Trends in Food Science & Technology 104 (2020) 268–272

Contents lists available at ScienceDirect

Trends in Food Science & Technology

journal homepage: www.elsevier.com/locate/tifs

Commentary

COVID-19 pandemic changes the food consumption patterns

Tome Eftimov[a,*], Gorjan Popovski[a,b], Matej Petković[b,c], Barbara Koroušić Seljak[a], Dragi Kocev[b,c,d]

[a] Computer Systems Department, Jožef Stefan Institute, 1000 Ljubljana, Slovenia
[b] Jožef Stefan International Postgraduate School, 1000 Ljubljana, Slovenia
[c] Department of Knowledge Technologies, Jožef Stefan Institute, 1000 Ljubljana, Slovenia
[d] Bias Variance Labs, d.o.o., 1000 Ljubljana, Slovenia

ARTICLE INFO

Keywords:
Artificial intelligence
COVID-19 pandemic
Dietary habits analysis
Food consumption
Food semantic annotation

ABSTRACT

Background: The COVID-19 pandemic affects all aspects of human life including their food consumption. The changes in the food production and supply processes introduce changes to the global dietary patterns.

Scope and Approach: To study the COVID-19 impact on food consumption process, we have analyzed two data sets that consist of food preparation recipes published before (69,444) and during the quarantine (10,009) period. Since working with large data sets is a time-consuming task, we have applied a recently proposed artificial intelligence approach called DietHub. The approach uses the recipe preparation description (i.e. text) and automatically provides a list of main ingredients annotated using the Hansard semantic tags. After extracting the semantic tags of the ingredients for every recipe, we have compared the food consumption patterns between the two data sets by comparing the relative frequency of the ingredients that compose the recipes.

Key Findings and Conclusions: Using the AI methodology, the changes in the food consumption patterns before and during the COVID-19 pandemic are obvious. The highest positive difference in the food consumption can be found in foods such as "Pulses/ plants producing pulses", "Pancake/Tortilla/Outcake", and "Soup/pottage", which increase by 300%, 280%, and 100%, respectively. Conversely, the largest decrease in consumption can be food for food such as "Order Perciformes (type of fish)", "Corn/cereals/grain", and "Wine-making", with a reduction of 50%, 40%, and 30%, respectively. This kind of analysis is valuable in times of crisis and emergencies, which is a very good example of the scientific support that regulators require in order to take quick and appropriate response.

1. Introduction

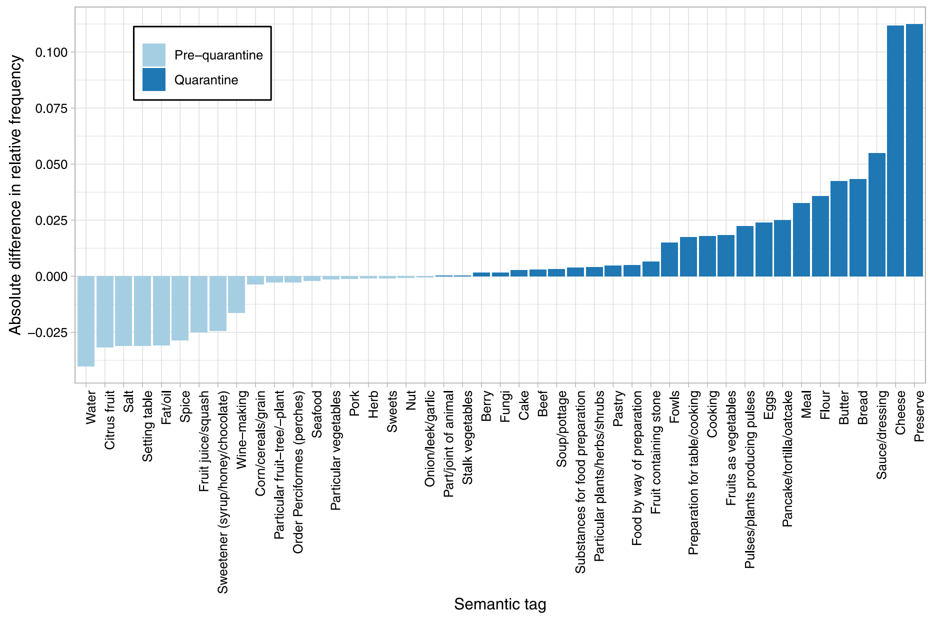
In late December 2019, a pneumonia disease appeared in Wuhan, China, which has spread globally resulting in the 2019/2020 coronavirus pandemic, known as COVID-19 disease and caused by the coronavirus-2 (Hui et al., 2020). Since both lives and livelihoods are at risk from the epidemic, the World Health Organisation (WHO) provides protective measures that we should take into consideration (Ghebreyesus, 2020). Some of the measures taken in almost all countries are border closures and quarantines, which affect all aspects of human life including food and agriculture systems.

