



Unveiling the Shifting Dietary Landscape: Plant-Based Foods Amidst the COVID-19 Era

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Authors' contributions

This work was carried out in collaboration among all authors. Author UA wrote the manuscript, conceptualized the study and investigated the work. Author AK Contributed in data collection and improved the writeup. Author FH Assisted in revising the original draft and did data curation. All authors read and approved the final manuscript.

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ABSTRACT

Manuscript addresses the present era COVID-19 pandemic as one of the global challenges. Still in 2024, the health professionals and scientists are searching and trying to figure out the complete answers about the origin of these zoonoses. In past years of pandemic, plant origin foods have

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become the preferred food choice for many people globally. In this article, we've discussed trends in plant-based foods around the world and some of the reasons for this change. It was found that there has been a notable shift in the sale of plant origin foods and a decrease in the sale of animal-based meat at the same time. Selling meat and seafood fell due to many factors, including lack of confidence due to the fear of viruses, rising prices and ethical standards. The marketing strategy of the meat substitute companies used may also be a factor. Although plant-based diets have continued to be adopted in these years, this trend seems to be accelerating in the Post pandemic. Another fact that post pandemic shifting towards the consumption of plant origin foods is reliance on a healthy diet which will not only boost the immunity but will also come up with other health-linked benefits. Plant origin foods are also more nutritious and health promoting than foods consisting of dairy, fish and meat. Via this study, we have analyzed that there needs to be a major change in the use of wild animals and domestic animals to prevent any risk of future zoonoses. As the global population increases, zoonosis may occur more frequently. Promoting the adoption of healthy plant-based foods worldwide and a contemporaneous decline in the animals used as sources of food is important and necessary to prevent future epidemics due to disease.

Keywords: Post-pandemic; diet; market; population; animal origin foods; plant origin foods; COVID-19.

1. INTRODUCTION

On 11 March, 2020, the disease of Coronavirus (COVID 19), was announced as a pandemic by the World Health Organization (WHO) [1], given the fact that numerous nations have now abandoned strict border closures and city-wide lockdowns in response to the WHO's announcement on May 5, 2023, that COVID-19 is no longer considered a public health emergency of international concern (PHEIC), this may indicate the end of the SARS-CoV-2 virus-related COVID-19 pandemic [2]. However, in January 2024, the economic and social destruction silently continues with over 774 million cases reported and over seven million deaths reported globally [3].

At the time of its initial appearance in Wuhan, China, it was originally considered to be pneumonia without any particular known cause [4-7]. Within a span of a few months, COVID 19 expanded to the entire world. Multiple early cases were noticed to be associated with the Huanan seafood wholesale market. Later, it was found that SARS-CoV-2 is the causative virus behind COVID-19. On further study at whole-genome level, there was a 96% match of SARS-CoV-2, which belongs to the Coronaviridae family, and bat coronavirus [8-10]. Bats are considered to be the reservoir hosts for the virus [11], but before the transmission to humans, Malayan pangolins are believed to be potential intermediate hosts. The strain of COVID-19 from which humans were specifically affected is thought to have been evolved to become fit for transmission among humans through contact [12]. Swine, as an intermediate host either in

place of or along with pangolins, is also a topic of debate [13]. With a history of zoonotic outbreaks originating from livestock farms, a probable bat-swine human interaction must have taken place linked with the current pandemic because of numerous swine factory farms in Wuhan, China [14]. Some opinions contemplated the idea to interlink the spread of Coronavirus and the geographical area of the pig industry located in Santa Catarina, Brazil [15]. The cause of increasing zoonosis in the world is due to the pattern of production and utilization of food [16].

The World Health Organization states that zoonosis happens when there is a transfer of infection from animals to humans. The organisms which cause zoonosis, includes viral, parasitic, and bacterial or may possibly be due to uncommon agents and can expand to humans [15]. These zoonotic outbreaks have always been there, even many thousand years back, however, currently this number is on a rise [16-17]. SARS-CoV 2 and MARS-CoV can be taken as examples for causing pandemics in the last 20 years [18]. In order to prevent such incidents, spillover pathogens and links behind zoonosis (livestock and wild animals both) needs to be meticulously analyzed [19] The most probable source of coronavirus seems to have come from the seafood market in Wuhan, where wild animals' sale takes place [20]. Resultantly, many experts suggested some critical measures to prevent such outbreaks in future, which included recommendation that authorities implement an invariable ban on consumption, selling and purchasing of wildlife, globally [21]. Prior to the pandemic, many species which are non-aquatic and mammals including birds and rabbits as an

example were being sold in the market [22]. Numerous species and strains of coronaviruses can utilize these animals as hosts. Viral pathogens being shed in the faeces of these animals could be a strong reason for the spread of infection as well as its transmission between species [23].

