A questionnaire survey of poultry layer farmers in Khartoum State, Sudan, to study their antimicrobial awareness and usage patterns

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An initial census of layer farms in Khartoum State, Sudan, was carried out in late 2007 and early 2008 and found that there were 252 layer farms with a total population of 2 221 800 birds. This paper reports the findings of the census. Based on this information, a structured questionnaire survey of 92 farms was then conducted in the state in April 2008 to collect data on antibiotic usage, demographic data and public health awareness. Ninety-eight per cent of participating farms comprised open-sided houses. It was found that 49% of the farms surveyed were on antibiotic treatment when the survey was conducted, whilst 59% of the farms had used antibiotics within the last 3 months. The study found that farmers and producers had a lack of knowledge about antimicrobial residues, their withdrawal periods and the risk posed by the consumption of these residues. The study also concluded that traditional farming systems in Sudan relied heavily on antimicrobial medication to control disease and almost half of the farms surveyed were treating their flocks with antimicrobials. In addition to this, there was a lack of disease control programmes which probably resulted in a massive use of antibiotics to control endemic diseases. This was further compounded by the absence of governmental supervision and control on the use of drugs.

Introduction

Khartoum State is responsible for almost 90% of Sudan's poultry production (Ministry of Agriculture, Animal resources and Irrigation 2005). Antimicrobials are used in layer hens in Sudan, mainly to treat and prevent bacterial infections. These antimicrobials are similar to those used in human medicine, which include aminoglycosides, tetracyclines, beta-lactams, quinolones, macrolides, polypeptides, amphenicols and sulphonamides (Stolker & Brinkman 2005).

A study that was conducted concurrently with this one showed that eggs from a high proportion of farms and layer houses contained antimicrobial residues (Sirdar 2010). Similarly, investigations in Nigeria and Tanzania showed that a high proportion of table eggs contained antimicrobial residues (Kabir *et al*. 2004; Nonga *et al*. 2010). This is very different to countries in Western Europe, Australia and North America, where it would be unusual to detect any antibacterial substances in table eggs. There is little known as yet about farmers' perceptions or other factors that play a role in the cause of this problem in some African countries. This study set out to attempt to gain a better understanding of what Sudanese poultry farmers know and think about antimicrobial use. Only through understanding these factors, the problem may eventually be resolved and lead to a healthier lifestyle for Africans. In addition, little has been published about the demographics of the poultry layer industry in Sudan, and so a secondary objective of this study was to carry out a census of the poultry layer industry in Khartoum State, Sudan.

Materials and methods

Census of layer farms in Khartoum State

A census to determine the size and structure of commercial layer farms in Khartoum State, Sudan, was conducted between December 2007 and January 2008. The sampling frame consisted of all known layer farms in the three localities of Khartoum State. The identification of farms was based on data from an internal publication by the State Ministry of Agriculture, Animal Resources and Irrigation of 2005, from day-old chick suppliers and from poultry veterinarians. In addition, information from farm owners about other farms was used to identify farmers not already listed. The sampling unit at the time of the survey was a layer farm producing eggs or pullets, or layer farms not currently in production. For each area the following was recorded: the location of each farm, the number of farms in each area, the number of layer houses per farm, the capacity of each layer house, and the farming system used.

Questionnaire survey

A structured questionnaire was designed to collect information on farm management procedures used on each layer farm, besides investigating local knowledge and understanding issues that surround antibiotic usage in food-producing animals.

The sampling frame for the questionnaire was all known layer farms that were producing eggs at the time of the survey in Khartoum State (Figure 1). Data were obtained on antibiotics recently used, antibiotics used in the last 3 months, reasons for using the antibiotics, diseases currently on the farm, diseases recorded in the last 3 months, withdrawal period, methods of storing antibiotics, quality control and policies of antibiotics usage in the poultry industry. Perceptions of the public health risk of antibiotic residues in table eggs were also investigated. In addition to that, the farming system, chicken breed, breeding system, number of chickens per house, number of houses per farm and current age of the flock were recorded. To determine the antibiotics used at the time of the survey, labels and empty bottles of antibiotics were collected and the data were recorded. All elements of the questionnaire were categorical variables, structured as closed ended questions. The only continuous questions regarded the age of the flock, the number of chickens per house and the number of houses per farm; these also were coded later and recorded as categorical variables.

