



The Impact of Covid-19 on the Livestock Industry and the Way Forward: A Review

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Abstract | The Covid-19 pandemic is causing many radical changes in the circadian rhythm of people around the world and it represents an unprecedented emergency with a grave societal threat. The protection of public health has become a priority. However, governments, policy and decision makers, and the global community must also recognize and attempt to mitigate the current and potential negative impacts of the pandemic on major sectors that contribute to food security, nutrition, and livelihoods. The livestock sector is a major contributor to these areas, especially for the world's most vulnerable populations. The main aim of this review is to summarize recent discoveries related to Covid-19 and how it affects the livestock industry. Even though the effects of the coronavirus pandemic and the extent of these effect on the livestock sector are still largely unquantified and yet to be fully felt, formal assessments are yet to commence. The immediate observations showed the disruptions of the livestock chains. Lessons from past epidemics showed that these disruptions may grow along with their dire socio-economic consequences. Since total and immediate eradication of Covid-19 is yet to be actualized, effort was made to provide the way forward that can be taken to protect the livestock sector, its activities, services, and products upon which the world relies.

Keywords | Covid-19, Food security, Livestock industry, Public health, Pandemic

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INTRODUCTION

The novel coronavirus known as SARS-CoV-2 (severe acute respiratory syndrome coronavirus - 2), has been reported as the pathogen involved in the coronavirus disease 2019 (Covid-19) outbreak which was later reported as Covid-19 pandemic by the World Health Organization (Lai et al., 2020; Mahdy, 2020). The viral disease was first identified in the hospitalized patients at the city

of Wuhan, the capital of China's Hubei Province (Zhu et al., 2020; Chauhan, 2020). After the first reported case, the disease has since spread throughout the globe, resulting in the ongoing 2019 – 2020 coronavirus pandemic. Covid-19 cases are reported in more than 200 countries in the world. Since the declaration of the Covid-19 outbreak on 31 December 2019, the 17 of July 2020 global number of cases has surpassed the thirteen million mark and the continental statistics are presented in Table 1.

Table 1: The continental statistics of Covid-19 cases as at July 17 2020.

Continents	Total cases	Recoveries	Active cases	Death	Reference
Africa	702,663	347,353	307,560	14,956	Africa CDC, 2020
Europe	2,649,381	1,569,524	871,526	198,667	Worldometer, 2020
Asia	3,259,103	2,281,112	869,724	76,525	Worldometer, 2020
South America	3,119,635	2,077,372	927,327	112,427	Worldometer, 2020
North America	4,341,463	2,033,722	83,003	193,242	Worldometer, 2020
Oceania	13,331	9,730	3,037	141,000	Worldometer, 2020

As of 17 July 2020, a total of 13,854,336 positive cases including 591,409 deaths were reported globally (WHO, 2020). According to WHO (2020), the 10 countries of the world with the highest number of Covid-19 cases are; United States of America (3,574,371), Brazil (2,012,151), India (1,005,637), Russia (751,612), Peru (341,586), South Africa (350,879), Mexico (324,041), Chile (323,698), United Kingdom (294,114), and Iran (267,061). In the African region, the World Health Organization reported on the 17 July 2020 that a total of 702,663 Covid-19 positive cases, with 14,956 deaths in the region, while the five most impacted countries in Africa are as follows; South Africa (350,879), Egypt (87,172), Nigeria (36,107), Ghana (27,060), and Algeria (22,549). However, the statistics on the continental percentages of Covid-19 recoveries and deaths were shown in Figure 1.

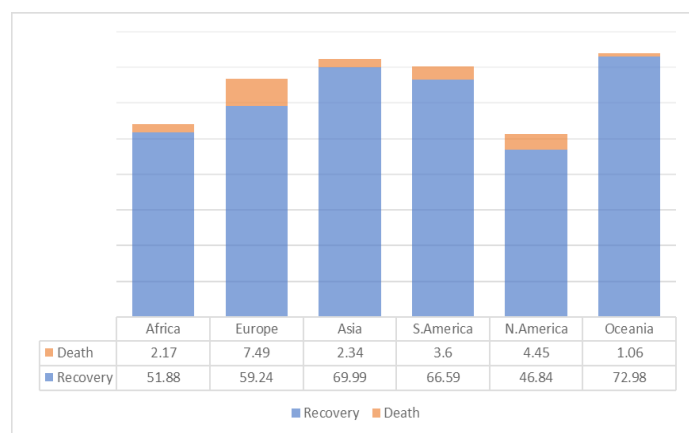


Figure 1: The percentage COVID-19 recoveries and death across the continents as at July 17 2020.

The coronavirus outbreak is an unfortunate incident, and it is a disease that doesn't respect borders as they spread. The coronavirus pandemic, its fear, and uncertainty have disrupted different sectors in different countries of the world, ranging from the livestock sector, to financial, educational, economic, entertainment, etc, and it has also dominated the news cycles. The global livestock industry has been largely impacted by the effect of Covid-19 (Samantha, 2020). The SARS-CoV-2, can spread from person to person through aerial infectious droplets (Dyal et al., 2020). Unfortunately, workers in the meat and poultry processing plants work closely with each other and thus, increased the risk of in-

fectious disease transmission, including respiratory illness outbreaks. As the employees of meat and poultry processing plants gets sick, followed by the labor shortage due to coronavirus effects, dozens of large processing plants were forced to close down (Onofrio et al., 2020). This has affected the livestock industry in a big way, considering the role of the industry in the affairs of life. The livestock industry that involves raising animals, feed processing, and the processing of the animal products for consumers has played an essential role in global economic development. According to Bettencourt et al. (2015), livestock plays an important social, cultural, and economic roles. It also provide food supply, protein (food) security, income, employment, and raw materials such as leather, wool, bone product, manure as fertilizer etc. Over the centuries, livestock has been the basis of human wellbeing through its contribution to the household economy, food security, and social status (Meisner et al., 2013). According to Robinson et al. (2014), the livestock industry affects the diet and health of many, and it has an estimated standing population of 1.43 billion cattle, 1.87 billion sheep and goat, 0.98 billion pigs, and 19.60 billion chickens.

