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Use of antibiotics among small-scale cattle farmers in rural areas in Queretaro, Mexico

Miguel Galarde-López[1]
0000-0002-9609-6419
Brenda Yoselin Cruz-Monsalvo[2]
0009-0001-3419-2659
Maria Elena Velazquez-Meza[3]*
0000-0003-0829-9740
José Alfredo Carranza-Velázquez[2]
0009-0007-9549-5075
Federico Alonso Zumaya-Estrada[3]
0000-0001-8764-4375
Berta Alicia Carrillo-Quiroz[3]
0000-0003-4651-1730
Sara Claudia Herrera-García[4]
0000-0002-5491-601X
Celia Mercedes Alpuche-Aranda[3]
0000-0002-5405-5256

[1] Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Centro Nacional de Investigación Disciplinaria en Salud Animal e Inocuidad, Ciudad de México, México

[2] Universidad Nacional Autónoma de México, Facultad de Medicina Veterinaria y Zootecnia, Centro de Enseñanza, Investigación y Extensión en Producción Animal en Altiplano, Querétaro, México

[3] Instituto Nacional de Salud Pública, Centro de Investigación sobre Enfermedades Infecciosas, Morelos, México

[4] Universidad Nacional Autónoma de México, Facultad de Medicina Veterinaria y Zootecnia, Secretaría de Medicina, Ciudad de México, México.

***Corresponding author**
Email address:
mevelaz@insp.mx

Abstract

The inappropriate use of antibiotics in the livestock sector has been described as one of the causes of the emergence of antimicrobial resistance. Information on antibiotic use in small-scale farms is limited. Our objective was to identify patterns of antibiotic use in small-scale cattle farms in Queretaro, Mexico. Cross-sectional study with 50 small-scale cattle farmers from rural areas surveyed in the municipality of Tequisquiapan, Queretaro between May–October 2022. Convenience sampling, non-probabilistic, small-scale cattle farms were selected using respondent-driven sampling methodology. A face-to-face survey was applied, structured in five sections: *i*) small-scale cattle farmers´ profile, *ii*) characteristics of small-scale cattle farms, *iii*) antibiotic use, *iv*) antibiotic prescription, and *v*) inventory of stored antibiotics vials. The data collected were processed and analyzed. Ninety-two percent of the small-scale cattle farmers were male, with an age range of 23 to 88 years (median 58.5, IQR 49–64.5). Seventy-four percent of the small-scale cattle farmers had a basic level of schooling. The animal census consisted of 968 animals. A total of 142 stored antibacterial products from nine antibiotic classes were recorded: 34.5 % were penicillin, 19 % oxytetracycline, 13.4 % gentamicin, 9.8 % florfenicol, and 8.4 % enrofloxacin. About 50 % of the stored antibiotics have a "watch" classification in the WHO AWaRe tool. Seventy-eight percent of small-scale cattle farmers throw empty antibiotic vials in the trash. Our study showed that small-scale cattle farmers had an important use of third generation cephalosporins, tetracyclines, and fluoroquinolones; antibiotics considered "watch" by the WHO.

Keywords: Antibiotics; Public Health; Antimicrobial resistance; Small-scale Cattle Farmers; Rural Livestock.

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Study contribution

This study described the purchase, use and final disposal of antibiotic agents used in small-scale cattle farms in rural areas of Queretaro, Mexico. We describe the type of antibiotics used, their prescription, use, storage, and final disposal, as well as their relationship with World Health Organization surveillance on these antibiotics. Our results evince the need for training on the prudent use of antibiotics in small-scale cattle farmers in rural areas.

Introduction

Antibiotic resistance is a public health problem related to the "One Health" approach.(1, 2) The World Organization for Animal Health (WOAH), Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO), and United Nations Environment Program (UNEP) are working on strategies to address this problem, such as antibiotic use control and surveillance of bacteria in human, animal, and environmental health.(3, 4)

Antibiotics are natural, synthetic, or semi-synthetic molecules, which could induce the death or interruption of bacterial growth.(5, 6) The sites of action and chemical composition of antibiotics allow them to be classified in different ways: spectrum of action, mechanism of action and/or chemical structure.(7) Antibiotics are used in the control, treatment, and prevention of bacterial diseases in animal production systems, as well as growth promoters, despite the fact that their use in this activity is prohibited.(6)

