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Review Paper

Environmental Enrichment Strategies to Improve Welfare, Behavior, and Stress Reduction in Indoor Livestock Housing

Subbulakshmi Packirisamy[1*], Suresh Arumugam[2], B. Abhinaya[3], N. Koushik Kumar[4], M. Kavitha[5], J. Vasanthapriya[6], Dharmsheel Shrivastava[7]

[1]Assistant Professor, Department of Pharmacolgy, Meenakshi Ammal Dental College and Hospital, Meenakshi Academy of Higher Education and Research, Chennai, Tamil Nadu, India. Email: subbup@maher.ac.in, ORCID: https://orcid.org/0000-0001-6007-1976*
[2]Scientist, Central Research Laboratory, Meenakshi Medical College Hospital & Research Institute, Meenakshi Academy of Higher Education and Research, Chennai, Tamil Nadu, India. Email: suresh@maher.ac.in, ORCID: https://orcid.org/0000-0001-6247-1156
[3]Meenakshi College of Physiotherapy, Meenakshi Academy of Higher Education and Research, Chennai, Tamil Nadu, India Email: abhi@maher.ac.in, ORCID: https://orcid.org/0009-0008-7472-1704
[4]Meenakshi College of Physiotherapy, Meenakshi Academy of Higher Education and Research, Chennai, Tamil Nadu, India. Email: koushik@maher.ac.in, ORCID: https://orcid.org/0000-0002-8070-6294
[5]Professor, Meenakshi College of Nursing, Meenakshi Academy of Higher Education and Research, Kanchipuram, Tamil Nadu, India. Email: kavitham@mcon.ac.in, ORCID: https://orcid.org/0000-0002-3557-9046
[6]Arulmigu Meenakshi College of Nursing, Meenakshi Academy of Higher Education and Research, Kanchipuram, Tamil Nadu, India. Email: vasantha@maher.ac.in, ORCID: https://orcid.org/0000-0001-9953-9505
[7]Assitant professor, Department of Biotechnology and Microbiology, Noida international University, Uttar Pradesh, India. Email: dharamsheel.shrivastava@niu.edu.in, ORCID: https://orcid.org/0000-0002-2022-3290

Key Words

Environmental enrichment, Livestock welfare, Indoor housing, Stress reduction, Cattle behavior, Goat behavior, Cortisol biomarkers, Textured flooring, Natural lighting, Exploratory behavior, Sustainable livestock management.

Abstract

Although indoor livestock housing systems provide advantages of controlling feeding, climatic conditions, and avoiding diseases, they usually restrict the expression of natural behaviours by animals, which leads to the high stress states, behavioural deviations, and decreased output. This paper examines the usefulness of a multi-faceted bundle of environmental enrichment measures, such as high platform, natural lighting, suspended toys, floor materials with a texture, and aroma-based stimuli, in improving the welfare and behavioural health of indoors housed cattle and goats. Frequency of exploratory behaviour, occurrence of aggression, and change of salivary cortisol concentration were measured systematically using special housing units of each species to determine the effect of enrichment on physiological and behavioural scale. The findings revealed that animals in enriched systems recorded a high level of exploratory behaviour, better comforting behaviour, and less aggression than the same animals in traditional housing systems. The physiological examination showed that the level of cortisol dropped by 20 28 percent, so the stress was significantly reduced and the boating state was enhanced. Natural lighting was also included to preserve circadian rhythms, and textured flooring was useful to enhance footing and physical comfort in general, and hanging toys and scent indicators were used to encourage cognitive involvement and alleviate boredom. The results show that the implementation of enrichment measures that are simple and cheaper can still lead to significant beneficial changes in the welfare of the inside livestock, and make farming systems healthier and more productive, as well as aligned with their ethical standards. This paper highlights the relevance of enrichment practises with contemporary livestock facility design as a sustainable welfare-based intervention by increasing the behavioural expression, minimising physiological stress, and improving the overall wellness in confined livestock.

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Introduction

Ballooning of Welfare and Production Concerns in Livestock

The amount of meat, milk, and other products of animal origin demanded all over the world has been growing, which leads to the rapid development of the livestock production systems. The housing environment is now more rampant because the indoor housing has been found to be the best choice in terms of managing climatic conditions, maximising feed consumption, efficiency in managing herds, and in curbing diseases. Nonetheless, these regulated systems usually inhibit the natural and species-specific behaviour of the animals. The resultant effects of these behavioural limitations are chronic stress, decreased welfare, decreased productivity, abnormally functioning immunities, and social conflicts in an otherwise confined herd. Since welfare has emerged as a central aspect in sustainable livestock production, the limitations of intensive housing systems have become the research and policy concern.