The growth of the livestock sector before the pandemic was a consequence of increased consumption of meat, beef, chicken, and other kinds of seafood globally (Wood, 2020). Change in people's lifestyle together with the preferences towards luxury food items were also the prime factors for the industry's growth. The livestock industry is segmented into dairy, meat, poultry, aquaculture, animal product processing plants, and others, but meat, poultry, and animal product processing plants are most affected due to the Covid-19 pandemic (Samantha, 2020). Considering the countries' perspective of the pandemic, the most affected countries are the United States, China, Italy, Germany, United Kingdom, France, Spain, and India (Wood, 2020). As the animal product processing plant workers get sick due to the increased rate of the novel coronavirus cases, it decreases the supply of meat and chicken, while most dairy farmers dumped their milk. This situation has disrupted the entire meat, milk, and chicken supply chain. Due to the Covid-19 pandemic, livestock farmers in the US are faced with an overwhelming challenge of not having a destination for their animals as a result of limited

space and the high cost of maintaining and keeping the animals (Baskst, 2020). This condition led to a very unfortunate problems of euthanizing the animals. According to Schouten (2020), as most processing plants are locked down, one of Brazil's leading poultry producers (BRF poultry plant) had to discard about 10,000 animals because they cannot supply them to meat processing plants. This situation has disrupted the entire livestock industry's supply chain. In another development, Onofrio et al. (2020) reported that the closure of some meat processing plants due to the coronavirus pandemic has led to oversupply of animals awaiting slaughter and low prices for farmers, but undersupply and high prices for consumers. It was reported that the shutdown of food chain services such as restaurant, hotels, and schools have also affected the growth of the livestock industry (Wood, 2020). Different countries of the world are announcing several relief packages in order to reduce the impact of coronavirus pandemic in the industry. Most pork, beef, and poultry farmers that supply animals to processing plants complained that the federal aid (relief package) is not sufficient to compensate for the loss of value per animal the Covid-19 pandemic has caused (Onofrio et al., 2020). However, understanding the structure of the novel coronavirus, mode of transmission and how to avoid it has become a priority. Therefore, this review seeks to highlight different discoveries related to the virus, the Covid-19 effects on the livestock industry, and the way forward. The safety of the processing plant workers will guarantee a certain level of increased animal processing and animal product supply, as well as, an increased supply of animals from the farmers to the processing plants.

THE CONCEPT OF COVID-19

The coronavirus (CoV) which causes Covid-19 was named SARS-CoV-2 by the international committee on taxonomy of viruses as the scientific name (OIE, 2020). Coronavirus is a family of RNA (ribonucleic acid) viruses. They are called coronaviruses because the particles shows a 'corona' (crown) trait of spike proteins around its lipid envelope. Coronavirus infections are common in animals and humans (El-Sabroun et al., 2020), while, some strains of coronavirus are zoonotic, but many strains are not zoonotic (OIE, 2020). Coronaviruses (CoV) has four genera that infect a variety of domestic and wild animals, as well as humans (Fan et al., 2019). Mammals particularly bats are the natural hosts of Alpha (α) – and Beta (β) – CoVs, while pigs and birds are the natural hosts of Gamma (γ) – and Delta (δ) – CoVs (Velavan and Meyer, 2020). Coronaviruses can mutate, which in turn increases their rate of transmission from animals to humans (Woo et al., 2020). SARS-CoV-2 is a novel beta coronavirus (β -coronavirus) that belongs to the subgenus sarbecovirus of the coronaviridae family (Mahdy, 2020; Li et al., 2020b). Coronavirus is among a

large group of viruses, the coronaviruses affecting humans can cause a range of symptoms, including fever, headache, runny nose, cough, sore throat, etc (Li et al., 2020a). Most of them are mild, but others tends to cause pneumonia and these kind of viruses are usually transmitted through direct contact with an infected host (Chen, 2020). According to OIE (2020), coronavirus can cause illness in humans, ranging from the common cold to more severe diseases such as Middle East Respiratory Syndrome (caused by MERS-CoV), and Severe Acute Respiratory Syndrome (caused by SARS-CoV). Detailed research showed that SARS-CoV was transmitted from civets to humans, while MERS-CoV is transmitted from dromedary camel to humans (El-Sabroun et al., 2020). An unknown origin of pneumonia was detected on humans, in the Wuhan city of Hubei Province of China, in December 2019 (Zhu et al., 2020). A new coronavirus was identified as the causative agent by the Chinese authorities. Since then, the coronavirus cases in human has been reported by almost all the countries of the world and the Covid-19 event has been declared by the World Health Organization to be a pandemic (OIE, 2020; WHO, 2020).

