

BARBACOA PRODUCERS' PERCEPTIONS OF ANIMAL WELL-BEING AND ADEQUATE SLAUGHTERING PRACTICES IN SLAUGHTERHOUSES AND THE MUNICIPAL ABATTOIR IN CAPULHUAC DE MIRAFUENTES, MEXICO

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ABSTRACT

This work examines the importance of the perception of good practices in the slaughtering and management of sheep in Capulhuac, State of Mexico, in terms of animal well-being, meat quality, and food security. Meat contamination can originate in slaughterhouses due to inadequate facilities, poor personnel practices, and inefficient maturation times. These factors produce stress in the animals, affecting the sensory characteristics of the meat (texture, color, and water retention) due to biochemical alterations, such as abnormal *post-mortem* pH levels. Therefore, the main actors of the sheep meat production chain (slaughterers and barbacoa producers) were interviewed. The information was evaluated using a discriminant analysis, a principal components factorial analysis, and a cluster analysis to characterize and cluster the perceptions. The results indicate that interviewees consider management before and after slaughtering and animal well-being as critical factors, relating these aspects to the quality of the meat. In addition, they consider that the education of operators in animal welfare is fundamental, along with the promotion of practices that ensure suitable living conditions for animals, such as adequate diets, freedom to move, and a lack of stress. Animal welfare affects the final product's quality and reflects an ethical commitment in production. Likewise, the need to improve slaughterhouse working conditions, such as implementing regulations that ensure humane treatment for animals during their raising and slaughter, is highlighted. This is critical to maintaining the competitiveness of the meat produced and meeting consumers' growing expectations for sustainable and ethically obtained products.

Keywords: Adequate slaughtering practices, animal well-being, food security, slaughterer, meat quality.

INTRODUCTION

Animal protein consumption has played an important role in the evolution of the human diet around the world. Meat contains the nine essential amino acids, including tryptophan, threonine, and lysine, which participate in the formation of bodily structures and the performance of vital biological functions (Njoga *et al.*, 2023). FAO (2023) classifies it as a source of high-quality protein, recommended for inclusion in the human diet to maintain a healthy lifestyle when consumed in moderation, in a proportion of 0.75 g per kilogram of body weight per day. In addition, meat provides energy benefits due to its fatty acids, and its content of vitamins and minerals promotes several biological functions of the organism. However, it is crucial to verify that all processes before obtaining the meat are adequately carried out, since its composition can easily be contaminated with microorganisms and become a vector of food-transmitted diseases (Schirone *et al.*, 2019). This highlights the importance of identifying and mitigating sanitary risk factors throughout the production chain (Mendonça *et al.*, 2019).

Meat production, particularly lamb barbacoa, is the main economic activity in the municipality of Capulhuac de Mirafuentes, State of Mexico, Mexico. Currently, nearly 70 % of its active population participates directly or indirectly in this production chain, including the introduction of animals, slaughtering of sheep, and commercialization of carcasses, as well as the production and distribution of barbacoa, generating local resources and promoting the interaction with external production chains within the country (Pulido *et al.*, 2018; Herrera-Haro *et al.*, 2019).

Despite being a small municipality, Capulhuac de Mirafuentes is known for providing the metropolitan area of the Valley of Mexico with three main products on weekends: barbacoa, lamb tripe, and broth. Barbacoa is obtained by steaming lamb meat in an underground hole, covered with bricks and pulque agave (Espejel-García *et al.*, 2015; Pillado-Albarrán *et al.*, 2017; Vázquez-Martínez *et al.*, 2018). Lamb *pancita* is prepared using the animal's viscera, finely chopped and mixed with epazote, onion, garlic, dried chilies, and spices. This mixture is stuffed into the lamb's stomach and steamed in a stone oven or stockpots, along with barbacoa. Finally, the broth is prepared from a mixture of water, chickpeas, dried chilies, rice, herbs, and seasonings, complemented with juices and fats released during the cooking of the barbacoa and *pancita*.

In this municipality, approximately 400 000 animals are slaughtered every year. However, as in other regions in Mexico, 90 % of the slaughtering destined for human food is carried out in municipal and private slaughterhouses, which often do not meet the necessary conditions to guarantee the well-being of the animal, nor do they have adequate desensitizing processes, which jeopardizes the quality and innocuousness of the meat, as well as being a risk to the health of consumers (Archundia-Velarde *et al.*, 2024). Nowadays, aspects related to breeding, transportation, and slaughtering methods, particularly those to ensure the absence of pain in the animals, are evaluated (Gallo and Tadich, 2008; Miranda-de la Lama, 2013; Solórzano *et al.*, 2019). The aim of this study was to identify barbacoa producers' perceptions of slaughtering practices

and perspectives on animal welfare among workers and municipal meat processors in Capulhuac de Mirafuentes.