The United Nations' Food and Agriculture Organisation (FAO) has already discussed the impact of the COVID-19 pandemic to the world's food and agriculture systems. They point out that, based on the highly globalized nature of today's food production and supply, commodities need to move from the world's source of grain supply to where they are consumed (Food and Agriculture Organization (FAO) of the United Nations, 2020). The protective measures the governments across the world have implemented restrict people's access to abundant, diverse and nutritiously sufficient sources of food. According to FAO, due to the various effects of the global pandemic, the overall global consumption will be limited while introducing changes to the global dietary patterns. In almost all countries access to the food markets is restricted and limited, while the restaurants and venues are closed. This further affects the way how people buy and consume food. These reasons also shifted the food consumption patterns to favor preparing meals and eating at home.

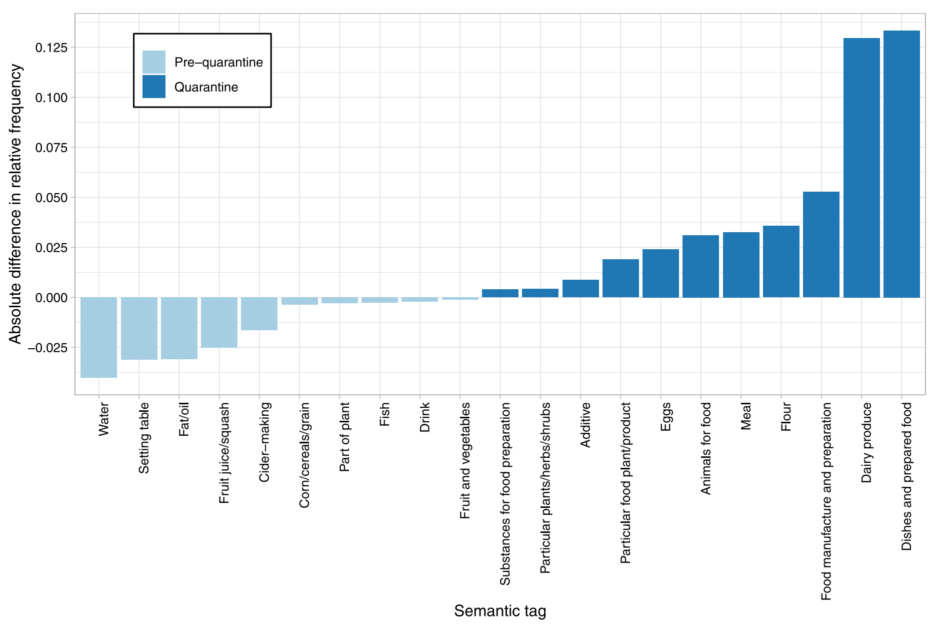
Furthermore, restrictions on shipments have lead to potential shortages of some food products, especially related to fresh fruits and

* Corresponding author.
E-mail addresses: tome.eftimov@ijs.si (T. Eftimov), gorjan.popovski@ijs.si (G. Popovski), matej.petkovic@ijs.si (M. Petković), barbara.korousic@ijs.si (B.K. Seljak), dragi.kocev@ijs.si (D. Kocev).

https://doi.org/10.1016/j.tifs.2020.08.017
Received 23 April 2020; Received in revised form 14 July 2020; Accepted 31 August 2020
Available online 2 September 2020



(a) Comparison on the last level from the Hansard hierarchy



(b) Comparison on a higher level from the Hansard hierarchy.

