



REVIEW

## The Impact of COVID 19 on the Meat Supply Chain in the USA: A Review

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OPEN ACCESS

Received June 25, 2022

Revised July 25, 2022

Accepted July 25, 2022

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**Abstract** The COVID 19 pandemic resulted in a considerable influence on the world economy. Being a big sector of the economy, the food supply chain struggled. The meat supply chain was most notably affected as every part of the supply chain from farm to shelf was closely inter-related. With the closure of businesses and restaurants the demand for at home food from grocery stores increased. Meat production facilities were impacted when the virus spread to the workers causing facilities to close or line speeds to slow. The combination of these two issues, in turn, led to there being less meat on the shelves. With less meat animals being harvested, there was less demand for livestock leading to farmers having an excess in slaughter ready animals. The decreased demand for livestock led to economic issues as money was lost in multiple sections of the supply chain. Aside from the economy and supply chain issues, other issues include concerns over the safety of meat products due to decreased safety protocols to increase line speed. Additionally, concerns of animal welfare with the excess of animals being culled were raised due to decreased capacity in processing facilities. While this review paper mainly focuses on characterizing the impact of COVID 19 on the meat supply chain in the USA, the compiled information should be able to provide practical insights to the meat/food industry across the globe to develop potential mitigating strategies against the COVID 19 and/or any similar pandemic incidences in the future.

**Keywords** COVID 19, meat supply chain, consumer concern, economy, agriculture

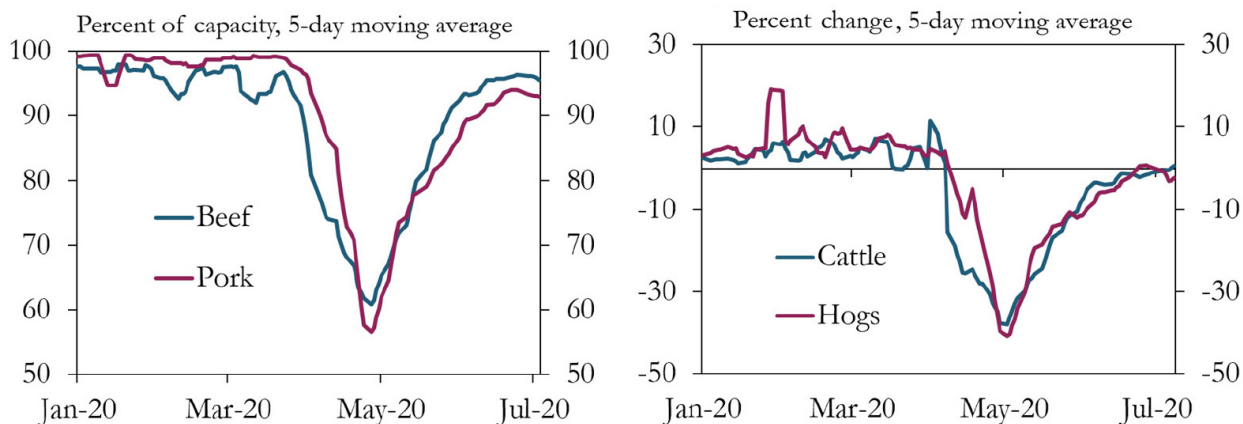
### Introduction

On March 13th, 2020, USA President Trump declared a nationwide emergency due to the rapid spread of the virus SARS-CoV-2 or COVID 19. COVID 19 caused workplaces to shut down, educational institutions to be suspended, as well as restrictions placed on travel and social gatherings. Every sector was impacted in some way whether that be direct or as a result of something else. The food supply chain suffered in many ways due to restrictions leading to closures of processing facilities in addition to workers getting sick. The meat supply chain was especially impacted as the restrictions on processing facilities led to repercussions elsewhere. There were less meat animals being slaughtered, leading to there being less of a demand for livestock.

With the closure of restaurants, there was an increased demand from the consumer. These issues led to negative impacts on the economy and put pressure on manufacturers to keep up with the demand of consumers. The decreased number of carcasses being processed due to restrictions and slowed lines led to a significant increase in price per beef carcass. This increase in carcass price accompanied by the decrease in supply led to increased prices for products destined for market such as beef steaks and ground beef. There was a rising concern from the consumer which led to investigations and studies to address potential issues surrounding food safety and animal welfare related to the incidence of COVID 19. Given the COVID 19 pandemic is an ongoing issue, there is limited published information about the influence of COVID 19 on the meat industry and retail sectors. This review paper mainly focuses on characterizing the impact of COVID 19 on the meat supply chain and subsequent impacts on consumers in the USA. However, the compiled information should be able to provide practical insights and potential implications to the meat/food industry around the world to develop potential mitigating strategies against the ongoing COVID 19 and/or any similar pandemic incidences in the future. Underlying issues in the meat supply chain were brought to life and have been and are being addressed.

