

International Journal of Agriculture Extension and Social Development

Volume 9; SP-Issue 8; August 2026; Page No. 30-38

Received: 02-06-2026
Accepted: 04-07-2026

Indexed Journal
Peer Reviewed Journal

The role of animal welfare in one health concept: A review

Divyanshu, Vikas Meena, Bhupender and G Jahnvi

Ph.D. Scholar, Livestock Production Management Division, ICAR–National Dairy Research Institute (NDRI), Karnal, Haryana, India

DOI: <https://www.doi.org/10.33545/26180723.2026.v9.i8Sa.4032>

Corresponding Author: Bhupender

Abstract

The One Health (OH) concept is an integrated, unifying approach that aims to sustainably balance and optimise the health of people, animals and ecosystems, recognising the fundamental interdependence of human, animal and environmental health (Zinsstag *et al.*, 2023; WHO, 2022; Prata *et al.*, 2022) ^[1, 2, 3]. Successful implementation of One Health depends on collaboration across the agriculture, animal health, human health and wildlife sectors (WHO, 2022). Animal welfare, how an animal copes physically and mentally with the conditions in which it lives, is increasingly recognised as a critical, though historically under-emphasised, pillar of this framework (Lymbery, 2025; WOA, 2022) ^[4, 5]. Good welfare exists when an animal is healthy, comfortable, well-nourished, safe, able to express natural behaviour and free from pain, fear and distress, as codified in the Five Freedoms and the Five Domains Model (Mellor *et al.*, 2020; Fraser, 2008) ^[6, 7]. This review synthesises classical and contemporary literature, including bibliometric, epidemiological and policy studies published between 2023 and 2025, to examine how animal welfare underpins disease prevention, food security, antimicrobial stewardship and surveillance within One Health. Poor welfare compromises immune competence and increases pathogen shedding, heightening zoonotic spillover and antimicrobial resistance (AMR) risk (Stevenson, 2023; Albernaz *et al.*, 2022; Aworh, 2024) ^[8, 9, 10], while integrated One Welfare approaches demonstrably improve human, animal and ecosystem outcomes (Pinillos *et al.*, 2016; Platto *et al.*, 2025) ^[11, 12]. The review concludes that embedding animal welfare explicitly within One Health governance, exemplified by ongoing efforts to include welfare provisions in the WHO pandemic treaty is essential to achieving resilient, sustainable and equitable health systems (Huang *et al.*, 2024) ^[13].

Keywords: One health, animal welfare, five freedoms, five domains model, zoonotic disease, antimicrobial resistance

1. Introduction

One Health refers to interdisciplinary collaboration among academic fields and transdisciplinary collaboration between academia and society at the human–animal– environment interface, generating benefits unattainable through single-sector action (Zinsstag *et al.*, 2023) ^[1]. The One Health High-Level Expert Panel (OHHLEP) defines it as an integrated, unifying approach that sustainably balances and optimises the health of humans, animals and ecosystems (WHO, 2022) ^[2]. Its successful implementation requires the agriculture, animal health, human health and wildlife sectors to work together, since the health of these domains is fundamentally interdependent (WHO, 2022; Prata *et al.*, 2022) ^[2, 3].

1.1 Historical Development of the One Health Concept

In the 1960s, veterinary epidemiologist Calvin Schwabe coined the term 'One Medicine' to highlight the shared interests of human and animal health (Schwabe, 1984) ^[15]. Growing interest in sustainable development subsequently drew attention to the inseparable links between human, animal and ecosystem health (Rapport *et al.*, 1999; Lebel, 2002) ^[16, 17]. In 2004, the Wildlife Conservation Society introduced the phrase 'One World, One Health' under the Manhattan Principles, later updated as the Berlin Principles on One Health in 2019 (Osofsky *et al.*, 2005) ^[18].

Systematic bibliometric analysis of the closely related One Welfare literature shows that publication activity in this space has accelerated sharply since 2019, with an increasing share of studies explicitly linking animal welfare, human wellbeing and environmental sustainability within a single analytic framework (Platto *et al.*, 2025) ^[12].

1.2 One Health in India

India formally embraced the One Health concept in response to the Avian Influenza (H5N1) pandemic. During 4–6 December 2007, the International Ministerial Conference on Avian and Pandemic Influenza was convened in New Delhi, hosted by the Government of India in cooperation with WHO, FAO, OIE, the World Bank and UNICEF and attended by representatives from 111 countries. At this meeting, the Government of India formally endorsed an integrated approach to animal and human health (Prejit, 2017) ^[19].

