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Welfare assessment of working equines using animal-based indicators in brick kiln operations

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Abstract

The welfare of working equines in developing countries represents one of the greatest unresolved challenges in contemporary animal ethics, yet systematic welfare assessment data from industrial settings remain scarce. This research presents a cross-sectional welfare assessment of 180 working equines (85 donkeys, 55 horses, 40 mules) employed in brick kiln operations across three provinces in coastal and highland Peru. Animals were evaluated using a standardised protocol of 24 animal-based welfare indicators adapted from the AWIN (Animal Welfare Indicators) donkey protocol and the Standardised Equine-Based Welfare Assessment Tool (SEBWAT), covering four welfare domains: nutrition, physical health, behaviour, and housing/environment. Each indicator was scored on a 3-point severity scale (0 = good, 1 = mild compromise, 2 = severe compromise), and domain scores were computed as a percentage of the maximum possible score within each domain, yielding a Composite Welfare Score (CWS) on a 0-100 scale. The overall mean CWS was 52.4 (SD 12.8), corresponding to moderate welfare compromise. Body wounds and lesions were the most prevalent finding (72.8% of animals), followed by harness-related injuries (68.3%), hoof overgrowth or cracks (64.4%), and limb abnormalities (58.3%). Donkeys had significantly lower welfare scores (mean 48.7) than horses (55.8) or mules (54.2; $p = 0.003$), driven primarily by poorer nutrition (BCS 2.1 versus 2.4) and higher wound prevalence. Body condition score was the single strongest predictor of composite welfare ($R^2 = 0.68$). Kiln type was a significant environmental modifier: animals at semi-mechanised kilns with reduced manual transport requirements scored 71.9 overall compared with 41.9 at traditional kilns and 60.3 at improved kilns ($p < 0.001$ for trend). These findings provide the first structured welfare baseline for brick kiln equines in South America and identify body condition, wound prevalence, and kiln modernisation status as key targets for welfare improvement programmes.

Keywords: Working equines, animal welfare assessment, brick kilns, donkeys, horses, mules, animal-based indicators, body condition score, welfare domains, Peru, AWIN protocol

Introduction

Assessing and improving the welfare of working equines in low-resource industrial settings is among the most complex challenges facing veterinary science today. An estimated 100 million horses, donkeys, and mules support the livelihoods of 600 million people in the developing world, yet these animals operate largely outside regulatory frameworks, veterinary oversight, and the welfare protections afforded to livestock in formal agricultural systems^[1, 2]. Brick kilns represent one of the most demanding work environments for equines, requiring animals to haul heavy loads of raw clay, moulded bricks, and fuel across unpaved, uneven terrain for 8-12 hours per day, often without adequate rest, shade, or water access^[3].

The scale of the challenge is considerable. The brick-making industry in South America, South Asia, and sub-Saharan Africa employs millions of equines. Peru alone has an estimated 600,000 working equines, a significant proportion of which serve the artisanal brick sector concentrated in the coastal desert and inter-Andean valleys^[4]. Despite this, no systematic welfare assessment of brick kiln equines has been published for the South American continent. The available literature comes almost exclusively from South Asian contexts, where Burn *et al.*^[5] and Pritchard *et al.*^[6] established that working equines in these settings suffer from high rates of wounds, lameness, malnutrition, and harness injuries.

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Welfare assessment methodology for working equines has advanced substantially in the past decade. The traditional reliance on resource-based indicators (e.g., access to water, shelter provision, stocking density) has been supplemented by animal-based indicators that measure welfare outcomes directly on the animal: body condition, wound prevalence, lameness, pain behaviour, and physiological stress markers [7]. The AWIN donkey protocol, developed under the European Union's Seventh Framework Programme, provides a standardised, validated set of animal-based indicators applicable across diverse management systems [8]. Similarly, the Standardised Equine-Based Welfare Assessment Tool (SEBWAT) offers a harmonised framework for horses and mules [9]. These tools enable quantitative, comparable welfare assessments that move beyond subjective impressions. The brick kiln environment presents specific welfare challenges that differ from other working equine contexts. Animals are exposed to extreme heat from kiln operations, particulate matter from clay dust and smoke, chemical residues from fuel combustion, and repetitive strain from hauling standardised loads on predictable routes [3, 10]. The seasonality of brick production, which peaks during dry months when demand is highest and water availability lowest, creates periods of intensified workload coinciding with reduced access to drinking water and fresh forage. Kiln modernisation programmes, which replace human- and animal-powered transport with mechanised conveyor systems, have the potential to reduce equine workload, but their impact on actual animal welfare has not been systematically evaluated [11].

