# Characterization of sheep slaughterhouses for barbacoa production in a municipality in the Central Mexican Plateau

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**Abstract:**

Ensuring the quality and safety of meat from slaughter animals is a matter of global concern. Among the factors that must be taken care of are the activities that generate stress to the animal during *antemortem* handling (transport, rest, and stunning), *postmortem* carcass handling (aging and storage), and hygiene practices in facilities and staff. This work aimed to characterize sheep slaughter units within the municipality of Capulhuac de Mirafuentes, State of Mexico, based on current Mexican regulations. For this, a principal component (PC) analysis was carried out, highlighting that those that represented the highest variability in the slaughter centers were the price of the carcasses and their products, place of marketing, slaughter volume, sex of the animal, and safety of the carcasses, which represented 50.4 % of the explained variance. A cluster analysis was also carried out, which represented the integration of four groups of slaughter descriptors ($P<0.05$). As a result, it was found that

65 % of animals are slaughtered in commercial premises and houses that do not comply with the technification described in the regulations; they also present deficient *antemortem* and *postmortem* handling of animals; it was also observed that 98.3 % of the establishments use a slaughter method called "descabellado" (pithing), not reported in NOM-033-SAG/ZOO/2014, coupled with the lack of knowledge of the staff on animal welfare issues. This affects the quality and safety of meat and puts consumers' health at risk.

**Keywords:** Slaughterhouses, Safety, Animal welfare, Meat quality, Cluster.

# Introduction

Slaughtering an animal constitutes the physicochemical change from muscle to meat[1]; this practice must ensure the humane, professional, and painless death of the animal, in addition to taking care that the animal is exposed to a low level of stress, guaranteeing animal welfare and the quality of the final product called meat[2].

The most important characteristics of fresh meat that determine quality, safety, and consumer acceptance are the physicochemical properties (pH, water retention capacity, color, and texture), organoleptic properties (softness, consistency, smell, taste, and color), and microbiological properties (absence of enteropathogenic bacteria and fungi)[3].

These properties are influenced by factors such as the production system (type of feeding, animal handling, and health, reproductive and genetic care), *antemortem* factors (transport, rest, fasting, and handling of the animal)[4], and *postmortem* factors (aging time and storage temperature)[2,3]. The operators' handling of animals during slaughter also has an impact[5].

Sheep meat is considered one of the most complete foods from a nutritional point of view in the human diet[6] because it provides essential fatty acids, proteins, and fats of high biological value[7] in addition to being rich in vitamins and minerals[8].

In Mexico, 95 % of the consumption of this meat is in the form of the typical dish called barbacoa, a product obtained from the steaming of sheep meat in an underground hole

covered with bricks, wrapped in leaves of pulquero maguey (*Agave salmiana* Otto), added with seasonings and spices; the remaining 5 % is consumed as fine cuts[9,10].

In the municipality of Capulhuac de Mirafuentes, State of Mexico, around 400,000 head of sheep are slaughtered annually to supply the demand of the country's central area[11]. In this municipality, around 8 thousand sheep carcasses are marketed weekly, which is why it is considered the number one producer and marketer of fresh sheep meat nationwide. This municipality, although it currently has a municipal slaughterhouse with an installed capacity to house 67 % of the slaughters, is exceeded, which has led producers to generate their own slaughter units, not knowing if they comply with current regulations, which puts animal welfare, meat quality, and the health of consumers at risk. For this reason, this work aimed to characterize sheep slaughter units within the municipality of Capulhuac de Mirafuentes, State of Mexico, based on current Mexican regulations.

# Material and methods

This study was defined as qualitative and descriptive research and was carried out in July 2022 in the municipality of Capulhuac de Mirafuentes (19°12'N, 99°28'W; 2700 m asl) in the State of Mexico (Central Mexican Plateau).

## Preparation of the survey

To create the survey, the following standards were consulted: NOM-008-ZOO-1994 (Animal health specifications for the construction and equipment of establishments for the slaughter of animals and those engaged in the industrialization of meat products, in those points that were appropriate)[12], NOM-033-SAG/ZOO/2014 (Methods for killing domestic and wild animals)[13], NOM-213-SSA1-2018 (Products and services. Processed meat products and the establishments engaged in their processing. Sanitary provisions and specifications)[14], NOM 194-SSA1-2004 (Sanitary specifications in establishments engaged in killing and slaughtering animals for human consumption, storage, transport, and sale)[15], NOM-120-SSA1-1994 (Hygiene and sanitary practices for the processing of food, and non-alcoholic and alcoholic beverages)[16], NOM-051-ZOO-1995 (Humane treatment in the movement of animals)[17]. Primary and secondary information was also obtained through field visits and unstructured interviews with owners and employees of slaughterhouses and municipal slaughterhouse staff.

Firstly, the survey was validated by academic experts and zootechnical veterinarians who carry out the sanitary inspection on behalf of the Institute of Health of the State of Mexico (ISEM, for its acronym in Spanish), and it was used to carry out a pilot test, which was applied to 10 producers, which were not included in the results of the research.