The inappropriate use of antibiotics in the livestock sector has been described as one of the main causes of the emergence and spread of antimicrobial resistance.(7–13) Therefore, there are different methodologies used to describe the use of antibiotics in production animals. However, these methodologies are not yet standardized, so each country applies different instruments and/or measurement systems, ranging from the production, purchase and sale of antibiotics, the use of antibiotics by veterinarians and/or farmers, to the milligrams/milliliters of antibiotics administered at the herd and/or animal level, so the results are not comparable.(13, 14)

Previous data have shown increased consumption of antibiotics in the animal sector, such as in broiler chicken and pig production.(10, 15, 16) However, data from developing countries remains scarce. Research on antibiotic use in different sectors and geographic regions can provide important evidence for public health.(12, 13, 16) Mexico has laws that establish norms and technical guidelines on the sale, prescription, and use of antibiotics in animals.(17) However, the training of livestock producers in rural sectors, who have maintained the same antibiotic use practices for years, has been unattended. The objective of this study was to identify patterns of antibiotic use in small-scale cattle farms in Queretaro, Mexico.

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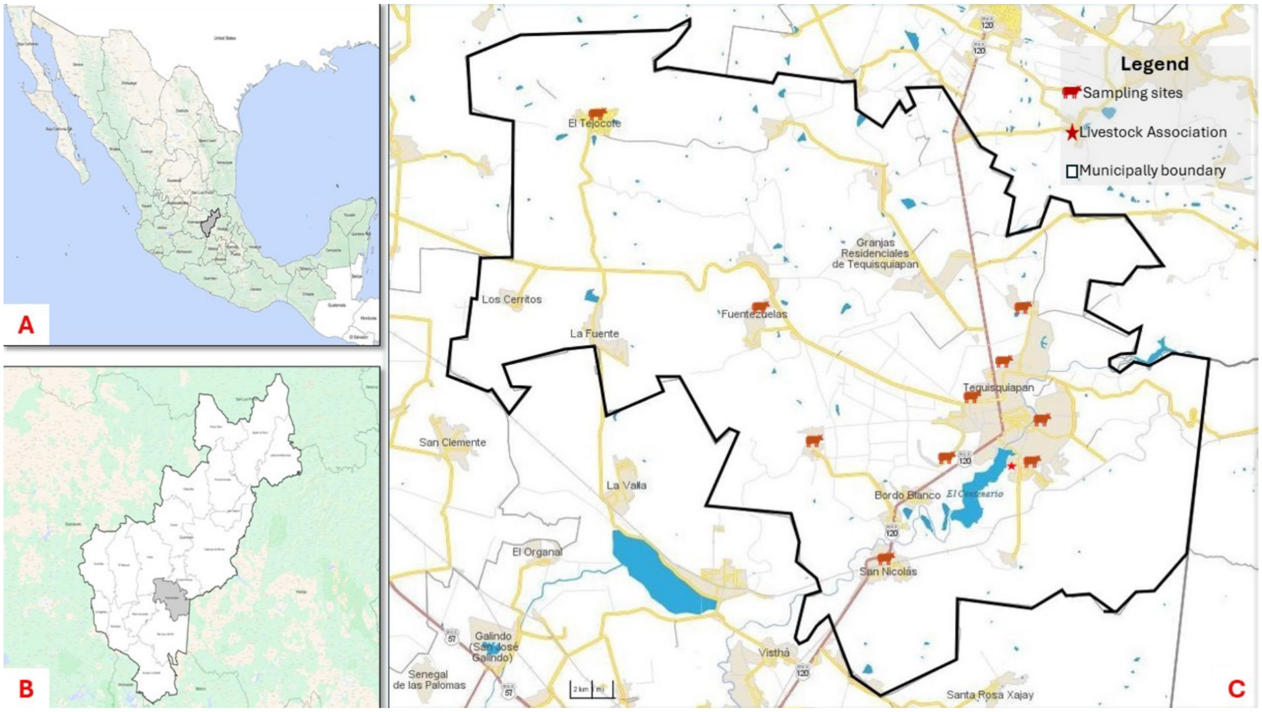

Figure 1. Geographical location of study site. A) Mexico, B) Queretaro State, C) Municipality of Tequisquiapan.

