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RESEARCH ARTICLE

Knowledge, Attitude and Practices (KAP) of Antibiotic Residues in Marketed Milk and Withdrawal Compliance among Dairy Farmers and Veterinarians in Pakistan: One Health Behavioral Risk Assessment

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ABSTRACT

The presence of antibiotic residues in milk is a chronic food safety issue in developing milk production systems. The aim of this study was to evaluate the knowledge, attitudes, and practices (KAP) related to antibiotic residues and withdrawal-period compliance among dairy farmers and veterinarians in Pakistan. This cross-sectional survey was conducted across Punjab and included 420 respondents (300 farmers and 120 veterinarians). A structured questionnaire was used for data collection, and descriptive statistics, chi-square tests and multivariate logistic regression were used for analysis. Knowledge was moderate, as 64% of respondents knew that antibiotics can be transferred to milk. However, withdrawal periods were correctly understood by only 36%. Misconceptions were common, including 49% of respondents who believed that boiling would remove residues. Attitudes toward milk safety were generally positive, with 78% identifying milk safety as important. However, reported practices were weak. About 61% of farmers sold milk during antibiotic treatment, 52% did not observe withdrawal periods, and 47% reported using antibiotics without veterinary advice. Education level, access to veterinary services and knowledge scores were significantly associated with safer practices ($p < 0.05$). The findings indicate a clear knowledge-practice gap, driven by economic constraints and inadequate regulatory enforcement. Targeted training, veterinary advisory support and stronger enforcement are required to reduce antibiotic-residue risks and improve public health protection.

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INTRODUCTION

Demand for animal-derived food products has risen worldwide, along with antimicrobial use in animal production. Antibiotics are important for disease management, but their overuse is a major driver of antimicrobial resistance and contamination of food products (Chantziaras *et al.*, 2014; Economou and Gousia, 2015; Van Boeckel *et al.*, 2015). Food-chain exposure is also relevant to antimicrobial resistance because resistant bacteria and drug residues can move between animals, food and humans (Aarestrup *et al.*, 2010; Marshall and Levy, 2011). Milk is one of the important food items in Pakistan and is consumed by all age groups. However, the dairy industry is mostly unorganized and poorly regulated. Withdrawal periods are important to ensure that antibiotic residues do not remain in milk. These residues are not reliably removed by routine processing methods such as boiling and may therefore become a continuous low-dose source of

antimicrobial exposure for consumers (Mitchell *et al.*, 1998; Oliver *et al.*, 2011). Smallholder dairy farming is the main livestock enterprise in Pakistan.

However, despite growing awareness of antimicrobial stewardship, monitoring studies have recently found traces of antibiotics in marketed milk. Poor treatment records and lack of farmer training and residue surveillance programs are common causes of residues. These factors decrease the effectiveness of the measures taken during the withdrawal period (Hajrulai-Musliu *et al.*, 2023; Bovino *et al.*, 2024).

Residual antimicrobials in milk are a potential threat to One Health. Low level exposure can lead to selection of resistance within microbial populations and can impact the microbiological quality of dairy products. Coordinated actions between producers, veterinarians and the authorities are therefore necessary for control to be effective (Manyi-Loh *et al.*, 2023; Medeiros *et al.*, 2024). There is limited access to veterinary care, and antibiotics are often used without prescription. Withdrawal periods may be unknown to farmers, and economic pressure can result in milk being sold during treatment (Ali *et al.*, 2020; Khan *et al.*, 2021). Moderate awareness and inadequate antimicrobial practices have also been reported in Pakistan (Ahmed *et al.*, 2022; Shah *et al.*, 2023; Latif *et al.*, 2025). However, there is a lack of specific studies on antibiotic residues in marketed milk and the behavioral factors behind withdrawal compliance. Farmers' and veterinarians' views have also not been sufficiently investigated. Behavioral research suggests that knowledge alone is not enough to change practice. Economic factors, enforcement and the absence of veterinary services are important determinants (Garforth *et al.*, 2013; Speksnijder *et al.*, 2015). This study aimed to identify the knowledge, attitudes and practices of dairy farmers and veterinarians toward antibiotic residues in milk and to determine predictors of unsafe practices in the context of a One Health approach in Pakistan.

