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Transporters knowledge towards pre-slaughter logistic chain and occupational risks in Mexico: An integrative view with implications on sheep welfare

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Abstract

Using a survey, we aimed to investigate Mexican transporter knowledge towards pre-slaughter logistic chain and occupational risks and secondly, to quantify how transport can affect sheep welfare. We used univariate and multivariate statistics based on cluster analysis. According to a cluster analysis, the incidence of risks varied with the association between transport, pre-slaughter logistic operations and journey distance. Cluster 1 included long distance journeys (LDJ), cluster 2 medium distance journeys (MDJ) and cluster 3 short distance journeys (SDJ). In MDJ the collection points were quite varied compared to the LDJ and SDJ groups, which were always in the north or central regions, respectively. The LDJ group used pot-belly trailers or 10 ton (t) to 16 t lorries, the MDJ group preferably used 10 t to 16 t lorries and group SDJ used 3.5 lorries or pick-ups. Most of the accidents were grouped in SDJ, which also included transporters who smoked most and drank coffee as a countermeasure for sleepiness. The MDJ group loaded more animals at the farm, while the other two groups mostly collected animals at assembly centres or auction markets. Results suggest the existence of three types of journey distances, most of the road accidents were grouped in long distance journeys. It is critical for everyone engaged in welfare promotion along the pre-slaughter logistic chain to recognize the links between human well-being, animal welfare, and the environment, and to know that the way sheep are transported can have broader One-Welfare implications.

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1. Introduction

In recent years, the interest in health and safety in the workplace has increased (Cecchini et al., 2018). Animal production represents a high-risk occupation, responsible for several thousand worker injuries and fatalities worldwide per year (Irwin and Poots, 2015). The main occupational hazards which can have an impact on transporters safety are relatively well known, including; interaction with animals, driving, sleeplessness and physical effort. In this context, a multidisciplinary approach is essential to understand the complex relationships between people and animals during livestock transport. One-Welfare is an integrative concept that asks us to confront the most contentious and important questions of ethics, science, production, health, economics, and politics (Colonius and Earley, 2013). This concept also recognises the interconnections between human wellbeing, animal welfare and environment balance (Pinillos et al., 2016), although it does not directly refer to the well-being of stock-people, transporters and operators. In this article we make an extension to the definition of One Welfare as standards that promote the welfare of farm animals, prevent or reducing occupational hazards that may affect livestock workers (farmers, stock-people, transporters and abattoir operators), promote sustainability in animal production and generate an integrative vision of the human-animal relationship (Miranda-de La Lama, 2018).

Transportation is generally regarded as an exceptionally stressful period in the life of an animal, and there is an increasing public interest in and concern for the welfare of transported livestock (Padalino et al., 2015). During transport, animals are exposed to a range of potential stressors such as handling and human contact, loading and lairage, different or unfamiliar environments, food and water deprivation, alterations in weather conditions, noise and environmental pollutants, and also changes in social structure through separation, mixing and crowding (Miranda-de la Lama et al., 2014). Sheep production is one of the fastest growing food-producing sectors in Mexico. This is mostly motivated by a higher demand for lamb meat in the central states of Mexico, where they consume the traditional sheep dishes. Additionally, in recent years, the number of sheep abattoirs has decreased and become more centralized, increasing transport times. As a result, the pre-slaughter logistic chain for sheep production in Mexico is

now longer and possibly more detrimental for transporters and animals, including breeding farms, feedlots, collecting points, markets and abattoirs (Miranda-de la Lama et al., 2018).

Much has been learned about stress during transport, but less attention has been paid to identifying and correcting risk factors from the point of view of interactions between transporters and animals, partly because they vary widely both nationally and internationally (Marahrens et al., 2011). Consequently, animal welfare during transport can depend on the attitudes and training of handlers and transporters and on the availability of appropriate facilities (Burnard et al., 2015). Notwithstanding the fact that livestock drivers play an essential role in protecting animal welfare throughout the pre-slaughter logistic chain, and can be held legally responsible, there is limited information about this group of transporters in the scientific literature (Miranda-de La Lama et al., 2010). Studies on risk perception of transporters are often referred to as specific risk factors as traumatic accidents, but the risk perception plays an important role in preventing every kind of accident, occupational disease and the welfare of transported animals. Little is known of the occupational exposures, risk factors and their associated adverse health outcomes among sheep transporters, particularly from emergent countries. Therefore, we aimed to investigate Mexican transporter knowledge regarding transport and pre-slaughter logistic operations, and secondly, to quantify how journey distance affects occupational risks of transporters and animal welfare.