The acting head of Biodiversity at the UN, in April 2020, immediately announced that an effective way to keep the pandemics at bay, is to stop wildlife market operations, for both dead and alive animals that are later consumed by humans. Public health authorities around the world and particularly in the US now see illegal trade of wild animals and wildlife markets as a major channel of pathogen transmission. This transmission can take place by either a close contact between humans and animals, dead or alive, or merely by consumption of them. As of 2023, these measures are imposed by many countries and it leads to a notable reduction in the pandemic spread. Moreover, farm animals or livestock can potentially become infected through contact with these wild animals and moisture in the environment of the wet market makes the spread even more potent [24]. Trade of exotic meat and selling of live animals must be condemned through properly imposed laws. In China, an outbreak of coronavirus resulted in a strict ban on using wild animals as items for oral

consumption. Outbreak of coronavirus made healthcare individuals across the globe focus on problems such as livestock and wet markets and a few of these perspectives have even made it to the headlines in the media. Such a magnitude of attention can possibly bring a change in the eating behavior of many individuals [25]. Some of the key factors that this paper highlights are: the change in food choice of the people after COVID-19 [26], its reasons and the future takeaway.

2. GLOBAL DIETARY MODIFICATIONS

COVID-19 era has been a novel situation for everyone in which the dietary habits are being the most affected as people are more and more attracted towards health promoting diets. There has been a notable decline in the market sales of animal-based foods and increased sales of plant origin foods. See main findings in Fig. no.1.

Pre COVID, the food selection was primarily based on the five senses but with the ongoing pandemic the diet related myths prevailed, our review shows that consumers showed more awareness towards selecting the foods that are proven to improve the immunity status. All these factors lead to ups and downs of sales and purchases of many food items in the food market.

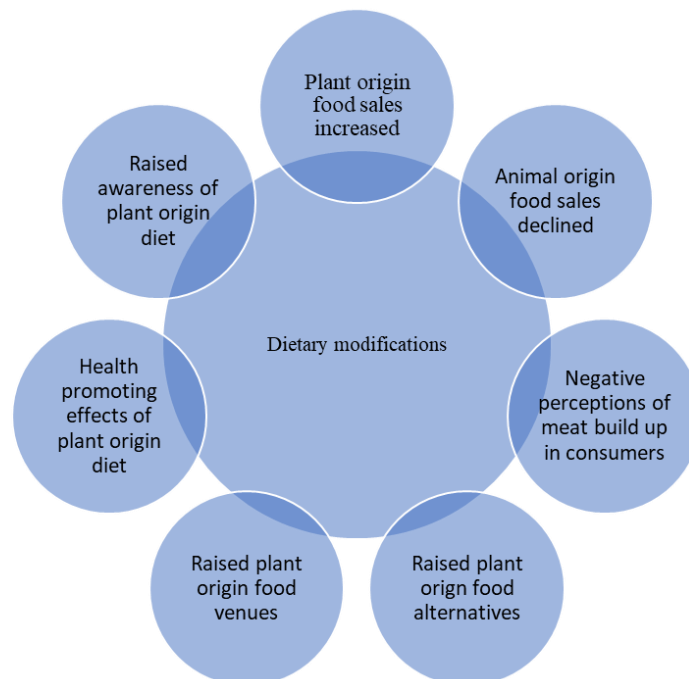


Fig. 1. Findings of this study (Pandemic and dietary modifications)

2.1 Plant Origin Food Vending and Animal Origin Food Vending

While the pandemic continued to spread, an amusing deflection was seen in the usual food choices of people. There was a significant increase in consumption of plant-based food which also included meat alternatives. This paper uses the terminology of “plant-based” and “vegan” conversely. Having said this, we completely acknowledge that plant-based eating relates to dietary choice alone, whereas veganism refers to the rights of animals. Sale of plant-based foods majorly exceeded overall food sales in the US, showing the shift in consumer preference during COVID-19. The peak of food buying came in March 2020 and it is notably evident that food sales of plant-based commodities increased by 90% [27] when compared to March 2019. Segmented breakdown of data revealed a 148% rise in the sale of vegan meats that continued to grow to 61% in the four weeks that followed. This showed a rate of growth two-times that of animal-based meat.