MATERIALS AND METHODS

From January to April 2025, a cross-sectional survey was carried out in selected districts of Punjab, Pakistan, to determine knowledge, attitudes and practices (KAP) related to antibiotic residues in milk and compliance with milk withdrawal periods. The total number of participants was 420, including 300 dairy farmers and 120 veterinarians. To ensure representation of farm size and veterinary practice settings, multistage convenience sampling was used.

A structured questionnaire was designed based on published literature and expert review. The questionnaire consisted of four parts: demographics, knowledge (8 items), attitude (5 Likert-scale items), and practices (6 items). The instrument was pre-tested with 25 participants, and minor adjustments were made for clarity and ease of understanding. Personal interviews were used to improve uniformity and reduce missing responses.

Responses were quantified using a scoring system. For knowledge questions, a score of 1 was given for a correct answer and 0 for an incorrect or "do not know" answer. Knowledge scores >=70% were defined as good. Attitude was measured on a 5-point Likert scale, and a mean score >=3.5 was considered a positive attitude. Practices were classified as safe or unsafe, and scores >=70% were considered good practice.

Ethical approval: Ethical issues were adhered to during the study. Respondents were asked to participate voluntarily, informed consent was obtained, and answers were kept confidential.

Statistical analysis: Data were analyzed in SPSS. Descriptive statistics were used to summarize the data. Chi-square tests were used to assess associations between categorical variables, and multivariate logistic regression was used to determine factors associated with unsafe practices. Odds ratios (OR) with 95% confidence intervals (CI) were computed. A p value <0.05 was regarded as statistically significant.

RESULTS

There were 420 participants in the analysis, of which 300 were dairy farmers (71.4%) and 120 were veterinarians (28.6%). The mean age of farmers was 42 +/- 11 years, which was higher than the mean age of veterinarians (35 +/- 7 years). All veterinarians had formal professional education, while only 48% of farmers had secondary education. Access to veterinary services was limited among farmers, with only 63% consulting veterinarians regularly. In addition, 39% of farmers kept more than 10 animals, indicating that most respondents were engaged in small- and medium-scale farming.

The knowledge-practice gap is summarized in Fig. 1. Sixty-four percent of participants correctly identified that antibiotics can enter milk after treatment. In contrast, only 36% correctly understood withdrawal periods. Awareness of the harmful effects of residues on human health was moderate (57%). A major misconception was also observed, as 49% of respondents believed that boiling milk would eliminate antibiotic residues.

When the data were stratified by participant type, veterinarians showed significantly higher knowledge levels than farmers (82% vs 34% good knowledge, respectively; $p < 0.001$). Knowledge levels were also higher among participants with higher education (Figure 4). These results suggest a significant disconnect between professional knowledge and

field-level practice. Most participants (78%) agreed that milk safety is a public health issue. Likewise, 84% agreed that structured training programmes are needed for farmers, and 71% believed that veterinary consultation should be compulsory before antibiotic use. Despite these positive attitudes, 29% of respondents still considered selling milk during antibiotic treatment acceptable under certain circumstances. This suggests that favorable attitudes may not necessarily translate into safe behavioral practices.

Unsafe behavior patterns were consistent in the practice-related findings (Figures 1 and 2). Most farmers (61%) reported that they sold milk during antibiotic treatment. Only 48% of respondents complied with the recommended waiting periods before marketing milk. Almost half of farmers (47%) reported using antibiotics without a veterinary prescription, while 69% kept no treatment records. A composite practice score showed that only 42% followed good practices, revealing a large discrepancy between knowledge and practice.

