bacteriological quality and safety of ready-to-consume milk and naturally fermented milk in Borana pastoral area, southern Ethiopia.

[11] Regasa, S., Mengistu, S., & Abraha, A. (2019). Milk Safety Assessment, Isolation, and Antimicrobial Susceptibility Profile of *Staphylococcus aureu*s in Selected Dairy Farms of Mukaturi and Sululta Town, Oromia Region, Ethiopia. 2019.

[12] Bihon, A., Syoum, A., & Assefa, A. (2018). Assessment of risk factors and isolation of *Staphylococcus aureu*s and Escherichia coli from bovine subclinical mastitic milk in and around Gondar, Northwest Ethiopia. Fao 2003, 85–89.

[13] Adugna, F., Pal, M., & Girmay, G. (2018). Prevalence and Antibiogram Assessment of *Staphylococcus aureu*s in Beef at Municipal Abattoir and Butcher Shops in Addis Ababa, Ethiopia. *BioMed Research International*, *2018*. https://doi.org/10.1155/2018/5017685

[14] Birhanu, M., Leta, S., Mamo, G., & Tesfaye, S. (2017). Prevalence of bovine subclinical mastitis and isolation of its major causes in Bishoftu. BMC Research Notes, 1–6. https://doi.org/10.1186/s13104-017-3100-0

[15] Beyene, T., Hayishe, H., Gizaw, F., Beyi, A. F., Abunna, F., Mammo, B., Ayana, D., Waktole, H., & Abdi, R. D. (2017). Prevalence and antimicrobial resistance profile of Staphylococcus in dairy farms, abattoir and humans in Addis Ababa, Ethiopia. *BMC Research Notes*, 1–9. https://doi.org/10.1186/s13104-017-2487-y

[16] Ayele, Y., Gutema, F. D., Edao, B. M., Girma, R., Tufa, T. B., Beyene, T. J., Tadesse, F., Geloye, M., & Beyi, A. F. (2017). Assessment of *Staphylococcus aureu*s along milk value chain and its public health importance in Sebeta, central Oromia, Ethiopia. 1–7. https://doi.org/10.1186/s12866-017-1048-9

[17] Seyoum, B., Kefyalew, H., Abera, B., & Abdela, N. (2017). Prevalence, Risk Factors and Antimicrobial Susceptibility Test of *Staphylococcus Aureu*s in Bovine Cross Breed Mastitic Milk in and Around Asella Town, Oromia Regional State, Southern Ethiopia. *Acta Tropica*. https://doi.org/10.1016/j.actatropica.2017.09.012

[18] Tolosa, T., Verbeke, J., Piepers, S., Tefera, M., Getachew, Y., Supré, K., & Devliegher, S. (2016). Milk production, quality, and consumption in Jimma (Ethiopia): Facts and producers ', retailers ', and consumers ' perspectives. *Preventive Veterinary Medicine*, *124*, 9–14. https://doi.org/10.1016/j.prevetmed.2015.12.016

[19] Tarekgne, E. K., Skjerdal, T., Skeie, S. I. V, Rudi, K., Porcellato, D., & Narvhus, J. A. (2016). Enterotoxin Gene Profile and Molecular Characterization of *Staphylococcus aureu*s Isolates from Bovine Bulk Milk and Milk Products of Tigray Region, Northern Ethiopia. 79 (8), 1387–1395. https://doi.org/10.4315/0362-028X.JFP-16-003

[20] Abebe, R., Hatiya, H., Abera, M., Megersa, B., & Asmare, K. (2016). Bovine mastitis : prevalence, risk factors and isolation of *Staphylococcus aureu*s in dairy herds at Hawassa milk shed, South Ethiopia. *BMC Veterinary Research*, 1–11. https://doi.org/10.1186/s12917-016-0905-3

[21] Makita, K., Desissa, F., Teklu, A., Zewde, G., & Grace, D. (2012). International Journal of Food Microbiology Risk assessment of staphylococcal poisoning due to consumption of informally-marketed milk and home-made yoghurt in Debre Zeit, Ethiopia. *International Journal of Food Microbiology*, *153* (1–2), 135–141. https://doi.org/10.1016/j.ijfoodmicro.2011.10.028

[22] Daka, D., Solomon, G., & Yihdego, D. (2012). Antibiotic-resistance *Staphylococcus aureu*s isolated from cow ' s milk in the Hawassa area, South Ethiopia. *Annals of Clinical Microbiology and Antimicrobials*, *11* (1), 1. https://doi.org/10.1186/1476-0711-11-26