The questionnaire was not subjected to pretesting or repeatability testing; it was designed in English and the contents were translated into Arabic during the interview. The validity of the questionnaire was assessed by comparing the results of the questionnaire with reliable criteria, that is, the related questions in the same questionnaire form and known facts such as the absence of rules and regulations of antibiotic usage in Sudan. The survey was carried out in April 2008, covering the whole State, and all information needed in the questionnaire form was captured through direct interview. The respondents were the owners or managers of the farms.

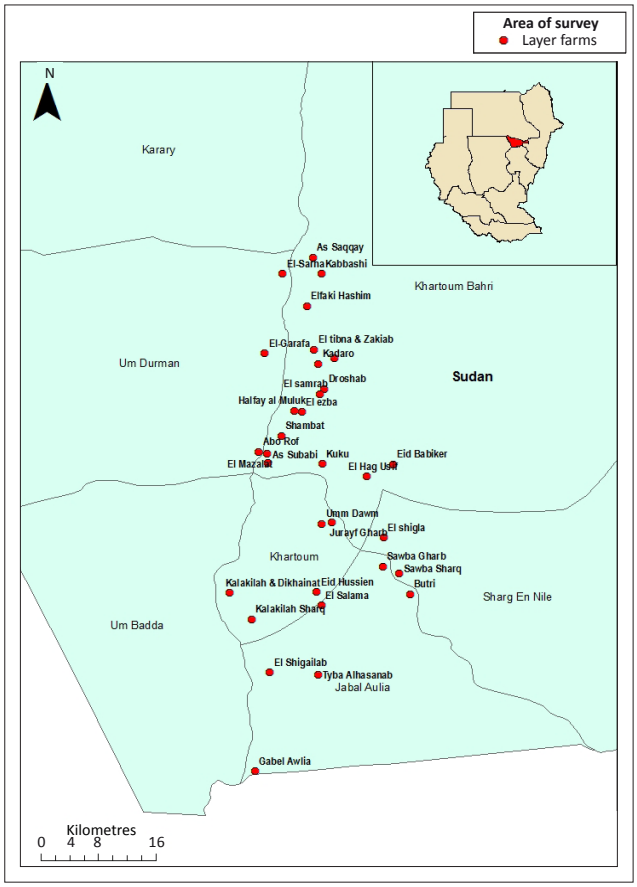

FIGURE 1: Location of farms surveyed in Khartoum State, Sudan, April 2008.

Thirty-four of the farms that participated in the questionnaire survey were correlated to results from a separate survey on their farms that investigated the presence of antimicrobial residues in eggs (Sirdar 2010). In this survey three eggs from each house on a farm were tested for antimicrobial residues and if one or more eggs were found to contain antimicrobial residues, the farm was considered as positive for residues in eggs. These 34 respondents' results were analysed further to determine whether there were any statistical associations between what farmers answered (Table 1) and the known presence of antimicrobial residues on their farms.

Data analysis

The information captured from the census was recorded and summarised (Table 2). The questionnaire data derived from all known layer farms was captured into, and analysed by using, EpiInfo™[1] version 3.5.1. Several descriptive statistics, including frequencies, means, medians and statistical associations between several factors were measured (Chi-square and Fisher Exact test). Strengths of associations were assessed by calculating Odds Ratios and data were stratified to look for any possible confounding effects. For the 34 selected farms, the association between questions answered (factors), and the presence or absence of antimicrobial residues in eggs on these farms in April 2008 (Sirdar 2010), was assessed by using the two-tailed Fisher Exact test (EpiCalc 2000 software[2]). Factors related to the presence or absence of antimicrobials on the farm ($p < 0.05$) were re-examined in a multivariate model by using multiple unconditional logistic regression to control confounding. Models were built by using forward elimination with switching because of the small sample size: those with $p > 0.05$ on the Wald test were removed one at a time until all factors left in the model were statistically significant at $p < 0.05$ (Thrusfield 2005). Logistic regression, therefore, was used to determine the best set of factors. Whilst a value of $p < 0.05$ was considered significant; p-values between 0.06 and 0.1 were considered numerically reportable as potential trends.

