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Underestimated economic and social burdens of non-Typhoidal Salmonella infections: The One Health perspective from Nigeria

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ABSTRACT

Background: The non-typhoidal salmonellosis (NTS) is a pathogenic bacterial zoonosis with substantial but often under-appreciated public health impacts. The NTS is prevalent in poultry and humans in Nigeria, yet its economic and social burden have not been determined through any empirical study. To bridge the gap, we evaluated the impact of NTS in social and economic terms.
Methods: Relevant population, economic and epidemiological data were retrieved from peer-reviewed publications, open sources and relevant authorities. Additional data were obtained through experts' opinions and field surveys. Using a customized and validated Microsoft Excel® tool, economic analysis was conducted.
Results: Using the year 2020 reference point, the burden of NTS was 325,731 cases and a total of 1043 human deaths, at a disability-adjusted life year (DALYs) of 37,321. The cost associated with infection in humans was US$ 473,982,068. A total loss of US$ 456,905,311 was estimated in poultry including the direct value of animal loss, US$ 224,236,769, loss from salvage slaughter and culling, US$ 220,386,556, and value of foregone production, US$ 12,281,987.
Interpretation: The outcomes of this important work provide empirical evidence to support informed decisions and investments in the control and eradication of human and poultry salmonellosis (NTS) in Nigeria.

1. Introduction

Salmonellosis is a pathogenic bacterial zoonosis with substantial public health impacts [1,2]. With over 2600 different serovars identified to date, *Salmonella* spp. are broadly divided into typhoidal and non-typhoidal Salmonella (NTS) serovars [3,4]. The NTS is one of the widespread causes of food-borne diarrhoeal diseases, while the invasive NTS (iNTS) is responsible for major bloodstream infections universally [1,3,5]. Humans are infected with NTS through contamination from poultry products (egg fragments, hatching eggs, chick boxes, fluff and faeces), partially cooked meat and raw eggs [2,3]. The global estimates of burden of NTS varied widely, including an estimates of over 27 million human cases and 200,000 deaths per annum [6,7]; approximately 79 million human cases and over 59,000 deaths annually [2]; and 93.8 million human infections and 155,000 fatalities annually [8]. Furthermore, in a recent ranked study in the USA, *Salmonella* spp. was the first-ranked foodborne pathogens, with the most significant cost of illness and the quality-adjusted life-year (QALY) losses [9].

The iNTS was estimated to cause 177–388 cases per 100,000 children under 5 years in Africa, but may reach up to 2000–7500 cases per 100,000 humans in immunocompromised HIV-infected adults, and a case fatality ranging between 20 and 25% [10]. In Nigeria, the poultry farm level prevalence of NTS range from 41.6 to 47.9% and the risk factors for NTS infection of poultry farms in Nigeria have been fully explored [4,11,12]. Based on a recent meta-analytic study, Nigeria has a burden of prevalence (in humans) of 1.9% (2732/143,756) Salmonella bacteremia and 16.3% (1967/12,081) Salmonella-associated gastroenteritis [13]. In addition, a total of 53 Salmonella serotypes have been identified in humans in the

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country including 39 associated with Salmonella-bacteremia and 31 associated with Salmonella-gastroenteritis [13].

The country has an estimated human population of approximately 219 million as of 2022 and has the largest market in sub-Saharan Africa, with a GDP PPP in excess of US$ 1 trillion for the year 2020 [11,14,15]. The agriculture sector contributes 24.1% of the country's GDP in the year 2020, with the poultry sector contributing approximately 25% of the agriculture GDP, and 6–8% to real GDP annually [16,17]. The 2020 poultry population in Nigeria was approximately 224 million [18], and is a major source of readily available and affordable animal protein (11). In 2019, the consumption of poultry products was approximately US$ 2 billion while the industry was worth US$ 4.2 billion [19].

