Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Changes in food behavior during the first lockdown of COVID-19 pandemic: A multi-country study about changes in eating habits, motivations, and food-related behaviors

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ABSTRACT

The COVID-19 pandemic resulted in severe, unprecedented changes affecting the world population. Restrictions in mobility, social distancing measures, and the persistent social alarm, during the first period of pandemic, resulted in dramatic lifestyle changes and affected physical and psychological wellbeing on a global scale.

An international research team was constituted to develop a study involving different countries about eating motivations, dietary habits and behaviors related with food intake, acquisition, and preparation. This study presents results of an online survey, carried out during the first lockdown, in 2020, assessing food-related

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behavior and how people perceived them to change, comparatively to the period preceding the COVID-19 outbreak.

A total of 3332 responses, collected from 16 countries, were considered for analysis [72.8% in Europe, 12.8% in Africa, 2.2% in North America (USA) and 12.2% in South America]. Results suggest that the main motivations perceived to drive food intake were familiarity and liking. Two clusters were identified, based on food intake frequency, which were classified as "healthier" and "unhealthier". The former was constituted by individuals with higher scholarity level, to whom intake was more motivated by health, natural concerns, and weight control, and less by liking, pleasure or affect regulation. The second cluster was constituted by individuals with a higher proportion of male and intake more influenced by affect-related motivations. During this period, a generalized lower concern with the convenience attributes of foods was noted (namely, choice of processed products and fast-food meals), alongside an increase in time and efforts dedicated to home cooking.

Understanding the main changes and their underlying motivations in a time of unprecedented crisis is of major importance, as it provides the scientific support that allows one to anticipate the implications for the future of the global food and nutrition system and, consequently, to take the appropriate action.

1. Introduction

When, in November 2019, the new coronavirus Sars-Cov-2 was firstly identified, it was not imaginable that the world would change abruptly only a few months later, with the surge of a global pandemic announced in March 2020. The rapid spread of the associated disease (COVID-19) imposed global movement restrictions and severe changes to civil and social activity. A considerable proportion of the world population was suddenly confined to their homes, with reduced social contact and recurrent information about increasing numbers of infections and deaths, resulting in drastic changes in daily habits and emotional well-being.

The link between the pandemic and nutrition and food-related behavior started to attract attention due to different concerns. For instance, different studies emerged, associating nutrition with immune system and the risk of developing severe forms of the disease. For example, the link between vitamin D deficiency [e.g. (Jain et al., 2020; Kenneth Weir, Thenappan, Bhargava, & Chen, 2020; Martineau & Forouhi, 2020)], or an association between the levels of vitamin C [e.g. (Carr & Rowe, 2020; Chiscano-Camón, Ruiz-Rodriguez, Ruiz-Sanmartin, Roca, & Ferrer, 2020)] and the severity of symptoms in COVID-19, have been reported. Obesity and related diseases, such as cardiovascular events, diabetes and hypertension, which are also somehow related to dietary habits, were also linked to a worst prognosis for the disease (Tamara & Tahapary, 2020), alerting individuals to the relevance that nutrition can have in this pathology.

In general, the potential relationship between nutritional status and disease severity may act as a driver of dietary changes. Besides the search for a better health condition, that may introduce variations in eating behavior, the effect that the pandemic can have on mood, mental health and emotional wellbeing (Salari et al., 2020) may also affect food intake and choices. Unbalanced eating behaviors are common in individuals with emotional disorders, depression and/or anxiety (Aoun et al., 2019). In fact, mood and emotions have been recognized as major drivers of food intake: meals eaten in positive or negative moods are significantly larger than meals eaten in a neutral mood (Patel & Schlundt, 2001). Moreover, stress, depression and sadness have been consistently associated with increased food intake and poor nutritional choices (Devonport, Nicholls, & Fullerton, 2019), including the increased preferences towards sweets rather than healthier snacks (Pilska & Nesterowicz, 2016). It should be noted, however, that patterns of hedonic or affective eating appears to be more common in females than in males (Manippa, Padulo, van der Laan, & Brancucci, 2017).

Research conducted during the COVID-19 pandemic seems to support to the hypothesis that mood and stress influence eating habits. For instance, a study with French participants showed that the circumstances of lockdown increased the choice of foods motivated by mood, namely processed meat, sweet-tasting beverages and alcoholic beverages (Marty, de Lauzon-Guillain, Labesse, & Nicklaus, 2021), whereas in an Italian study, almost half of the participants reported using food as a means of comfort during the pandemic or increasing food intake to feel better (Renzo et al., 2020). Another study with French undergraduate students suggested that stress during the first week of confinement was associated with greater likelihood of incurring in maladaptive eating behaviors, such as binge eating or dietary restriction (Flaudias et al., 2020).