Secondly, the data collected was used to generate a final survey structured with open-ended, closed, and multiple-choice questions in order to facilitate its application; it integrated 74 questions according to the most important specifications mentioned by university experts and sheep producers, as shown in Table 1.

## Sample size

The number of establishments evaluated was calculated using a simple random sampling, considering a finite population. The components of the formula were a confidence value of 95 % (Z=1.96), a precision of 5 %, an estimator of variance equal to 0.25 [$\sigma 2= \pi(1-\pi)$], and a value of N=65, based on the database of the establishments registered in the operating register of the Municipal Council of Capulhuac. The sample size obtained was n=57.

## Study description

The surveys were conducted using a purposive random probabilistic sampling method due to the high number of sheep slaughters that are carried out. To minimize the error, it was mentioned that participation would be voluntary, and it was ensured that the owners and managers of the establishments did not know the day of sampling in addition to not offering any economic remuneration to the participating establishments and indicating that all the information would be confidential and only for research purposes.

## Statistical analysis

Two multivariate statistical techniques were used: principal component analysis and cluster analysis. The information from the survey, which was applied to 57 sheep slaughter units (SSUs), was first used to carry out a discriminant analysis in order to eliminate those variables that did not allow the differentiation of sheep slaughter units. Subsequently, the variables that permitted differentiation were used to perform the principal component method

for factor extraction, the Kaiser-Mayer-Olkin (KMO) index, and Bartlett's test of sphericity to measure the correlation between variables. Those variables with a communality (h<0.9) were not included in the factor analysis because it indicated that these variables were not correlated with the new factors. The factors selected were those with eigenvalues ≥1. To better understand the factors obtained, an orthogonal rotation method (Varimax) was carried out; consequently, the scores of the factors in the analysis were estimated using the regression method and saved as new variables. Subsequently, a hierarchical analysis of clusters was carried out to identify similarities and differences in the slaughter rooms. The distance used was the squared Euclidean distance as a measure of similarity and clustering, performed by Ward's method. To select the most significant variables that would allow differentiation between the groups obtained, the non-parametric tests of Kruskal-Wallis and Mann-Whitney were performed, considering the characteristics of the study and the variables.

# Results

## Discriminant analysis

The discriminant analysis results allowed to rule out 28 variables that did not present a significant difference ($P>0.05$). Therefore, only 46 variables were finally considered for subsequent analyses, which allowed the explanation of the variability of the sheep slaughter descriptors (Table 2).

**Table 2:** Discriminant analysis results

| Slaughter variables or descriptors selected | Slaughter variables or descriptors discriminated |
|---|---|
| | |
| 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20, 24, 26, 27, 28, 29, 30, 32, 33, 34, 36, 37, 38, 39, 43, 44, 45, 46, 47, 48, 50, 54, 55, 57, 58, 59, 65, 67, 69 | 2, 16, 21, 22, 23, 25, 31, 35, 40, 41, 42, 49, 51, 52, 53, 56, 60, 61, 62, 63, 64, 66, 68, 70, 71, 72, 73, 74 |

Thirteen (13) principal components (PCs) were obtained, which explained 78.64 % variability of the data (Table 3), which were renamed according to the variables that were correlated. Three groups were formed, where it can be observed that the study variables, price of carcasses and byproducts, which represented 22.58 %, and place of commercialization of products, with 9.96 %, were the ones that generated the highest values. Subsequently, the second component was integrated by the following variables: volume of slaughter, sex of the

animal, factors affecting the safety of the carcasses, generation of waste, social impacts, and hygiene practices of the staff; as a third component of importance, it was only the variable of training of staff; these three principal components together represented 46.14 % of the variability.

**Table 3:** Principal components of sheep slaughter in the municipality of Capulhuac de Mirafuentes

| PC | Name | CV | Eigenvalue | Percentage 1 | Percentage 2 |
|---|---|---|---|---|---|
| PC1 | Price of carcasses and byproducts | 7, 8, 9, 10, 11, 12 | 9.71 | 22.58 | 22.58 |
| PC2 | Place of marketing | 5, 6 | 4.28 | 9.96 | 32.54 |
| PC3 | Volume of slaughter | 3, 4 | 2.81 | 6.54 | 39.09 |
| PC4 | Sex of the animal | 13, 14 | 2.53 | 5.89 | 44.99 |
| PC5 | Factors affecting carcass safety | 32, 34, 50, 55, 69 | 2.32 | 5.39 | 50.38 |
| PC6 | Generation of waste and social impacts | 20, 57, 59 | 2.16 | 5.03 | 55.42 |
| PC7 | Staff hygiene practices | 45, 46, 47, 48, 54, 58 | 1.94 | 4.51 | 59.92 |
| PC8 | Staff training | 54 | 1.61 | 3.75 | 63.67 |
| PC9 | Slaughterhouse infrastructure | 15, 17, 26, 27, 29, 30, 65 | 1.61 | 3.63 | 67.30 |
| PC10 | Factors affecting meat quality | 33, 37 | 1.41 | 3.29 | 70.59 |
| PC11 | Type of slaughterhouse | 1 | 1.28 | 2.98 | 73.58 |
| PC12 | Stunning method | 55 | 1.14 | 2.65 | 76.24 |
| PC13 | Rest period before slaughtering | 19 | 1.05 | 2.40 | 78.64 |

PC= principal component; CV= correlated variables; Percentage 1=% of the total variance explained; Percentage 2= cumulative % of the explained variance.

