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Perspective

Pigs, Biomes, and the Pork Peril: A One Health and One Welfare Meta-Narrative

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Abstract: Global pork production and consumption occupy a dominant yet insufficiently scrutinized position within modern food systems, with 1.5 billion pigs slaughtered each year, a staggering loss of animal life. This perspective synthesizes published evidence and opinion from microbiology, epidemiology, environmental science, and public health to examine risks associated with industrial pig production, including zoonotic pathogen emergence, antimicrobial resistance (AMR), environmental degradation, and chronic disease burdens. The classification of processed meat as carcinogenic by the World Health Organization reinforces the need for critical reassessment of pork-centric production and consumption systems. High-density pig farming amplifies microbial spillover, ecological pressure, and public health vulnerability through intensive resource use, antibiotic dependence, and waste externalities. The convergence of these risks within industrial swine systems warrants particular attention. Accordingly, transitioning both industrial pig production and processing toward less risk-intensive and more adaptable alternatives based on diversified, agroecological food systems entailing aquaculture, sustainable dairying, poultry, and plant-based food cultivation can provide pragmatic pathways to resilient, health-conscious, and sustainable food supplies that operate within planetary boundaries. This direction aligns with sustainable food policies and frameworks advanced by international governing bodies and directly operationalizes the integrated One Health and One Welfare frameworks.

Keywords: swine production; zoonoses; antimicrobial resistance; climate risk; cancer risk

1. The Overlooked Toll

In October 2015, the World Health Organization's International Agency for Research on Cancer (WHO/IARC) published a monograph detailing the carcinogenic risks associated with red and processed meats [1]. Globally, pork accounts for approximately 34% of total meat consumption [2], while products derived from swine constitute up to 64% of the processed meat market share [3]. When we refer to processed meat, it most predominantly includes pork products (bacon, sausage, hot dogs, pepperoni, ham, and cold cuts like bologna and salami) [3].

The WHO/IARC monograph classified processed meat, of which pork products form the predominant component, as a group-1 carcinogen, placing it in the same category as tobacco in terms of established carcinogenicity [1]. A decade later, researchers in the United Kingdom have called for the introduction of cigarette-style health warnings on bacon and ham packaging, citing their potential association with increased bowel cancer risk [4]. Due to non-availability of such a labeling system warning consumers about pork's inherent risks and nitrite use in processed pork, about 54,000 Britons over the years developed bowel cancer, which has cost the NHS about £3bn [4]. In California, the labeling of bacon is subject to the state's Proposition 65 law, which requires warning labels for processed meats, such as bacon.

Pork remains one of the most widely consumed meats worldwide; however, its production and consumption present a range of significant biological and environmental challenges that have largely been ignored and warrant urgent attention.

Beyond its carcinogenic classification, the rapidly expanding swine production industry carries far-reaching implications, including contributions to pathogen emergence, antimicrobial resistance (AMR), adverse effects on gut health, elevated risks of cancer and other chronic diseases, environmental pollution, and substantial role in global carbon emissions.

2. Epidemiological Overview

Several pathogenic bacteria and parasites including *Trichinella spiralis* (which causes trichinosis), *Taenia solium* (the pork tapeworm responsible for taeniasis and neurocysticercosis), *Toxoplasma gondii*, *Leptospira* spp., *Listeria monocytogenes*, *Streptococcus suis, Salmonella* spp., *Campylobacter jejuni*, *Brucella* spp., *Clostridioides difficile, Clostridium botulinum*, and *Yersinia enterocolitica* may be associated with pork production and consumption, among other food-animal and environmental reservoirs [5–7]. Decades of epidemiological studies and outbreak reports consistently point towards pork as a significant source of human infection with these agents.

Additionally, pork is a source of broad-host-range enteric pathogens with wide host tropism such as *Salmonella*. Their presence in pork is a critical zoonotic risk whereby the infection is acquired mainly via fecal-oral routes involving pigs, with latent carriers shedding bacteria during stressful transport and slaughter conditions and that it contaminates multiple tissues, including lymph nodes and intestinal tract, escalating carcass contamination risks during processing [8–10]. The evolution and global spread of swine-adapted extensively drug-resistant *Salmonella* strains are generally linked to intensive farming and pork trade [11].