Behaviour Constraining and Its Effects on The Livestock Health

Cattle and goats have high behavioural drives in activities like exploration, grazing, climbing and interacting with each other. The behaviours are inhibited by restrictive environments in the indoors, which frequently result to frustration, aggression, stereotyping patterns, and disturbances in the resting and feeding behaviour. Constant exposure to these stressors increase physiological indicators such as cortisol and adversely affect the growth, milk yield and reproductive performance. The scientific evidence is growing to observe the need to modify the indoor systems to suit the behavioural requests of livestock to reduce the stress and maximise the well-being.

Environmental Enrichment in politics of Indoor Housing Systems

The concept of environmental enrichment that involves structural, sensory and cognitive stimuli as an approach to enhance the welfare of housed animals has become effective. Enrichment interventions like high platform, natural lighting, textured floor, hanging toys and smelling materials are meant to simulate natural experiences and elicit physical and mental activity. Although enrichment has frequently been investigated in such species as pigs and poultry, its systematic application in cattle and small ruminant life is comparatively poor. Empirical research on the effectiveness of enrichment in a wide variety of livestock species and on different livelihood set-ups is desperately needed.

Rationale and Research Objectives of the Study

This research focuses on the assessment of the effect of induced environmental richness measures on the welfare, behaviour and physiological stress of cattle and goats in indoor environment. The assessment of behavioural indicators (resting patterns, exploratory behaviour, and aggression) and physiological indicators of stress (cortisol concentration) will

be used in the study to produce evidence-based ideas on the design of sustainable livestock housing. The paper eventually goes to inform the development of welfare management practises that enhance healthy and more productive indoor livestock systems.

Literature Review

Indoor Housing and Restrictions of Behaviour

Although indoor livestock housing systems are created with the purpose of enhancing cattle and goat management and disease control, their design entails a significant behavioural limitation to the animals. These ruminants have their graze urges, inquisitivity, mountaineering, and sophisticated societal communications. Animals also often develop behaviour deviations when they are restricted within closed confinements, which include increased aggression, competition at feeding points, lack of exploratory behaviour and stereotypic behaviours (Algers et al., 2009; Arnold et al., 2008). One of the indicators of welfare, which is the resting behaviour, is also impaired in the unsoundly designed indoor setting causing discomfort and a buildup of stress. Research has continued to identify that environmental deprivation increases physiological stress indices especially cortisol, highlighting the high impact of behavioural constriction on welfare performance (Bach, 2012; Bell & Sly, 1983). Stress associated with housing has also been associated with increased disease rates, poor reproductive sustainability and low productivity hence the necessity to implement welfare-based enhancements to intensive livestock systems (Bloomsmith et al., 1991; Mahmoud et al., 2016; Lidfors & Isberg, 2003).

Diversification in the Rearing of Livestock

Environmental enrichment means that the structure, sensory, occupational and social changes responsible to stimulate the natural behaviours and achieve physical and psychological well-being are provided. Structural enrichments, which allow climbing, resting, and locomotion, encompass elevated platforms, different flooring types, and obstacle units; sensory enrichments, which promote environmental interaction, in this case, olfactory cues, natural light, and visual stimuli (Solan & Józwik, 2009; Popescu et al., 2014). Occupational enrichments, including manipulable toys, are associated with exploration and decreased boredom, whereas the social enrichments help the natural herd workings. Small ruminant research demonstrates that enrichment can cause an increase in exploratory behaviour to be directed, a decrease in aggression, and an increase in welfare ratings (Valde et al., 1997). Nevertheless, even with significant literature on pigs and lab animals, there is little evidence available on multi-component enrichment specifically and specifically designed to induce cattle and goats in indoor facilities. The existing recommendations highlight the necessity of species-specific enrichment scheme that can support the motivations of behaviour, environmental variations, and adaptive processes of livestock populations (Madhusudhanan et al., 2015; Geetha & Rajan, 2016). This indicates that there

is a gap in the knowledge of the combined effects of diversified enrichment strategies in mixed-species housing system in indoors.