## Cluster analysis

Figure 1 shows the dendrogram of the clusters formed from the slaughter environments.

**Figure 1:** Hierarchical clusters (dendrogram) of clustering analysis from slaughter descriptors (N=46)
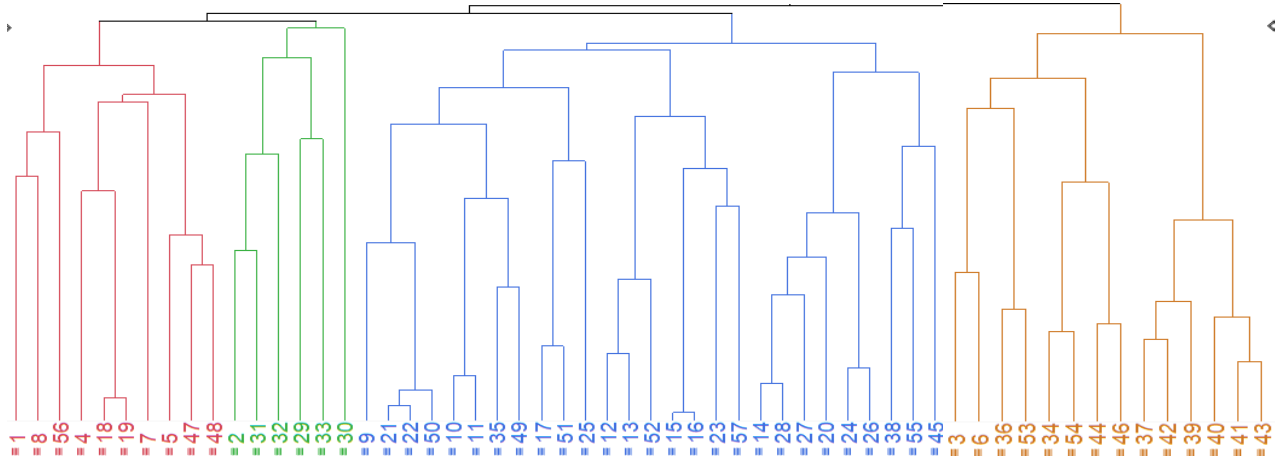


## Description of clusters by similarities in slaughter environments

### Cluster 1

Made up of 10 SSUs (sheep slaughter units), it is characterized by being composed of only private establishments that slaughter an average of 31 animals per week (male sheep in 84 %) for the sale of meat in the municipality of Capulhuac and the commercialization of barbacoa in the metropolitan area of Mexico. As for carcasses, two types are marketed: tough carcass (adult animals) at a price of $91.00 and tender carcass (animals under 9 mo of age) at a price of $97.00; they also market byproducts such as viscera ($163.00), legs ($34.00), head ($53.00), and the dish called barbacoa and sheep belly at a price of $391.00 per kilo; regarding the infrastructure conditions of the establishments that comply with current regulations, they have an area for unloading animals and a loading area for carcasses and viscera, with rest pens where the animals are given a time of 12 to 24 h, and the joints of the floors and walls are easy to clean.

The slaughter area has sanitary mats with disinfectant solution. All areas of the slaughter unit are kept free of pests, and domestic animals are prevented from entering; all employees wear face masks and are prohibited from entering the slaughter area with any type of accessory. Regarding *postmortem* handling, the establishments have freezers, giving them an aging time of 1 to 6 h, separating and identifying the viscera by an animal. Nonetheless, they do not have pens to identify sick animals. They do not have a pest control plan or protections in windows and vents that help reduce the entry of dust, rain, and insects, and in general, the blood that

is discarded is composted; as for the liters of water used per animal, it ranges from 7 to 12 L (Table 4).

## Cluster 2

Made up of 6 SSUs, it comprises three types of slaughterhouses: the municipal slaughterhouse, slaughterhouse facilities with private staff, and private slaughter units; in general, they are units with large slaughter volumes (average of 86 animals per week). Their primary purpose is the sale of meat, byproducts, and barbacoa in the municipality of Capulhuac and, mainly, for resale. They market two types of carcasses: tender, for $99.00, and tough, at $89.00; they are also characterized by the marketing of byproducts such as viscera: $151.00, legs: $35.00, head: $53.00, and the marketing of a dish called barbacoa and sheep belly for $360.00/kg. As for the preference for slaughter by sex of the animals, they do not give it importance. The infrastructure complies with the disembarkation area and loading area of carcasses and viscera; they also have pens for sick animals and rest pens, giving a period of between 13 and 24 h. They comply with materials in floor and wall joints that facilitate cleaning. The cleaning of pens, ramps, tunnels, *antemortem* baths, and drying and draining areas is carried out every day due to the high volumes of slaughter, complying with the identification of viscera by animal. There is no compliance with pest control and sanitary mats. The protections in windows and vents are not in good condition to reduce the entry of dust, rain, and harmful fauna. There are no signs that tell staff to wash their hands after using the restrooms. There are no measures to prevent the entry of domestic animals into the slaughter, carcasses, and viscera areas. Nor is it ensured that all plant areas are kept free of insects, birds, or rodents. The staff complies very little with the existence of clothing or personal belongings in the slaughter area. There is no prohibition on employees entering the slaughter or carcass processing areas with jewelry, clips, earrings, rings, watches, or bracelets. The blood is discharged into the public drainage. The water expenditure for processing the animal ranges from 25 to 48 L.