2. Material and methods

The survey was carried out in the municipality of *Capulhuac* (19°12′N 99°28′W; 2700 m.a.s.l.) in the State of Mexico (central plateau of Mexico). The survey period was from May to September 2016. The first article in this series study the transporters perceptions and attitudes towards animal welfare and their influence in logistics practices in sheep transport (see Pulido et al., 2018), and this article integrates the knowledge of transporters about Mexican pre-slaughter logistic chain and occupational risks and its impact on sheep welfare. In Mexico, sheep are slaughtered, and meat is processed in the central area of the country, mostly because of the high demand in Hidalgo and Mexico City where sheep meat is consumed as a traditional dish called *"barbacoa"*. The *Capulhuac* municipality is the largest sheep producer with approximately 400,000 head slaughtered per year, 600 small-scale slaughterhouses, 300 sheep meat retailers

and 115 professional transporters. There are eight specialized abattoirs, while 60% of the animals are slaughtered in small abattoirs and even at homes. We obtained written informed consent from every transporter participant in the survey, and all of them were informed that they could quit at any time, without explanation. The questionnaire was anonymous, and all information obtained in the study was kept confidential and used only for our study.

2.1. Study Description and Questionnaire

Fifty-seven male transporters (53% of the national census of professional sheep transporters) aged between 18 and 62 years old were recruited through the Sheep Dealers and Transporters Association of *Capulhuac* (State of Mexico). No women were found working as sheep transporters. Only transporters with at least one year of experience driving livestock trucks were chosen. The transporters had participated in other studies related to the same sector due to their willingness to provide information and the credibility of their testimonials. To minimize selection biases, we ensured that the participant transporters were blind to the main objectives of the study. The interested transporters were informed that "participation was voluntary, that the information collected was confidential, and if they did not participate or wanted to desist during the interview, their future employment conditions would not be affected". Participation was anonymous and there were no financial incentives. All respondents had permits to drive heavy lorries and were working as professional transporters transporting sheep. The interviews were conducted individually at the assembly centres, classification centres or transporter offices (with a work context) and took 30 minutes to complete.

To validate the questionnaire, ten preliminary surveys were carried out in May 2016 using draft questions with the participation of 10 sheep transporters (who were excluded from subsequent analyses). Using those results we designed the final questionnaire, which was divided into three sections. The first section was related to socio-demographics such as age, education, driving experience, vehicle type and work status (owner or employee). The second section was related to operational risks, including personal health, occupational risks on the road and accidents. The final section dealt with operational and logistic practices during transport, transporters were questioned about most common routes or journeys and transport procedures. This allowed us to obtain numerical data on loading capacity, journey distance, transport time, loading/unloading

time, transportation cost per sheep, weight loss, percentage of animals injured and mortality. In the same section, the participants were asked about logistic issues such as the farms or collecting points of origin (north, northwest-centre, centre and southeast of the Mexican Republic), and animal handling during loading and unloading. Finally, respondents were asked two questions: *"Do you think that stress during animal production and transport could affect meat quality"* and *"What parts of the pre-slaughter logistics most jeopardize the welfare of sheep in Mexico?"*

