Technology adoption in animal production units in the Valle del Mezquital Hidalgo, Mexico

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The objective of this study was to determine training needs and the rate of technology adoption (TAI) in animal production units in Hidalgo, Mexico. Seventy livestock producers from 19 municipalities were interviewed. Training needs were assessed in five areas: genetics and reproduction, nutrition, health, management, and ecotechnologies. Technology adoption was measured using a weighted index of 20 technologies distributed across these five areas. The highest levels of production were found in sheep (24%) and cattle (21%). The main training needs were in management (2.9), nutrition (2.8), and health (2.3), while genetics and reproduction (1.31) and ecotechnologies (1.17) were lower priorities. The highest TAI was observed in dairy cattle (51.6%) and beef cattle (50.2%), followed by pigs (35.4%), which were considered to have an intermediate technological level. Poultry (26.6%), goats (24.0%), and sheep (19.2%) were classified as having a low technological level. In genetics and reproduction, adoption was high in cattle; in nutrition, both dry cattle and pigs stood out; while in animal health and ecotechnologies, adoption was low. The findings suggest that extension efforts aimed at promoting technology adoption should consider species-specific needs, type of production, and production zones, as well as the socioeconomic and technical-productive context of the production units.

Keywords: Technology adoption index, rural extension, small livestock keepers, technical assistance, knowledge sharing

Introduction

Small-scale livestock production plays a critical role in rural livelihoods by contributing to household food security, income diversification, and economic resilience in the face of environmental and economic shocks (Chao, 2024; Kumari et al., 2022). In developing regions, animal production systems managed by smallholders often function as complementary activities within diversified livelihood strategies, frequently relying on family labor, limited capital, and locally available resources.

Despite their socio-economic importance, these systems often exhibit low productivity and limited sustainability due to inefficient management practices and restricted access to appropriate technologies (Chandran et al., 2023). The adoption of improved practices in animal nutrition, health, genetics, and reproduction is frequently constrained by limited access to technical assistance, financial restrictions, and weak institutional support (Peraza et al., 2020).

In this context, rural extension systems play a key role in facilitating technology transfer through capacity building, knowledge exchange, and sustained technical support (Chao, 2024). However, these systems face significant challenges, including fragmentation, lack of institutional continuity, and limited alignment between research, public policies, and local needs (Shasani et al., 2020). Effective extension programs require not only the provision of technical information but also the strengthening of producers' capacities, the integration of empirical knowledge, and the implementation of contextually appropriate technologies (Chandana et al., 2022; Suess-Reyes & Fuetsch, 2016).

In the Mezquital Valley, Hidalgo, Mexico, livestock production units are predominantly family-managed, small-scale, and traditional, which limits both productivity and sustainable development in the sector. Understanding producers' training needs and levels of technology adoption is therefore essential for designing effective, context-sensitive extension interventions. Accordingly, the objective of this study was to identify training needs and estimate the Technology Adoption Index in livestock production units in the Mezquital Valley, with the aim of guiding differentiated and context-appropriate extension strategies.

Materials and Methods

The study was conducted between May and August 2024 in municipalities located in the Mezquital Valley, Hidalgo, Mexico. A total of 70 livestock producers were selected through purposive sampling, considering the geographic location of production units and their participation in technical assistance programs supported by the Universidad Politécnica de Francisco I. Madero.

A descriptive research design was employed using a semi-structured diagnostic questionnaire. The instrument collected information on production characteristics, species managed, and perceived training needs. Training needs were assessed across five areas: genetics and reproduction, feeding, animal health, management, and eco-technologies. Producers evaluated each area using a four-point Likert-type scale ranging from "not necessary" (1) to "very necessary" (4), following the methodology proposed by Hijam et al. (2015). Mean scores equal to or greater than 2.50 were interpreted as indicating a need for training.

A training program was carried out for the generation of the Technology Adoption Index (TAI) through the evaluation of 20 technological elements related to five training areas: 1) genetics and reproduction, 2) feeding, 3) management, 4) health, and 5) ecotechnologies (Vélez et al., 2013). The weighting defined for the areas of genetics and reproduction, feeding and health was 25 points, for management and ecotechnologies 15 and 10 points respectively (Vargas et al., 2015). A value was given for each of the 25 technologies evaluated within each discipline.