## Cluster 3

This group comprises 26 SSUs; it includes private slaughterhouses and slaughterhouse facilities with private staff, which have an average slaughter volume of 60 animals per week (65 % male sheep). They are sheep from different states of the republic, which are slaughtered, and their meat and byproducts are marketed only in the municipality of Capulhuac, with two types of carcasses: tough, at an average price of $88.00, and tender, at $97.00. They also sell byproducts such as viscera: $159.00, legs: $36.00, and head $53.00.

The regulations they comply with include the existence of a pest control plan and easy-to-clean floor and wall joints, prevention of entry of domestic animals into the slaughter area, and a carcass aging time (7 to 12 h). All areas of the plant are kept free of insects, birds, and rodents; the viscera of each carcass are also identified to be inspected and they have freezers. As for the employees, all wear masks and partially comply with the non-existence of clothing or personal objects in the slaughter area. The regulations that are not complied with include the lack of sanitary mats at the entrances of the establishments. The blood is marketed within the municipality for preparing a moronga-type dish (blood sausage). The water they use in processing is 13 to 24 L per animal.

## Cluster 4

Made up of 14 SSUs, only slaughters in slaughterhouse facilities with private staff that kill and process the least number of animals (27/wk). They use all the animals to prepare barbacoa and belly ($379.00/kg), which are only marketed in the metropolitan area of Mexico City; they process 76 % of male sheep to prepare barbacoa. The regulations they comply with are that the establishment has an area for unloading animals and a loading area for carcasses and viscera. They have pens for sick or suspicious animals, give a rest time before slaughter of between 13 and 24 h, have a pest control plan, have easy-to-clean floor and wall joints, prevent domestic animals from entering the slaughter area, allow an aging time of carcasses between 7 and 12 h, all have freezers, all employees wear face masks and comply with the non-existence of clothing or personal belongings in the slaughter area; the regulations they do not comply with are that there are no sanitary mats and a pest control plan, they do not have easy-to-clean joints between floors and walls either, they do not prevent the entry of domestic animals in the slaughter, carcass, and viscera areas, they give a deficient aging time of between 7 and 12 h, they do not keep the areas of the company free of insects, birds, and rodents; employees are not prohibited from entering the slaughter and carcass processing areas with jewelry, clips, earrings, rings, watches, or bracelets; the viscera of each animal are not identified, and they spend an average of 7 to 12 L (Table 5).

**Table 5:** Main differences in strengths and weaknesses between clusters

|  | Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4 |
|---|---|---|---|---|
| Strengths in sheep slaughter | They give an appropriate rest period before slaughter of 13 to 24 h[4] | The establishment has pens for sick or suspicious animals[4] | They control pests[4] | They give an appropriate rest period before slaughter 13 to 24 h[4] |
|  | They comply with the existence of sanitary mats with disinfecting | They give an appropriate rest period before | They comply with preventing domestic animals from | They allow an aging period, as indicated by the |

| | | | |
|---|---|---|---|
| solution, as indicated by the standard[4] | slaughter of 13 to 24 h[4] | entering the slaughter, carcass, and viscera areas[4] | standard NOM-194-SSA1-2004, which is 7 to 12 h[4] |
| They comply with easy-to-clean floor and wall joints[1] | They comply with daily washing of pens, ramps, tunnels, *antemortem* baths, and drying and draining areas[4] | They allow an adequate aging time (7 to 12 h)[4] | |
| They comply with preventing the entry of domestic animals into slaughter, carcass, and viscera areas[4] | They comply with having easy-to-clean floor and wall joints, as indicated by the norm | They fully comply with the use of face masks by production staff[3] | They fully comply with the use of face masks by production staff[3] |
| They are very compliant in the use of face masks in production staff[3] | The comply with preventing the entry of domestic animals into slaughter, carcass, and viscera areas, as indicated[4] | They handle blood properly (sale)[4] | They use between 7 to 12 L of water per animal slaughter |
| They handle the blood properly (compost), as indicated[4] | They fully comply with the use of face masks by production staff, as indicated in the standard[3] | They give a very long rest period before slaughter of 24 to 48 h[4] | They wash ramps, tunnels, *antemortem* baths, and drying and draining areas weekly; for this reason, they do not comply[4] |
| They fully comply with the identification of viscera of each carcass, as indicated[4] | The establishments do not have a pest control plan, as indicated by the norm | They wash ramps, tunnels, *antemortem* baths, and drying and draining areas weekly; for this reason, they do not comply[4] | The establishments do not have a pest control plan[4] |
| They use between 7 to 12 L of water per animal slaughter | They do not comply with the existence of a sanitary mat with a disinfectant solution at the entrance to the slaughter area[4] | They do not comply with the existence of a sanitary mat with a disinfectant solution at the entrance to the slaughter area[4] | They do not comply with the existence of a sanitary mat with a disinfectant solution at the entrance to the slaughter area[4] |

