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Survival in Pandemic Times: Managing Energy Efficiency, Food Diversity, and Sustainable Practices of Nutrient Intake Amid COVID-19 Crisis

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The COVID-19 pandemic led to an economic crisis and health emergency, threatening energy efficiency consumption, sustainable food diversity, and households' nutrition security. The literature documented that environmental threats can divert attention from renewable energy and food security challenges that affect humans' environmental behaviors. The COVID-19 crisis has consistently influenced environmental behaviors, as it primarily decreased income and disrupted food systems worldwide. This study investigated the COVID-19 consequences on household income, sustainable food diversity, sustainable energy consumption, and nutritional security challenges. The study used a self-structured online survey due to non-pharmaceutical restrictions and collected data from 728 households. The investigators applied t-test and logit regression to analyze the data for drawing results. Descriptive statistics show that COVID-19 has adversely affected the income of more than two-thirds (67%) of households. The pandemic has influenced households' food consumption, energy, and dietary patterns to safeguard their income. The t-test analysis indicated that households' food diversity and energy consumption significantly declined during the pandemic, and households consumed low-diversified food to meet their dietary needs more than twofold compared to pre-pandemic levels. The results showed that all nutrient consumption remained considerably lower in the COVID-19. Cereals are the primary source of daily dietary needs, accounting for over two-thirds of total energy and half of the nutrient consumption amid COVID-19. The share of vegetables and fruits in household energy consumption dropped by 40 and 30%. Results exhibited that increasing monthly income was inversely associated with worsening food diversity and intake with energy efficiency. Compared with farmers and salaried employment, wage earners were 0.15 and 0.28 times more likely to experience a decline in consuming food diversity. Medium and large households were 1.95 times and 2.64 times more likely than small, to experience decreased food diversity consumption. Launching a nutrition-sensitive program will help minimize the COVID-19

impacts on energy consumption, food diversity, and nutritional security for low-income individuals. This survey relied on the recall ability of the households for the consumed quantities of food commodities, which may lack accuracy. Longitudinal studies employing probability sampling with larger samples can verify this study's insightful results.

Keywords: energy efficiency, COVID-19, sustainable practices, dietary diversity, nutrients; energy intake, technolog innovation

INTRODUCTION

The sustainable practice of energy efficiency products are useful to deal with environmental problems. In the global society, humans need sustainable economic growth for better lifestyles. In the prevailing challenging crisis, technology-driven circular economy practices in energy production and consumption patterns are useful as technology-led circular economy's sustainable practices help achieve energy efficiency and human food consumption patterns. The COVID-19 crisis that began in late 2019 posed massive consequences on individuals' lives across the globe (IEA, 2020). Experts expect that this pandemic economic and health crisis can become a turning point for the present world (NCOC, 2021). Public trust in energy-saving knowledge for renewable energy consumption amid COVID-19 has become a challenging situation (Rosak-Szyrocka et al., 2021a; Rosak-Szyrocka and Żywiołek 2022; Żywiołek et al., 2022). It has influenced people in adopting more sustainable lifestyles to consume efficient energy resources to minimize environmental issues (Kanda and Kivimaa, 2020; Muhammad et al., 2020; Sarkis et al., 2020). Some studies have warned that the pandemic situation can divert experts' concentration from ecological issues and weaken pro-environmental motivations and behaviors (Rosenbloom and Markard, 2020). However, past literature evidence-related to environmental stimulants and behavioral shifts stay fragmented (Weersink et al., 2020). Several past studies have identified enriched environmental motivation (O'Connor and Assaker, 2021; Schiller et al., 2021). Some studies have not found the major effects of economic crises on public environmental motivation (Lucarelli et al., 2020; Rousseau and Deschacht, 2020; Rousseau et al., 2021).

Likewise, some studies have reported increased global environmental friendly behaviors (Rosak-Szyrocka et al., 2021b; Żywiołek et al., 2021). It includes recycling and waste disposal, sustainable food consumption, energy efficiency (Tiwari et al., 2022), and sustainable travel behavior (Kim et al., 2021; O'Connor and Assaker, 2021; Tchetchik et al., 2021). Some studies identified more environmentally harmful human behaviors, such as increased usage of plastic products (Prata et al., 2020). Food consumption, technology-enabled energy efficiency and nutriment security exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 1996). According to this definition, food security has four dimensions, which are food availability, food access, utilization, and stability. Each dimension of food security also emphasizes nutritional considerations and the term "food and nutrition security" is used to differentiate between quantity and quality (Thompson et al., 2009). Food and nutritional insecurity are attributed to many complex and multidimensional factors like low education level, limited employment opportunities, an abundance of unskilled workers, poor infrastructure, market interventions, inflation, gender discrimination, food waste, and shortages (Cole et al., 2018; Haq et al., 2021). These factors along with climate change and economic slowdowns were responsible for increasing food consumption insecurity in developing countries (FAO et al., 2019; FSIN, 2020).

The provision of sufficient energy and sustainable practices of nutritious food security to the large population of the world is an enormous challenge faced by the global food systems with energy efficiency challenges. The world is still a home of more than 0.8 billion hungry people and about 2 billion people are consuming a nutrient-poor diet disturbing their growth and life expectancy (FAO et al., 2019). Therefore, more than one-fourth of the world's total population is obese and more than 462 million individuals are underweight (WHO, 2020a). A large proportion of the nutrient-deficient people live in low and middle-income countries (WHO, 2020b). COVID-19 is further deteriorating the food consumption items and nutrition insecurity situation in the world and the numbers related to food-insecure people are likely to increase dramatically around the world especially in low and middle-income countries.

COVID-19 pandemic is a health and economic crisis threatening the food and nutrition security of vulnerable communities worldwide primarily through decreasing income and disrupting food systems. Income impacts of COVID-19 are likely to be severe for the people residing in low and middle-income countries due to already widespread unemployment in these countries and public health measures will further diminish the livelihood opportunities. People will have to buy low-cost and fewer food items to feed their families declining the demand for nutrient-rich food items. Moreover, non-pharmaceutical measures taken globally to contain COVID-19 infections disrupt the nutrition of households by affecting all processes of the food supply chain (production, processing, distribution, consumption, and disposal) especially for perishable farm commodities (vegetable, and fruits) which are an important source of necessary nutrients (Headey and Ruel, 2020). Market distortions triggered by COVID-19 and non-pharmaceutical measures disrupt food market equilibrium and cause price instability. This can instigate people to shift from diversified food consumption of nutrient-rich perishable commodities to less costly nutrient deficient and monotonous diets (Headey and Alderman, 2019). As a result prevalence of malnutrition is likely to increase among people. Malnutrition occurs when an

individual's food does not contain the required amount of necessary nutrients. Nutrients such as protein, calcium, phosphorus, iron, zinc, and iodine are needed only in smaller quantities to maintain good health and growth but a lower intake of these nutrients than the required amount can have severe consequences on human health. Perishable commodities like vegetables, fruits, meat, fish, etc. are considered nutrient-rich foods worldwide and therefore, consumption of diverse food commodities is necessary to obtain these nutrients in the required quantity (energy, protein, calcium, phosphorus, zinc, iron, and iodine). Lower intake of these essential micronutrients than recommended quantity can have severe consequences on the health and well-being of the people (WHO, 2020a). Thus, the COVID-19 outbreak poses an additional threat to global food and nutrition security.

The adverse COVID-19 impacts will not uniformly distributed among sectors, regions, societies, and countries due to differences in resources and some sectors will be hit harder compared to others. Similarly, circular economy (CE) describes a model of consumption and production that involves multiple activities like sharing, reusing, restoring and recycling to improve the life cycle of the product (Lehmann et al., 2022). The circular economy explores the circular business model (Awan et al., 2020; Alhawari et al., 2021). Hence, CE described extensive changes production as well as in consumption (Camacho-Otero, et al., 2018). The majority (40–85%) of the food producers in developing countries consists of small producers and the COVID-19 outbreak adversely affected the ability of these producers resulting in food shortages in these countries. Moreover, COVID-19 had devastating effects on the livelihood sources of the poor population, and more than 71 million people were added into severe poverty (UN, 2021). The situation is particularly worrisome in light of the evolving nature of the COVID-19 pandemic for developing countries. Ultimately, the pandemic outcomes, social distancing and public preventive attitudes severely influenced the economies (Aqeel et al., 2021; Li et al., 2021; Paulson et al., 2021; Aqeel et al., 2022; Ge et al., 2022; Yu et al., 2022). The circular economy's principle can play a vital role in rehabilitating the economies from the crises of production and consumption (Awan and Sroufe 2019; Ikram et al., 2021). The consumer plays a crucial role in purchasing, using, and discharging the used products (Maitre-Ekern and Dalhammar, 2019). Circular economy regarding food systems entails "generating the minimum waste in the food system, utilizing by-products and food waste, re-use of food, nutrient recycling, and changing diet towards more diverse and more efficient food patterns" (Jurgilevich et al., 2016) (Bhutto et al., 2021; Cheng et al., 2021; Rashid Khan et al., 2021).

Pakistan is a developing country and the food and nutrition security situation was already dire in Pakistan before the COVID-19 outbreak. In Pakistan, the majority of the people was consuming fewer food items lacking essential nutrients (Abbas et al., 2021; Aman et al., 2022; Liu et al., 2022; Rahmat et al., 2022; Yao et al., 2022). More than one-fifth of the country's total population was undernourished and COVID-19 crisis has made it worst (Abbas 2020a; Shuja et al., 2020a; Abbas 2021; Wang et al., 2021; Zhou et al., 2021; Fu and Abbas 2022). More than 52 million people were earning less than 1.25 dollars per day (FAO, 2020a) and two-fifth of the total population was multi-dimensionally poor. Similarly, more than 17% of the total children under the age of 5 years faced stunted growth in the country (FAO et al., 2019). More than 70% of the population uses iodine less than body requirement (GNR, 2020). The nutrition security will further deteriorate in the country and the nutrient deficiency problem is expected to increase significantly due to the COVID-19 pandemic in the country (Abbas 2020b; Shuja et al., 2020b; Mamirkulova et al., 2022), especially in those regions, which have already a high prevalence of food and nutrition insecurity (FAO, 2020b).

The Government of Pakistan adopted non-pharmaceutical measures like wearing a mask, restricting movement and social gathering, suspension of intercity and interprovincial traveling. Further, shifting educational institutions to online through technology-enabled tools, lockdowns at the micro and macro level, and making PCR test and quarantines compulsory for inbound passengers to control the spread of the pandemic in the country due to absence of authentic cure and insufficient vaccines during the pandemic period (Haq et al., 2020). No doubt that these measures assist the government to contain the spread of viral disease in the country but the COVID-19 pandemic and public health measures also have adverse impacts on the economy; as a result, poverty is projected to increase by 33.3% in the country (Rasheed et al., 2021). Even though COVID-19 is affecting the livelihood of the majority of the population, the informal workforce who are 73% of the total labor force working outside agriculture will be hardest hit by COVID-19 and millions of those workers can lose their livelihood source (Bokhari, 2020; Islam et al., 2020).

The government of Pakistan is trying hard to minimize the adverse impacts of COVID-19 on the income and nutrition of the poor people by providing direct cash transfers but the limited economic resource of the country is a hurdle in meeting the needs of all the vulnerable communities in the country. Except for providing cash transfer to the people, the government also adopted an expansionary monetary and fiscal policy to minimize the impacts of COVID-19 on the economy (GoP, 2021). Even though the government took different policy initiatives to minimize the adverse effects of the pandemic on food and nutrition security, they are no panacea.