Beyond food choice and intake, other aspects of food behavior, such as product prioritization and habits of acquisition and meal preparation, can also be influenced by the movement restrictions and the social and psychological modifications induced by the pandemic (e.g., Laguna, Fiszman, Puerta, Chaya, & Tárrega, 2020). A study using an Artificial Intelligence methodology found changes in the choice of recipes, with increasing interest in cooking foods such as pulses (e.g., beans, lentils), flatbreads (e.g., pancakes, oatcakes) and soups, and less interest for recipes involving ingredients such as fish (i.e., Perciform) and grains (e.g., corn, cereal) (Eftimov, Popovski, Petković, Seljak, & Kocev, 2020). The threats of disruptions to the supply chain and fears of food scarcity were associated to changes in acquisition behavior, such as, impulsive or obsessive buying (Islam et al., 2020). Restrictive measures, such as limiting retail stores' opening hours, were also amongst the factors affecting consumer purchase behaviors. Despite reports of increases in the amounts of food purchased in response to these measures (e.g., stockpiling), food waste did not seem to grow in proportion, due to factors such as better shopping planning, improved cooking and food management skills, or the higher preference for non-perishable products (Ben Hassen, El Bilali, Allahyari, Berjan, & Fotina, 2021; Jribi, Ben Ismail, Doggui, & Debbabi, 2020; Pappalardo, Cerroni, Nayga, & Yang, 2020; Roe, Bender, & Qi, 2021). Unsurprisingly, online grocery shopping has risen considerably during this period, as well as the use of meal delivery systems (Ali, 2020; Ben Hassen, El Bilali, & Allahyari, 2020; Chenarides, Grebitus, Lusk, & Printezis, 2021; Poelman et al., 2021).

The main objective of the present study was to provide a comprehensive overview of how eating motivations, food frequency consumption, and food-related behaviors were perceived to occur and/or to change during the first period of COVID-19 pandemic. As such, it aimed to identify clusters of individuals according to their dietary habits, during this period, and to infer how socio-demographics, body mass index (BMI), motivations, and food related behaviors may be associated with those clusters. Moreover, it was our objective to compare the clusters in terms of their changes in eating behavior. To have a global picture, data was collected in 16 countries from Africa, Europe, North America and South America.

2. Material and methods

The protocol of the study was approved by the Ethical Committee of the University of Evora (Ref - GD/14849/2020), and all the researchers from each country participated in the elaboration of the questionnaire and agreed to its content and its means of dissemination. The 16 countries integrating the study were Portugal, Spain, Italy, Poland, Czech

Republic, Lithuania, Croatia, Austria, Brazil, Costa Rica, Cape Verde, Saint Tome Principe, Angola, United States of America (USA), Morocco, and Tunisia. The research was conducted in accordance with the guidelines given in the Declaration of Helsinki.

2.1. Study design

A cross-sectional, multi-country study was developed, consisting of an anonymous electronic survey, programmed in LimeSurvey (LimeSurvey GmbH, Germany) (Supplementary material A). The survey took an average of 15–20 min to complete and encompassed different dimensions of food behavior, namely: 1) sociodemographics and COVID-19-associated restrictions (16 questions); 2) Eating motivations (30 questions); 3) Food consumption frequency (24 questions); and 4) Food-related behaviors (namely, changes in the purchase, preparation, and management of food) (19 questions). Data were collected for all countries between April and June 2020, during the period when the number of cases peaked.

Participant recruitment was made through a snowball method starting with private and official e-mail contacts followed by the release of the link on social media (Facebook, Linkedin, Twitter, Whatsapp) and other institutional and media sites.

2.1.1. Sociodemographic questionnaire

A brief sociodemographic questionnaire was developed to obtain a general characterization of the sample and gain an understanding of the living conditions during lockdown.

General sociodemographic variables included age, sex, self-reported height and weight, educational attainment, household size and composition, and socioeconomic status (levels of monthly income). BMI was calculated by dividing the self-reported weight (kg) by the square of height (m^2).

