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Multifaceted Role of Veterinarians in Mitigating Zoonotic Diseases, Sustainable Livestock Production and One Health Integration

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Abstract

Food security is a broad term; however, a brief definition of food security is the continuous accessibility of adequate safe and nutritious food to swelling population of the world produced under sustainable, equitable and competitive conditions so that, consumers can enjoy a healthy and productive life. Food security has become an inevitable challenge due to population growth over the last few centuries and the change in food preferences of consumers worldwide. The significance of this matter is evident from the fact that it is directly or indirectly a part of UN SGDs and is one of the burning topics recognized by one health approach. Livestock-based food products are essential in ensuring food availability, one of the 4 As of food security. Veterinarians have a crucial role to play in this regard as they are directly linked with the production, processing and marketing of livestock-based products. Additionally, they play a pivotal role in controlling zoonotic food-borne diseases and combating other livestock-associated diseases. Therefore, they should be part of policy-making organizations to overcome the challenge of food insecurity. This paper discusses food security, its public health impact, growing population, food consumption trends and the role played by the livestock in meeting this concern. This paper also discusses food-borne zoonotic diseases and their effects on food safety. Lastly, it stresses the multifaceted role of veterinarians in confronting food insecurity.



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Introduction

Food security being an elementary part of one health seems difficult to define due to its multidisciplinary nature. Innumerable fields of study such as agronomy, economics, public policy and economics have their jargon for this [1]. Despite technological progress that advances the methods and conditions for manufacturing and dispensing a variety of foods and food products, starvation and malnourishment still threaten people around the world. Without over-toning, simply food security is the availability of sufficient and nutritious food (at markets and farms), food affluence, food reservoir stability and biological utilization [2]. Food insecurity, the state of being without reliable access to a sufficient quantity of safe, nutritious food, is a persistent problem. The significance of food security is in progression over time because it is difficult to provide safe and nutritious food to the increasing gene pool. Innumerable zoonotic and metabolic diseases occur due to a lack of maintenance of food safety [3]. Ensuring food security not only reduces problems like obesity, malnutrition, micronutrient deficiency and famine but also promotes peace, prosperity and stability in the society of a nation [4]. In Pakistan, the food gap is 30 percent due to the food procurement and distribution system, illegal movement of food commodities and poor monitoring of the marketing system and can be fulfilled if 30 percent of production sources increased and 35 percent of available food is unassessed prompted by physical, economical and natural factors like flood, catastrophes [5]. Food provision is a fundamental human need and a top priority of a nation. The public area where a nutrient-rich diet is unavailable leads to cardiac issues, anemia, overweight and chronic diseases.

Furthermore, families facing poverty problems delay medical care to buy food items due to budget constraints and when poor nutrition leads to health issues ultimately it becomes more uneconomical [6]. Food systems play a key role in food security because they are shaped by dynamic interactions in the bio-geophysical and human environments. Urbanization, globalization and climate change are some of the factors influencing food systems and their effects on food security, with climate change posing the biggest obstacle [7]. If food security is interpreted as “access to enough food for an active and healthy life” livestock can make a significant contribution; as livestock food products contribute 27% to agricultural food output of food security. Animals are key sources of food specifically primary quality

proteins (amino Acids), carbohydrates, minerals, vitamins and other micronutrients. In addition, animal proteins are more digestible and metabolized effectively [8]. Compared to phyto-based foods, animal-based foods are not only rich in essential minerals but are also easier to metabolize and assimilate. Environmental degradation, competition for resources, increasing food demands and the integration of agriculture into an international economy threaten the sustainability of many food production systems. Food consumption by people is based on pillars of food security. Product supply and security focuses on the adequacy of food supplies. Food access, food quality and safety and food pricing directly impact consumer food stress and consumption behavior [9]. The food preparation and distribution system consist of global, national, regional and local food systems. Local food systems consist of small farmers, but heterogeneous products and supply chains are short in which farmers play all roles including storage, packing, transportation, distribution and advertising (Fig. 1). However, the barriers to local food systems include small farms and limited access to mainstream research, training and education in marketing. Due to this, they can't be helpful in food security [10].

