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Original Article

The relationship between COVID-19 and food supply suggest some animal-origin foods as an excellent vehicle of SARS-Cov-2

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Summary

In the present study, we evaluated the impact of animal-origin food consumption on the recent pandemic of Coronavirus-19 (COVID-19). Thus, the relationship among animal-origin food supply as independent factor and total cases of COVID-19 as a dependent variable was assessed. In this regard, the relevance between the consumption quantity of foods (n = 20) and the number of total case of COVID-19 in worldwide countries (n = 215) was evaluated. Food supply (kg/capita/yr.) was estimated in each country based on the latest available data of FAO. The results showed an association between a group of animal-origin foods and TC. Regression, Bayes, and Lasso's findings demonstrated that eggs and freshwater fish have a high positive correlation with TC. We suppose an important role for animal-origin foods concerning COVID-19 as a cross-contamination pathway. In conclusion, a noticeable vehicle for SARS-Cov-2 may be some of the animal-origin foods. The perspective is the development of surveillance of SARS-Cov-2 in the food production chain. Also, chicken's eggs and freshwater fish may be leading vehicles for SARS-Cov-2 by cross-contamination.

Keywords: animal, COVID-19, foodborne, SARS-cov2

Introduction

In the course of the pandemic COVID-19, most countries worldwide attempt to minimize person-to-person contact and travel (Chinazzi et al., 2020). Despite many countries' efforts to decrease the transmission by the human-to-human way, the rapid spread demonstrates the incumbency of inquiries on other feasible transmission routes. The hypothesis for this study was to evaluate the possibility of foodborne transmission (FBT) or cross-contamination by animal-origin foods. Transmission of Middle East respiratory syndrome virus, a similar virus to SARS-Cov-2, through infected food ingestion (Chan et al., 2015) strengthened our hypothesis. Moreover, several previous studies have reported a possible foodborne exposure to SARS-CoV-2 (Shao et al., 2011; Panel and Biohaz, 2011; Newell et al., 2010;

Todd and Grieg, 2015). Furthermore, the experts of the World Health Organization (WHO) have pointed the data gap in the association and correlation between viruses and foodborne disease (FAO/WHO, 2008). The reason for the current study was to investigate the impacts of food supply on TC of COVID-19.

Materials and Methods

Descriptive statistics of the evaluated variables are presented in Table 1. Indeed, we studied the association between the consumption quantity of foods (n = 20) and the number of total case (TC) of COVID-19 in worldwide countries (n = 215). We considered TC as a dependent variable and food supply as an independent variable. Food supply (kg/capita/yr.) was considered in each country according to the latest available data of FAO. The numbers of data belonging to the studied countries are shown in Table 1. The first aim of the current study was to determine the effect of animal-origin food on TC; however, we deliberated six plant-origin foods to compare with them. The statistical methods included regression with PROC REG, least absolute shrinkage and selector operator (LASSO) regression with PROC GLMSELECT, and Bayes analysis with PROC GENMOD of SAS 9.2. In Bayesian, visual examination of the trace plot displayed proper mixing for all independent variables. The *P*-value in the Geweke Diagnostics table indicated that the mean estimate of the Markov chain is stable over time. Considerably, the positive probability that B1 greater than 0 is estimated. All the data and SAS code for an application of the used statistical methods are provided as supplementary materials.

Histogram of TC, freshwater fish, and eggs beside their logarithmic transformation are presented in Figures 1 and 2. We used natural logs for the transformation of variables. Interestingly, the precision of the model with non-transformed data was very low in the present analyses. By transformation of data, the accuracy of the model was improved to an acceptable level. Diagnostics panels and selective criteria of a regression model are shown in Figure 3. Besides, the adjusted R-squares of the fitted models are demonstrated in Table 2. Of note, we started the data analyses in March 2020 for the first time. Subsequently, we frequented it several times with updated COVID-19 data on April, May, June, and September 2020. Finally, we represented the latest findings.

Data

The data of COVID-19 was downloaded from worldometers.info/coronavirus/ on 10 September 2020. We obtained the livestock statistics from FAOSTAT (http://www.fao.org/faostat/en/#data/CL) and the data of crops from (http://www.fao.org/faostat/en/#data/CC).

Table 1. Descriptive statistics of the studied foods (n = 20) besides total cases of COVID-19.