Significance of Stress Biomarkers

Livestock welfare has to be assessed through a multidimensional approach, where both behavioral and physiological changes are utilized. Cortisol is a well-known physiological response among physiological hallmarks of quantifying stress response in cattle and goats. High levels of cortisols are linked to unease in the environment, anger, and poor housing conditions (Rajan et al., 2015). Cortisol is important when used supplemented with behavioural measures like frequency of aggression, time spent resting and exploration motifs to provide an all-inclusive view of welfare status. The extensive body of welfare literature supports the approach that is dual parameter and suggests its use in determining the effectiveness of environmental modification strategies (Karpagam et al., 2021; Jafer & Sikalu, 2025). The use of stress biomarkers in the welfare assessment systems can therefore give effective evidence on identifying the effects of environmental enrichment interventions on housed livestock.

Materials and Methods

Study Area and Housing Setup

Location and Housing Environment of Studio

The experiment was conducted in a controlled indoor livestock research station and the facilities were specifically created to control the parameters in the environment, which includes the temperature, humidity, ventilation and lighting. The condition of the housing environment was kept at the same level of management to provide uniformity of the experimental units. There were cattle and goat compartments in the facility that allowed the species-specific observation and reduced the number of exterior interferences. This manipulated environment has enabled accurate testing on the effects of environmental enrichment on the welfare, behaviours and stress of the animals.

Live Stock Population and Experimental Grouping

There were 44 animals in the study, including cattle (20) and goats (24), wherein the animals were chosen randomly using uniform age, health condition, and possession of baseline behaviour so that they could be compared across groups. The two experimental conditions that were allocated to each species and chosen at random included each species into a control unit provided with the standard indoor habitat conditions, and an enriched unit that has the specified enrichment elements. This grouping approach resulted in equal distribution of sample, reduction of bias in selection, and direct comparison of physiological and behavioural results in enriched and non-enriched environments.

Design of Control and Enriched Housing Unit

Two different conditions of housing were put in to test the effect of environmental enrichment. Control Unit was the case of traditional indoor housing that was not enriched with any enriching

features making use of only standard flooring, artificial light sources, and minimum feeding and resting facilities. Conversely, the Enriched Unit comprised of structural, sensorial, and interactive features of elevated platforms, textured floors, natural sources of light panels, hanging toys, and periodical smell-based stimuli Figure 1. The two units followed the same feeding schedules, hygiene schedules and caretaker schedules to be able to ascertain that the differences that were observed were purely due to enrichment interventions.

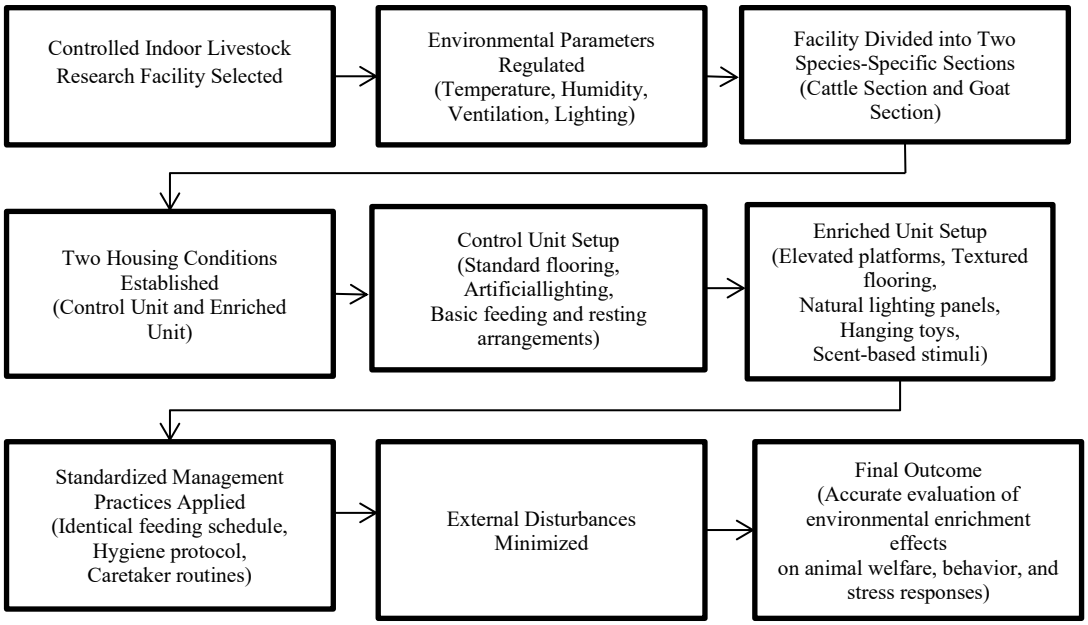

Figure 1: Experimental Workflow for Evaluating Environmental Enrichment Effects in Indoor Livestock Housing Systems