Previous workers have made efforts to estimate the cost of animal health challenges globally and in Nigeria, including for multiple pathogens [2,20,21], Salmonella [1,8], avian influenza [22], and African swine fever [23], among others. Animal diseases cause significant, often undervalued economic losses through morbi-mortality, treatment and intervention cost, effects on production and productivity, and human health components (livelihoods, psychosocial and zoonotic impacts). It is therefore important to continue to estimate the burden of animal disease and relative microbiological hazards that may originate through animal-sourced food system to prioritise interventions aimed at mitigating these impacts. The aim of this work was to determine the economic and social costs and consequences of NTS in human and poultry in Nigeria, using the year 2020 as a reference point. The outcome should provide empirical information to guide informed decision, investment, and adequate planning for human and animal health interventions against poultry salmonellosis (NTS) in Nigeria.

2. Materials and method

This work is a follow-up on the previous one where Salmonella isolates were obtained and characterized from samples collected from poultry farms in North central Nigeria where *Salmonella enterica*, *S. arizonae*, *S. paratyphi* and *S typhi* were recovered at prevalences of 41.6%, 0.2%, 1.9% and 2.3% respectively [4].

Table 1
Input data for the computation of economic and social costs of non-typhoidal salmonellosis for the year 2020 in Nigeria.

Poultry	Intensive (large-scale)	Intensive (small and medium-scale)	Free-range/Semi-intensive (indigenous)	Total		Source
Year 2020 poultry population	33,968,841	118,377,487	72,168,465	224,514,793		[18].
Price per carcass yield (Naira)	2240	2002	2000			Carcass weight (1.4–1.6 kg) [28,29].
Price of poultry meat (kg) (Naira)	1400	1400	850			[29].
Price of eggs (Naira)	37	37	30			[29]
No of eggs laid per hen/year	250	180	40			Experts' opinions, [21].
Price of culled animal (or % decrease in price due to culling) (Naira)	1340	741	739			Experts' opinions, [21,30].
Price reduction for culled bird (Naira)	40%	63%	63%			Experts' opinions, [21].
Number of cases	6,793,768	26,043,047	10,825,270	43,662,085		Experts' opinions, field survey, [18].
Number of deaths	2,717,507	10,417,219	2,706,317	15,841,044		Experts' opinions, field survey, [18].
Number of salvage slaughter	2,038,130	10,417,219	8,118,952	20,574,302		Experts' opinions, field survey, [18].
Number of culls	1,698,442	3,906,457	108,253	5,713,152		Experts' opinions, field survey, [18].
Number (eggs lost in survivor hen per year)	38	27	3			Experts' opinions, field survey, [18].
Humans	**Livestock keepers**				**Consumers**	
Number of humans involved in the poultry value chain	9,627,904	33,552,135	20,454,954	63,634,993	27,407,441	[21].
Number of cases	1155	40,263	147,276	188,694	137,037	FMoH, Experts' opinions.
Number of deaths	4	129	471	604	439	FMoH, Experts' opinions.
Duration of disease in days	6	6	3		3	FMoH, Experts' opinions.
Average age of infection	20	16	16		25	FMoH, Experts' opinions.
Year 2020 human population	208,327,405				[14].	
Exchange rate (Naira to US$) (2020)	380.26				[31].	
Exchange rate (US$ PPP) (2020)	144				[32].	
DALYs weight (Salmonella)	0.21					
Average life expectancy	55 years				[33].	
VSLY (US$)	11,353				[26].	
GDP, US$ PPP 2020 (Naira)	N406,878,200,000,000				(US$ 1.07 trillion) [34].	
Percentage Livestock VA (2020)	1.39%				[16,19].	
Livestock VA, US$ PPP (Naira) (2020)	N5,655,606,980,000				US$14,873,000,000) [35],	
Animal production losses (2020)	N128,886,753,387				[21].	
GDP in 2020 (Naira)	N164,382,595,400,000				(US$432,290,000,000), [34].	
AG GDP %	24.1%				[17].	
Loss as a % of GDP	0.08%				Calculation using [–,17,19,21,26,32,34].	
Loss as a % of AG GDP	0.33%				Calculation using [–,17,19,21,26,32,34].	