Food Consumption & Growing Population

The population is increasing exponentially and will raise the challenge of food insecurity; consequently, cannot be ignored [11]. With a rising population, the

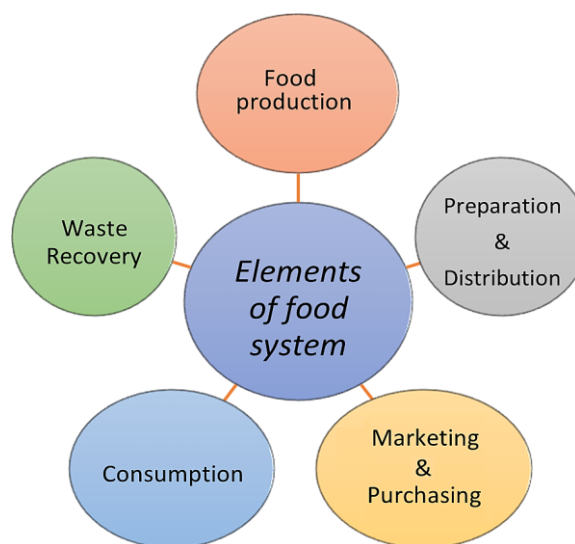


Fig. 1 The farm-to-fork continuum: the elements of the integrated food system.

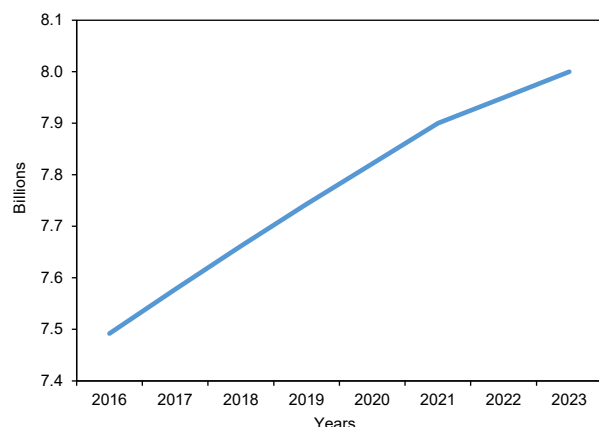


Fig. 2 Population growth curve: global trends, 2016-2023 [18]; <https://www.worldometers.info/world-population/>

increase in food demand by 60 percent by the year 2050 is also inevitable [12]. The growing population is bringing diversity to food consumption practices and preferences. These trends depend upon different factors like the personal choice of the consumer, availability, price of the food, demographic limits and economic status [13]. There is a noticeable difference between food supply when high and low-income countries are compared. High-income countries get double the supply as that of low-income countries. The developed countries take most of their nutritional energy from carbohydrates, then fats. They also get to consume dairy and meat products (Fig. 2). While underdeveloped countries cannot cherish the luxury of dairy and meat [14]. Meat from poultry, large animals and swine are the main sources of animal protein at the global level [15]. Demand for animal products like eggs, milk and meat has increased as the rich country consumes most of the protein from animal sources [16]. While looking at the US, the increase in meat consumption is evident in the rest of the countries. The highest consumption is of red meat, followed by increasing demand for poultry [17]. With the improvement in the economy of most Asian

countries, meat consumption is also increasing. An increase in livestock is also evident but meat consumption is still less as compared to other parts of the world, as it depends upon the per capita income and consumption. If the same situation prevails, this will lead to the import of meat to fulfill the requirements and meat demand of the increasing population [19]. The Chinese population still prefers plant-sourced protein but the demand for animal-source protein especially pork is increasing [20]. An increase in meat demand is also seen in India. Meat preferences are largely affected by religious limits. Chicken meat is generally accepted in India as it doesn't have any religious constraints to it and also because of the low cost [22]. Food security issues are also quite evident in Pakistan, where the incidence is largest in Sindh and Baluchistan and lowest in Khyber Pakhtunkhwa [22]. The population of Pakistan is growing at a fast pace. To cope with the increased demand for food, cultivable land has also increased fivefold. Being a potential producer of wheat, Pakistan still has to import it which enlightens the loopholes in food security assurance [23]. Meat is considered the main source of protein in Pakistan. Per capita consumption of meat has also increased [24]. A growing population comes with the dangers of unsustainability. Food consumption trends are also affected by climate change. Agricultural production systems must deal with problems associated with it, like food insecurity and differences in food supply to rich and poor countries and then make policies to cope with the growing population [25].