THE EMERGENCE AND MECHANISM OF COVID-19 SPREAD

The Covid-19 pandemic has crippled most of the economic sectors of different countries. It has also disrupted the normal life of every individual, and the rate of spread is a big concern to different countries of the world. It all started at the end of 2019, in Wuhan city of China at the Hunan seafood market where up to 50 people were infected (El-Sabroun et al., 2020). Although, the Chinese government notified the World Health Organization about the infection which was described as pneumonia with an unidentified cause (Shereen et al., 2020). Different live animals that are frequently sold at the Hunan seafood market includes; frogs, bats, birds, snakes, rabbits, and marmots (Wang et al., 2020). The National Health Commission of China went further to release some details concerning the epidemic on January 12, 2020, they suggested that the infection was a novel coronavirus after the sequence-based study of the isolate (Shereen et al., 2020). There was a suggestion that the infected patients with coronavirus induced pneumonia in China may have visited the seafood market where live animals were sold. It was also suggested that the infected person must have handled, contacted, or consumed byproducts of infected animals (Chauhan, 2020). However, more studies revealed that some of the infected persons have not visited the seafood market. It was observed that the virus spreads from human to human, which was later reported worldwide (EC, 2020). The close contact with infected individuals increases the Covid-19 spread through coughing, sneezing and large or small infectious droplets

Table 2: The biological characteristics of SARS-CoV-2

Feature	SARS-CoV-2	Reference
Emergence date	December 2019	Hui et al (2020), Huang et al (2020)
Area of emergence	Wuhan, China	Mahdy (2020), EC (2020)
Date of fully controlled	Not controlled yet	
Key host	Bat	Bolles et al (2011), Lu et al (2019), Perlman (2020).
Number of countries infected	More than 215	Worldometer (2020)
Entry receptor in humans	ACE2 receptor	Shi et al (2003), Lu et al (2019), Tian et al (2020).
Mild signs and symptoms	Cough, fatigue, headache, loss of taste or smell, congestion or runny nose, diarrhea, vomiting, fever, sore throat and dry throat.	El-Sabrou et al (2020), Chan et al (2020), Riou and Althaus (2020), Tian et al (2020).
Severe signs and symptoms	Shortness of breath, acute cardiac injury and acute kidney injury.	Chauhan (2020)
Most affected sector	Livestock sector	Dyal et al (2020)
Disease caused	SARS, COVID-19	Dong et al (2020).
World total infected patients	13,987,746	Worldometer (2020)
World total recovered patients	8,311,861 (59.42 % Recovery rate)	Worldometer (2020)
World total death	593,538 (4.24 % mortality rate)	Worldometer (2020)

(aerosols). It was reported that the infectious droplets or aerosols can gain access to human lungs through natural orifices such as the nose or mouth (Phan et al., 2020; Riou et al., 2020; Parry, 2020; Li et al., 2020a). The infectious droplets (aerosols) of SARS-CoV-2 can maintain its infectiousness for hours and survive on hard surfaces for a few days (Chauhan, 2020). In the aerosols of SARS-CoV-2, the median half-life is approximately 1.1 hours. Its survival on stainless steel is 5.6 hours and 6.8 hours on plastic (Van Doremalen et al., 2020). The virus could not be isolated from cardboard after 24 hours exposure with infectious droplets, while no virus was found on plastics and stainless steel after 72 hours exposure with infectious droplets (depending on the inoculum shed). This confirms the fact that fomite transmission of SARS-CoV-2 is possible since the virus can survive and remain infectious for hours and days on surfaces (Xiao et al., 2020; Van Doremalen et al., 2020). Apart from the fomite transmission of SARS-CoV-2, the mode of transmission of the virus is significant for human contamination to dogs and cats (EC, 2020). Even though the contamination routes are not clear, the main route of the virus transmission is mainly through droplets emitted during coughing, sneezing, talking or breathing. It has been established that transmission can occur through fomites by hand-to-mouth, conjunctiva or by touching the nose with hands contaminated with infectious droplets or saliva (Chen, 2020; Xiao et al., 2020). However, it is important to note that most of the common habits such as licking and kissing increases or facilitates the transmission of the virus between sick people and their pets. Public health officials now recognize that people may spread the disease before

they become symptomatic. The newly revised estimates from the Centers for Disease Control and Prevention suggested that 40 % of Covid-19 cases are asymptomatic, and half of all the current cases are transmitted by incubatory carrier (Groth, 2020).

THE SYMPTOMS OF COVID-19

The Covid-19 patients' clinical manifestations were reported by the Center for Disease and Control (CDC) and World Health Organization (WHO). The symptoms are ranged from mild to severe as shown in Table 2.

The initial recognized main clinical symptoms includes; fever, cough, and shortness of breath (Groth, 2020), meanwhile, the incubation period is ranged from 2 – 14 days. The time from the manifestation onset to the development of pneumonia is approximately 5 days while the time for the onset of severe hypoxemia and intensive care unit admission is about 7 – 12 days (Chauhan, 2020). The manifestations of Covid-19 look a lot like flu. According to CDC, common flu symptoms includes fever, cough, sore throat, muscle ache, and headache. In another development, the bio-marker testing showed that positive patients had elevated levels of some serum enzymes such as, alanine aminotransferase (ALT), aspartate aminotransferase (AST), as well as creatine kinase (CK) (Guan et al., 2020). It has been documented that higher levels of serum enzymes indicated the release of an aminotransferase from the cytoplasm to the blood-stream probably due to the damaged liver or other organs (Abida et al., 2017; Oyeagu et al., 2019). However, there are no confirmed symptoms recorded on the infected animal until now.