Spatial analysis

The mapping program, Google Earth version 4.3,[3] was used to trace the farms and areas of sampling and to record the coordinates of all the farms sampled in Khartoum

1.http://www.cdc.gov/epiinfo/epiinfo.htm

2.EpiCalc 2000, version 1.02, Joo Gilman & Mark Myatt 1998, Brixton books.

3.http://earth.google.com/download-earth.html

TABLE 1: The association between factors associated with antimicrobial residues and the presence of antimicrobial residues in eggs.

Group variable	Unique value	Number of farms tested	Number of farms positive (%)	*p*-value (Fisher Exact test)
Locality	Bahry	15	11	1.00
	Khartoum	19	14	–
Chicken breed	Hisex	14	11	–
	Bovan	5	3	–
	Lohman	5	3	0.81
	Hyline	2	2	–
	Mixed	2	2	–
	Unknown	6	4	–
Breeding system	All-in All-out	11	10	0.21
	Multi-age	23	15	–
Number of chickens per house	100–500	4	3	–
	500–1000	28	20	1.00
	1000–2000	1	1	–
	> 2000	1	1	–
Number of houses per farm	1	19	13	–
	2	10	8	0.92
	3	2	2	–
	≥ 4	3	2	–
Age (Months)	4–8	8	6	–
	8–12	17	12	–
	12–16	2	1	1.00
	> 16	2	2	–
	Multi-age	2	2	–
	Unknown	3	2	–
Antibiotics in use now	Yes	16	13	0.44
	No	18	12	–
Antibiotics used in the last 3 months	Yes	21	15	1.00
	No	13	10	–
Purpose of antibiotic usage	Therapeutic	22	15	–
	Prophylactic	6	4	1.00
	Therapeutic and prophylactic	5	4	–
	Others	1	1	–
Route of administration	Water	33	24	–
	Feed	0	0	–
	Water and Feed	0	0	–
	Others	1	1	–
Follow withdrawal period	Yes	7	3	0.06
	No	27	22	–
Do drugs pass from chicken body to eggs?	Yes	5	2	0.1
	No	29	23	–
Do drugs in eggs affect human beings?	Yes	4	4	0.55
	No	30	21	–
Storage of drugs	Storeroom	22	17	–
	Fridge	9	6	0.35
	Chicken house	2	2	–
	Others	1	0	–
Any Quality Control Measures to eggs (e.g. fumigation, cracked eggs, cleaning … etc.)	Yes	3	2	1.00
	No	31	23	–
Rules and regulations of antibiotic usage	Yes	1	1	1.00
	No	33	24	–
Governmental Body responsible for rules and regulations	Yes	0	0	1.00
	No	34	25	–
Diseases on farm now	Yes	10	6	0.39
	No	24	19	–
Diseases on farm in last 3 months	Yes	17	12	1.00
	No	17	13	–

State. All coordinates were entered into the spreadsheet program, Excel (Microsoft Corporation, USA 2003). Data were converted from Excel files for use in ArcView 9.3 (Esri Redlands 2009). Africa, Sudan and Khartoum State shape files were downloaded from www. maplibrary.org[4]. Maps of Khartoum State showing the sampling locations were created by using ArcView 9.3.

4.www.maplibrary.org/stacks/Africa/Sudan/Khartoum/index.php

TABLE 2: Areas covered in the survey and the proportion of farms surveyed in each area in Khartoum State, 2008.

Number	Locality	Area surveyed	Total number of farms	Number of farms surveyed	Proportion of farms surveyed (%)
1	Bahry	El-selait	13	6	46
2	Bahry	El-kadaru & Droshab	13	6	46
3	Bahry	El-hag Usif & El-shigla (Sharq Elniel)	10	2	20
4	Bahry	Shambat	16	8	50
5	Bahry	El-kabashi	12	7	58
6	Bahry	El-faki Hashim	12	4	33
7	Bahry	El-sagai	13	4	31
8	Bahry	El-tibna & Zakiab	18	12	6
9	Bahry	El-samrab	5	1	20
10	Bahry	El-mazalat	3	1	33
11	Bahry	El-sababi	5	3	60
12	Khartoum	Soba	11	9	82
13	Khartoum	Tyba Hassanab	8	1	13
14	Khartoum	El-shegailab	5	1	20
15	Khartoum	El-kalakla & Dikhainat	17	16	9
16	Khartoum	El-kalakla North	5	5	100
17	Khartoum	El-geraif West	12	6	50
Total		**17**	**178**	**92**	**52**

Ethical considerations

The project was an approved University of Pretoria research project (V047-07), which included ethical approval by the Animal Use and Care Committee. No live animals were used in the study.