Materials and methods

Ethical statement

This research did not involve animals and therefore did not require the approval of the Comité Interno para el Cuidado y Uso de los Animales (CICUA) of the Facultad de Medicina Veterinaria y Zootecnia of the Universidad Nacional Autónoma de México. However, the confidentiality of the small-scale cattle farmers was maintained.

Study design and population

Cross-sectional study (May-October 2022), through the application of a survey at 50 small-scale cattle farmers in rural areas of the municipality of Tequisquiapan, Queretaro, Mexico (Figure 1). The selection of the small-scale cattle farmers had a non-probabilistic design, being selected at convenience through the respondent-driven sampling (RDS) methodology,[18] this was based on the premise that each respondent would recommend the inclusion of new subjects in the sample.

The survey was applied in a face-to-face to small-scale cattle farmers and contained seventy items, divided in five sections: *i*) small-scale cattle farmers´ profile, *ii*) characteristics of small-scale cattle farms, *iii*) antibiotic use, *iv*) antibiotic prescription, and *v*) inventory of stored antibiotics vials. In addition, the survey includes characteristics of the animals in production, such as number of animals, sex, breeds, among others. Some questions were taken from previously validated studies by Okello E et al.,[11] which were modified and piloted according to this study.

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Table 1. Characteristics of study population

Characteristic		Small-scale cattle farmers n = 50 (%)	± SE*	CI 95 % ** Lower Upper
Sex	Female	4 (8)	3.87	2.92–20.03
	Male	46 (92)	3.87	79.96–97.07
Age (year)	Median (IQR)	58.5 (49–64)	1.75	53.91–60.95
Highest level of education completed	Primary education	20 (40)	6.99	27.06–54.50
	Secondary education	17 (34)	6.76	21.93–48.56
	Medium or high education	11 (22)	5.91	12.36–36.06
	Not respond	2 (4)	2.79	0.95–15.27
Destination of the production	Self-consumption	3 (6)	3.39	1.86–17.61
	Local sale	40 (80)	5.71	66.11–89.12
	Others	7 (14)	4.95	6.64–27.13
Veterinary assistance	Yes, at all times	16 (32)	6.66	20.27–46.54
	Only when necessary	29 (58)	7.05	43.56–71.18
	No	5 (10)	4.28	4.09–22.43
Parasite control	Yes	48 (96)	2.79	84.72–99.04
	No	2 (4)	2.79	0.95–15.27
Application of antiparasitic	Annually	4 (8)	3.95	2.98–20.41
	Half-yearly	44 (88)	4.36	77.13–95.82
	No	2 (4)	2.04	0.26–13.95
Antiparasitic drugs	Ivermectin	24 (48)	7.13	34.19–62.11
	Ivermectin/Albendazole	16 (32)	6.66	20.27–46.54
	Albendazole	4 (8)	3.87	2.92–20.03
	Nothing	6 (12)	4.64	5.33–24.80

* Standard error of proportion
** Confidence interval to 95 %

Data analysis

A descriptive analysis of the variables of interest was performed with median and interquartile range (IQR), as well as standard error of proportion and 95 % confidence intervals (CI 95 %). Data analysis like was performed with the statistical program of data science STATA (v.15 Stata Corp, College Station, TX).[(19)]

Results

We obtained n = 50 surveys of small-scale cattle farmers, of which 8 % were women and 92 % men. The age range of small-scale cattle farmers was 23–88 years (median 58.5, IQR 49–64.5). Seventy-four percent of small-scale cattle farmers (n = 37/50) have basic education as the highest level of education completed. Fifty-eight percent (n = 29/50) of the small-scale cattle farmers seek the services of a veterinarian only when necessary. In terms of parasite control, 96 % of small-scale cattle farmers reported administering antiparasitic to their animals, most of them twice a year (91 %). Ivermectin and albendazole were the main antiparasitic drugs used (Table 1).

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The animal census consisted of 968 animals (median 13, range 1–68), of these 763 were cows and 210 were bulls. Sixty-eight percent of the cattle were crossbred, followed by Holstein (10 %), Charolais (6 %), Limousin (6 %), Angus (6 %), Beefmaster (2 %) and Brahman (2 %) breeds. The main destination of these animals was local sales (80 %) and, to a lesser extent, self-consumption (3 %).