Animal welfare refers to the physical health, mental state and capacity of an animal to cope with its environment, encompassing biological functioning, emotional experience and the expression of natural behaviour (OIE, 2019; Fraser, 2008) ^[7]. Because welfare can be approached from veterinary, agricultural, consumer and animal-management perspectives, stakeholders often hold differing conceptions of what constitutes 'good welfare' (Nordquist *et al.*, 2017)

[20]. WOAHA defines animal welfare as 'the physical and mental state of an animal in relation to the conditions in which it lives and dies' (WOAH, 2019) [21]. Welfare is now central to modern livestock production, directly shaping animal health, productivity, food safety, environmental sustainability and public health (Fraser, 2008; Broom, 2011; FAO, 2019) [7, 22, 23] and the One Health movement has further highlighted its close interconnection with human wellbeing and ecosystem integrity (Pinillos *et al.*, 2016; Garcia Pinillos, 2018) [11, 24].

2. Animal Welfare: Concept and Scientific Basis

Animal welfare is a multi-faceted subject with scientific, ethical, economic and political dimensions, requiring an interdisciplinary approach that draws on physiology, veterinary science, ethology and comparative psychology (Lund *et al.*, 2006) [25]. WOAHA describes good welfare as existing when an animal is healthy, comfortable, well-nourished, safe, able to express innate behaviour and free from pain, fear and distress (WOAH, 2022) [5].

2.1 The Five Freedoms

Recognising the need for standardisation of welfare practice, a UK Government commission chaired by Sir Roger Brambell produced the 1965 Brambell Report, which first articulated criteria later formalised as the Five Freedoms by the Farm Animal Welfare Council (Brambell Committee, 1965; FAWC, 1979) [26, 27]. In 2009, the European Union expanded this framework through the

Welfare Quality project.

- Freedom from hunger or thirst: ready access to fresh water and a nutritious diet
- Freedom from discomfort: an appropriate environment including shelter and a comfortable resting area
- Freedom from pain, injury or disease: including prompt diagnosis and treatment
- Freedom to express normal behaviour: sufficient space, proper facilities and company of the animal's own kind
- Freedom from fear and distress: conditions and treatment that avoid mental suffering

2.2 The Five Domains Model

The Five Domains Model, first formulated in 1994 and subsequently revised in 2001, 2004, 2009, 2012, 2015 and 2017, offers a more dynamic and comprehensive welfare-assessment framework than the Five Freedoms (Mellor & Reid, 1994; Mellor *et al.*, 2020) [28, 6]. The first three domains nutrition, environment and health, address internal physical imbalances, while the fourth domain, behaviour, addresses restrictive confinement and the presence or absence of other animals, including humans (Mellor & Stafford, 2001) [29]. The fifth domain, mental state, integrates the first four to capture the animal's overall affective experience. The 2020 revision explicitly incorporated human-animal interactions as a distinct contributor to welfare outcomes, reflecting growing recognition that handling quality materially shapes affective state (Mellor *et al.*, 2020) [6].

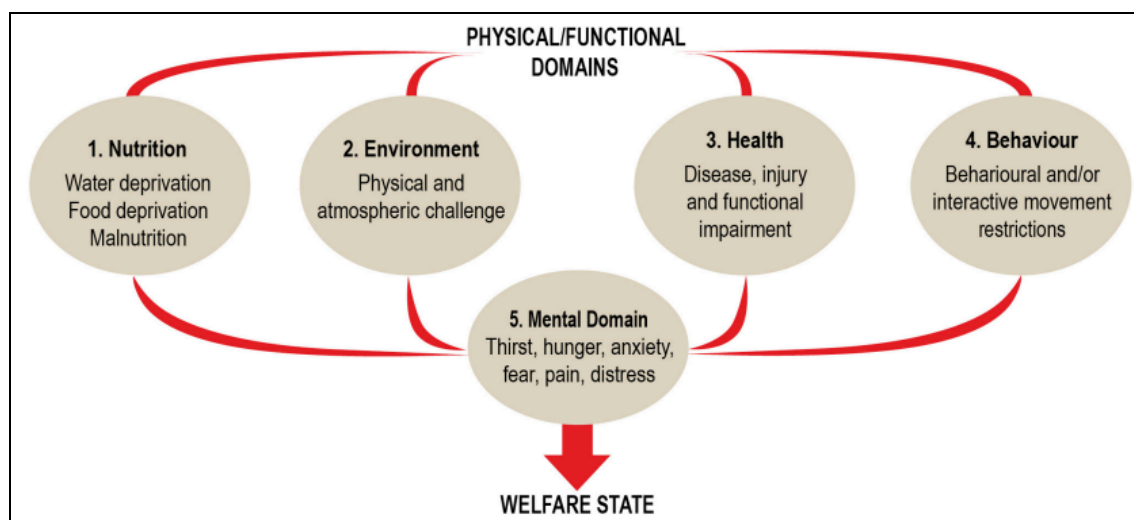


Fig 1: The Five Domains Model of animal welfare (adapted from Mellor & Reid, 1994; Mellor *et al.*, 2020) [28, 6]