Federal Ministry of Health = FMoH; GDP = Gross domestic product; PPP = Purchasing power parity; DALYs = Disability-adjusted life years; VSLY = Value of statistical life year; VA = Value added; N = Naira, AG GDP = Agriculture Value Added GDP. Additional data inputs are available in the Supplementary Tables S1 – S7.

2.1. Data sources and evaluation tool

We used the semi-automated Microsoft Excel® costing tool developed as part of the disease estimation process under the Food and Agriculture Organization of the United Nations' (FAO) Africa Sustainable Livestock 2050 [21, Supplementary materials S1 – S7]. Extensive economic, population and poultry sector data were obtained from various sources including: 1). The United Nations' Department of Economic and Social Affairs, Population Division, 2). The World Bank, 3). The Nigerian Federal Ministry of Agriculture and Rural Development (FMARD), 4). The Federal Ministry of Finance, Nigeria, 5). The National Agricultural Extension and Research Liaison Services (NAERLS), 6). Peer reviewed literatures, 7). Field surveys, 8). Experts' opinions and calculations made from these various sources (Table 1; Supplementary Tables S1 – S7).

2.2. Additional data and expert elicitation protocol for assembling information on zoonoses and AMR

Currently, in Nigeria, the information system may not always provide the government with sufficient and robust information on the incidence, prevalence and impact of zoonoses on society. It is therefore challenging to have a single source of comprehensive dataset for measuring economic evaluations, and return on investment aimed at prevention, management and control of animal diseases and zoonoses. We utilised the Google form (https://docs.google.com/forms/d/e/1FAIpQLSefH1i8YASvewU1y1x-OS0sgyuvWJnOuaECXKH9ReLV4YaYZw/viewform?vc=0&c=0&w=1&flr=0) to collect data briefs on humans and poultry from key informant, experienced stakeholders and value chain actors in the poultry industry. We also utilised the Africa Sustainable Livestock 2050 (ASL2050) expert elicitation protocol to assemble information on selected zoonoses and antimicrobial resistance using consensus of judgements of carefully selected experts [21]. It should be noted that experts were drawn using the snowballing sampling approach through which 30 animal health and 11 human health experts were obtained [21. These tools provided additional sources of data needed to measure the impact of zoonoses on society in monetary terms especially where industry, population and economic data were insufficient, unreliable or physically impossible to gather such data from current datasets. Data obtained through Google forms were evaluated for measure of central tendencies (absolute counts, minimum, median, average, maximum and mode) and those from experts' opinions were triangulated with field surveys, literature search and official statistics [2,21,24].

2.3. Estimation of burdens of non-typhoidal salmonellosis

We estimated the losses in humans (social cost) and poultry (economic cost) using the input data described above and the excel spreadsheet developed by the Africa Sustainable Livestock project [21].

To estimate the social cost of the disease, the Disability-Adjusted Life Years (DALYs) method was used as proposed by the World Health Organization (WHO) in quantifying the burden of disease from mortality and morbidity [2,25]. One DALY represents a one year of healthy life lost (a health gap measure that combines both time lost due to premature mortality and the time spent in illness). Following the methodology of Herrera et al. [26], the "cost" of one DALY has been defined as the willingness to pay for a DALY, which was determined based on the Value of Statistical Life (VSL). The VSL available for the United States was discounted to a yearly value and transferred into the Nigerian context using the benefit transfer methodology described in Hammit and Robinson [27].

The loss of production was calculated by estimating the value of animals lost and the value of forgone production (including losses from decrease in egg production, culling and salvage slaughter) as presented in the detailed study of FAO [21]. Input data and sources are detailed in Table 1.

3. Results

The results are presented in three sections as described below.