The rise and fall of plant-based and animal-based meats respectively, has an inverse relation to each other. On comparative analysis of data taken from slaughterhouses in 2020 and 2019, by the United Kingdom Department for Environment, Food and Rural Affairs; slaughtering of prime cattle, clean sheep and clean pig decreased by 7.3%, 4.9% and 2.1% respectively, in 2020 [28]. The Food and Agriculture Organization of the United Nations, presented a report which claimed that if numerical data from 2020 was to be taken, it is expected that it will show a 3% decline in consumption of meat per capita, globally which is the largest yearly decline since 2000 [29]. The pandemic had an adverse effect on the market of meat products in Southeast Asia. Because of a huge blow to the livestock and cattle industry, shortage of supply, and decreased profits, a slow rate of growth was estimated during the pandemic. Due to low consumption of meat and less availability of raw materials, meat producers of Southeast Asia were seriously restrained [30].

Throughout the pandemic, the vending of fish and seafood crashed to a notable level. Fishing companies, groups and the seaports were seen as potential contact sites for the spreading of the COVID-19 infections due to the mobility nature of fishermen and also the raised frequency of the international people [31]. Several fisheries

intimate partial or complete closure leading to a severe decline in fishing activities all around the globe. Moreover, there's a forceful and notable decline in stipulation for seafood's, limitations to properly approach cold storage, and closure in the shipping and the air cargo services [32]. Routine work related to the Fish Exchange in Portland, US and Maine faced a severe reduction from sixty thousand to concerning twenty thousand pounds per week throughout the pandemic [33]. The imminent closure of several restaurants in the US has reduced market demand significantly. Additionally, sales of the its fisheries decreased up to 95% due to factors like as geographic location, species, gear types, and mismanagements [34].

2.2 COVID-19 Pandemic and Customer's Awareness of Meat

Meat perception of the consumer and the COVID-19 is key concern with the coronavirus outbreak is the prevalence of elevated rates of infections found in employees at animal processing plants and the slaughterhouses for animal meat. Usually, the contaminated environment in these setups lead to animal disease spread. Routinely, there are many operational and structural procedures that interfere with the one's personal hygiene and safety, therefore the established cleanup and medical aid of worksites. These setups even maintain low temperatures and extreme relative humidity, also massive amounts of aerosols and the droplets, and use several stainless-steel surfaces that aid in the virus sustainability longer than on the paper surface. Circumstances like this, beside socio-cultural and the financial hurdles being faced by the employees, aid in transmission and spread of SARS-CoV2[35,36]. Unsurprisingly, a chain of the SARS-CoV-2 zoonoses that took place in the space of three months (March and June 2020) in meat factories resulted in various meat plants to shut operations (see Table no 1), particularly in the North America and parts of Europe, as well as some in France, United Kingdom, Germany, Canada, the United States and France [37,38].

Gütersloh and Warendorf within the West German state of North Rhine Westphalia, with a total of 640,000 locals, came back in the strict lockdown situations after seeing above 1,400 staff and employees at a meat packaging plant found positive for COVID-19[44]. Food processing plants especially the meat processing plants in Tydfil, Wrexham, Anglesey, Kirklees,