3. The Three Interdependent Pillars of One Health

3.1 Human Health

Human health denotes complete physical, mental and social well-being, not merely the absence of disease. Within the One Health framework, human health is shaped by zoonotic disease, food safety, antimicrobial resistance, environmental pollution and ecosystem change, requiring collaboration with veterinary and environmental sectors (WHO, 1948; CDC, 2023) [30, 31].

3.2 Animal Health

Animal health encompasses the physical and mental well-being of domestic animals, wildlife and companion animals,

including freedom from disease, injury and suffering. Healthy animals underpin food production, livelihoods and biodiversity and reduce the risk of zoonotic transmission to humans; animal welfare is regarded as an integral component of animal health (WOAH, 2023) [32].

3.3 Environmental Health

Environmental health concerns the condition of natural and built environments affecting human and animal health, including air and water quality, soil health, climate stability, biodiversity and waste management. Environmental degradation, pollution, deforestation and climate change accelerate disease emergence and adversely affect both

human and animal populations (UNEP, 2022; Zinsstag *et al.*, 2018) ^[33, 34].

4. The Economic and Public-Health Case for One Health Integration

Evidence for the benefits of One Health spans health-service delivery, zoonoses control, food safety and security,

integrated AMR surveillance, water and sanitation, infrastructure sharing and cross-sector communication (Zinsstag *et al.*, 2018) ^[34]. The COVID-19 pandemic starkly illustrated the cost of fragmented surveillance across environmental, entomological, wildlife, livestock and human sectors and the catastrophic socio-economic consequences of failing to integrate them (Tan, 2021) ^[35].

Table 1: Summarises documented economic and public health returns from integrated approaches.

Domain	Added Value of One Health Integration	Reference
Health services	Joint human–animal vaccination services for mobile pastoralists improve access to healthcare	Schelling <i>et al.</i> , 2005 ^[36]
Zoonoses control	Mass livestock vaccination against brucellosis is more societally profitable; dog rabies vaccination is cheaper than human post-exposure prophylaxis	Roth <i>et al.</i> , 2003 ^[37] ; Zinsstag <i>et al.</i> , 2009 ^[38]
Surveillance & response	Integrated West Nile virus surveillance in Italy saved over €1 million (2009–2015) versus separate systems	Paternoster <i>et al.</i> , 2017 ^[39]
Infrastructure	Shared laboratories for zoonotic and highly contagious diseases cut operating costs by 26% versus separate facilities	World Bank, 2012
Communication	The Dutch Q-fever outbreak, with several thousand human cases, could likely have been contained by sustained veterinary–public-health communication	Enserink, 2010

5. Animal Welfare as an Integral Component of One Health

The well-being of animals is deeply interconnected with human and environmental health: good welfare supports disease prevention, food safety and security, biodiversity protection and sustainable ecosystems (Pinillos, 2018) ^[24]. Improving farm-level welfare has been shown to reduce stress-induced immunosuppression, the incidence of infectious disease, shedding of human pathogens by farm animals, antibiotic use and AMR and the environmental footprint of livestock production (Rushen, 2005; Alhussien *et al.*, 2024) ^[40, 41].

5.1 Animal Welfare and Animal Health: Animal health under welfare-conscious conditions encompasses both physical and mental well-being and the ability to express

normal behaviour, aligning directly with the Five Freedoms (WOAH, 2024) ^[42]. The European Food Safety Authority notes that food-chain safety is directly related to animal welfare, given the close link between welfare, animal health and foodborne disease (EFSA, 2022) ^[43]. Future pandemic prevention planning must therefore include improved biosecurity and welfare at the animal–human interface (Zinsstag *et al.*, 2005) ^[44]. However, legislated animal protection remains highly uneven across jurisdictions, with some states lacking any animal-protection law and others facing significant enforcement gaps (Goetschel, 2021; Goetschel & Ferrari, 2018; GAL Association, 2023) ^[45, 46, 47]. The American Bar Association has called for an international convention establishing binding standards for the care and treatment of animals to protect public health, the environment and animal wellbeing (ABA, 2021) ^[48].