3.1. Losses in humans (social costs)

Overall, the total economic losses associated with NTS in Nigeria for the year 2020 was US$ 930,887,379 with approximate losses in humans (social costs) and animals (poultry sector) being 50.9% (US$ 473,982,068) and 49.1% (US$ 456,905,311) respectively (Table 2). The losses in the human population were further disaggregated into losses in workers in the poultry value chain (livestock keepers, 64.1%; US $303,911,990), and the general populace (consumers, 35.9%; US $170,070,078) (Table 2). Among the livestock keepers, a significant percentage of the social costs (77.9%) was borne by the value chain stakeholders in the free-range and semi-intensive (indigenous) poultry stock (Sector 4). Approximately 21.6% and 0.6% of the social costs were borne by the value chain stakeholders (humans) in the commercial intensive (small and medium-scale) (Sector 3), and intensive large scale and commercial operations (Sectors 1 and 2) (Table 3). In total, 188,694 and 137,037 cases were estimated among poultry keepers and consumers respectively; with 1043 deaths and 324,689 survivors predicted to be directly associated with NTS in the year 2020 in Nigeria. The estimated DALYs was 13,391, which translated to the social cost above (US$ 473,982,068.00; Table 3).

3.2. Losses in poultry (economic costs)

Approximately 61% (US$278,732,259) of the total losses in poultry (chickens) originated from the intensive small and medium scale farms, while 23.95% (US$109,412,575) was from the free-range and semi-intensive (indigenous) poultry (Table 4). The direct values of poultry lost were 61.4% (US$42,187,375), 51.9% (US$144,537,197) and 34.3% (US$37,512,197) of the total losses in each evaluated sector (Intensive large-scale; Intensive small and medium-scale; and free-range and semi-intensive (indigenous) poultry) (Table 4). Specifically, the total value of animals lost, the value of loss from salvage slaughter and culling, and the total value of forgone production were US$224,236,769 (49.1%), US $220,386,556 (48.2%) and US$ 12,281,987 (2.7%) respectively (Table 4).

3.3. Pattern of antimicrobial use in the different sectors of the poultry industry

Based on the consensus of experts' opinions, the intensive small and medium-scale poultry farms as well as the intensive large poultry farms significantly access and used antimicrobials (92.5%), with only 62% of getting antimicrobials through recognised means (formal sources from veterinary drug stores or from veterinarians [36 – 38]) compared with the free-range and semi-intensive indigenous farms' access and use (49.2%), and access through the recognised means (13%) respectively (Fig. 1a). Similarly, 90.9% of the intensive small and medium-scale poultry farms as well as the intensive large farms have observed significant increase in the use of antimicrobials in the last decade compared with just 20% in the free-range and semi-intensive indigenous poultry farms (Fig. 1b). While 92% of the stakeholders in the intensive small and medium-scale poultry farms and the intensive large farms were seriously concerned with the observed trends in antimicrobial usage in poultry farms, it was shown that only 60% of the free-range and semi-intensive indigenous poultry farms stakeholders were seriously concerned (Fig. 1c). Among the human experts, 100% of them confirmed to have observed a significant increase in antimicrobial use in humans in the last decade. Only 20% and 80% were moderately and highly concerned about the trend respectively.

Table 2
Overall economic and social costs of non-typhoidal salmonellosis in poultry and humans for the year 2020 in Nigeria.

Poultry	Intensive (large-scale)	Intensive (small & medium-scale)	Free-range/Semi-intensive (indigenous)	Total		
Value of animals lost (US$)	42,187,375	144,537,197	37,512,197	224,236,769		
Value of forgone production (US$)	26,573,102	134,195,062	71,900,378	232,668,542		
Total loss in animals (US$)	68,760,477	278,732,259	109,412,575	456,905,311		
Loss as a % of livestock GDP	0.00%	0.00%	0.00%	0.01%		
Loss as a % of national GDP	0.00%	0.00%	0.00%	0.00%		
Loss per case (US$)	10	11	10	10		
Loss per case, as percentage of healthy animal	65%	77%	73%			
Human (social)		**Losses in Livestock keepers**		**Total for livestock keepers**	**Total for consumers**	**Total human loss**
Value of mortality (US$)	1,643,368	63,814,550	233,426,044	298,883,961	167,075,760	
Value of morbidity (US$)	50,490	1,759,506	3,218,033	5,028,029	2,994,318	
Total social cost (US$)	1,693,857	65,574,056	236,644,077	303,911,990	170,070,078	473,982,068
Social cost as % of GDP	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Overall losses in poultry and humans (US$)				930,887,379

All calculations were conducted at an exchange rate of Naira 380.26 to US$ 1.00.

