Commencing Mad Cow to Public Health; BSE socio-economic Impact and Zoonotic Perspective

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ABSTRACT

Bovine Spongiform Encephalopathy (BSE), also referred to as Mad Cow Disease, has become a significant public health issue with significant consequences for both society and the economy. This study examines the social and economic consequences of BSE (bovine spongiform encephalopathy) and studies its potential to be transmitted to humans. It addresses the complex network of relationships between human health, agriculture, and the environment. The socio-economic research examines the impact of BSE outbreaks on the agricultural sector, including the substantial financial losses experienced by farmers, the meat industry, and associated businesses. Moreover, this study investigates the widespread impact on international trade, consumer choices, and public trust in food safety, highlighting the importance of efficient risk communication and crisis management measures. This research examines the possible transmission of BSE from animals to people, with a specific focus on the zoonotic perspective. Gaining knowledge on the processes of zoonotic transmission is essential in order to effectively prevent the occurrence of novel human prion disorders. This study examines the scientific information on how BSE can be transmitted and evaluates the dangers and uncertainties connected with BSE as a zoonotic concern.

In conclusion, this comprehensive analysis provides insights into the complex interplay between BSE, public health, and socio-economic factors. The findings contribute to a better understanding of the challenges posed by BSE and offer valuable information for policymakers, health professionals, and stakeholders involved in managing the impact of zoonotic diseases on both human health and the broader societal landscape.

Keywords: Bovine Spongiform Encephalopathy, Mad Cow Disease, One Health, Public Health, Zoonosis

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1. INTRODUCTION

Zoonotic diseases are those which have the ability to transmit from animals to humans and are caused by different pathogenic organisms that can be bacteria, viruses, parasites, and prions. This pose a serious concern to public health since it is estimated that zoonotic diseases account for 60% of recognized infectious diseases and 75% of new infectious illnesses (Kulkarni et al.2015). According to research, these diseases cause around 2.5 billion morbidities and 2.7 million mortalities each year, resulting in significant economic losses (Spence et al. 2022). In our current culture, governments prioritize zoonotic disease prevention and control via public health measures and the implementation of a multidisciplinary strategy known as "One Health." In treating these severe illnesses, this strategy recognizes the connection of human, animal, and environmental health (Ghai et al. 2022).

BSE, sometimes known as "mad cow disease," is deadly neurological illnesses that have an impact on the livestock. There is certain class of diseases known as transmissible spongiform encephalopathy (TSEs) that also includes Mad Cow disease and BSE, which may affect humans and other animals and result in the development of BSE in cattle. A prion protein that is aberrant causes misfolding and aggregation of other normal proteins, resulting in brain damage (Prusiner 1998; Belay and Schonberger 2002). (. BSE was thought to be the sole strain of prion disease in cattle until now. In humans the occurrence of BSE C is associated with the emergence of a prion disease called the variant Creutzfeldt Jakob disease (Kong et al. 2008).

BSE, also known as mad cow disease was first discovered in the mid-1980s, in the United Kingdom and rapidly spread across Europe and other countries around the globe. BSE is mainly transmitted by contaminated feed. The worries about BSE crossing species barriers and posing a threat to humans became a reality when the first case of Creutzfeldt Jakob disease (vCJD) was diagnosed in 1996. These concerns arose from the belief that BSE could potentially lead to illness in humans. It was later discovered that consuming beef products contaminated with the BSE prion was indeed responsible for vCJD cases (Collins et al. 2002).

BSE has been categorized as a zoonotic disease by the World Health Organization (WHO). Although the number of vCJD cases has dropped considerably during the 1990s, but still exists as public health issue. BSE outbreaks have had substantial economic consequences, such as lowered beef consumption, prominent culling of infected animals and trade restrictions on beef products from affected countries (Jin et al. 2004).