#	Variable (kg/capita/yr)	Abbreviation	N	Mean	Std Dev	Minimum	Maximum
1	Pig meat	pig	169	14.66	15.52	0.00	71.48
2	Bovine meat	bov	174	11.20	9.00	0.78	55.48
3	Cheese	che	173	4.97	6.55	0.00	30.82
4	Cream	cre	159	1.21	2.76	0.00	18.45
5	Eggs	Egg	174	7.08	5.09	0.16	19.15
6	Fresh water fish	freshf	174	3.38	4.54	0.00	34.00
7	Honey	hon	168	0.36	0.46	0.00	3.51
8	Whole milk	milk	174	59.17	48.93	0.96	258.44
9	Poultry meat	poul	174	20.56	16.46	0.42	72.87
10	Demersal fish	demer	173	3.40	4.93	0.00	33.45
11	Cephalopods	ceph	171	0.44	0.96	0.00	6.70
12	Butter, Ghee	butg	174	1.25	1.64	0.00	9.25
13	Marine fish, Other	marf	172	2.74	4.87	0.00	28.19
14	Aquatic plants	aqp	162	0.20	1.91	0.00	22.41
15	Beverages, Alcoholic	bev	171	3.20	3.87	0.00	26.90
16	Rice (milled equivalent)	rice	174	30.95	36.20	0.95	171.73
17	Potatoes and products	potato	174	34.89	33.65	0.05	183.16
18	Maize and products	maiz	170	21.71	28.52	0.00	158.40
19	Wheat and products	wheat	174	70.92	46.85	1.89	222.40
20	Wine	wine	169	6.27	9.49	0.00	51.41
	Total cases (per country)	TC	215	130744.74	619823.34	3	6558095

Results

The present results confirmed that eggs and freshwater fish have a high positive relation with TC with a coefficient of more than 0.72 with a *P*-value of 0.01 (Table 3). The presented data in Table 3 shows the need for tracing of SARS-COV-2 in the production or processing of animal-origin foods. Bayes results indicate that there is a 0.99 probability of a positive correlation between eggs and TC, adjusted for the other covariates. The number of animal-origin foods and their role in the current results showed some variation. This variation depends on the different statistical models, but the findings are consistent in general. Here, the data of the present statistical models affirm each other in the case of eggs. The results of LASSO are more reliable than stepwise regression and Bayes according to the Akaike's information criterion (AIC; smaller value is a better model fit;

Table 2). Therefore, we focused more on the results of the LASSO model.

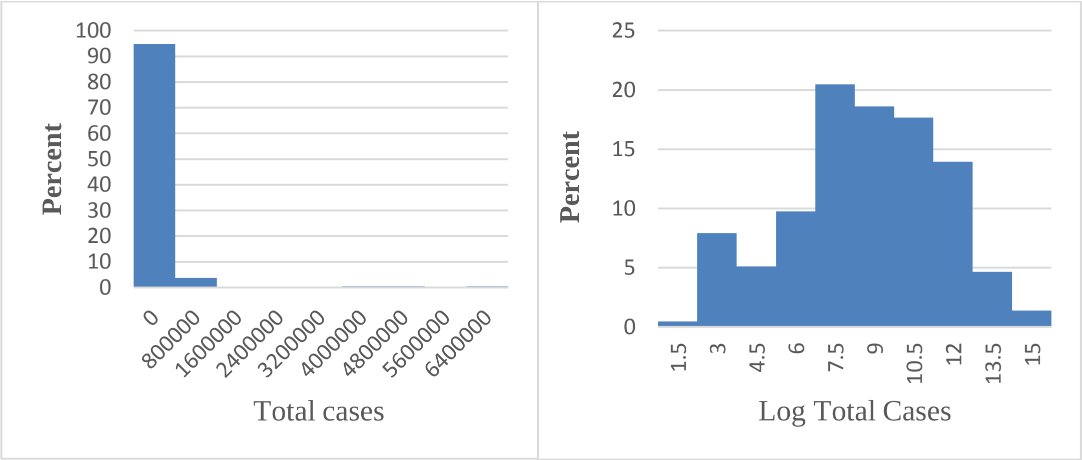

Fig. 1. Histogram of total cases before (left) and after (right) logarithmic transformation.