Chi-square analysis was used to determine the relationship between key variables and safe practices. Practice outcomes were significantly associated with education level ($\chi^2 = 8.12$, $p = 0.009$), with higher education linked to safer practices. Compliance with withdrawal periods was also positively associated with access to veterinary services ($\chi^2 = 5.76$, $p = 0.018$). Knowledge score was significant ($\chi^2 = 9.45$, $p = 0.006$), but knowledge alone was not sufficient to predict practice.

The independent predictors of unsafe practices were identified by multivariate logistic regression analysis (Figure 3). Low knowledge was the strongest predictor, with participants who had poor knowledge being almost twice as likely to report unsafe practices (OR = 1.94, 95% CI: 1.32-2.85, p = 0.002). Limited access to veterinary services was also associated with risk (OR = 1.71, p = 0.009), and low education level was an independent risk factor (OR = 1.63, p = 0.018). There were no significant differences in practice outcomes by farm size (p > 0.05).

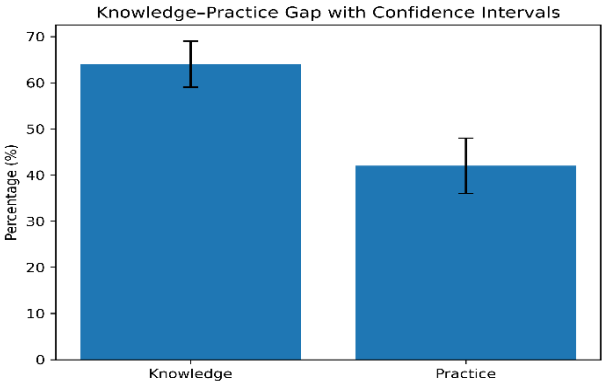

Fig. 1: Knowledge-practice gap. Knowledge (64%) exceeded good practice (42%), indicating a behavioral gap.

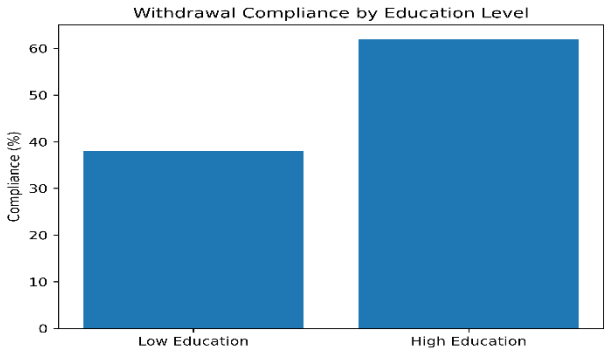

Fig. 2: Withdrawal compliance. Overall, 48% of respondents were compliant and 52% were non-compliant with withdrawal periods.

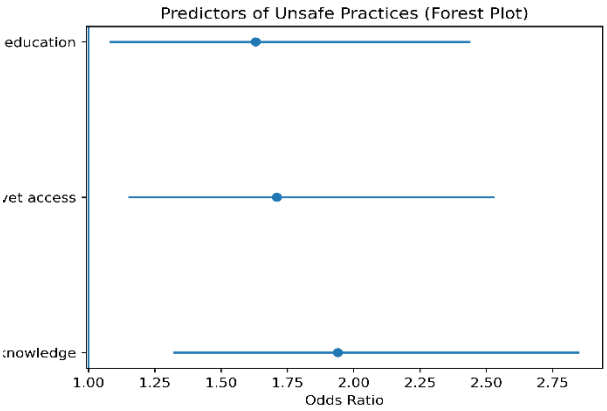

Fig. 3: Logistic regression forest plot. Low knowledge, low education and lack of veterinary access increased the risk of unsafe practices.