DOES COVID-19 SPREAD FROM ANIMAL TO HUMAN AND VICE VERSA?

It is assumed that SARS-CoV-2 originates from animals and transmitted to humans, as it maintains human – to – human transmission (Ji et al., 2020). The four different genera that cause infection to a variety of wild and domestic animals, as well as, humans have been reported (Fan et al., 2019). Bats (mammals) are the natural hosts of Alpha (α) and Beta (β) coronavirus, while livestock such as; pigs, chicken, and cows are the natural hosts of Gamma (γ) and Delta (δ) coronavirus (Velavan et al., 2020). According to Woo et al. (2020), the mutation ability of the coronaviruses increases their rate of transmission from animals to humans. The first reported case was the hospitalized patients in Wuhan which were associated with the Hunan seafood wholesale market (Zhu et al., 2020). In this market, live animals such as bats, poultry, snakes, frogs, rabbits, marmots, and hedgehogs are sold to humans for consumption which suggests a possible zoonotic infection (Malik et al., 2020). Therefore, it is important to understand the susceptibility of animals to SARS-CoV-2 to control Covid-19. The SARS-CoV-2 is widely distributed in the human population and there is a possibility that certain species of animals get infected through close contact with infected humans (Mahdy, 2020). The SARS-CoV-2 infections on animals may have some implications for animal and human health, for wildlife conservation, animal welfare, and biomedical research. According to Mallapaty (2020), some animal species such as cats, and maybe dogs are sensitive to the infection by SARS-CoV-2, but chickens, ducks, and pigs are less sensitive and not likely to catch this virus. Laboratory studies (OIE, 2020) showed that cats are the most susceptible species for SARS-CoV-2 among all the animal species investigated so far, and they can be affected with clinical disease, as well as, transmit the infection to other cats. The studies also reported that dogs show susceptibility to the infection, but they appear to be affected less compared with ferrets or cats. It was reported that pets (dogs and cats) are being infected with SARS-CoV-2, and none of these reports suggested that pets are sources of infection for people (El-Sabroun et al., 2020). The current evidence from a few domestic animals that have tested positive for SARS-CoV-2 showed that the infections are attributed to close contact with infected personnel (AVMA, 2020). The laboratory studies of infection with SARS-CoV-2 indicate that Syrian, ferrets, cats, and hamsters shows some potential for serving as animal models of human infection, while, pigs, dogs, chicken, and ducks do not (Shi et al., 2020). Although, molecular modelling and *in vitro* studies showed that multiple animal species may theoretically be able to be infected with SARS-CoV-2 without defining the definitive intermediate host cycle (AVMA, 2020). In another development, Zhou et al. (2020) reported that genetic sequence data revealed that

the SARS-CoV-2 is a close relative of other coronavirus found circulating in *Rhinolophus* bat populations, and this means that SARS-CoV-2 can be zoonotic. AVMA, (2020) argued that, there is little or no evidence that domestic animals are easily infected with SARS-CoV-2 under natural conditions and no evidence to date that they transmit the virus to people. However, the primary mode of transmission of Covid-19 in humans is through a person – to – person spread which has been confirmed and caused outbreaks in several countries around the globe (Shereen et al., 2020; Dyal et al., 2020; WHO, 2020). It was reported that the SARS-CoV-2 rate of replication is very slow in avian such as chicken, but ferrets, and cats are permissive to infection (Shi et al., 2020). These findings corroborates with the study of Perlman and Netland (2009), that chickens are resistant to the infection by SARS-CoV-2. Other findings from the experimental infection research showed that poultry and pigs are not susceptible to SARS-CoV-2 (OIE, 2020). However, further research will be needed to validate or dispute these findings.

THE IMPACT OF COVID-19 ON THE LIVESTOCK INDUSTRY

The livestock industry is one of the largely affected by the coronavirus pandemic. Farmers have reportedly dumping commodities such as milk and produce (Bakst, 2020). These commodities are supposed to be supplied to consumers but due to the Covid-19 pandemic, the commodities no longer have a destination. In the darkened doom caused by Covid-19 pandemic, livestock, and poultry farmers have destination problems for their animals due to the closure of dozens of large processing plants since most employees tested positive for Covid-19 which led to little or no labor (Onofrio et al., 2020). Since the farmers are faced with destination problems for their animals, they are equally struggling with the problem of space for their animals on the farm. As a result of these challenges, most farmers are forced into requiring their animals to be euthanized with or without government compensations (Bakst, 2020). Farmers are counting their losses due to the effect of the Covid-19 pandemic as experts warn of future food shortage (Yahaya et al., 2020).

The increased consumption of animal products has been the driving force responsible for the growth of the livestock industry. However, the recent Covid-19 outbreak took a toll on all the sectors of the economy, including the livestock sector, with the pandemic inflicting damages in different countries that worth millions to farmers and processing plants. The lockdown that led to the closure of hotels, schools, restaurants, and other eateries (major consumers of animal products), as well as, the processing plants increased the frustrations of most farmers who have lost more than 40 % of their resources because they find

it difficult to sell but they keep producing (Yahaya et al., 2020). Kevany (2020) reported that smaller and more sustainable livestock farmers in the UK are the hardest hit by Covid-19 pandemic. The effects of coronavirus pandemic on the livestock sector are still largely unquantified and yet to be fully felt. There is still no formal assessment of the Covid-19 pandemic impact in different countries of the world on the livestock sector, but current observations shows some disruptions to the livestock value chain.

