Welfare Assessment of Dairy Farms Based on Animal-based Indicator of Welfare

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Authors' contributions

This work was carried out in collaboration among all authors. Author CK designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author MLK managed the analyses of the study. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Animal welfare is an essential component of sustainable dairy farming but still in India it is in nascent phase and standard protocol for assessment of welfare of all livestock species specially farms animals not developed yet. The main aim of this study to evaluate the welfare status of dairy cattle using ten output-based indicators across small, medium, and large dairy farms in Haryana. The indicators included body condition score, cow comfort index, cow cleanliness score, lameness score, human–animal relationship, mastitis incidence, hock injury score, abnormal behaviors,

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average productivity, and reproductive efficiency which is already explored in India. The data for measurement of those indicators for different types of farms were done as per scale suggested by DAWA Scale developed in India by NDRI Karnal. Data were collected through field observations and farmer interviews. Statistical analysis showed significant variation in welfare scores among farm sizes, with large farms generally exhibiting better comfort and body condition, while medium farms had higher mastitis incidence and behavioral abnormalities. Principal Component Analysis (PCA) was employed to interpret multidimensional welfare data. PC1, accounting for the majority of variance, represented comfort and health-related parameters, while PC2 was associated with behavioral stress and human interaction. The bi-plot clearly clustered farms based on their welfare characteristics, demonstrating the value of PCA in identifying risk patterns. This study highlights the importance of integrating animal or output-based indicators into national welfare monitoring systems and provides a replicable, data-driven framework for evaluating dairy cattle welfare in India.

1. INTRODUCTION

India accounts for approximately 24% of global milk production, contributing nearly 230 million tonnes of milk annually (BAHS, 2023-24). This substantial output plays a vital role in supporting the livelihoods of rural households and significantly contributes to the national economy. However, alongside this growth, there is increasing concern among consumers regarding the welfare conditions of dairy animals, particularly on farms supplying milk and milk products (Hristov *et al.*, 2011). Numerous animal welfare issues are commonly reported on Indian dairy farms, including lameness, mastitis, metabolic disorders, injuries, infertility, and poor nutrition—all of which can severely compromise the well-being and productivity of dairy cows (Barnett & Hemsworth, 1990, Ward *et al.*, 2002). Among the various methods for assessing animal welfare, animal-based or direct indicators—such as the incidence of disease, occurrence of mastitis, body condition score (BCS), lameness, hock lesions, reproductive health, quality of stockmanship, and overall cleanliness of the farm—are considered the most reliable for evaluating the welfare of dairy cattle (Carenzi & Verga, 2009). In regions like Haryana, these issues are prevalent across farms of all sizes (Kumar *et al.*, 2017). Health disorders in dairy animals have a direct impact on productivity. For instance, Huzzey *et al.* (2007) found that cows diagnosed with metritis produced approximately 8 kg less milk per day during the first three weeks of lactation. Mastitis remains a major welfare concern and a leading cause of economic loss in the dairy sector, with Capdeville and Veissier (2001) emphasizing its adverse effects on both animal health and farm profitability. Van Doep *et al.* (1998) observed that

cows reared on pasture exhibited lower rates of clinical mastitis and lower BCS compared to those housed in confinement systems, highlighting the influence of management practices on animal welfare. Body condition serves as a critical welfare indicator, affecting productivity, reproductive performance, health, and longevity. Both overconditioned and emaciated cows may signal underlying nutritional deficiencies, metabolic disorders, or poor management (Whay *et al.*, 2003). Lameness is another serious concern, often resulting in reduced milk yield, compromised fertility, and higher culling rates (FAWC, 1998). The primary causes of lameness include sole ulcers, white line disease, digital dermatitis, and interdigital dermatitis (Vokey *et al.*, 2001). As a highly visible and measurable condition, lameness serves as an indicator of both animal suffering and management shortcomings (Cook *et al.*, 2004). Hock lesions, typically caused by inadequate or uncomfortable lying surfaces, also indicate poor housing conditions. These injuries are closely associated with lameness, decreased productivity, and financial losses, thus serving as significant indicators of compromised animal welfare (Kester *et al.*, 2014). This highlights the need for the identification of risk patterns and supports evidence-based improvements in animal welfare practices. The present study aims to assess the welfare status of dairy cattle across small, medium, and large dairy farms in India, using ten animal-based indicators. By employing Principal Component Analysis (PCA), the study offers a data-driven framework to categorize farms based on key welfare attributes, facilitating the identification of risk patterns and supporting evidence-based improvements in animal welfare practices.