The Technology Adoption index (*TAI*) was calculated from a nominal value of 100, representing full adoption of the 25 evaluated technological elements. The index was estimated using the following equation:

$$TAI = \sum_{i=1}^{25} Pk(i)\, Vi \qquad (1)$$

Where *TAI* is the Technology Adoption index; *i* represents the technological element (i = 1, …, 25); V_i is the value assigned to the *i* -th technological element, ranging from 0 to 100; and *Pk*(*i*) is the weighting coefficient corresponding to traning area ($k = 1, \ldots, 5$) to which the *i* –th technological element belongs.

The weighting coefficient satisfy the following condition:

$$\sum_{K=1}^{5} Pk = 100 \qquad (2)$$

The IAT assessment was associated with three levels in the production units, according to the methodology proposed by Vélez et al., (2013): values from 0 to 33 low corresponds to low technological level, from 33 to 66 intermediate technological level, and higher than 66 high technological level.

Descriptive statistics were used to summarize production characteristics. Analysis of variance was conducted to examine differences in training needs and technology adoption among species, and Tukey's test was applied for mean comparisons using Minitab 2018.

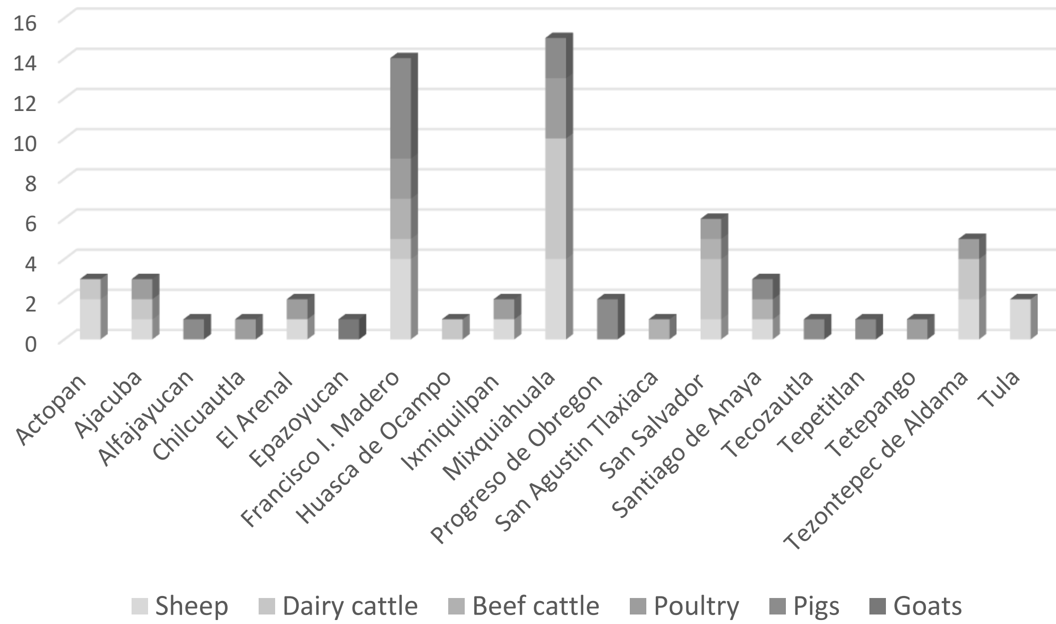
Results

Identification of production units

The 70 participating production units were distributed across 19 municipalities, with higher representation in Mixquiahuala, Francisco I. Madero, and San Salvador (Figure 1.)