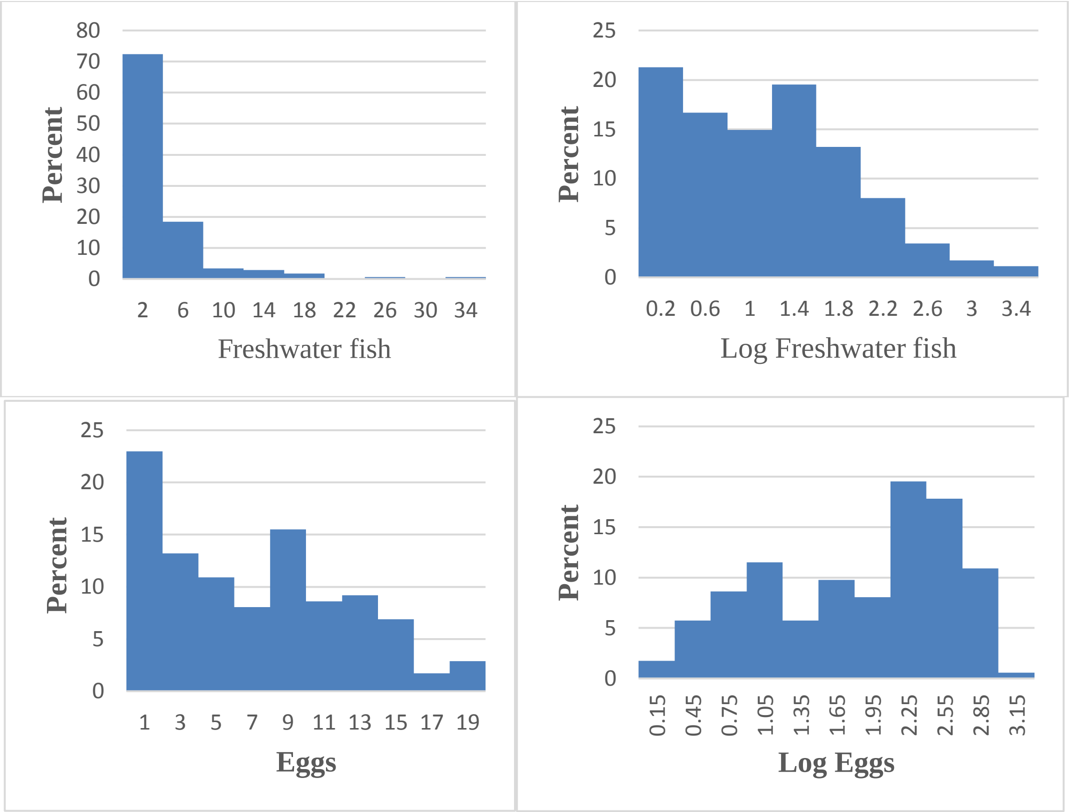

Fig. 2. Histogram of fresh water fish and eggs before and after logarithmic transformation.

Discussion

The impact of a group of animal-origin foods on TC was remarkable in our analysis, suggesting a possible effect of animal-origin food as FBT via vehicle or cross-contamination routes. Possible transmission pathways of COVID-19 based on the present findings and the bibliography illustrated in Figure 4. Kingsbury et al., (2020) reviewed the potential for FBT of COVID-19, but they could not insure the usage of the data observed on other coronaviruses to SARS-CoV-2. It seems that the persistence of viruses in refrigeration temperature might propose a justification of the association between COVID-19 and animal-origin foods (FAO/WHO, 2008). Promkuntod et al. (2006) recommend considering precautions to prevent the spread of avian influenza by consuming of quail eggs.