Table 3
Economic and social costs of non-typhoidal salmonellosis in humans for the year 2020 in Nigeria.

Salmonellosis parameters	Poultry keepers			Total Poultry keepers	Total Poultry consumers
	Intensive (large-scale)	Intensive (small & medium-scale)	Free-range/Semi-intensive (indigenous)		
Ref. year	2020	2020	2020	2020	2020
DALY Weight	0.21	0.21	0.21	0.21	0.21
Number of cases in humans	1155	40,263	147,276	188,694	137,037
Number of deaths in humans	4	129	471	604	439
Number of survivors	1152	40,134	146,804	188,090	136,599
Disease duration in years	0.02	0.02	0.01		0.01
Average age of infection	20	16	16		25
YLL	129	5025	18,380	23,534	13,156
YLD	4	139	253	396	236
DALY=YLL + YLD	133	5163	18,633	23,930	13,391
Social cost(DALY*VSLY) (US$)	1,693,857	65,574,056	236,644,077	303,911,990	170,070,078
Total social costs in humans (US$)					473,982,068

DALYs = Disability-adjusted life years; YLL = years of life lost; YLD = years lost due to disability; VSLY = Value of statistical life year. All calculations were conducted at an exchange rate of Naira 380.26 to US$ 1.00.

4. Discussion

We have estimated the overall economic burden of NTS in Nigeria for the year 2020, which came to US$ 930,887,379 (3.19% of the national budget). This represented a significant proportion in a country, which revised national budget for 2020 stood at 10.51 trillion naira ($29.19 billion) (https://www.reuters.com/article/nigeria-budget-idUSL8N2DA6Q9). Considering that the poultry sector contributed between 6 and 8% to real GDP for the year 2020, and approximately 25% of the agriculture GDP [16,17], the significance of these losses becomes more glaring. There is however lack of documentary evidence that the national government has taken account of this point, in planning and intensifying efforts to mitigate the impacts of NTS in humans and poultry. The only earlier estimates made in the past was conducted as part of the Africa Sustainable Livestock 2050 project in Nigeria [21]. The NTS typically presents as an acute onset of fever, abdominal pain, diarrhoea, nausea and sometimes vomiting, while the illness may last for 2–7 days [2]. In response to such acute self-limiting gastrointestinal illnesses, the households, particularly the poor in the rural and peri-urban households, and where healthcare services are hard to reach, primarily resort to habitual use of antibiotics and herbal medication, with high levels of self-prescription compared to antibiotic prescriptions that originate through the pharmacists [39]. In particular, metronidazole, tetracycline, amoxicillin, ampicillin or the Amplicox (a combination of ampicillin and cloxacillin) have been reported to be regularly abused [39]. In view of these observation, cases of NTS at the healthcare facilities may have been grossly underreported as only more serious cases may get to the hospital.

Comparing the case of NTS to other zoonotic diseases, which have occurred in Nigeria in recent times: 1). The highly pathogenic avian influenza subtype H5N1 (HPAI H5N1), which is a rapidly fatal disease in poultry and humans that occurred in 2006–2008, and has continued to date, and somewhat become endemic in Nigeria. This virus may presents in different subtypes. HPAI H5N1, may cause 70,000–145,000 household members to fall into poverty through loss of livelihoods associated with poultry, whereas, NTS is more insidious but will affect a lot more people through morbidity ($\leq$ 325,731 humans) but much lower mortality ($\leq$ 1043) [40]. In comparison, COVID-19, a largely public health issue, will produce much larger loss (up to 34.1%) loss in the country's GDP, amounting to US$ 16 billion, primarily from the services sector and within a short period [41]. The burden of NTS is also lower than the associated burden in malaria, an endemic human disease, which burden of illness in Nigeria may be in excess of 25% of the GDP [42].