Antibiotic residues found in pork may promote the growth of resistant gut bacteria, further complicating human health outcomes. Consequently, the consumption of predominantly processed pork is associated with health risks beyond infection including obesity and cardiovascular disease [12] and possibly via mechanisms tied to gut microbiota alterations and inflammation [13]. Moreover, heavy use of antibiotics in pig production leads to residues widely dispersed through manure and wastewater that permeate soils and water sources. This not only degrades microbial ecosystem integrity but also threatens drinking water safety and facilitates the proliferation of fecal bacteria and associated antimicrobial resistance genes (ARGs), leading to a significant crisis [14–16]. In addition, the pork industry also plays a major role in the global antimicrobial consumption quagmire, exacerbating AMR with grave public health implications. Worldwide, about 99,500 tons of antimicrobials were used in livestock in 2020, with pigs consuming a significant share estimated at roughly 172 mg per kg of animal weight, produced largely due to routine use of antibiotics as growth promoters, as well as for disease prevention, and toward therapeutic regimens in intensive farming systems [17,18]. This widespread use selects for resistant bacteria in swine, which can transfer to humans through contaminated meat, direct contact, or environmental pathways. For instance, groundwater and manure runoff spread these bacteria and ARGs further [14–16]. The global magnitude of AMR is devastating: bacterial resistance directly caused 1.27 million deaths in 2019, about 1.14 million in 2021 with an estimated 1.91 million deaths in 2050; projections warn of over 39 million direct deaths from 2025 to 2050 [19,20].

Pork-associated viruses significantly impact human health by acting as zoonotic disease agents capable of crossing species barriers and causing both acute and chronic illnesses. The list of swine origin viruses which could be associated with disease including potentially zoonotic infections or experimental infections is rather long and alarming: swine enteric alphacoronavirus (SeACoV), foot-and-mouth disease virus (FMDV), classical swine fever virus (CSFV), porcine epidemic diarrhea virus (PEDV), porcine reproductive and respiratory syndrome virus (PRRSV), porcine circovirus type 2 (PCV2), swine hepatitis E virus (swine HEV), swine influenza virus (SIV), porcine sapovirus (Porcine SaV), torque teno sus virus (TTSuV), African swine fever virus (ASFV), and Senecavirus A (SVA) [21]. Some of these viruses, even if not directly associated with human infections, could very well form the trajectory of future emerging viral diseases. Because swine serve as highly suitable permissive hosts [22], viral gene re-assortment within these animals can generate novel strains with pandemic potentials. Ultimately, the role of pigs as intermediates or amplifiers in emerging zoonotic virus spillovers is widely recognized in the literature and several of these viruses simultaneously carry devastating economic and veterinary public health impacts.

Pigs serve as great reservoirs of influenza viruses with extended host tropism and thereby infection risks in different species including humans, and pose pandemic risks [23]. From a biosecurity perspective, swine hosts represent a genuine threat posing as 'mixing vessels' capable of re-assorting avian, human, and swine influenza strains, promoting viral mutation and augmenting pandemic risks [23]. Other viruses such as Nipah cause deadly encephalitis. Though some swine-specific viruses, such as African swine fever, do not infect humans, they indirectly threaten food security and global economies. The most immediate and well-documented viral infection risk emanates from Hepatitis-E virus infection leading to hepatitis. Although it might be often asymptomatic or mild, it can lead to acute liver failure, especially in vulnerable populations [24].

The impact of pork on gut health goes beyond infections, as it also affects the very balance of the gut microbiome. Regular consumption, especially of processed pork products, has been linked to reduced microbial diversity with deleterious impact on inflammatory and metabolic pathways. The incidences of Type-2 diabetes and consumption of red meat, pork in particular, have risen simultaneously and consumption of processed meats have shown increased association with diabetes risk in observational studies [25]. Literature is replete with reports of elevated levels of trimethylamine-N-oxide (TMAO), fasting insulin, and C-reactive protein in association with pork consumption and pointing at increased inflammation, metabolic dysfunction, and an elevated risk for adverse cardiovascular events. High TMAO levels were observed in experimental animals fed by diets rich in pork meat and processed pork, together with western background diets [26]. A recent analysis of the data from large genome-wide association studies found that higher pork intake was significantly associated with increased risk of atrial fibrillation [27].

In the long term, and often in conjunction with other lifestyle factors, high intake of pork or its processed products can contribute to the development of Non-Alcoholic Fatty Liver Disease (NAFLD) and potentially other forms of chronic liver disease [28]. Some studies suggest a correlation between dietary pork and mortality due to cirrhosis. While the link is complex, there could be certain components in pork that likely exacerbate liver damage [29].