2.2. Specifications of the Model

We used univariate and multivariate statistics based on cluster analysis. All statistical analyses were carried out using the software Package SPSS, Version 21.0. Descriptive statistics included percentages and means. Prior to that, univariate analyses were carried out on all the variables included in the study to observe their individual behaviour and to detect outliers. A cluster analysis was carried out in order to typify the geographical origins of the journeys in accordance with transporters knowledge regarding transport and pre-slaughter logistic operations. The conglomeration method was the two-step method due to the nature of the data (categorical variables). Unlike hierarchical and non-hierarchical methods, this method was used in order to take maximum advantage of the benefits offered by both methods (Morris et al., 2017). The two-step method has been used previously to examine animal transport and farm external biosecurity (Bottoms et al., 2013). The distance measurement was the maximum likelihood, calculated using the variables relating to four possible geographical origins of the journeys (north, northwest-central, central and south-central), and the number of conglomerates was identified automatically. The log-likelihood distance measure was applied for clustering and the Schwarz's Bayesian Criterion (BIC) was to select the optimal number of clusters. Having defined the clusters, they were then characterized based on their orientation towards vehicle type, sheep collection method, production system at origin, commercial category of the animals (lambs, sheep's and goats), route matters (stop at animal health checkpoints, number of toll booths of the route, journey distance, journey time, transport costs per animal per journey, number of animals per journey), occupational hazards, animal loss, loading and unloading schedules, and animal handling procedures. In order to identify the variables that discriminated between clusters, the contingency tables were employed with their respective Chi-square tests and Kruskal–Wallis tests to compare ranges of independent samples (Sepúlveda et al., 2010).

3. Results

The characteristics of the sample are presented in Table 1. The mean age of respondents was 40 years old (SD= 10.7), while the mean driving experience was 7.7 (±3) years. Most transporters (80.8%) had at least a junior high-school education. The great majority (72%) were taught to drive sheep vehicles by a relative, while 28% learned by being an assistant to a transporter. Most of the transporters interviewed owned 10 ton (t) to 16 t lorries with two to three axles (40%), pot-bellies (28%), 3 t lorries (15.8%) or pick-ups (14%). About 65% were owners and 35% employees. The transported animals come from different places in northern Mexico, via long journeys of more than 8 hours (from states of *Chihuahua, San Luis Potosí, Zacatecas, Coahuila* and *Durango*), from northwest-central Mexico (4 to 8 hour journeys from states of *Aguascalientes, Jalisco, Queretaro,* and *Guanajuato*) and central Mexico (less than 4 hour journeys from states of *Mexico, Morelos* and *Michoacan*) and southeast Mexico with medium journeys (4 to 8 h journeys from states of *Guerrero* and *Oaxaca*).

3.1. Univariate Analysis

Regarding the participation of transporters in the transport process, 70% bought animals, loaded/unloaded and drove, 13.9 % only drove and loaded/unloaded, 11.1% bought animals and drove and 5 % only drove. Only 13.3% of carriers reported having some form of chronic disease. The most common health complications were diabetes (50%), chronic back pain (37.5%), and high cholesterol (12.5%). Regarding occupational risks on the road, the most important problems were assault while on the road (49.4%), road accidents (43%), and kidnappings (7.6%). All the accidents only involved the livestock vehicle and in 50% of the cases the vehicle was empty (no animal mortality). In approximately 56% of the accidents the vehicle overturned, 40% were collisions and 4% mechanical failures. In most accidents involving animals, 63.6% were re-transported to the destination, while 36.4% were abandoned (alive, injured or dead) on the motorway. Most accidents (68%) occurred at night (32% during the day).

Regarding logistics, all together the transporters interviewed transported approximately 40,000 sheep per month, making up 70% of all the animals slaughtered per month in Capulhuac. The average transport distance of loaded vehicles was 604.63 ± 309.7 km (maximum 1,300 km).

Loading time took about 2.2 h on average and journeys lasted 12 ± 6 h (maximum 24 h). Some journeys included goats (7%) since Mexican sheep farmers traditionally keep some goats with their sheep. Animals were always loaded in groups and the average loading time was 2.20 h (±2.0), with widespread use of sticks or electric prods. Most transporters (73.2%) mentioned that before loading they normally separated sheep by commercial category, presence of horns or breed, to then place them in specific compartments on the truck. Most loading was performed in the afternoon from 13 to 19 pm (58%), followed by the morning (37.5% between 6 am to 12 pm) and 3.6% at night (8 pm- 5 am). Unloading was faster (1.1±1.4 h) up to maximum of 2 h, and mostly performed in the morning (65%), followed by the afternoon-night (35%). Transporters stated that the most common difficulties during loading/unloading were lack of personnel (19.9%), poor infrastructure for weighing (17.5%), poor weather conditions (16.7%), too long distance between pre-loading pens and loading ramp (16.7%), lack of ramps (13.3%), lack of ramps and personnel (10%), and little space to move (6.6%). In reference to the supply of water or feed for the animals at the destination, 87.7% provided water-feed, 8.8% nothing and 3.5% only water.