2.1.2. Eating motivations

The Eating Motivation Survey (TEMS - Renner, Sproesser, Strohbach, & Schupp, 2012) was used with the aim of answering the questions on why we eat what we eat. The questionnaire comprises fifteen reasons (scales) for choosing foods, as for example, Health (e.g., "to maintain a balanced diet"), Convenience (e.g., "because it is easy to prepare"), Pleasure (e.g., "in order to indulge myself") or Price (e.g., "because it is inexpensive"). The brief version of TEMS, which has been previously confirmed to be replicable across countries despite the differences in eating environments (Sproesser et al., 2018, 2019), includes 45 items/questions (corresponding to 3 items per scale, in a total of 15 scales), which were previously selected based on criteria of factor loading, cross-loading between factors, correlated error terms and fit between item and content of the scale.

In the present study, we used 10 scales of the brief version of the TEMS. These scales were chosen to reflect motivations that were deemed particularly relevant for understanding changes in eating behavior in the context of a pandemic, omitting scales that were not applicable under a confinement situation, such as sociability, for example. The adopted scales were chosen by consensus between three of the authors, taking into consideration the aim of this study: Liking, Habits, Need & Hunger, Health, Convenience, Pleasure, Natural concerns, Price, Weight control and Affect regulation. The items were translated to the native languages of the 16 countries that participated in the study, by native speakers. Each of the 3 items per scale was evaluated using a 7-point rating scale, ranging from 1 (*never*) to 7 (*always*). For each item, participants were additionally asked to choose whether that item/motivation was less relevant, more relevant, or equivalent, compared to their habitual behavior before the pandemic.

2.1.3. Food frequency consumption

A Food Frequency Questionnaire was used to assess current eating habits. The items included 24 food groups, representing the main food groups assessed through Food Frequency Questionnaires (FFQs) (Lopes, Aro, Azevedo, Ramos, & Barros, 2007). The 24 food groups considered were the following: dairy products, red meat, white meat, fish, eggs, vegetables, potatoes, grains, bread, breakfast cereals, fresh fruit, butter or margarine, olive oil, pulses, nuts, cakes and cookies, chocolates, sweet snacks, salty snacks, processed foods, wine, beer, spirits, black coffee, or tea. In some cases, adaptations were made in the examples provided for each food group, in an effort to better reflect each country's dietary habits (e.g., "pirão", that is a kind of bread made with mandioc flour was added, as example for bread section, for African countries' questionnaires). The frequency of consumption of each food/food group was rated using 8-point scales (0 = *never or less than once a month*; 1 = *2–3 times per month*; 2 = *once a week*; 3 = *2–3 times per week*; 4 = *4–6 times per week*; 5 = *once a day*; 6 = *2–3 times per day*; and 7 = *3 times or more per day*). For each food group, participants were additionally asked to indicate whether the frequency was lower, higher, or equivalent, compared to their usual behavior before the pandemic.

2.1.4. Food-related behaviors

The food life cycle is defined as the set of operations and processes taking place from the stages of production to the final transformation into health outcomes (Sobal, Khan, & Bisogni, 1998). Within this global system, we were interested in the variables pertaining to the consumer subsystem, that is, the stages of Acquisition (input), Preparation (transformation) and Consumption (output). For the purpose of this study, we developed 18 items covering these three domains. Items related to Acquisition included buying contexts (to buy food from grocery stores or markets near home; to buy food from large superstores or supermarkets; to buy food from apps and/or online stores; to buy food in large quantities), and preferences (to purchase products from organic farming; to acquire locally produced foods; to grow or produce your own foods). The Preparation subscale included items on involvement (to dedicate time to prepare meals; to make new dishes or try new recipes; to order take-away meals) and waste management (to try not to waste food; to plan shopping and meals; to be aware of products' expiration dates/shelf life, paying attention to food waste). The Consumption subscale included items regarding changes in appetite, control over diet and changes to eating schedules (to feel appetite/desire to eat; to maintain control over the type of food and the amount eaten; to maintain a varied/balanced diet; to look for foods that provide the sensation of comfort; to eat meals at fixed/predictable times; to snack between meals). Answers were given on 7-point rating-scales ranging from 1 (*Never*) to 7 (*Always*). Participants were asked to select whether the frequency was lower, higher, or equivalent, when compared to their usual behavior before the pandemic.