Livestock Production & Food Security

Livestock production is vital for sustainable food security, particularly in low-income areas and marginal habitats unsuitable for crop production. With the increase in the global population, the demand for animal products will rise, making livestock production vital in achieving sustainable

Table 1 Globalized consumption of animal-derived food items in 2016 and 2019.

Animal-based food products	Consumption in 2016	Consumption in 2019
Dairy cattle	21.63M tons	49.8M tons
Beef cattle	67.74M tons	64.5M tons
Sheep & meat goats	0.14M tons	0.13M tons
Horses	7.27M tons	7.70M tons
Aquaculture	0.64M tons	0.56M tons
Hogs	42.04M tons	61.8M tons
Turkeys	8.97M tons	10.6M tons
Layers	14.83M tons	19.2M tons
Broilers	-	60.8M tons
Dogs & cats	-	8.6M tons

<https://www.afia.org/feedfacts/feed-industry-stats/animal-food-consumption/> [26].

Table 2 Zoonotic outbreaks of food-borne microbes [35-39].

Foodborne pathogens	Outbreaks	Years	Areas	Food-product associated
<i>Campylobacter</i>	2	1.2012 2.2014	Northeastern America Utah	1. uncooked chicken livers; 2. raw milk
Nontyphoidal <i>Salmonella</i>	78	2010-2019	China	Uncooked/contaminated meats & eggs
<i>Salmonella</i> <i>Typhimurium</i>	8	1.2011 2.2012 3.2013 4. 2014 5.2017 6.2018 7.2019 8.2020	-	1. Clinical microbiology labs 2. Hedgehogs 3. Ground beef 4. Clinical microbiology labs & live poultry 5. Clinical microbiology labs 6. Chicken salad 7. Pet hedgehogs 8. Pet hedgehogs
<i>Salmonella</i> <i>enteridis</i>	5	1.2010 2.2012 3.2015 4.2018 5.2021	-	1. Shelled eggs 2. Ground beef 3. Raw, frozen, stuffed chicken entrees 4. Pet guinea pigs/shelled eggs 5. Raw frozen breaded chicken products
<i>Salmonella</i> <i>heidelberg</i>	3	1.2013 2.2014 3.2016	-	1. Chicken 2. Chicken 3. Dairy calves
<i>Salmonella</i> I 4, [5], 12:i:	1	1.2024	-	1. Charcuterie meats
<i>Salmonella</i> <i>litchfield</i>	2	1.2008 2.2022	-	1. cantaloupes 2. fish
<i>Salmonella</i> <i>infantis</i>	3	1.2015 2.2018 3. 2021	-	1. Pork 2. Raw chicken 3. Italian meat
<i>Staphylococcus</i>	2	1.2014 2.2018	Italy Vietnam	Unknown food source
<i>Escherichia coli</i>	11	1.2006 2.2007 3.2008-2010 4..2015 5.2016 6.2018 7.2019 8.2022 9.2024	Slaughterhouse in Athol	1. Mexican restaurant chain 2. Ground beef patties/frozen pizza 3. Beef 4. Rotisserie Chicken salad 5. Contaminated ground beef, veal & bison 6. Ground beef 7. Ground bison 8. Frozen falafel & ground beef 9. Raw cheddar cheese
<i>Listeria</i> <i>monocytogenes</i>		1.2012 2.2013 3.2014 4.2015 5.2016 6.2016 7.2018 8.2019 9.2020 10.2021 11.2022 12.2023 13.224	-	1. Ricotta Salata cheese 2. Cheese 4. Ice- cream 5. Raw milk 6. soft raw milk cheese 7. Deli ham/pork products 8. Deli sliced meat & cheeses; hard-boiled eggs; Enoki mushrooms 9. Deli meats 10. freshly cooked meat queso fresco 11. Ice cream brie & Camembert cheese 12. Ice cream 13. Raw cheddar cheese; queso fresco; Cotija cheese