2. MATERIALS AND METHODS

The study was conducted across selected dairy farms located in Haryana, India. A total of 50 dairy farms were purposively selected and categorized into small farms (20 farms) medium farms (20 farms) and large farms (10 farms) having, 10-20 animals, 21-50 animals and more than 50 animals respectively. This classification helped account for the variation in resource availability, infrastructure, and management practices. From each farm, a representative sample of lactating cows was randomly selected for assessment, resulting in a total sample size of 311 animals. Selection criteria included cows in mid-lactation with no severe health disorders unrelated to management. A set of 10 validated output-based welfare indicators were used for the assessment, based on established protocols developed by NDRI Karnal and the welfare score of each indicators were measured using protocol suggested by (Kamboj *et al*, 2022). The animal based dairy animal welfare indicator used as per Kamboj, *et al.,* (2022) were body condition score (BCS), cow comfort index (CCI), cow cleanliness score, lameness score, human–animal relationship, mastitis incidence, hock injury score, abnormal behaviors (vices), average productivity (milk yield/day) and reproductive efficiency.

2.1 Statistical Analysis and Discussion

The data were analyzed using SPSS version XX / R version XX. Descriptive statistics (mean ± SE) were calculated for each indicator. Differences in welfare scores across farm categories were analyzed using ANOVA, followed by post-hoc Tukey tests where applicable. To explore underlying dimensions of animal welfare and group clustering, Principal Component Analysis (PCA) was applied. Variables were standardized before PCA, and eigenvalues >1 were used to extract components. Loadings above 0.60 were considered significant for interpretation.

3. RESULTS AND DISCUSSION

The body condition score (BCS), were found to be better in large dairy farms (2.80) may due to care and perception that better feeding gives more return followed by medium (2.20) and small dairy (2.20) farms. The cow comfort index (CCI) significant difference were found between small dairy (2.80) farms and medium (3.13) dairy farms. In cleanliness level of dairy farms which

was measure by cow cleanliness score were found significant difference between medium (1.75) and small dairy farms (2.30) which may due better managed by farms having less number of animals. Lameness score were almost similar in all types of dairy farms although lameness cases observed in medium dairy farms which may be due to ignorance of providing good floor or bedding materials or less care or overlook of hoof status periodically individual cows. Better human animal interaction were found between small and large dairy farms as compared to medium dairy farms which may be more care by large dairy farms owner or individual care by small dairy farms owner, although no significant difference were found in all three types of dairy farms. The incidence of mastitis in ware almost similar in large and small dairy farms although significant difference was found between medium and rest two groups of animals which may be due to less precaution or negligence of farms to prevent the incidence of mastitis. No significant difference was observed between all the three groups in hock injury which indicates almost similar types of housing provided by farmers in all categories of farms. The abnormal behaviour which is often seen in dairy farms due to bad management practices by dairy farms was almost similar in large (0.30) and small dairy farms (0.15) but significant difference were observed in comparison to medium dairy farms (1.17).

The average productivity in medium dairy farms was found to be better in medium dairy farms as compared to other but no significant difference were found. Reproductive efficiency was also similar in all types of dairy farms and there were no significant difference was observed between these three groups. The mean welfare scores revealed variations among different farm sizes (Table 1). Large farms recorded the highest overall welfare score (24.85 ± 0.40), followed by medium (24.30 ± 0.38), and small farms (23.00 ± 0.40). Body Condition Score, Cow Comfort Index, and Cow Cleanliness Score were significantly higher (P<0.05) in large farms, indicating better nutritional management and housing conditions. Mastitis Incidence and abnormal behaviors were more pronounced in medium farms, suggesting challenges in hygiene management and potential behavioral stress due to stocking density or handling practices. Lameness score and hock injury score remained relatively consistent across all farm sizes, pointing to common flooring and movement-related issues.