Table 1. Cases of foodborne SARS-CoV-2 contamination

| Country | Date | Food group | Significant details |
|---------|-------------|------------------------|---|
| Canada | May-2020 | Chicken | 18 food inspectors at the Cargill meat production facility in High River, Alberta, were infected with COVID-19. At the Quebec processing facility owned by Cargill, 64 workers had COVID-19 [39]. |
| China* | August 2020 | Frozen wings (chicken) | Longgang District conducted tests and rankings for cold chain food. In a viral nucleic acid test, one frozen chicken wing surface sample from Brazil tested positive. |
| China* | Jan-2021 | Ice cream | SARS-CoV-2 nucleic acid was detected in three of Tianjin Bridge Road Food Company's ice cream products. |
| China* | July-2021 | Rice | Pakistani rice import was suspended after the bags were found to be carrying the COVID-19 virus |
| China* | Mar-2021 | Dairy | SARS-CoV-2 nucleic acid was tested positive dairy products outside packaging, all of the products were destroyed, and they were never entered the Chinese food market. |
| China* | July-2022 | Mango | Imports from Macau, 20 mango crates tested positive for SARS-CoV-2. All of the products were destroyed, and their entry into food market was halted |
| Germany | May-2020 | Chicken | At a meat packing company in the city of Coesfeld, more than 200 workers acquired COVID-19 virus [40]. |
| Germany | June-2020 | Chicken | In North Rhine-Westphalia, at the Tonnies " meat processing factory, 651 employees confirmed that they suffered COVID-19 infections [41]. |
| UK | June-2020 | Chicken | The COVID-19 outbreak forced poultry meat producers 2 Sisters Foods, Rowan Foods, and Kepak Ltd to cease their operations [42]. |
| US | Apr-2020 | Chicken | As of April 23, 115 businesses that produce meat or poultry had reported instances of COVID-19, and 4913 workers had been diagnosed with the virus (resulting in an overall infection rate of 3.0%). Twenty worker fatalities linked to COVID-19 have been reported [43]. |

*Source: Chinese disease control center (Website: www.chinacdc.cn)

and Merthyr within Great Britain additionally became a high-risk area with over 450 people found COVID-19 positive [45]. Among 115 meat or poultry processing setups in 19 states within the North American country, 4,913 workers were positive with COVID-19 and 20 people's deaths associated with COVID-19 was reported as well [34]. Previously, the most important reported bunch accounted for 1,550 cases joined to only one meat-packaging and processing plant in a Canadian province (Alberta) [46].

With terminations of the meat handling plants because of Coronavirus flare-ups, shoppers might have had worries about meat deficiencies and meat security (because of its conceivable pollution with the infection), causing more popularity going towards the plant-based other options. It is additionally conceivable that shoppers might have been worried about meat costs since the decrease in the accessibility of

meat could bring about cost increments. A greater expense for meat would additionally lessen the interest for meat. There is likewise the likelihood that shoppers might have purposely challenged meat to remain in fortitude with laborers from slaughterhouses and meat handling plants [47]. A review directed in China during the pandemic showed an expanded interest for a plant-based diet recently. Aside from eating fewer carbs for the purpose of losing weight, the review members considered a plant-based diet more secure for utilization, conceivably suggesting doubt in meat [48]. A concentrate by Forsa on the dietary patterns of Germans somewhere in the range of 2015 and 2022 dispatched by the Government Priest of Food, Julia Klöckner, showed that the country's day to day meat consumption as a level of the typical German cosine declined among the respondents from 34% to 26% [49].

2.3 Plant Origin Dietary Substitutes and Venues

During this recent zoonosis, a notable disturbance was observed in the market sales of meat and seafood, plant origin meat alternative companies such as Beyond Meat and Impossible Foods with better marketing and retaining ideas have the tendency to gain more and more popularity among the consumers [50]. The popularity of plant-based meat alternatives increased by 463% in 2020-2022, according to Grubhub's "Year in Food" trends report, which analyzed 30 million orders from delivery platforms. In the US, Illinois, Massachusetts, California, Oregon, and New York occupy the top five spots. Also, the delivery firm DoorDash showed a 433% increase in plant origin substitutes in six months from January 2020 to the end of June 2020 in its newly published report "DoorDash Deep Dish." [51].

Another study from an online hoteling report (Happy Cow platform) focused on how restaurants were being affected by the COVID-19 pandemic. Since the outbreak of COVID-19, 517 vegan restaurants have newly opened and 413 have closed, making an overall 104 vegetarian restaurants currently available throughout the world [52]. The results represent solely the vegan places, which may have significantly raised the overall count of hotels and restaurants offering "vegan-friendly" or plant origin food options. Even more plant-based options are being offered by fast-food restaurant chains. Subway, the world's largest chain, has launched Meatless Meatball Marinara sub sandwiches at all of its UK stores after the product sold out in early 2020. Best vegetarian sandwich award was also won by them which was organized by the People for Social Treatment of the Animals [53]. Starbucks, meanwhile stands as the third widely spread retail chain, has also expanded its menu globally to include more plant-based products including the Singaporean Impossible Rendang Pie, Beyond Meat dishes, and Oatly milk alternatives in China, and many other locations [54].