Results

Census of commercial layer farms in Khartoum State, Sudan

The census covered all three localities of the state: Khartoum North (Bahry), Khartoum and Omdurman. The census showed that there were 252 layer farms containing 764 commercial layer houses in the state, with a total capacity of 2 221 800 birds. The locations of layer farms sampled in the entire Khartoum State are shown (Figure 1).

Questionnaire analysis

The questionnaire survey was conducted in April 2008. Ninety-two farms participated in the survey. The questions and the results of the questionnaire survey, have been summarised (Table 3).

Layer farms in 17 different production areas were surveyed (Table 2). Eleven areas (65%) were in Bahry Locality and the remainder (35%) was in Khartoum Locality. There were no farms in production in Omdurman Locality whilst the survey was conducted. About 59% of the farms that were surveyed were in Bahry Locality and 41% were in Khartoum Locality. A high proportion of farms were surveyed in Kalakla North (100%), Kalakla and Dikhenat (94%), and Soba Garb (82%) areas. In contrast, farms in Tyba Hassanab were the least surveyed (13%), because owners in this area were not willing to participate in the survey. Only a few farms were included in El-samrab and El-shegailab, because the total number of farms in these areas was low and houses were found to be used as layer rearing houses at the time of the survey.

Only one out of twelve closed systems in Khartoum State was prepared to take part in the questionnaire survey, which unfortunately biased the survey towards farms with traditional open houses. The majority of the farmers interviewed were small-scale producers who had a maximum of 1000 birds (95%) that were mainly distributed into one or two houses (83%).

The most common breed in the survey was Hisex (51%), as it is considered to be the most tolerant of the breeds to high ambient temperatures. In addition to that, Hisex was introduced to Sudan over 3 decades ago and the local supplier had established a good business-relationship with the farmers. Nevertheless, Lohman (13%) and Hyline (5%), both only introduced to the Sudanese market in the last 4 years by foreign companies, were starting to capture a good share of the market. Bovan breed (a Dutch breed introduced to Sudan in the 1980s) shared 9% of the total breeds found in the state, whilst the unknown breeds (not including indigenous breeds) kept by the owners interviewed, were 14%.

Thirty-seven per cent of the farms surveyed had multiple ages on the same farm. When comparing this figure with the all-in all-out breeding system (63%), it gives an erroneous idea of age distribution because most of the farms surveyed had only one house on the farm that was used for egg production at a time. In 68% of the surveyed farms, the age of the flocks varied from 4 to 12 months. Although there was one age group within each layer house, the distance between layer houses on a farm, or between farms, was less than 30 meters, indicating that even when the system used is all-in all-out, it could be affected also by other age groups on the farms and between farms.

From the answers to the questionnaire ($n = 92$), it was found that the odds of antibiotic use at the time of the survey were 21 times greater on farms that had concurrent disease

TABLE 3: Topics covered by the questionnaire and the questionnaire survey results, Khartoum State, 2008.