Fig. 1. Absolute differences between the relative frequencies of each semantic tag.

vegetables, fish and fish products, and other food products of similar perishable nature. This furthermore affects seasonal workers, like those working on farms. Consequently, this further affects and decelerates the food production process. Another economic factor is that during the pandemic, many people are exposed to limited earnings at least on some scale, which could additionally have an impact on global food consumption patterns.

2. Food consumption pattern analysis using AI

To explore the COVID-19 impact on food consumption, we decided to make a quick study analyzing recipes for the preparation of food published before and during the quarantine. This data is easily accessible and may reflect dietary habits of people during the quarantine. We collected two sets of recipes published on `AllRecipes` – i.e., the largest food social network where everyone can discover and share recipes (https://www.allrecipes.com/). Checking the statistics about this network (Allrecipes, 2020), we can see that it covers cuisine from 24 countries, there are 1.5 billion visits per year, and 68 percentage of users are female. The first data set is a collection of recipes published before the quarantine started. It is a mix of recipes from the categories *Diet and Health*, *World Cuisine*, and *Cooking Style*. Our aim was to globally explore the impact on food consumption, not limited only to a specific diet or region. The second data set consists of recipes published and classified under the category of *Quarantine Cooking* and they are also coming from different diets and regions. Our data sets for pre-quarantine and quarantine period consist of 69,444 and 10,009 recipes, respectively.

To analyze the recipes, we applied our recently proposed methodology, DietHub, based on artificial intelligence (AI) (Petković, Popovski et al., 2020). It takes as an input the textual description of the preparation process of a recipe (disregarding the list of ingredients as our focus is on understanding the textual data), and as output produces a list of main ingredients automatically annotated using food semantic tags available in the Hansard corpus (Alexander & Davies, 2015). Those semantic tags describe the meaning of food-related concepts (such as names of food ingredients and cooking procedures) specified in the textual description. Namely, such concepts in collectively gathered recipes are written in various ways; while some contributors use literary language, others use spoken language or even dialects. Therefore, an annotation task is a challenging one and requires advanced computer techniques. We should also mention that the methodology DietHub uses food semantic tags that are organized in a hierarchy, starting from broader food concepts (i.e. food groups) and going down to more specific food concepts (i.e. food subgroups). DietHub is trained using an annotated corpus of recipes, known as FoodBase (Popovski et al., 2019), and is based on representational learning (learning embeddings for recipe description) coupled with predictive modeling (in our case, hierarchical multi-level classification) (Kocev et al., 2013; Petković et al., 2017). In a nutshell, by using this methodology, we are able to extract the main ingredients from each recipe, where the ingredients are annotated with hierarchical semantic tags from the Hansard corpus.

3. COVID-19 impact on food consumption patterns

By applying the AI methodology on the pre-quarantine and quarantine data sets of recipes, we automatically assigned the semantic tags of the ingredients used in the recipes. Next, we compared the relative frequency of the ingredients (i.e., the food semantic tags) that compose the recipes. The relative frequency of each semantic tag was calculated by dividing the count of semantic tag in each data set with the number of recipes in that data set. Since our food semantic tags are organized in a hierarchy, we made the comparison twice, once using the food semantic tags that are on the deepest level of the hierarchy (i.e., to the most specific ingredients, e.g. cheese, butter), and then using the tags on a higher level leaf (i.e., to more general food concepts, e.g. diary produce). The results are presented in Figs. 1 and 2.