We estimated a disability-adjusted life years (DALYs) associated with NTS in 2020 to be 37,321; and more specifically, a total of 325,731 cases

Table 4
Economic costs of non-typhoidal salmonellosis in poultry for the year 2020 in Nigeria.

Salmonellosis parameters	Intensive (large-scale)	Intensive (small & medium-scale)	Free-range/ Semi-intensive (indigenous)	Total
Number of cases in poultry	6,793,768	26,043,047	10,825,270	43,662,085
I. Value of animals Lost (US$)				
Number of deaths	2,717,507	10,417,219	2,706,317	15,841,044
Value of animals lost (US$)	42,187,375	144,537,197	37,512,197	224,236,769
II. Loss from salvage slaughter and culling				
Number of salvage slaughter*	2,038,130	10,417,219	8,118,952	20,574,302
Number of culls*	1,698,442	3,906,457	108,253	5,713,152
*this number may exceed the number of cases if the whole flock is culled / slaughtered				
Value of loss from salvage slaughter and culling (US$)	23,306,641	125,179,537	71,900,378	220,386,556
II. Value of foregone production				
Number of survivors	339,688	1,302,152	–	1,641,841
Number of eggs lost per year in survivors	38	27	3	
Total value of forgone production (US$)	3,266,461	9,015,526	–	12,281,987
Total losses in poultry (US$)				456,905,311

All calculations were conducted at an exchange rate of Naira 380.26 to US$ 1.00.

and a total of 1043 human deaths was linked to NTS, with 64.1% of the social costs associated with the poultry keepers than the general populace which accounted for only 35.9%. This observation calls for systematic surveillance for NTS in humans, particularly the poultry keepers, and the need to intensify eradication of poultry salmonellosis in farmed poultry stock [13]. Two particular results were interesting. First, a significant percentage of the social costs (77.9%) originated from the free-range and semi-intensive (indigenous) poultry stock (Sectors 3 and 4). It should be understood that most of these category of farmers reside in the rural and peri-urban often unplanned areas, and public health facilities may be inadequate or hard to access, there are imbalanced ratio of health workers to patients at such facilities, and the direct and indirect costs to patients may be relatively higher [43]. These may be directly linked to findings in the study of Adeyemi et al. [39] where households regularly self-medicate using antibiotics and herbal medication, based on options of patients and household to adopt alternative cheaper healthcare measures due to impoverishment, with consequent contribution to underreporting and underestimation of cases of NTS in Nigeria [13,43]. Secondly, although NTS is perceived as a disease of livestock, especially poultry, in view of the different serotypes of *Salmonella enterica* subsp. Enterica present in poultry [11,12], the larger proportion of the total losses (50.9%) directly related to losses in humans (social costs), pointing to the fact that human costs of salmonellosis may have been underestimated highly in the past.

It is unsurprising that the significant proportion of the losses in poultry (chickens) originated from the intensive small and medium scale farms and the free-range and semi-intensive (indigenous) poultry. These poultry sectors (3 and 4) contribute approximately 85% of the total poultry population in Nigeria, mainly in the small town, peri-urban shanties and unplanned rural areas, operate with low biosecurity and sources of day-old chicks that feed the system which may not always be standardised [30]. The aforementioned issues are significant risk factors for infection of poultry farms with Salmonella organism in Nigeria [4,12,30]. The total value of forgone production accounted for only 2.7% of the total losses in the poultry sector, an indication that poultry farmers hardly destroy and clean out the farms completely post infection, which is the standard recommended practice. The aforementioned factor can be a precursor to maintenance of infection in poultry farms and re-infection of new stock as emphasised in earlier study by [4].

It is noteworthy to indicate that despite the efforts made by the national and subnational government in Nigeria, the experts still observed significant usage of antimicrobials in both human and animal health, especially in the intensive small and medium-scale poultry farms, the intensive large poultry farms, and the human health facilities. There is a need for more stringent measure to control dispensing and access to antimicrobials if efforts put in to date will yield any measurable progress.