2.2. Population recruitment, eligibility criteria and data privacy

Due to the restrictions imposed by COVID-19, recruitment strategy consisted in dissemination of the online survey link through social media (Facebook, Linkedin, Twitter, WhatsApp), through researchers' network (private and official e-mail contacts), and institutional and media sites. This strategy was similar across the different countries. Only people that accepted to participate, by giving their consent for data usage in the first question on the questionnaire, were included. All of them had to report being older than 18. A total of 7134 potential participants initiated the survey, but only 3332 were included in the analysis, as these were the ones that completed the whole questionnaire.

2.3. Statistical analysis

Statistical analysis was performed using SPSS 27.0 software considering an alpha level of 5% by an Applied Statistics Spec. Exploratory analysis included calculation of mean, standard deviation, median, percentiles, percentages, and plots. The differences for sex, age and BMI were assessed using Mann-Whitney test, whereas for school level,

monthly income, number of children, confinement situation, and labor Chi-squared test was used. Given the large sample size, in addition to the *p* value, the effect size was also examined and interpreted.

To identify groups of participants with similar nutritional habits, a cluster analysis was used. First, hierarchical cluster analysis using the farthest neighbor method for calculating distances between clusters was performed to obtain the dendrogram and analyze the range of clusters. Further, K-means method was employed. The following cluster-variables (frequency of intake) were considered: milk, red meat, white meat, vegetables, complex carbohydrate, fresh fruit, butter and margarine, olive oil, pulses, cookies and cakes, chocolate, sweet snacks, salty snacks, processed foods, wine, beer, and spirits. The final number of clusters was based on the interpretability and reliability of the cluster solution, and the F statistics were also assessed for interpretation purposes.

In the comparison between clusters for the demographic characteristics and for the domains of eating motivations, the Chi-squared test, Mann-Whitney and MANOVA tests were used, respectively.

Principal component analysis (PCA) was used to summarize data gathered from the changes in nutritional habits and estimate the number of components emerging from that. The variables obtained from the items of the questionnaire concerning the level of change in the frequency of intake of each food group, comparatively to the habitual behavior before the pandemic were the ones used for this analysis, considering them as ordinal variables, with the responses: “less than before”, “equal”, and “more than before”. Initially, the correlation matrix of the standardized variables was examined, and the number of components to retain was based on eigenvalues, total of explained variance, and scree plot examination. A Varimax rotation was performed. The overall Kaiser–Meyer–Olkin (KMO) measure and Bartlett’s test of sphericity were examined, which are required for a good analysis.

Additionally, the component loadings generated from PCA that summarized the changes in food ingestion were compared between clusters and sexes using MANOVA with Bonferroni’s adjustment. Additionally, the regression coefficients were correlated with age using the Pearson correlation test.

3. Results

3.1. Global trends in food-related behavior during the pandemic period

3.1.1. Demographic characterization of participants

A total of 3332 complete responses were obtained and kept for analysis. Most of the respondents were women (71.6% vs. 28.4% men) and 73.2% had no children living with them. Most of the participants (84%) had a graduation or post-graduation (Bachelor, Master or PhD degree). A total of 83.8% participants were confined (Table 1). Significant differences were observed between men and women considering age ($p = .002$) and BMI ($p < .001$), which were higher in men than in women, as well as in monthly income ($p < .001$), number of children ($p = .034$) and confinement circumstances ($p < .001$) (Table 1).

3.1.2. Eating motivations

The main eating motivations were evaluated. Eating due to liking and according to habits were the most often reported motivations (mean classifications of 5.5 ± 1.3 and 5.4 ± 1.4, respectively) whereas affective factors (e.g., frustration, sadness) were perceived to have a lower impact on eating practices (mean classification of 2.4 ± 1.4). In terms of perceived changes, due to the pandemic situation, “pleasure” and “affect regulation” were the motivations for which increases were reported by a higher proportion of participants (Supplementary Table 1).

3.1.3. Food frequency patterns and motivations

On average, foods like dairy products, vegetables, fresh fruit and coffee/black tea were consumed 5–6 times per week. Eggs, vegetables, and fresh fruits were the foods perceived by a larger proportion of participants as increasing in consumption frequency during the studied period. These foods/drinks were only surpassed by chocolate, which 26.9% of participants perceived to eat with higher frequency than before the pandemic (Supplementary Table 1).