3.1. Statistical analysis of relative frequencies of food semantic tags

The absolute differences between the relative frequencies for each semantic tag during the quarantine and pre-quarantine in both cases are presented in Fig. 1. By inspecting the graph for the more specific semantic tags in Fig. 1(a), we can note that the frequency of tags such as *Bread*, *Pancake/Tortilla/Oatcake*, *Cheese*, *Flour*, *Butter*, *Pastry*,*Eggs*, *Sauce/dressing*, has increased during the quarantine, while for semantic tags such as *Seafood*, *Citrus fruit*, *Salt*, *Spices*, *Fat/oil*, *Corn/cereals/grains*, *Sweetener (syrup/honey/chocolate)*, *Fruit juice/squash*, has decreased. Similar observations can be made for the more general semantic tags, as depicted in Fig. 1(b).

Additionally, we illustrate the difference between the relative frequencies of each semantic tag during the quarantine and pre-quarantine, divided by the relative frequency of the semantic tag during the pre-quarantine period (Fig. 2). These graphs show the fold change of semantic tags that has occurred during the quarantine. Most startling discovery is the 300% increase of the frequency of the semantic tag *Pulses/plants producing pulses*. This semantic tag includes the following items dry beans, dry peas, chickpeas, cow peas, pigeon peas, lentils, Bambara beans, vetches, and lupines. Next, there is a ~280% increase of *Pancake/Tortilla/Oatcake*, and ~180% increase of *Soup/pottage*. Furthermore, the frequency of the following tags has increased for more than ~100% in the quarantine period: *Pastry*, *Fruit containing stone*, *Cake*, and *Beef*. On the other side, the tags with reduced frequency include the semantic tag *Order Perciformes (perches)* (i.e., fish) (~50% reduction), *Corn/cereals/grain* (~40% reduction), *Wine-making* (~30% reduction), and with ~10% reduction *Citrus fruit*, *Pork*, *Water*, *Seafood*, *Fruit juice/squash* and *Herbs*.

3.2. Health implications

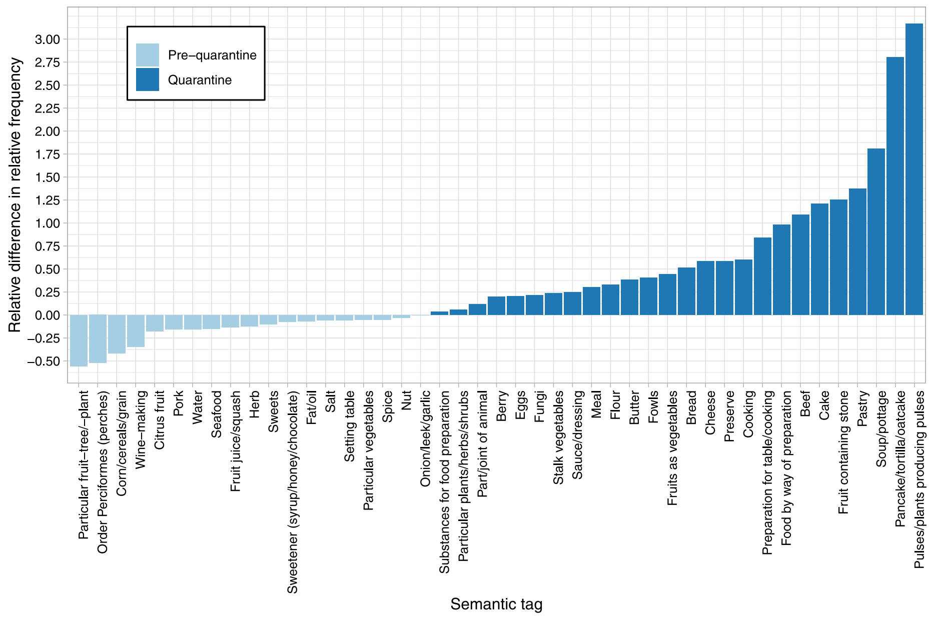
From the figures, we could conclude that from the perspective of health, it is very positive that the frequencies of salt, fat/oil, sweets and fruit juice/squash have decreased during the quarantine. This can be justified by the fact that home-made dishes contain less salt, fat and sugar than the pre-processed ones. It is also great to see that the frequencies of stalk vegetables, fruits as vegetables, fruit containing stone, berries and pulses have increased. More worrisome is the outcome of decreased frequencies of corn/cereals/grain, seafood, citrus fruits, particular vegetables and fruit, herbs and nuts, which present main ingredients of healthy diet (such as the Mediterranean diet). From the perspective of agriculture, we should explore in more details our outcome of increased eggs and beef, and decreased seafood, pork and corn/cereals/grain. This may impact both the health of environment and global economy.