4.1. Limitations of the study

Our work is subject to a number of limitations. First, while we have made effort to evaluate the comprehensive economic and social costs of Non-Typhoidal Salmonella infections in Nigeria, we are aware that it is generally impossible to measure everything necessary for a comprehensive analysis. Even when measurements are available, they may not adequately represent values appropriate for the analysis at hand [44]. Secondly, we assumed linear costs for lost units without considering the cost corresponding to discounted values, the costs of treatment and prevention. Hence, our evaluation may therefore be partially attributable to the overall costs. In a data-scarce environment like Nigeria, wherein comprehensive costs of prevention and control are not well detailed, especially in the sectors 1–3 of the poultry industry, this may serve a major limitation to conduct a comprehensive cost evaluation. Furthermore, our estimate does not take into account the cost of reducing the loss and an incompressible limit of loss inherent in the socio-economic and behavioural context from Nigeria. It was difficult to estimate these items during the evaluation.

Fourthly, we use computational model to estimate some costs and disease simulation rather than a direct clinical trial with control group, using data from the line ministry, the stakeholders and experts. We are aware that this may be subject to a degree of bias of experts submitting the data, and all outputs/outcomes are as meaningful as the input values [44,45]. While we advocate for a disease-specific collation of economic dataset informing future analysis, it becomes difficult to conduct a nationwide clinical trials for an insidious but impactful disease like NTS due to regulations and time, and using data from other country may introduce geographical context and bias. Finally, the time factor may be a limitation to this type of economic evaluation carried out in this work as the industry is very dynamic in growth, disease contexts change, and many variables of interventions (prevention, management, treatment and controls) may demand regular remodelling using datasets available for the industry.

5. Conclusions

Our work has highlighted the burden of non-typhoidal salmonellosis in Nigeria, and the level of under-appreciation of its impact in the human population. Importantly, we have demonstrated that in developing countries like Nigeria, where there are constraints in public and animal health infrastructures, the overall ramifications of NTS have