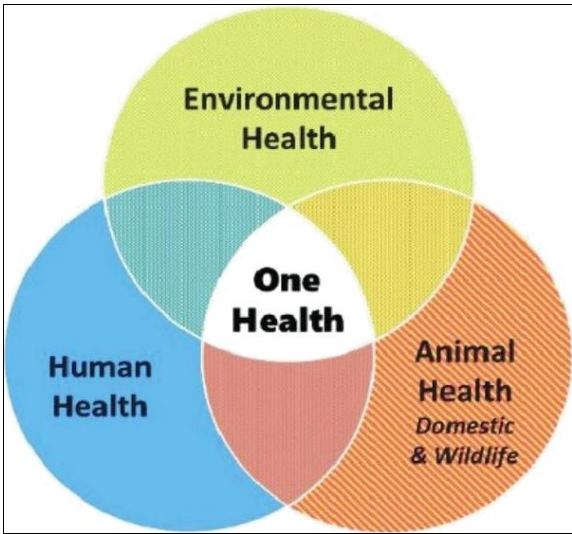


Fig 2: The interrelationship between animal welfare and animal health within One Health (adapted from WOA, 2024)

5.2 Animal Welfare and Human Health

The human–animal relationship spans emotional, economic and social dimensions. Companion animals provide emotional support and reduce stress and loneliness, while working animals such as horses and oxen remain

indispensable to many agricultural communities; their welfare directly affects human livelihoods and economic stability. Globally, an estimated 92 billion land animals are produced annually for food, making agriculture the largest single arena of human–animal interaction (Lymbery, 2025)

[4]. More than 60% of new and emerging infectious diseases affecting humans originate in animal populations and the frequency and severity of such spillover events have been rising over time (European Commission, *n.d.*). Non-therapeutic use of antibiotics that are also used in human medicine, applied for disease prevention in farm animals, continues to carry significant negative consequences for human health (The Pew Commission on Industrial Farm Animal Production, 2008) [49].

Health benefits of pet ownership include reductions in distress and anxiety, decreased loneliness and depression and improved physical activity, reinforcing the case for welfare-conscious companion-animal care as a determinant of human mental health.

5.3 Animal Welfare and Environmental Health

Environmental health under a welfare-conscious lens concerns the physical, chemical, biological, social and psychosocial factors in the environment that determine health outcomes (Ratjen *et al.*, 2025) [50]. Because animal suffering occurs irrespective of national borders, a universal, coordinated system for alleviating unnecessary suffering and improving welfare is increasingly framed as a humanitarian and ecological imperative, particularly as climate change reshapes the risk landscape for both livestock and wildlife (Zinsstag *et al.*, 2018) [34].

6. Legislative and Policy Frameworks for Animal Welfare

A series of legislative milestones has shaped modern animal-welfare governance, though coverage and enforcement remain inconsistent internationally (Cowan, 2016; Goetschel & Ferrari, 2018) [51, 46].

- Animal Welfare Act of 1970
- Animal Welfare Act Amendments of 1976
- Improved Standards for Laboratory Animals Act of 1985
- Protection of Pets Act 1990
- Animal Welfare Amendments to the 2002 Farm Bill
- Animal Fighting Prohibition Enforcement Act of 2007
- Animal Welfare Amendments to the 2008 and 2014 Farm Bills

Beyond domestic legislation, civil-society organisations have pushed for animal-welfare provisions within the WHO pandemic treaty, negotiated following the COVID-19 pandemic. Thematic analysis of proposals from FOUR PAWS, the Wildlife Conservation Society and Action for Animal Health identify five priority themes: prevention of zoonotic spillover, the One Health approach, animal-health systems and infrastructure, sustainable and ethical animal management and policy coherence and governance (Huang *et al.*, 2024) [13]. As of the most recent negotiating rounds, animal welfare remains without binding provisions in the OHLEP framework, prompting calls for a dedicated technical working group and ultimately, a UN convention on animal welfare, health and protection (CABI One Health, 2024).