## COVID 19 Impacts

The COVID 19 virus cannot be transmitted through livestock, therefore, it does not have a direct impact on livestock production like other diseases, such as *Escherichia coli* and avian influenza. The pandemic itself, however, has had a major impact on production with restrictions on transportation and the closure of processing plants. When the pandemic was declared in the USA in early March 2020, many beef, pork, and poultry meatpacking and processing facilities were forced to reduce production line speeds or even close due to the spread of COVID 19 through the workforce (Balagtas and Cooper, 2021). As of May 2020, approximately 4,200 meatpackers at 115 processing plants in the USA had contracted COVID 19 (Campuzano et al., 2020). Of the production plants that remained open, restriction protocols were set in place to help prevent spreading of the COVID 19 virus. Once COVID 19 protocols were starting to be implemented in the meat industry, primarily in meat and poultry production plants, the goal of the food processing facilities was to remain open. The protocols included monitoring workers of the virus as well as increasing the sanitary and cleaning methods of the plants (Zielińska-Chmielewska et al., 2021). The restriction that had the biggest impact was the slowing of the production line. The slowing of the production lines caused there to be less meat processed during the day, as much as a 45% decrease or similar reported (Cowley, 2020). As shown in Fig. 1, the capacity for both beef and pork started dropping drastically in the USA around April 20<sup>th</sup>, about a month after the pandemic struck. The limited processing capacity not only led to less meat being produced, but also affected the supply chain further up on the agricultural side. As a result of transportation restrictions and production plants not being able to accept more product, many farmers had to dispose of stored crops and products that were spoiled. As well as farmers having a surplus of animals, especially pigs and cows (Aday and Aday, 2020). The surplus of harvest ready animals was not as concerning with poultry as their life cycle from hatching to harvest is much shorter. Therefore, when slaughterhouses began to reach capacity, less eggs were hatched. On the other side of the supply chain, there is the problem of insufficient products both in quality and quantity for the consumer. There was a surplus of food products that were already made or were being made in the early stages of the pandemic. For example, chicken wings were in surplus early on due to restaurants being shut down and sporting competitions being canceled. Many other prepackaged meats and meat products were already packaged in bulk for these types of retail. However, in later stages of the pandemic when restrictions began to relax, the food shortages seen also began to affect other retailers. For example, some restaurants had to stop selling beef hamburgers due to the shortage (Aday and Aday, 2020).



**Fig. 1. USA beef and pork plant capacity utilization & daily cattle and hog slaughter.** The chart on the left shows the capacity of USA production plants to hold beef and pork, the y axis representing percent capacity while the x axis is referring to the date. The chart on the right shows the amount of cattle and hogs that were slaughtered by the same USA production plants, with the y axis referring to the change in percentage, while the x axis is in days. Adapted from Cowley (2020) with permission of Federal Reserve Bank of Kansas City.

As fewer animals were being slaughtered due to slowed production lines and the closing of production plants, there was a decrease in the amount of product accompanied with an increase in demand. The insufficient amount of meat on the shelves led to limitations being placed in supermarkets to limit the number of packages of meat that consumers can buy. There have also been other concepts/questions as to what could be causing the shortage of meat on the shelves. Once the pandemic hit, the USA exports of pork to China increased. It has been questioned about the possibility of the exports causing the shortage or at least potentially exacerbating it. A number of other countries raised trade restrictions in order to prevent shortages and to protect the domestic supply first. However, the USA had not placed restrictions on meat supply trading and continued if not increased trade as a result, raising concern from consumers on potential meat shortages or blame for shortages seen on retail shelves (Balagtas and Cooper, 2021).

