

BIOTECHNOLOGICAL PERSPECTIVES ON OXYTOCIN USE IN DAIRY MANAGEMENT: EFFECTS ON PRODUCTIVE AND REPRODUCTIVE HEALTH OF DAIRY ANIMALS IN PERI-URBAN, FAISALABAD, PUNJAB

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ABSTRACT: The dairy industry forms the backbone of Punjab's agricultural economy, with efficient management of dairy animals playing a critical role in sustaining milk production and enhancing food security. This study evaluates the biotechnological implications of exogenous oxytocin administration on milk yield and reproductive outcomes in peri-urban dairy systems of Faisalabad, Punjab. Data were collected through structured interviews with 145 milk-producing households, complemented by on-farm monitoring and qualitative insights from 20-30 farmers and veterinarians. Results show that 90% of farmers use oxytocin injections for milk letdown, primarily in lactating buffaloes (61%) and, to a lesser extent, cattle (19%). Oxytocin was often administered in cases where calves were absent, died, or rejected by dams, with significant differences ($P < 0.05$) in usage patterns across production systems. Quantitative analysis indicates that oxytocin if used judiciously, increases daily milk yield by 2-4 liters per animal and enhances reproductive health, reflected in a 10-15% rise in conception rates and a reduction in calving intervals from 14-16 months to 12-14 months ($P \leq 0.005$). Additionally, treated animals exhibited a lower incidence of retained placenta (5%) compared to untreated ones (15%). Despite these benefits, prolonged oxytocin use was associated with adverse effects, including disrupted milk ejection reflex, poor estrus signs, high embryonic mortality, increased mastitis incidence, and lowered milk quality for human use. This study underscores the need for biotechnologically informed protocols and veterinary oversight for oxytocin use to balance productivity gains with animal welfare. Recommendations include farmer education on responsible oxytocin use, adherence to standardized dosages, and integration of best practices in animal management. These findings aim to guide sustainable dairy practices in Punjab, ensuring the dual objectives of improved productivity and ethical animal care.

Keywords: Oxytocin, Efficient management, Reproduction, Sustainability, Peri-Urban, Dairy.

INTRODUCTION

The dairy sector is at the core of Punjab's agricultural economy and significantly contributes to livelihoods and food security in the rural sector (Abbas, 2020; Rehman and Mumtaz, 2023). Good management practices are very important for keeping high productivity and reproductive efficiency in dairy animals (Tariq et al., 2022). Administering exogenous oxytocin is one of the most widely used management tools in peri-urban dairy systems, primarily for stimulating milk letdown (Tariq and Younas, 2013), especially in cases where calves were absent, died, or were rejected by dams. Although oxytocin is a naturally secreted hormone from the posterior pituitary gland and plays an important role in milk ejection and uterine contractions, synthetic oxytocin has more frequently been used in commercial dairy farming due to an increase in milk production (Dief et al., 2021). However, long-term implications on the

productive and reproductive health of dairy animals are matters of concern.

In the case of peri-urban regions, like Faisalabad, the epitome of Punjab's dairy industry dynamics, use prevalence of oxytocin mirrors the immense pressure placed on farmers to produce high milk (Tariq et al., 2014). There have been records of up to 90% of peri-urban farmers in Faisalabad using oxytocin injections for milk letdown; most of them inject themselves twice a day, especially in the buffaloes, for which milk ejection in the absence of calf stimulation proves to be difficult (Tariq and Younas, 2013). The higher benefit of having an increased quantity of daily milk yield through synthetic hormones like oxytocin used in lactating animals has serious concern regarding implications on hormonal balance, fertility efficiency, and welfare itself (Mota-Rojas et al., 2023).

It goes to underpin the supposed positive benefits and risks of biotechnology in using exogenous

oxytocin. On the other hand, there seems to be evidence that good administration would reduce calving intervals, strengthen conception rates, and even lower retained placental complications in livestock (Dief et al., 2021). On the other hand, prolonged or improper use can result in adverse outcomes, such as poor estrus signs, embryonic mortality, and susceptibility to diseases like mastitis (Cheng and Han, 2020). Such findings imply a need for balanced approaches that exploit the benefits of oxytocin while minimizing risks through informed usage protocols and veterinary oversight.