| Weaknesses in sheep slaughter | They wash ramps, tunnels, *antemortem* baths, and drying and draining areas weekly; for this reason, they do not comply with the standard[4] | They do not comply with preventing the entry of domestic animals into slaughter, carcass, and viscera areas[4] | They do not comply with the identification of viscera of each carcass[4] | Floor and wall joints are not easy to clean[4] |
|---|---|---|---|---|
| | The establishment has a pest control plan[4] | They allow a very short carcass aging time of 1 to 6 h[4] | They spend between 13-24 L per animal | They do not comply with preventing the entry of domestic animals into slaughter, carcass, and viscera areas[4] |
| | They allow a very short carcass aging time of 1 to 6 h | They have no freezers[4] | | They have no freezers[4] |
| | | They do not give an adequate destination for the blood (drainage)[4] | | They do not give an adequate destination for the blood[4] |
| | | The viscera of each carcass are not identified[4] | | The viscera of each carcass are not identified[4] |
| | | They spend between 25-48 L per animal | | |

* Qualitative variable, ** Quantitative variable, Likert scale (not compliant, very little compliant, partially compliant, substantially compliant, fully compliant), [1](NOM-008-ZOO-1994), [2](NOM-033-SAG/ZOO/2014, [3](NOM-213-SSA-1 2018), [4](NOM-194-SSA1-2004), [5](NOM-120-SSA1-1994), [6](NOM-051-ZOO-1995).

# Discussion

In Mexico, there are few studies that have documented the conditions in which sheep are slaughtered in different areas of the country and their effect on the health of consumers. The results of this study describe the conditions of the slaughter of more than 400 thousand sheep per year in Capulhuac, which are destined for human consumption through the sale of meat as fine cuts and barbacoa, a very popular dish to consume especially on Saturdays and Sundays in different areas of the metropolitan area of Mexico City, in addition to their use in social events[18]. Three types of sheep slaughter establishments were characterized: the first corresponds to all the animals slaughtered in the municipal slaughterhouse of Capulhuac with hired staff. The second corresponds to all animals slaughtered in an alternate outdoor area with pens, pools, and concrete tables, which the slaughterhouse rents to the general public to

carry out the slaughter of sheep, and the third corresponds to slaughterhouses with private establishments, of which 35 % have the adequate infrastructure and facilities to carry out the slaughter of sheep and 65 % correspond to premises and houses conditioned to carry out these activities.

It was also found that the three types of SSU have pens for the *antemortem* rest period of the animals. Nevertheless, they have poor management regarding rest time and prolonged fasting, factors related to the generation of periods of stress to the animal; this can be explained by the long distances that animals travel. Capulhuac is characterized by being an introducer of animals, which come mainly from the states of Coahuila, Zacatecas, and Jalisco and have even been imported from other countries such as New Zealand[19,20]. However, meat producers give the same rest times without considering truck infrastructure, distances, or transportation times, crucial factors that can trigger the formation of dark, firm, and dry (DFD) meats and thus affect carcass yield and consumer preference[21-25]. They have between one and five employees, their usual clothing being street clothes covered with an apron and plastic boots, not complying with the regulations.

The hygiene habits they comply with in full are the washing and disinfection of hands, forearms, and nails before entering the slaughter areas and the prohibition of employees from smoking, drinking, eating, and spitting in areas of slaughter and processing of carcasses. Regarding the desensitization method, less than 2 % use a method approved by the NOM-033-ZOO/SAG-2014 standard, such as the use of a penetrating captive bolt gun and electro-desensitization, methods that guarantee the unconsciousness of the animal and the null generation of suffering, while the rest (98 %) use a method that they locally call "descabellado", which refers to a method of killing reported by SADER and known as "puntilla" (pithing), which consists of a process of destruction of nervous tissue in the brainstem region to ensure the death of the animal; it is performed by inserting a "puntilla" (knife) that injures the medulla oblongata when it enters the atlanto-occipital joint, causing motor paralysis but there is no immediate loss of consciousness, leaving the cerebral faculties intact[26]. This method, despite being recommended in health emergencies, could violate the standard for methods to kill domestic and wild animals (NOM-033-SAG/ZOO-2014) as it is unknown if it nullifies the generation of stress and pain to the animal. The above are determining factors, as reported by some researchers[6] who observed that a deficient slaughter method could result in poor-quality meats with a shorter shelf life.

Regarding *postmortem* handling, it can be observed that none of the slaughter establishments has cooling chambers for the correct aging of meat, and only 12 % give it a time of between 12 and 48 h, while the rest are characterized by marketing hot carcasses, a detrimental factor for the tenderness of the meat, as mentioned in a study[27] that evaluated different aging times of sheep meat, concluding that the tenderness of the meat increases as the aging time of the carcasses increases. On the other hand[28], it is pointed out that pre-slaughter handling and

aging time, as well as meat storage conditions, play a determining role in the quality of the final product, which is consistent with what has been reported[29], which indicates that the stress generated by the poor handling of animals together with the deficient conditions of aging and storage of carcasses affects the loss of carcass weight, tenderness and generates cuts with dark colorations, directly affecting the sensory characteristics of the meat and thus the purchase decision or conditioning its sale to lower prices[30].