In response to the increased demand for meat, accompanied by the decrease in the number of animals being slaughtered, less product was produced, and consequently, meat prices rose. As seen in Table 1, meat prices rose drastically not only in the USA, but across the world. The biggest increases occurred at the beginning of the pandemic around March and April of 2020. Prices eventually became more stable in May 2020 and stopped rising. The highest price variation was seen in Beijing in the hog market. In the USA, the largest increase was seen in beef cuts with an increase in 39.1%. These were beef cuts commonly used in the production of ground beef, including chuck, round, brisket, and loin strip (Ijaz, 2021). Ground beef prices had surged about 6% (Patton et al., 2021). In contrast to this rise in typically lower quality beef cuts, the prices of primal cuts, such as the ribeye and tenderloin, decreased by 42% (Peel, 2021). The decreased price of primal cuts was primarily due to the closure of restaurants where consumers more often purchase a higher quality steak. Another drastic increase in the price of beef cuts occurred in April 2020 to early May 2020, resulting in a price increase of 150% (Peel, 2021). This second increase in price occurred due to the lack of production months prior. The increase in price for pork and chicken was not quite as drastic, being 17.7% and 10.5%, respectively (Richards and Vassalos, 2020). The wholesale price of both beef and pork carcasses significantly rose with peaks of \$459/cwt and \$44/cwt respectively. These peaks were seen in May 2020 and can be compared to the prices in February 2020 of \$210/cwt for beef and \$4/cwt for hogs (Lusk et al., 2020).

The COVID 19 virus has also had a negative effect on production with the decrease of migrant workers, whether that be due to travel restrictions or sickness itself. Not only has this directly impacted the food processing industry, but also with

**Table 1. Impact of COVID 19 on price fluctuations of different meat types in different regions of the world**

Region/country	Impact timing	Meat prices fluctuations	Meat type	References
USA	March 6–April 10, 2020	↑39.1%	Beef cuts (chuck, round, brisket, and loin strips)	(Peel, 2021)
		↓42%	Beef primal cuts (rib eye and tenderloin)	
	April 10–May 8, 2020	↑150%	Beef cuts (chuck, round, brisket, and loin strips)	
	May, 2020–June, 2020	↑26.2%	Fresh beef prices	
South Carolina, USA	May, 2020	↑21.7%	All meat categories	(Richards and Vassalos, 2020)
		↑17.7%	Pork	
		↑10.5%	Chicken	
		↑100%	Ground beef	
USA	March, 2020	↑21.4% (\$255/cwt in March, 2020 and \$210/cwt in February, 2020)	Wholesale beef	(Lusk et al., 2020)
	May 15, 2020	↑118.5% (\$459/cwt on May 15, 2020)	Wholesale beef	
		↑388% (\$44/cwt on May 15, 2020 and \$9/cwt in February, 2020)	Wholesale pork	
Canada	April, 2020	↓40%	Pork	(Weersink et al., 2021)
	September, 2020	↑40%	Pork	
European countries	March–April 2020	↑Prices	All meat categories	(Aker, 2020)
	May, 2020	Prices stabilized	All meat categories	
China (Beijing, Shandong, and Hubei)	January–April 2020	↑Prices	All meat categories	(Yu et al., 2020)
Indonesia	June–July 2020	↓5.93% (Rp.930/kg)	Chicken meat	(Surni et al., 2020)
Malang Regency, Indonesia	October, 2020	↓Prices	Chicken meat	(Nurahmi and Zalizar, 2021)
Latvia	March–June 2020	↓Prices	All meat categories	(Grinberga-Zalite et al., 2021)
Worldwide	January–December 2020	↓7%–18% (pork 17.6%, beef 10.4%, sheep 7.3%, poultry 7.0%)	All meat categories	(Elleby et al., 2020)

Adapted from Ijaz et al. (2021) with CC-BY.

livestock production and crop production and processing. This shortage of farm workers existed well before COVID 19 (USDA, 2022). However, COVID 19 has caused the recruitment of workers for the meat industry to drop, as well as migrant labor restrictions leading to there being fewer employees in meat processing plants. Subsequently, the manpower shortage is a primary factor in the bottlenecking of the meat supply chain.