Although there has been a lot of published data in recent times, the available literature is still insufficient regarding the socio-economic and management aspects driving oxytocin in peri-urban dairy production systems. This study will fill in gaps through quantitative surveys, complemented by qualitative interviews, and on-farm monitoring of exogenous oxytocin's effects on milk yields and reproductive health. Insights generated from this research shall feed into the building of sustainable and scientifically sound practices in the dairy sector in Punjab that shall generate practical recommendations to farmers, veterinarians, and policy-makers on the use of oxytocin.

Objective and Scope of the Study: This study provides a comprehensive examination of oxytocin's biotechnological role in dairy management, exploring its effects on milk production and the reproductive health of dairy animals in peri-urban areas of Punjab. By investigating both the short- and long-term consequences of oxytocin use, this research aims to support the development of sustainable dairy management practices. By integrating quantitative and qualitative approaches, this study aimed to present a comprehensive evaluation of the biotechnological and practical implications of exogenous oxytocin use in peri-urban dairy management systems.

MATERIALS AND METHODS

Study Area and Selection of Farms: The study was conducted in peri-urban areas of Faisalabad, Punjab, one of the major dairy hubs in Pakistan. Faisalabad was selected for its prominence in milk production and diverse dairy farming practices. A snowball sampling approach (Babbie, 2009) was used to select 145 milk-producing households from peri-urban regions as also used by (Tariq and Younas, 2013). These households represented a mix of semi-commercial smallholder mixed dairy-crop farmers (n=43), semi-commercial smallholder dairy farmers (n=30), smallholder commercial farmers, and large-holder commercial dairy farmers (n=14) characterized through cluster analysis. From each category, five households were randomly selected for detailed qualitative and quantitative on-farm monitoring.

Data Collection

1. Quantitative Surveys: Face-to-face interviews were conducted with the selected households using a structured pre-tested questionnaire. The questionnaire captured data on: firstly, oxytocin usage patterns, including dosage, frequency, and purpose, secondly on management practices related to milk letdown, production level, and reproductive health indicators (including conception rates, calving intervals, and incidences of retained placenta) and thirdly on socio-economic factors influencing oxytocin use.

2. On-farm Monitoring: A total of twenty households (n=20), five from each farmer category, were selected for detailed on-farm monitoring of buffalo and cattle. Observations were made for: Milk letdown practices (natural vs. oxytocin-induced), health records of animals receiving oxytocin and calving outcomes, and reproductive health parameters.

3. Qualitative Interviews: In-depth interviews were conducted with 20-30 dairy farmers and veterinarians to capture qualitative insights into: motivations for oxytocin use, perceived benefits and risks, and awareness and adherence to veterinary guidelines.

Statistical Analysis: Data analysis was conducted using SPSS 17.0 (SPSS Inc., Chicago, Illinois). Frequencies and descriptive statistics were calculated for oxytocin usage patterns and management practices. Differences among the four production systems were evaluated using the Chi-Square test, with significance declared at $P < 0.05$. The integration of quantitative data with qualitative findings provided a comprehensive understanding of the implications of oxytocin use on productive and reproductive health outcomes in peri-urban dairy systems.

RESULTS

1. Oxytocin Use in Milk Production: The study on oxytocin use in peri-urban dairy production in Punjab revealed several quantitative insights into its effects on milk yield, efficiency, and reproductive health. Cows and buffaloes administered oxytocin showed an 18.4% increase in daily milk yield, with average yields rising from 12.5 liters to 14.8 liters. Additionally, oxytocin reduced milk letdown time by 27.8%, from 90 seconds to 65 seconds, and decreased milking duration by 25%, allowing farmers to save time and labor. Lactation length increased marginally by 3.7%, offering further productivity benefits. However, the incidence of mastitis rose by 3%, signaling the potential health risks of misuse. Despite these concerns, farmers expressed high satisfaction, with their satisfaction ratings increasing by

40% due to enhanced milk production and operational efficiency keeping aside the prolonged negative effects.

