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Gastrointestinal nematodes in sheep and their anthelmintic resistance. A subject under discussion in Mexico

Nematodos gastrointestinales en ovinos y su resistencia antihelmíntica. Un tema en discusión dé México

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Abstract

Sheep production in Mexico represents an economically important livestock activity, which is developed under different production systems, depending on the region of the country where the production unit is located. Sheep farming, like other livestock activities, has limitations associated with infectious diseases, such as parasitic diseases caused by gastrointestinal nematodes, which have a negative impact by generating high mortality rates and reducing productive and reproductive parameters. The basic control strategy is based on the use of anthelmintic drugs derived from benzimidazole, macrocyclic lactones and imidazothiazoles, currently, the effective use of this type of drugs is threatened and restricted by the increase in populations of resistant gastrointestinal nematodes (*Haemonchus* spp., *Cooperia* spp., *Oesophagostomum* spp., *Trichostrongylus* spp., *Teladorsagia* spp., *Chabertia* spp., *Ostertagia* spp., and *Nematodirus* spp. The purpose of this review was to analyze the current situation of resistance to anthelmintics in gastrointestinal nematodes in sheep in different regions of Mexico, in order to show their resistance, distribution and prevalence.

Resumen

La producción de ganado ovino en México, representa una actividad pecuaria importancia económica, que se desarrolla bajo diferentes sistemas de producción, dependiendo de la región del país donde se encuentre la unidad de producción. La ovinocultura como otras actividades pecuarias presentan limitaciones, asociadas a enfermedades infecciosas, como las parasitarias, causadas por nematodos gastrointestinales, que impactan de forma negativa, al generar altas tasas de mortalidad y disminuir parámetros productivos y reproductivos. La estrategia básica de control se sustenta en el uso de fármacos antihelmínticos derivados del bencimidazol, lactonas macrocíclicas e imidazotiazoles, actualmente, el uso eficaz de este tipo de fármacos se ve amenazado y restringido por el aumento de poblaciones de nematodos gastrointestinales resistentes (*Haemonchus* spp., *Cooperia* spp., *Oesophagostomum* spp., *Trichostrongylus* spp., *Teladorsagia* spp., *Chabertia* spp., *Ostertagia* spp., y *Nematodirus* spp.) distribuidos en el territorio nacional. La presente revisión tuvo como propósito analizar el panorama actual de la resistencia a

Palabras clave:

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ovinos,
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antihelmínticos en nematodos gastrointestinales de ovinos en las diferentes regiones de México, con la finalidad de evidenciar su resistencia, distribución y prevalencia.

Introduction

Sheep farming is one of the most important livestock activities in the world, due to the production of meat for human consumption, constituting an important source of nutrients such as proteins, vitamins, minerals, etc[1].

In Mexico, the climatological characteristics allow the implementation of different sheep production systems, according to the geographical regions of the country, even in adverse weather conditions, which prevent the practice of other livestock activities[2].

Environmental factors, such as climate, humidity, season and region play an important role in the availability of vegetation, which can be used as a forage resource to reduce feed costs, however, they are a determining factor in the prevalence of parasitosis in sheep production units (PU), favoring their development and permanence in the available pastures[3].

Parasitosis in sheep represents one of the main sanitary problems worldwide, directly affecting young animals, limiting their growth and, in adults, their productivity[4]. Gastrointestinal nematodes (GIN) generate limitations in animal health and production, since these parasites present biological characteristics, such as high prolificacy, adaptability and resistance to adverse climatic conditions, which favor their high prevalence[5].

In most PUs, the use of anthelmintic drugs (AH) represents one of the most effective tools in the control of GIN. The appropriate and rational use of these drugs allow animals to express their productive potential, avoiding economic losses due to nematodiasis. The rapid development of GIN populations with AH resistance is a threat that affects the efficacy of these drugs as parasite control tools. Therefore, it is imperative to monitor the development and spread of resistant parasite populations in different parts of the world[6].

The high efficacy of chemical AH drugs in parasite control promoted their continued use in PUs[7]. Thus, the implementation of chemical control as the only strategy resulted in the gradual loss of the AH effect, developing parasite populations with anthelmintic resistance (AR)[8].

AR is a generational phenomenon, in which the drug decreases its efficacy at concentrations at which it normally has an effect on a susceptible parasite population[9]. The loss of GIN susceptibility to the drug is associated with genetic and biochemical modifications that allow the parasites to survive and transmit resistance alleles to their progeny, which represents an increase in nematode populations with resistance alleles[1].