As for employees, no establishment provides adequate work clothes, nor is it required to disinfect footwear before entering the slaughter area. In 50 % of slaughterhouses, there were problems with pests, such as rodents, birds, insects, or domestic animals in the slaughter areas, coinciding with what was observed by others[31], who mention that the presence of pests reflects the poor cleaning conditions in worktables, vehicles, utensils, and work clothing. On the other hand, the staff lacks training as it was found that more than 90 % are unaware of good practices in animal slaughter and welfare, elements of utmost importance[32] according to the author of a study that evaluated the effectiveness of training staff in the handling and killing of animals and its effect on the quality of meat, concluding that appropriate equipment and staff training significantly improve the efficiency of the process, ensuring animal welfare and meat quality.

In 93 % of the handling of the carcasses of the establishments, *antemortem* examinations are not performed, in addition to not bathing animals, which has the purpose of reducing the microbiological load that the animal brings, such as remains of excrement, urine, or soil[33], results that coincide with a reported study[34] that found irregularities in veterinary inspection, compromising the safe reception of animals and increasing the risks of introduction of foodborne disease (FBD) causative agents from farms to the slaughterhouse.

# Conclusions and implications

The three types of establishments formed do not have basic knowledge about animal welfare standards, and adequate staff training is lacking. The conditions of infrastructure, staff, and waste handling are not acceptable to ensure the safety and quality of the slaughter in accordance with current regulations. Particularly, of the three types of establishments to carry out the slaughter, the municipal slaughterhouse is the one that, to a certain extent, adheres to a higher level of compliance with current regulations. Nevertheless, the facilities are already old and lack the necessary technology for the number of animals slaughtered, and there is limited staff, thus causing long periods in the slaughter process. It is suggested that training programs be implemented by pertinent official authorities in order to improve the conditions in the slaughter process following the current regulations. It is also recommended to

condition and technify the facilities of the municipal slaughterhouse of Capulhuac de Mirafuentes to guarantee Good Slaughter Practices and the safety of the marketed meat, as well as make the installed capacity efficient to the current demand in the slaughter processing of this municipality.

## Acknowledgments

**Table 1:** Survey questions

| | | |
|---|---|---|
| (1) Type of slaughterhouse?* | (26) Are the floors of the slaughter facilities waterproof, homogeneous, and of characteristics that allow them to be easily cleaned and disinfected? (Yes, No)*[5] | (51) Is the *antemortem* inspection performed? (Yes, No)*[4] |
| (2) Origin of animals?* | (27) Is there a sanitary mat with a disinfectant solution at the entrance to the slaughter area? (Yes, No)*[4] | (52) Who performs the *antemortem* sanitary inspection?*[4] |
| (3) How many animals do you slaughter a week? (N)** | (28) Are the floor and wall joints easy to clean? (Yes, No)*[1] | (53) Do you perform *antemortem* bathing? (Yes, No)*[4] |
| (4) How often are sheep slaughtered? (N)** | (29) Are windows and vents provided with well-maintained protections to reduce the entry of dust, rain, and harmful fauna? (Yes, No)*[1] | (54) Are staff trained to do their jobs? (Likert Scale)*[5] |
| (5) Destination for the carcasses?* | (30) Are there signs instructing staff to wash their hands after using restrooms? (Yes, No)*[4] | (55) Stunning method?*[2] |
| (6) Place of marketing?* | (31) Does the establishment have an exclusive area for the temporary deposit of waste and garbage, delimited and outside the production area? (Yes, No)*[4] | (56) Are there rails or hooks for handling the carcasses? (Yes, No)*[4] |
| (7) Tender carcass price? ($/kg)** | (32) Are domestic animals prevented from entering slaughter, carcass, and viscera areas? (Yes, No)*[4] | (57) Destination for blood?*[4] |
| (8) Tough carcass price? ($/kg)** | (33) Carcass aging time? (hours)*[4] | (58) Do you have containers for disinfecting knives? (Yes, No)*[1] |
| (9) Viscera price? ($/kg)** | (34) Are all plant areas kept free of insects, rodents, birds, or other animals? (Yes, No)*[4] | (59) Are the viscera of each carcass identified? (Likert scale)*[4] |
| (10) Leg price? ($/kg)** | (35) Is the water used to wash equipment and utensils drinkable? (Yes, No)*[4] | (60) What are the viscera deposited in?*[1] |
| (11) Head price? ($/kg?) ** | (36) Do you have a cooling chamber? (Yes, No)*[4] | (61) Are there separate rooms for handling green and red viscera? (Yes, No)*[1] |
| (12) Barbacoa price? ($/kg)** | (37) Do you have freezers? (Yes, No)*[4] | (62) Is *postmortem* inspection performed? (Yes, No)*[4] |
| (13) Percentage of male sheep sold (%)** | (38) How many employees work in the establishment? (N)**[5] | (63) Who performs the *postmortem* sanitary inspection?**[4] |
| (14) Percentage of ewes sold (%)** | (39) Is there no presence of clothing or personal belongings in the slaughter area? (Likert Scale)*[5] | (64) Are there incinerators? (Yes, No)*[1][4] |
| (15) Does the establishment have an animal unloading area and a loading area for carcasses and viscera? (Yes, No)*[4] | (40) Are there lockers where employees can store their belongings? (Yes, No)*[3] | (65) What is the destination for confiscated viscera and carcasses*[4] |