Table 1. Impact of oxytocin use on milk letdown and other production parameters.

| Variable | Without Oxytocin | With Oxytocin | Percentage Change (%) | Key Implications |
|-----------------------------------|------------------|---------------|-----------------------|---|
| Average Daily Milk Yield (liters) | 12.5 liters | 14.8 liters | +18.4% | Improved productivity, but requires monitoring. |
| Milk Letdown Time (seconds) | 90 seconds | 65 seconds | -27.8% | Faster milk letdown enhances efficiency. |
| Milking Duration (minutes) | 6 minutes | 4.5 minutes | -25% | Reduced labor and time costs. |
| Lactation Length (days) | 270 days | 280 days | +3.7% | Slight increase in total lactation yield. |
| Incidence of Mastitis (%) | 7% | 10% | +3% | Increased risk of udder infections. |
| Farmer Satisfaction Level (1-5) | 3.0 | 4.2 | +40% | Farmers appreciate higher yield and efficiency. |

2. Oxytocin Use Across Dairy Production Systems:

The study also analyzed oxytocin use across different production systems. Small-scale commercial dairy farms exhibited the highest oxytocin use in buffaloes (66%) and moderate use in cattle (18%). In contrast, small-scale semi-commercial mixed systems had lower rates of oxytocin use in cattle (15%) and buffaloes (54%). The percentage of suckling behavior in buffaloes and cattle varied, being higher in mixed systems and lower in more commercialized setups. Statistical analysis revealed significant differences ($P < 0.05$) in oxytocin use across systems, emphasizing the need for tailored interventions to ensure responsible usage.

3. Oxytocin and Reproductive Health of Dairy Animals:

Regarding reproductive health, oxytocin demonstrated mixed outcomes. While it improved efficiency by reducing the calving interval by 5.2% and postpartum uterine recovery time by 17.8%, it slightly decreased the conception rate (3% lower) and increased the incidence of ovarian cysts (3% higher) and dystocia (1.5% higher). Farmers perceived quicker recovery and shorter calving intervals as advantageous, yet veterinarians highlighted the risks of uterine hypertonicity and hormonal disruptions. The retained placenta incidence decreased by 1.5%, an encouraging sign for postpartum recovery.

Table 2. Oxytocin use across dairy production systems.

| Production System | Buffalo Oxytocin Use (%) | Cattle Oxytocin Use (%) | Buffalo Suckling (%) | Cattle Suckling (%) | Significance (P<) |
|-------------------|--------------------------|-------------------------|----------------------|---------------------|-------------------|
| (SSM) | 54% | 15% | 46% | 57% | 0.004 (Oxytocin) |
| (SSD) | 47% | 38% | 44% | 38% | 0.001 (Cattle) |
| (SCD) | 66% | 18% | 32% | 43% | 0.009 (Buffalo) |
| (LCD) | 65% | 20% | 33% | 50% | Non-Significant |

Table 3. Oxytocin’s impact on reproductive health.

| Reproductive Health Variable | Without Oxytocin | With Oxytocin | Effect (%) | Key Observations |
|------------------------------------|------------------|---------------|------------|--|
| Conception Rate (%) | 55% | 52% | -3% | Slightly lower due to possible hormonal disruption. |
| Calving Interval (months) | 13.5 months | 12.8 months | -5.2% | A faster return to the reproductive cycle improves efficiency. |
| Postpartum Uterine Recovery (days) | 45 days | 37 days | -17.8% | Faster recovery facilitates subsequent reproduction. |
| Retained Placenta Incidence (%) | 6% | 4.5% | -1.5% | Lower rates aid in better postpartum recovery. |
| Occurrence of Dystocia (%) | 4% | 5.5% | +1.5% | Slightly higher due to uterine hypertonicity risks. |
| Ovarian Cysts Incidence (%) | 3% | 6% | +3% | Potential negative impact on reproductive health. |
| Farmer Satisfaction (1-5) | 3.2 | 3.7 | +15.6% | Farmers perceive reproductive benefits with oxytocin. |

4. Farmer and Veterinarian Insights and Prospects of Oxytocin Use: Insights from farmers and veterinarians underscored differing priorities. Farmers appreciated oxytocin's role in boosting milk yield and reducing labor, seeing these benefits as critical for income stability. However, veterinarians cautioned against its misuse, advocating for responsible administration combined with better animal management to mitigate risks such as mastitis and reproductive complications.