Based on the above, a literature review on AR in GIN in sheep in Mexico was proposed. A search was carried out in the following databases: Google Scholar, Redalyc, SciELO and Scopus, considering a publication period between 1968 and 2020. The keywords used were nematodes, AH, resistance. Publications

with incomplete data or irrelevant papers were eliminated. Full-text documents with information about AR in GIN in sheep in Mexico were reviewed and analyzed.

Development

Parasitic diseases in sheep. In Mexico, parasitic diseases are among the most frequent and important, since they cause biological and economic inefficiency in livestock systems, affecting productive parameters[10]. The causative agents of gastrointestinal parasitosis in small ruminants are diverse, so their biological behavior and effects on the animal depend on the parasite involved[11].

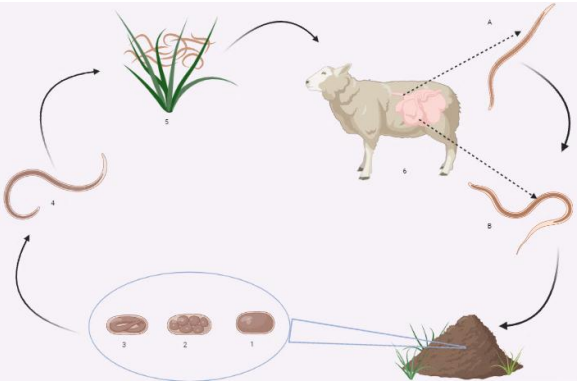
A parasitic disease is the consequence of an imbalance between the agent, host and environment, generating characteristic clinical manifestations. It has been documented that the use of antiparasitic drugs not only has an impact on parasitosis in the host, but also has a negative impact on free-living nematode populations, generating an environmental modification[12].

In general, parasites that affect sheep are categorized into two large groups, i) external parasites and ii) internal parasites. For the latter group, it is considered necessary to carry out periodic sampling of feces, at least once a month, to determine the behavior of parasitosis and identify the ideal time for the administration of antiparasitic treatment[13].

Sheep suffer from severe helminth infections, being more evident in young animals, due to the lack of development of some immunological processes[14]. One of the most pathogenic nematodes, *Haemonchus* spp. migrates in L_3 phase to the gastric mucosa walls, and from there, it feeds as an adult worm[10]. Other genera such as *Cooperia* spp., *Ostertagia* spp., *Trichostrongylus* spp., *Teladorsagia* spp., and *Oesophagostomum* spp., are of similar importance, given their effect on other sections of the gastrointestinal tract[15].

The order Strongylida has morphological characteristics such as buccal capsule, reproductive apparatus, lobes of the copulatrix bag and the shape of the cuticle ridges, which allow inferring their kinship, in addition, they have tropism for the abomasum, where they establish themselves to feed on the host's blood, causing notable anemias in a period of 10-12 days[16].

Figure 1 NGI life cycle: morulated egg (1), embryonated egg (2), first instar larva (3), second instar larva (4), third instar larva or infective larva (5) and fourth instar larva or adult (6)



The life cycle of nematodes corresponds to the monoxenous type (Figure 1), i.e., it has no intermediate hosts. This cycle comprises the following stages: morulated egg (1), embryonated egg (2), first instar larva (3), second instar larva (4), and third instar larva or infective larva (5).

During this stage, the infective larvae maintain their second instar larval cuticle, conferring resistance to environmental factors, which allow their survival for more than 1 year in pastures. If the temperature and humidity conditions are optimal, they move by means of hydrotropism, arriving from the soil to the tip of the pasture by means of water droplets located on the surfaces of the pasture, and are thus ingested by a sheep[16].

After being ingested, the infecting larvae penetrate the gastrointestinal mucosa, where they undergo a final ecdysis to fourth stage larvae (6), inside the abomasal mucosa, in the case of *Teladorsagia* and *Haemonchus* (6B), or in the small intestine, in the case of *Nematodirus* spp., *Trichostrongylus* spp. or *Cooperia* spp. Adults located in the target organ live an average of 1-3 months, depending on the nutritional status, physiological stage, and immune response of each animal[17].

Parasitosis by GIN generally occurs in mixed infections, mainly associated with climatic regions. As a result of the invasion of both the abomasum and intestine, a parasitic gastroenteritis is generated, which can cause the death of the affected animals, or alter animal welfare conditions[18].