MATERIALS AND METHODS

Population studied

The study was aimed at slaughterers that produced barbacoa at the Barbacoa Producers' Association of Capulhuac de Mirafuentes, Mexico. A total sample of 58 individuals was considered based on a simple randomized sampling, considering a finite population, with a trust value of 95 % ($Z = 1.96$), an accuracy of 5 %, a variance estimator equal to 0.25 [$\sigma^2 = \pi(1-\pi)$] and a value of $N = 65$, which accounted for 85 % of the association. To minimize error, participation was announced as voluntary, and producers were assured that establishment owners and slaughterers were unaware of the sampling day, as well as that there would be no economic retribution for participating establishments, indicating that all information would be kept confidential and used solely for research. The study was conducted from February to May 2022.

Survey design

All information was gathered by conducting face-to-face surveys with slaughterers and barbacoa producers who work at the municipal meat processors and sheep producers. The structure of the questionnaire was validated by experts on the topic in the Faculty of Veterinary Medicine and Zootechnics of the Autonomous University of the State of Mexico. The survey included 22 descriptors related to the slaughtering and the production of barbacoa. The questions were focused on the producer's perception and were measured using an ordinary scale consisting of five points: 1, definitely not; 2, probably not; 3, indifferent; 4, probably yes; and 5, definitely yes.

Statistical analysis

Two multivariate statistical techniques were used. Based on the survey data collected, a principal components analysis was conducted for factor extraction, along with the Kaiser-Meyer-Olkin (KMO) index and Bartlett's test of sphericity to measure the correlation among variables. Variables with communality ($h < 0.9$) were not included in the factorial analysis factor, since these variables were not correlated with the new factors. The selected factors had eigenvalues ≥ 1 .

To better understand the factors identified, an orthogonal rotation method (Varimax) was carried out. The scores were estimated using the regression method and kept as new variables. A hierarchical cluster analysis was performed to identify similarities and differentiate the perceptions of the slaughterers. The squared Euclidean distance was used as a similarity measure, and clustering was performed using Ward's method. To select the most significant variables and differentiate the clusters obtained, the Kruskal-Wallis non-parametric test and the Mann-Whitney test were performed. Analyses were performed using SAS v15.0 (SAS Institute Inc., 2002).

RESULTS AND DISCUSSION

The physical and mental conditions of the animals during their raising and transportation, along with the stages before and after slaughtering, which include the resting period, the desensitization method, hygiene-sanitary management of the carcass, and maturation, are determining factors to preserve the innocuousness and quality of the meat (García-Díez *et al.*, 2023). This approach has gained particular importance among the different actors of the production chain, from health authorities to final consumers, who demand responsible practices that ensure safe, sustainable, and ethically produced foods (Mendonça *et al.*, 2019).

Slaughterhouses are a critical link in the production chain of barbacoa, as it takes the transformation of muscle tissue into meat, which is sterile in normal animals under normal physiological conditions at the time of their death (Terlouw and Gagaoua, 2022). Diverse extrinsic factors determine the presence of microorganisms, as well as meat color, flavor, and texture. Among the main risk factors are deficiencies in infrastructure, inadequate equipment operation (Joshi *et al.*, 2003; Aguayo-Ulloa *et al.*, 2021), poor hygienic practices of the personnel (Ashuro *et al.*, 2023), and inappropriate maturing times (Álvarez *et al.*, 2022). These problems are particularly relevant in municipal slaughterhouses, where sanitary control and regulatory compliance are frequently limited.

General characteristics of barbacoa producers and slaughterers

Results showed that 100 % of the participants were men, of whom 51.7 % were between 45 to 60 years old, reflecting an economically active middle-aged population (Table 1). Regarding their educational level, 46.6 % reported having finished high school, whereas 27.6 % only finished elementary school, displaying a predominance of basic academic formation. Most interviewees had more than 10 years' experience in slaughtering and barbacoa preparation, which suggests a transmission of practical and traditional knowledge of the craft.