Figure 1

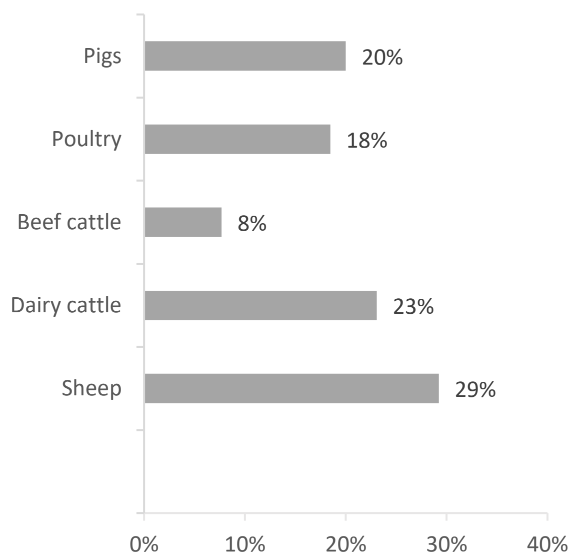
Cooperating livestock production units in municipalities in the State of Hidalgo, Mexico.



Sheep production was the most prevalent species, followed by dairy cattle. Pig and poultry production systems were also frequently represented among the units, while beef cattle and goat production occurred at lower proportions. This distribution indicates the predominance of small-scale livestock systems with a focus on species commonly managed under family-based production conditions (Figure 2).

Figure 2

Livestock species present in production units



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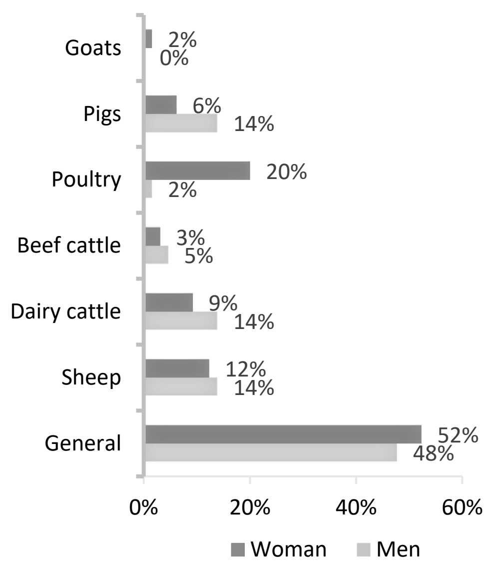
Women were responsible for 56% of the production units, particularly in poultry, sheep, dairy cattle, and goat systems, highlighting their central role in small-scale livestock management in the region. Men managed 44% of the production units, with higher representation in sheep, dairy cattle, and pig production systems (Figure 3).

Figure 3

Proportion of cooperating producers by livestock species



Training needs in the Valle del Mezquital, Hidalgo Mexico

The assessment of training needs in livestock production units of the Valle del Mezquital, Hidalgo, revealed highly significant differences among training areas within livestock species ($p \leq 0.001$), while no statistically significant differences were observed among species (Table 1). Mean values equal to or greater than 2.5 were considered indicative of a perceived training need.

Table 1

Mean scores of perceived training needs by livestock species in production units of the Mezquital Valley, Hidalgo, Mexico.

Species	n	Genetics and Reproduction	Feeding	Health	Management	Ecotechnologies
General	70	1.31^{bc}	2.8^{aAB}	2.37^{aB}	2.9^{aA}	1.17^{BC}
Sheep	17	1.58^{aB}	3.25^{aA}	2.05^{aB}	2.87^{aA}	1.12^{aB}
Milk cattle	15	1.27^{bc}	2.88^{aA}	2.26^{aAB}	2.86^{aA}	1.4^{aBC}
Pigs	14	1.28^{bC}	2.85^{aA}	2.01^{aB}	2.92^{aA}	1.07^{aA}
Birds	14	$1.21^{(a)\,(B)\,(C)}$	$2.64^{(a)\,(A)}$	2.71^{aA}	2.92^{aA}	1.07^{aB}
Beef cattle	5	$1.20^{(a)\,(B)\,(C)}$	3.21^{aA}	2.8^{aAB}	3.0^{aA}	1.2^{aB}
Goats	5	$1.40^{(a)\,(B)\,(C)}$	1.61^{bB}	3.4^{aA}	3.20^{aA}	1.1^{aB}

Note. Different lowercase letters within a column indicate significant differences among species ($p \leq 0.05$). Different uppercase letters within a row indicate significant differences among training areas within the same species ($p \leq 0.001$).

Across all production units, management (2.90) and feeding (2.80) registered the highest mean scores, indicating the greatest perceived need for training, followed by animal health (2.37). In contrast, genetics and reproduction (1.31) and ecotechnologies (1.17) showed mean values below the established threshold, suggesting a lower perceived need for training in these areas.