Regarding the question "Do you know what an antibiotic is?", four dimensions of knowledge were recognized by small-scale cattle farmers: *i)* 36 % mentioned that antibiotics are drugs used to treat diseases caused by bacteria, *ii)* 24 % associated antibiotics with diseases caused by different pathogens, *iii)* 6 % referred to antibiotics as drugs used to prevent diseases, and *iv)* 24 % did not know what an antibiotic was. Regarding the question "Do you know what antimicrobial resistance is?", two dimensions of knowledge were recognized by small-scale cattle farmers: *i*) 52 % did not know what antimicrobial resistance was, *ii*) 24 % noted that drugs (e.g., penicillin) are no longer effective in treating infections and that bacteria are resistant to treatments.

Consistent with the statements regarding antibiotic use, 80 % of the small-scale cattle farmers stated that "saving and prolonging the life of animals" was the main objective of antibiotic use. Ninety-two percent of the small-scale cattle farmers stated that the decision on which antibiotics to purchase is made by a veterinarian. Twenty-eight percent of the participants stated that the active ingredient and the brand of antibiotics, respectively, are defining characteristics in the selection and purchase of antibiotics. The local livestock association in Tequisquiapan was the main site for buying and selling antibiotics for 60 % of small-scale cattle farmers. Eighty-two percent of the of small-scale cattle farmers mentioned that they bought antibiotics without a prescription, and that they could still buy antibiotics even if the veterinary prescription was mandatory, respectively (Table 2).

According to the responses of small-scale cattle farmers, the main route of antibiotic administration in animals was the intramuscular route. Forty percent of small-scale cattle farmers reported that the veterinarian administers the antibiotics and another 46 % reported that a person instructed by a veterinarian administers the antibiotics. Seventy percent of small-scale cattle farmers did not administer antibiotics in feed, while 4 % did so for disease prevention (prophylaxis). On the other hand, 84 % of small-scale cattle farmers reported not administering antibiotics in the water, while 16 % only administered them when the animals were sick (Table 2).

Microbiological testing is not performed in 86 % of the animal production systems surveyed. Only 22 % of small-scale cattle farmers reported having some kind of antibiotic use protocol, and 38 % of them mentioned having an antibiotic inventory. However, 78 % of small-scale cattle farmers obtained the body weight of the animals based on a visual empirical estimation and choose the antibiotic dosage according to the printed recommendations of the vial (68 %). Eighty-six percent of small-scale cattle farmers stated that a veterinarian determined the antibiotic treatment duration; for the selection of a second antibiotic, 84 % of small-scale cattle farmers rely on the veterinarian's indications. Seventy-six percent of small-scale cattle farmers indicate a withdrawal period of 15 days after the application of an antibiotic. In addition, 78 % of small-scale cattle farmers throw empty antibiotic vials in the trash (Table 2).

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Table 2. Statements about the use of antibiotics

Statement		Small-scale cattle farmers n = 50 (%)	± SE*	CI 95 % ** Lower upper
What do you consider to be the most important reason for using antibiotics in animal husbandry?	It is impossible to produce animals without antibiotics	6 (12)	4.64	5.33–24.80
	To save and prolong the life of animals	40 (80)	5.71	66.11–89.12
	Antibiotics help to improve production	2 (4)	2.79	0.95–15.27
	They are not important; it is possible to raise animals without using antibiotics	2 (4)	2.79	0.95–15.27
Who decides to purchase antibiotics?	Owner	3 (6)	3.39	1.86–17.61
	Veterinarian	46 (92)	3.87	79.96–97.07
	By recommendation of the pharmacy staff	1 (2)	2.00	0.26–13.69
Characteristics that define the selection and purchase of antibiotics	Active substance	14 (28)	6.41	17.02–42.43
	Trade name	14 (28)	6.41	17.02–42.43
	For being broad-spectrum	3 (6)	3.39	1.86–17.61
	Price	7 (14)	4.95	6.64–27.10
	Application route	2 (4)	2.49	0.95–15.27
	Veterinary advice	10 (20)	5.71	10.87–33.88
Place of antibiotic purchase	Livestock association	31 (62)	6.93	47.45–74.66
	Veterinary pharmacy	9 (18)	5.48	9.41–31.66
	Acquires them from a veterinarian	10 (20)	5.71	10.87–33.88
Do you buy antibiotics with a prescription?	Yes	9 (18)	5.48	9.41–31.66
	No	41 (82)	5.48	68.33–90.58
If antibiotics were only available by prescription, could you buy them over the counter anywhere?	Yes	41 (82)	5.48	68.33–90.58
	No	9 (18)	5.48	9.41–31.66
What is the main route of administration of antibiotics in animals?	Intramuscular	35 (70)	6.54	55.49–81.36
	Intravenous	11 (22)	5.91	12.36–36.06
	In food or water	1 (2)	2.00	0.26–13.69
	Other	3 (6)	3.39	1.86–17.61
Which of the following best describes the application of antibiotics in livestock?	Antibiotics are applied by a veterinarian	20 (40)	6.99	27.06–54.50
	Antibiotics are applied by any person according to the veterinarian's instructions	23 (46)	7.11	32.38–60.24
	Antibiotics are applied according to one's own knowledge of the disease without consulting a veterinarian	3 (6)	3.39	1.86–17.61
	Antibiotics are applied as indicated on the product label	4 (4)	3.87	2.92–20.03