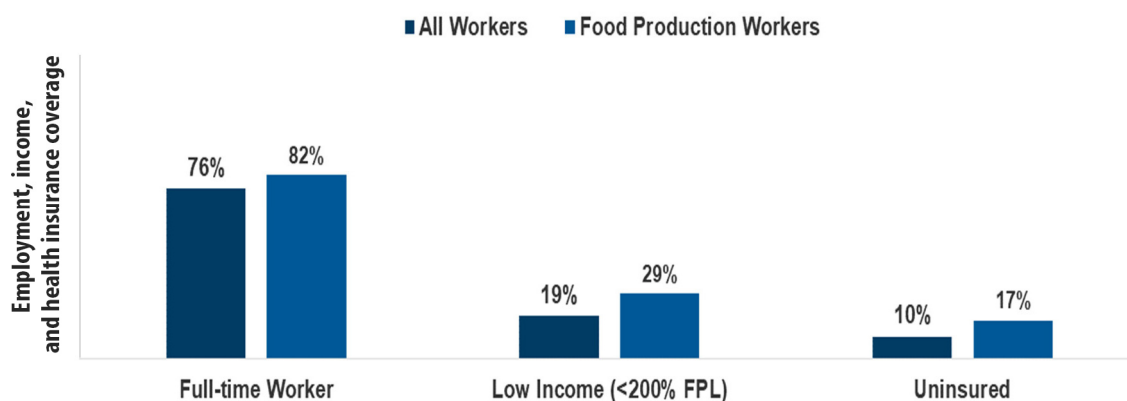
### Supply chain issue

One major concern of food companies during the pandemic is employee's health. Accompanying this was the concern of being able to maintain a proper workforce to keep production levels up to meet the consumer's demand. Numerous employees were not capable of working due to sickness (COVID positive or required quarantine) or as well as people

choosing not to work due to the fear of COVID 19. Due to conditions and methods of meat processing facilities, COVID 19 is easily transmissible and spread to workers: Social distancing decreased due to standing close together on the production line, yelling across the plant and to others due to noise which led to more droplets being spread in the air, busses, and car sharing. All of this contributed to at least 54,036 workers who contracted the virus and 232 worker deaths in the meat industry within the USA (Campuzano et al., 2020). Workers in production facilities have lower incomes, which results in having limited to no insurance coverage, which makes coming to work a risk. Fig. 2 compares food production workers to all other workers. There is a higher percentage of full-time food production workers, however, the percentage of food production workers that are classified as earning low income is much higher. This lowered income explains the higher percentage who are uninsured. In many cases, workers also have no paid sick leave so this led to workers coming in even if they were sick (Artiga and Rae, 2020).

It was found that cold and dark environments lacking ultraviolet light, characteristic of the environment in meat processing facilities, allows COVID 19 to remain viable longer, allowing for an increased spread of COVID 19 (Gulland, 2020). With these cold temperatures allowing the virus to be preserved, it can then easily transfer into the cold noses of workers. Thus, as the increase in the spread of the virus is inevitable when workers must shout in a noisy working condition, these particles are spread into the cold air where more can be produced (Gulland, 2020). This phenomenon can be further backed as other factories and processing facilities that do not have a cold environment did not have the outbreaks seen in meat processing facilities.

A couple of studies have been conducted by Chin et al. (2020) to examine the stability of the COVID 19 virus on different surfaces and at different temperatures. Chin et al. (2020) determined that COVID 19 was much more stable and remained infectious/activated at colder temperatures, 4°C, much longer than when incubated at higher temperatures, 70°C. It was also determined that COVID 19 was much more stable on smooth surfaces, especially stainless steel, and remained detectable for 7 days (Chin et al., 2020). Furthermore, stainless steel surfaces accompanied by the colder temperatures allows for the virus to be very stable and can be transmissible for much longer. The average ambient temperature of meat processing plants is no higher than 10°C, which allows the meat or meat product to remain around 3°C once stored (Federal Register, 1997). The cold environment accompanied by the even colder meat allows for the perfect environment for COVID 19 to remain stable



**Fig. 2. Employment, income, and health insurance coverage among food production workers compared to all workers in 2018.** This figure compares aspects of working between food production workers and all other workers based on the percentages of full-time workers, low income, and uninsured. The classification for low income is based off the federal poverty level (FPL) in the year 2018. Adapted from Artiga and Rae (2020) with CC-BY-NC-ND.

and infectious for longer. It was also found that the virus is susceptible to standard disinfectants, so ensuring that spaces are sanitized properly would be able to prevent additional spreading of the COVID 19 virus (van Doremalen et al., 2020).

A similar study was done that measured the viability of two different strains of COVID virus of different surfaces (van Doremalen et al., 2020). The strain of interest is the strain that caused the pandemic, COVID 19. The study reported the viability of COVID 19 for 72 hours on stainless steel, which is a type of common materials used in slaughter facilities and meat processing plants (van Doremalen et al., 2020). All the issues surrounding employee health and the increased risk of spreading the virus in the meat processing environment contributed to food production facilities being reduced, suspended, or even shut down, which was more prominent in the meat processing industry. In late April of 2020, the capacity in meat processing facilities had dropped approximately 25% because of the pandemic (Aday and Aday, 2020).