Group Variable	Unique value	Number	%
Number of farms surveyed	Bahry	54	59
	Khartoum	38	41
	Total	**92**	**100**
Farming system	Open	91	99
	Closed	1	1
	Total	**92**	**100**
Chicken breed	Unknown	13	14
	Hisex	47	51
	Bovan	9	10
	Lohman	12	13
	Hyline	5	5
	Mixed	6	7
	Total	**92**	**100**
Breeding system	Multi-age	34	37
	All-in All-out	58	63
	Total	**92**	**100**
Number of chickens per house	100–500	6	7
	500–1000	81	88
	1000–2000	2	2
	> 2000	3	3
	Total	**92**	**100**
Number of houses per farm	1	52	56
	2	25	27
	3	9	10
	≥ 4	6	7
	Total	**92**	**100**
Age or Month (Farm)	Unknown	4	4
	4–8	27	29
	8–12	36	39
	12–16	6	7
	> 16	4	4
	Multi-age	15	17
	Total	**92**	**100**
Antibiotics in use now	No	47	51
	Yes	45	49
	Total	**92**	**100**
Antibiotic used in the last 3 months	Do not know	8	9
	No	30	33
	Yes	54	58
	Total	**92**	**100**
Purpose of antibiotic usage†	1	56	61
	2	12	13
	3	22	24
	4	2	2
	Total	**92**	**100**
Route of administration‡	1	89	97
	2	2	2
	3	1	1
	Total	**92**	**100**
Understanding of withdrawal period	No	69	75
	Yes	23	25
	Total	**92**	**100**
Selling eggs during and after using drugs	No	2	2
	Yes	90	98
	Total	**92**	**100**
Do drugs pass from chicken's body to eggs?	No	77	85
	Yes	14	15
	Total	**91**	**100**
Do drugs in eggs affect human beings?	No	81	89
	Yes	10.0	11
	Total	**91**	**100**
Any Quality Control Measures for eggs?	No	87	95
	Yes	5	5
	Total	**92**	**100**
Means of storage of drugs§	1	50	54
	2	2	2
	3	28	30
	4	3	3
	5	4	5
	6	5	6
	Total	**92**	**100**
Rules and regulations of antibiotic usage	No	87	95
	Yes	5	5
	Total	**92**	**100**
Governmental Body responsible for rules and regulations¶	1	1	1
	2	88	97
	3	2	2
	Total	**91**	**100**

Table 3 continues →

TABLE 3 (Continues...): Topics covered by the questionnaire and the questionnaire survey results, Khartoum State, 2008.

†, 1, therapeutic; 2, prophylactic; 3, therapeutic and prophylactic; 4, do not know.
‡, 1, water; 2, water and feed; 3, water and eye drop.
§, 1, store room; 2, fridge; 3, chicken house; 4, pharmacy; 5, storeroom and fridge; 6, others.
¶, 1, National standardisation and metrology; 2, no governmental body; 3, State Ministry of Agriculture, Animal Resources and Irrigation.

(7 < OR < 36, 95% Confidence Interval), which implies that usage was more for treatment than for prophylaxis. This is supported further by the finding that farms that have used antibiotics in the 3 months prior to the survey had 18 times greater odds of concurrent disease during the same period (OR = 18; 6 < OR < 54, 95% Confidence Interval; Chi-square = 32; $p < 0.01$). When the use of antibiotics were more closely examined, it was found that the association between prophylactic uses of antibiotics and the presence of diseases on farms was insignificant (p-value = 0.15), whilst the association between therapeutic and prophylactic use at the same time with the presence of disease on farms, was significant with a p-value = 0.02. The odds of antibiotics used for therapeutic purposes were 17 times greater on farms that had diseases than on those that did not have diseases. The fourth strata (purpose of antibiotic use unknown) showed an insignificant association with disease on farms. The Summary Odds Ratio of the stratified analysis was 22; the Adjusted Odds Ratio was 27, Chi-square was 37, and p-value < 0.01, which suggested some confounding effect within 'purpose for use of antibiotics'. When placed into a logistic regression model, there was still a strong association between therapeutic use and the presence of disease (OR = 15), but the association was no longer significant (Wald $p > 0.05$) and this was probably because of low numbers in some of the strata.

Farmers who indicated that they did not know drugs in eggs can affect human beings, were much more likely not to know that drugs pass from chicken body to eggs (OR = 28; 95% Confidence Interval = 6 < OR < 141); (Chi-square = 23; $p < 0.02$). These comprised 83% of the farmers, and therefore suggest a widespread lack of knowledge about drug behaviour and its effects amongst Sudanese farmers.

Information was available on 34 farms as to the antimicrobial status of their eggs, that is, whether residues had been detected in one or more eggs (Sirdar 2010), and consequently

the association between what famers answered, and the presence or absence of antimicrobial residues was examined. The factors considered for farms positive for antimicrobial residues in Khartoum State have been listed (Table 1). The Fisher Exact test showed no significant association between any of the factors examined in the questionnaire and the presence of antimicrobial residues on the farms, with the exception of whether they followed a withdrawal period or not. The majority (92%) of farmers on farms where antimicrobials were found indicated that they did not follow a withdrawal period. A number of regression models were created by using various combinations of factors. In none of the models were any of the factors shown to be statistically significant. The last two factors that were eliminated from the models were adherence to a withdrawal period, and whether farmers thought drugs passed from a chicken's body to its eggs.