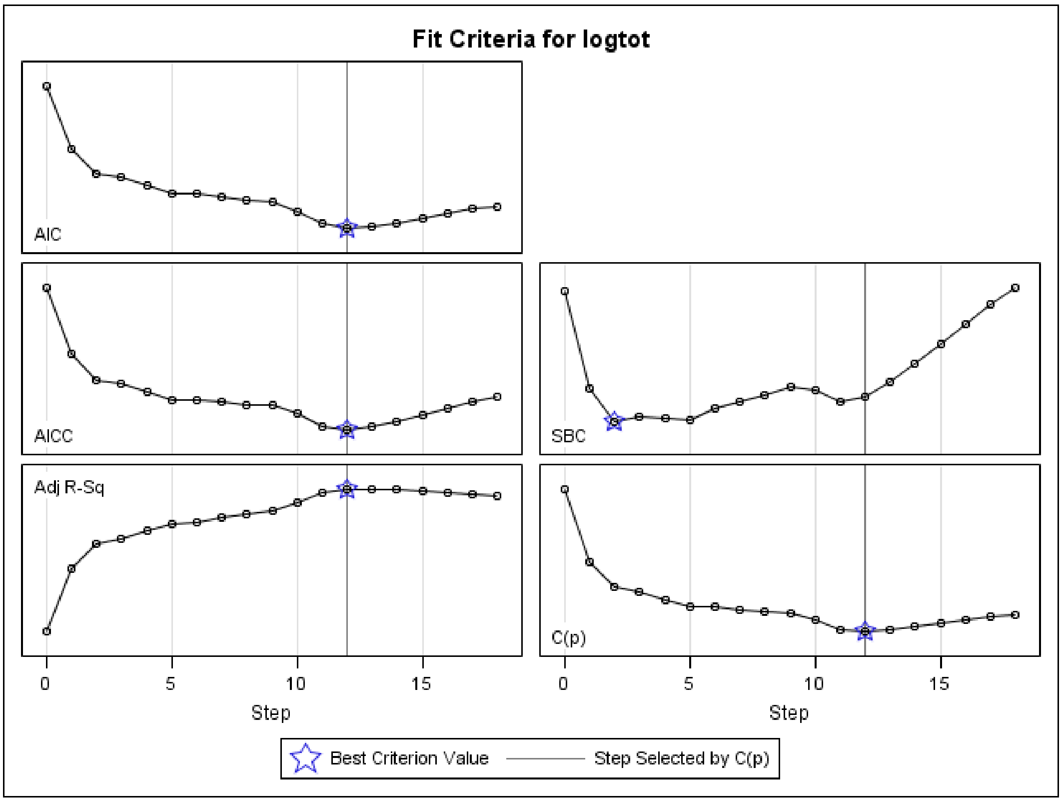

Fig. 3. Criteria suggest stopping the selection (GLMSELECT proc of SAS). Fit criteria of LASSO analysis. logtot: logarithm of total cases

The persistence of coronavirus has been previously investigated in milk (Hamdi, 2013). Waltenburg et al. (2021) reported confirmed COVID-19 among workers in cheese manufactures. A healthy recommendation concerning COVID-19 is to prevent the consumption of raw and/or undercooked animal food products (Moy, 2020). Moreover, kitchen instruments can transmit the virus among foods (Williams, 2012); accordingly, animal origin food may be a suitable vehicle for

SARS-COV-2 because the virus will survive longer inside them. Furthermore, the diagnostic methods of the virus in food are not complete, and there are many limitations (Bosch et al., 2018). Until now, the diagnosis of viruses in food science technology has focused on bivalve molluscs. Based on our results, we suggest a development of virus detection technics on all animal-origin foods. Very recently, it was reported that the high-fat tissue in the human body could impact the pathogenesis of COVID-19 (Maffetone and Laursen, 2020). Therefore, consumption of high-energy foods increases the risk of COVID-19. We tried to verify high energy foods resting in our statistical models. Although, the transmission risk of SARS-COV-2 through wine consumption (as a high-calorie food) is zero, we kept it in our statistical model. Based on the results of the statistical analysis, wine did not stayed among significant foods (Table 3). Thus, it was concluded that exclusively, the high-energy content of a food does not keep it in the fitted model. Therefore, in addition to the energy content of a food, there must be “something else” in it, i.e., SARS-Cov-2, based on our hypothesis. So animal-origin food may be as a vehicle rather than its high-calorie effect in the long term.

Table 2. Accuracy parameters of R-Square, Adjusted R-square, AIC and number of data (n) in the fitted models.

	Stepwise	LASSO	BAYES
R-Square	0.33	0.47	-
Adjusted-R Square	0.31	0.42	-
AIC	-	313	562
n	131	131	130

In other words, we should focus on the FBT of animal-origin-foods rather than the immunity response over a long period of time. In June 2020, more than 1,500 workers were infected with COVID-19 at a German slaughterhouse (Moulson, 2020); this guided us to verify the association between COVID-19 and animal-origin food. Another risk factor of the relationship between the food supply and COVID-19 may be the contact of hands with contaminated food during handling.

Table 3. The coefficients of multivariate analyses. All variables are logarithmic transformed data.

Variable	**Stepwise**	**Lasso**	**Bayes**
Pig meat		-0.26	0.36
Bovine Meat		0.12	0.75
Cheese			0.35
Cream		-0.18	0.19
Eggs	0.85	0.98	0.99
Freshwater fish		0.72	0.99
Honey		-1.18	0.03
Whole milk			0.34
Poultry meat			0.38
Demersal fish			0.47
Cephalopods			0.36
Butter/ghee		0.19	0.84
Marine fish(other)	-1.49	-1.32	-1.00
Aquatic plants			0.38
Beverages(Alcoholic)			0.18
Rice(Milled Equivalent)		0.30	0.95
Potatoes and products		0.37	0.96
Maize and products		0.39	0.99
Wheat and products		0.34	0.91
Wine			0.64