At the species level, sheep production units reported higher training needs in feeding (3.25) and management (2.87), whereas genetics and reproduction (1.58) and ecotechnologies (1.12) received lower scores. Dairy and beef cattle production units exhibited similar patterns, with higher perceived needs in feeding, management, and health. Pig and poultry units also showed elevated scores in management and feeding. Goat production units presented the highest perceived training needs in animal health (3.40) and management (3.20). Overall, the results indicate that perceived training needs were more strongly associated with specific production areas than with livestock species.

Adoption of technologies in animal production units

Livestock production units in the Valle del Mezquital exhibited statistically significant differences in the adoption of technological components across the evaluated training areas study region showed significant differences ($p < 0.05$; Table 2). In the area of genetics and reproduction, dairy and beef cattle producers were the ones that adopted the technologies in the highest proportion with 85.6% and 60.0% respectively, on the contrary, sheep producers had the lowest level of adoption with 25.64%. In the area of feeding, cattle producers had the highest adoption, followed by pig and poultry producers, while sheep and goat producers reported the lowest adoption with significant statistical difference ($p < 0.05$).

Table 2

Technology adoption by area and technology adoption index (TAI) in livestock production units in the Valle del Mezquital Hidalgo, Mexico.

Species	N	Genetics and reproduction	Feeding	Management	Health	Ecotechnologies	TAI
Milk cattle	15	85.6^{A}	64.0^{A}	10.6^{A}	45.3^{A}	13.3^{A}	51.6^{A}
Beef cattle	5	60.0^{AB}	80.0^{A}	8.0^{A}	48.0^{A}	20.0^{A}	50.2^{AB}
Pigs	14	57.1^{AB}	42.8^{AB}	7.6^{A}	32.8^{A}	10.7^{A}	35.4^{AB}
Birds	14	19.4^{AB}	50.0^{AB}	9.5^{A}	31.4^{A}	0.0^{B}	26.6^{BC}
Goats	5	35.2^{AB}	16.0^{B}	8.0^{A}	40.1^{A}	0.0^{B}	24.0^{BC}
Sheep	17	25.6^{B}	33.0^{B}	3.14^{A}	16.4^{B}	0.0^{B}	19.2^{C}

Note. Different uppercase letters within a column indicate statistically significant differences among livestock species ($p \leq 0.05$).

Regarding feeding technologies, cattle production units exhibited the highest adoption levels, followed by pig and poultry units. Sheep and goat production units reported the lowest adoption rates, with statistically significant differences observed among species ($p \leq 0.05$). In the management area, no statistically significant differences were detected among species ($p > 0.05$); overall adoption levels were low, ranging from 3.1% in sheep units to 10.6% in dairy cattle units. In the health area, sheep production units exhibited the lowest level of technology adoption (16.4%), differing significantly from the other species ($p \leq 0.05$), which showed comparable adoption rates. Adoption of ecotechnologies was generally limited across production units; only pig and cattle production units reported adoption in this area, whereas no adoption was observed in goat, sheep, or poultry units.

The overall Technology Adoption Index (TAI) indicated that dairy cattle production units had the highest level of technology adoption (51.6%), followed closely by beef cattle units (50.2%). Pig, poultry, and goat production units exhibited similar intermediate adoption levels, while sheep production units showed the lowest TAI (19.2%). Based on these values, pig and cattle production units can be classified as having an intermediate technological level, whereas poultry, goat, and sheep production units are characterized by a low technological level, according to the criteria proposed by Vélez et al., (2013).

Discussion

Divergence was found in this study between the areas in which farmers perceive the greatest need for training and those in which they have achieved the greatest adoption of technologies. The gap between training needs and the Technology Adoption Index (TAI) allows identifying dual scenarios: high need with intermediate level of adoption, high need with low and intermediate adoption, low need with intermediate adoption and low need with low adoption.