It is thought that the disease spreads mostly when cattle ingest feed infected with meals especially, meat meal and bone meal which is regarded as the principal mode of transmission, thus controlling the food chain in terms of BSE is a serious issue. For example, in 2008, South Korea prohibited the importation of beef from the United States owing to worries about the possible spread of BSE disease in South Korea (Park and Sohn 2013).

Initially, the public's perception of BSE was manifested by neglect and denial on the part of government authorities and the livestock sector. Unfortunately, as the situation became evident, this method merely exacerbated it. This event emphasized the importance of public health transparency, communication, and risk mitigation methods (Dowler et al. 2006). Moreover, careless actions resulted in recurring outbreaks, the first occurring in the United Kingdom in 1985 and then spreading to European and non-European nations, affecting nearly 1,90,000 cattle (Karanikolaou 2022).

2. SOCIO-ECONOMIC IMPACT OF BSE

2.1. THE ECONOMIC IMPACT OF BSE ON THE LIVESTOCK INDUSTRY AND RELATED SECTORS

BSE has the potential to have a significant economic effect on the cattle and other industries. It caused significant economic losses which are due to the deaths, slaughtering, and culling of vulnerable

animals (Belay and Schonberger 2002). Countries that reported BSE cases suffered a drop in worldwide beef exports during the early stages of the outbreak (Kimberlin 1992). Furthermore, BSE had a significant impact on other livestock-related industries, such as the meat processing and rendering industries. Concerns about the spread of BSE through meat and bone meal reduced demand for these food products, resulting in decreased revenue for cattle and other related industries (Henson and Mazzocchi 2002).

Before the slaughtering policy, farmers bore all the losses, however farmers were financially compensated when the slaughtering policy was implemented. In the Czech Republic, for example, between February 2001 and the end of 2014, total 18,79,749 cows were tested, and 4,243 cows were culled. During this time, the Czech Republic gave farmers EUR 7,7,52,000 in compensation. As a result, governments suffered significant economic losses in the form of testing expenses, costs of culling animals, and compensation costs paid to the farmers (Pospíšil 2015).

Additionally, the implementation of BSE prevention and control measures, including feed restrictions and monitoring programs, caused substantial costs for the cattle industry and related sectors. For example, when a case of BSE was discovered in the Canadian province of Alberta in May 2003, the borders were restricted and international trade of beef and live animals was constrained. Since 47% of Canadian-produced beef was previously exported, this halt had a significant effect on the Canadian economy (Mathews et al. 2006). Agriculture and industries linked with the trading, transportation, and storage of beef and live animals are among the sectors of Canadian economy that are impacted by BSE (Petigara et al. 2011). The demand for beef in the US might decrease up to 15% during the BSE outbreak. In 2003, $4 billion in exports constituted 10% of US beef output, and the beef restrictions caused a reduction in exports by 82% (Yeboah et al. 2007). This resuls int low income and loss of jobs of farmers and families working in the livestock and agriculture industry severely affected their health by increasing the ongoing uncertainty and stress among them (Mitra et al. 2009).

3. BSE'S SOCIOCULTURAL IMPACT ON CONSUMER CONFIDENCE AND FOOD SAFETY REGULATIONS

The global impact of Bovine Spongiform Encephalopathy (BSE) on consumer confidence and the requirements for food safety has been significant. Following the 1980s discovery of BSE, the general public and legislators were concerned about the safety of beef products (Yeung and Morris 2001). However, Pritchett and coworkers have investigated the social consequences of BSE on consumer trust and food safety standards such as those in United Kingdom, where it is discovered that the BSE outbreak had a considerable harmful impact on consumer trust in beef products (Pritchett et al. 2005). Similarly, Canadian research found that the BSE epidemic reduced beef consumption while increasing the number of alternative protein sources (Umberger 2003). Another study carried out in the European Union discovered that the BSE outbreak resulted in a large fall in beef output and consumption, which adversely affected the economy (Knowles et al. 2007). Many countries implemented strict food safety regulations in response to the BSE crisis. These steps included increasing BSE testing and bans on certain cattle products. As a result, these measures have substantially impacted the livestock industry and related sectors. Overall, the impact of BSE on consumer confidence and food safety standards had a substantial effect on society (Henson and Jaffee 2008).