Material and Methods

Material

A cross-sectional welfare survey was conducted at 24 brick kilns in three provinces of Peru: Ica (coastal desert; $n = 10$ kilns), Arequipa (inter-Andean valley; $n = 8$), and Junin (highland; $n = 6$), between May and October 2024. Kilns were purposively selected to represent three technology levels: traditional (manual moulding, animal-powered clay and brick transport, open-pit firing; $n = 10$ kilns, 72 animals), improved (semi-automated moulding, animal transport retained, improved kiln design; $n = 8$ kilns, 64 animals), and semi-mechanised (mechanised clay mixing and conveyor transport for bricks, animals used only for raw material delivery; $n = 6$ kilns, 44 animals). All equines present and working at each kiln

on the assessment day were enrolled, yielding a total of 180 animals: 85 donkeys, 55 horses, and 40 mules. The research protocol was approved by the Institutional Animal Ethics Committee of the National University of San Marcos (Protocol CIEA-2024-0087) and complied with Peruvian national animal welfare legislation (Law 30407).

Methods

Welfare assessment followed a modified protocol combining elements of the AWIN donkey protocol [8] and SEBWAT [9]. Twenty-four animal-based indicators were assessed across four domains: nutrition (body condition score on a 1-5 scale, access to water, feed availability, evidence of dental problems), physical health (body wounds and lesions, limb abnormalities, hoof condition, eye abnormalities, nasal discharge, signs of pain on palpation, skin condition, ectoparasites, harness-related injuries), behaviour (response to assessor approach, response to palpation, stereotypic behaviour, ear position, head carriage, general demeanour), and housing/environment (shade availability, lying area, tethering method, environmental hazards). Each indicator was scored on a 3-point severity scale: 0 (good/absent), 1 (mild compromise), or 2 (severe compromise). Domain scores were computed as the percentage of the maximum possible score within each domain, with 0 representing perfect welfare and 100 representing maximum compromise; scores were then inverted so that higher values indicate better welfare.

Body condition was scored using the validated 5-point scale for donkeys (Pearson and Ouassat [12]) and the Henneke 9-point scale converted to 5-point equivalents for horses and mules. A BCS of 2 or below was classified as poor. All assessments were conducted by two trained veterinarians with demonstrated inter-observer reliability (Cohen's kappa above 0.80 for all indicators, established in a pilot session of 20 animals). Each animal was assessed at its work site during a standard working day.

Statistical analysis used linear mixed models with kiln as a random effect and species, age category (below 5, 5-10, above 10 years), sex, and kiln type as fixed effects. Post-hoc pairwise comparisons used Tukey's HSD. Pearson correlation assessed the relationship between BCS and composite welfare score. Logistic regression identified predictors of "poor welfare" (CWS below 40). All analyses were performed in R 4.3.2 using the lme4 and emmeans packages, with significance at $p < 0.05$.

Results

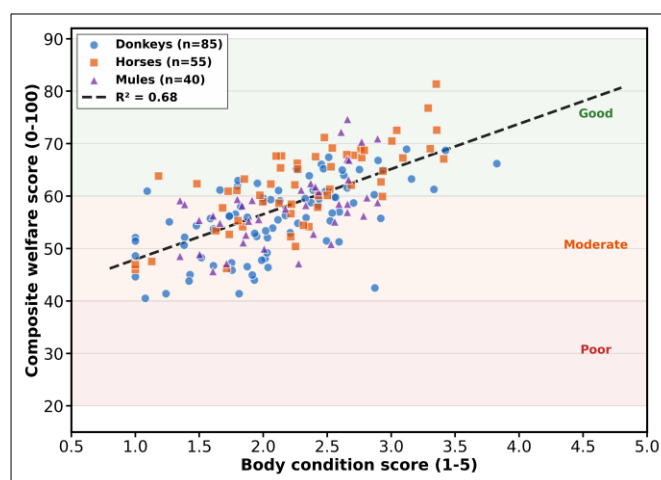


Fig 1: Relationship between body condition score (BCS) and Composite Welfare Score (CWS) for 180 working equines across three species. Background shading indicates welfare classification zones. The overall linear relationship ($R^2 = 0.68$) demonstrates that body condition is the single strongest predictor of composite welfare in this population