The processing unit of the livestock sector has been implicated in the rapid spread of the virus (Covid-19). The workers in these processing plants not only work closely together but more importantly, they live together in very cramped conditions where there is no possibility of keeping a social distance (Bakst, 2020). Several meat processing plants across Germany have closed temporarily after many workers found positive for Covid-19. According to Young (2020), more than 90 workers were found positive for the Covid-19 at a processing plant in Dissen, Lower Saxony, Germany. Due to the outbreak of Covid-19 at a processing plant in Coesfeld, Germany where more than 270 of 1200 workers discovered positive, the State of North Rhine-Westphalia announced mass testing of the industry employees. Young, (2020) reported that an outbreak at a processing plant in Bavaria, Straubing-Bogen District coincided with the number of infection reaching or attaining the “emergency brake” level of 50 cases per 100,000 residents, and State that exceeds this point is allowed to re-impose lockdown restrictions. Again, on the 22 May 2020, public health officials in Germany are grappling with an outbreak among many workers at a processing plant in Rheda-Wiedenbrück and more than 730 workers have found positive at the Tönnies Group processing plant. A meat processing plant owned by Asda in West Yorkshire, England became the third plant to confirm an outbreak after about 150 workers felt ill with the virus at the end of May 2020 (Halliday, 2020). Halliday (2020) reported that the Kober plant in the UK which supplies bacon to Asda supermarkets and employs more than 500 people was closed due to the Covid-19 pandemic. According to Halliday (2020), the “2 Sisters Food Group” known as the UK’s main supplier of supermarket chicken closed down their Anglesey plant for a few weeks after 58 people were infected with the coronavirus. In Australia, more than 62 Covid-19 cases were linked to a cluster at Cedar Meats processing plant in Melbourne West which led to the shutdown of most of the processing plants in the country (Andrews, 2020). More than 100 people were infected by Covid-19 in two French abattoirs, one of them is in the Central Val de Loire Region near the city of Orleans, while, the other is in the Northwestern Region of Brittany. According to Leoty (2020), the regional health officer reported that 63 of the 209 workers at the Breton

slaughterhouse, France had so far been infected in the first week of May 2020, while 74 cases among 400 workers at the processing plant in Fleury-Les-Aubrais, near Orleans was documented. The processing facilities in the Brazilian States of Rio Grande do sul, Santa Catarina, and Parana were hit hard by a spike in the cases of Covid-19 (Schouten, 2020). Meanwhile, these States account for almost 70% of poultry and 65% of pork production in the country. The Covid-19 cases looks more serious in Rio Grande do Sul, the Southeast State of Brazil. The State Health Department epidemiological bulletin, in mid-May 2020, showed that 18 processing plants were affected by the coronavirus pandemic (Colin, 2020). These processing plants now have more than 528 workers who have been infected with the Covid-19, while, another 2,595 revealed flu-like symptoms and were considered suspected cases. It was reported that almost 30,000 people are working in the Brazilian meat processing industry and going by the statistics of Covid-19 in the processing plants, the potential virus spread will be huge in this sector (Schouten, 2020). The shutdown of many processing plants in the USA due to Covid-19 related cases generated fear of meat shortage and price rises, while farmers are being forced to consider depopulating or euthanizing their animal (Kevany, 2020). For instance, Iowa state is the biggest pig producing state in the US and the political leaders in the state have warned that producers could be forced to kill 700,000 pigs a week affected by processing plant shutdown (Colin, 2020). According to a 2016 report by the Federal Government Accountability office, illnesses among meat and poultry workers were relatively high compared with other manufacturing sector workers (Samantha, 2020). Even before the pandemic began, meat and poultry workers were less likely to report illness due to fear of job loss. The circumstance and climate in which employees work in the processing plants make social distancing virtually impossible (News Break, 2020). More than 3,400 Covid-19 positive cases in 62 processing plants were revealed in the 23 States of America by April 23, 2020 (Bagenstose et al., 2020). On May 1st 2020, over 99 processing plants with confirmed cases of Covid-19 were reported in the US with over 6,800 workers who had been infected with 25 death (Leah, 2020). By the end of April 2020, the US Center for Disease Control and Prevention reported that there were at least 115 facilities with Covid-19 cases across 19 State as shown in Table 3.

Table 3: April 2020 report on employees with COVID-19 in meat and poultry processing industries in USA for 19 States

State	Types of affected processing plants	Affected number of processing plants	No. of employees in affected plants	No. & percentage of COVID-19 cases among employees	No. & percentage of COVID-19 related deaths
Colorado	Beef, bison, lamb, poultry	5	7,248	139 (1.9)	5 (3.6)
Delaware	Poultry	6	9,411	336 (3.6)	4 (1.2)
Georgia	Poultry	14	16,500	388 (2.4)	1 (0.3)
Illinois	Beef, pork, poultry	5	6,680	112 (1.7)	1 (0.9)
Iowa	Beef, pork	2	2,075	377 (18.2)	N/A
Kansas	Beef, poultry, other	6	16,600	106 (0.6)	0 (0)
Kentucky	Pork, poultry	2	1,333	18 (1.4)	1 (5.6)
Mississippi	Poultry	9	9,548	123 (1.3)	0 (0)
Missouri	Beef, pork, poultry	3	3,690	36 (1.0)	0 (0)
Nebraska	Beef, pork, poultry	12	19,911	588 (3.0)	1 (0.2)
North Carolina	Pork, poultry	5	14,600	166 (1.1)	0 (0)
Ohio	Pork	1	710	10 (1.4)	0 (0)
Pennsylvania	N/A	22	N/A	858 (-)	1 (0.1)
South Dakota	Beef, pork	2	4,600	794 (17.3)	2 (0.3)
Tennessee	N/A	3	N/A	132 (-)	0 (0)
Texas	Beef, poultry	2	4,800	113 (2.4)	1 (0.9)
Virginia	Poultry	10	7,072	128 (1.8)	2 (1.6)
Washington	Beef	1	1,400	100 (7.1)	1 (1.0)
Wisconsin	Beef, pork	5	4,400	389 (8.8)	0 (0)
Total	Beef, bison, lamb, pork, poultry, other	115	130,578	4,913 (3.0)*	20 (0.4)^y