[23] Abera, M., Habte, T., & Aragaw, K. (2012). Major causes of mastitis and associated risk factors in smallholder dairy farms in and around Hawassa,. 1175–1179. https://doi.org/10.1007/s11250-011-0055-3

[24] Haftu, R., Taddele, H., & Gugsa, G. (2012). Prevalence, bacterial causes, and antimicrobial susceptibility profile of mastitis isolates from cows in large-scale dairy farms of Northern Ethiopia. 1765–1771. https://doi.org/10.1007/s11250-012-0135-z

[25] Monistero, V., Graber, H. U., Pollera, C., Cremonesi, P., Castiglioni, B., Bottini, E., Ceballos-Marquez, A., Lasso-Rojas, L., Kroemker, V., Wente, N., Petzer, I. M., Santisteban, C., Runyan, J., dos Santos, M. V., Alves, B. G., Piccinini, R., Bronzo, V., Abbassi, M. S., Said, M. Ben, & Moroni, P. (2018). *Staphylococcus aureu*s isolates from bovine mastitis in eight countries: Genotypes, detection of genes encoding different toxins and other virulence genes. *Toxins*, *10* (6). https://doi.org/10.3390/toxins10060247

[26] Deurenberg, R. H., Vink, C., Kalenic, S., Friedrich, A. W., Bruggeman, C. A., & Stobberingh, E. E. (2007). The molecular evolution of methicillin-resistant *Staphylococcus aureu*s. *Clinical Microbiology and Infection*, *13* (3), 222–235. https://doi.org/10.1111/j.1469-0691.2006.01573.x

[27] Collaborators, A. R. (2022). Articles Global burden of bacterial antimicrobial resistance in 2019 : a systematic analysis. 399. https://doi.org/10.1016/S0140-6736(21)02724-0

[28] Krishnamoorthy, P., Suresh, K. P., Jayamma, K. S., Shome, B. R., Patil, S. S., & Amachawadi, R. G. (2021). An understanding of the global status of major bacterial pathogens of milk concerning bovine mastitis: A systematic review and meta-analysis (scientometrics). *Pathogens*, *10* (5). https://doi.org/10.3390/pathogens10050545

[29] Zelalem, A., Sisay, M., Vipham, J. L., Abegaz, K., Kebede, A., & Terefe, Y. (2019). The prevalence and antimicrobial resistance profiles of bacterial isolates from meat and meat products in Ethiopia : a systematic review and meta-analysis. 1–14.

[30] Ou, Q., Peng, Y., Lin, D., Bai, C., Zhang, T., Lin, J., Ye, X., & Yao, Z. (2017). A Meta-Analysis of the Global Prevalence Rates of *Staphylococcus aureu*s and Methicillin-Resistant S . aureus Contamination of Different Raw Meat Products. 80 (5), 763–774. https://doi.org/10.4315/0362-028X.JFP-16-355

[31] Mengistu, D. A., & Tolera, S. T. (2020). Prevalence of Microorganisms of Public Health Significance in Ready-to-Eat Foods Sold in Developing Countries: Systematic Review and Meta-Analysis. In *International Journal of Food Science* (Vol. 2020). https://doi.org/10.1155/2020/8867250

[32] Molineri, A. I., Camussone, C., Zbrun, M. V., Suárez Archilla, G., Cristiani, M., Neder, V., Calvinho, L., & Signorini, M. (2021). Antimicrobial resistance of *Staphylococcus aureu*s isolated from bovine mastitis: Systematic review and meta-analysis. *Preventive Veterinary Medicine*, *188*. https://doi.org/10.1016/j.prevetmed.2021.105261

[33] Laxminarayan, R., Sridhar, D., Blaser, M., Wang, M., & Woolhouse, M. (2016). *Achieving Global Targets for Antimicrobial Resistance. Science. 2016; 353 (6302): 874–5. 9286* (August).

[34] Neill, J. O. '. (2014). Antimicrobial Resistance: Tackling a crisis for the health and wealth of nations The Review on Antimicrobial Resistance Chaired. December.

[35] Alemu, B., Assefa, A., Bedasa, M., Amenu, K., & Wieland, B. (2021). Antimicrobial resistance in Ethiopia : A systematic review and meta-analysis of prevalence in foods, food handlers, animals, and the environment. *One Health*, *13*, 100286. https://doi.org/10.1016/j.onehlt.2021.100286