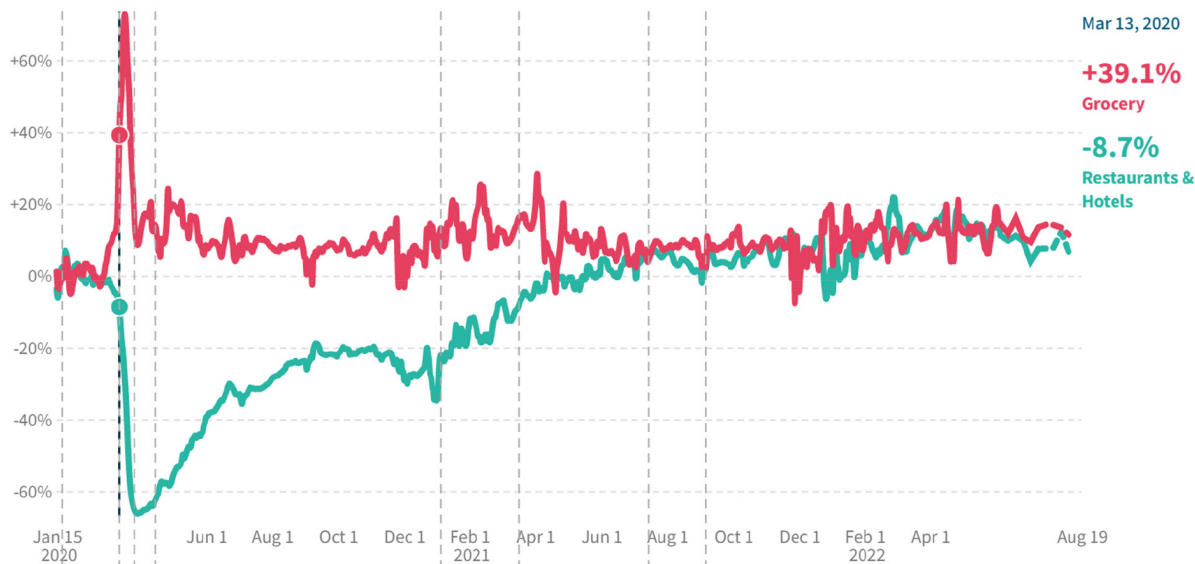
### **Shift in production**

As restaurants and other big food selling venues such as sport stadiums began to shut down, the meat supply chain struggled. The shift from producing more products in bulk for industry use to more individually packaged at home goods was difficult. The transition was costly and contributed to the increase in meat prices. The transition also led to a slowdown in production plants as well, leading to less demand for livestock. The shift from purchasing away from home foods to at home foods led to these disruptions in the supply chain. Foods that are typically consumed away from home, like at a restaurant, are packaged differently. As restaurants closed there were many of these large, packaged products that had no destination. Other difficulties included establishing new contracts, changing from large bulk packages to smaller more individual packages, changing food labels to meet the requirements of retailers, etc.; these were a few examples of why the transition between away from home food to more at home food was difficult and costly (Hobbs, 2021). This difficulty of switching and the time it takes to do so is called a lag phase and it changes depending on the species. Eggs and wings from broilers come much quicker due to the faster reproduction time and growth unlike beef cattle, which have a much longer breeding cycle. There are much fewer issues with chicken supply due to this discrepancy.

Fig. 3 shows the change in consumer spending on groceries versus at restaurants. When the pandemic was declared on March 13<sup>th</sup>, 2020, the drastic change in consumer spending occurred. There was a major increase in the spending on groceries accompanied by a major decrease with the spending in restaurants. This change in spending peaked around March 20<sup>th</sup>, 2020, and from there they slowly returned to their normal pre-pandemic state where they are about equal. It can also be seen that even as the pandemic has died down in April 2022, the amount of spending for both grocery and restaurants are consistently higher than pre-pandemic numbers. The shift in production has also changed the demand of consumers. The closure of restaurants and the increased purchase of groceries has resulted in a change in demand for different cuts and types of meat. Consumers are less likely to purchase a high-end expensive steak and would more likely opt for something cheaper. It is unknown how long this change of demand due to COVID 19 will last and if the view by consumers will ever revert back.