Although several studies explored the impact of COVID-19 on food consumption patterns, none of the prior studies measured the impact of COVID-19 on nutritional quantity and quality of households (Eftimov et al., 2020; Shahbaz et al., 2021b; Galali, 2021; Grant et al., 2021; Güney and Sangün, 2021; Huber et al., 2021; Janssen et al., 2021; Shahbaz et al., 2022). In the challenging situation of the pandemic, the vaccine availability is not easy to access (Su et al., 2021a; Su et al., 2021b; Su et al., 2021c; Su et al., 2021d). Besides, the literature related to the effects of COVID-19 on the daily intake of essential nutrients is also rare. This study aimed to bridge this gap in the fresh literature. This study has addressed this identified gap in the literature.

This research first intended to look at the quantity (energy efficiency) and quality (food diversity) of food consumed by households before and during the COVID-19 period. The

study hypothesized that food and nutrition security had deteriorated during the 1-year COVID-19 outbreak. The study's second objective was to compare the intake of essential nutrients needed for body growth before and during the COVID-19 periods. The hypothesis was that nutrient intake during the pandemic had decreased compared to the normal period. The third objective was to determine the share of different food groups in energy and nutrient provision to the households before and during COVID-19. The hypothesis was that the efficient energy intake and nutrients from perishable food commodities (vegetables and fruits) decreased during COVID-19 than during normal periods. Besides, this research also explored the factors determining whether sustainable practices of food diversity and energy efficiency deteriorated during the COVID-19 period.

This study is the first that explores the sustainable practices for energy efficiency goals, food consumption, and nutrition security of households during the pandemic. It would assist in yielding significant contributions for helping decision-making on sustainable practice to meet energy efficiency goals, sustainable dietary consumption, and how technology-enables tools helped humans in the COVID-19 pandemic in Pakistan and worldwide. This pandemic's economic crisis has affected environmental behaviors, sustainable food consumption, and green decision-making to achieve energy efficiency. This study investigates the degree of change in the environmental behavioral change of people for green energy and sustainable food consumption. This research provides valuable insights for decision-makers to note individuals' environmental behavior for seeking green energy and sustainable consumption of food with its potential drivers in the ongoing economic crisis. This research study significantly contributes to the growing scientific literature, which helps us understand, predict, and avoid potential negative consequences on individuals' environmental inspirations and behaviors caused by the COVID-19 crisis and similar economic and health crises that may arise again the future. Such emergencies cause economic and ecological challenges for humans worldwide. This study provides important implications for health experts and policymakers who emphasize lower food and nutrition security. Most importantly, this study helps to cope with any emergency environment that might arise in the future again. This study's potential beneficiaries include government departments, stakeholders' of food supply chain, and nutritionists, who are primarily responsible for ensuring healthy and sustainable human health.

MATERIALS AND METHODS

Questionnaire and Data Collection

This current research employed online survey for data collection due to rising infections and non-pharmaceutical measures imposed by the government to contain the viral disease in the country (Aman et al., 2021; Moradi et al., 2021a; Paulson et al., 2021; Farzadfar et al., 2022). A well-structured questionnaire consisting of three main sections was constructed on Google form and the link was shared through social media and communication applications like WhatsApp, Facebook, Instagram, and email. The first section of the questionnaire was about the socioeconomic characteristics of the households (Yoosefi Lebni et al., 2020; Moradi et al., 2021b). The second section of the questionnaire was about the impact of COVID-19 on income and coping strategies adopted by households to mitigate the income effect (Shuja et al., 2020a; Maqsood et al., 2021). The third section was about the consumption of 69 daily food items, which are a part and parcel of households' kitchens. Of the food items used in the study, 3 were cereals, 27 were vegetables, 17 were fruits, 4 were milk and milk products, 8 were pulses, 5 were meat items, 2 were fat and oil, and 3 were spices. This section was divided further into subparts according to the categorization of food items in the country. The data collection instrument did not include food items such as chocolates, sweets, biscuits, cakes, etc. which are used only on special occasions like birthdays and marriage ceremonies in the country. The potential respondents were informed about the purpose and time required to complete the information before starting the survey and only after getting consent to participate and publish the results of this study, they were guided toward the survey. The formula by Krejcie and Morgan (1970) is helpful for researchers and we also employed this formula to draw the desired sample size for the present study.

$$n = \frac{X^2 * N * P * (1 - P)}{d^2 * (N - 1) + (X^2 * P * (1 - P))}$$

Where.

n = Sample size.

X^2 = Chi Square for specified confidence level at 1 degree of freedom.

N = Population Size = (Total households in Pakistan).

P = Population proportion (Assumed 0.50 here).

D = Margin of error (3.6 % in current study).

This formula resulted in a total sample size of 725 for the current study. The investigators collected data through an online survey from 740 households in February and March 2021. The study conducted initial screening, removed 12 incomplete responses, and eliminated them from the final analysis. Therefore, we performed the final analysis based on 728 responses. The questionnaire was prepared in the national language (Urdu) for better understanding to ensure the participation of the maximum number of households. The respondents enquired about their gender, residential district, and area. The results showed that both female and male participants adequately represented their respective population segments. Besides, the households recruited for this survey belong to regions scattered in rural and urban areas all over the country.

Conceptual Framework

The conceptual framework of this research comprises four main constituents: the first component is COVID-19 and non-pharmaceutical measures; the second component is COVID-19 impacts; the third component is household characteristics, and the fourth component of the study is the dietary intake of households (**Figure 1**). The implications of COVID-19 are the

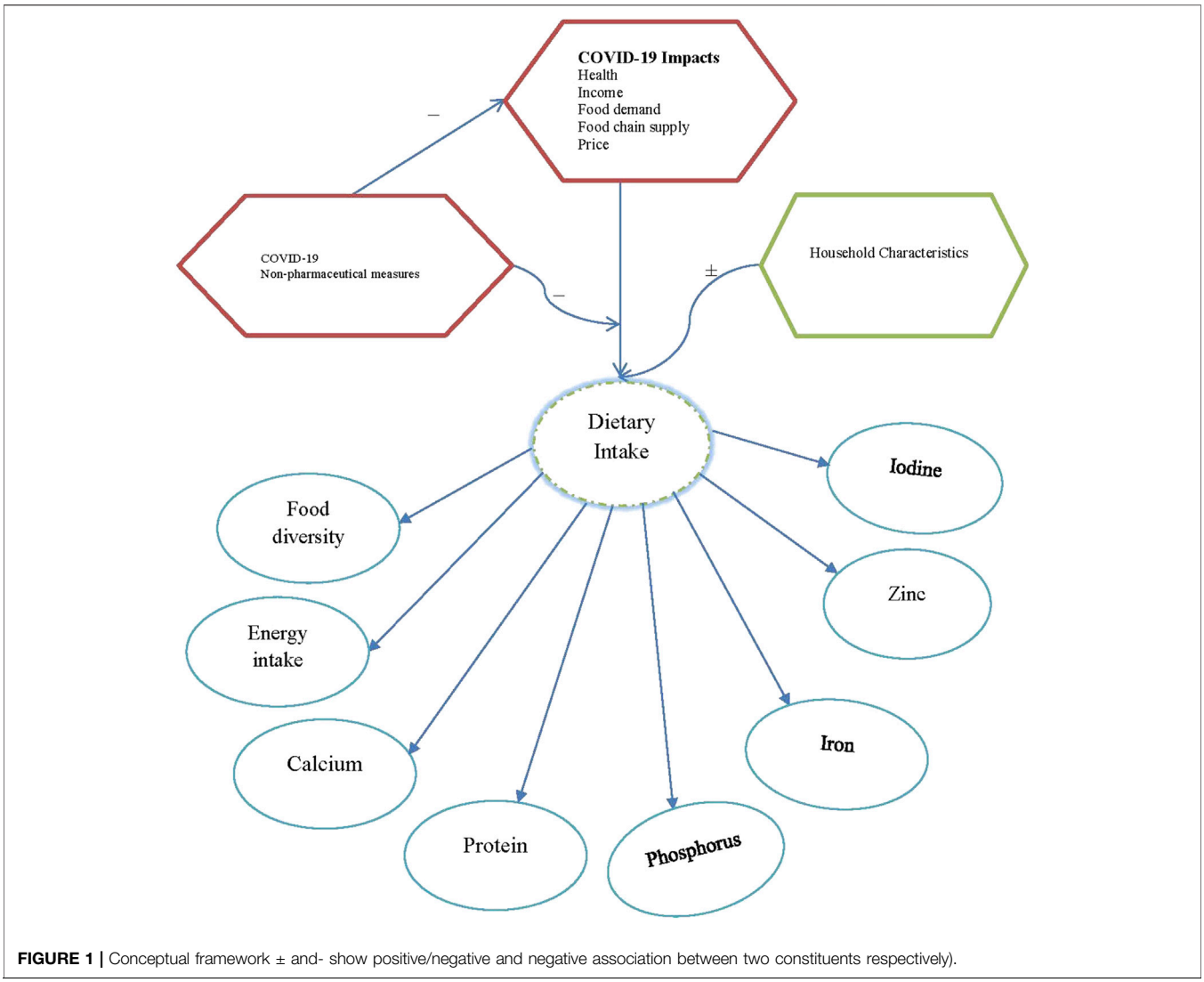

FIGURE 1 | Conceptual framework ± and- show positive/negative and negative association between two constituents respectively).

witnessed and predicted adverse effects of the pandemic on society in the country. For instance, the pandemic has changed households' food purchasing and eating behaviors (Ben Hassen et al., 2021). Similarly, COVID-19 has also adversely affected the socio-economic conditions of the households (Carroll et al., 2020). Moreover, the COVID-19 pandemic has left millions of people unemployed (Fana et al., 2020), decreased income (Radulescu et al., 2020; Shahbaz et al., 2021a), restricted mobility and logistics (Haq et al., 2020; An et al., 2021), distorted food supply chains (Aday and Aday, 2020), and increased food prices worldwide (Asante and Mills, 2020). These multi-dimensional impacts of the pandemic affect the dietary intake of households. Therefore, the current linear production and consumption system exert tremendous pressure on the current food systems (Giudice et al., 2020). There is a need for a new economic model that generates a sustainable food system. This model should increase the volume of circulating nutrients and matter, reduce food wastage, and diversify the consumption of nutrients parallel to the minimum use of auxiliary inputs such as energy (Jurgilevich et al., 2016). The dietary intake here refers to food diversity, energy intake, and consumption of necessary nutrients like protein, calcium, phosphorus, iron, zinc, and iodine. Moreover, household characteristics are also important determinants of dietary intake during COVID-19 as some people will be affected more than others depending on socioeconomic status, gender, and livelihood sources.