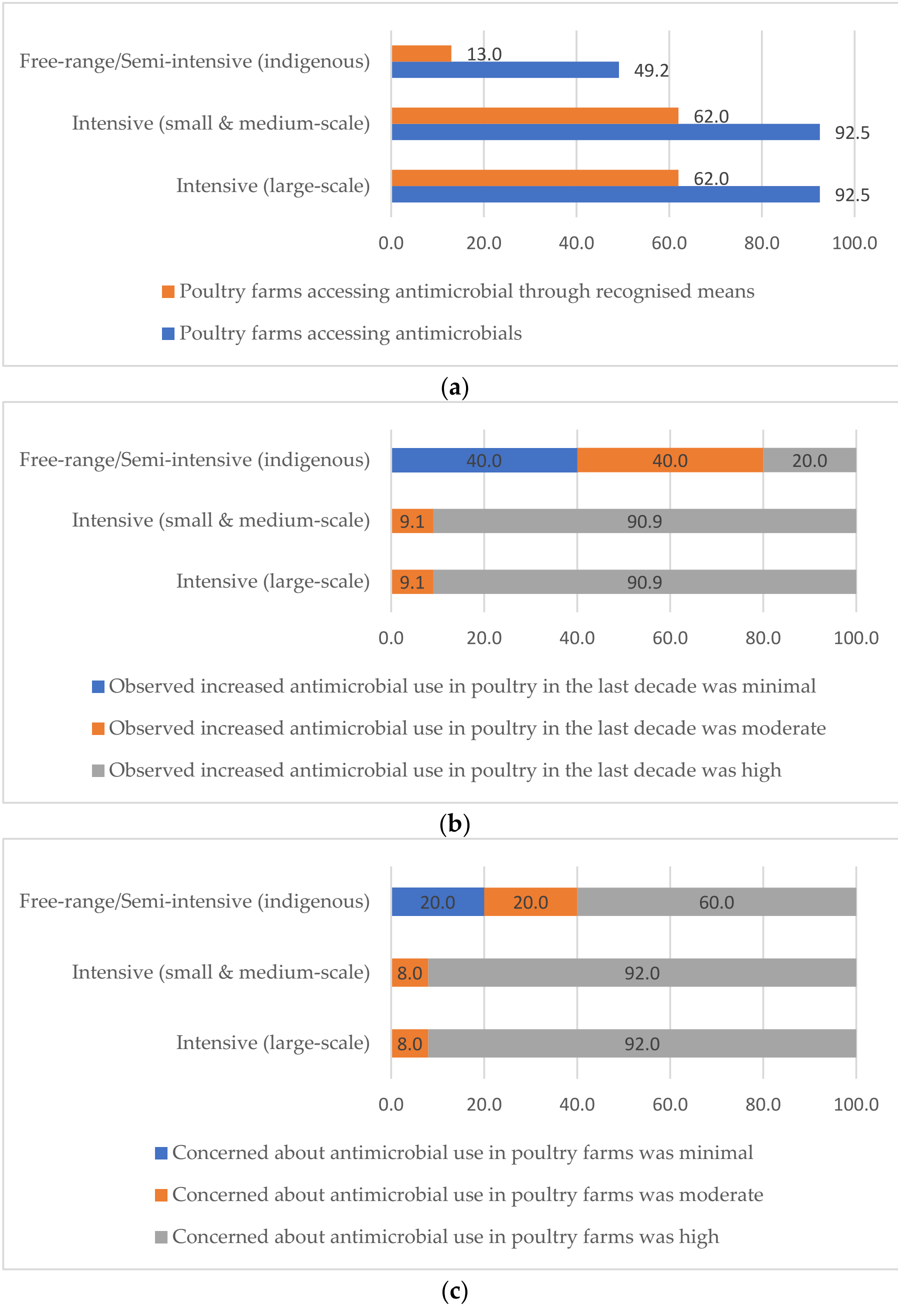

Fig. 1. Experts' opinions elicitation on a. Antimicrobial use practice in poultry; b. Degree of increased use of antimicrobial in poultry; c. Degree of concern on increased use of antimicrobial in poultry.
Note that 100% of the human health experts observed increased antimicrobial use in humans in the last decade, and only 20% and 80% were moderately and highly concerned about the trend respectively. It should be noted that the most common antimicrobials used in poultry are: Tetracycline, Streptomycin, Penicillin, Nalidixic acid, Metronidazole, Gentamycin, Furazolidone, Furaltadone, Erythromycin, Enrofloxacin, Chloramphenicol and Ampicillin [38].

consequences that are detrimental to patients (human and animal), the economy and the country as a whole. It is believed that findings from this study should stimulate discussions on the effort at control and eradication of poultry salmonellosis, and by extension the reduction in the burden of NTS and iNTS in humans in Nigeria.

Author contributions

Conceptualization, A.O.S. and F.O.F.; methodology, A.O.S., J.O., A. U., U.P., A.F.R., O.M. and F.O.F.; software, U.P., A.F.R., O.M. and F.O.F.; validation, U.P., A.F.R., O.M. and F.O.F.; formal analysis, A.O.S., J.O., A. U., and F.O.F.; investigation, A.O.S., A.U. and F.O.F.; resources, A.O.S. and F.O.F.; data curation, A.O.S., A.U., and F.O.F.; writing—original draft preparation, A.O.S., and F.O.F.; writing—review and editing, all authors; visualization, U.P., A.F.R., O.M. and F.O.F.; supervision, U.P. and F.O.F.; project administration, F.O.F.; funding acquisition, A.O.S. and F.O.F. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of Federal University of Technology, Minna (Ethical Review Committee approval number: 000030, May 2022). It also got ethical approval of the Research Ethics Committee of the Faculty of Veterinary Science, University of Pretoria, with ethical approval number REC 142–22 (April 2023).

Informed consent

All respondents to the data brief independently filled the consent form (Attached as appendix 1).

Declaration of Competing Interest

The authors declare no conflict of interest.

Data availability

All data utilised in this work are open sourced in the various institutions' websites (Table 1) or on request from the Federal Ministries of Health, Agriculture or other mentioned Federal Agencies in Nigeria.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.onehlt.2023.100546.

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