4. BSE'S PUBLIC HEALTH SIGNIFICANCE; VARIANT CREUTZFELDT-JAKOB DISEASE (VCJD) LEADING TO MASTERING PRIONS' BIOLOGY

Prions are the infectious organisms that cause BSE, and their unique features make them difficult to study and explain. Prions are deformed variants of the normal protein PrP, which is found throughout

the body, especially among neurons in the central nervous system. The normal protein is changed into the misfolded prion in an infected human or animal, and this prion then builds up in plaques that cover the sick brain as seen in Fig. 1. When PrP misfolds into prion form, it becomes extremely resistant to standard disinfection treatments and may start a chain reaction that results in folding errors across other PrP molecules (Morales et al.2007).

The misfolding and deposition of prions in the brain causes the neurodegenerative symptoms of BSE and associated disorders like vCJD. While the exact process of prion transmission is still unknown, it is obvious that it may spread via infected animal products including meat, bone meal, and other byproducts (Collinge 2005).

5. TRANSMISSION OF BSE

BSE is not a contagious disease and therefore, it cannot be transmitted by simple contact between cattle and other animals. But it can be transferred to other species including domestic or farm ruminants and cats through consumption of contaminated feed which is the primary route of transmission (Doherr 2003). Feed contamination occurs as a consequence of incorporation of contaminated additives such as meat and bone meal (MBM) and specified risk materials (SRM) that contain prion protein derived from infected cattle directly by the rendering plant or indirectly from the slaughterhouse (Nathanson et al.1997; Umberger 2003). The infectious agent, prion is not entirely inactivated by standard rendering methods

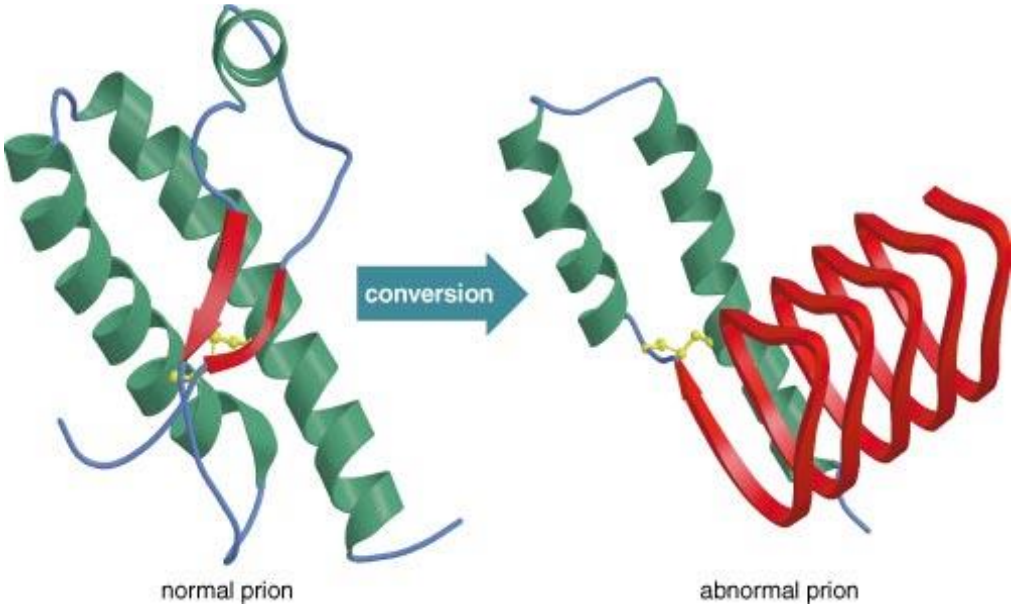

Fig. 1: In a healthy individual, the normal prion molecule (left) typically resides on the surfaces of cells, including neurons in the brain. Whereas the misfolded protein molecule (right) is critically involved in transmissible spongiform encephalopathy (Image courtesy of Paul Brown)