Principal components analysis

Eight principal components (PC) were identified, which explained 73.9 % of the variability of the data (Figure 1, Table 2), and were named depending on the correlated variables.

PC 1. Animal management before and during slaughtering

This factor had the greatest contribution (Table 2), explaining the variance among survey respondents (17.82 %) and involving aspects of the application of regulations on the management of animal well-being before and during animal slaughtering. It was composed of three correlated descriptors: Do you consider that slaughterhouses comply with adequate regulations to slaughter animals? Do you believe slaughterhouses manage animals adequately before slaughtering? Do you believe slaughterhouses manage animals correctly during slaughtering? For barbacoa producers, this phase was a more relevant procedure for workers during slaughtering.

Table 1. General characteristics of barbacoa producers and slaughterers interviewed in the municipality of Capulhuac de Mirafuentes, State of Mexico.

	Barbacoa producers	Number of interviewees (n)	Percentage of interviewees (%)
Gender			
	Female	0	0
	Male	58	100
Age (years)			
	18–30	6	10.3
	30–45	14	24.1
	45–60	30	51.7
	>60	8	13.8
Level of studies			
	Elementary	16	27.6
	Middle	27	46.6
	High School	12	20.7
	University	3	5.2
Origin			
	Urban	2	3.4
	Rural	56	96.6
Experience (years)			
	1–3	1	1.7
	4–6	2	3.4
	7–10	12	20.7
	>10	43	74.1

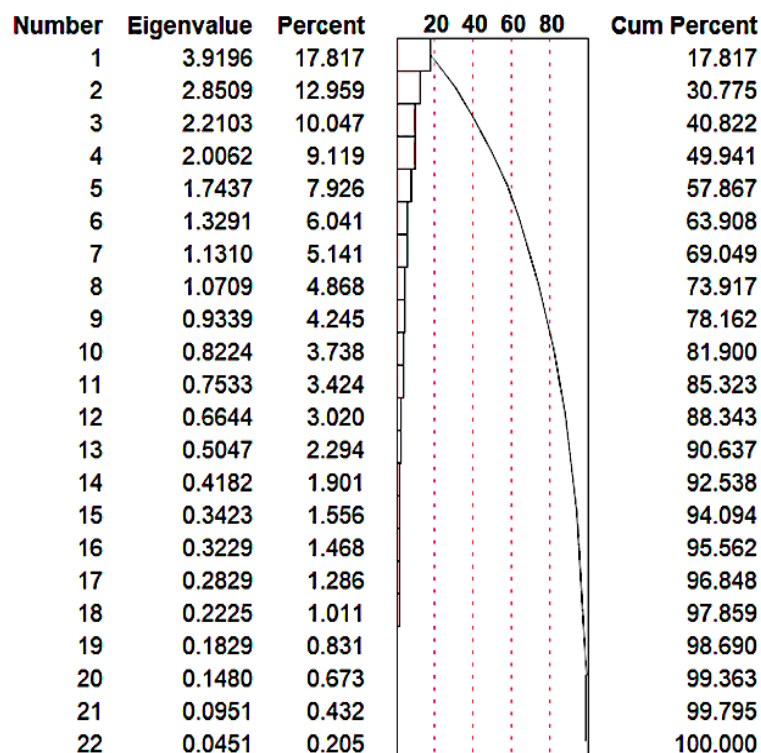


Figure 1. Communalities and eigenvalues of the principal components (PC) and their contribution towards the explanation of the variance (%) of the data in barbacoa producers in Capulhuac de Mirafuentes, State of Mexico.

Table 2. Principal components (PC) in the perception of barbacoa producers on the slaughtering of sheep in the municipality of Capulhuac de Mirafuentes, State of Mexico.

PC	Name assigned to the component	Correlated variables	Eigenvalue	Total variance explained (%)	Explained variance accumulation (%)
PC1	Animal management before and after slaughtering	7, 8, 9	3.91	17.81	17.81
PC2	Stress effects on the sensory characteristics of the meat	4, 5, 17, 18, 22	2.85	12.96	30.77
PC3	Knowledge and perception of slaughterers on animal well-being	3, 10, 12, 14	2.21	10.05	40.82
PC4	Regulations of animal well-being and its importance for meat quality	11, 13	2.00	9.11	49.90
PC5	Perception of the existence of emotions in draft animals	1, 19	1.74	7.90	57.86
PC6	Importance of the relation between adequate livestock practices and animal well-being	6, 15	1.33	6.04	63.90
PC7	Importance of animals expressing the five freedoms of animal well-being during transportation to the slaughtering area	16	1.13	5.14	69.09
PC8	Importance of the actors involved in the barbacoa production chain, knowing the regulations of animal well-being	20, 21	1.07	4.86	73.91