Parasitic gastroenteritis in clinical phase is characterized by watery diarrhea, opaque coat, anorexia, anemia and general loss of body condition. However, in subclinical cases, the effects of GIN are evidenced with a negative impact on productive parameters, with low milk production, low weight gain, and retarded growth of the animals, without showing the characteristic clinical signs[19].

Main nematodes in sheep, according to their geographical location in Mexico. The southeast of Mexico is characterized by warm climates with a subdivision into warm humid and warm sub-humid, the relative humidity and temperature are factors that favor the development of parasites in PU[2].

González-Garduño et al.[20] conducted a study on 242 animals in a slaughterhouse in the state of Tabasco, and found that 57.4 % of the animals were parasitized with some genus of parasite. The main nematode species identified were *Haemonchus contortus* in the abomasum, *Cooperia curticei*, *Trichostrongylus colubriformis*, *Strongyloides papillosus* and *Bunostomum trigonocephalum* in the small intestine. *Oesophagostomum columbianum* and *Trichuris ovis* in the large intestine. The three main ones were: *H. contortus*, *O. columbianum* and *T. colubriformis* with average counts of more than 1009, 813 and 335 adults, respectively.

López-Ruvalcaba et al.[21] analyzed the gastrointestinal contents of 122 sheep from different municipalities of Villahermosa, Tabasco, considering aspects such as age, gender, physiological state and month of sampling, in the count of total adult nematodes and by species. The nematode species reported were: *H. contortus*, *T. colubriformis* and *C. curticei*. In addition, the presence of the cestode *Moniezia expansa*. In sheep from 31 to 36 months of age, the parasite loads determined, by GIN count (49±143) were lower than in animals of all other ages, concluding that the age factor may influence the prevalence of this type of parasites.

Under this scheme, Hernández-Rojas et al.[22] analyzed the prevalence of GIN, as well as the genera present in grazing sheep at the beginning of the dry season in the upper part of the municipality of Cuetzala del Progreso, Guerrero, Mexico, the authors determined a nematode prevalence of 77.63 %, reporting the elimination of 595 eggs per gram of feces (HPG). The genera of GIN identified were: *Haemonchus* spp., 32 %, *Cooperia* spp., 30 %, *Trichostrongylus* spp., 17.33 %, *Oesophagostomum* spp., 13.67 % and the genus *Strongyloides* spp., 7 %, concluding that grazing sheep at the beginning of the dry season presented a high prevalence of GIN, with the predominant genera being *Haemonchus* spp., and *Trichostrongylus* spp.

In the northern zone of Mexico, parasitosis have a behavior linked to the different climatic conditions and even less than optimal conditions for their development, inferring that the low prevalence of nematodes present in sheep is due to a break in the life cycle, as mentioned by Medina et al.[23] who determined that the season of sampling, as well as the geographic

region, influence the prevalence of parasites, the species present and the frequency of infected animals.

There are few reports on the identification of GIN in sheep in this area; however, cases of endoparasites of bighorn sheep, considered an ecologically important species, have been reported in the state of Baja California Sur, according to León-Frias[24] who identified 5 species of endoparasites, including *Skrjabinema ovis*, a nematode that also has the capacity to infect domestic sheep.

For the central region, some reports have been made, such as that of George-Sánchez & Quiróz-Romero[25], who observed the presence of GIN, pulmonary and hepatic in sheep in the municipality of Soltepec, 85 % of the samples were positive for the protozoan *Eimeria* spp., the species were: *E. ovina* 45.55 %, *E. ashata* 11.86 %, *E. ovinoidalis* 8.86 %, *E. faurei* 5.88 %, *E. parva* 7.23 %, *E. granulosa* 6.96 %, *E. pallida* 4. 04 %, *E. ninakohlyakimovae* 3.39 %, *E. crandallis* 2.74 % and *E. punctata* 1.14 %, the amount of oocysts per gram of feces (OPG) ranged from 498 to 3333. Regarding nematodes, 68.12 % of the sheep were positive for strongyloides, 30 % for *S. papillosus*, 9.31 % for *Trichuris* spp., 8.75 % for *Nematodirus* spp., 21.25 % for *Dictyocaulus filaria*, 5 % for *Muellerius capillaris* and 19.37 % for *Fasciola hepatica*. The average HPG of nematodes ranged from 73.75 to 1695.25. The nematode genera identified were: *Haemonchus* spp., 40 %, *T. axei* 25 %, *Ostertagia* spp., 11.7 %, *Oesophagostomum* spp., 9.7 %, *Cooperia* spp., 4.5 %, *Bunostomum* spp., 2.5 %, *Nematodirus battus* 2 %, *Strongyloides papillosus* 1.5 % and *Nematodirus spathiger* 1 %.