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Statement		Small-scale cattle farmers n = 50 (%)	± SE*	CI 95 % ** Lower upper
Which of the following best describes the management of antibiotics during cattle feeding?	Antibiotics are not administered in the feed	35 (70)	6.54	55.49–81.36
	Antibiotics are administered in the feed to prevent disease (prophylaxis)	2 (4)	2.79	0.95–15.27
	Antibiotics are administered in feed only when animals are sick	13 (26)	6.26	15.44–40.33
	Antibiotics are administered in feed only as growth promoters	0 (0)	00.0	–
Which of the following best describes the management of antibiotics in water?	Antibiotics are not administered in the water	42 (84)	5.23	70.58–91.99
	Antibiotics are administered in the water to prevent disease (prophylaxis)	0 (0)	0.00	–
	Antibiotics are administered in water only when animals are sick	8 (16)	5.23	8.00–29.41
	Antibiotics are administered in the water only as growth promoters	0 (0)	0.00	–
Laboratory tests	Yes	7 (14)	4.95	66.44–27.13
	No	43 (86)	4.95	72.86–93.35
Protocols	Yes	11 (22)	5.91	12.36–36.06
	No	39 (78)	5.91	63.93–87.63
Inventories	Yes	19 (38)	6.93	25.33–52.54
	No	31 (62)	6.93	47.45–74.66
Records	Yes	13 (26)	6.26	15.44–40.33
	No	37 (74)	6.26	59.66–84.55
How do you estimate the body weight of the animal?	Based on your own experience	39 (78)	5.91	63.93–87.63
	Based on the veterinarian's experience	7 (14)	4.95	6.64–27.13
	On a scale	3 (6)	3.39	1.86–17.61
	Animal category (calf, cow)	1 (2)	2.00	0.26–13.69
Estimate dosage	Based on product label (mL/kg)	34 (68)	6.66	53.45–79.72
	Based on active product (mg/kg)	4 (8)	3.87	2.92–20.03
	Based on animal category	5 (10)	4.28	4.09–22.43
	Based on the degree of disease of the animal	5 (10)	4.28	4.09–22.43
	Based on previous results	2 (4)	2.79	0.95–15.27
Duration of treatment	I decide the duration of treatment	2 (4)	2.79	0.95–15.27
	Follow veterinarian's instructions	3 (86)	4.95	72.86–93.35
	Follow the instructions of the seller	3 (6)	3.39	1.86–17.61
	Follow label instructions	2 (4)	2.79	0.95–15.27
Use a second antibiotic	Veterinarian's indication	42 (84)	5.23	70.58–91.99
	Based on previous results	6 (12)	4.64	5.33–24.80
	Someone's recommendation	1 (2)	2.00	0.26–13.69

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Statement		Small-scale cattle farmers n = 50 (%)	± SE*	CI 95 % ** Lower upper
	Microbiological test results	1 (2)	2.00	0.26–13.69
How much time is allowed to elapse between the last application of antibiotics in livestock and the consumption of the milk or meat they produce?	< 24 hours	1 (2)	2.00	0.26–13.69
	1–7 days	5 (10)	4.28	4.09–22.43
	8–14 days	5 (10)	4.28	4.09–22.43
	15–29 days	16 (32)	6.66	20.27–46.54
	> 30 days	22 (44)	7.09	30.58–58.35
	Don't know	1 (2)	2.00	0.26–13.69
Discard of antibiotics vials	Trash	39 (78)	5.91	63.93–87.63
	In some land or specific site	7 (14)	4.95	6.64–27.13
	In a special container	1 (2)	2.0	0.26–13.69
	Someone or a company checks the waste	3 (6)	3.39	1.86–17.61