because they are resistant to inactivation, and can endure high temperatures and harsh chemicals. As a result, rendered protein generated from diseased animals, such as meat-and-bone meals, may carry the infectious agent. Animals that ingest feed that has been made from contaminated meat products get diseased (Taylor 1999). However, there is no empirical proof of horizontal transmission of BSE, but it may be spread vertically in a herd, making the cattle a dead-end host for the agent and there is also no confirmation of BSE transmission via physical contact of humans with live-infected cattle (Somerville et al. 2019). However, ingesting infected meat and meat products and utilizing specified bovine offals (SBO) such as brains, spinal cords, and other tissues or meat products manufactured from them are feasible routes for BSE to spread to humans (Cassano-Piche et al. 2009).

These contaminated meat-containing infectious agents can cause a food-borne zoonotic disease named variant Creutzfeldt-Jakob disease (vCJD) **(**Prater 2003**).** The most prevalent TSE in humans is CJD which can be transferred horizontally by lymphoid and neural tissues and blood whereas vCJD can be transferred by blood transfusions, organ transplants, and infected surgical tools (Sutton et al. 2006). Both classic CJD and new variant CJD can be cross-transferred by intracerebral inoculation as shown in Fig. 2 (Douet et al. 2014).

6. CLINICAL SIGNS

The clinical signs and side effects of variant Creutzfeldt-Jakob sickness (vCJD) are numerous and frequently vague, which makes conclusion troublesome. The clinical sickness starts with neurological side effects like social anomalies, sadness, nervousness or mental trips, appendage or joint agony, excruciating paraesthesia or dysaesthesia, and advances to additional particular neurologic side effects like mental degradation, ataxia, or wild developments. In later stages, myoclonus or choreatic movements, including akinetic mutism, usually emerge (Zerr and Poser 2002; Conti and Arnone 2016).

7. DIAGNOSIS

The primary challenge is making an early and accurate diagnosis of diseases caused by neurodegenerative protein misfolding. Human prion diseases like CJD are important because prions are fatal, contagious, and resistant to decontamination (Orrú et al. 2015). In vCJD, prion protein is found in the lymph nodes, tonsil, spleen, and appendix and similar organ damage is caused by other TSEs (Llewelyn et al. 2004). Furthermore, some genetic factors can increase a person's vulnerability to vCJD infection (Saba and Booth 2013).