COVID-19 = coronavirus disease 2019. N/A = not available. X = Exclude cases from Pennsylvania and Tennessee because number of employees (denominator) is not available from these state. Y = Exclude cases from Iowa in the denominator because information on number of deaths is not available from this state. (Dyal et al., 2020).

Table 4: The impact of COVID-19 on different unit chains of the livestock industry (UCLI)

UCLI	Effects	Implications
Animal production	Limited access to animal feeds	The restriction of movement and illness are implicated for the low workforce and limited supply of raw materials. As the supply routes are disrupted, it will slow down the feed supply.
	Limited access to inputs and services	Farmers' access to breeding materials and stock replacement (such as, day-old chicks and semen) were curtailed due to the interruption and restriction of movements of national and international trade routes.
	Limited access to market	The limited access of farmers to markets, slaughterhouses/processing facilities means that they have to keep their stock longer or discard milk, leaving them with higher cost of production which translate to economic losses.
Processing unit	Limited processing capacity	The workforce in the processing plants was low due to the lockdown and COVID-19 related illness to the employees. It reduces the output of the plants.
	Compromised storage and conservation	The processors were forced to stock up beyond their capacity due to transport restrictions as well as changes in retailing and consumption habits.
	Restricted informal business	Majority of informal meat and dairy processing plants are found in the developing countries (up to 90%). The COVID-19 issues has taken away the outlet small scale producers, who often lack the capacity to sell to formal market.

Transportation	National transport restriction	Transport was compromised due to lockdown and movement restriction. It slowed the rate of livestock supply and livestock product.
	International transport restriction	Different countries that export livestock products and farmers or traders whose income rest on export were affected due to trade restrictions.
Sales and consumption	Reformed retailing and product demand	The coronavirus pandemic changed the retailing and product demand. It forced the consumers to gravitate towards online or e-commerce food delivery platforms and supermarkets.
	Consumer purchasing power reduction	There is a low purchasing power for most of the 'daily pay' or informal workers who lost their jobs due to lockdowns and quarantine. This is worst in countries with little or no social safety nets.
	Drop in the demand and public procurement	There is a steep fall in food demands due to the closure of restaurants, schools and reduced tourism. School closure truncated school feeding which deprived millions of children access to food.

UCLI = Unit chains of livestock industry. (FAO, 2020).

There are up to 130,578 workers in the meat and processing plants located in the 19 States, at least 4,913 (approximately 3% of the workforce) workers were diagnosed positive with Covid-19, while 20 deaths were reported (Dyal et al., 2020). The percentage of diagnosed workers with Covid-19 was ranged from 0.6 % to 18.2 %, while the percentage of employees that died of Covid-19 infection ranged from 0 % to 5.6 %. Covid-19 cases were also seen in other congregate settings, including long-term care facilities (McMicheal et al., 2020), acute care hospitals (Heinzerling et al., 2020), and homeless shelters (Mosites et al., 2020). Similarly, the crowded settings for employees in meat and poultry processing plants could lead to a high risk of SARS-CoV-2 transmission. Considering the crowded nature of workers in the processing plants and the rapid outbreaks of respiratory disease, there is a need to give attention to worker's safety. However, Covid-19 cases among employees in the processing plants could be as a result of transmission at the workplace or in the community (Shaw et al., 2020; Dyal et al., 2020).

As mentioned earlier, the impact of Covid-19 on the livestock industry remains unquantifiable. It is important to note that every unit chains of the livestock sector felt the shock of the coronavirus pandemic as shown in Table 4.

Movement restrictions disrupted feed supply routes, as well as, ingredient supply to the factories, which affected the production of animals. It also crippled the pastoralists' ability to feed their animals (FAO, 2020). Some services such as delivery and use of vaccines and medicines were interrupted (OIE, 2020) which may give rise to new epidemics, including those involving animal diseases that may cause major livestock losses (eg African swine fever in East and Southeast Asia), and outbreaks of diseases transmissible to humans (FAO, 2020). The processing unit is one of the highest hits of the Covid-19 pandemic. Most processing plants lost their employees due to quarantine