* Standard error of proportion
** Confidence interval to 95 %

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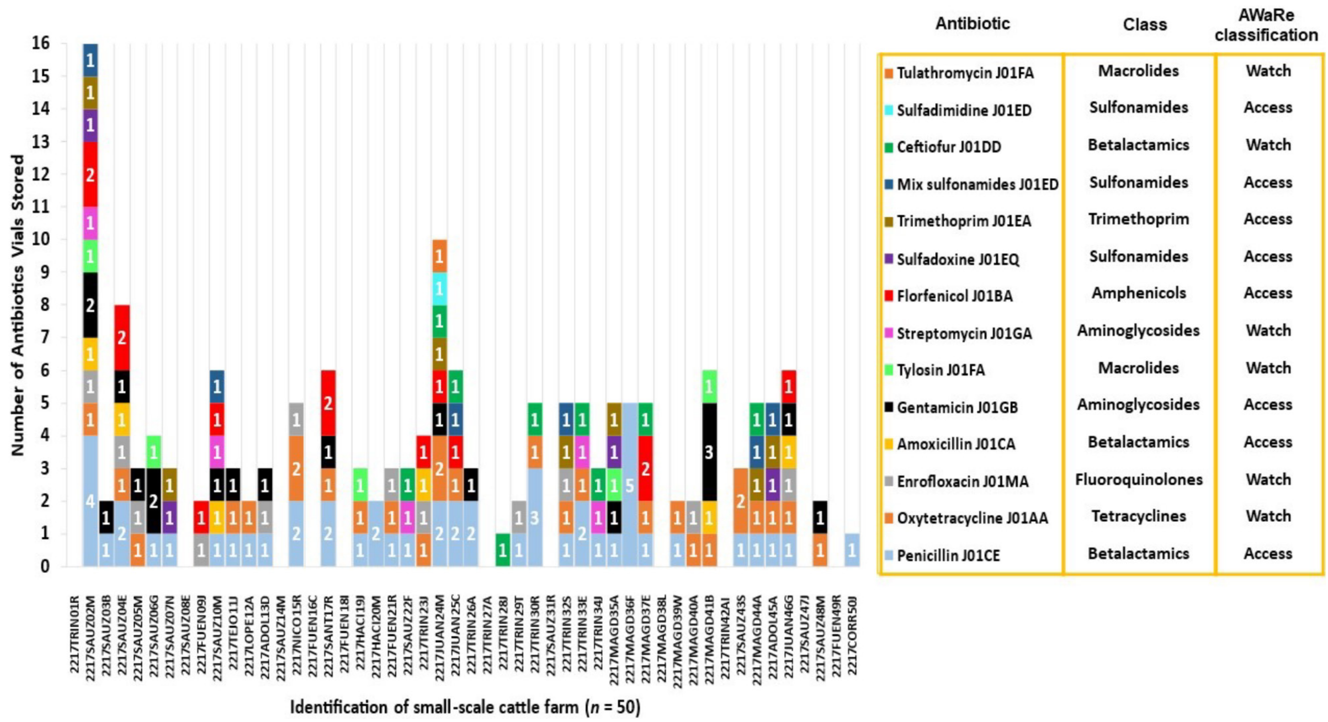

Figure 2. Antibiotics vials stored by small-scale cattle farmers, for use in their animals. AWaRe classification: acronym refers to the WHO's *access-watch-reserve* classification of antibiotics.[20]

Of the thirteen small-scale cattle farmers who did keep animal records, 9/13 recorded the date treatment began, 8/13 the dose, 10/13 the route of administration and 9/13 the duration of treatment, but none documented the clinical diagnosis. Of the seven small-scale cattle farmers who have performed microbiological testing, only one reported receiving antimicrobial susceptibility results and four more have necropsied animals.