Soca et al.[26] carried out a study in sheep in Villa del Carbon, State of Mexico, and identified infective larvae of nematodes, determining that 46 % corresponded to *Haemonchus* spp., 25 % to *Cooperia* spp. Montalvo-Aguilar & de Gives[12] identified the most prevalent nematodes in the northeastern region of the state of Tlaxcala, sampling 21 herds, identified *Haemonchus* spp., *Teladorsagia* spp., *Trichostrongylus* spp., *Cooperia* spp, and *Nematodirus* spp.

As evidenced in the studies described above, the presence of mixed infections by GIN in sheep is directly influenced by the climatic conditions prevailing in the different regions, the characteristics of the host (age, gender, breed, etc.) and the sanitary management implemented in each PU, which explains the variations in the epidemiological patterns that have been reported in the different regions of Mexico[27].

Environmental factors, such as humidity and temperature, govern the geographical distribution, as well as the prevalence of infective larvae of GIN. For this reason, in areas with tropical climates, mainly in summer, an increase in the prevalence of these parasites is observed. However, in recent years, the effects of climate change have generated environmental alterations that favor the adaptation process of GIN and, therefore, their prevalence. The adaptation process is associated with the high genetic diversity they possess, thus increasing the biotic potential of GIN, allowing their survival and dissemination in geographic areas considered to be at low risk[16].

In regions close to the equatorial zone, such as the south-southeast region of Mexico, high temperatures and constant humidity favor the development and permanence of infective larvae of GIN in pastures throughout the year[28]. On the other hand, cold and arid regions have extreme environmental conditions that restrict the development of GIN on an annual basis, thus, the risk decreases as latitude increases. Cases of nematodiasis in these regions are of minor importance because the favorable conditions for their development are brief, preventing their survival for prolonged periods[29].

The economic losses associated with nematodiasis vary between regions and seasons of the year, depending on the environmental conditions, as well as

the efficiency of the parasite control measures implemented in the PU. The economic impact can be direct, causing the death of animals, or indirect, negatively impacting productive or reproductive parameters, such as weight gain, feed conversion and fertility[16]. The economic impact on PUs is often exacerbated by poor animal feeding and increasing drug resistance[30].

The use of highly effective commercial AH, recommended for parasite control, was aimed at maximizing herd health, productivity and profitability, and although it was successful for several years, nowadays increasing levels of resistance are being experienced, which have become generalized in different regions of Mexico, mainly due to the mobilization of livestock[19].

Resistance of GIN in sheep. Diseases caused by nematodes in sheep PU are associated with various long-term clinical complications. Infections can occur in any area of the body, depending on the target organ; in the case of GIN, they affect various organs of the gastrointestinal tract[30].

The efficacy of available AH is limited by evolutionary, ecological and dietary factors, thus the availability and use of AH is restricted and threatened by increasing drug resistance in nematode populations[31]. Three classes of AH are routinely administered in PU against nematode infections: benzimidazoles (BZ) (mebendazole, fenbendazole and albendazole), macrocyclic lactones (LM) (ivermectin and moxidectin) and imidazothiazoles (IMZ) derivatives (levamisole)[8], against which previous studies have reported a decrease in their efficacy. mentioned that the introduction of Pelibuey sheep and their crosses with Dorper and Kathadin improve productive parameters, but increase their susceptibility to GIN, leading to the frequent use of chemical AH in the south-southeast region of Mexico.

Gonzales-Garduño et al.[20] when evaluating the in vitro and in vivo efficacy of albendazole, levamisole and ivermectin, the three main AH used in the control of GIN in sheep, observed that levamisole presented 30 % efficacy against a monospecific strain of *H. contortus*, on the other hand, a mixture of albendazole + levamisole, presented 65 % efficacy and ivermectin 87 % efficacy. This loss of efficacy is evidence of the degree of resistance that has been gradually generated to different drugs, reducing the therapeutic resources for parasite control.

Nematodes possess biological and genetic characteristics that favor the development of AR populations such as short life cycles, high reproduction rate, high evolution rate and extremely high population sizes, producing generational genetic mutations[33].

The gradual emergence of resistance occurs within a population in response to chemical exposure exerting selective pressure, killing susceptible parasites, but allowing others with a degree of resistance to survive. However, the speed and extent of resistance is influenced by other factors, such as the intensity of use of drugs from a single family, under- or over-dosing, lack of management in the processing of animal feces, as well as government regulation in the sale of AH drugs[34].