https://www.cdc.gov/foodborne-outbreaks/active-investigations/all-foodbornetbreak-notices.html?CDC_AAref_Val=https://www.cdc.gov/foodsafety/outbreaks/lists/outbreaks-list.html [35]

<https://www.cdc.gov/campylobacter/outbreaks/outbreaks.html> [37]

food security, especially in developing countries (Table 1). Animal products contribute approximately one-third of global human protein consumption, as a result, developed countries are relying on them for dietary protein. Animal products are vital in preventing malnutrition in developing countries where diets consist of staple foods, while also serving as a significant income source for smallholders [27]. Due to the high rate of income growth and rapid urbanization Per capita consumption of milk and meat products in developing Asia is increasing day by day but in Latin America, per capita milk and meat consumption has declined over the same period, because the region is already built up. [28]. Increasing demand for animal products requires more animals to be produced, but producing more animals will have an environmental effect, so there is a need to introduce the concept of vertical genetic improvement in livestock production (*i.e.*, the number of animals need not increase for gaining the required animal products. More efficient livestock production systems with lower stocking rates can encourage smallholders in the developing world to contribute significantly to future red meat production [29]. Monogastric animals are important in this regard, as they are the main providers of meat, but they are not included in development programs; also, attention should be given to the creation of facilities that will benefit the small-scale producer, rather than major investments in big slaughterhouses and dairy plants. [30] Livestock animals are fed on crop products, by-products and roughage, if we switch towards more grain feedstuff then it will increase the input-output productivities of livestock systems because grains have a higher nutritional value than roughages. [31]. Livestock production diversity is also a key factor in ensuring food security. Households engaged in diversification experience fewer months of food deficit and have higher livestock sales compared to those that don't diversify. So, there is a need to promote diverse livestock production to mitigate food insecurity [32]. However zoonotic diseases in animals also compromise food security. we can say that Compromised food safety is also a food security issue. These zoonotic diseases pose a risk to humans who consume these animals, even when the animals are sick, raising concerns about food integrity. Food insecurity, with limited access and availability, can force people to turn to alternate food sources like shrub meat, exposing them to further disease risks. [33]. To reduce the risk of zoonotic diseases, animal health biosecurity should be adopted. These biosecurity measures should

include spraying livestock for vector control, isolating livestock at the market, inspecting livestock at the markets and quarantining livestock at the markets. By adopting these measures, these zoonotic food-borne illnesses can be controlled, ensuring a safe and secure food supply [34].

Zoonotic Diseases and Food Security

The lack of collaboration between the human health, food safety and animal health sectors has been a significant issue in ensuring food safety and food security, leading to major incidents (Table 2). Zoonotic diseases primarily originate from animals raised for food, including viruses like Avian influenza and Rift Valley Fever, bacteria like *Salmonella* and *Campylobacter* and parasites like *Taenia* and *Echinococcus*. Some diseases can be effectively treated on farms, such as brucellosis and *Taenia solium*. For instance, viral diseases like Avian influenza adversely affect backyard poultry, the sole source of animal protein in third-world countries. Unlike sudden viral outbreaks, bacterial food-related zoonoses develop slowly in industrialized settings where pathogens like *Salmonella* and *Escherichia coli* are prevalent. Collaboration and control measures are crucial to address these challenges in food safety [40, 41]. If we are to escape and survive, we must alter our perspective on the biosphere and pathogens. We are in a socio-economic death spiral. A new theory of pathogen-host evolution is introduced here. A model that predicts that disease emergence should be uncommon and followed by business as usual. To take advantage of those new hosts during colonization, novel genetic mutations are required. Changes among potential hosts are uncommon because ecological specialization brought on by coevolutionary interactions limits pathogen variation, geographic host ranges and host ranges [42]. Food bioterrorism involves the deliberate contamination of food and water with biological agents, posing a threat to human consumption. Various pathogens can be used, affecting the food chain from farm to table (Table 3). Developing countries with weak food safety infrastructure are particularly vulnerable. The consequences include public health impact, economic ramifications and social and political implications, with potential targets being civilian populations and military personnel. Unusual outbreaks may indicate covert biological attacks or the escape of prohibited agents from facilities [43]. *Bacillus anthracis*, the agent of anthrax and *Clostridium botulinum*, the cause of botulism, are examples of dangerous pathogens that