7. Integration of One Health and One Welfare

The One Health and One Welfare approaches jointly recognise the interdependence of human, animal, and environmental health, advocating collaborative, cross-disciplinary action to achieve optimal outcomes for all three domains (One Health Commission, *n.d.*) [52]. Integrating animal health and welfare enhances disease prevention and food security, promotes sustainable livestock production, advances shared One Health/One Welfare objectives, and improves surveillance and early disease detection (Racciatti *et al.*, 2023) [53]. A 2025 bibliometric review of the global One Welfare literature confirms that these integrative aims are increasingly reflected in publication trends, although explicit measures of human wellbeing or environmental sustainability remain inconsistently incorporated into formal welfare-assessment protocols (Platto *et al.*, 2025) [12].

7.1 How Animal Welfare Affects Human Health

- Welfare status directly influences zoonotic disease risk
- Stress in animals weakens immune defences, increasing susceptibility to infection
- Poor welfare drives increased antimicrobial use and resistance
- Emotional bonds between humans and animals affect human mental health
- Robust welfare standards contribute to global public-health resilience (Dawkins, 2022) [54]

8. Animal Welfare in the Prevention of Zoonotic Diseases

Zoonotic disease risk is elevated by practices associated with organic farming and by keeping companion animals and horses in poor welfare conditions (Vlaanderen *et al.*, 2019) [55]. WHO estimated 121,268 new cases of zoonotic tuberculosis in 2010, including approximately 10,545 deaths attributable to *Mycobacterium bovis* worldwide (WHO, 2015) [56]. Approximately three in four emerging infectious diseases are zoonotic, with the majority (71.8%) originating in wildlife (CDC, 2023; Chomel, 2009) [31, 57]. Systematic review of zoonotic-risk research from 2018–2023 found that fewer than 5% of wildlife-focused studies integrated human, animal and environmental data collection simultaneously, underscoring a persistent gap between One Health rhetoric and research practice (Kuhn *et al.*, 2024) [58]. The burden of endemic and emergent zoonoses falls disproportionately on low-resource settings, where farmers and pastoralists living close to animals, combined with poor water and sanitation infrastructure, elevate infection risk (Grace & Cook, 2022; Grace *et al.*, 2017) [59, 60]. These diseases are frequently under-reported, under-diagnosed and under-treated, compounding morbidity and mortality in already strained public-health systems (Schelling *et al.*, 2007; Tan, 2021) [61, 35]. Recent analysis indicates that the annual frequency of zoonotic spillover events has risen by roughly 5% and associated deaths by nearly 9% over the past six decades, driven by deforestation, land-use change and wildlife trade (Bhatia *et al.*, 2024) [62].