Discussion

Census of layer farms in Khartoum State, Sudan

The census conducted in this study was necessary because the unpublished census conducted in 2005 by the State Ministry of Agriculture, Animal Resources and Irrigation, after the Avian Influenza (AI) outbreak, only recorded farms affected by AI and did not differentiate between broiler and layer farms (Ministry of Agriculture, Animal resources and Irrigation 2005). This census proved to be a challenge because most farms are not registered with the local authorities, the land ownership or occupancy was not always recorded, and the land use was fluid. The initial information on farm locations was dependent on the internal data of the State Ministry of Agriculture, Animal Resources and Irrigation, which were not complete. In order to expand on this information, a snowball approach was adopted by using information gathered from the original field veterinarians and farm owners to locate other farms in the area. In addition, the day-old chicks' suppliers provided useful data about layer farms in the state and further farms were located from unpublished reports**.** Whilst the census was not ideal, the result was more extensive than previous censuses carried out in the layer industry of Sudan, and thus contributed valuably to the update of available information on this production sector.

The last census conducted by the State Ministry of Agriculture, Animal Resources and Irrigation, in 2005, showed that there were 527 poultry (broiler and layer) farms in Khartoum State, whilst this census revealed that there were 252 layer farms in the State, with 166 farms (66%) located in Bahry, 78 farms (31%) in Khartoum, and 8 farms (3%) in Omdurman Locality. Most of the farms in Bahri Locality were smallholdings. The farms were generally clustered in groups of 10–20 farms along the Nile, with most farms in the cluster neighbouring each other. For this reason, when conducting the spatial analysis, the main challenge was to record the coordinates of each farm sampled because there were small differences of seconds and even fractions of seconds between them.

Almost 50% of the farms recorded at the time of the census were not producing eggs for various reasons, which included:

- That many farmers lacked the financial resources to restock their farms after the depopulation and condemnation of carcasses that resulted from the 2006 Avian Influenza (AI) outbreak. The Sudanese government had only compensated the farmers with 60% of the direct cost (carcass price) divided into three payments. At the time of the census, many farmers had not yet received full compensation. This problem was compounded by the dramatic increase in animal feed prices during 2008.
- A shortage of day-old chicks, because the suppliers were unable to cover the whole demand associated with the ban of day-old chicks and fertile egg imports after the AI outbreak. This lead to an increase in the price of day-old chicks, making it cost-ineffective for small-scale producers.
- The lack of government protection of small-scale producers. This made them highly vulnerable to the effects of disease, market forces and the weather. Furthermore, there were no State-run or industry-run disease control programmes; therefore the introduction of diseases such as Newcastle Disease and salmonellosis caused massive fatalities and chronic respiratory disease that resulted in severe production losses.
- That farmers who use traditional housing for breeding can produce only during the cooler winter months (from late October until January).
- That some farms were in the downtime period preparing for another cycle.
- That the pullets were not yet in lay.
- That farmers switched from layer to broiler production. Usually in Sudan, farmers raise day-old laying chicks until they start to lay, and then continue in the same house until the end of their production cycle. After the culling of the batch, the farmer may use the same farm for producing broilers or to start a new cycle of layers.

The data provided by this census do not therefore cover the full production potential of the Sudanese layer industry. It does, however, provide a baseline and guide for researchers and officials who wish to compile a more complete database concerning the poultry industry. In addition to that, it will serve as a primary source of data for all who are interested in the Sudanese poultry industry. The government in Sudan has subsequently established a census forum to create their own database of all livestock farms in the state and they will benefit from the data provided in this research.

Questionnaire survey

Ninety-two farms participated in the questionnaire survey conducted in April 2008. The participants of the questionnaire were 52% of the total number of farms (178 farms) in the areas surveyed. The main reason for the low participation was that some farms were not in production at the time of the questionnaire, as explained above. Other reasons included the absence of the farm owner or manager, or a refusal to participate for personal reasons.

It was clear from the survey that traditional farming systems relied heavily on antimicrobial medication to control disease; 49% of farms were treating their flocks with antimicrobials, whilst a further 9% had used antimicrobials within 3 months prior to this survey. The main purpose of the antibiotics was to treat (61%) a variety of diseases including salmonellosis (30%) and chronic respiratory disease (25%). This high level of disease is believed to be as a result of the type of housing, poor environmental sanitation, poor biosecurity, close grouping of farms and poor management.