This convergence could be associated with the production approaches of the systems. Generally, these species are market oriented, they acquire their feed inputs in the local market at high costs and therefore demand assistance in feed technologies that allow them to increase production efficiency and increase their profit margin. In this sense, when technologies are perceived as practical, economically viable and backed by adequate technical support, adoption becomes feasible and sustainable (Chao, 2024; Kumari et al., 2022). Sharma and Rlyazuddin (2024) document a similar phenomenon in sheep farmers in northern India, where sustained training in feeding resulted in the adoption of multi-nutrient blocks, rationing strategies and pasture rotation, evidencing the effectiveness of extension models aligned with immediate farmer needs (Becerra-Encinales et al., 2024).

In this study, the area of animal health, particularly in minor species such as sheep, goats and poultry, represents a case of high need for training, but with low technological adoption, which indicates that production units identify and prioritize sanitary practices (vaccination, deworming, and biosecurity), however, they have limitations in technical knowledge, infrastructure and access to technical assistance services, thus generating a low level of implementation of sanitary technologies. Kumar et al. (2022) agrees for poultry that disease management is an area of greatest demand for training by producers and where the adoption of technologies is positively correlated with the socio-economic and educational background of producers. Sinha and Bhasin (2024) and Thangjam et al. (2024), mention that in family animal production systems sanitary training is ineffective if it is not accompanied by accessible inputs and reinforced by recurrent technical visits. In this sense, our findings confirm that health training is necessary but tends to fail when it is not articulated by a functional institutional environment and a long-cycle extension model.

In the area of genetics and reproduction, an inverse phenomenon is observed, with low demand for training, but moderate levels of technological adoption, especially in cattle production units. The higher adoption of technological elements is consistent with what has been reported in other studies where artificial insemination, selection and genetic improvement in cattle is associated with a vertical process induced by breeding companies and government programs that promote its use to improve milk and meat yields (Meena et al., 2017; Singh et al., 2024). Thus, reproductive technologies are used, without learning processes or capacity building for producers (Meena et al., 2017; Shakya et al., 2019).

The management of waste from livestock units and the use of alternative energies are ecotechnologies practices with low levels of demand for training and low levels of adoption, which reflects a structural disconnection between environmental sustainability proposals and the productive logic of family units. Singh et al. (2023) point out that, in highly precarious rural contexts, eco-technologies are only adopted when they offer tangible, short-term economic benefits (Chandana et al., 2022; Suess-Reyes & Fuetsch, 2016). In the case of Valle del Mezquital, characterized by its subsistence economy and low risk tolerance, these technologies are still considered secondary or inaccessible.

The findings on training needs and technological adoption in livestock production suggest that the design of interventions should prioritize areas where there is a convergence between training needs and technological feasibility (feeding, management and basic health) and intervention strategies should be designed for induced technologies (genetics and reproduction) that are in low demand (eco-technologies) to strengthen the capacities of producers (Becerra-Encinales et al., 2024; Peraza et al., 2020). Effective extension models should emphasize continuous technical support, on-farm demonstrations, farmer field schools, and peer learning, while recognizing differences among livestock species, producers' socio-economic conditions, and territorial contexts. Promoting producers' active participation and integrating empirical knowledge into extension processes are key to improving the adoption, efficiency, and sustainability of small-scale livestock systems (Chandana et al., 2022; Saha et al., 2023; Suess-Reyes & Fuetsch, 2016).

In this context, the adoption of technologies and innovations is strongly influenced by the support and training provided by government institutions and research centers. This aligns with what was noted by Silvert et al. (2022), who state that, in the absence of connections with external actors and institutions, farmer groups and communities tend to become distrustful and less open to innovation and change

Conclusions

This study highlights critical implications for extension strategies in small-scale livestock systems. The observed divergence between perceived training needs and technology adoption emphasizes the importance of aligning interventions with both producer priorities and the feasibility of technological implementation. Training should be prioritized in feeding, basic management, and animal health, where high demand coincides with opportunities for measurable improvements in productivity and efficiency.

Low adoption of health technologies in minor species, as well as limited uptake of eco-technologies across all units, indicates structural and institutional barriers that constrain implementation. Effective extension programs should integrate not only technical knowledge but also access to inputs, infrastructure, and sustained technical support. Tools such as on-farm demonstrations, farmer field schools, and continuous technical visits could enhance adoption, particularly for practices requiring repeated application or supervision.

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