The overall mean composite welfare score across all 180 animals was 52.4 (SD 12.8), placing the population in the moderate welfare category. Scores ranged from 22.1 (a donkey at a traditional kiln in Ica with a BCS of 1.0) to 81.3 (a horse at a semi-mechanised kiln in Arequipa with a BCS of 3.5). Of the 180 animals, 28 (15.6%) scored below 40 (poor welfare), 118 (65.6%) scored between 40 and 60 (moderate), and 34 (18.9%) scored above 60 (good).

Species differences were significant ($F = 5.87$, $p = 0.003$). Donkeys had the lowest mean CWS (48.7, SD 12.1), followed

by mules (54.2, SD 11.4) and horses (55.8, SD 13.6). Post-hoc analysis confirmed that donkeys differed significantly from both horses ($p=0.004$) and mules ($p=0.021$), while horses and mules did not differ from each other ($p=0.64$). The species difference was driven primarily by the nutrition domain, where donkeys scored 15.3 points lower than horses ($p<0.001$), reflecting their lower mean BCS (2.1 versus 2.4) and reduced access to supplementary feed.

Table 1: Welfare domain scores (mean, SD) by species. Higher scores indicate better welfare

Domain	Donkeys (n=85)	Horses (n=55)	Mules (n=40)	p-value	Post-hoc
Nutrition	40.2 (11.8)	55.5 (14.2)	51.4 (12.6)	<0.001	D < H,M
Physical health	51.4 (14.1)	58.7 (15.3)	55.9 (13.8)	0.012	D < H
Behaviour	56.8 (10.4)	59.2 (11.7)	57.4 (10.9)	0.42	NS
Housing/Environ.	46.3 (16.2)	49.8 (17.1)	52.1 (15.4)	0.14	NS
Composite (CWS)	48.7 (12.1)	55.8 (13.6)	54.2 (11.4)	0.003	D < H,M

D = donkeys; H = horses; M = mules; NS = not significant

Table 2: Logistic regression model for poor welfare status (CWS < 40). Results for significant predictors retained in the final model

Predictor	OR	95% CI	p-value	Sensitivity	Recommendation
BCS ≤ 1.5	8.4	4.1-17.2	<0.001	82.1%	Immediate feeding intervention
Traditional kiln type	5.7	2.4-13.5	<0.001	71.4%	Prioritise for modernisation
Age > 12 years	3.2	1.5-6.8	0.003	64.3%	Workload reduction protocol
Donkey species	2.8	1.3-6.1	0.009	60.7%	Targeted nutrition programme
≥ 3 harness injuries	2.4	1.1-5.2	0.027	57.1%	Harness redesign/padding
No shade access	2.1	1.0-4.4	0.048	53.6%	Shade structures mandatory