Almost all the antibiotic classes were found in the Sudanese market for purchase either as separate products or as products in combination with multivitamins and minerals. Oxytetracycline, however, has the added advantage of a highly competitive price, a broad-spectrum coverage and is combined with multivitamins, so that it is the most commonly used antibiotic, with 25% in current use and 23% having used it in the last 3 months. These findings agree with Babiker *et al*. (2009), who classified salmonellosis and respiratory disease as highly prevalent in layer flocks in Khartoum State. Oxytetracycline appears to be widely used on poultry farms in Africa; Mitema *et al*. (2001), Kabir *et al.* (2004) and Nonga *et al*. (2010) found that it was the most used antibiotic in Kenya, Nigeria and Tanzania, respectively. Other commonly used antibiotics were tylosin (19%) and the broad-spectrum enrofloxacin (14%) which is used to treat infectious coryza and *Mycoplasma* infections in birds, and colistin (14%) which is used to treat diarrhoea (Reinhardt *et al.* 2005).

In all poultry production systems globally, the preferred method of treatment by 97% of the farms was by the mass medication of drinking water. Feed was not used as route of administration because the feed mills used for food preparation tend not to fully homogenise small quantities of drugs in feed, which results in an uneven distribution of drugs in the feed. Furthermore, sick birds will continue to drink, but will not eat.

Prophylactic antimicrobial therapy was less common and was not associated with disease ($p < 0.15$). This finding was expected because small-scale farmers may not be able to afford the cost of treating prophylactically as a result of their limited resources.

The failure of the logistic regression models to show any significant associations between the known presence of antimicrobials in eggs on a farm, and certain answers given by farmers, was most likely because of the small sample size in the stratified data (Table 1), which reduced the power of the tests. The forward selection process with replacement nevertheless still produced a model that was consistent with the Fisher Exact test results, indicating that the major factor associated with the presence of antimicrobials in eggs was a lack of compliance with withdrawal period and a lack of understanding that residues can pass from the chickens to eggs. It highlights the importance of risk communication and how ignorance of an African public about the behaviour of antimicrobials in chickens and humans is probably the single most important contributor to the fact that many African countries have antimicrobial residue problems.

Most Sudanese farmers do not believe that drugs in eggs affect human beings, or that drugs can pass from the chicken body to its eggs**.** There was a significant association between those (85% of respondents) who believed that drugs do not pass from the hens' bodies to their eggs, and those (89% of respondents) who do not believe that drugs in table eggs can affect human beings ($p < 0.02$). Furthermore, 75% of the farmers apparently did not understand the concept of a drug withdrawal period in eggs. An overwhelming majority of respondents (95%) were not aware of any government regulations pertaining to the sale of eggs during the withdrawal period of antimicrobials. This is partially because there is an absence of any rules and regulations in Sudan governing antimicrobial use in poultry production or animal production. It was, therefore, not surprising that 98% of the farmers questioned, continued to sell eggs whilst their hens were on antibiotic treatment. The lack of knowledge about the withdrawal periods is greater than for farmers from Tanzania (Nonga *el al*. 2010), where 80% knew about the withdrawal period, but still sold eggs during this period. In the same way as the Sudanese poultry farmers, the Tanzanian farmers were unaware that antimicrobials in eggs have any detrimental effect on human beings. The problem was compounded further by a lack of quality control measures applied to egg products, such as cracked eggs, grading of eggs, cleaning of dirty eggs or fumigation of eggs. In Sudan, 95% of farmers do not apply any quality control measures to eggs.

Conclusion

The census conducted in this study concluded that there was a gap in information in the layer industry in Sudan and that this study provided more reliable baseline information than was previously available. There is still a need for more efficient census data for the poultry industry in Sudan.

The main reason for the high prevalence of antimicrobial residues in the layer industry was probably the lack of knowledge of farmers and producers about antimicrobial residues, their withdrawal periods, and the risk posed by the consumption of these residues.

The study also concluded that traditional farming systems in Sudan relied heavily on antimicrobial medication to control disease and almost half of the farms surveyed were treating their flocks with antimicrobials. In addition there was a lack of disease control programmes which probably resulted in a massive use of antibiotics to control endemic diseases. The situation was compounded further by the absence of governmental supervision and control on the use of drugs.