During the survey, fourteen producers had at least one sick animal, of which five were associated with digestive infections, two with respiratory infections and one with reproductive infections. In addition, in five of these animals the veterinarian prescribed/applied antibiotics, using 1–2 different antibiotics: mix of three sulfonamides (sulfamethazine-sulfamerazine-sulfadiazine), penicillin G, oxytetracycline, and marbofloxacin). Two small-scale cattle farmers noted the commercial name of the antibiotic used and seven the active substance of the antibiotic. Seven had noted the dose in milligrams/kilogram of body weight, and four more in milliliters/kilogram of body weight, with intramuscular administration, no veterinarian performed antibiograms.

A total of 142 antibiotics stored in small-scale cattle farms were recorded, identifying fourteen active ingredients from nine different classes: penicillin (34 %), oxytetracycline (19 %), gentamicin (13 %), florfenicol (10 %), enrofloxacin (8 %), and sulfadimidine (0.7 %) (Figure 2). It should be noted that twenty-eight of the products had already expired and were still in stock.

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Discussion

This study focuses on the use of antibiotics in small-scale cattle farms in rural areas of the municipality of Tequisquiapan, Queretaro, Mexico. After an exhaustive search of the literature, we found no previous studies, so this would be the first study conducted on a population of small-scale cattle farmers in rural areas of our country. Our research showed that the small-scale cattle farmers had a median age of 58.5 years and 70 % had basic education as the highest level of education completed. This may probably be related to poor knowledge in the use of antibiotics, coupled with a lack of veterinary advice. Similar age characteristics were recorded in a study of dairy farmers in Australia; however, they did not explore the level of education of the participants.(21)

Although the use of antimicrobials in the livestock sector is increasing due to the high demand for animal protein,(10) there are differences in the ways animals are produced and antibiotics are used, because while intensive systems tend to use large amounts of antibiotics prescribed by a veterinarian, extensive production systems tend to use the same classes of antibiotics almost always without veterinary intervention, as observed in this study.

Regarding the antibiotics stored by small-scale cattle farmers, an important use of third generation cephalosporins, tetracyclines, and fluoroquinolones was observed; antibiotics considered "watch" by the World Health Organization (WHO).(20) These results are like those reported by Benavides et al.,(22) who detected in their study the use of oxytetracycline (31 %), penicillin (21 %), gentamicin (19 %) and ceftiofur occasionally. In another study conducted with dairy farmers in Australia,(21) of the antibiotics they had in storage, oxytetracyclines (66 %) and penicillin (62 %) were the most frequent, these results are similar to those found in our work. On the other hand, a study conducted with dairy farmers in the United Kingdom (2018), penicillin was the main class of antibiotics used (58.3 %), followed by aminoglycosides (47 %), and in smaller proportion tetracyclines (3 %) and fluoroquinolones (0.6 %), results that differ from our study because they are intensive production systems focused on milk production.(23)

However, the way in which antibiotic consumption is monitored in animals is different in each region, so results may not be comparable due to variable analysis based on quantity (dose) or antimicrobial application (frequency of treatment), although "quantity" describes antibiotic consumption, it does not provide detailed information on treatment.(13) For example, enrofloxacin, which are used in a lower dose compared to penicillin, may be undervalued, which would imply that quantification of the amount of antibiotics used should be explored beyond the mere quantitative variable.(16)

Although some authors have defined different variables to determine antibiotic consumption;(13) due to the type of study population and extensive production systems, it is almost impossible to determine the amount of antibiotics used in animals with the variable defined daily dose per animal (DDDA), due to the absence of clinical records in this livestock sector. However, the data obtained evidenced the absence of a defined dose based on the body weight of the animal, establishing this dose based on the experience of the farmers to estimate a body weight of each animal to be treated, therefore, the actual dose administered does not always correspond to the recommended dose.

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The existing legislation in Mexico regarding the prescription and sale of antimicrobials in the agricultural sector contemplates the Mexican Official Standard NOM-064-ZOO-2000, *Guidelines for the classification and prescription of veterinary pharmaceutical products by the risk level of their active ingredients*, however our results evidenced the commercialization of antimicrobials without a medical prescription.(17) About 50 % of the antibiotics stored by small-scale cattle farmers had a "watch" classification in the WHO AWaRe tool (Access, Watch and Reserve) for the selection and use of antibiotics.(20)

Ideally, antibiotics used in the livestock sector should not be related to antimicrobials used mainly in human medicine, the responsibility for the development of clinical diagnostic protocols, as well as the prescription of antimicrobials lies on the one hand with veterinarians, and on the other hand with those responsible for sales, who must comply with current legislation to supply antimicrobials with medical prescription to farmers.(17)