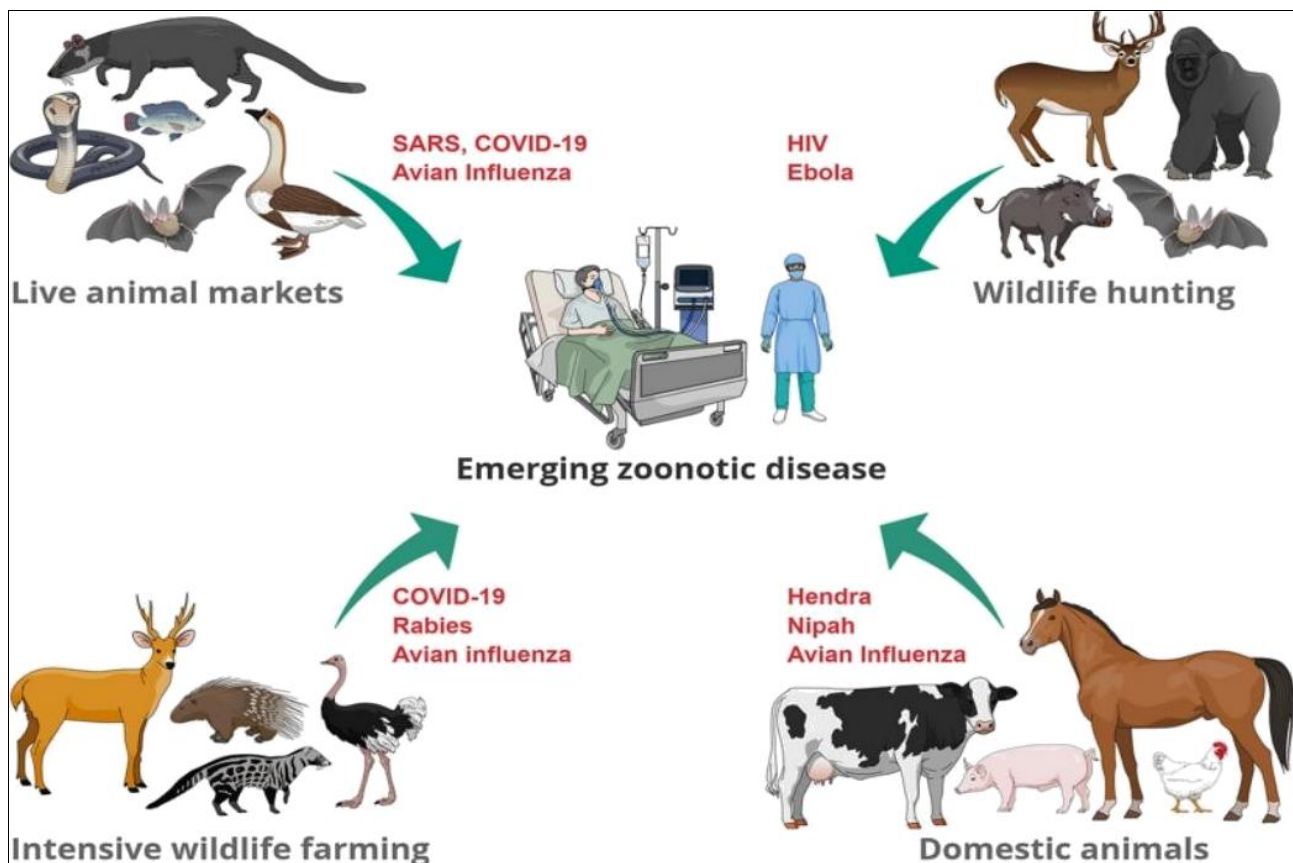


Fig 3: Global drivers and distribution of zoonotic disease risk at the animal–human–environment interface (WHO, 2015; Bhatia et al., 2024) [56, 62]

Many One Health initiatives focus on the human–livestock–wildlife interface because several major pandemics and (re)emerging infectious diseases have originated there, including SARS-CoV, SARS-CoV-2, Zika virus, avian influenza and Nipah virus (Kuhn *et al.*, 2024) [58].

9. Lessons from COVID-19 for One Health and Animal Welfare

COVID-19 revealed the depth of interlinkage between animal welfare, human wellbeing and environmental health, strengthening calls for integrated welfare policy (Butterworth & Bracke, 2021) [63]. Increased reliance on animal models — mice, ferrets and non-human primates for vaccine and drug development raised renewed concerns about experimental ethics and animal stress (Singh *et al.*, 2021) [64]. The pandemic exposed weaknesses in global health-security architecture, prompting reviews of how institutions, tools and operational frameworks assess and build capacity at the human–animal–environment interface and challenged prior assumptions about the practical value of integrated approaches such as One Health (WHO, 2022; The Independent Panel for Pandemic Preparedness and Response, 2021; Haider *et al.*, 2020) [2, 65, 66].

10. Animal Welfare and Antimicrobial Resistance (AMR)

AMR is a growing global health threat closely tied to animal welfare. Nearly three-quarters of the world's antibiotics are administered to farmed animals, largely to offset the disease pressure created by crowded, intensive production conditions, prompting WHO warnings about the risk of a

post-antibiotic era in which currently treatable diseases could again become lethal; experts estimate that unchecked AMR could cause roughly 10 million deaths annually by mid-century (O'Neill, 2016; Davies, 2021) [67]. Global projections suggest that, absent stronger policy intervention, antimicrobial use in food-producing animals will continue to rise through 2030, driven primarily by growth in livestock biomass rather than per-animal use intensity (Mulchandani *et al.*, 2023) [68].

Non-therapeutic use of antimicrobials is applied across species largely to prevent diseases that are themselves consequences of intensive production systems (Rollin, 2011) [69]. The human-health consequences of such use are well documented: antibiotic use for growth promotion or routine disease prevention has been linked to the spread of resistant infections, including methicillin-resistant *Staphylococcus aureus* (MRSA), in humans living near large-scale livestock operations (Carrel *et al.*, 2014; Silbergeld *et al.*, 2008) [70, 71]. In the United States, approximately 80% of antibiotics sold are used in farm animals, primarily for non-therapeutic purposes. By contrast, therapeutic antibiotic use — administered at a full dose for the minimum period needed to treat disease — is considered ethically necessary and carries markedly lower resistance-selection pressure than prolonged, low-dose, non-therapeutic use (Silbergeld *et al.*, 2008) [71].