Measuring Food Diversity and Important Nutritional Indicators

Food diversity is a vital measure of diet quality and intake of various food commodities within or across diverse food groups delivers both the required energy and nutrients necessary for healthy growth and body development (Haq et al., 2021). Food items that are a regular part of a household's diet is classified into six food categories in Pakistan namely cereals, vegetables, fruits, meat and pulses, dairy products, and fats and oils (FAO and GoP,

2021). The households must consume food items proportionally from all food categories to achieve high food or diet diversity. Thus, households consuming food items from a few food categories will have lower food diversity compared to those households consuming food items from more food categories. The Simpson index was used to measure the food diversity of the households in this study which not only indicates diversity in the diet but also used to indicate the nutritional sufficiency of families (Ruel, 2003; Nguyen and Winters, 2011). Energy (calorie) share of each food category was used to estimate the food diversity of households by using the below formula;

$$FD = 1 - \sum_{c=1}^{n} p_i^2$$

Where.

FD = Food diversity

$p_{i=}$Energy share of the *i*th food category

n = Total food categories

c = 1 . . . . . 6.

Simpson diversity index's value remains between 0 and 1. Here, 1 indicates the infinite food diversity and 0 shows no food diversity. The respondents were also categorized based on their food diversity scores into low (0.00–0.33), moderately (0.34–0.66), and highly (0.67–1.00) diversified households. Thus, food diversity was estimated for households before and during COVID-19.

Except computing food diversity for the households, daily intake of energy (kcal) and important nutrients (calcium, protein, phosphorus, iron, zinc, and iodine) essential for the human body was also estimated from the food items consumed by the households. A composite food table index jointly prepared by FAO and GoP (2001) was used to estimate the daily intake of nutritional indicators during the normal and COVID-19 period from the consumed amount of food items for the households. A normal adult needs 1,600–3,000 kcal/day to sustain the body weight (Zawn, 2021). Therefore, households were divided into three groups according to their per day calorie consumption. Households consuming <1,600 kcal/day were categorized as low, households taking 1,600–3,000 kcal/day were considered normal, and households with daily intake >3,000 were considered as high-calorie consumptions.

Moreover, to check whether food diversity, energy intake, and important nutrients had worsened or not, quantities of nutritional indicators during COVID-19 were subtracted from normal period quantities and the difference greater than zero indicated a worsened nutritional security for the households.

Empirical Methods

The collected data were analyzed by using descriptive statistics (mean, frequency, and standard deviation), t-test, and logit regression model. Household characteristics and coping measures adopted to minimize the impact of COVID-19 on income were examined through descriptive statistics. The difference in food diversity, energy, and nutritional indicators' intake before and during COVID-19 was analyzed by using the t-test. Moreover, determinants of whether food diversity and energy intake of households had worsened during the COVID-19 pandemic were investigated through logit regression expressed as

$$y_i = \alpha_i + \beta 1 F_i + \beta 2 L_i + \beta 3 I_i + \lambda x_i + \mu$$

Where.

yi = binary outcome variable for household.

B1, β2, and β3 are parameters of family size (F), livelihood source (*L*), and monthly income I for *i*th household

x_i = *i*th Household's characteristics

β = Household characteristics' coefficient.

α_i = Constant

μ = error term.

Two separate logit regression models were used to determine the determinants of food diversity and energy intake of households. In the first model, y takes the value 1 if the food diversity of a household was worsened due to COVID-19 and 0 otherwise. In another model, y was assigned the value 1 if the energy intake of households deteriorated during COVID-19 than normal periods and 0 otherwise. Family size, monthly income, and source of livelihood are three predictors of key interest in the study. Thus, the research mainly focused that how food diversity and energy intake of households with different family sizes, income sources, and monthly income levels are affected by the COVID-19 pandemic. The household was categorized into low (>PKR50000), medium (PKR50000-PKR100000), and high income (<PKR100000) quantiles according to their monthly income. The other predictors used in the study were household characteristics such as age, gender, educations, residential area, agricultural land, and market possession of agricultural land.

TABLE 1 | Summary of the households' characteristics.

Characteristics	Mean	Standard Deviation
Gender (Female = 1)	0.42	0.49
Age of the respondent (Years)	47.58	11.73
Education (Years)	11.05	4.76
Residence (Rural = 1)	0.57	0.49
Agricultural land (Acre)	3.98	7.68
Family size (Members)		
Small (0–4)	0.23	0.51
Medium (5–8)	0.52	0.50
Large (>9)	0.25	0.43
Livelihood source		
Farming	0.26	0.39
Salaried employment	0.24	0.44
Self-employment	0.19	0.42
Foreign remittances	0.17	0.34
Wage	0.14	0.28
Monthly income quantile (PKR)		
Low (<50,000)	0.63	0.35
Medium (50,000–100,000)	0.26	0.32
High (>100,000)	0.11	0.32

1 USD = PKR193, as of 15 May 2022.

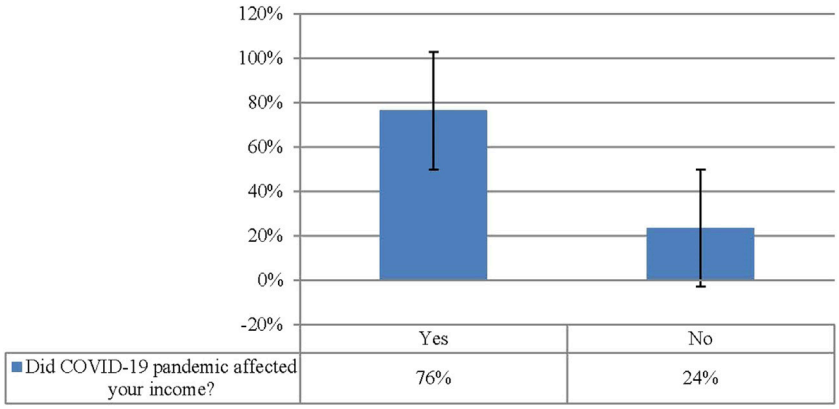

FIGURE 2 | Income impact of COVID-19 pandemic.

RESULTS AND DISCUSSION

The sustainable practice of energy efficiency products ar useful to deal with environmental problems. In the global society, humans need sustainable economic growth for better lifestyles. In the prevailing challenging crisis, technology-driven circular economy practices in energy production and consumption patterns are useful as technology-led circular economy's sustainable practices help achieve energy efficiency and human food consumption patterns. The COVID-19 crisis that began in late 2019 posed massive consequences on individuals' lives across the globe (IEA, 2020). Experts expect that this pandemic economic and health crisis can become a turning point for the present world. It has influenced people in adopting more sustainable lifestyles to consume efficient energy resources to minimize environmental issues (Kanda and Kivimaa, 2020; Muhammad et al., 2020; Sarkis et al., 2020). Some studies have warned that the pandemic situation can divert experts' concentration from ecological issues and weaken pro-environmental motivations and behaviors (Rosenbloom and Markard, 2020). However, past literature evidence-related to environmental stimulants and behavioral shifts stays fragmented. Several past studies have identified enriched environmental motivation (O'Connor and Assaker, 2021; Schiller et al., 2021). Some studies have not found the major effects of economic crises on public environmental motivation (Lucarelli et al., 2020; Rousseau and Deschacht, 2020; Rousseau et al., 2021). (Schacht and von Zimmerman, 2020; Čadová, 2020). Likewise, some studies have reported increased global environmental friendly behaviors. It includes recycling and waste disposal, sustainable food consumption, energy efficiency, and sustainable travel behavior (Kim et al., 2021; O'Connor and Assaker, 2021; Tchetchik et al., 2021). Some studies identified more environmentally harmful human behaviors, such as increased usage of plastic products (Prata et al., 2020).

This study is the first that explores the sustainable practices for energy efficiency goals, food consumption, and nutrition security of households during the pandemic. It would assist in yielding significant contributions for helping decision-making on sustainable practice to meet energy efficiency goals, sustainable dietary consumption, and how technology-enables tools helped humans in the COVID-19 pandemic in Pakistan and worldwide. This pandemic's economic crisis has affected environmental behaviors, sustainable food consumption, and green decision-making to achieve energy efficiency. This study investigates the degree of change in the environmental behavioral change of people for green energy and sustainable food consumption. This research provides valuable insights for decision-makers to note individuals' environmental behavior for seeking green energy and sustainable consumption of food with its potential drivers in the ongoing economic crisis. This research study

TABLE 2 | Measures to minimize COVID-19 income impact with regular income source (%).

Adopted Strategy	Farming	Salaried Employed	Self-Employed	Foreign Remittances	Wage Earner
Borrowing	31.58	22.73	29.30	26.98	27.66
Credit	21.05	20.45	15.49	3.17	19.15
Using previous saving	36.84	39.77	56.34	61.90	12.77
Sold house items/livestock/land	25.26	9.09	11.27	12.70	25.53
Government support	3.37	0.00	1.08	2.94	4.77
Charity/help	3.16	0.00	0.00	14.29	25.53
Cultivation of own kitchen items	33.26	10.23	33.80	9.52	17.02
Stop purchasing non-food items	20.00	18.18	36.62	30.16	50.94
Change in dietary pattern	35.79	30.68	66.20	53.97	70.21

Multiple options.

TABLE 3 | Food diversity and daily per capita energy intake situation in pre and during COVID-19.

Food Diversity	Pre-COVID 19	During COVID-19
	0.48	**0.45***
Energy intake (kcal/day)	2427.61	2126.66*
Food diversity categories (Simpson index score)		
Low (0.00–0.33)	0.17	0.36*
Moderately (0.34–0.66)	0.67	0.53*
High (0.67–1.00)	0.16	0.11*
Energy intake categories (Kcal/day)		
Low (0–1,599)	0.20	0.33*
Normal (1,600–3,000)	0.55	0.49**
High (>3,000)	0.25	0.18*

*, and ** show that the mean is statistically different at 1 and 5% respectively.

TABLE 4 | Mean daily per capita nutrient intake situation before and COVID-19 period.

Nutrients	Pre COVID-19	During COVID-19
Protein (g/day)	98.88	87.96[a]
Calcium (mg/day)	514.30	452.06[a]
Phosphorus (mg/day)	1108.48	990.97[a]
Iron (mg/day)	30.63	27.29[a]
Zinc (mg/day)	20.21	18.00[a]
Iodine (ug/day)	85.37	76.26[a]

[a]*Show that the mean is statistically different at 1%.*

significantly contributes to the growing scientific literature, which helps us understand, predict, and avoid potential negative consequences on individuals' environmental inspirations and behaviors caused by the COVID-19 crisis and similar economic and health crises that may arise again in the future. Such emergencies cause economic and ecological challenges for humans worldwide.

Socio-Economic Characteristics of the Households

Socioeconomic characteristics of the households affect the dietary choices and consumption of food items. **Table 1** depicts the summary of the socioeconomic characteristics of the participating households. More than two-fifths of the total households consisted of females. The average age of the participants was 47.58 years. The mean education of the households was more than 11 years. The education level of the households participating in this study was higher compared to the previous studies conducted in the country. This is not surprising as the survey was conducted online expected to be completed by the people who were using social media applications and could answer the queries without any support. Almost three-fifths of the total households were living in rural areas. The reason may be that more than 60% of the country's population still resides in rural areas (PBS, 2018). The average agricultural landholding was less than 4 acres. The findings related to family size revealed that more than half of the total households consisted of medium size families. Only less than one-fourth of total households had small families. The plausible explanation of large family size is that majority of the households live in a joint family system in the country and more than one family lives under one roof headed by a single member of the family (Haq et al., 2021). Farming was the regular source of income for more than one-fourth of the households. Foreign remittances from millions of overseas Pakistanis working outside the country are also an important source of income for their households as well as for the economy of the country. Moreover, agriculture and remittances play an important part to decrease poverty among households (Liu et al., 2020). This was also depicted in the finding, as a large proportion of the participating households were dependent on foreign remittances. The other main livelihood sources were salaried employment, self-employment, and wages. Almost two-thirds of the households belonged to low-income quantile and more than one-third of the household belonged to medium-income quantile. This might be because Pakistan belongs to the lower-middle-income category of countries (World Bank, 2020). See **Table 1** below.