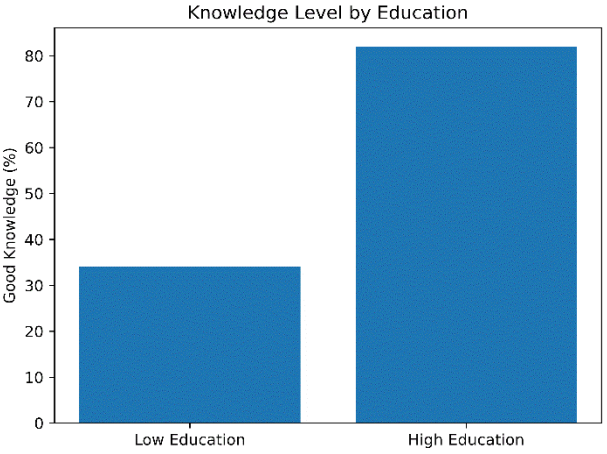

Fig. 4: Knowledge level stratified by education. Participants with higher education showed markedly higher knowledge levels (82%) compared with the low-education group (34%).

DISCUSSION

The main finding of this study is clear that knowledge does not always translate into safe practice. This gap has been reported in several settings but remains unresolved (Ali *et al.*, 2020; Ahmed *et al.*, 2022). Awareness of withdrawal periods was especially low. This is important because withdrawal compliance directly affects the presence of residues in marketed milk. Similar gaps have been observed in recent Pakistani studies (Rafique *et al.*, 2023; Iqbal *et al.*, 2024; Latif *et al.*, 2025). The belief that boiling removes antibiotic

residues remains common. This is important because heat-stable residues can persist in milk and influence consumer risk perception (Mitchell *et al.*, 1998; Oliver *et al.*, 2011). Economic pressure is a major factor. Farmers depend on daily milk income, and discarding milk during treatment may not be feasible. As a result, milk may be sold during treatment. This behavior has also been reported in other developing livestock systems (Speksnijder *et al.*, 2015; Redding *et al.*, 2019).

Veterinarians exhibited greater knowledge, but their influence on field practices appeared limited. This indicates weak regulatory control and easy access to antibiotics through informal markets. Prescription control is frequently not enforced, and similar behavioral drivers of antimicrobial use have been reported elsewhere (Caudell *et al.*, 2017; Dyar *et al.*, 2017).

Results indicate that both structural and economic elements are important determinants of withdrawal compliance. Farmers can be aware of the value of residue avoidance but find they still have to sell milk due to financial pressures. This has been observed in dairy production systems with limited implementation of antimicrobial stewardship programs (ASPs) as well (Bovino *et al.*, 2024; Chahine *et al.*, 2025). Another is the impact on microbial ecosystems from exposure to residues. There is also recent evidence that the growth of bacteria and the fermentation process in dairies is affected by levels of some antibiotics that are legal. This discovery reinforces the importance of having regular residue monitoring along the milk chain (Hajrulai-Musliu *et al.*, 2023; Morandi *et al.*, 2024).

Rapid residue screening at milk collection centres could enhance compliance and enhance consumer protection. These actions may be combined with veterinary advisory services and form part of a wider strategy of mitigating antimicrobial resistance in a One Health approach (Abedi-Firoozjah *et al.*, 2024; Medeiros *et al.*, 2024).

Safe practices were strongly associated with access to veterinary services. This indicates that strengthening advisory systems could have an immediate impact. Antibiotic residues have One Health implications for both antimicrobial resistance and food safety. Repeated low-dose exposure can contribute to selection pressure for resistant bacteria, particularly where antimicrobial use in animals is poorly regulated (Aarestrup *et al.*, 2010; Marshall and Levy, 2011; FAO, 2016; WHO, 2017).

Overall, interventions should be holistic and should combine farmer education, veterinary advisory services, economic support for discarded milk, residue monitoring and enforcement of antibiotic sales regulations.

Conclusion

Unsafe antibiotic-use practices remain common in dairy farming in Pakistan. Knowledge was moderate, but withdrawal compliance and safe practices were low. Economic and structural factors appear to drive unsafe behavior. Integrated One Health strategies are needed to improve withdrawal compliance, strengthen veterinary oversight and minimize public health risks.

Conflict of Interest: The authors show no conflict of interest.

Authors' contribution: UI and MTR conceived the research idea, performed the experiments, and wrote the manuscript.

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