At the chemical level, components abundant in pork such as polycyclic aromatic hydrocarbons, heme iron, heterocyclic amines, and N-nitroso compounds have the potential to inflict oxidative damage on colon cells, contributing to the development of colorectal cancer [30–32]. Supporting these findings, animal studies reveal that pork proteins could drive oxidative stress and low-grade inflammation in the colon, disrupt beneficial bacteria, and alter gene expression related to immunity and metabolism [33]. Wary of these evidences, major health authorities classify processed meat as carcinogenic and red meat including pork as probably carcinogenic to humans [1]. Scientific studies have shown that eating large quantities of processed red meat, which predominantly includes pork, increases the risk of colorectal cancer. The evidence for processed pork products such as bacon and ham is stronger than for unprocessed cuts, but excessive consumption of either is associated with an increased risk of colorectal cancer and associated mortality [1,34].

Although the interaction of dietary proteins and autoimmunity is largely understudied, dietary proteins have been proposed as one of the risk factors for the autoimmune disorders. It has been reported that pig proteins indicated high number of unique autoimmune epitopes corresponding to human proteins [35]. A study reported that the abattoir workers while processing brains of pigs developed autoimmune neurological disorders [36] with IgG specific antibodies to myelin basic protein (MBP) found in 75% of workers [37]. It has been shown that numerous pig-derived autoimmune epitopes were specific to multiple sclerosis epitopes that were found to be expressed in all tissues of the human body and could be present similarly in pigs. Interestingly, pigs shared unique epitopes with antigens involved in other autoimmune disorders, such as Goodpasture syndrome, autoimmune atherosclerosis, dermatomyositis and bullous pemphigoid [35].

The environmental footprint and impact of global food production including pork production is substantial and mitigation through various measures is suggested [38]. Globally, producing 1 kg of pork meat emits up to 7 kg of CO_2-equivalent as upper limit, with some systems reporting even higher emissions [39,40]. The vast majority of these emissions come from feed production and manure management, while processing and transportation contribute smaller, yet meaningful shares [39,40]. Beyond climate impacts, pig farming requires substantial land and water resources. It also contributes heavily to nutrient runoff causing eutrophication, soil and water contamination, and significant biodiversity loss [39]. The scale of production is staggering as between 1.3 and 1.5 billion pigs are slaughtered globally each year amplifying the environmental burdens tremendously [41,42]. To put this into perspective, pork's footprint rivals that of chicken but is considerably far larger than plant-based protein sources like lentils in terms of greenhouse gas emissions, water use, and land occupation [38,39].

While organic pork production is often viewed as a more environmentally friendly choice, it still contributes significantly to greenhouse gas emissions due to feed intake and manure methane emissions coupled with lower yields [40,43]. Another critically underappreciated environmental hazard lies in the processing industry's waste streams: offal, hides, discards, and manure. These byproducts frequently contaminate waterways, aquifers, and surrounding soils with excessive nutrients, harmful pathogens including antibiotic-resistant bacteria and toxic compounds [44]. Runoff from pig farms introduces high levels of nitrogen, phosphorus, heavy metals, and pathogens into local ecosystems, exacerbating eutrophication, oxygen depletion in aquatic systems, and jeopardizing crop and human health [14,15,44].

While it is worthwhile to mention the advances made in animal husbandry, biosecurity, and regulatory oversight, as well as pork's nutritional value as a source of protein and fat, and asserted production efficiencies, including potential land-use reductions and farming-related benefits to rural livelihoods, these advantages are insufficient to offset the well-documented health and environmental risks associated with modern industrial pork production. It is possible that some phrases and idioms will obscure environmental and health impacts of intensive pork production. Notions such as 'feed the world' and 'regenerative agriculture' frame industrial pork as necessary or sustainable, while claims about production efficiency per unit of meat distract from the massive overall emissions, waste, and resource use. Manure is sometimes lauded as 'black gold', yet in reality, large-scale waste management poses serious pollution risks. By downplaying absolute emissions and methane contributions, these narratives shield intensive swine farming from meaningful climate accountability.