The development of national guidelines alone does not guarantee that the recommendations issued in standards or guidelines will be implemented in veterinary practice, so it should be carried out through a managed and adequate antimicrobial plan between prescribers (veterinarians) and antibiotic use by farmers. Therefore, it would be necessary to provide farmers with economic protocols and diagnostic tests that facilitate discrimination between causative agents and their antimicrobial susceptibility profiles, which help to improve the use of antimicrobials in each context, in addition to training programs on the use, dosage and adverse consequences of inappropriate use of antibiotics as an important aspect to be addressed in their production practices.(1–3, 12)

An important point to highlight in our study is the exploration of how small-scale cattle farmers dispose of empty antibiotics vials, since a high proportion of farmers deposit their vials in the trash, which represents a risk to the environment due to spreading antibiotic residues to the soil and bodies of water.(1, 4) This study has the limitation of not obtaining information from medical records, because they are not used in this context; however, it reflects that in this population antimicrobials are not used as growth promoters, but as an element to keep the animal alive. In addition, the survey included questions that may have resulted in biased reporting due to perceived "appropriate" responses rather than actual behaviors or opinions.

Conducting this research in an unattended sector of animal production (small-scale cattle farmers in rural areas) is the beginning of small local actions that will translate into regional efforts. Although there are still few studies on the subject in the rural sector, some authors report a decrease in antibiotic use due to training interventions with small-scale farmers.(24) Training of the different actors who prescribe and use antibiotics will undoubtedly be a key step to improve the use of antibiotics.

Conclusions

This study showed that small-scale cattle farmers had an important use of third generation cephalosporins, tetracyclines, and fluoroquinolones; antibiotics considered "watch" by the World Health Organization. Small-scale cattle farmers request the services of a veterinarian mainly when animals are sick, which means that

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veterinarians indicate which antibiotics to buy, how to apply them and the timing of treatment. Therefore, the use of antibiotics in small-scale cattle farmers has curative purposes for the animals. The studies on the use of antibiotics in small farms can generate evidence that can contribute to propose guidelines aimed at improving the use of antibiotics and thereby decreasing the impact of antimicrobial resistance.

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Data availability

The data set associated with this research is available in the SciELO Data repository doi: 10.48331/scielodata.QBT2OA.

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Conflicts of interest

The authors have no conflict of interest to declare regarding this publication.

Author contributions

Conceptualization: M Galarde-López, BY Cruz-Monsalvo, ME Velazquez-Meza, JA Carranza-Velázquez.
Data curation: M Galarde-López, BY Cruz-Monsalvo, SC Herrera-García.
Formal analysis: M Galarde-López, BY Cruz-Monsalvo, ME Velazquez-Meza.
Investigation: M Galarde-López, BY Cruz-Monsalvo, FA Zumaya-Estrada.
Methodology: M Galarde-López, BY Cruz-Monsalvo, ME Velazquez-Meza, JA Carranza-Velázquez, FA Zumaya-Estrada.
Project administration: ME Velazquez-Meza, CM Alpuche-Aranda.
Resources: M Galarde-López, BY Cruz-Monsalvo, JA Carranza-Velázquez.
Software: M Galarde-López, BY Cruz-Monsalvo, BA Carrillo-Quiroz, SC Herrera-García.
Supervision: M Galarde-López, ME Velazquez-Meza, JA Carranza-Velázquez, CM Alpuche-Aranda.
Validation: M Galarde-López, ME Velazquez-Meza, JA Carranza-Velázquez, FA Zumaya-Estrada, CM Alpuche-Aranda.
Visualization: M Galarde-López, BY Cruz-Monsalvo, BA Carrillo-Quiroz, SC Herrera-García.
Writing-original draft: M Galarde-López, BY Cruz-Monsalvo, ME Velazquez-Meza, JA Carranza-Velázquez, FA Zumaya-Estrada, BA Carrillo-Quiroz, SC Herrera-García, CM Alpuche-Aranda.
Writing-review and editing: M Galarde-López, BY Cruz-Monsalvo, ME Velazquez-Meza, JA Carranza-Velázquez, FA Zumaya-Estrada, BA Carrillo-Quiroz, SC Herrera-García, CM Alpuche-Aranda.

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