Model AUC = 0.89 (95% CI: 0.83-0.95). Hosmer-Lemeshow $p = 0.41$

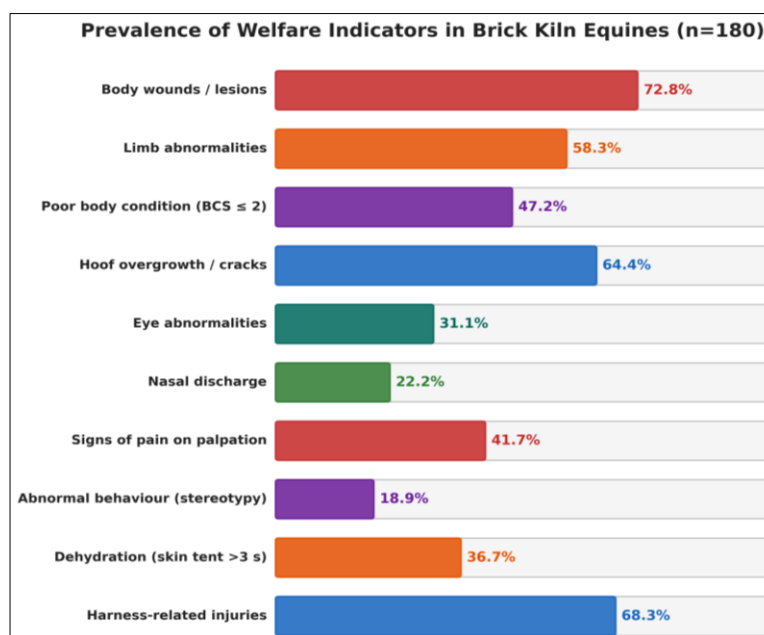


Fig 2: Prevalence of ten key welfare indicators across all 180 brick kiln equines. Body wounds and lesions (72.8%) and harness-related injuries (68.3%) were the most commonly observed welfare compromises

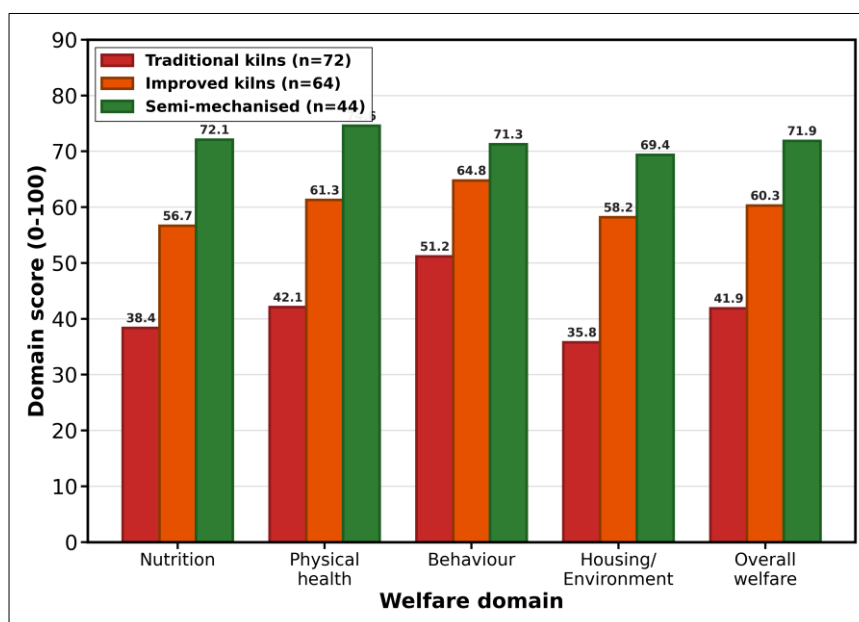


Fig 3: Welfare domain scores by kiln type. Semi-mechanised kilns scored significantly higher than traditional kilns across all domains ($p < 0.001$ for each). Improved kilns occupied an intermediate position

Interpretation

The data reveal three interconnected patterns. First, welfare in brick kiln equines is predominantly compromised in the nutrition and physical health domains, with wounds, harness injuries, and malnutrition affecting the majority of animals. Second, donkeys bear a disproportionate welfare burden, likely because they are assigned heavier relative workloads (as a fraction of body weight) and receive less supplementary feeding than horses. Third, kiln modernisation is associated with substantially better welfare outcomes, with a 30-point CWS difference between traditional and semi-mechanised operations. This last finding is particularly important because it suggests that welfare improvements can be achieved through structural changes to the production system rather than relying solely on owner education, which has had limited success in other working equine contexts [13].

Discussion

The principal findings are that working equines in Peruvian brick kilns experience moderate welfare compromise overall, that body wounds and malnutrition are the dominant welfare issues, and that kiln modernisation is the strongest environmental predictor of welfare status.

These results are consistent with findings from South Asian brick kiln surveys. Burn *et al.* [15] reported wound prevalence of 75% and poor body condition in 52% of donkeys at brick kilns in the Middle East and North Africa, figures almost identical to the present findings (72.8% and 47.2%, respectively). The consistency across continents and cultures suggests that the brick kiln environment itself, rather than culturally specific husbandry practices, drives the welfare pattern. The physical demands of hauling heavy loads over rough terrain, combined with poorly designed harnesses and limited access to veterinary care, create a predictable set of welfare outcomes that transcend geographic context.