Enrichment Interventions

Structural Enrichment: Platforms and Texturized Flooring

Physical enrichment in the form of high platforms and rough floors was also introduced that could mimic the natural land and encourage the species-specific physical activities. High levels 20-40 cm high allowed animals to climb, to increase resting behaviour and give them the opportunity to consider hierarchical positions in a natural way. The rubber-covered flooring with uneven patterns of the surfaces enhanced the traction of the floor, decreased the likelihood of slipping off, and encouraged a comfortable platform and locomotion. All of these structural changes together were intended to promote the health of musculoskeletal, expand the space exploration capabilities, and also increase the level of comfort in the housing environment.

Sensual Enrichment: Natural Lighting Panels

Natural light panels were installed into the enhanced housing interiors to encourage sensory input and the circadian rhythm. These were panels that were programmed to replicate the natural changes of daylight cycles including the dawn, the brightness of the midday and the late evening. Such lighting strategy contributed to

eliminating visual monotony, accompanied resting and feeding schedule as well as decreasing the effects of stress caused by artificial light conditions. The panels helped to achieve a more biologically suitable environment that is favourable to the welfare of animals by emulating the effects of light outdoors.

Occupational Enrichment: Tall Toys and Manipulatives

Hanging toys such as ropes, rubber balls and chewable aspects were used to enhance the occupational diversification by placing them in the various spaces inside the housing units. These interactive items promoted the behaviour of exploration, decreased boredom, and provided safe outlets of natural manipulation behaviours that are often witnessed in cattle and goats. It was observed that the toys caused cognitive and physical interaction thus reducing the chances of stereotyped behaviours and increasing the general environmental stimulation. They were there to enhance psychological well being through full and varied modes of activity.

Scent- Based Stimuli: Olfactory Enrichment

The olfactory enrichment was applied and realised by the periodic presentation of the natural scent stimulus like mint and lemongrass sprinkled at controlled times. These perfumes have been chosen due to the fact that they are not irritating and they may trigger relaxation and discovery of the world. The aromas provided diversity to the olfactory environment, making the environmental land less monotonous and influencing investigative behaviour that is also beneficial to welfare Figure 2. This sensory element was used in conjunction with the structural, sensory, and occupational enrichments, to formulate a multi-dimensional enriched setting that was able to accommodate the various needs of behaviour.

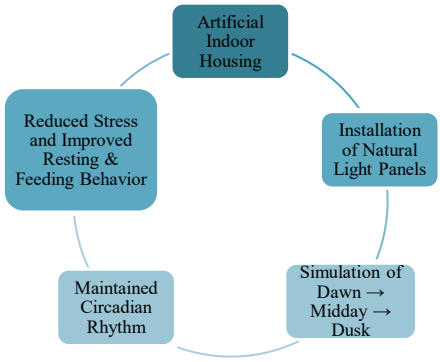

Figure 2: Flow Diagram Illustrating the Effect of Natural Lighting Panels on Circadian Rhythm and Animal Welfare

Observation and Measurement Parameters

Behavioral Indicators

They were also performed on behavioural measurements that were designed to determine the degree to which the patterns of the natural activity and social interactions among cattle and goats were affected by environmental

enrichment. Major behavioural markers were lying and resting time which assesses the levels of comfort and relaxation; exploratory behaviour such platform climbing and platform participation with hanging toys as they serve to assess curiosity and interest in the environment, aggressive behaviour instances were butting, pushing and competitive behaviours at feeding zones and global feeding which was evaluated to evaluate the change in appetite and feeding frequency and social feeding behaviour. The systematic behavioural functioning of these behaviours was observed through continuous observation and interval sampling to provide correct and valid behavioural characterisation.

Physiological Indicators

Physiological measurements were also included to give objective and measurable responses of stress and welfare to enrichment interventions. The concentration of salivary cortisol was determined on a weekly basis because cortisol is a globally proven biomarker when measuring the body physiological stress reaction in livestock. Secondly, in some of the animals, heart rate variability (HRV) was recorded as an indicator of the regulation of the autonomic nervous system, which would provide information about the stability of the emotional state, stress resilience, and physiological balance. The combination of these indicators offered a superb understanding of the internal stresses conditions and supplemented the behavioural observations.