So, the role of hygienic principles in food handling and packaging needs to be studied. It has been suggested that possible transmission of the SARS-CoV-2 may occur through food intake from infected animals or cross-contaminated food (Oakenfull and Wilson, 2020). Similarly, WHO recommends that COVID-19 does not have FBT, and suitable food safety practices could prevent the probability of FBT (WHO, 2021). Implementation of appropriate safety food practices for all animal-origin foods should be studied. In this regard, it has been previously suggested that an acquisition of SARS coronavirus by consumption of contaminated food is possible (Yépiz-Gómez et al., 2013). Furthermore, oral infection of SARS-Cov-2 could not be excluded from the transmission routes (FAO/WHO 2008).

When we write this paper, the number of TC has already passed 80 million cases. We propose that the role of FBT of COVID-19 may be more noticeable than previously thought. The impact of animal-origin foods, which included eggs and freshwater fish, on TC was remarkable in the present analysis. Notably, we are not able to interpret all considerable impacts and their magnitude at present. Interpretation of the main parameters could be the subject of the further researches. Besides, in food science technology, it is essential to raise the detection of viruses to all animal-origin foods, e.g., Quevedo et al. (2020) have suggested some methods for inactivation of Coronaviruses in the food industry. The high negative correlation between marine fish consumption and TC is a curious observation that we suggest for the future studies.

Conclusion

Regardless of the awareness, knowledge, and readiness of many countries for COVID-19 during early 2020, why did it extend very quickly? It seems that FBT has got less consideration relative to other pathways of transmission. Animal-origin food may have a noticeable role in the transmission of the SARS-Cov-2. The perspective is to increase the surveillance of SARS-Cov-2 in the food production chain. For future researches, we suggest studying the possibility of animal-origin foods as a leading vehicle/preserver for SARS-Cov-2.

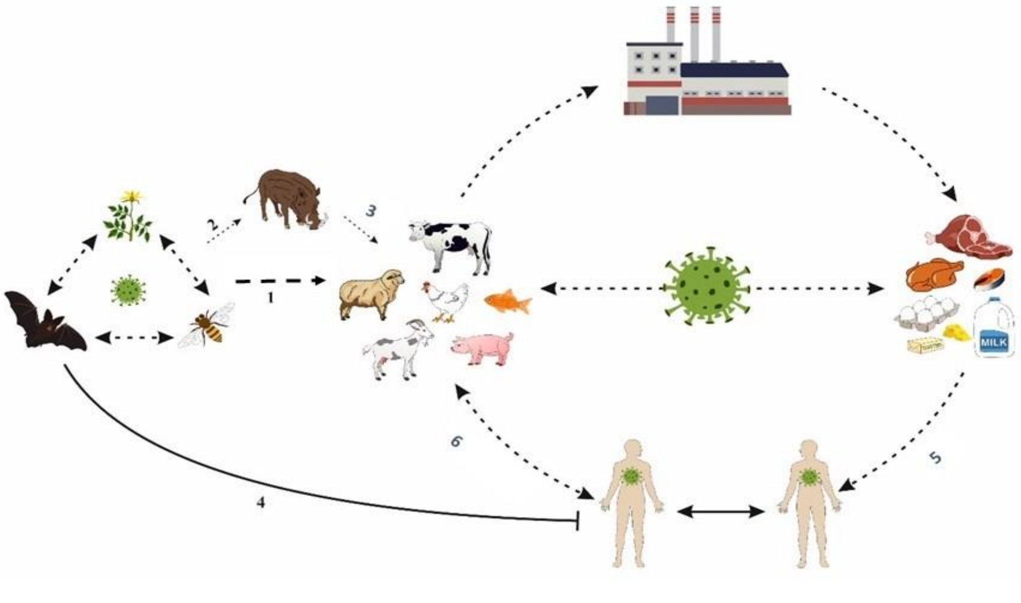

Fig. 4 Potential transmission ways of COVID-19 based on the results of our analysis and bibliography. The dashed lines: possible pathways. The Solid lines: proven pathways. References: **1**: (Babayan et al., 2018 ; Bourgarel et al., 2019); **2 and 3**: (Miller et al., 2017; Babayan et al., 2018); **4**: (Tao et al., 2020); **5**: (Dhama et al., 2020; this study); **6**: (Shao et al. 2011).

Data and materials availability

All data are available in DOI: 10.13140/RG.2.2.15759.10404

Acknowledgement

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Conflict of interest statement

The authors have declared no competing interest.

Ethical approval

Not applicable

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