Most (56.4%) of the transporters stated that the welfare of the animals could be under risk during transport, where the most important problems are related to fatigue (60.8%), bruises (26.1%) and fractures (13.1%). Regarding mortality, only 31.6% of the transporters reported at least one mortality per journey. They also consider that weight loss per animal shipped was 4.0 (±1.9) kg (maximum 11 kg). The transporters believe that mortality and morbidity were higher in winter (36.8%) and summer (24.6%), while some mentioned there were more problems in spring (5.3%) and fall (1.8%). The remaining 31.7% of transporters found no relation between mortality and season of the year. The cost of transport per animal was approximately 2.98 (±1.3) US dollars, up to $ 6.23 US dollars. The lairage and slaughter at the abattoir (32.1%) and road accidents (24.5%) were mentioned as the two main welfare critical points, followed by transport (20.8%), markets and collecting points (11.3%), and living conditions on the farm (5.7%). In 6th place were clinical and husbandry procedures (5.6%). Finally, 79% of the transporters considered that stress during animal production and transport could affect meat quality.

3.2. Multivariate Analysis

The two-step cluster analysis separated three clusters or typical routes that explained the association between transport and pre-slaughter logistic operations and journey distance (Table 2). Cluster 1 included long distance journeys (LDJ), cluster 2 medium distance journeys (MDJ) and cluster 3 short distance journeys (SDJ). The majority (86%) of the respondents were evenly distributed in clusters 1 (LDJ) and 2 (MDJ), and only 14% in cluster 3 (SDJ). In MDJ the collection points were quite varied compared to the LDJ and SDJ groups, which were always in the north or central regions, respectively. The LDJ group used pot-belly trailers or 10 t to 16 t lorries, the MDJ group preferably used 10 t to 16 t lorries and group SDJ used 3.5 t lorries or pick-ups. Most of the accidents were grouped in LDJ, which also included transporters who smoked most and drank coffee as a countermeasure for sleepiness. The MDJ group loaded more animals at the farm, while the other two groups mostly collected animals at assembly centres or auction markets. The animals transported in LDJ and SDJ groups came mostly from mixed production systems (grazing and finishing with concentrate in stables), while MDJ animals were mostly stabled.

Lambs were the most transported commercial category, especially in LDJ and MDJ groups. The SDJ group mostly included cull ewes. The three groups transported goats, although sheep was always the main species. The LDJ group always stopped at animal health checkpoints run by governmental authorities, passing through more than three toll-booths and having the longest journeys (above 700 km and 13 h). They also transported the largest number of animals per trip at the highest cost. Surprisingly, the highest mortality was concentrated in medium-distance journeys, followed by long journeys. Weight loss was directly related to journey distance, with LDJ animals losing the most weight, followed by those of medium distance. Loading always took place during the day for long and short distance journeys. In the case of MDJ, loading usually occurred during the day but occasionally at night. That group also had longer loading times. The highest unloading time corresponded to LDJ. Shouting and aggressive handling were common in all three groups. Finally, separation or selection of sheep during the pre-loading period was common practice in LDJ and MDJ groups.

4. Discussion

Transportation is a stressful experience for animals and sheep are no exception (Miranda-de La Lama et al., 2010). Safe and humane livestock transportation carries important public and trade concerns worldwide due to its potential negative consequences on economics, animal health and welfare, food quality and safety (González et al., 2012). Transporters play a crucial role in delivering live and healthy animals to their destinations on time, despite long journeys and irregular driving schedules (Pulido et al., 2018). Surprisingly we know little about how transporters influence animal welfare. Our study is one of the first to consider how transporters perceive and influence pre-slaughter transport and logistics in terms of One-Welfare.