Principal Component Analysis (PCA) was conducted to reduce dimensionality and understand the relationships among the 10 indicators. The first two principal components (PC1 and PC2) explained a significant proportion of the total variance (e.g., PC1 = ~52.3%, PC2 = ~28.7%, cumulative ~81%). PC1 was primarily influenced by indicators such as body condition score, cow comfort index, and cow cleanliness score, representing overall animal comfort and management quality. PC2 was shaped by abnormal behaviors, mastitis incidence, and human–animal relationship, reflecting stress and health management factors. The biplot (Fig. 1) demonstrated that large farms clustered closely with indicators reflecting better welfare (e.g., body condition, comfort). Medium farms were associated with higher abnormal behavior and mastitis, likely due to transitional management systems where increased herd size outpaces housing and hygiene adjustments. Small farms appeared more aligned with productivity and reproduction, though lacking in cleanliness and cow comfort. These groupings suggest that farm size directly influences the welfare profile, and that output-based indicators are effective tools for classifying and benchmarking welfare status.

Table 1. Welfare indicators

No.	Indicator	Max Score	Small Farms	Medium Farms	Large Farms	Overall
1	Body Condition Score	4	2.00 ± 0.21	2.20 ± 0.33	2.80 ± 0.25	2.33 ± 0.24
2	Cow Comfort Index	5	2.80 ± 0.19 a	3.13 ± 0.50 b	3.20 ± 0.31 ab	3.04 ± 0.12
3	Cow Cleanliness Score	4	2.30 ± 0.27 a	1.75 ± 0.23 b	2.70 ± 0.29 a	2.25 ± 0.28
4	Lameness Score	4	3.65 ± 0.17	3.33 ± 0.49	3.70 ± 0.16	3.56 ± 0.12
5	Human–Animal Relationship	3	1.80 ± 0.26	1.71 ± 0.41	2.10 ± 0.20	1.87 ± 0.12
6	Mastitis Incidence	4	1.70 ± 0.24 a	2.09 ± 0.33 b	1.65 ± 0.25 a	1.81 ± 0.14
7	Hock Injury Score	3	2.15 ± 0.18	2.14 ± 0.34	2.05 ± 0.18	2.11 ± 0.03
8	Abnormal Behaviors	2	0.15 ± 0.08 a	1.17 ± 0.36 b	0.30 ± 0.13 a	0.54 ± 0.32
9	Average Productivity	8	4.85 ± 0.36	5.23 ± 0.93	4.85 ± 0.41	4.98 ± 0.13
10	Reproductive Efficiency	3	1.60 ± 0.18	1.54 ± 0.30	1.50 ± 0.21	1.55 ± 0.03
	Total Score	40	23.00 ± 0.40	24.30 ± 0.38	24.85 ± 0.40	24.05 ± 0.55

Note: Superscript a, b denote significant differences at P<0.05
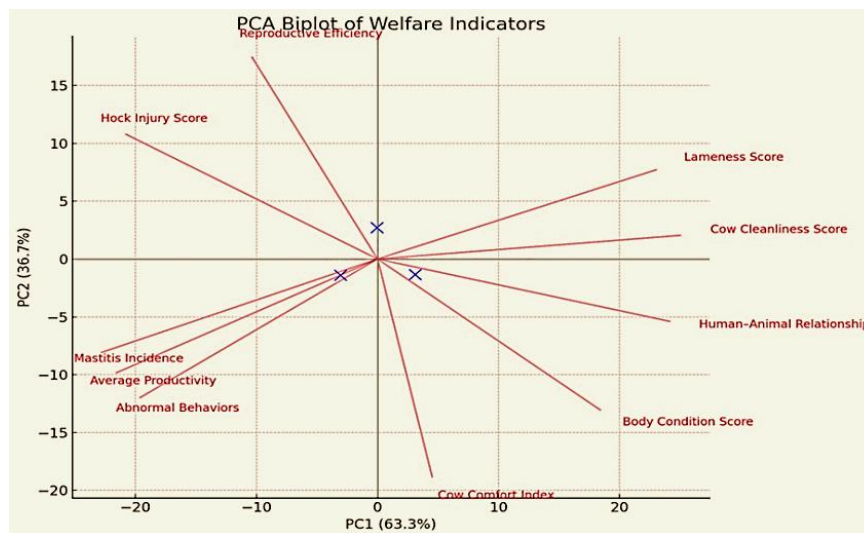
Fig. 1. PCA Biplot of 10 animal based indicators

Table 2. Expected PCA output and interpretation

Principal Component	High Loading Indicators	Interpretation
PC1 (Animal Health)	Mastitis, Lameness, Hock Injury, Cow Cleanliness	Reflects animal health and hygiene management quality.
PC2 (Comfort & Behavior)	Cow Comfort Index, Abnormal Behavior, Human-Animal Interaction	Reflects animal comfort, space allowance, and behavioral signs of stress.
PC3 (Productivity)	Average Productivity, Reproductive Efficiency	Reflects management practices influencing production and fertility.
PC4 (Nutritional Status)	Body Condition Score, Cow Comfort	Indicates feeding adequacy and stall comfort.