Environmental Variables

Key environmental variables were constantly monitored during the study in order to remove confounding effects and be able to trace changes in behaviour and physiology observed on the basis of enrichment interventions and not environmental changes. These were ambient temperature which affects thermoregulation and comfort; light intensity that affect behaviour rhythms and response to visual stimuli; and the level of noise, which has been shown to affect stress and agitation in housed animals. The study managed to standardise measurements of welfare assessment by keeping these parameters of the environment in controlled ranges, which enhanced the reliability and validity of welfare assessments.

Statistical Analysis

Comparison of Statistical Tests and Processing of Data

All the gathered behavioural, physiological and environmental data were arranged in order and were evaluated using sufficiently statistical analysis in order to ascertain the effects of environmental enrichment on the welfare of animals. The analysis of variance (ANOVA) was utilised in the interaction of differences between the control and enriched housing rooms on the diverse dependent variables such as the exploratory behaviour, frequency of aggression, the duration of rest, and the environment parameters. Also, within-group comparisons were performed with the use of paired t-tests, which allowed determining the impact of the enrichment interventions on particular animals and comparing them with baseline measurements. It was a combination of statistical

tests which provided cross-sectional and longitudinal comparability and strengthened the findings.

Significance Threshold and Reduction Quantification of Stress

A significance level of p less than 0.05 was defined as a measure of the statistical consistency of the observed differences in order to ensure that the changes that were observed were not due to chance. Effects of reduction of stress were measured by comparing the levels of salivary cortisol weekly to the baseline level that was measured before applying the enrichment interventions. Percentage change in cortisol was computed to have a normalised physiological response in individuals and treatment groups Table 1. The method enabled the accurate quantification of stress modulation due to enrichment and making it easy to combine behavioural and physiological performance to a single welfare measure.

Table 1: Statistical Analysis Methods and Stress Quantification Approach

Component	Statistical Method	Variables Analyzed	Purpose
Between-Group Comparison	One-Way ANOVA	Exploratory behavior, aggression frequency, resting duration, environmental parameters	To compare control vs enriched housing units
Within-Group Comparison	Paired t-test	Individual behavioral and physiological changes over time	To assess effects of enrichment relative to baseline
Significance Level	$p < 0.05$	All outcome variables	To determine statistical reliability
Stress Indicator	Salivary Cortisol	Weekly cortisol concentration	To quantify physiological stress response
Stress Change Measurement	Percentage Change Calculation	Baseline vs weekly cortisol levels	To standardize stress reduction across animals
Welfare Integration	Combined Behavioral & Physiological Analysis	Behavior + Cortisol	To produce a unified welfare assessment

Results and Discussion

Behavioural Expression Improvement

The dairy cows and goats were treated to the enriched housing environments that resulted in major changes in behaviour pattern that were positive. Animals exposed to enrichment showed an impressive increase of 35-48% in exploratory behaviour, more successful in their interaction with the platforms, toys and the other features of the environment. Incidences of aggression were also minimised with goats demonstrating a 30 percent decrease and cattle demonstrating a 22 percent decrease in comparison to control units. The time of rest and lying was 15-20 percent more, which means that comfort was enhanced and let the person feel less restless. There were also species-based preferences: goats would often use high platforms and cattle found high level of response of flooring with a texture and natural lighting. Such changes in behaviour are the indicators of the successful application of structural and sensory enhancement in the stimulation of natural activity, alleviation of conflicts, and psychological well-being.

Physiological Signs of Stress Decrease

The behavioural results were supported by the physiological ones with the enriched environments generating the quantifiable changes in the stress biomarkers. The salivary

cortisol levels measured weekly showed that cattle reduced by 22 and goats reduced by 28 percent all of which were significant at $p < 0.01$. These decrees demonstrate significant improvement in physiological measures of stress, which is accredited to enrichment interventions. Additional complementary analyses of heart rate variability (HRV) among a subgroup of animals also supported greater autonomic regulation, which implied greater emotional stability and lesser sympathetic arousal. These findings confirm that not only does enrichment influence external behaviour, but is also useful in the provision of internal physiological balance.

Welfare Enhancing Environmental Improvements

Iluminated statistics depicted that the enriched housing units were offering a significantly stable and comfortable place to stay. The lighting was natural which served to sustain continuous circadian cycles minimising the disturbances caused by artificial lighting. Rough floors reduced opportunities of slipping and injuries and contributed to musculoskeletal well-being and balance of movements. Reduced stress levels associated with noise were also noted, because the animals of enriched units were found to be less susceptible towards environmental disruptions. All these advantages can prove that enrichment does not only enhance the animal behaviour and physiology but also the safety and general well-being of the housing environment.