and sick leave, contributing to the reduced processing capacity of the plants (Leoty, 2020; Dyal et al., 2020). The restrictions on transportations disrupted the movement, import, and export of animal products. According to FAO (2020), meat export dropped in Latin America, especially in Argentina and Uruguay, and this has further dropped the farmer's revenues. Again, farmers discarded their animals (such as chickens) and dairy milk due to lack of spaces and high cost of production as the movement restrictions persisted (Schouten, 2020). Changes in sales and consumption as a result of the pandemic means that some countries adopted e-commerce food delivery platform. For instance, China increased its volume by 400 percent in February 2020 using an online platform, while its pre-Covid-19 share of fresh food consumption was only 3% (FAO, 2020). While some farmers in Europe and North America seem to be able to create alternative and direct channels with consumers, countries with uneducated farmers, as well as, limited penetration of e-commerce, processing industries or supermarkets will find it difficult to sell their produce. The spread of fake news and rumors can also affect the demand and consumption of animal products. There were rumors that livestock animals transmit Covid-19, and people stopped buying and eating animal products (El-Sabrouit et al., 2020; McNamara, 2020; McNamara et al., 2020). FAO (2020) reported that chicken sales were reduced after social media posts which created an impression that humans could contract Covid-19 by consuming chickens.

THE WAY FORWARD

The rapid spreading of the Covid-19 and its deadly nature on the victims caused a total and/or partial lockdown in different countries of the world. Even under the curse of the Covid-19 pandemic, there are no proven therapies for the treatment of Covid-19 with exception of some different clinical trials in many countries to generate the safest and most effective vaccine for Covid-19. There are also

other trials on chloroquine, hydroxychloroquine, intravenous immunoglobulin, and Chinese medicines in a bid to contain or treat Covid-19 (Chauhan, 2020). Although there is no available peer-reviewed published safety data on the treatment of Covid-19, hydroxychloroquine is widely used (Phua et al., 2020). The World Health Organization commenced a solidarity trial in March 2020 which was aimed to test drugs and drug combinations (Remdesivir, chloroquine and hydroxychloroquine combination, Ritonavir/Lopinavir and Interferon-beta) against SARS-CoV-2. WHO intends to apply the trial drugs which was aimed to cut down the time needed to generate robust evidence about the drugs that can effectively work. Meanwhile, the first patient for this trial was one from Oslo University Hospital, Norway (WHO, 2020). The organization for economic co-operation and development has launched a platform to provide timely and comprehensive information on different policy responses in countries around the globe, as well as, viewpoints and advice (OECD, 2020). However, one of the steps going forward must be to invest heavily in public health and emergency preparedness. For instance, the USA spends approximately \$275 per person per year (2.5 % of all health care spending) despite spending about twice as much per capita on health care as the average among other organizations for economic and co-operation development nations (Chauhan, 2020). There should be universal health coverage, bi-directional sharing of information between the low income and high-income countries, and greater investment in healthcare by different countries of the world (Bradley, 2020).

The livestock industry is one of the sectors that received the greatest impact or shock of the Covid-19 pandemic. Different relief packages have been announced by different countries of the world in order to reduce the effect of the Covid-19 pandemic on livestock farmers and meat processing plants (Onofrio et al., 2020). The coronavirus pandemic has created a new way of life in different societies of the world and the livestock industry is not left out. Therefore, humanity must learn to adjust and move on with life because the virus may not be wiped out anytime soon. To ensure continuity of operations in the livestock sector, the CDC advises that workers may be permitted to continue work, provided they remain asymptomatic, as well as, the provision of additional precautions to protect them and the community (CDC, 2020). The center for disease control and prevention outlined some critical guideline that should be adhered to by the workers who are exposed but remain asymptomatic before and during their work shift; **Pre-screen:** before the employees starts work, the employers should measure their temperature and assess their symptoms. It should be mentioned that temperature checks should take place before the individual enters the facility.

Regular monitoring: should take place to access the employee's temperature or symptoms, and this should be carried out under the supervision of their employer's occupational health program.

The employee should maintain 6 feet apart and practice social distancing as work duties permit in the workplace. Disinfect and clean work-spaces regularly such as offices, bathrooms, common areas and shared electronic equipment.

If the employee develop any manifestation during the day, they should be sent home immediately. The surfaces in the workplace should be cleaned and disinfected. The information should be compiled on persons who had contact with the employee developing symptoms during and 2 days before the symptoms. Other workers at the facility who had close contact within 6 feet of the employee during this time should be considered exposed (El-Sabroun et al., 2020; CDC, 2020).

Generally, the food production industry is considered critical infrastructure as described by the United States Department of Homeland Security, and its workers should operate in an enhanced safety environment (Krebs, 2020). Center for Disease Control suggested that health care providers should be consulted when the Covid-19 exposed workers decide to return to work, since testing has become more widely available, and this will enhance the rapid detection and addressing of Covid-19 in the processing plants. The interim recommendations for meat and poultry processing plants must be interpreted and applied for each processing plant (CDC, 2020). To protect workers from different threats in meat and poultry processing plants, the preferred approach was to apply strict biosafety and biosecurity measures like removing exposure source, installing engineering control, implementing effective sanitation and cleaning, as well as, improving administrative measures. There should be temperature monitoring and symptom screening on employees and visitors to prevent the entrance of the Covid-19 infection into a processing plant. Meanwhile, it is important to highlight the structural, operational, sociocultural, and economic challenges with their recommendations in response to Covid-19 among workers in the processing plants (Dyal et al., 2020) as described in Table 5.