| | | |
|---|---|---|
| (16) Does the establishment have an identified area with water intake and drainage for washing and disinfecting transport? (Yes, No)*(4) | (41) Do employees show up to work neat? (Yes, No)*(5) | (66) Are carcasses washed after skin removal? (Yes, No)*(4) |
| (17) Does the establishment have pens for sick or suspicious animals? (Yes, No)*(4) | (42) Do they wear a cap? (Likert Scale)*(5) | (67) How many liters of water are used per animal? (L)** |
| (18) Does the establishment have pens for the rest period before the slaughter? (Yes, No)*(4) | (43) Do they wear face masks? (Likert Scale)*(3) | (68) Where is the wastewater discharged?*(4) |
| (19) Rest period before the slaughter? (hours)**(4) | (44) Is footwear disinfected before entering the slaughtering area? (Likert Scale)*(3) | (69) Is there signage for dangerous areas? (Likert Scale)*(5) |
| (20) How often are pens, ramps, tunnels, *antemortem* baths, and drying and draining areas washed?**(4) | (45) Does the establishment provide appropriate clothing for work? (Likert Scale)*(3) | (70) Do you have any health promotion programs?* (Yes, No)*(5) |
| (21) Does the establishment have drainage? (Yes, No)*(4) | (46) Are employees prohibited from entering the slaughter or carcass processing areas with jewelry, clips, earrings, rings, watches, or bracelets? (Likert Scale)*(5) | (71) Do you know what good slaughter practices are? (Yes, No)**(5) |
| (22) Does the establishment have restrooms? (Yes, No)*(4) | (47) Are employees prohibited from smoking, drinking, eating, and spitting in slaughtering and carcass processing areas? (Likert Scale)*(5) | (72) Are staff trained in GSP? (Yes, No)*(5) |
| (23) Are the restrooms located outside the slaughter and carcass processing facilities? (Yes, No)*(4) | (48) What type of clothing do employees wear to work?*(5) | (73) Do you know what animal welfare is? (Yes, No)*(6) |
| (24) Does the establishment have a pest control plan? (Yes, No)*(4) | (49) Is access to the slaughter rooms restricted to sick staff? (Likert Scale)*(5) | (74) Do you carry out animal welfare practices? (Yes, No)*(6) |
| (25) Floor and wall building material?*(1) | (50) Are staff required to wash and sanitize their hands and forearms and brush their nails before entering processing areas? (Likert Scale)*(3)(5) | |

N (number), * Qualitative variable, ** Quantitative variable, Likert scale (not compliant, very little compliant, partially compliant, substantially compliant, fully compliant), [1](NOM-008-ZOO-1994), [2](NOM-033-SAG/ZOO/2014, [3](NOM-213-SSA1-2018), [4](NOM-194-SSA1-2004), [5](NOM-120-SSA1-1994), [6](NOM-051-ZOO-1995).

**Table 4:** Relevant and important characteristics of the four clusters formed in the sheep slaughterhouses in the municipality of Capulhuac de Mirafuentes