The interpretation is based on the analysis of the internet-sourced recipes posted by people from around the world. Considering this kind of data sources, research has already shown that people have problems judging how healthy a meal is and need a support in a form of dietary recommendations (Trattner & Elsweiler, 2017). Also the results of the study, presented in this communication, indicate that dietary recommendations prepared by experts (Barazzoni et al., 2020; EFAD, 2020) need to be communicated more extensively during the quarantine. This is especially important for those with special nutrition needs, such as obese people, patients with non-communicable chronic diseases, pregnant and lactating women, seniors having several chronic diseases, and of course for individuals with SARS-CoV-2 infection.

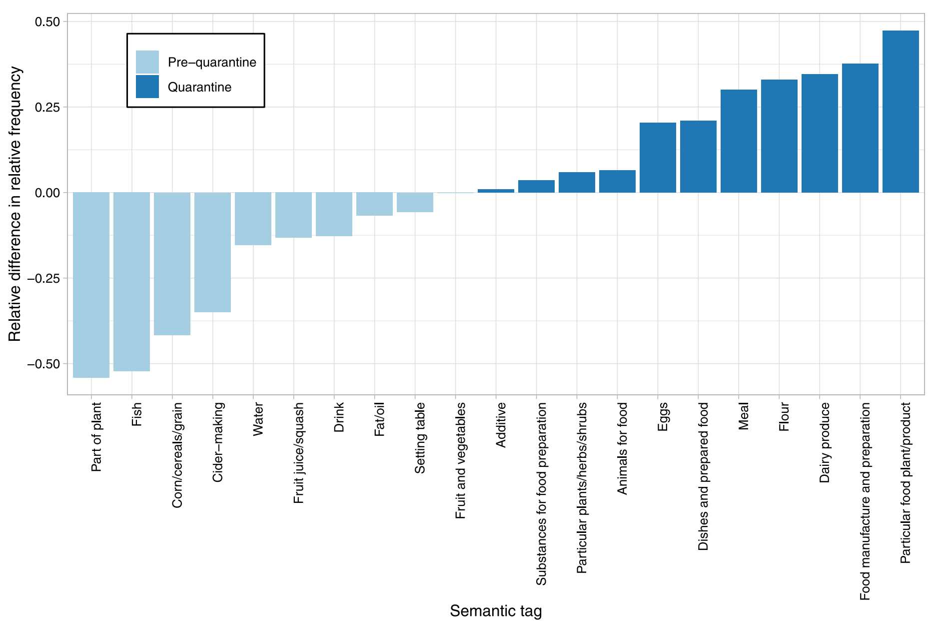
4. Conclusion

By applying DietHub – an AI-based methodology, we are able to analyze the impact of the COVID-19 pandemic to the food consumption patterns. From the results, the changes in the meal patterns are obvious. This may have consequences (positive and negative) related to the human and environment health as well as to the global economy. It can be expected that such meal patterns will remain stable across the quarantine duration, and most probably the patterns after the quarantine will change in comparison to the ones before, due to the changes from the pandemic (different types of food will be produced and manufactured due to the quarantine). With regard to the generalization, working with publicly available social data might undermine the conclusions obtained. However, the large quantity of data collected compensates for that risk.