Table 3 Foodborne bacterial culprits and consequences [45].

Causative agent	Gram staining	Source	Symptoms	Prevention
<i>Staphylococcus aureus</i>	G ⁺	Commensal on the skin, nose and mucous membranes of healthy humans and animals	Diarrhea, vomiting, low-grade fever, chills, headache, abdominal cramps, nausea and vomiting without fever are typical symptoms.	Cooking food thoroughly
<i>Non typhoidal salmonella</i>	G ⁻	Salmonellosis outbreaks involve raw, unsafe food, cross-contamination, poor hygiene and long preparation gaps.	Gastrointestinal symptoms include nausea, vomiting, stomach cramps, diarrhea, mild fever, headache, prostration and muscle weakness.	Salmonella-related food spoilage is managed through biosecurity, biocontainment and improved processing techniques.
<i>Campylobacter</i>	G ⁻	Wild birds are natural hosts, acting as reservoirs or susceptible species.	Diarrhea, fever, vomiting	Campylobacteriosis control requires sanitation, hygiene, HACCP, food handling, cooking, biosecurity, essential oils and immunization for effective prevention.
<i>Escherichia coli</i>	G ⁻	<i>E. coli</i> infects healthy animals' intestinal microflora, including humans and is primarily caused by fetal shedding.	Symptoms include hemorrhagic colitis, hemolytic uremic syndrome, kidney failure, diarrhea, abdominal pain, vomiting and thrombocytopenic purpura.	Sanitation practices improve <i>E. coli</i> O157:H7 control, reducing food safety, health and herd resistance through intervention techniques.

can be used as bioweapons due to their high virulence and resistance [44].

Role of Veterinarians in Addressing Food Insecurity

One of the most formidable challenges faced by the world today is food insecurity and the provision of ecologically sustainable food to the rapidly growing population. This global concern cannot be addressed without taking into consideration the expertise of veterinarians as they are directly associated with the production, nutrition and welfare of food-producing animals. In addition, they also ensure that the food is safe for consumption and marketed properly [46]. Three billion population out of the estimated population of 10 billion will consume protein-rich meat, fish, poultry and dairy products by 2050. To meet this increasing demand, there is a need to encourage pastoral production of beef, milk and mutton together with better animal nutrition, health and disease control. However, pastoral production requires veterinary medicine to change accordingly [47]. The role of veterinary professionals is multifaceted as they have expertise in multidisciplinary approaches in addition to just preventing and curing diseased animals (Fig. 3). The role of veterinarians in food security is evident from their contribution to combating zoonoses and the eradication of rinderpest from the face of the earth.