PC 2. Effects of stress on the sensory characteristics of the meat

This component had the second-highest contribution to the explanation of variance among respondents (12.96 %). It includes aspects related to the effects of the slaughtering methods on meat quality characteristics, particularly the impact of stress on the animals. It is composed of five variables: Do you believe the methods and/or ways of slaughtering affect the features of the lamb meat? Do you believe that the animals that suffer generate undesirable meat? Do you believe that farm animals should be free of fear and stress? Do you consider that farm animals feel pain? Do you believe that stress in animals during production and transportation affects the quality of meat and its by-products? For this group of barbacoa producers, it is important that the workers use slaughtering methods that conform to regulations and understand that proper management has a positive impact on the meat's properties.

PC 3. Knowledge and perception of slaughterers on animal well-being

This component explained 10.05 % of variance among survey respondents and is composed of four variables related to education and knowledge on animal well-being. These variables range from living conditions in the flock to practices before

slaughtering: Do you consider slaughterhouses to be an important link in the sheep production chain? Do you believe animals experience pain, anguish, and fear before slaughtering? Do you think education on animal well-being is necessary for slaughterhouse operators and workers? What is your level of knowledge on the living conditions of farm animals? For this group of barbacoa producers, education on animal well-being is crucial, from growth to slaughter.

PC 4. Regulations on animal well-being and their importance for meat quality

This component explained 9.12 % of variance and covers knowledge on regulation to guarantee animal well-being, from standards of living in the flock to slaughtering practices. It includes three variables: Do you consider lamb to be important for the municipality of Capulhuac de Mirafuentes? Do you believe new laws on animal well-being are necessary to avoid abuse in slaughterhouses? Do you believe stress in animals during production and transportation affects the quality of the meat you eat? This group considers it a priority to review and modify regulations on animal well-being for drivers and producers, ensuring their compliance as per the current demands of the consumer society.

PC 5. Existence of emotions in draft animals

This factor was composed of two variables, which represent 7.9 % of the variance explained. This includes the importance of the sheep slaughterhouses in the municipality (perception of work-income sources), as well as the perception of survey respondents on the emotions felt by farm animals.

PC 6. Importance of adequate livestock practices for animal well-being

This component represented 6.04 % of variance and is based on two variables: the perception of respondents on the animals raised in complete freedom and the perception of the implementation of adequate practices in animal management, feeding, care, and health. In this component, little interest is shown by respondents regarding the different forms of sheep production raised for slaughtering.

PC 7. Importance of animals expressing the five freedoms of animal well-being during transportation to the slaughtering area

This component consisted of only one variable, which represented 5.14 % of variance. As in PC 6, respondents displayed little interest in whether drivers allow animals to express natural behaviors of their species during their transportation from the production area to the slaughterhouse.

PC 8. Importance of knowing the regulations of animal well-being in the barbacoa production chain

This component consisted of two variables that make up 4.86 % of the variance explained. These variables reflect respondents' perception as to whether the available

information in Mexico regarding the well-being of farm animals and the need to implement improvements in their protection in the country is adequate. PCs 6, 7, and 8 had the lowest perception by respondents, with an explanation of 16.05 % of the accumulated variance, while PCs 1 to 5 explained 57.87 %.

For slaughterhouse operators and barbacoa producers, the most important factors influencing the final product are proper animal management before and after slaughter, with a focus on reducing stress during desensitization. Likewise, they also considered the importance of implementing animal well-being principles from an early age as a key factor, promoting conditions that ensure the physical and emotional comfort of the animals throughout their productive life. This integral vision is consistent with recommendations by international organizations such as the World Organization for Animal Health (WOAH), which underscore the relation between animal well-being, public health, and food quality. However, these results contrast with earlier studies. Vimiso *et al.* (2012) found that consumers and traders prioritize price, color, and fat content of the meat as main factors, without linking them directly to animal well-being practices. This disparity suggests a gap in the perception of the consumer regarding factors that determine meat quality.

Cluster analysis

Four clusters were formed (Figure 2), which describe the differences found in the perceptions of slaughterers in the barbacoa production chain.