### **Solutions: Government policy**

In order to maintain a constant supply of meat while avoiding losses and waste within the supply chain, governmental policies will be necessary, especially in the case of the COVID 19 pandemic. An important part of policy that needs to be implemented mainly surrounds the food waste that is produced, both on the consumer and production level. Another common issue seen in the meat supply chain is that when big production facilities would shut down all of the surrounding area would struggle. Therefore, it would be important to promote smaller local production facilities for food and agriculture producers. If



**Fig. 3. Change in consumer spending on grocery vs. restaurants.** The figure illustrates the amount of consumer spending put towards groceries as well as restaurants and hotels during the COVID 19 pandemic period. Adapted from Economic Tracker (2020) with permission of Opportunity Insights.

there were more small-scale regional production facilities then if one shut down due to COVID, there is potential that it would not affect the surrounding communities nearly as much (Zielińska-Chmielewska et al., 2021).

In the USA, President Trump issued an executive order on April 28, 2020, invoking the Defense Production Act. This act allowed processing facilities to remain open as they did not have to close based on state and local legislation. This considered processing facilities as essential businesses. However, even though this executive order was passed, some meat processing facilities were still forced to close due to COVID 19 outbreaks among workers (Zielińska-Chmielewska et al., 2021).

An issue arose questioning the meat processing facilities' ability to utilize their market power in order to earn overly increased profits (Balagtas and Cooper, 2021). This question has been raised due to the ease of access and ability to easily change the prices of meat and price for livestock. The circumstance allows for the meat packing industry to make large profits. There have been many lawsuits put up against some large meat processing facilities, as well as an investigation by the USA Justice Department. These lawsuits were raised in response to the widening price spread margin between livestock and retail meat costs (Ma and Lusk, 2021). Government policies would need to be set in place to prevent large meat processing plants from abusing their market power, however, much research has been done to conclude that large meat processing facilities are not abusing their market power. It has been asked if having more small-scale production facilities would help prevent drastic price spreads or help prevent large processing facilities from abusing their market power. However, it has been shown that even if there were only small processing facilities and no market power available, large prices spreads would still result due to an exogenous disruption such as COVID 19 (Ma and Lusk, 2021).

Many states have implemented legislation to help support the introduction of small and medium sized processing facilities. The same type of financial support has come from the federal level along with passed bills allowing these small processing facilities to have more access to large markets. The rationale behind this is to allow the small processing facilities to be able to compete with the larger processing facilities. The increased competition will allow for there to be a wide spread of small processing facilities across an area rather than just having one large facility supplying the market. This is all in hopes that when an exogenous factor, such as COVID 19 causes a production facility to shut down there will be less repercussions (Ma and Lusk, 2021).



## Implemented plans and changes

One thing that had been implemented to the food supplying sector was a plan for potential second or third waves of COVID 19. These plans heavily incorporate flexibility which was lacking pre-pandemic and could be seen in the beginning of the pandemic. The plans have also adapted to the needs of retail businesses as well as building a larger more diverse customer base with different needs. COVID 19 has required increased health and hygiene practices along with social distancing. In response to these practices, there has been increased automation and digitization to help in the prevention of the spreading of the COVID 19 virus, as well as other illnesses, or in the event of another pandemic. Robots currently do simple jobs such as unloading, loading, packaging, and quality control checks. Further automation in production plants is difficult due to the many different sizes and shapes of carcasses. However, due to the COVID 19 pandemic, there has been an accelerated push to finding methods to further increase automation. One key component to automation is how cost-effective it can be. The cost-effectiveness depends on the ability of robotics to ramp up productivity, enhance quality control, and improve food safety compared to the average worker (Weersink et al., 2021). The pandemic has helped the cost-effective side as a result of the slowed lines due to less workers and COVID 19 protocols. Robots would also be helpful with the current worker shortage in meat processing plants that has been seen before and during the COVID 19 pandemic as robotics could take over simple tasks that are currently being filled by workers. Digitization has increased in the form of making transactions from paper to digital. The pandemic has increased digitization as there has been an increase in remote working from home, as well as less business travel due to restrictions (Hobbs, 2021).