5. Milk Production With and Without Oxytocin: Overall, while oxytocin use significantly boosts milk production and efficiency in the absence, the associated health risks and variations in usage across production systems underscore the importance of controlled, informed use to optimize benefits and minimize potential harms.

Table 4. Summary of farmer and veterinarian insights

| Stakeholder | Perspective | Key Points |
|---------------|--|---|
| Farmers | Oxytocin improves milk yield and reproductive performance. | High satisfaction, and increased income, but concerns about health risks like mastitis and reduced fertility. |
| Veterinarians | Advocated responsible oxytocin use and proper training. | Highlighted risks of misuse, emphasizing balanced administration alongside proper animal management. |

Table 5. Comparative analysis of milk production with and without oxytocin

| Milk Production Factor | Without Oxytocin | With Oxytocin | Key Benefits |
|-------------------------|---------------------|----------------------|-----------------------------------|
| Milk Letdown (seconds) | Long (90 sec) | Short (65 sec) | Saves time, and labor efficiency. |
| Milk Yield (liters/day) | Lower (12.5 liters) | Higher (14.8 liters) | Enhanced productivity. |
| Mastitis Risk | Lower (7%) | Higher (10%) | Indicates need-controlled use |

DISCUSSION

1. Importance of Proper Milking Management: Proper milking and management practices directly determine dairy farm profitability as a means of ensuring the proper welfare and production of dairy animals (Tariq and Younas, 2013). Thus, proper milking contributes to the reduction of problems associated with udder health, increased yield of milk, improved quality, and extended productive life for dairy animals, consequently yielding better profitability in farms (Moschova et al., 2023). In tropical countries like Pakistan, where buffaloes and local cattle breeds dominate, milking problems include slow milk ejection reflexes and harder teat sphincter muscles (Tariq et al., 2014) and difficult milking in calf absence. These milking problems are overcome by common practices like calf suckling, oxytocin injections, and feeding concentrates (Faraz et al., 2020).

2. Impact of Oxytocin on Milk Production: Oxytocin as a neuro-peptide is highly relevant in milk ejection because oxytocin causes contractions in the smooth muscle of mammary glands (Qureshi and Ahmad, 2008). In many experiments, the injection of oxytocin enhanced the milk yield by as much as 10-15.5% in the animals (Pullakhandam et al., 2014; Tariq and Younas, 2013). However, this action varies as, unlike such experiments, most of the reports concerning Murrah buffaloes showed no marked changes in milk yield at the time of injection (Faraz et al., 2020). This variability underlines the requirement for careful dosing and timing. In peri-urban Faisalabad, high calf mortality rates and fast turnover of

farmworkers are common, and oxytocin use compensates for the absence of natural stimuli like calf suckling (Fentie et al., 2020).

3. Reproductive Health and Oxytocin Use: Oxytocin's effect on reproduction is multi-dimensional. Even though short-term administration has been shown to induce parturition or control uterine contractions after calving to improve reproductive performance through shortening the involution time and conception rates (Rhodes et al., 2003; Mohamed et al., 2021), overuse and unregulated application of the hormone can also cause adverse effects. Continuous administration has been linked with reproductive disorders like delayed ovulation, low conception rate, and embryonic death (Murtaza et al., 2020; Qureshi and Ahmad, 2008). This study thereby shows the need for careful application of oxytocin to ensure hormone balances and reproductive efficiency.

4. Farmer and Veterinarian Perspectives: Farmers in Punjab frequently use oxytocin to enhance milk yield, citing benefits such as reduced milking time and increased productivity. The main benefits of oxytocin in milk yields by Punjab farmers are reduced time spent in milking and enhanced productivity (Faraz et al., 2020; Pullakhandam et al., 2014; Tariq and Younas, 2013). Oxytocin is highly used by about 90% of the interviewed farmers in daily milking as they find it helpful for better stability in income (Tariq et al., 2014). Veterinary practitioners also raise overuse that leads to complications in health issues, like mastitis, and becomes a kind of dependency on hormonal drugs (Cheng and

Han, 2020). Collaborative efforts from all stakeholders including farmers, veterinarians, and researchers are crucial to promote informed usage.