From a cultural and psychological perspective, pork consumption elicits strong aversions within many religiously observant and aesthetically sensitive communities. The famous 'yuck factor', associated with pigs' omnivorous behavior (and coprophagy emanating from their long-standing associations with filth) remains influential, with approximately 30–40% of the global population abstaining from pork for religious, cultural, or personal reasons. Major world religions and cultural traditions explicitly prohibit pork consumption [45,46].

3. The Path Forward

The converging infection risks and zoonotic hazards, biosecurity imperatives, the massive ecological footprint, as well as significant cultural avoidance collectively paint pork, whether conventionally or organically produced, as a problematic and high-risk food commodity [5,6,9,10,13,45,46]. The accumulating evidence from microbiology, epidemiology, environmental science, and social research underscores the necessity for global societies to consider transitioning away from pork consumption. Simply mitigating impacts through incremental measures falls short of resolving the multifaceted challenges or successfully operationalizing the tenets of the One Health and One Welfare frameworks.

Shifting to alternate protein sources aligns powerfully with international sustainability goals. The most evidence-based, health-promoting, and ecologically sustainable path forward lies in transition toward healthier and more affordable alternatives such as seafood, poultry, dairy, and vegetables. The available evidence supports reducing dependence on intensive pork production systems and encouraging diversified dietary and agricultural transitions that may mitigate environmental and public health burdens. It supports the United Nations' Sustainable Development Goals such as (a) responsible consumption & production (SDG 12), (b) climate action (SDG 13), (c) life below water (SDG 14), and (d) life on land (SDG 15) by reducing resource-intensive livestock pressures and mitigating biodiversity loss. Such a shift would align with and reinforce the European Union's *Green Deal* and *Farm to Fork* strategies, which prioritize nutritious, sustainable diets and aim to curb AMR and agricultural environmental impacts [46–48]. It is estimated that replacing animal-based foods including pork with safe alternatives could sharply cut food's environmental impact in terms of global agricultural land use, water demand, greenhouse gas emissions, and biodiversity decline and would pave the Paris Agreement's 1.5 °C pathway further on [38,49].

There could be some reservations to the opinions presented herein. For instance, infestations, such as trichinellosis, might be reduced simply through proper cooking. In addition, any intensive farming system—whether pigs, poultry, or cattle—brings its own environmental and zoonotic challenges. So, while it is important to recognize that all livestock systems carry some level of zoonotic risks, pigs stand out scientifically and epidemiologically. Due to their unique biology, microbial spillovers, environmental stresses, and public-health vulnerabilities integrate in particularly potent ways. This integrative convergence is intensified by their physiological resemblance to humans and their ability to harbor and amplify a wide range of pathogens. Furthermore, the fact that pork surpasses the most heavily industrially processed meat classes introduces additional nutritional and chemical concerns that extend beyond the farming stage [1,7,43,46].

Finally, lumping all red meats together discourages a more nuanced conversation about the individual and critical impacts such as those of pork. The ruminant and poultry production systems form backbones of some of the major agrarian economic systems; they are biologically safer, aesthetically and culturally more acceptable and yield valuable co-products such as milk, hides, fibers, or eggs. Pork production, on the other hand, is almost exclusively meat-focused, rendering it economically narrow and environmentally costly. Phasing down industrial pork production and aligning transitions with the Food and Agriculture Organization's Strategic Framework (2022–2031), the One Health Initiative approach, and recommendations from IPES-Food might facilitate a shift away from narrowly optimized, high-intensity production models toward more circular, diversified, and context-sensitive systems. In this context, greater emphasis on well-managed aquaculture, sustainable poultry, diversified dairying systems, and vegetable-based food systems offers viable pathways for reducing environmental pressures while maintaining nutritional security. This shift supports international policies on sustainable livestock transformation, which advocate for reducing the ecological footprint of high-density farming to mitigate zoonotic disease risks and AMR. Consequently, phasing out industrial pig farming and processing in favour of the above-mentioned alternative food production systems in a conscious and prudent manner represents a practical and policy-viable path forward. This will allow us to advance in the context of the IPES-Food and UN goals of building resilient, diversified supply chains that stay within planetary boundaries while ensuring long-term global food security.

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Data Availability Statement

There were no sharable data generated as a part of this publication since it is an opinionated article.

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Conflicts of Interest

NA is an editorial board member of DBGS and an author of a book titled 'The Last Pig-Ending the Pork Peril'.

Use of AI and AI-Assisted Technologies

No generative AI or any large language models or AI tools were used to deduce opinions and thoughts brought about in this article.

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