A recent UK evaluation of the 2019–2024 AMR National Action Plan within the beef subsector found substantial progress in data collection, farmer and veterinary engagement and herd-health planning, but noted that further reductions in antimicrobial use depend on continued

investment in welfare-focused disease prevention rather than reactive treatment (Bennani *et al.*, 2024) ^[72]. Heat stress research further demonstrates that thermal and other environmental stressors compromise immune competence in dairy cattle and other livestock, increasing both disease incidence and the perceived need for antimicrobial intervention (Alhussien *et al.*, 2024) ^[41].

10.1 Welfare-AMR Pathways on Farm: A significant proportion of antimicrobials administered to livestock are excreted unmetabolized, contaminating soil and water and contributing to the broader environmental dissemination of

resistance genes (FAO, 2018) ^[73]. Studies of multidrug-resistant *Salmonella* in abattoir environments highlight risks to both animals and workers, underscoring the need for improved hygiene practices and stricter antibiotic controls in animal farming (Aworh, 2024) ^[10]. As a direct example, genetic selection for rapid growth in broiler chickens can outpace skeletal development, producing pain, injurious pecking and ammonia-laden waste that irritates the eyes and mucous membranes of both animals and workers — illustrating how production-driven welfare compromise and AMR risk are mechanistically linked (The Pew Commission on Industrial Farm Animal Production, 2008) ^[49].

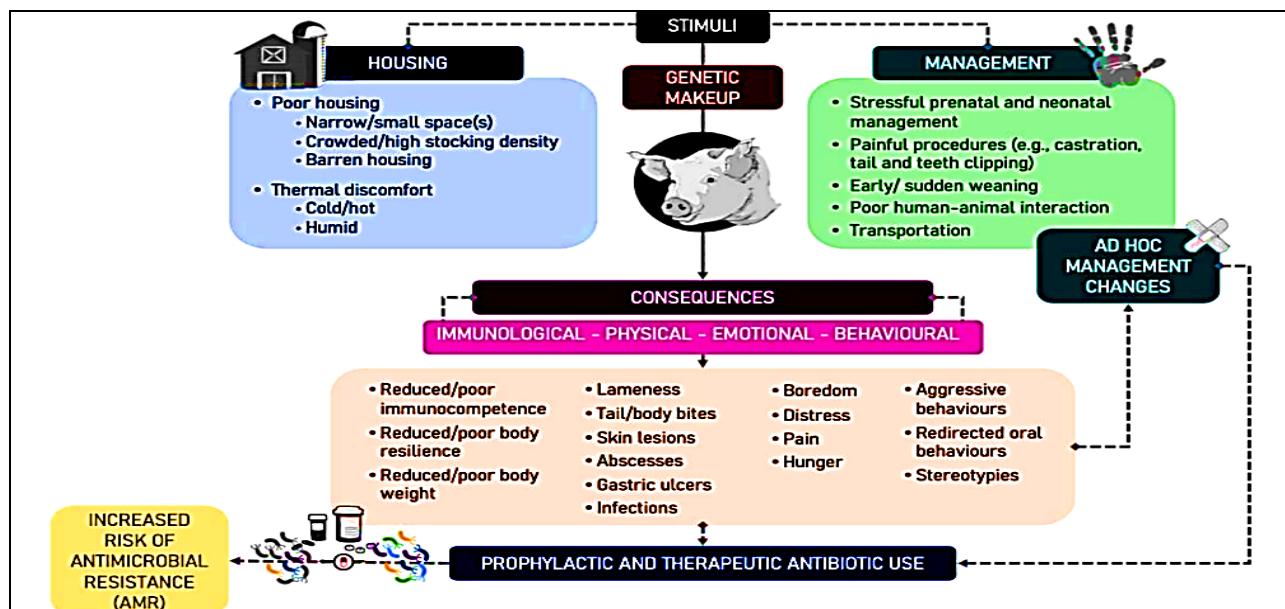


Fig 4: Biological pathway linking human-modulated welfare stressors to antimicrobial resistance risk in pigs (adapted from Albernaz *et al.*, 2022) ^[9]

Reviews of the broader livestock–disease–AMR nexus conclude that biosecurity measures alone are insufficient without parallel improvements in husbandry and welfare that reduce baseline stress and disease risk; the joint EMA/EFSA Scientific Opinion specifically calls for improved husbandry to reduce the need for antimicrobials in the first place (Stevenson, 2023) ^[8].