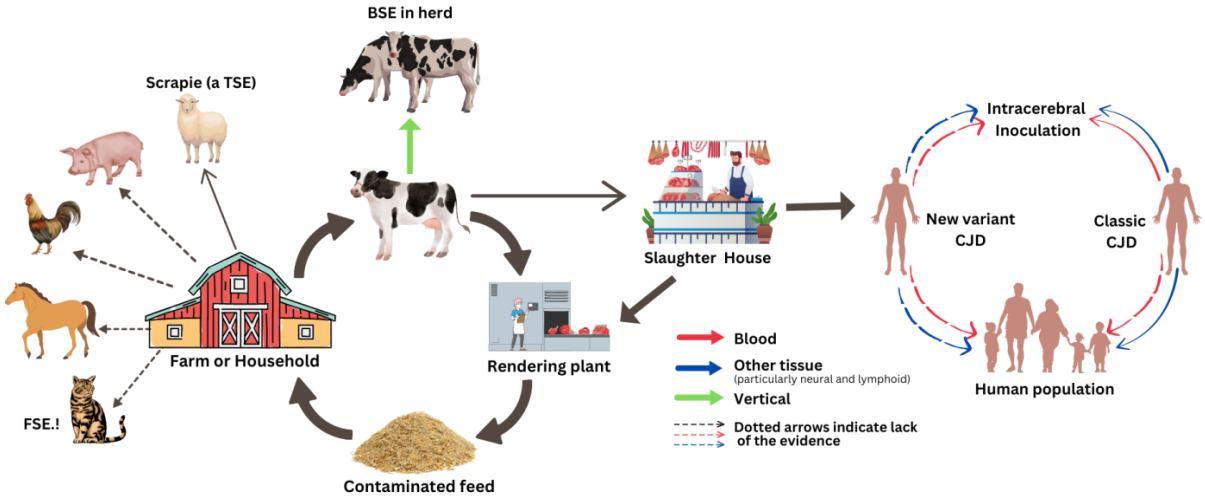

Fig. 2: The demonstration cycle of BSE infection and exposure of other species to products of a cow origin. Solid arrows (--) indicate direct exposure to cattle-derived products (cattle-derived food, cattle feed), Solid green arrows show vertical transmission, and dotted arrows (.....) indicate exposure to feed produced for pigs or poultry, and cats. Colored broken arrows (-.-.) and solid arrows indicate transmission within humans.

However, there are several diagnostic methods such as biomarkers and imaging technologies that can assist with diagnosis but, there is no authoritative test for diagnosing vCJD during life, and analysis are

made through clinical assessment along with technology like MRI, EEG, and conventional cerebrospinal fluid (CSF) biomarker analyses. But, these tests do have certain limitations, and only post-mortem analysis of brain tissue can provide a confirmatory diagnosis (Zerr et al. 2009).

A few efficient methods include protein misfolding cyclic amplification (PMCA) technology which is fit for generating prions from blood tests, and the improvement of a blood test in light of the location of prion protein antibodies (Saá et al. 2006) and Real-time quaking-induced conversion (RT-QuIC) that can identify prion-seeding activity in brain homogenates from sporadic CJD patients of any subtype. RT-QuIC had 96% sensitivity and 100% specificity for CSF PrPCJD detection (Zanusso et al. 2016).

Whereas, in cattle, the early identification of BSE cases is crucial in stopping the disease from spreading and minimizing the transmission risk to humans. For early diagnosis, rapid symptomatic tests, such as ELISA and Western smear, are used to confirm the presence of BSE prions in cerebrum tissues. These tests have successfully increased the ability to detect cases at an early stage, which is essential for preventing the spread of this fatal disease (Hayashi et al. 2004).

8. INVESTIGATING THE IMPLICATIONS OF VCJD FOR GENERAL HEALTH AND ITS IMPACT ON HUMAN WELL-BEING

Variant Creutzfeldt-Jakob Disease (vCJD) is a fatal and uncommon neurological disease that affects individuals. It is thought that ingesting BSE-tainted beef products causes the illness. The first case of vCJD was discovered in the Assembled Realm in 1996. Since then, more than 231 instances have been documented around the world (Ward et al. 2018).

The public health implications of vCJD are serious as Classic CJD effects mostly individuals at the of of 60 or 70 years (Boesenberg et al. 2005) whereas, vCJD has a majority of cases reported under the age of 30 and an extended duration of disease suggesting that, it can affect a larger population over a longer period of time (Ghani et al. 2003).

Furthermore, it is important to note that vCJD lacks a cure and has limited treatment options available (Blajchman et al. 2004). There are worries regarding the spread of vCJD through blood transfusions and other medical procedures. Consequently, strict measures have been established to screen blood donors to minimize the spread of vCJD (McManus et al. 2022). Aside, from the impact of disease itself, vCJD had reaching consequences on public health. The emergence of BSE and vCJD in the UK caused a loss of trust regarding the safety of beef and other animal products. As a result, regulations were implemented to prevent the disease from spreading (Oosterveer 2002). Additionally, BSE outbreaks had implications for agricultural and food industries, as well as public health systems, and vCJD has health implications and is a major concern for health authorities worldwide (Burnett 2008).