Impact of COVID-19 on Income

There is consensus among the scientific community that COVID-19 will have severe implications on the income of the households without discriminating ethnicity, society, region, and border. The level of severity may vary among different groups as people already poor are likely to suffer more due to COVID-19 (Kansiime et al., 2021). More than two-thirds of the participating households affirmed that the COVID-19 had negatively affected their earnings (**Figure 2**). Besides income effect, households also cited other challenges like stress, anxiety, restricted social gathering, and interpreted work schedules faced due to COVID-19.

Coping Measures to Minimize COVID-19 Pandemic Effect on Income

Table 2 disaggregates the measures by the regular livelihood source adopted by the respondents to cushion the severe implications of the pandemic on their income. More than two-thirds of the self-employed and wage workers were forced to change their dietary pattern during the COVID-19 pandemic which was also the most adopted measure by the households dependent on foreign remittances and farming indicating the severity of the impact on their main livelihood source. The reason may be the countrywide lockdown imposed to contain the spread of the viral disease. More than one-third of the households engaged in self-employment and farming activities for their livelihood started to cultivate their kitchen commodities like vegetables. The possible explanation may be COVID-19 induced supply/demand shocks creating market instability leading to inflation. The prices of food commodities increased more than 4% during COVID-19 compared to the previous year (Neill, 2021). Moreover, the negative impact of COVID-19 also forced households to stop buying non-food items (clothes, and shoes) to minimize the impact of the pandemic on their income, and more than a half and one-third of the households dependent on wages and self-employment respectively, took this measure.

TABLE 5 | Share of food groups in daily per capita energy and nutrients before and during COVID-19.

Food Group	Energy		Protein		Calcium		Phosphorus		Iron		Zinc		Iodine	
Items	**Before Covid-19**	**During Covid-19**	**Before Covid-19**	**During Covid-19**	**Before Covid-19**	**During Covid-19**	**Before Covid-19**	**During Covid-19**	**Before Covid-19**	**During Covid-19**	**Before Covid-19**	**During Covid-19**	**Before Covid-19**	**During Covid-19**
Cereals	1646.89	1471.68	48.10	43.81	143.07	129.80	581.73	517.42	20.07	18.24	13.15	11.96	23.55	22.75
Vegetables	158.91	113.83	6.04	4.86	115.25	96.61	133.41	109.53	4.20	3.59	1.21	1.04	31.09	26.30
Fruits	66.95	61.70	1.14	0.82	24.71	18.22	25.14	17.93	1.01	0.72	0.23	0.21	3.64	2.77
Dairy products	60.01	58.29	3.67	3.55	130.07	125.25	102.95	98.88	0.56	0.54	0.34	0.33	2.77	2.19
Meat and pulses	277.26	227.90	25.17	22.25	92.43	73.94	258.95	241.14	4.38	3.80	5.13	4.33	17.02	16.06
Fats and oil	208.06	184.27	14.55	12.45	8.77	8.23	6.30	6.08	0.42	0.40	0.15	0.14	7.30	6.19
Spices	9.53	9.00	0.22	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

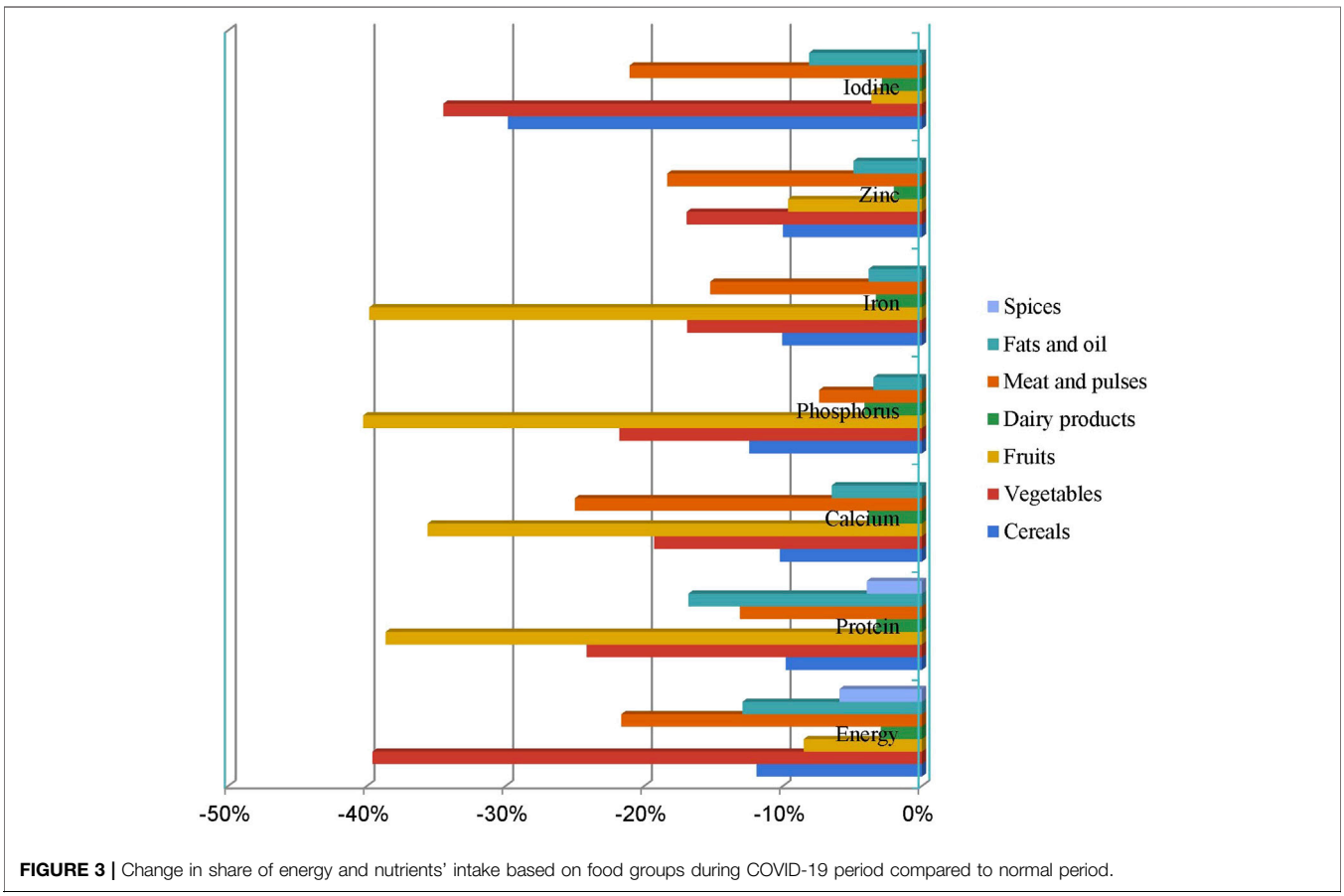

FIGURE 3 | Change in share of energy and nutrients' intake based on food groups during COVID-19 period compared to normal period.

COVID-19 wrought havoc on the world economy without border distinction and therefore, more than two-thirds of the families dependent on the foreign remittances had to use their previous savings during COVID- 19. More than one-fourth of the households having livelihood source wages and farming had to sell their assets to compensate income losses caused by COVID-19. Similarly, more than one-third of the households had to borrow from relatives, friends, family, etc. to meet their needs during a pandemic. Mawejje (2019) and Yilma et al. (2014) also reported the adoption of similar strategies by the household to decrease adverse income impacts of different disasters. See **Table 2** below.

Food Diversity and Daily Per Capita Energy Intake Before and During COVID-19

The results related to food diversity and daily energy intake revealed that the food and nutrition security situation had

TABLE 6 | Determinants of worsened food diversity.

Predictors	Coefficient	Standard Error	Odd Ratio
Gender (1 = Female, 0 = Male)	0.481**	0.23	1.618
Age of the respondent (Years)	0.004	0.01	1.004
Education (Years)	0.009	0.01	1.009
Residence area (1 = Rural, 0 = Urban)	0.121	0.219	1.128
Agricultural land (Acre)	−0.231*	0.030	0.794
Family size (Members) (a)			
Medium (5–8)	0.670**	0.270	1.950
Large (>9)	0.974*	0.310	2.640
Livelihood source (b)			
Farming	−1.873*	0.339	0.154
Salaried employment	−1.291*	0.261	0.275
Self-employment	−2.893*	0.288	0.055
Foreign remittances	−3.414*	0.330	0.033
Monthly income quantile (PKR) ©			
Medium (50,000–100,000)	−2.227*	0.335	0.108
High (>100,000)	−1.665**	0.348	0.189
Constant	2.50*	0.75	6.86

**, and ** show the statistical difference at 1%, and 5% level respectively.*

(a) = base category small family size (1–4), (b) = base category wage earners,© = base category low-income quantile (<PKR50000).

deteriorated during the 1 year of the pandemic (**Table 3**). The outcomes of food diversity also indicated that households were not consuming food items from all groups proportionally and their daily food consumption requirement was fulfilled by only a few food groups before and during COVID-19. The comparison of diversity scores before and during COVID-19 depicted that households used less diversified food during the year of COVID-19 compared to the normal period. Moreover, the proportion of households in the low diversity category had increased more than two folds during COVID-19. More than two-thirds of the households were using moderately diversified food before which decreased to half of the households during the pandemic period. The reason may be COVID-19 induced income and market shocks. The other reason for the low diversity level prevailing among household may be that calories from nutrient-rich perishable commodities such as vegetable, fruits, and meats are 10% more costly compared to calories from cereals (wheat, rice, and maize) in low and middle-income countries aggravating the shift to nutrient deficient and monotonous diets (Headey and Alderman 2019).

The per capita calorie consumption of households reduced significantly during the pandemic compared to pre-COVID-19. This may be because of the change in the dietary pattern of the households compelled by the lower-income and shrinking economy of the country during COVID-19 (World Bank, 2020). The proportion of households consuming less than 1,600 per capita kcal/day increased considerably due to the influx of 13 percent additional households during COVID-19. Households with normal and high daily per capita energy intake also decreased 6 and 7% respectively during the pandemic compared to the normal period. See **Table 3** below.

Intake of Essential Nutrients Before and During the COVID-19 Pandemic

Intake of essential nutrients in recommended quantity is necessary for good health, disease prevention, and well-being of the people. **Table 4** presents the results related to the mean daily per capita intake of vital nutrients. The findings showed that the mean per capita intake of all necessary nutrients reduced significantly during COVID-19 than the normal period. Per capita, calcium consumption was already lower among households than the recommended nutrition intake (800 mg/day) during the normal period and COVID-19 had stretched this gap further. Per capita intake of calcium and phosphorus decreased by 62 mg/day and 118 mg/day respectively during the pandemic compared to pre-COVID-19. Similarly, iron intake decreased more than 3 mg/day during COVID-19. Households were only taking half of the recommended level of the iodine (150 ug/day) before COVID-19 and the situation had become worse during pandemic as the per capita intake of Iodine during COVID-19 reduced considerably. The reason may be the use of less diversified food by the households enforced by COVID-19 induced livelihood shocks resulting in lower-income. Low income limits the ability of households to consume healthy foods (Penne and Goedemé, 2021). See **Table 4** below.