## Consumer perspective

There are some major issues that have arisen concerning the consumers' meat consumption with regards to the shortage of meat supply due to COVID 19. The primary concern could be the food security and sustainability due to several major meat facilities being shut down. Food security is a person's access to food in both a physical and economic standpoint. During the pandemic, food security was more associated with the consumers' ability to access food instead of the availability of food (Aday and Aday, 2020). Subsequently, there is a growing concern for maintaining a healthy diet, which is essential for providing required nutrients and supporting the immune system. Without proper access to food the ability to maintain healthy diets is difficult. The raise in meat prices led to people buying more processed or manufactured foods, developing poor and less nutritious diets (Patton et al., 2021). Also, there were concerns about food safety that rose during the pandemic. Since the agriculture industry has not been able to continue business as usual, there has been the potential for negative impacts on food quality, freshness, and safety, which hinders the market as well as affordability.

With the increase spread of food safety in response to COVID 19, many consumers became more concerned about where the food they are eating comes from and the large workforce responsible for the food ending up there. This was due to the periods of time when the pandemic would peak in numbers and people would rush to the store to stock up on essential goods, meat being one of them. The excessive buying from consumers led to shelves being quickly emptied. Consumers had also been concerned about the quality of the products in which were being produced due to the lax safety requirements. Surveys were given in one study to gather data on consumers' perspective on the relaxation of food safety and environmental regulations (Tonsor et al., 2021). It was initially seen as an increase in concern by the consumer. This in turn could lead to a decrease in meat consumption, which is hard on the meat supply chain, as well as the economy.

There were safety concerns on the production side of the supply chain. During the first few months of the pandemic as production speeds slowed down, production decreased and the stock on shelves lowered. In response to this lack of meat, the



Food Safety Inspection Service allowed the production line to be sped up in the processing facilities of all beef, pork, and poultry. The USA Food and Drug Administration also relaxed on safety protocols to allow for the switch from food packaged for commercial use to be packaged as at home food. However, this temporary mitigation protocol not only led to potential food safety issues, which might put the consumer at risk of getting sick, but the increased line speeds also heightened the risk of contracting the COVID 19 virus among workers. As a result, the meat industry could gain negative perceptions from consumers about the meat that they eat. This negative perception could lead to decrease in buying which in turn results in less profit. There was also a concern of COVID 19 being able to be spread through meat, especially salmon. However, COVID 19 is not able to be transmitted through food (Aday and Aday, 2020). Pathogens can be spread through animal flesh, however, there has not been any recorded incidents of transmission from animal flesh to humans due to the acidic environment of the human stomach (Aday and Aday, 2020). Even though there has not been any evidence of COVID 19 being transmitted through animal flesh, the thought and fear behind it has led to a backlog which affects other parts of the food industry. This fear has led to less product being bought, which spreads not only from not buying salmon, but not buying other meats as well.

In general, the consumer is most concerned with the food's safety, taste, nutrition, and price, as core food values according to many studies. With the COVID 19 pandemic, consumers began to become even more so concerned with these values, especially safety and supply. Consumers have tried to seek reassurance that the quality and safety of their food does not decrease. The governments of different countries have taken steps to ensure that trade of essential goods such as foods are still maintained despite the trade ban on non-essential goods. At the beginning of the COVID 19 pandemic, price was proven to be the most focused of food purchasing attributes (Hobbs, 2021). Before the pandemic, quality attributes, such as meat color and purge/drip in the package were the focus when it came to purchasing meat.

COVID 19 has raised awareness of food waste or food that is lost in the production process. Production loss was around 1/3 and has remained about the same throughout the COVID 19 pandemic. However, food waste at the household level has slightly increased mainly as an effect of the panic buying done by consumers. When the consumers buy a surplus of products, they are unable to use them all before they spoil, leading to them being thrown out. Also, consumers had taken up different forms of cooking and baking as a hobby due to being locked in. They stockpiled more ingredients and supplies than they needed or could possibly use, leading to spoilage (Aday and Aday, 2020; Fleetwood, 2020).

An animal welfare issue rose when the capacity for animals at slaughterhouses began to fill up. The demand for animals at production facilities decreased due to this decreased capacity leaving farmers with animals in excess. Animals in excess are often euthanized, but there were some cases in which farm animals were donated to animal sanctuaries or sold to other individuals at auctions instead of being killed. The animal welfare issue was more prominently seen with the excess of pigs. In 2018 there was an outbreak of African Swine fever in China, resulting in China needing more pigs to be imported. As the USA is a big exporter of pigs to China, the pork industry increased production of pigs to send to China. As COVID 19 struck, however, the swine industry in the USA were faced with an excess of pigs due to the ramped production. This excess surplus eventually led to upwards of 10 million pigs being euthanized, using the American Veterinary Medical Association's approved methods. The most common of these methods used were captive bolt stunning or a gunshot. Another method that caused concern to animal welfare was with ventilation shut down. This method involved shutting all access to ventilation causing the pigs to eventually suffocate in their own carbon dioxide (Grandin, 2021). This method is of concern for animal welfare as it is often not done properly, and pigs are left suffocating for close to a day (Harsh, 2020). There were also instances of controversial slaughter via a method of using foam containing Nitrogen gas leading to quicker suffocation. This method has been declared inhumane from the European Food Safety Authority (Kevany, 2020).