| No | Slaughter variable or descriptor | Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4 | Value of ($P$) |
|---|---|---|---|---|---|---|
| 1 | SSU number | 10 | 6 | 26 | 14 | |
| 2 | Type of slaughterhouse | Private slaughterhouses (100%) | Private slaughterhouses (33.4%), the Municipal Slaughterhouse (16.6%), Slaughterhouse facilities with private staff (50%) | Private slaughterhouses (84.6%), Slaughterhouse facilities with private staff (15.4%) | Slaughterhouse facilities with private staff (100%) | 0.0001 |
| 3 | How many animals are slaughtered per week | 31±26.8 | 86±114.0 | 60±58.0 | 27±30.0 | 0.1078 |
| 4 | How often sheep are slaughtered | Weekly | Weekly | Weekly | Weekly | 0.2285 |
| 5 | Destination for the carcasses | Meat and barbacoa sale | Meat and barbacoa sale | Sale of meat | Barbacoa | 0.0001 |
| 6 | Place of marketing | Capulhuac and Mexico City Metropolitan Area | Capulhuac | Capulhuac | Mexico City Metropolitan Area | 0.0001 |
| 7 | Tender carcass price/kg | 96.9±4.03 | 99.4±8.00 | 97.0±6.25 | N/C | 0.0001 |
| 8 | Tough carcass price/kg | 91.50±4.03 | 89±8.00 | 88±6.50 | N/C | 0.0001 |
| 9 | Viscera price/kg | 163±10.59 | 151±18.60 | 159±13.20 | N/C | 0.0001 |
| 10 | Leg price/pcs | 34±5.27 | 35±5.00 | 36.30±4.05 | N/C | 0.0001 |
| 11 | Head price/pc | 53±4.40 | 50±0.00 | 53.04±5.50 | N/C | 0.0001 |
| 12 | Barbacoa price/kg | 391±16.93 | 360±28.28 | N/C | 379±24.66 | 0.0001 |
| 13 | % of sheep sold | 84.44±7.26 | 50±20.54 | 65.83±20.14 | 76.5±22.11 | 0.0001 |
| 14 | % of ewes sold | 16.67±5.47 | 50±20.54 | 34.2±16.32 | 23.5±14.12 | 0.0001 |
| 15 | The establishment has an area for unloading animals and a loading area for carcasses and viscera | Yes (100%) | Yes (100%) | No (100%) | Yes (100%) | 0.0001 |
| 16 | The establishment has pens for sick or suspicious animals | No | Yes | No | Yes | 0.0001 |
| 17 | The establishment has pens for the rest period before the slaughter | Yes | Yes | Yes | Yes | 0.3930 |
| 18 | Rest period before the slaughter | 13- 24 h | 13-24 h | 24-48 h | 13-24 h | 0.0490 |
| 19 | How often are pens, ramps, tunnels, *antemortem* baths, and drying and draining areas washed? | Weekly | Daily | Weekly | Weekly | 0.0172 |
| 20 | The establishment has a pest control plan | No | No | Yes | No | 0.0053 |
| 21 | There is a sanitary mat with a disinfectant solution at the entrance to the slaughter area | Yes | No | No | No | 0.0012 |
| 22 | The floor and wall joints are easy to clean | Yes | Yes | Yes | No | 0.0001 |

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|---|---|---|---|---|---|
| 23 | The windows and vents are provided with well-preserved protections to reduce the entry of dust, rain, and harmful fauna | No | No | No | No | 0.0580 |
| 24 | There are signs instructing staff to wash their hands after using the restrooms | No | No | No | No | 0.8340 |
| 25 | Domestic animals are prevented from entering slaughter, carcass, and viscera areas | Yes | No | Yes | No | 0.0001 |
| 26 | Carcass aging time | 1-6 h | 1-6 h | 7-12 h | 7-12 h | 0.0470 |
| 27 | There is a cooling chamber | No | No | No | No | 0.3643 |
| 28 | There are freezers | Yes | Yes | Yes | Yes | 0.0253 |
| 29 | How many employees work in the establishment | 1-5 | 1-5 | 1-5 | 1-5 | 0.9080 |
| 30 | All areas of the plant are kept free of insects, birds, and rodents | Yes | No | Yes | No | 0.0001 |
| 31 | There is no presence of clothing or personal belongings in the slaughter area | Fully compliant | Very little compliant | Partially compliant | Fully compliant | 0.0164 |
| 32 | Meat product establishment managers provide clean work clothes to workers | Not compliant | Not compliant | Not compliant | Not compliant | 0.7601 |
| 33 | They wear face masks | Substantially compliant | Fully compliant | Fully compliant | Fully compliant | 0.0035 |
| 34 | Footwear is disinfected before entering the establishment | Not compliant | Not compliant | Not compliant | Not compliant | 0.0980 |
| 35 | Employees are prohibited from entering the slaughter or carcass processing areas with jewelry, clips, earrings, rings, watches, or bracelets | Not compliant | Not compliant | Not compliant | Not compliant | 0.0481 |
| 36 | Employees are prohibited from smoking, drinking, eating, and spitting in the slaughter and carcass processing areas | Fully compliant | Fully compliant | Fully compliant | Fully compliant | 0.4727 |
| 37 | What type of clothing employees show up to work in | Plastic apron and rubber boots | Plastic apron and rubber boots | Plastic apron and rubber boots | Plastic apron and rubber boots | 0.0708 |
| 38 | Staff must wash and sanitize their hands and forearms and brush their nails before entering the processing areas | Fully compliant | Fully compliant | Fully compliant | Fully compliant | 0.0766 |
| 49 | Staff are trained to do their jobs | Not compliant | Not compliant | Not compliant | Not compliant | 0.0609 |
| 40 | Stunning method | Pithing | Pithing | Pithing | Pithing | 0.0609 |
| 41 | Destination for the blood | Compost | Drainage | For sale | Drainage | 0.0193 |
| 42 | There are containers for disinfecting knives | Fully compliant | Not compliant | Fully compliant | Not compliant | 0.1743 |
| 43 | The viscera of each carcass are identified | Fully compliant | Fully compliant | Fully compliant | Not compliant | 0.0041 |
| 44 | What is the destination for the confiscated viscera and carcasses | Incinerated | Incinerated | Incinerated | Incinerated | 0.0697 |
| 45 | How many liters of water are used per animal | 7-12 L | 25-48 L | 13-24 L | 7-12 L | 0.0238 |
| 46 | There is signage for dangerous areas | Not compliant | Not compliant | Not compliant | Not compliant | 0.1245 |

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