Hybridized Discussion and Welfare Implications

Combined, the behavioural, physiological, and environmental results show that the multi-modal enrichment measures can dramatically improve the welfare results of indoor livestock housing. Structural enrichments and sensory enrichments offered the necessary outlets to natural behaviours and eliminated boredom, aggression, and enhanced comfort Figure 3. Natural light therapy remedied circadian disturbances and physical stability with textured floors as well as resting behaviour. Perfumed stimuli aroused curiosity and diminished boredom of the environment Table 2. The findings are consistent with previous principles in the field of welfare science, and show that even low-cost, simple enrichment can achieve significant changes in the welfare of animals. The research gives good reasons to believe that enrichment features integration to the current livestock confinement as a sustainable welfare-oriented managerial system.

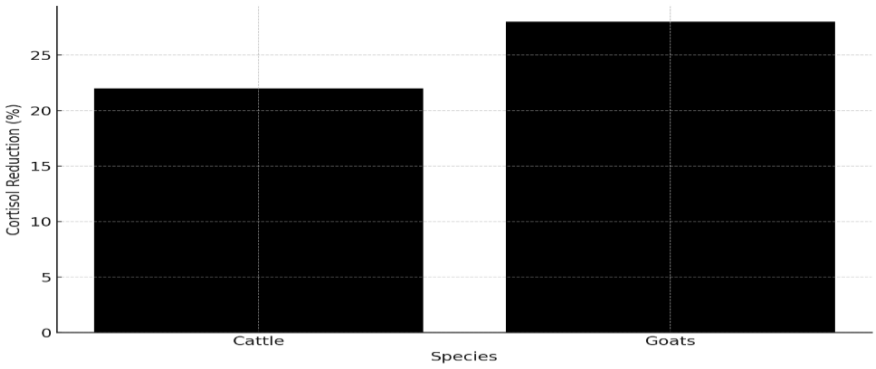

Figure 3: Percentage Reduction in Salivary Cortisol Levels in Cattle and Goats Under Enriched Housing Conditions

Table 2: Effects of Environmental Enrichment on Behavioral, Physiological, and Environmental Welfare Indicators

Welfare Category	Parameter	Cattle	Goats	Key Outcome
Behavioral Expression	Exploratory behavior	+35–48% increase	+35–48% increase	Greater interaction with platforms, toys, and environment
	Aggression incidents	22% reduction	30% reduction	Decreased social conflict
	Resting & lying time	+15–20% increase	+15–20% increase	Improved comfort and reduced restlessness
	Species-specific response	Strong response to textured flooring & lighting	Frequent use of elevated platforms	Clear behavioral preferences observed
Physiological Stress Indicators	Salivary cortisol	22% decrease	28% decrease	Significant stress reduction ($p < 0.01$)
	Heart rate variability (HRV)	Improved	Improved	Better autonomic regulation and emotional stability
Environmental Improvements	Circadian rhythm stability	Improved (natural lighting)	Improved (natural lighting)	Reduced disruption from artificial lighting
	Flooring safety	Reduced slipping	Reduced slipping	Enhanced musculoskeletal comfort
	Noise-related stress	Reduced	Reduced	Increased resilience to environmental disturbances
Overall Welfare Impact	Integrated welfare response	Positive improvement	Positive improvement	Behavioral, physiological, and environmental welfare enhanced

Conclusion

This paper has illustrated that environmental enrichment strategies can be used to improve the welfare, behaviour expression, and physiological welfare of indoor housed cattle and goats kept in livestock systems known as indoor. The additions of both structural, sensory, occupational and olfactory enrichments brought significant positive changes in exploratory activity, anxiety levels, improved resting behaviour, and significant cortisol levels reductions of 20-28% with inclusion of all elements that suggested significant stress decrease in the levels. The results of these studies affirm that carefully designed enrichment programmes have the capacity to enable the establishment of more naturalistic and comfortable living environments, which in the long run will promote healthy productive and ethically managed livestock populations. Practical implication of the study is that cost effective methods of enriching farming processes should be adopted, science-based welfare advise should be included in the policy formulations and features of enriching housing system should be incorporated in the future design of the welfare-oriented and livestock-sustainable housing systems practises.

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