9. MANAGEMENT OF BSE

When it comes to controlling and managing BSE, conducting tests on animals before their death is crucial for assessing and managing the risks associated with it. Indeed, a BSE eradication programme may be justified by the use of a serum-based test that would enable the evaluation of the dairy cattle population (Lasch et al. 2003). Following are a few examples of BSE regulations, restrictions, and risk mitigation measures.

9.1. FEED BANS

The feed boycott is the most effective technique for preventing BSE. This should be achieved by following standards that limit the feeding of animal protein to ruminants, lowering the risk of BSE transmission through contaminated feed (Bradley and Wilesmith 1993).

9.2. RESTRICTION ON THE USE OF CERTAIN PROBABILITY MATERIAL IN ANIMAL FEED

Specific risk materials (SRM) and specified bovine offals (SBO) which are parts of the animal that are more likely to contain BSE prions include the brain, spinal cord, and certain other tissues. There should be a ban on the use of these materials to make feed safe for feeding the animal which is one of the main animal health control measures (Ducrot et al. 2013).

9.3. SPECIFIED IMPORT REGULATIONS

There should be specified regulations on the imports of meat and meat products from a country which have a significant number of BSE cases as it can enter the food chain of another country and eventually the burst of BSE cases in that area (Coffey et al. 2005).

9.4. ANIMAL IDENTIFICATION AND TRACEABILITY

During a BSE outbreak, animal identification and traceability systems can be useful in locating and identifying infected animals. Animal identification and traceability systems, such the National Animal Identification System, have previously been implemented in the United States which proved an effective way of controlling the spread of BSE (Greene 2010).

9.5. A LIMITED BLOOD DONOR PROHIBITION STRATEGY

A limited blood donor exclusion policy is an effective way to reduce the spread of vCJD through blood transfusion. This policy restricts the donation of blood from one who has been exposed to BSE prions (Tyshenko and Krewski 2010).

9.6. RISK ASSESSMENT AND MANAGEMENT

It is essential to use early risk assessment and managment to identify, recognize, and limit the possibility of BSE contamination in order to reduce the risk of its transmission. (Todd 2020). Within the European Association, there is a working body called BIOHAZ that provides risk assessments and guidance on BSE-related matters (EFSA 2007).

10. CONTROL MEASURES

There are a number of measures that can be implemented to control the risk of BSE transmission including to avoid to serve the remaining feed of one ruminant to the others and a banning on the use of specified risk materials (SRM) and meat and bone meals (MBM), animal identification and traceability, specified import regulations and surveillance of high-risk animals (Lewis et al. 2010; Yamanouchi and Yoshikawa 2007). For high-protein feed supplement, farms use meat-and-bone meal (MBM) which may cause disease. BSE is more likely to affect dairy cattle than beef cattle. During the outbreak, the later are regularly suckled and rarely fed concentrate feeds. Dairy cow calves are taken from their mothers at birth and nurtured on milk replacements before being weaned on to hay and concentrates, which frequently include MBM (Smith and Bradley 2003). Infected bovine residues having bone marrow, if consumed by humans can spread disease with clinical signs to them. This risk can be mitigated by using a consistent delivery cycle of crude bone material (Sogal et al. 1999).

Prions can survive in the harsh environment for an extended period of time, making disinfection difficult. Indeed, even the PrPSc is very impervious to sanitizers, bright radiation, heat, ionizing radiation, and

formalin, especially if present in tissues, dried natural material, or at an extremely high titer (Dudhatra et al. 2011). That's why cooking does not completely inactivate the infectious agent in the meat as it can endure high temperatures, so it is possible to get BSE from eating improperly cooked beef (Coghlan 2001). A single permeable burden autoclave cycle at 134-138°C for 18 minutes has also been recommended for inactivation; however, the prion protein may not be completely destroyed at these temperatures (Antloga et al. 2000).