Furthermore, veterinary professionals have an eagle eye on post-mortem and antemortem operations, lab testing and quality controls, ensuring that safe and sustainable animal-based food is consumed by humans [46]. The role of veterinarians is crucial in the food chain as they are the front-line army in fighting livestock diseases, checking livestock and livestock-derived food producers and overlooking transboundary animal diseases. Veterinarians have huge responsibility to combat AMR through the efficient and lawful use of antibiotics in food-producing animals. Also, vets in the private sector carry out regular surveillance of reportable diseases and may serve as part of regulatory authorities at the onset of any outbreak. Veterinary expertise has evolved and so should the interaction between vets and the state to regulate the food chain [48]. Likewise, the ancient role of vets in meat production, meat inspection, antemortem and postmortem needs to be modified to ensure hygienic practices. Only disease-free animals should be present for slaughtering and allowed to enter the food chain. The vets working at slaughterhouses also keep an eye on diseases that call for attention at the level of farms [49]. Vets also have a major role to play in enforcing biosecurity measures as the adoption of these measures will ensure food security by reducing the cost of production, improving animal welfare, lowers the chances of zoonotic and other livestock-associated diseases. Additionally, farm limits

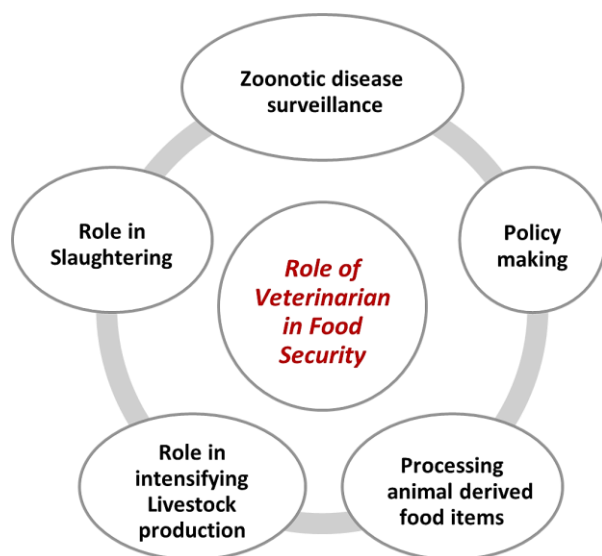


Fig. 3 The formidable role of veterinarians in ensuring global food security.

(control devised to avoid contact with other animals), maintenance and sanitation of livestock premises, restriction of animal movement (to avoid TADs) and control of external parasites (to avoid the chances of disease transmission) serve as major measures of disease control [50]. Veterinary parasitologists also have a role to play in ensuring food security as they combat parasitic infections (due to endoparasites as well as ectoparasites) affecting meat, milk and fiber production [51]. Food vets contribute to providing safe food from the level of farm to fork in the most hygienic measure possible. They have a keen eye on each step from production at the farm, through slaughtering, processing, storage, distribution the marketing of animal-based food [52]. Transmission of food-borne zoonotic diseases can be avoided by employing the use of animal vaccines and curative/prophylactic drugs, adoption of hygienic slaughtering measures and meat inspection, vector control, milk pasteurization, quality control and risk analysis. Veterinarians have the role of implementing the abovementioned control strategies, thus, ensuring the providence of safe food to the consumers [53]. Keeping into account the above discussion, it is necessary to uplift the status in both rural and urban communities of development to eradicate poverty and hunger globally. Additionally, the academia of veterinary students should be revised and one health issues including food security should be emphasized. Owing to the crucial share of veterinarians in every step of the food chain, they should be included in policy-making organizations concerned with food security [46].

Conclusions

In a nutshell, food insecurity is a serious concern that needs to be paid heed to. Unfortunately, both the developed and developing countries of the world are sweeping this issue under the rug. The governmental officials of the world need to arise from the dead before the world suffers from hunger. Veterinarians play a significant part in ensuring food security, food safety, food defense and food nutritional quality, all of which are concerned with 'zero hunger'. They directly or indirectly contribute to all 4 As of food security, *i.e.*, availability, accessibility, affordability and adequacy. Thus, it is the need of the hour to recognize the veterinary community as the frontline soldiers in battling hunger and food security. The status of vets should be uplifted and the academia of veterinary students should include a major part of health concerns like food security. The role of the vets in ensuring food security still needs to be explored further. Major responsibility lies on the shoulder of veterinarians all over the world in relieving the populous world from food insecurity.

Conflict of Interest

The authors have no conflicts of interest.

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