Cluster 1

This was composed of the largest number of barbacoa producers (20), with a middle-high school education level, on average. This cluster stood out for having differences

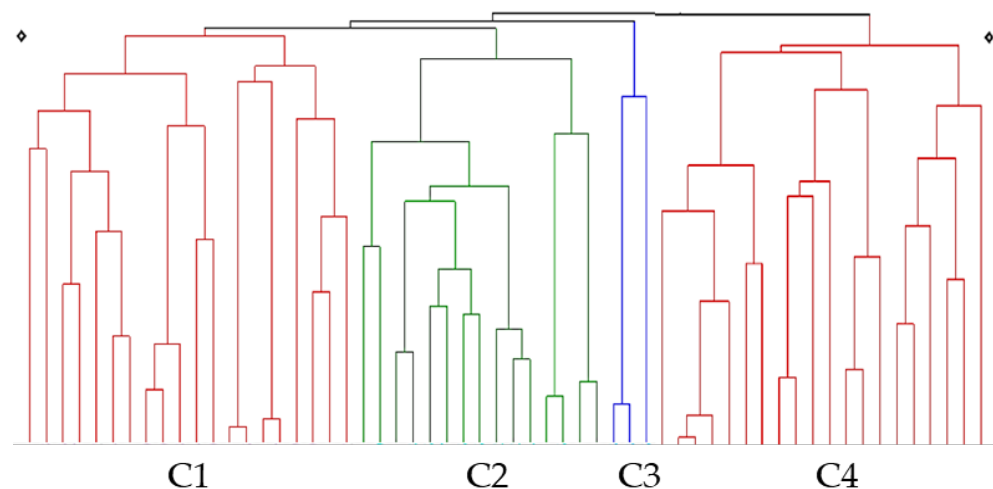


Figure 2. Hierarchical clusters (dendrogram) of the analysis on perceptions of slaughterers and barbacoa producers from Capulhuac de Mirafuentes, State of Mexico.

($p < 0.05$) with the other clusters. This group claims that slaughterhouses are probably not an important element in the lamb production chain. In their vision, which they share with cluster 3, there is undoubtedly no impact of the methods and/or ways of slaughtering on the characteristics of the lamb. Likewise, they consider that animals that suffer do not generate desirable meat. Likewise, they agree with cluster 2 that there is surely not enough information on the well-being of farm animals in Mexico.

Cluster 2

This was composed of 15 barbacoa producers with an elementary-middle school education, who displayed significant differences in perception ($p \leq 0.05$) in comparison to the other clusters. For this group, the importance of the well-being of farm animals was the lowest among clusters. It also featured the lowest level of knowledge on the living conditions of farm animals. Additionally, it coincides with cluster 1 that there surely is not enough information on the well-being of farm animals in Mexico.

Cluster 3

Composed of three barbacoa producers with an elementary-middle school education, this cluster displays significant differences ($p \leq 0.05$) with the other groups, mainly regarding not considering that farm animals feel pain, although they are aware that they probably have emotions. Likewise, they consider that stress produced in animals during production and transportation probably does not affect the quality of the meat. On the other hand, they agree with cluster 2 that new laws are required regarding the well-being of animals to avoid the abuse of animals in slaughterhouses.

Cluster 4

Composed of 15 barbacoa producers with elementary-middle school education. They display significant differences ($p \leq 0.05$) with other clusters in their belief that slaughterhouses probably do not manage animals correctly during pre-slaughter and slaughtering. This cluster probably does not believe that slaughterhouses comply with adequate regulations to slaughter animals ($p \leq 0.05$).

The cluster analysis showed that most participants were rural men with a medium education level (middle or high school). This characteristic is relevant, as mentioned by Ashuro *et al.* (2023), who showed that handlers with higher education levels displayed significantly better personal hygiene practices and a greater willingness to participate in training programs. On the other hand, Tegegne (2017) found a strong correlation between education and knowledge on food security, as well as with the washing of hands. Gil *et al.* (2024) points out that the hygienic handling of meat is related to the level of education of the operators, so long as there is constant supervision and training, with the latter two practices being relevant for slaughterers and barbacoa producers, who believe that they are not being implemented in Capulhuac de Mirafuentes (Table 3).

Table 3. Key characteristics identified in the clusters formed by the perception analysis of slaughterers and barbacoa producers in Capulhuac de Mirafuentes, State of Mexico.