The use of output-based indicators, which directly assess the animal's response to its environment, offers a realistic and measurable approach to welfare monitoring. This study revealed clear trends in welfare performance relative to farm size, with large farms generally performing better, likely due to better infrastructure, feeding strategies, and training. However, increased herd size in medium farms without proportional investment in comfort and care infrastructure may compromise welfare, as seen in increased mastitis and abnormal behaviors. These findings underscore the importance of not just scaling up production, but doing so with an emphasis on animal-centered management. The PCA analysis effectively distilled complex, interrelated welfare data into key components, demonstrating that comfort, cleanliness, and behavioral stress are the principal drivers differentiating welfare status among farms. This method can be adopted as a decision-support tool by policymakers, veterinarians, and extension agents to monitor farms systematically, Identify critical welfare gaps and recommend targeted improvements. The summary of expected PCA output and interpretation of all indicators were given in Table 2.

Small farms had lower BCS and cleanliness, suggesting nutrition and hygiene challenges. Medium farms showed higher abnormal behaviors, possibly due to crowding or stress. Large farms had better comfort and body condition, but higher mastitis incidence, possibly due to intensive production stress. Output-based indicators vary significantly by farm size. Cow comfort index and abnormal behavior are key differentiators in medium farms. Mastitis and BCS play a major role in determining welfare scores. Total welfare score is highest in large farms, suggesting economies of scale help.

3.1 PC1: "Comfort and Health" Axis

PC1 represents the overall physical welfare status, largely driven by comfort, cleanliness, body condition, and productive capacity. Farms scoring high on PC1 are likely to have better-managed animals in terms of housing, nutrition, mobility, and reproduction. Large farms, which scored well on indicators like BCS and comfort, are likely to cluster along this component.

3.2 PC2: "Behavioral Stress and Human Interaction" Axis

PC2 reflects stress-related welfare issues, including behavioral abnormalities and negative human-animal interactions. These are often associated with poor handling, overstocking, or inconsistent management. Farms scoring high on this component are more likely to have animals showing stress, aggression, fear, or poor udder health. Medium farms, which had higher values for abnormal behavior and mastitis, are more aligned with PC2. Farms with high PC1 scores generally show good welfare, reflecting well-managed environments. Farms with high PC2 scores may have hidden stressors, even if productivity appears acceptable. PCA helps categorize farms and prioritize interventions. PC1 → Invest in comfort and feeding. PC2 → Train staff, reduce stress, improve handling.

4. CONCLUSION

The present study aimed to evaluate the welfare status of dairy farms in India using output-based indicators analyzed through Principal Component Analysis (PCA). The analysis revealed that a few key indicators—such as lameness score, body condition score, mastitis incidence, cow cleanliness score, and average productivity—contributed most significantly to the variation among farms and can serve as reliable proxies

for overall animal welfare. The PC1, which explained 63.3% of the variance, was primarily associated with productivity and health-related indicators.PC2, accounting for 36.7% of the variance, was influenced more by behavioral and comfort-related parameters. This multivariate approach effectively reduced dimensionality while preserving critical information, allowing for a comprehensive yet manageable interpretation of animal welfare conditions. The clusters formed in the biplot suggest variability in welfare practices across farms, indicating the need for targeted interventions. In conclusion, output-based indicators combined with PCA provide a scientifically robust and practical framework for welfare assessment in dairy farms. This approach can assist policymakers, veterinarians, and farm managers in identifying welfare gaps and implementing evidence-based improvements, ultimately enhancing both animal wellbeing and farm productivity.

ETHICAL APPROVAL AND CONSENT

All procedures were carried out following institutional animal welfare guidelines. Farmers provided informed consent before data collection.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author (s) hereby declares that NO generative AI technologies such as Large Language Models and text to image generators have been used during writing and editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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