11. Animal Welfare in Food Safety and Food Security

Stress and poor welfare increase the release and virulence of several zoonotic pathogens, including *Salmonella*. Evidence consistently shows that improved farm-animal welfare enhances food safety, while communities that invest in animal care sustain farming continuity and the availability of animal-derived products, with positive knock-on effects for climate resilience, farming sustainability and disaster management (Pinillos *et al.*, 2016) ^[11].

12. Recent Advances and Emerging Research (2023–2025)

A growing body of recent scholarship reinforces and extends the classical welfare–One Health literature summarised above. The first global bibliometric review of the One Welfare literature (2013–2024) confirms a marked rise in interdisciplinary publications explicitly linking

animal, human, and environmental wellbeing, though it also identifies persistent gaps in the incorporation of human and environmental indicators into formal welfare-assessment tools (Platto *et al.*, 2025) ^[12]. Complementary behavioural-science perspectives argue that animal welfare and One Health research should adopt shared ethical principles — holistic, unbiased and inclusive of marginalised stakeholders — when balancing competing interests in applied research (Yeates, 2024) ^[74].

On the policy front, thematic analysis of civil-society engagement with the WHO pandemic treaty negotiations (2020–2024) identifies animal welfare as a recurring but still underformalised theme, with recommendations to embed welfare provisions explicitly within future treaty text to address the systemic drivers of pandemic risk (Huang *et al.*, 2024) ^[13]. On the epidemiological front, systematic review of wildlife zoonotic-risk studies published between 2018 and 2023 shows limited integration of the three One Health domains within individual research designs, despite conceptual endorsement of the framework (Kuhn *et al.*, 2024) ^[58], while global analysis of spillover trends confirms a measurable, ongoing increase in both event frequency and associated mortality (Bhatia *et al.*, 2024) ^[62].

On antimicrobial stewardship, projections through 2030 indicate that antimicrobial use in foodproducing animals

will keep rising unless livestock biomass growth is addressed alongside use intensity (Mulchandani *et al.*, 2023)^[68], while sector-specific evaluation of the UK's AMR action plan in beef cattle highlights welfare-focused disease prevention as a more sustainable lever than reactive antibiotic use (Bennani *et al.*, 2024)^[72]. Physiological research continues to substantiate the welfare–immunity–disease pathway, with heat-stress studies confirming that thermal stressors impair leukocyte function and increase infection susceptibility in dairy cattle and buffalo (Alhussien *et al.*, 2024)^[41], and pig-focused pathway analyses tracing specific human-modulated stressors through to elevated AMR risk on farm (Albernaz *et al.*, 2022)^[9].

13. Challenges and Future Directions

- Harmonising animal-welfare legislation and enforcement across jurisdictions, given the wide variation identified by global welfare-law databases (GAL Association, 2023)^[47]
- Embedding binding animal-welfare provisions within OHHLEP and the WHO pandemic treaty (Huang *et al.*, 2024; CABI One Health, 2024)^[13]
- Improving genuinely tri-domain (human–animal–environment) study designs in zoonotic-risk research, which remain rare in practice (Kuhn *et al.*, 2024)^[58]
- Decoupling livestock-sector growth from rising antimicrobial use through welfare-based disease prevention (Mulchandani *et al.*, 2023; Bennani *et al.*, 2024)^[68, 72]
- Strengthening climate-resilient husbandry to offset the welfare and disease risks of heat and environmental stress (Alhussien *et al.*, 2024; Zinsstag *et al.*, 2018)^[41, 34]
- Expanding One Welfare assessment protocols to formally incorporate human and environmental indicators alongside animal-based measures (Platto *et al.*, 2025)^[12]

14. Conclusion

Animal welfare is not peripheral to One Health but constitutes one of its foundational pillars. Good welfare reduces stress-induced immunosuppression, limits pathogen shedding and zoonotic spillover, curbs the antimicrobial use that drives resistance, and underpins food safety, food security, and sustainable livestock production (Rushen, 2005; Pinillos *et al.*, 2016; Stevenson, 2023)^[40, 11, 8]. Contemporary research from 2023–2025 reinforces these classical findings while highlighting persistent gaps: welfare provisions remain largely absent from binding global health governance, tri-domain research integration is still uncommon, and antimicrobial use trends in livestock remain on an upward trajectory absent stronger welfare-based prevention (Huang *et al.*, 2024; Kuhn *et al.*, 2024; Mulchandani *et al.*, 2023)^[13, 58, 68]. Closing these gaps by formally embedding animal welfare within One Health policy, surveillance, and research design is essential to achieving resilient, equitable, and sustainable health outcomes for people, animals, and the environment alike.

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