Share of Food Groups in Daily Per Capita Energy and Nutrients' Intake

Table 5 depicts the disaggregated share of each food group in daily per capita energy and nutrients delivery to the households. Per capita, energy, and nutrient intake from all seven groups of the food items declined noticeably during the COVID-19 period than the normal period. Cereals were the main source of energy and all essential nutrients for the households before and during COVID-19 periods. Cereals accounted for more than two-thirds

TABLE 7 | Determinants of deteriorated daily per capita energy intake (kcal/day).

Predictors	Coefficient	Standard Error	Odd Ratio
Gender (1 = Female, 0 = Male)	0.42*	0.196	1.525
Age of the respondent (Years)	0.007	0.009	1.007
Education (Years)	−0.011	0.010	0.989
Residence area (1 = Rural, 0 = Urban)	−0.073	0.186	0.93
Agricultural land (Acre)	−0.038**	0.013	0.962
Family size (Members) (a)			
Medium (5–8)	0.269	0.276	1.308
Large (>9)	0.190	0.310	1.201
Livelihood source (b)			
Farming	−0.666*	0.260	0.514
Salaried employment	−0.454**	0.215	0.635
Self-employment	−1.175*	0.217	0.309
Foreign remittances	−1.364*	0.248	0.256
Monthly income quantile (PKR) ©			
Medium (50,000–100,000)	−0.9*	0.269	0.406
High (>100,000)	−0.658*	0.276	0.518
Constant	1.58*	0.468	4.853

**, and ** show a statistical difference at 1%, and 5% level respectively.*

(a) = base category small family size (1–4), (b) = base category wage earners,© = base category low-income quantile (<PKR50000).

of the total daily per capita calories intake before and during the COVID-19 period. Even though the amount of the calories provided during COVID-19 decreased significantly, the overall percentage share in the total calories provision remained unchanged. The results corroborate with the previous study by Haq et al., 2020 who also reported that more than 66% of the calories were provided by cereals in the Punjab province of Pakistan. Similarly, cereals also accounted for one-half of the daily per capita proteins, phosphorus, iron, and zinc of the households. Meat and pulses were the second-largest contributing group to the daily per capita energy intake accounting for more than 11% percent of the total calories consumed by the households during and normal COVID-19 period. Fats and oils were also important sources of energy for the households. The share of the dairy products in energy and nutrient provision remained stable during COVID-19. The possible explanation may be that dairy products are self-produced by households without dependence on the market. The share of the vegetable in the daily per capita calorie supply to the households reduced 55 kcal/day during COVID-19. It shows the decrease in the consumption of vegetables and this may be because the market interruption caused by COVID-19 prompted supply and demand shocks. See **Table 5** below.

Change in Share of Energy and Nutrients' Intake Based on Food Groups During Pandemic Compared to Normal Period

Figure 3 displays the percentage change in energy and nutrients' intake segregated by food groups. Daily per capita energy and nutrients intake of the households witnessed the highest decrease from perishable farm commodities (vegetable, and fruits) among all food groups during the COVID-19 period compared to the normal period. For example; daily per capita, energy intake from vegetables decreased 40% during the pandemic in comparison to pre-COVID-19. Similarly, the daily per capita intake of all nutrients except zinc from fruits decreased by more than 30% during 1 year of COVID-19 than the normal period. The results agree with the previous study by Harris et al. (2020) who also reported that people prefer cheaper foods over expansive nutrient-rich perishable commodities. The share of cereals in households' daily per capita intake also decreased more than 9% among all nutrients during COVID-19. Similarly, the share of meat and pulses also shrank more than 22% in daily per capita energy, and calcium intake during COVID-19 while this contraction was more than 18% in zinc consumption. The COVID-19 will have severe implications on all four dimensions of food security by disrupting all stages of the food supply chain. Similarly, public health measures taken by the countries can destroy perishable commodities fruits and vegetables (Laborde et al., 2020; Nicola et al., 2020). Even in advanced countries like Canada overstocked perishable commodities were destroyed or dumped (Bellany and Corkery, 2020). Besides, the increasing prices and lower-income could also be one of the main reasons affecting the consumption of farm commodities ultimately leading lower level of nutrition intake.

Determinants of Worsened Food Diversity During COVID-19

Female households were 1.618 times more likely to suffer from worsened food diversity during COVID-19 compared to males (**Table 6**). The reason might be that females had scarce opportunities to work already compared to males in the country and the COVID-19 pandemic has made these chances scanter. The other reason could be that the average labour force participation of females was only 21% compared to males (81%) % in Pakistan (International Labour Organization, 2020) due to

the persistence of gender gaps in wages and access to education. These gaps are expected to wider further during COVID-19 which ultimately will affect the food diversity and nutrition diversity of females in the country. A household with one acre of land was 0.794 times less likely to report worsened food diversity during COVID-19. The reason may be that while other people might be struggling to purchase food items due to a decrease in purchasing power and unavailability of food items; a household with its land can increase food diversity by cultivating diverse food items. There was a significant positive association between increasing family size and worsening food diversity. Medium and large-sized families respectively were 1.95 and 2.64 times more likely to experience deteriorated food diversity compared to small-sized families. A plausible explanation is that families with a large number of persons need food items in bulk quantity and COVID-19 induced income and price shocks may force these families to compromise on the variety and quality of the consumed food over quantity. Kansiime et al. (2021) also reported that households in Kenya and Uganda had significantly reduced the consumption of vegetables, fruits, and fish during COVID-19.

Farmers and salaried households respectively were 0.15 and 0.28 times less likely to indicate worsened food diversity than wage earners during COVID-19. Wage-earners working in informal sectors are the most vulnerable group of people of the society in low and middle-income countries as they are wholly dependent on daily and weekly wages without stable monthly income but tighter measures imposed in these countries severely harmed the wage earners' income. According to Chriscaden (2021), more than half of the world workforce may lose their employment sources mostly in countries with large informal economies. Pakistan has a large informal economy and 73% of the labour force outside agriculture is engaged in informal sectors for their livelihood (Bokhari, 2020). Islam et al. (2020) also stated that millions of informal workers can lose their livelihood source during COVID-19. Therefore, the food and nutrition quality of wage earner is probably to suffer more compared to other occupations.

The findings also depicted a significant inverse relationship between increasing monthly income and worsening food diversity. The households with their income levels in the second and third income quantile were respectively 0.11 and 0.19 times less likely to suffer from falling food diversity than households in the first income quantile. This finding further demonstrates that low-income people are more vulnerable to unhealthy and monotonous diets during the pandemic. This is maybe because the availability of more income affects healthy food choices. Arndt et al. (2020) stated that non-pharmaceutical measures imposed worldwide will hurt the food security of low-income people. See **Table 6** below.

Determinants of Deteriorated Daily Per Capita Energy Intake (Kcal/Day)

Table 7 summarizes the factors that determine whether the daily per capita energy intake of households deteriorated during 1 year of the COVID-19 pandemic. Females compared to males were 1.525 times more likely to experience decreased daily per capita energy intake. The reason might be gender differences prevailing in the country. Higher gender differences are linked to higher under nutrition in the country (Tariq, 2018) one acre of agricultural land was likely to increase the daily per capita energy intake of households by 0.962 times.

Households engaged in farming and salaried employments for their livelihood were respectively 0.51 and 0.64 times less likely to experience declined daily per capita energy intake in comparison to wage earners during COVID-19. The above results of calorie source indicated that a major share of the daily calories was provided by cereals and cultivation of cereal crops for home consumption is the primary purpose of the farmers. They store these cereals for home consumption for the whole year at the time of harvesting and on the other hand wage earners purchase these cereals daily, weekly, and fortnightly making them dependent on market outcomes for their energy. Similarly, salaried persons were also receiving their salary throughout the pandemic year which helped them to maintain their energy intake better than wage earners. Wage-earners were 0.30 and 0.26 times more likely to report the decreased per capita energy intake compared to self-employed and foreign remittances dependent households respectively.

Consistent with the overhead findings on the inverse correlation between rising monthly income and deteriorated food diversity households in low-income quantile were more likely to reveal the adverse effects of COVID-19 on their daily per capita energy intake. For example, households whose income level was less than PKR50000 were 0.41 and 0.52 times more likely to suffer from aggravated per capita energy intake than households having income between PKR 50000–100000 and higher than PKR 100000 respectively. This further proves that low-income people were more susceptible to food and nutrition insecurity. See **Table 7**.

CONCLUSION

In the prevalent economic crisis, technology-enabled circular economy practices for achieving green energy efficiency in production and sustainable consumption patterns are vital because technology-led sustainable practices help achieve energy efficiency an food consumption patterns. There is evidence that the COVID-19 economic and health crisis has changed many environmental behaviors. Have these changes taken place because of new situational constraints and opportunities developed by the pandemic related measures. Have these changes driven the challenges in response to environmental effects on people.

This research measured the effects of the COVID-19 pandemic on sustainable patterns income, food diversity, and energy and nutrition intake of households in Pakistan. Pakistan imposed non-pharmaceutical measures to curb the spread of the pandemic like all other countries. Results related income effect show that COVID-19 had severely impacted the income of more than two-thirds of the total households. COVID-19 implications on income forced the majority of households to change their dietary patterns. Additionally, households also adopted other measures like use of previous saving, cultivation of own kitchen items, borrowing, and stop purchasing non-food items to minimize income losses caused by the viral disease.

The outcomes related to food diversity and daily energy intake pointed out that households were fulfilling their daily energy requirement from only a few food groups before and COVID-19 further amplified the already worse situation of food diversity. The proportion of households also increased more than two folds in the low diversified group during COVID-19 compared to the normal period. Similarly, households in normal and high-energy intake groups also reduced significantly during COVID-19. Moreover, intake of essential nutrients declined significantly during COVID-19 than before.

The findings regarding the share of each group in daily energy and nutrients intake revealed that the portion of all food groups reduced significantly in energy and nutrient provision to the households during the pandemic. The results also indicated that more than two-thirds of daily energy intake and half of the nutrients' daily consumed quantity were provided by the cereals pointing out the monotonous nature of the diet of the household. The share of dairy products in energy and nutrient provision remained stable during COVID-19. Percentage change in the share of each group depicted that share of nutrient-rich perishable commodities witnessed the highest decrease in energy and nutrients provided to the households during COVD-19.

Logistic regression outcomes indicated that wage earners were the most vulnerable group of people to the pandemic in terms of diet diversity and energy intake compared to those engaged in agriculture, salaried jobs, self-employment, and foreign remittances dependents. The small-sized families were less likely to suffer from deteriorated food diversity than medium and large size families during the COVID-19 pandemic. The significant negative association of increasing monthly income with deteriorated food diversity and energy intake confirmed that the food and nutrition security of households with low income were likely to suffer more compared to higher income levels due to COVID-19. The small sized families and highly stabilized income can contribute majorly in Circulating food systems that is based on the circular economy principle.