Table 1 presents cases of AR in Mexico, and shows its distribution in the northern, central and southern regions of the country, considering a period between 2003 and 2009, highlighting that the group of AH mostly applied throughout the country belong to the group of LM, BZ and, to a lesser extent, levamisole hydrochloride. The most prevalent genera were *Haemonchus* spp., *Cooperia* spp., *Oesophagostomum* spp., and *Trichostrongylus* spp. The least prevalent genera with respect to geographical distribution were *Teladorsagia* spp., *Chabertia* spp., *Ostertagia* spp., y *Nematodirus* spp.

Mechanisms involved in the development of resistance to anthelmintics. A series of elements are involved, such as increased production of hydrolytic enzymes, modification of the active site, decreased membrane permeability and increased reflux pumps[45].

Table 1 Cases of anthelmintic resistance distributed in Mexico

Location	Anthelmintic	Genres	Author
Yucatán	Bencimidazoles Levamisol	*Haemonchus* spp. *Trichostrongylus* spp. *Oesophagostomum* spp.	[35]
Huimanguillo, Tabasco	Bencimidazoles	*Haemonchus* spp. *Ostertagia* spp. *Oesophagostomum* spp.	[36]
Campeche	Bencimidazoles Lactonas macrociclicas	*Trichostrongylus*	[37]
Chiapas	Albendazol Levamisol Ivermectina	*Haemonchus contortus* *Cooperia curticei*	[38]
Veracruz	Levamisol	*Cooperia* spp. *Haemonchus* spp. *Ostertagia* spp. *Oesophagostomum* spp.	[39]
Campeche	Ivermectina Albendazol Levamisol	*Cooperia* spp. *Haemonchus* spp. *Oesophagostomum* spp.	[40]
Texcoco Puebla Morelos	Albendazol Closantel	*Cooperia* spp. *Haemonchus* spp. *Teladorsagia* spp. *Oesophagostomum* spp. *Trichostrongylus* spp. *Chabertia* spp. *Nematodirus*	[41]
Tabasco	Bencimidazoles Imidazoles Lactonas macrociclicas	*Haemonchus* spp. *Trichostrongylus* spp. *Oesophagostomum* spp.	[42]
Estado de México	Albendazol Ivermectina	*Cooperia* spp. *Trichostrongylus colubriformis* *Haemonchus* spp.	[43]
Huasteca Potosina	Lactonas macrociclicas Bencimidazoles Imidazotiazol	*Haemonchus* spp. *Trichostrongylus* spp. *Oesophagostomum* spp. *Cooperia* spp.	[44]

The BZ are the first models studied with respect to resistance; these AH are a group of broad-spectrum drugs used in both humans and animals, especially in small ruminants for approximately 40 years[46].

The manifestation of resistance to this group of drugs is linked to changes in the gene that encodes the target receptor (β-tubulin). These act by binding to the tubulin of the nematodes, altering the balance of the microtubules and causing their depolymerization, thus immobilizing and killing the helminth[30].

In the research conducted by Chaudry et al.[46], determined the diversity of β-tubulin resistance mutations, BZ of isotype 1, the genetic structure of *H. contortus* from sheep and *Haemonchus placei* from cattle in the southern United States, a low level of genetic differentiation was observed in 6 populations of *H. placei* and 7 of *H. contortus* analyzed, which allowed inferring that there is a high gene flow between parasite populations. It appears that variations in DNA sequences differ at the species level in nematodes. Thus, characterization of genetic markers to differ between genetically close species becomes more complex, an example of which is the described codon 167 in *Trichostrongylus circumcincta* and not in resistant *T. colubriformis*[47].

It has been pointed out that the amino acid codons

(167, 198 and 200) are important residues in the BZ binding pocket, and their effect on drug sensitivity has been functionally proven[48].

IMZs act as cholinergic agonists at nicotinic acetylcholine receptors of nematode neuromuscular junctions causing depolarization and spastic paralysis. Mutations conferring parasite resistance are mediated through the disappearance of acetylcholine receptors, although physiological mechanisms and the formation of polymorphisms are likely to differ among resistant parasites[49].

Strains of *H. contortus* and *T. colubriformis* resistant to levamisole, morantel and pyrantel have been reported, which, although they are different drugs, have the same mechanism of action on susceptible helminths[50]. In this regard, Martin et al.[51] suggested that the normal function of the levamisole receptor is modified, i.e., the active channels of the resistant nematodes remain open for a shorter time and thus, there is less depolarization and consequently less contraction.