Consequently, it was concluded that a solution to the residue problem would be intensive extension and educational

programmes on responsible and appropriate antibiotic use. This would include avoidance of certain antibiotics and the following of withdrawal periods, coupled with the government formulating simple regulations for the use of antibiotics and their withdrawal. Furthermore, farmers should be educated on alternative methods of infectious disease management, such as vaccination, environmental sanitation and disease containment, which would decrease the use of antibiotics.

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Competing interests

The authors declare that they have no financial or personal relationship(s) which may have inappropriately influenced them in writing this paper.

Authors' contributions

This work was conducted by M.M.S. (National Cooperative Corporation) as part of his MSc in Epidemiology at the University of Pretoria. M.M.S. (National Cooperative Corporation) was involved in all aspects of the project and carried out the fieldwork for the project and some of the laboratory analysis. The principle supervisor for this project was B.G. (University of Pretoria) who was responsible for the design and management of the project and the guidance of M.M.S. (National Cooperative Corporation) in all aspects of the project, but particularly in the epidemiology. J.P. (University of Pretoria) acted as a co-supervisor and provided assistance and inputs principally into the microbiological components of the project. All three of these authors contributed extensively to the writing of this article. S.B. (University of Pretoria) acted as a co-supervisor to M.M.S. (National Cooperative Corporation) and as a poultry consultant.

References

Al-Ghamdi, M., Al-Mustafa, Z., El-Morsy, F., Al-Faky, A., Haider, I. & Essa, H., 2000, 'Residues of tetracycline compounds in poultry products in the eastern province of Saudi Arabia', *Public Health* 114, 300–304. http://dx.doi.org/10.1016/S0033-3506(00)00350-4

Babiker, M.A., Tawfeig, A., Yahia, I.E. & Noura, K., 2009, 'Mortality and disease status in layer chicken flocks reared in traditional farms in Khartoum, Sudan', *International Journal of Poultry Science* 8, 264–269. http://dx.doi.org/10.3923/ijps.2009.264.269

Kabir, J., Umoh, V.J., Audu-Okoh, E., Umoh, J.U. & Kwaga, J.K.P., 2004, 'Veterinary drug use in poultry farms and determination of antimicrobial drug residues in commercial eggs and slaughtered chicken in Kaduna State, Nigeria', *Food Control* 15, 99–105. http://dx.doi.org/10.1016/S0956-7135(03)00020-3

Ministry of Agriculture, Animal resources and Irrigation, Khartoum State, Sudan, 2005. Internal publication.

Mitema, E.S., Kikuvi, G.M., Wegener, H.C. & Stohr, K., 2001, 'An assessment of antimicrobial consumption in food producing animals in Kenya', *Journal of Veterinary Pharmacology & Therapeutics* 24, 385–390. http://dx.doi.org/10.1046/j.1365-2885.2001.00360.x

Nonga, H.E., Simon, C., Karimuribo, E.D. & Mdegela, R.H., 2010, 'Assessment of antimicrobial usage and residues in commercial chicken eggs from small holder poultry keepers in Morogoro Municipality, Tanzania', *Zoonoses and Public health* 5, 339–344.

Reinhardt, A.K., Gautier-Bouchardon, A.V., Gicquel-Bruneau, M., Kobisch, M. & Kempf, I., 2005, 'Persistence of *Mycoplasma gallisepticum* in chickens after treatment with enrofloxacin without development of resistance', *Veterinary Microbiology* 106, 129–137. http://dx.doi.org/10.1016/j.vetmic.2004.11.016, PMid:15737482

Sirdar, M.M., 2010, 'Antibiotic residues in commercial layer hens in Khartoum Sate, Sudan, 2007–2008', Master thesis, Dept. Production Animal Studies, University of Pretoria.

Stolker, A.A. & Brinkman, U.A., 2005, 'Analytical strategies for residue analysis of veterinary drugs and growth-promoting agents in food-producing animals–a review', *Journal of Chromatography A* 1067, 15–53. http://dx.doi.org/10.1016/j.chroma.2005.02.037, PMid:15844509

Thrusfield, M., 2005, *Veterinary Epidemiology,* 3rd edn., Blackwell Science Ltd., Oxford, United Kingdom.