The study outcomes recommend the following measures to assist in maintaining sustainable food and nutrition security of the households during the pandemic. First, Government needs to increase the outreach and assistance amount of current social security programs to deliver its benefits to the maximum vulnerable groups, which meet their food needs fully because present social security programs meet neither of the two above requirements. For this purpose, structural changes in social security programs are recommended that take into account family needs during such catastrophes. Secondly, the government needs to start nutrition-sensitive educational programs for the awareness of the people to decrease the adverse impacts of pandemic induced food and nutrition security shocks.

Lastly, it is worth mentioning here that data was collected online due to non-pharmaceutical measures imposed in the country to control the rising infections but it does not limit the generalizability of our outcomes, as the majority of parameters were adequate to represent the population. The data provided important insights on the food and nutrition status of the households, which can be of interest to policymakers of Pakistan as well as in other developing countries. Future researchers can extend this research by using alternative sampling methods.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

Ethics review and approval/written informed consent was not required as per local legislation and institutional requirements.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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REFERENCES

Abbas, J. (2021). Crisis Management, Transnational Healthcare Challenges and Opportunities: The Intersection of COVID-19 Pandemic and Global Mental Health. *Res. Glob.* 3, 100037. doi:10.1016/j.resglo.2021.100037

Abbas, J. (2020a). The Impact of Coronavirus (SARS-CoV2) Epidemic on Individuals Mental Health: The Protective Measures of Pakistan in Managing and Sustaining Transmissible Disease. *Psychiat Danub* 32 (3-4), 472–477. doi:10.24869/psyd.2020.472

Abbas, J. (2020b). The Role of Interventions to Manage and Reduce Covid-19 Mortality Rate of the COVID-19 Patients Worldwide. *Found. Univ. J. Psychol.* 4 (2), 33–36. doi:10.33897/fujp.v4i2.158

Abbas, J., Wang, D., Su, Z., and Ziapour, A. (2021). The Role of Social Media in the Advent of COVID-19 Pandemic: Crisis Management, Mental Health Challenges and Implications. *Risk Manag. Healthc. Policy* 14, 1917–1932. doi:10.2147/RMHP.S284313

Aday, S., and Aday, M. S. (2020). Impact of COVID-19 on the Food Supply Chain. *Food Qual. Saf.* 4 (4), 167–180. doi:10.1093/fqsafe/fyaa024

Alhawari, O., Awan, U., Bhutta, M. K. S., and Ülkü, M. A. (2021). Insights from Circular Economy Literature: A Review of Extant Definitions and Unravelling Paths to Future Research. *Sustainability* 13 (2), 859. doi:10.3390/su13020859

Aman, J., Abbas, J., Lela, U., and Shi, G. (2021). Religious Affiliation, Daily Spirituals, and Private Religious Factors Promote Marital Commitment Among Married Couples: Does Religiosity Help People amid the COVID-19 Crisis? *Front. Psychol.* 12, 657400. doi:10.3389/fpsyg.2021.657400

Aman, J., Abbas, J., Shi, G., Ain, N. U., and Gu, L. (2022). Community Wellbeing under China-Pakistan Economic Corridor: Role of Social, Economic, Cultural, and Educational Factors in Improving Residents' Quality of Life. *Front. Psychol.* 12, 816592. doi:10.3389/fpsyg.2021.816592

An, Y., Lin, X., Li, M., and He, F. (2021). Dynamic Governance Decisions on Multi-Modal Inter-city Travel during a Large-Scale Epidemic Spreading. *Transp. Policy* 104, 29–42. doi:10.1016/j.tranpol.2021.01.008

Aqeel, M., Abbas, J., Raza, S., and Aman, J. (2021). Portraying the Multifaceted Interplay between Sexual Harassment, Job Stress, Social Support and Employees Turnover Intension amid COVID-19: A Multilevel Moderating Model. *Found. Univ. J. Bus. Econ.* 6 (2), 1–17.

Aqeel, M., Rehna, T., Shuja, K. H., and Abbas, J. (2022). Comparison of Students' Mental Wellbeing, Anxiety, Depression, and Quality of Life during COVID-19's Full and Partial (Smart) Lockdowns: A Follow-Up Study at a 5-Month Interval. *Front. Psychiatry* 13, 835585. doi:10.3389/fpsyt.2022.835585

Arndt, C., Davies, R., Gabriel, S., Harris, L., Makrelov, K., Robinson, S., et al. (2020). Covid-19 Lockdowns, Income Distribution, and Food Security: An Analysis for South Africa. *Glob. Food Secur.* 26, 100410. doi:10.1016/j.gfs.2020.100410

Asante, L. A., and Mills, R. O. (2020). Exploring the Socio-Economic Impact of COVID-19 Pandemic in Marketplaces in Urban Ghana. *Afr. Spectr.* 55 (2), 170–181. doi:10.1177/0002039720943612

Awan, U., Kanwal, N., and Bhutta, M. K. S. (2020). "A Literature Analysis of Definitions for a Circular Economy," in *Logistics Operations and Management for Recycling and Reuse*. Editor P. Golinska-Dawson (Berlin, Heidelberg: Springer Berlin Heidelberg), 19–34. doi:10.1007/978-3-642-33857-1_2

Awan, U., and Sroufe, R. (2019). Interorganisational Collaboration for Innovation Improvement in Manufacturing Firms's: the Mediating Role of Social Performance. *Int. J. Innov. Mgt.* 24 (05), 2050049. doi:10.1142/s1363919620500498

Bellany, Y. B. D., and Corkery, M. (2020). *Dumped Milk, Smashed Eggs, Plowed Vegetables: Food Waste of the Pandemic*. The New York Times. Available at: https://www.nytimes.com/2020/04/11/business/coronavirus-destroying-food.html (Accessed March, 2022)

Ben Hassen, T., El Bilali, H., Allahyari, M. S., Berjan, S., and Fotina, O. (2021). Food Purchase and Eating Behavior during the COVID-19 Pandemic: A Cross-Sectional Survey of Russian Adults. *Appetite* 165, 105309. doi:10.1016/j.appet.2021.105309

Bhutto, T. A., Farooq, R., Talwar, S., Awan, U., and Dhir, A. (2021). Green Inclusive Leadership and Green Creativity in the Tourism and Hospitality Sector: Serial Mediation of Green Psychological Climate and Work Engagement. *J. Sustain. Tour.* 29 (10), 1716–1737. doi:10.1080/09669582.2020.1867864

Bokhari, J. (2020). How to Formalise the Informal Economy. Available from https://www.dawn.com/news/1565728 (Accessed March 21, 2021).

Camacho-Otero, J., Boks, C., and Pettersen, I. (2018). Consumption in the Circular Economy: A Literature Review. *Sustainability* 10 (8), 2758. doi:10.3390/su10082758

Carroll, N., Sadowski, A., Laila, A., Hruska, V., Nixon, M., Ma, D. W. L., et al.Guelph Family Health Study (2020). The Impact of COVID-19 on Health Behavior, Stress, Financial and Food Security Among Middle to High Income Canadian Families with Young Children. *Nutrients* 12 (8), 2352. doi:10.3390/nu12082352

Cheng, Y., Awan, U., Ahmad, S., and Tan, Z. (2021). How Do Technological Innovation and Fiscal Decentralization Affect the Environment? A Story of the Fourth Industrial Revolution and Sustainable Growth. *Technol. Forecast. Soc. Change* 162, 120398. doi:10.1016/j.techfore.2020.120398

Chriscaden, K. (2021). Impact of COVID-19 on People's Livelihoods, Their Health and Our Food Systems. Available from https://www.who.int/news/item/13-10-2020-impact-of-covid-19-on-people's-livelihoods-their-health-and-our-food-systems (Accessed March 30, 2021).

Cole, M. B., Augustin, M. A., Robertson, M. J., and Manners, J. M. (2018). The Science of Food Security. *NPJ Sci. Food* 2 (1), 14–18. doi:10.1038/s41538-018-0021-9

Čadová, M. B. (2020). *Česká veřejnost o globálních problémech - červen 2020*. Tisková zpráva [Czech public on global issues–June 2020. Press release]. Centrum pro výzkum veřejného mínění. Available at: https://cvvm.soc.cas.cz/media/com_form2content/documents/c2/a5251/f9/oe200807.pdf.

Eftimov, T., Popovski, G., Petković, M., Seljak, B. K., and Kocev, D. (2020). COVID-19 Pandemic Changes the Food Consumption Patterns. *Trends food Sci. Technol.* 104, 268–272. doi:10.1016/j.tifs.2020.08.017

Fana, M., Torrejón Pérez, S., and Fernández-Macías, E. (2020). Employment Impact of Covid-19 Crisis: from Short Term Effects to Long Terms Prospects. *J. Ind. Bus. Econ.* 47 (3), 391–410. doi:10.1007/s40812-020-00168-5

FAO and GoP (2001). *Pakistan Dietary Guidelines for Better Nutrition*. Available from http://www.fao.org/fileadmin/templates/food_composition/documents/regional/Book_Food_Composition_Table_for_Pakistan_.pdf (Accessed March 28, 2021).

FAO (2020b). National Agrifood Systems and COVID-19 in Pakistan Effects, Policy Responses, and Long-Term Implications. Available from https://reliefweb.int/report/pakistan/rapid-assessment-possible-impact-covid-19-livelihoods-food-security-nutrition-and (Accessed March 23, 2021).

FAO (1996). *Rome Declaration on World Food Security and World Food Summit Plan of Action*. Room, Italy: Food and Agriculture organization.

FAO; IFAD; UNICEF; WFP; WHO (2019). *The State of Food Security and Nutrition in the World 2019. Safeguarding against Economic Slowdowns and Downturns*. Rome: FAO.

FAO. (2020a). Inputs from HiHi-FAO Pakistan to the Corporate Umbrella Programme for COVID-19 Response. Available from http://www.fao.org/food-coalition/take-action/detail/en/c/1331359/ (Accessed March 16, 2021).

Farzadfar, F., Naghavi, M., Sepanlou, S. G., Saeedi Moghaddam, S., Dangel, W. J., Davis Weaver, N., et al. (2022). Health System Performance in Iran: a Systematic Analysis for the Global Burden of Disease Study 2019. *Lancet* 399 (10335), 1625–1645. doi:10.1016/s0140-6736(21)02751-3

FSIN (2020). Global Report on Food Crises 2020. Food Security Information Network. Available from https://www.fsinplatform.org/global-report-food-crises-2020 (Accessed January 28, 2021).

Fu, Q., and Abbas, J. (2022). Reset the Industry Redux through Corporate Social Responsibility: The COVID-19 Tourism Impact on Hospitality Firms through Business Model Innovation. *Front. Psychol.* 12, 795345. doi:10.3389/fpsyg.2021.795345

Galali, Y. (2021). The Impact of COVID-19 Confinement on the Eating Habits and Lifestyle Changes: A Cross Sectional Study. *Food Sci. Nutr.* 9 (4), 2105–2113. doi:10.1002/fsn3.2179

Ge, T., Abbas, J., Ullah, R., Abbas, A., Sadiq, I., and Zhang, R. (2022). Women's Entrepreneurial Contribution to Family Income: Innovative Technologies Promote Females' Entrepreneurship amid COVID-19 Crisis. *Front. Psychol.* 13, 828040. doi:10.3389/fpsyg.2022.828040

Giudice, F., Caferra, R., and Morone, P. (2020). COVID-19, the Food System and the Circular Economy: Challenges and Opportunities. *Sustainability* 12 (19), 7939. doi:10.3390/su12197939

GNR (2020). The Burden of Malnutrition at a Glance. Available from https://globalnutritionreport.org/resources/nutrition-profiles/asia/southern-asia/pakistan/ (Accessed April 3, 2021).