Resistance to levamisole is widely distributed in the world and represents a serious problem that limits the treatment of helminths. However, resistance to this drug is difficult to find in nematodes such as *H. contortus*, but common in *T. colubriformis* and *Oesophagostomum* spp. Therefore, the slow spread of resistance in parasites such as *H. contortus* can be explained by the autosomal recessive nature, and possibly determined by more than one gene[52].

Becerra-Nava et al.[39] reported that the percentage of PU with levamisole-resistant GIN in the state of Veracruz was 34 %, only 3 PU had GIN populations susceptible to levamisole. The genera that exhibited resistance to the drug were *Cooperia* spp. the most resistant genus, followed by *Haemonchus* spp., *Ostertagia* spp., and *Oesophagostomum* spp. Over the years, new drugs were developed to control helminthiasis and replace drugs that had lost their effectiveness, which led to the introduction of LM[53].

LM are high affinity agonists on glutamate receptors, associated with chloride channels and GABA (γ-aminobutyric acid) receptors, attenuating their activity. This causes a concentration of chloride ions, hyperpolarization of the nematode neuron and thus causes paralysis of the parasite[31].

Chloride channels are composed of 5 protein subunits, 3 subunits a, b and c combine to form the pentamer. GluCl receptors are located mainly in somatic muscle cells, pharyngeal pump and uterus, so that exposure of the target parasite to LM affects motility, feeding capacity and fecundity[54].

It seems that resistance would be associated with mutations of 2 subunits of the chloride channel in the resistant parasite, although in the same species such as *H. contortus*, differences between polymorphisms have been reported. Some authors have described the role of the GluCl receptor in the development of resistance to LM[44].

As a general rule, long-acting drugs are more likely to select for resistance than short-acting drugs, as are the most effective drugs, because during the elimination phase, the parasites are exposed to a gradual decrease in the concentrations reached by the drug in persistence, which would allow the establishment of resistant infective larvae, while susceptible larvae are eliminated[53].

Currently, the use of AH continues to be an important pillar in the control of parasites, due to its practicality, however, it is imperative that its frequency of use has a decrease in the PU. To achieve a decrease in the frequent use of AH, it is important to consider that the drug may vary according to the category of animals to be treated, the species of parasites involved, time of year, presence or absence of shelter, toxicity, drug residues and susceptibility or resistance to the drugs in each geographical region[56].

From the ecotoxicological point of view, all drugs

represent a risk of contamination for non-target organisms. AHs are currently not exempt from the risks associated with their presence and circulation in the environment. Therefore, it is necessary to emphasize the negative impact that revolves around anthelmintic therapy[30].

Conclusion

AR is a problem that has worsened in the last decade worldwide, due to the lack of technological development, which has not reduced the use of drugs in the control of nematodiasis in sheep. This review allows us to assess the current situation in Mexico with respect to the distribution of AR cases in GIN in different geographical regions of the country.

The implementation of the chemical control strategy seemed to have solved many of the problems associated with the control of GIN in PU, using broad-spectrum AH such as BZ, LM and IMZ derivatives, which during the first decades of use had a remarkable effect in the control of parasitosis. However, in the last 10 years there has been a gradual resurgence of problems associated with GIN, but now with resistance to drugs used years ago. As a consequence, resistance developed through genetic-evolutionary mechanisms allows the survival of NGI that have a negative impact on animal production, PU profitability, food safety and the environment.

Parasitosis caused by AH-resistant NGI in sheep PU are distributed throughout most of the Mexican territory, with a greater presence in the south-southeast region of Mexico, due to the favorable environmental conditions of the region (humidity and temperature). The most prevalent genera reported are *Haemonchus* spp., *Cooperia* spp., *Oesophagostomum* spp., and *Trichostrongylus* spp., and with lower prevalence; *Teladorsagia* spp.

Currently in Mexico and in the world, integrated parasite control should be the strategy of choice to control infections caused by GIN, limit the development of resistance, avoid the circulation of anthelmintics that cause damage to non-target organisms, favor animal production and guarantee food safety.

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Conflicts of interest

The manuscript was prepared and reviewed with the participation of the authors, who declare that there is no conflict of interest that could jeopardize the validity of the presented results.

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Ethical considerations

The research complied with the ethical standards of the information process.

Authors' contribution to the article

Los autores realizaron el levantamiento de la información y recopilación bibliográfica, así como revisión y redacción del artículo final.

Research limitations

The authors point out that there were no limitations in the present research work.

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