The engineering way of controlling Covid-19 involved stationing workers to avoid facing each other and adjusting the fans to prevent them from blowing air from one worker directly to another (Shaw et al., 2019). Hand hygiene in the processing plants requires not only hand washing stations but also enough availability and use of alcohol-based hand sanitizer in areas where hand-washing facilities do not exist (Mosites et al., 2020). The cleaning

Table 5: Noticed challenges and recommended alterations in practice in response to Covid-19 among workers in meat and poultry processing plants

Features	Threats to effective prevention and control of Covid-19	Suggested changes to be practiced in the facility
Structural	Keeping physical distancing during breaks and when employees enter and exit the facility.	Regulate the start and stop times of breaks and shifts, add outdoor break rooms.
	Keeping physical distancing on production line.	Mount physical barriers between workers.
	Excluding symptomatic workers.	Screen all workers and visitors entering the facility and plan for effective isolation for workers who become ill at work.
Operational	Keeping physical distancing on production line.	Decrease the rate of animal processing.
	Following the face covering suggestions.	Require universal face covering and providing training on donning and doffing.
	Following the cleaning and disinfection guidelines.	Assign additional staff to sanitize “high touch” areas (handles, buttons, and railings) more frequently. Add more hand sanitizer dispensers.
Sociocultural	Communicating through language and cultural barriers.	Disseminate messaging in languages spoken among the work force.
	Majority of the employees live in crowded, multigenerational settings.	Educating the employees on some behavioral patterns to adopt in order to limit the spread of the virus while at home.
	Majority of the employees share transportation to and fro work.	Increase the number of vehicles to shuttle routes.
Economic	Employees incentivized to work while ill.	Adopt personal policies that guarantee additional medical leave and disability benefits without loss of seniority or pay. Attendance bonuses should be removed.

Covid-19 = coronavirus disease 2019. (Dyal et al., 2020).

and sanitization of the processing plants involve thorough cleaning and disinfection of the surfaces in line with the usual facility standard operating procedures. It is important to know that the “high touch” area (such as handles, buttons, and railing) should be disinfected with environmentally safe products against Covid-19 and are approved under the facilities’ disinfection standard operating procedures. The exploration of administrative control of Covid-19 will actively encourage symptomatic workers to stay at home. The personnel policies emanating from the administrative control allow sick workers to go on leave without loss of seniority or pay and this will encourage symptomatic workers to stay home (Wei et al., 2020). The removal of any incentive that might encourage workers to come to work while symptomatic can reduce the risk of Covid-19 cases in the workplace. The isolation of workers who become ill while at work, with policies that encourage social distancing and hand-washing in all worksite settings are some of the essential administrative controls of reducing the risk of Covid-19 cases at the workplace. The face cloth coverings are recommended by the CDC to help prevent transmission as a complement or support to social distancing in the public setting. The use of face cloth covering in the processing plants should be considered when distancing is not feasible but they are not a replacement

for adequate distancing (Shaw et al., 2020). The potential contamination of the face-covering should be giving attention. Most importantly, the face-covering should also be worn in non-production areas such as entrances, exits, break rooms, shared vehicles, and other areas in which keeping of social distancing is challenging. The use of personal protective equipment (PPE) has been the usual operation of the processing plants to protect workers against hazards, and workers should continue using PPEs required for their jobs. There should be proper donning and doffing of PPE to prevent contamination of the workers. The PPEs should be disposed of or properly disinfected and stored when not in use (Dyal et al., 2020). The periodic infection control and occupational safety and health training should be made available for all workers and supervisors which should be tailored to literacy levels and preferred languages. Dyal et al. (2020) stated that training programs on Covid-19 should include; what workers must do when they are sick before or at work, symptoms of Covid-19, medical leave policies, social distancing recommendations, proper donning and doffing of PPE and face coverings, hand hygiene practices, testing availabilities, and potential routes of transmission at work and in the community.

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The training should be handled by competent trainers where social distancing can be maintained using a tongue language of workers. The trainers should also consider the differences in the workers' level of education to increase the level of understanding.

Similarly, the CDC provided additional activities that should be observed at the processing plants to reduce the infection rate of Covid-19, and they include the following; Workers should distance from sharing headsets or other objects that are close to the mouth or nose.

Employers should arrange and make a plan for constant cleaning of commonly touched surfaces.

It is important to ensure that the face masks of both employers and employees do not interfere with their assigned work, hence, they should consider pilot testing of the face mask.

The employers should engage the facility maintenance staff to increase the exchange of air in the room.

There should be adequate physical distance among workers when they take their breaks together. The employers should consciously or deliberately roll out a plan to stagger the break periods of their employees to avoid large congregation in the break room. Again, there should be a conscious effort by the workers to avoid sharing food or utensils.

In conclusion, the novel coronavirus pandemic has affected the livestock industry greatly. Governments should make every effort to provide palliatives for farmers and meat/poultry processing plants for their losses in the circumstances of full/partial lockdown due to the Covid-19 pandemic. Unfortunately, there is still no confirmed or available vaccine against Covid-19 and it seems the virus may not go away anytime soon. In the foggy endemic nature of the Covid-19, life must go on and in doing this, farmers should avoid contact with wild animals and the WHO standard recommendations should be followed. As part of the national Covid-19 response, the recognized risk to meat and poultry plant operations needs urgent action to reduce infection risk to workers, preserve facility function, and maintain the food supply. There should be a collaborative implementation of administrative controls, engineering controls, improved cleaning and disinfection, and source control in meat and poultry processing plants to reduce the Covid-19 cases among workers that are providing a lifeline in this critical industry.

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AUTHOR'S CONTRIBUTION

All authors contributed equally.

CONFLICT OF INTEREST

No potential conflicts of interest were reported by the authors.

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