GoP (2021). Governmnet of Pakistan; Ministry of Finance. Islamabad, Pakistan: Ministry of Finance, Economic Affairs Wing. Available from http://www.finance.gov.pk/ (Accessed March 21, 2021).

Grant, F., Scalvedi, M. L., Scognamiglio, U., Turrini, A., and Rossi, L. (2021). Eating Habits during the COVID-19 Lockdown in Italy: The Nutritional and Lifestyle Side Effects of the Pandemic. *Nutrients* 13 (7), 2279. doi:10.3390/nu13072279

Güney, O. I., and Sangün, L. (2021). How COVID-19 Affects Individuals' Food Consumption Behaviour: a Consumer Survey on Attitudes and Habits in Turkey. *Br. Food J.* 123 (7), 2307–2320. doi:10.1108/bfj-10-2020-0949

Haq, S. U., Boz, I., and Shahbaz, P. (2021). Adoption of Climate-Smart Agriculture Practices and Differentiated Nutritional Outcome Among Rural Households: a Case of Punjab Province, Pakistan. *Food Sec.* 13, 913–931. doi:10.1007/s12571-021-01161-z

Haq, S. U., Shahbaz, P., and Boz, I. (2020). Knowledge, Behavior and Precautionary Measures Related to COVID-19 Pandemic Among the General Public of Punjab Province, Pakistan. *J. Infect. Dev. Ctries.* 14 (08), 823–835. doi:10.3855/jidc.12851

Harris, J., Depenbusch, L., Pal, A. A., Nair, R. M., and Ramasamy, S. (2020). Food System Disruption: Initial Livelihood and Dietary Effects of COVID-19 on Vegetable Producers in India. *Food Sec.* 12 (4), 841–851. doi:10.1007/s12571-020-01064-5

Headey, D. D., and Alderman, H. H. (2019). The Relative Caloric Prices of Healthy and Unhealthy Foods Differ Systematically across Income Levels and Continents. *J. Nutr.* 149 (11), 2020–2033. doi:10.1093/jn/nxz158

Headey, D. D., and Ruel, M. T. (2020). "The COVID-19 Nutrition Crisis: What to Expect and How to Protect," in *COVID-19 and Global Food Security* (Washington, DC: International Food Policy Research Institute), 38–41. chapter 8.

Huber, B. C., Steffen, J., Schlichtiger, J., and Brunner, S. (2021). Altered Nutrition Behavior during COVID-19 Pandemic Lockdown in Young Adults. *Eur. J. Nutr.* 60 (5), 2593–2602. doi:10.1007/s00394-020-02435-6

IEA (2020). Global Energy Review 2020. Available at: https://www.iea.org/reports/global-energy-review-2020 (Accessed December 15, 2021).

Ikram, M., Sroufe, R., Awan, U., and Abid, N. (2021). Enabling Progress in Developing Economies: A Novel Hybrid Decision-Making Model for Green Technology Planning. *Sustainability* 14 (1), 258. doi:10.3390/su14010258

International Labour Organization (2020). ILOSTAT Database [database]. Available from https://ilostat.ilo.org/data/ (Accessed April 12, 2021).

Islam, M. A., Barna, S. D., Raihan, H., Khan, M. N. A., and Hossain, M. T. (2020). Depression and Anxiety Among University Students during the COVID-19 Pandemic in Bangladesh: A Web-Based Cross-Sectional Survey. *PLoS One* 15 (8), e0238162. doi:10.1371/journal.pone.0238162

Janssen, M., Chang, B. P., Hristov, H., Pravst, I., Profeta, A., and Millard, J. (2021). Changes in Food Consumption during the COVID-19 Pandemic: Analysis of Consumer Survey Data from the First Lockdown Period in Denmark, Germany, and Slovenia. *Front. Nutr.* 8, 60. doi:10.3389/fnut.2021.635859

Jurgilevich, A., Birge, T., Kentala-Lehtonen, J., Korhonen-Kurki, K., Pietikäinen, J., Saikku, L., et al. (2016). Transition towards Circular Economy in the Food System. *Sustainability* 8 (1), 69. doi:10.3390/su8010069

Kanda, W., and Kivimaa, P. (2020). What Opportunities Could the COVID-19 Outbreak Offer for Sustainability Transitions Research on Electricity and Mobility? *Energy Res. Soc. Sci.* 68, 101666. doi:10.1016/j.erss.2020.101666

Kansiime, M. K., Tambo, J. A., Mugambi, I., Bundi, M., Kara, A., and Owuor, C. (2021). COVID-19 Implications on Household Income and Food Security in Kenya and Uganda: Findings from a Rapid Assessment. *World Dev.* 137, 105199. doi:10.1016/j.worlddev.2020.105199

Kim, J., Yang, K., Min, J., and White, B. (2021). Hope, Fear, and Consumer Behavioral Change amid COVID-19: Application of Protection Motivation Theory. *Int. J. Consum. Stud.* 46, 558–574. doi:10.1111/ijcs.12700

Krejcie, R. V., and Morgan, D. W. (1970). Determining Sample Size for Research Activities. *Educ. Psychol. Meas.* 30 (3), 607–610. doi:10.1177/001316447003000308

Laborde, D., Martin, W., Swinnen, J., and Vos, R. (2020). COVID-19 Risks to Global Food Security. *Science* 369 (6503), 500–502. doi:10.1126/science.abc4765

Lehmann, C., Cruz-Jesus, F., Oliveira, T., and Damásio, B. (2022). Leveraging the Circular Economy: Investment and Innovation as Drivers. *J. Clean. Prod.* 360, 132146. doi:10.1016/j.jclepro.2022.132146

Li, Z., Wang, D., Abbas, J., Hassan, S., and Mubeen, R. (2021). Tourists' Health Risk Threats amid COVID-19 Era: Role of Technology Innovation, Transformation, and Recovery Implications for Sustainable Tourism. *Front. Psychol.* 12, 769175. doi:10.3389/fpsyg.2021.769175

Liu, Q., Qu, X., Wang, D., Abbas, J., and Mubeen, R. (2022). Product Market Competition and Firm Performance: Business Survival through Innovation and Entrepreneurial Orientation amid COVID-19 Financial Crisis. *Front. Psychol.* 12, 790923. doi:10.3389/fpsyg.2021.790923

Liu, Y., Amin, A., Rasool, S. F., and Zaman, Q. U. (2020). The Role of Agriculture and Foreign Remittances in Mitigating Rural Poverty: Empirical Evidence from Pakistan. *Risk Manag. Healthc. Policy* 13, 13–26. doi:10.2147/RMHP.S235580

Lucarelli, C., Mazzoli, C., and Severini, S. (2020). Applying the Theory of Planned Behavior to Examine Pro-environmental Behavior: The Moderating Effect of COVID-19 Beliefs. *Sustainability* 12 (24), 10556. doi:10.3390/su122410556

Maitre-Ekern, E., and Dalhammar, C. (2019). Towards a Hierarchy of Consumption Behaviour in the Circular Economy. *Maastricht J. Eur. Comp. Law* 26 (3), 394–420. doi:10.1177/1023263x19840943

Mamirkulova, G., Mi, J., and Abbas, J. (2022). Economic Corridor and Tourism Sustainability amid Unpredictable COVID-19 Challenges: Assessing Community Well-Being in the World Heritage Sites. *Front. Psychol.* 12, 797568. doi:10.3389/fpsyg.2022.797568

Maqsood, A., Abbas, J., Rehman, G., and Mubeen, R. (2021). The Paradigm Shift for Educational System Continuance in the Advent of COVID-19 Pandemic: Mental Health Challenges and Reflections. *Curr. Res. Behav. Sci.* 2, 100011. doi:10.1016/j.crbeha.2020.100011

Mawejje, J. (2019). Financial Inclusion, Shocks and Coping Strategies: Survey Evidence from Uganda. *Afr. J. Econ. Manag. Stud.* 10 (3), 286'298. doi:10.1108/ajems-10-2018-0325

Moradi, F., Tourani, S., Ziapour, A., Abbas, J., Hematti, M., Moghadam, E. J., et al. (2021a). Emotional Intelligence and Quality of Life in Elderly Diabetic Patients. *Int. Q. Community Health Educ.* 42 (1), 15–20. doi:10.1177/0272684X20965811

Moradi, F., Ziapour, A., Abbas, J., Najafi, S., Rezaeian, S., Faraji, O., et al. (2021b). Comparing the Associated Factors on Lifestyle between Type 2 Diabetic Patients and Healthy People: A Case-Control Study. *Int. Q. Community Health Educ.* 272684X211022158. doi:10.1177/0272684X211022158

Muhammad, S., Long, X., and Salman, M. (2020). COVID-19 Pandemic and Environmental Pollution: A Blessing in Disguise? *Sci. Total Environ.* 728, 138820. doi:10.1016/j.scitotenv.2020.138820

NCOC (2021). COVID-19 STATS. Available from: https://ncoc.gov.pk/ (Accessed March 17, 2021).

Neill, A. O. (2021). Pakistan: Inflation Rate from 1985 to 2025. Available at: https://www.statista.com/statistics/383760/inflation-rate-in-pakistan/ (Accessed April 4, 2021).

Nguyen, M. C., and Winters, P. (2011). The Impact of Migration on Food Consumption Patterns: The Case of Vietnam. *Food Policy* 36 (71), 87. doi:10.1016/j.foodpol.2010.11.001

Nicola, M., Alsafi, Z., Sohrabi, C., Kerwan, A., Al-Jabir, A., Iosifidis, C., et al. (2020). The Socio-Economic Implications of the Coronavirus Pandemic (COVID- 19): A Review. *Int. J. Surg.* 78, 185–193. doi:10.1016/j.ijsu.2020.04.018

O'Connor, P., and Assaker, G. (2021). COVID-19's Effects on Future Pro-environmental Traveler Behavior: An Empirical Examination Using Norm Activation, Economic Sacrifices, and Risk Perception Theories. *J. Sustain. Tour.* 30, 1–19. doi:10.1080/09669582.2021.1879821

Paulson, K. R., Kamath, A. M., Alam, T., Bienhoff, K., Abady, G. G., Abbas, J., et al. (2021). Global, Regional, and National Progress towards Sustainable Development Goal 3.2 for Neonatal and Child Health: All-Cause and Cause-specific Mortality Findings from the Global Burden of Disease Study 2019. *Lancet* 398 (10303), 870–905. doi:10.1016/s0140-6736(21)01207-1

PBS (2018). Population Census. Available from https://www.pbs.gov.pk/content/population-census (Accessed March 19, 2021).