2.4 A Plant Origin Diet and its Vast Health Benefits

The growing demand for the plant origin diets have attributed day by day by the increasing perception of the advantages of a healthy living and the strong reliance that it can lead to betterment in immunity. A recent pan-India

serosurvey conducted by Council of Scientific Vegetarians and the Industrial Research has found nearly 40 institutions to have lower COVID-19 seroprevalence in vegetarians and might have a relatively reduced infection risk [55]. The gut microbiota found in the human GI tract is known to provide important health benefits to the host [56]. Researchers from Hong Kong have identified three key outcomes in COVID-19 patients: a) conformation of gut microbiota is persistent with the seriousness of the disease and enormity of the plasma assembly of several inflammatory chemokines, cytokines, and the blood markers of the tissue injury; b) bacteria residing in the gut area that are mainly comprised of *Eubacterium rectale*, *prausnitzii*, *Faecalibacterium*, and including a multiple other varieties of the *bifidobacteria* with well documented immunomodulatory traits were depleted out; c) the persistence of the abnormal composition of the gut microbiota persists even after the virus is cleared out of body [57]; Updated research shows a beneficial linkage among the health promoting plant origin food intake and the "good" microbes residing in body [58]. It concludes that plant origin foods impose a replenishing effect on the host's gut microbiome with favorable and healthy microbes in establishing a strong and useful symbiotic relationship with the host's microbiota, leading to vast health benefits notably boosting the immune system [59]. For instance, dietary fiber, that is predominantly present in the green plants, has appeared to sustainably grow *lactobacilli* like *E. rectal*, *Ruminococcus*, and *Rosebria*, and hinder the growth of poisonous species of the *Clostridium* and *Enterococcus*. Plant produced secondary metabolites like the Polyphenols are present entirely in the plants and are also known to support the growth of *bifidobacteria* and *lactobacilli* [60].

Many risk factors studied in the past interlinked with the infection of COVID-19 and mortality are related to nutritional assessment, nutritional status and a particular essential micronutrients or macronutrient. A nutritionally sound and a balanced diet primarily consisting of nuts, whole grains, vegetables and fruits is connected with many useful health well-beings as this diet is balanced by providing the ideal nutrients to the human body like minerals, vitamins, polyphenols and healthy unsaturated fatty acids [61]. There has been a level I and II evidence documenting the use of vitamins C, D, and B in curing of coronavirus-like lungs alveoli damaging respiratory diseases, acute respiratory distress

syndrome, and sepsis [62,63]. Micronutrient vitamin D benefits in reducing COVID infections and mortalities has been well documented [64]. Many foods naturally contain low levels of vitamin D, but some plant sources like yeast, fungi and algae are rich in vitamin-D and provitamin-D [65]. Seaweeds, fungi and mushrooms are becoming foods of interest in Asian cuisine, especially in Korean, Chinese and Japanese societies, and hence Asian countries have been able to manage COVID-19 outbreaks and reduce mortality.

It is worth noting that further investigation is vital on nutrient intervention to govern the possible relevance. Previous studies have also shown that common fruits contain many natural compounds with anti-coronavirus infection properties. A study showed the high potential of Tannic acid (found in fruits such as apples, berries and grapes) as the developmental part of anti-COVID curative, as it plays a vital role as a strong hindrance of two self-dependent enzymes (the cellular TMPRSS2 protease and a major viral protease), suppressing SARS-CoV-2 zoonosis to some extent [66].

2.5 The Flow and Market Prices of Plant Origin Foods

A study was conducted using data from Google Trends to search out the internet search on word "Vegan" in various languages, the results were found to have hit the all-time record previously set in 2019. Top three places were held by Israel, UK and Australia with the most interest in plant-origin foods. Additionally, the awareness and trend to consume more plant origin foods is now double as compared to five years back [67]. In a study of 1,475 participants, the vegetarian diet got the highest quality rating of all diets, documented in the the 2010 Healthy Eating Index and Mediterranean Diet Score sheet [68]. Additionally, recent recommendations were made on reducing the overall consumption of unhealthy foods worldwide by EAT-Lancet Commission for healthy eating and using the sustainable food system. Shockingly, the report also included reducing meat by more than 50% by 2050, supporting local and global ecosystems, while advocating to meet the world's nutritional needs [69]. With the pandemic and lockdowns in the past years. People had more time to cook and enjoy the home prepared meal. As a result, in 2024 more and more people are aware of plant-based food importance and incorporation of this micronutrient rich diet in their daily lives.