Study variable Respondents	Cluster 1 20	Cluster 2 15	Cluster 3 3	Cluster 4 15	$p \leq 0.05$
Do you believe sheep slaughterhouses are important for the municipality of Capulhuac de Mirafuentes?	5	5	5	5	0.092
Do you believe lamb is important for the municipality of Capulhuac de Mirafuentes?	5	5	5	5	0.088
Do you believe slaughterhouses to be an important link in the sheep production chain?	2	5	5	5	0.001
Do you believe the methods and/or ways of slaughter affect the properties of the lamb?	1	5	1	5	0.001
Do you believe that animals that suffer generate less desirable meat?	1	5	1	5	0.001
Do you believe the meat from animals raised in complete freedom is better?	5	5	5	5	0.365
Do you believe slaughterhouses comply with adequate regulations for slaughtering animals?	5	5	1	2	0.015
Do you believe slaughterhouses handle animals correctly during pre-slaughtering?	5	5	4	2	0.001
Do you believe slaughterhouses handle animals correctly during slaughtering?	5	5	4	2	0.001
Do you believe animals experience feelings of pain, anguish, and fear before being taken to be slaughtered?	5	5	5	5	0.45
On a scale of 1 to 10, how important is the well-being of farm animals to you?	8	8	8	10	0.004
Do you believe slaughterhouse operators and workers should be educated on animal well-being?	5	5	5	5	0.8
Do you believe new laws are needed regarding animal well-being to avoid the abuse of animals in slaughterhouses?	5	4	4	5	0.006
What is your level of knowledge on the living standards of farm animals?	Medium	Low	High	Low-medium	0.012
Should farm animals be well-fed, warm, and healthy?	5	5	5	5	0.131
Should farm animals be able to express the natural behaviors of their species?	5	5	5	5	0.451
Should farm animals be free from fear and stress?	5	5	5	5	0.138
Do farm animals feel pain?	5	5	2	5	0.005
Are farm animals able to feel emotions (positive or negative)?	5	5	4	5	0.041
Do you believe there is enough information in Mexico on the well-being of farm animals?	1	1	2	2	0.037
Do you believe the well-being and the protection of farm animals in Mexico should be improved?	5	5	5	5	0.767
Do you believe stress in animals during production and transportation can affect the quality of the meat consumed?	5	5	2	5	0.002

1: definitely not; 2: probably not; 3: indifferent; 4: probably so; 5: definitely so.

In general terms, survey respondents consider the slaughtering of sheep and the marketing of meat and barbacoa as imperative economic activities for the municipality of Capulhuac de Mirafuentes, and they are aware that farm animals should be well fed, warm, and free from fear or anguish. However, they do not understand the negative impact that omitting such conditions may have on meat safety and quality. This is one of the main consequences related to the appearance of the dark, firm, and dry meat (DFD) syndrome, which reduces tenderness, sensorial acceptability, and yield of the carcass, with a direct influence on the acceptance of consumers (Koscinczuk, 2014; Quiroz-Osorio *et al.*, 2016; Hernández-Hernández *et al.*, 2023).

Several authors point out that muscle undergoes physical and biochemical changes due to a reduction in blood flow, which interrupts oxygen uptake by myoglobin to the mitochondria. This process triggers a series of enzyme adaptations that try to obtain energy from the stored glycogen (Zhang *et al.*, 2019) through the metabolic pathway of anaerobic glycolysis. This produces small amounts of ATP, carbon dioxide, and lactic acid (Zhao *et al.*, 2022), which produce pH levels higher than 5.6 *post-mortem* in the carcass, with direct repercussions on the sensory characteristics perceived by consumers (meat texture, color, taste, and water-retaining ability) (Terlouw and Gagaoua, 2023). As a result, it is critical to implement humane and standardized procedures that reduce animal suffering while ensuring safe and high-quality meat.

CONCLUSIONS

Slaughterers and barbacoa producers in the municipality of Capulhuac de Mirafuentes identify the lack of education as the main problem in topics related to animal well-being. This aspect is essential to guarantee that animals are raised under conditions that allow them to express the natural behaviors of their species. Additionally, it ensures that their nutritional and physical health needs are met and that stress is minimized throughout the whole production process. These factors are acknowledged to have a direct impact on the sensory properties of meat, such as taste, texture, and overall quality. For this reason, training programs focusing on adequate livestock production and animal well-being, as well as slaughtering and food safety, must be implemented to contribute to improving productive practices in municipal slaughterhouses. These actions guarantee a safe and high-quality end product for the consumer.

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