Penne, T., and Goedemé, T. (2021). Can Low-Income Households Afford a Healthy Diet? Insufficient Income as a Driver of Food Insecurity in Europe. *Food Policy* 99, 101978. doi:10.1016/j.foodpol.2020.101978

Prata, J. C., Silva, A. L. P., Walker, T. R., Duarte, A. C., and Rocha-Santos, T. (2020). COVID-19 Pandemic Repercussions on the Use and Management of Plastics. *Environ. Sci. Technol.* 54 (13), 7760–7765. doi:10.1021/acs.est.0c02178

Radulescu, C. V., Ladaru, G. R., Burlacu, S., Constantin, F., Ioanăş, C., and Petre, I. L. (2020). Impact of the COVID-19 Pandemic on the Romanian Labor Market. *Sustainability* 13 (1), 271. doi:10.3390/su13010271

Rahmat, T. E., Raza, S., Zahid, H., Abbas, J., Mohd Sobri, F., and Sidiki, S. (2022). Nexus between Integrating Technology Readiness 2.0 Index and Students' E-Library Services Adoption amid the COVID-19 Challenges: Implications Based on the Theory of Planned Behavior. *J. Educ. Health Promot* 11 (1), 50. doi:10.4103/jehp.jehp_508_21

Rasheed, R., Rizwan, A., Javed, H., Sharif, F., and Zaidi, A. (2021). Socio-economic and Environmental Impacts of COVID-19 Pandemic in Pakistan—an Integrated Analysis. *Environ. Sci. Pollut. Res. Int.* 28 (16), 19926–19943. doi:10.1007/s11356-020-12070-7

Rashid Khan, H. u., Awan, U., Zaman, K., Nassani, A. A., Haffar, M., and Abro, M. M. Q. (2021). Assessing Hybrid Solar-Wind Potential for Industrial Decarbonization Strategies: Global Shift to Green Development. *Energies* 14 (22), 7620. doi:10.3390/en14227620

Rosak-Szyrocka, J., Abbas, A. A., Akhtar, H., and Refugio, C. (2021a). Employment and Labour Market Impact of COVID-19 Crisis - Part 1 – Analysis in Poland. *Syst. Saf. Hum. - Tech. Facil. - Environ.* 3 (1), 108–115. doi:10.2478/czoto-2021-0012

Rosak-Szyrocka, J., Zywiolek, J., Kulinska, E., and Matulewski, M. (2021b). Analysis of Enterprises' Readiness in for Industry 4.0 Implementation: the Case of Poland. *Eur. Res. Stud. J.* 24 (3), 615–628. doi:10.35808/ersj/2374

Rosak-Szyrocka, J., and Żywiołek, J. (2022). Qualitative Analysis of Household Energy Awareness in Poland. *Energies* 15 (6), 2279. doi:10.3390/en15062279

Rosenbloom, D., and Markard, J. (2020). A COVID-19 Recovery for Climate. *Science* 368 (6490), 447. doi:10.1126/science.abc4887

Rousseau, S., and Deschacht, N. (2020). Public Awareness of Nature and the Environment during the COVID-19 Crisis. *Environ. Resour. Econ.* 76, 1149–1159. doi:10.1007/s10640-020-00445-w

Rousseau, A.-F., Prescott, H. C., Brett, S. J., Weiss, B., Azoulay, E., Creteur, J., et al. (2021). Long-Term Outcomes After Critical Illness: Recent Insights. *Critical Care* 25 (1), 108. doi:10.1186/s13054-021-03535-3

Ruel, M. T. (2003). Operationalizing Dietary Diversity: A Review of Measurement Issues and Research Priorities. *J. Nutr.* 133, 3911S–3926S. doi:10.1093/jn/133.11.3911s

Sarkis, J., Cohen, M. J., Dewick, P., and Schr¨oder, P. (2020). A Brave New World: Lessons from the COVID-19 Pandemic for Transitioning to Sustainable Supply and Production. *Resour. Conservation Recycl.* 159, 104894. doi:10.1016/j.10.1016/j.resconrec.2020.104894

Schacht, J., and von Zimmerman, P. (2020). Multi-Species Coexistence, COVID-19 and Urban Design. Available at: https://journal.urbantranscripts.org/article/multi-species-coexistence-covid-19-urban-design-johanna-schacht-and-philine-von-zimmermann/ (Accessed March 10, 2022).

Schiller, B., T¨onsing, D., Kleinert, T., B¨ohm, R., and Heinrichs, M. (2021). Effects of the COVID-19 Pandemic Nationwide Lockdown on Mental Health, Environmental Concern, and Prejudice against Other Social Groups. *Environ. Behav.* 54 (2), 516–537. doi:10.1177/00139165211036991

Shahbaz, P., ul Haq, S., Boz, I., Aziz, B., and Hafeez, A. (2022). Gendered Impact of COVID-19 on Consumption of Perishable and Nonperishable Food Commodities in Pakistan. *J. Agribus. Dev. Emerg. Econ.* 12 (4), 1–14. doi:10.1108/jadee-02-2022-0041

Shahbaz, P., ul Haq, S., and Boz, I. (2021b). Implications of COVID-19 Related Non-pharmaceutical Measures on Household Livelihood and Food Security in Pakistan. *J. Agribus. Dev. Emerg. Econ.* 12 (3), 400–413. doi:10.1108/jadee-07-2021-0175

Shahbaz, P., Ul Haq, S., Khalid, U. B., and Boz, I. (2021a). Gender-based Implications of the COVID-19 Pandemic on Household Diet Diversity and Nutritional Security in Pakistan. *Br. Food J.* 124 (3), 951–967. doi:10.1108/bfj-05-2021-0464

Shuja, K. H., Aqeel, M., Jaffar, A., and Ahmed, A. (2020a). COVID-19 Pandemic and Impending Global Mental Health Implications. *Psychiatr. Danub* 32 (1), 32–35. doi:10.24869/psyd.2020.32

Shuja, K. H., ShahidullahAqeel, M., Khan, E. A., and Abbas, J. (2020b). Letter to Highlight the Effects of Isolation on Elderly during COVID-19 Outbreak. *Int. J. Geriatr. Psychiatry* 35 (12), 1477–1478. doi:10.1002/gps.5423

Su, Z., McDonnell, D., Abbas, J., Shi, L., Cai, Y., and Yang, L. (2021a). Secondhand Smoke Exposure of Expectant Mothers in China: Factoring in the Role of Culture in Data Collection. *JMIR Cancer* 7 (4), e24984. doi:10.2196/24984

Su, Z., McDonnell, D., Cheshmehzangi, A., Abbas, J., Li, X., and Cai, Y. (2021b). The Promise and Perils of Unit 731 Data to Advance COVID-19 Research. *BMJ Glob. Health* 6 (5), e004772. doi:10.1136/bmjgh-2020-004772

Su, Z., McDonnell, D., Li, X., Bennett, B., Segalo, S., Abbas, J., et al. (2021c). COVID-19 Vaccine Donations-Vaccine Empathy or Vaccine Diplomacy? A Narrative Literature Review. *Vaccines (Basel)* 9 (9), 1024. doi:10.3390/vaccines9091024

Su, Z., McDonnell, D., Wen, J., Kozak, M., Abbas, J., Segalo, S., et al. (2021d). Mental Health Consequences of COVID-19 Media Coverage: the Need for Effective Crisis Communication Practices. *Glob. Health* 17 (1), 4. doi:10.1186/s12992-020-00654-4

Tariq, R. (2018). Gender and Nutrition. Avaialbale from https://www.thenews.com.pk/print/351059-gender-and-nutrition (Accessed April 12, 2021).

Tchetchik, A., Kaplan, S., and Blass, V. (2021). Recycling and Consumption Reduction Following the COVID-19 Lockdown: The Effect of Threat and Coping Appraisal, Past Behavior and Information. *Resour. Conservation Recycl.* 167, 105370. doi:10.1016/j.resconrec.2020.105370

Thompson, B., Amoroso, L., and Meerman, J. (2009). *Promoting the Expression "Food and Nutrition Security (FNS)". A Strategy Note from the Nutrition and Consumer Protection Division*. Rome: Food and Agriculture Organization of the United Nations.

Tiwari, S., Rosak-Szyrocka, J., and Żywiołek, J. (2022). Internet of Things as a Sustainable Energy Management Solution at Tourism Destinations in India. *Energies* 15 (7), 2433. doi:10.3390/en15072433

UN (2021). End Hunger, Achieve Food Security and Improved Nutrition and Promote Sustainable Agriculture. Available from https://sdgs.un.org/goals/goal2 (Accessed March 20, 2021).

Wang, C., Wang, D., Abbas, J., Duan, K., and Mubeen, R. (2021). Global Financial Crisis, Smart Lockdown Strategies, and the COVID-19 Spillover Impacts: A Global Perspective Implications from Southeast Asia. *Front. Psychiatry* 12 (1099), 643783. doi:10.3389/fpsyt.2021.643783

Weersink, A., von Massow, M., and McDougall, B. (2020). Economic Thoughts on the Potential Implications of COVID-19 on the Canadian Dairy and Poultry Sectors. *Can. J. Agric. Economics/Revue Can. d'agroeconomie* 68 (2), 195–200. doi:10.1111/cjag.12240

WHO (2020a). Malnutrition. Available from https://www.who.int/news-room/fact-sheets/detail/malnutrition (Accessed March 31, 2021).

WHO (2020b). Micronutrient. Available from https://www.who.int/health-topics/micronutrients#tab=tab_1 (Accessed March 31, 2021).

World Bank (2020). Pakistan - World Bank Data. Available from https://data.worldbank.org/country/pakistan (Accessed April 02, 2021).

Yao, J., Ziapour, A., Abbas, J., Toraji, R., and NeJhaddadgar, N. (2022). Assessing Puberty-Related Health Needs Among 10–15-Year-Old Boys: A Cross-Sectional Study Approach. *Arch. Pédiatrie* 29 (2), 307–311. doi:10.1016/j.arcped.2021.11.018

Yilma, Z., Mebratie, A., Sparrow, R., Abebaw, D., Dekker, M., Alemu, G., et al. (2014). Coping with Shocks in Rural Ethiopia. *J. Dev. Stud.* 50 (7), 1009–1024. doi:10.1080/00220388.2014.909028

Yoosefi Lebni, J., Abbas, J., Khorami, F., Khosravi, B., Jalali, A., and Ziapour, A. (2020). Challenges Facing Women Survivors of Self-Immolation in the Kurdish Regions of Iran: A Qualitative Study. *Front. Psychiatry* 11, 778. doi:10.3389/fpsyt.2020.00778

Yu, S., Abbas, J., Draghici, A., Negulescu, O. H., and Ain, N. U. (2022). Social Media Application as a New Paradigm for Business Communication: The Role of COVID-19 Knowledge, Social Distancing, and Preventive Attitudes. *Front. Psychol.* 13, 903082. doi:10.3389/fpsyg.2022.903082

Zawn, V. (2021). How to Eat 1,200 Calories a Day. Available from https://www.medicalnewstoday.com/articles/326343 (Accessed March 25, 2021).

Zhou, Y., Draghici, A., Abbas, J., Mubeen, R., Boatca, M. E., and Salam, M. A. (2021). Social Media Efficacy in Crisis Management: Effectiveness of Non-pharmaceutical Interventions to Manage COVID-19 Challenges. *Front. Psychiatry* 12, 626134. doi:10.3389/fpsyt.2021.626134

Żywiołek, J., Rosak-Szyrocka, J., and Jereb, B. (2021). Barriers to Knowledge Sharing in the Field of Information Security. *Manag. Syst. Prod. Eng.* 29 (2), 114–119. doi:10.2478/mspe-2021-0015

Żywiołek, J., Rosak-Szyrocka, J., Khan, M. A., and Sharif, A. (2022). Trust in Renewable Energy as Part of Energy-Saving Knowledge. *Energies* 15 (4), 1566. doi:10.3390/en15041566

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