Effective chemical disinfectants such as sodium hydroxide and sodium hypochlorite should be applied to surfaces for more than 1 hour at 20°C for equipment's and rendering should be done at a temperature of 1330 ^{0}C under a pressure of three bars for a minimum of 20 minutes. If there is a high risk of contracting highly infectious CJD tissue, many medical professionals advise to use disposable instruments in neurosurgery. These suggested decontamination strategies will lower titers, but they might not be 100% effective when handling the highly infectious material, such as those tissues which are preserved in aldehyde fixative or dried organic matter (Whitehead et al. 2011).

11. OBSERVATION PROGRAMS FOR EARLY RECOGNITION OF BSE CASES

Surveillance programs play a vital role to monitor BSE prevalence and in the early detection of BSE cases. In these programs, the health of animals is carefully observed, their movements are closely tracked, and they are thoroughly tested to confirm if BSE is present in the population (Dennis 2007). Many countries around the world have initiated the strict surveillance programs to effectively monitor and track BSE in cattle herds and mandate testing for all cattle before slaughter for human consumption (Stärk et al. 2006). For example, in the European Association, obligatory testing is performed on all dairy cattle over a specific age at the timeof slaughtering to check if there is something wrong with the meat before it goes dispatched for public consumption The National Animal Health Monitoring System (NAHMS) conducts dairy cattle reviews in the US to screen and analyze the predominance of BSE (Salman 2003). Moreover, the USDA has put in place a program, for monitoring BSE that involves testing cattle at risk and selectively sampling cattle (Fox et al. 2005).

In addition, surveillance programs also include the monitoring and examination of the animal feed supply chain to ensure that no contaminated substances are given to cattle. This surveillance involves conducting tests on feed samples to identify any BSE prions and enforcing restrictions on using high-risk materials in the feed (Sapkota et al. 2007).

12. FUTURE DIRECTIONS FOR BSE RESEARCH AND MANAGEMENT

Several research studies have explored the factors that could influence the spread of BSE. When researching prion diseases, it is critical to consider factors such as the age of the animals, their sensitivity to disease, and their exposure to substances that might contain prions (McCutcheon et al. 2011). They have also investigated how diseases can spread beyond regions by affecting tissues and muscles (Gough and Maddison 2010). They have been dedicating their efforts to discovering ways to prevent and treat BSE. These endeavors include implementing regulations regarding the use of animal feed and enhancing monitoring systems to identify and control outbreaks (Kumagai et al. 2019).

Furthermore, remarkable progress has been made in the progress of developments aimed at killing prions in food (Laible et al. 2015). The understanding of BSE and prion diseases has gotten more advanced, which has opened up opportunities for the development of treatment approaches. For example, current studies are exploring the advantages of RNA interference (RNAi) and immunotherapy in the management of prion diseases (Colini Baldeschi et al. 2020). The goal of the research has been

to develop prescriptions that can prevent the transition of common prion proteins into infection-causing structures (Zaib et al. 2023).

13. CONCLUSION

In conclusion, the journey from mad cow to public health has been long and complex. In the 1990s, there were substantial concerns about public health due to the discovery of Bovine Spongiform Encephalopathy (BSE) in cattle and its possible transmission to people by ingesting beef products that were contaminated. BSE was first linked to variant Creutzfeldt-Jakob disease (vCJD) in humans in the United Kingdom, and strong efforts have been made to restrict its spread among cattle and reduce the risk of human infection. Despite the fact that there haven't been many vCJD cases, there is still a lot of concern about the long-term health effects of BSE and vCJD. Prions diseases usually have long incubation period and it may take years to fully understand their nature and effect. But, ongoing research is helping us to better understand the transmission dynamics, and allowing us to create more accurate diagnostic tools while additionally chasing potential treatments and vaccines. Rigorous measures should be carried out to prevent the spread of BSE. Nonetheless, we must remain vigilant at all times in order to fully understand and address the disease's public health implications. This journey in a one health perspective demonstrates the significance of maintaining vigilance, control measures, conducting research, and collaborating globally to protect public health.

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