Where the present data diverge from earlier work is in the quantification of the kiln modernisation effect. The 30-point CWS difference between traditional (41.9) and semi-mechanised (71.9) kilns represents a shift from moderate-to-poor welfare to good welfare, a magnitude of effect rarely achieved by owner-education interventions alone. In semi-

mechanised kilns, equines are used only for raw material delivery rather than continuous brick transport, reducing their daily workload by an estimated 60-70%. This reduced workload translates directly into fewer wounds, better body condition (because energy expenditure falls while feed intake is maintained), and lower harness injury prevalence because animals spend fewer hours in harness [11].

The donkey-specific welfare deficit deserves particular attention. Donkeys are often perceived as more resilient and less sensitive to pain than horses, leading to heavier relative loading, less feed provision, and delayed veterinary attention [14, 15]. This perception is not supported by equine pain research, which has demonstrated that donkeys exhibit subtler pain behaviours that are frequently missed by handlers, rather than experiencing less pain [16]. The finding that donkey nutrition scores were 15 points lower than horse scores despite both species working at the same kilns suggests a systematic bias in resource allocation that could be addressed through targeted nutrition guidelines specifying minimum feed allowances indexed to body weight and workload.

The strong correlation between BCS and composite welfare (R -squared = 0.68) has practical implications for monitoring. Body condition scoring is a rapid, non-invasive assessment that can be performed by trained non-veterinary observers, making it a feasible surveillance tool for welfare programmes. A BCS threshold of 1.5 identified 82% of animals with poor overall welfare (Table 2), suggesting that this simple metric could serve as a first-tier screening tool for directing veterinary resources.

Conclusion

This research set out to establish a quantitative welfare baseline for working equines in Peruvian brick kilns, to identify the animal- and environmental-level factors most strongly associated with welfare outcomes, and to assess whether kiln modernisation translates into measurable welfare benefits.

The key findings are that the 180 equines assessed had a mean composite welfare score of 52.4 on a 0-100 scale, placing the population in the moderate welfare compromise category. Body wounds (72.8%), harness injuries (68.3%), hoof problems (64.4%), and limb abnormalities (58.3%) were the most prevalent welfare issues. Donkeys scored significantly

lower than horses and mules, driven by poorer nutrition and higher wound prevalence. Body condition score was the strongest single predictor of overall welfare ($R^2 = 0.68$), and kiln type was the strongest environmental predictor, with semi-mechanised kilns achieving welfare scores 30 points higher than traditional kilns.

From a practical standpoint, five interventions are recommended. First, targeted nutrition programmes for donkeys, specifying minimum daily feed allowances of 1.5–2.0% of body weight in dry matter, should be introduced at all kiln types. Second, harness redesign using padded breastcollars rather than unpadded rope or wire harnesses would directly address the 68.3% prevalence of harness-related injuries. Third, a routine hoof care programme with farrier visits at 6–8 week intervals would address the 64.4% prevalence of hoof overgrowth and cracks, which contribute to lameness and reduced work capacity. Fourth, shade structures at loading and rest areas should be mandatory, particularly at traditional kilns where 78% of animals had no shade access. Fifth, kiln modernisation programmes should incorporate animal welfare metrics alongside environmental and occupational health targets, since the data show that reduced manual transport is the single most effective welfare intervention.

The body condition score threshold of 1.5, which identified 82% of animals with poor overall welfare, should be adopted as a practical monitoring tool. Welfare organisations, veterinary authorities, and kiln operators could use this simple metric for routine surveillance without requiring specialised equipment or advanced training. A traffic-light system (BCS above 2.5 = green, 1.5–2.5 = amber, below 1.5 = red) would provide an actionable framework for triggering interventions. Future research should address several limitations of this cross-sectional design. Longitudinal monitoring of the same animals across brick production seasons would reveal whether welfare deteriorates during peak production and recovers during the off-season. A larger sample including kilns from other South American countries (Bolivia, Colombia, Ecuador) would test the generalisability of the kiln-type effect. Physiological stress markers (salivary cortisol, heart rate variability) should be incorporated alongside the animal-based indicators to provide a more complete welfare picture. And economic modelling of the welfare-productivity relationship whether healthier, better-fed animals work more efficiently and have longer productive lives would provide kiln owners with a financial incentive for welfare investment that complements the ethical argument.

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