## Contrary arguments

It has been questioned whether food supply chains that are dominated by large scale operations are more or less resilient than those with many small sized production plants. This tension has existed well before COVID 19, but the virus has caused the concern to grow as many wonder how to properly prevent food shortages. The issue with having a lesser amount of large processing facilities is that if one facility shuts down or even slows production, it has a large impact as a whole and affects a widespread area. It has been thought that having many smaller production facilities could mitigate this issue. The question arises wondering if having a more dispersed system of smaller-scale facilities brings along more resilience. The answer to this question has been found to depend on many factors, both short and long term. Having fewer large-scale operations is more efficient considering the scale and scope economies. The goal of the scale and scope economies is to spread out the cost of equipment and buildings across a longer time period while in the meantime producing even more product, leading to a lower average cost. The scale economy focuses on creating a larger output to bring in more revenue (Green, 2020). The scope economy focuses on having a larger range of products to target more buyers to also increase profits. The consumer benefits from this as if the costs for the production facilities is lower, the prices of the product will be lower. Having many small-scale operations is less efficient as there are higher costs due to there being less opportunity of this scale and scope economy due to less resources being available (MacDonald, 2000). It is possible however, that these small-scale facilities could be more flexible. With the small-scale operations, producers can have more one-on-one connections to buyers and easier networking, which allows for more inputs to be secured along with new buyers. Small-scale operations are less vulnerable to failure when one facility is shut down. However, these systems cost more as they are less efficient, increasing the cost for consumers, as well as requiring much more labor than the large-scale plants as there are many more jobs available. Having a system that requires more workers is disadvantageous in a pandemic as there are less workers available in general, decreasing food chain resilience. Medium-long term effects are typically result from uncertainty within the food supply chain. This uncertainty being the duration and severity of the closures and disruptions due to COVID 19. There is an economic attribute to this uncertainty due to closures and mass layoffs of non-essential businesses resulting in the income of consumers to decrease. A decreased income of consumers could potentially decrease the demand for meat or cause consumers to resort to cheaper substitutions and alternatives. It is difficult to predict these medium-long term effects due to that uncertainty. Another sense of uncertainty is the recurrent lockdowns that were being placed. It was unknown when or if these would be reinstated, which would close restaurants, bars, and other food services. The issue is not necessarily when or if the lockdowns would return, but how long they would last and the severity of them (Hobbs, 2021).

## Conclusion

The COVID 19 virus has had a huge impact on the meat supply chain as well as the economy, impacting both directly and indirectly with closures of businesses to workers getting the virus. These issues led to the increased demand for meat products while meat processing facilities struggled to keep up due to decreased line speeds and lowered workforce. Farmers were affected due to there being less of a demand for animals as there was a lowered capacity at processing facilities. All these things led to the negative impacts that were seen in the economy. Most of these issues have resolved with the meat supply chain except for the occasional issue when a new variant of COVID breaks out causing a surge in consumer demand. COVID 19 brought attention to a lot of issues within the supply chain. These issues are being addressed and potential solutions are being made to prevent the meat supply chain issue from happening again in the future. Remodeling the infrastructure of

processing plants would be desirable to have more small-scale production facilities rather than a few larger ones. Furthermore, moving to more automation in processing facilities would be helpful to prevent the failures due to lack of workers. Automation can ensure that production capacity will not be lowered in a pandemic so that food quality, quantity, and safety will not be compromised.

## Conflicts of Interest

The authors declare no potential conflicts of interest.

## Acknowledgements

This work was also supported by the USDA National Institute of Food and Agriculture, Hatch-Multistate project 1006773.

## Author Contributions

Conceptualization: Kim YHB. Investigation: Whitehead D. Writing - original draft: Whitehead D. Writing - review & editing: Whitehead D, Kim YHB.

## Ethics Approval

This article does not require IRB/IACUC approval because there are no human and animal participants.

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