A fresh study found that home-cooked plant origin meals were 40% cheaper than the meat and fish meals (£1.77 / person for fish/meat meals and £1.06 / person for the plant origin meals), and it reduced the preparation time by one-third. Based on a seven-day calculation, food diaries collected from the internet from approximately 11,000 persons in the UK [70]. Globally, Coronavirus has affected more than 55 million local and domestic workers, and a lot of them were actually affected by reduced working hours, loss of income, or even complete unemployment. [71]. Reduced overall prices of plant origin foods compared to meat and fish may also have played their roles in raising the amount of people switching to plant origin diets during the times of crisis.

COVID-19 might have spurred an ongoing burgeoning popularity toward healthier, plant-based diets. Growing awareness of the negative effects of meat intake on the human health and the environment, as well as the social issues related to animal right protection, increased the demands for plant origin diets which is also well promoted by the athletes and the popular celebrities. According to a report by "Acumen Research and Consulting", worldwide vegetarian food retailing is expected to touch US\$24.3 billion by 2026, growing at a staggering CAGR (compound annual growth rate) of approximately 9.1% during the foretell period 2019-2026 [72].

3. POST PANDEMIC RECOMMENDATIONS

One of the vital lessons learnt from the COVID-19 pandemic is to understand the harshness of this disease and work collectively to eliminate the dangers and threats at animal-human ecosystems where they interfere in each other's habitat [73]. In 2010, three of the world's top organizations, the World Health Organization for animal health, WHO and FAO have joined hands and started to collaborate to eradicate the zoonotic diseases. Also, a survey from the World Bank aggregated the total financial losses from past six zoonotic outbreaks accounted for a total of 80 billion US dollars between 1997 to 2009 [74]. In light of this zoonotic disease, all countries should work together and ensure safety in the future. During the ongoing zoonosis, consuming the vegetable oils with optimal ratios of polyunsaturated fatty acids is highly recommended to provide the essential fatty acids necessary to fight against the cardiovascular diseases. Post COVID, blended oils with good

ratios of omega 3 and omega 6 should be incorporated into our daily lives for better cardiovascular health [75]. With the start of COVID pandemic, the consumers became increasingly informed about the status of their health and what is best for them in terms of raising immunity. Consumers should be demanding higher transparency in terms of what they are eating and how it is produced. This would improve their understanding and unlock more dietary options which would make a population more resistant to possible future pandemics. Consumers should be kept updated about the latest disease-diet linkage, foods curing diseases and helping them fight against modern diseases. Healthy population will result in less outbreaks to appear and greater resistance. Consumer's health should be prioritized and must be protected at the government levels with awareness programs to promote more plant-based foods, trades of wildlife at animal markets must be illegal or strong regulations must be enforced and human interaction should be minimized with the wild animals through controlling the animal hunting. Only when the steps and recommendations are taken up, the risk of human exposure with the wild life would be reduced and prevent animal viruses and pathogens from entering the human habitat. Reducing human to animal habitat interference will prevent many such zoonotic pandemics in the future. Positive dietary modifications that we have experienced during this pandemic will prove most effective if they are made part of a population's dietary habits throughout one's life. Well Established and regarded government agencies, like the FAO and WHO might play a crucial role in motivating and encouraging restaurants, hotels, colleges hospitals and schools to provide the plant origin food substitutes, interact on the social platforms and media to market a healthy vegetarian life-style, and supply plant origin food's nutritional steering to all our health professionals.

4. CONCLUSION

COVID-19 era has been a novel situation for everyone in which dietary habits are being the most affected as people are more and more concerned with eating health promoting plant-based diet foods. The market of animal-based food was seen declining during this period which is again expected to regain the pre pandemic state with time. Disease situations, lockdowns and food myths have changed the food patterns, which has led to food insecurity and shortage of

certain foods in the market. Multi-disciplinary health specialists and authorities working globally ought to collaborate with each other to provide and implement common sense and find the solutions to the dietary issues. Emphasis should be given on complete eradication, or at least fairly reduce using farm and wild animals for any specific purpose, notably as food source, so as to diminish future pandemics because of zoonosis.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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