For future work, a more detailed study of the changes in meal patterns for the complete duration of the quarantine will need to be prepared. More detailed in a sense to include localization by considering specific regions, and specialization by considering different diets (e.g., vegan, vegetarian, gluten-free etc.). These kind of studies open future possibilities for personalized as well as general recipe recommender systems. Additionally, since the COVID-19 pandemic is still currently ongoing, we are planning to repeat the analysis in this work, once sufficient data is available.



(a) Comparison on the last level from the Hansard hierarchy



(b) Comparison on a higher level from the Hansard hierarchy.

Fig. 2. Relative differences between the frequencies of each semantic tag. The values on the graphs should be interpreted as percentage increases of the values in the quarantine period as compared to the non-quarantine period. For example, having a relative difference of 1, means that the frequency has increased for 100% in the quarantine period, compared to the non-quarantine period.

Acknowledgments

This work was supported by projects from the Slovenian Research Agency [research core grant numbers P2-0098 and P2-0103, and project grant numbers J2-9230 and Z2-1867), and the European Union's Horizon 2020 research and innovation programme (FNS-Cloud, Food Nutrition Security) [grant agreement 863059].

The information and the views set out in this publication are those of the authors and do not necessarily reflect the official opinion of the European Union. Neither the European Union institutions and bodies nor any person acting on their behalf may be held responsible for the use that may be made of the information contained herein.

References

Alexander, M., & Davies, M. (2015). The hansard corpus 1803-2005. Retrieved from URL: http://eprints.gla.ac.uk/115023/. (Accessed 07 April 2020).

Allrecipes (2020). 20 amazing allrecipes facts and statistics (2020). URL: https://expandedramblings.com/index.php/allrecipes-facts-statistics/.

Barazzoni, R., Bischoff, S. C., Krznaric, Z., Pirlich, M., & Singer, P. e. b. t. E. C. (2020). Espen expert statements and practical guidance for nutritional management of individuals with sars-cov-2 infection. *Clinical Nutrition*, http://dx.doi.org/10.1016/j.clnu.2020.03.022.

EFAD (2020). Covid-19 information on nutritional support. URL: http://www.efad.org/en-us/covid-19/.

Food and Agriculture Organization (FAO) of the United Nations (2020). Q&a: COVID-19 pandemic – impact on food and agriculture. Retrieved from URL: http://www.fao.org/2019-ncov/q-and-a/en/. (Accessed 07 April 2020).

Ghebreyesus, T. A. (2020). *WHO Director-General's Opening Remarks at the Media Briefing On COVID-19*. World Health Organization, Geneva, Switzerland, 11 March 2020.

Hui, D. S., I Azhar, E., Madani, T. A., Ntoumi, F., Kock, R., & Dar, O. (2020). The continuing 2019-nCoV epidemic threat of novel coronaviruses to global health—The latest 2019 novel coronavirus outbreak in Wuhan, China. *International Journal of Infectious Diseases*, *91*, 264–266.

Kocev, D., Vens, C., Struyf, J., & Džeroski, S. (2013). Tree ensembles for predicting structured outputs. *Pattern Recognition*, *46*(3), 817–833.

Petković, M., Džeroski, S., & Kocev, D. (2017). Feature ranking for multi-target regression with tree ensemble methods. In A. Yamamoto, T. Kida, T. Uno, & T. Kuboyama (Eds.), *Discovery Science* (pp. 171–185). Springer International Publishing.

Petković, M., Popovski, G., Seljak, B. K., Kocev, D., & Eftimov, T. (2020). Diethub: dietary habits analysis through understanding recipe's content. (in press).

Popovski, G., Seljak, B. K. s., & Eftimov, T. (2019). Foodbase corpus: a new resource of annotated food entities. *Database*, *2019*.

Trattner, C., & Elsweiler, D. (2017). Investigating the healthiness of internet-sourced recipes. In *International World Wide Web conference committee (IW3C2)* (pp. 489–498).