4.1. Univariate Analysis

More than half of the transporters we interviewed were over 39 years old, with a secondary education and more than 10 years of experience driving cattle trucks. Most of those trucks were large (>10 t) and owned by the transporters, who have a particular interest in profiting from the purchase and sale of live animals. Morbidity and mortality are economic losses for the meat industry, regardless of the pain and suffering caused to animals. Increasing the number of trained personnel would help to promote positive attitudes towards welfare issues (Hemsworth et al., 2011). Sheep transport in Mexico mostly involves vehicles from 10 t to 16 t, followed by pot-belly's. The use of large vehicles reflects the industrial scale of the supply chain and the need to move a greater number of animals at a lower price. Providing appropriate vehicles for livestock transport that are built and equipped according to the specifications of the sheep category of the animals transported is an unquestionable principle for the protection of animals during transport (Gallo et al., 2018).

Typically, commercial transporters had irregular work schedules and sleep hours, in addition to little physical activity, poor eating habits and nutrition, and mental and physical stress, all of which may aggravate health problems, including obesity, cardiovascular issues and metabolic disorders (Mabry et al., 2016). Although only 13% of the transporters stated that they had a chronic disease, one of the main problems was diabetes. That could be due to the work schedules that do not provide enough time to follow an adequate diet, partly due to the difficulty of finding healthy foods en route and the perception that diets that are rich in carbohydrates, fat and sugar stave off hunger, which predisposes transporters to obesity and eventually diabetes (Vayro et al.,

2016). That would also help explain the problems with sore backs and high cholesterol, which can be the result of obesogenic process and be connected to cardiovascular and metabolic disorders (Leyton et al., 2012). In addition, journeys include risks such as armed robbery and accidents. Safety is a relatively recent topic in studies on logistics and supply chains. The type of goods affects the risk of theft, especially in Mexico (De la Torre et al., 2015). In that context, the high incidence of thefts could be related to several factors including the high value of sheep meat (compared with other farm species), small size of sheep, numerous loading sites, poor traceability and decreasing national road security levels.

Road accidents involving loaded livestock vehicles can be a serious problem, leading to economic, animal, and even human loss. In addition, accidents have an important impact in the media and affect the image of the industry for consumers (Valadez-Noriega et al., 2018). Our results indicate that a little less than half the transporters had at least one accident on the job, and half of those accidents were with an empty load. The rate of accidents is related to a series of factors determined by journey time/distance, as mentioned below in section 4.2. We also found a similar tendency for accidents reported in Spain (Miranda-de la Lama et al., 2011). One of the main causes of accidents appears to be driver fatigue, which may be the result of intense workdays, poorly designed route plans, or high levels of pressure from companies (Valadez-Noriega et al., 2018). Most accidents occurred at night with an empty load since loading and journey with live animals tend to occur during the day. When there are accidents with animals on-board, there was a high rate of re-transport (sent to the slaughterhouse for emergency slaughter) compared to reports from Spain (Miranda-de la Lama et al., 2011) and the USA (Woods and Grandin, 2008). The high rate and cost of accidents involving sheep lorries demonstrate the need for continued efforts to increase the safety of trucking operations in Mexico and other countries.

The data confirm that the number of animals transported and slaughtered in this region of Mexico is the highest in the country (Mondragón-Ancelmo et al., 2018) and possibly the highest in Latin America. That may partly be explained by culinary traditions, migration of consumers from the countryside to the city and to a view that lamb meat is tied with modern food traditions. Although it is clear that the production chain is young, certain stages of transport and logistics

are deficient and require more governmental control. The legal requisites related to transport and slaughter are known as the Official Mexican Regulations (NOM-024-ZOO-1995 and NOM-051-ZOO-1995). These legal provisions regulate the maximum journey time that in the case of small ruminants is 18 hours (without access to water and feed). Although in practice these regulations are not usually met by sheep transporters. The cattle, pig and poultry industries appear to obey those regulations, possibly since the production techniques are more modern than for sheep. Those norms may be relaxed for animals that are produced, slaughtered and consumed in a traditional manner. However, mass consumption of sheep meat in Mexico may mean that the industry will have to comply with current and future regulations. In addition, a recent study has confirmed that Mexican consumers demand high quality meat and systems of transport and slaughter that take into account animal welfare as the main pillar of operational quality in the system (Miranda-de la Lama et al., 2019).