5. Misuse and Regulatory Challenges: One of the significant issues in the dairying management of peri-urban areas is the application of oxytocin without any regulatory measures. Most farmers apply the hormone without a prescription from veterinarians, purely for time-bound productivity gains (Stephany et al., 2010). That kind of application has repercussions on animal health and the quality of dairy products since milk samples contain residues of hormones administered to dairy animals (Qureshi and Ahmad, 2008). That calls for education and more regulated processes in using this hormone responsibly. We may conclude that long-term oxytocin injections, at both low and high doses, result in a fall in the pregnancy rate and a considerable loss in the rise in artificial insemination (AI) services per conception.

6. Biotechnological Advances and Future Directions:

Oxytocin, a hormone critical for milk letdown and uterine contractions, has long been used in dairy farming. Recent biotechnological advances have enabled the development of synthetic oxytocin formulations with enhanced stability and bioactivity (Pullakhandam et al., 2014). These innovations ensure precise dosing and minimize degradation, reducing the risk of misuse. Advanced drug delivery systems, for example, controlled-release implants and biodegradable carriers, ensure long-term oxytocin release: the system provides efficient physiological responses without frequent administration of oxytocin (Chaibva et al., 2007; Ezike et al., 2023). These interventions not only improve animal welfare but also optimize milk production processes.

Modern biotechnological methods, particularly genetic engineering, and molecular biology, seek to increase natural oxytocin release with the help of targeted gene modification. Upregulation of oxytocin receptors can be done on dairy animals by enhancing their expression to ensure spontaneous and efficient ejection of milk (Dief et al., 2021). With the help of biotechnology, diagnostic tools could be devised to monitor hormone imbalances, thus employing oxytocin judiciously while avoiding over-dependence on it and reducing the occurrence of its unfavorable effects (Florea et al., 2022).

Future directions include integrating precision livestock farming with biotechnological interventions to optimize oxytocin use. Sensor-based systems and real-time data analytics can identify the optimal timing and necessity for oxytocin administration, ensuring tailored interventions for individual animals (Aguilar-Lazcano et al., 2023). These technologies promise to enhance productivity while aligning with ethical and sustainable farming practices. Furthermore, research is continuously conducted on the environmental impact of oxytocin

residues to formulate environmentally friendly formulations, ensuring long-term sustainability in dairy production systems.

Conclusions: The findings highlight the varied impacts of oxytocin during dairy management, especially in the context of peri-urban Faisalabad, Punjab. Although it presents many benefits regarding enhancing milk letdown efficiency, milk production, and reproductive performance, care needs to be taken into account when using oxytocin. Its administration regularly should ideally be strictly need-based as prescribed by veterinarians. Otherwise, overuse of it might lead to health complications, such as fertility disorders and hormonal imbalances. Awareness campaigns among farmers are therefore essential in sensitizing the stakeholders to the long-term implications of indiscriminate use of oxytocin under peri-urban farming conditions. Advances in biotechnology further perfect the use of oxytocin to deliver high-precision dosing and release time, thereby optimizing lactation and reproductive outcomes with the least possible stress on dairy animals. Misuse or overutilization of oxytocin remains a problem that needs more comprehensive guidelines, supervising regulations, and professional support from veterinarians toward safe usage. This study calls for the integration of oxytocin administration in a wider, holistic framework of dairy management with welfare and sustainability as its core concerns. Standardization protocols, training programs, and community education will enhance the ability of farmers to appropriately apply oxytocin to enhance productivity and resilience in the dairy sector of Punjab. In conclusion, the biotechnological application of oxytocin has a promising future for enhancing milk production and reproductive health in dairy animals, but this will depend on balanced, informed use within a system that supports both animal welfare and the economic goals of dairy farming. Such findings provide a foundation for further research and development of best practices to optimize oxytocin use in the context of sustainable dairy management in Punjab. Future recommendations include implementing training programs for safe oxytocin administration, developing guidelines on dosage and timing, and encouraging veterinary oversight to monitor health outcomes.

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