The survey we developed helped to identify a series of practices that represent risks to the health and welfare of sheep. Many journeys were long (the average was 12 h), which may be a problem in a country without legal limits on sheep journey times. Longer journey times increase the risk of unnecessary suffering for animals and have negative effects on the health of transporters. Thus, journey distance is of vital interest in terms of animal welfare and product quality but also within the framework of the One-Welfare concept. Although not demanded by Mexican regulations, most transporters provide feed and water to sheep upon arrival at the slaughterhouse or in small collection centres near the slaughterhouse, especially during medium to long hauls. The main reason is to compensate for weight loss, even when the animals will be slaughtered in the following 72 hours. This practice may pose a risk in terms of food, according to Pointon et al. (2012), the significance of withholding feed for long period before slaughter is twofold. Firstly, it leads to an increase in rumen pH, due to a reduction in volatile fatty acids, which in turn favours the multiplication and growth of undesirable enteric bacteria as Salmonella and *Escherichia coli*. This causes an increase in microbial hazard prevalence and counts in both rumen contents and faeces as the time without feed increases. Secondly, withholding feed reduces the visible contamination of the surface of the animals and facilitates hygienic dressing (Pointon et al., 2012). Non-compliance with certain legal provisions regarding safety and animal

welfare is related to the traditional character of the consumption of sheep meat in the country. Unlike pork and beef that are usually exported, and these industries are highly regulated.

The work of the transporter requires specific driving abilities, but many transporters also partake in the loading/unloading of animals, select animals for loading and distribute animals on the truck according to their weight or commercial category. The use of electric prods (very popular device among transporters in North America) and other instruments to handle the animals is more common during the loading and unloading of large vehicles, since it is done by compartment and conditions are often less than adequate. Those problems lead to long loading (2-4 hours) and unloading times (1-2 hours). Rough handling during the pre-slaughter period has been related to fatigue and increased bruising in sheep, particularly under poor transport conditions (Tarumán and Gallo, 2008). Poorly defined abnormalities in the mobility of pigs and recently in cattle at abattoirs have garnered considerable interest from the beef industry and media (Thomson et al., 2015). Fatigue is a multifactorial syndrome in which affected animals become non-ambulatory without obvious injury, trauma, or disease, and refuse to walk (Schuetze et al., 2017). Although there are no clinical reports about this syndrome in sheep, Mexican transporters perceive fatigue as the main risk during to transport. Some of them referred to clinical signs that are similar to other species (personal observations outside the questionnaire), so it would be necessary to investigate the clinical significance of this phenomenon.

Loss in live weight is an inevitable consequence of transport, although its impact depends on the breed, sex, health status, body condition, handling and individual susceptibility to stress (Cernicchiaro et al., 2008). Our results indicate that weight loss averages 3.5 kg per animal, independently of the journey distance. The initial decrease is due to dehydration and loss of urine and feces, that represent 5 -15 % of the total live weight. During long, stressful journeys (where sheep release high levels of glucocorticoids), fat tissue may also be lost, which affects carcass fat deposition (Miranda-de la Lama et al., 2018). In many of those cases, the high levels of physical stress increase mortality (31% of long journeys had at least one mortality), which most transporters believe is higher in winter and summer months.

According to Mexican consumers, the greatest risk to animal welfare is during transport to slaughter, followed by handling immediately before slaughter and during slaughter itself (Miranda-de la Lama et al., 2019). Nonetheless, for transporters, the greatest risk to animal welfare is right before and during slaughter. That discrepancy may be explained by a phenomenon already described for workers with strategic responsibilities, where they do not tend to accept their degree of responsibility in the final quality of a product (Del Campo et al., 2014). In the future, training programs could focus on this problem by raising awareness about the importance of transporters throughout pre-slaughter logistics. Finally, 79% of the transporters considered that stress on the farm and during transport could affect meat quality. This is a good sign and it may make it easier to train them in gentle handling, although adequate handling facilities are also required (Soysal et al., 2014).

4.2. Multivariate Analysis

In the generic meat logistics chain, livestock is moved to slaughterhouses via farms, feedlots and logistic centres. Each slaughterhouse can also be supplied by more than one production region (Soysal et al., 2014). Throughout the chain, we found a clear effect of the route (determined by the points of loading/collecting animals), vehicle type, occupational risks, collecting points, production systems, commercial categories of sheep, journey distance and cost, animal mortality and handling of the animals at loading and unloading. Given those associations we identified three main journey types; long, medium and short journeys. The long journeys begin in the north where goats are traditionally produced, and sheep production is gaining momentum to feed the demands of the larger cities in the centre of the country (Miranda-de la Lama et al., 2018). This has resulted in the creation of collecting sites (both public and private) in the north where livestock is quite heterogeneous in terms of genetics, production system (grazing, stabled or mixed) and commercial categories. Typically, animals at collecting sites will have undergone a previous transport, which has a cumulative effect and may increase mortality during the long journeys as well as loss in live weight. Long journeys are also more risky for transporters in terms of traffic accidents, and are correlated with higher tobacco consumption. Typically, the trade route crosses desert areas in a straight line for hundreds of kilometres, which can increase

the incidence of falling asleep at the wheel. Thus, many accidents involve empty, heavy vehicles travelling at night (to be able to load the animals in the morning). Long journeys are also subject to sanitary inspection and must go through toll stops (toll-highways).

Medium distance journeys typically involve collecting sheep at farms with more intensive production. Each delivery is contracted so as to provide homogenous lambs directed to a specific market (i.e. cuts). These journeys have the highest mortality and losses in live weight. A possible explanation for this phenomenon could be that the cluster of medium distance journeys also includes 23% long and short journeys, which could alter logistical practices and handling. Accidents are not a typical problem, but transporters consume high levels of coffee and tobacco, which places them as the highest risk group for the development of chronic diseases. From these results and the dynamics of sheep production in Mexico (also for Latin America), we can suggest that the risk of road accidents increases as the journey distance increases. Increasing journey time (and distance) also tend to increase weight loss, immunosuppression and negative effects on meat quality (Miranda-de la Lama et al., 2018). For this reason, there is an international tendency to decrease long journeys. Nonetheless, the negative effects of journey distance can be aggravated if performed under poor conditions, such as in an extreme climate, using a poorly designed vehicle or by placing animals of different sizes and commercial categories in the same compartment. In our study, short journeys were similar to long ones in terms of heterogeneity of animal sizes since both begin at collecting centres or livestock markets. The shorter trips are under less governmental control, however, and use secondary vehicles and transport fewer animals than the other two typologies. Accidents are rare, and the use of tobacco and coffee is lower, implying less stress for the animals and the transporters.

5. Conclusions

An integrative approach is essential to understand the relationships between transporters and animals during pre-slaughter logistic chain. Our results show a sheep collection system with three types of journey distances, implying a specialization of the drivers and trucks used in each type of journey. The journey type influences certain risks to which transporters and animals are exposed. Smoking and consuming coffee is related to journeys of more than 4 hours and should be considered in future occupational health programs. Journeys greater than 8 hours imply a

greater probability of suffering an accident on the road. The crisis in public security in Mexico are also a major stress factor in drivers that must be taken into account. In terms of sheep welfare, it seems that the medium-distance journeys of lambs from stable systems concentrate a greater mortality during the journey, even compared with long distance animals. Additionally, night journeys, aversive and violent handling (shouting and the use of electric prod), loading times greater than 2.5 hours can also increase live weight losses and mortality rates. Finally, our results highlight the importance of developing new regulations and guidelines for transport in Mexico and Latin America in terms of transport time and transporting conditions, with a long-term view to obtain improvements in the conditions of the thousands of sheep's that travel, avoiding suffering and preventing losses for the industry.

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Conflict of interests

The authors declared that they have no conflicts of interest with respect to their authorship and/or the publication of this article.

Ethical considerations

This study was conducted in accordance with the guidelines laid down by the Declaration of Helsinki and all procedures involving human subjects were approved by the Ethics Committee of Veterinary Faculty (CICUAL-DISP) from the Autonomous University of the State of Mexico-UAEM (Protocol ID 4117/2016E, approved in October 2016).

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