Table 2 shows the results of the K-means cluster analysis used to identify groups of participants based on similar food frequency variables. The analysis of the cluster centers and F statistics identified two meaningful clusters that differed according to the frequency of food consumption. The taxonomy description of the two clusters were: Cluster 1 (labeled ‘Healthier diet”; $n = 2165$) was characterized by a balance in the frequency of consumption of the various types of food. Cluster 2 (labeled ‘Unhealthier diet”; $n = 1167$) was characterized by a higher frequency of food consumption when compared to Cluster 1, and a closer look at the results showed that the variables that mostly contributed to the classification were cookies and cakes, chocolate, sweet snacks, salty snacks, and processed food.

Table 3 shows the characteristics of the clusters (*heathier* vs. *unhealthier* diet) according to sociodemographic aspects and eating motivations. The clusters did not differ according to age and BMI ($p > 0.05$), and a small difference in sex distribution was observed: the

Table 1
Participants’ sociodemographic characteristics [number (%)]

Parameters		Men (N = 946)	Women (N = 2386)	p-value
Age (Mean ± SD)		39.1 ± 14.5[a]	37.4 ± 13.5[b]	0.002
BMI (Kg/m^2)		25.5 ± 4.5[a]	23.9 ± 4.8[b]	0.0005
School level	Elementary school	17 (2)	43 (2)	0.878
	High school	136 (14)	342 (14)	
	Graduate/post graduate	791 (84)	1998 (84)	
Monthly income	Low	115 (14)	444 (21)	0.0005*
	Medium	431 (51)	1047 (49)	
	High	296 (35)	637 (30)	
Children	None	668 (71)	1772 (74)	0.034*
	1 or more	277 (29)	615 (26)	
Confinement situation	Confined	732 (78)	2056 (86)	0.0005*
	Not confined	210 (22)	328 (14)	
Labor	Employed (occupied)	643 (68)	1558 (66)	0.275
	Not Employed (not occupied)	71 (8)	198 (8)	
	Student	225 (24)	623 (26)	

Different upper letters mean significant differences between gender (p-value < 0.05), according to Mann-Whitney test; * p-value based on Chi-square test

Table 2
Final cluster centers of nutritional variables (means). The cluster-variables that contributed most to the classification are indicated in dark gray color.

	Cluster 1 *Healthier diet* (n=2165)	Cluster 2 *Unhealthier diet* (n=1167)	F statistics
f1_milk	4.96	5.61	113.44
f2_redMeat	3.18	3.91	212.55
f3_whiteMeat	3.58	4.05	96.96
f6_Vegetables	5.49	5.72	20.28
fHCcomplx	4.60	5.17	229.44
f11_FreshFruit	5.48	5.89	52.04
f12_ButterMarg	3.79	5.07	390.49
f13_OliveOil	4.94	5.71	154.82
f14_Pulses	3.66	4.26	125.98
f16_CookiesCakes	3.15	5.01	1,379.36
f17_Chocolate	2.88	4.74	1,282.43
f18_SweetSnack	1.79	3.57	1,193.02
f19_SaltySnack	2.08	3.74	1,253.92
f20_Processed	2.00	3.20	651.36
f21_Wine	2.18	3.40	382.89
f22_Beer	1.82	2.86	359.36
f23_Spirits	1.42	2.25	311.72

Table 3
Description of the clusters according to sociodemographic aspects and eating motivations (TEMS).

			Cluster 1 *Healthier diet*	Cluster 2 *Unhealthier diet*	p-value*
n			2165	1167	–
Gender	Female	%	**73**	**69**	0.017
Age	Years	Mean (SD)	38.1 (13.9)	37.5 (13.6)	0.187
Body mass index	Kg/m^2	Mean (SD)	24.3 (4.5)	24.5 (5.3)	0.196
School level	Elementary school	%	**1.9**	**3.9**	<0.001
	High school		**12.3**	**15.7**	
	Graduate/Post-grad degree		**81.8**	**78.1**	
Confinement	Confined	%	84	84	0.814
	Not confined		16	16	
Labor	Occupied	%	66	65	0.257
	Not occupied		8	10	
	Student		26	25	
Income	Low	%	17.5	15	0.052
	Medium		45	43	
	High		26.5	31	
	Not declared		11	11	
Children	None	%	74	71	0.082
	With kids under 12y		26	29	
	Africa		302 [71]	123 [29]	
Continent	Europe	n [%]	1586 [65.4]	839 [34.6]	<0.001
	South and Central America		252 [62]	154 [38]	
	North America#		25 [33]	51 [67]	
TEMS Liking		Mean (SD)	**5.5 (1.4)**	**5.6 (1.2)**	0.005
TEMS Health			**5.3 (1.5)**	**4.9 (1.6)**	<0.001
TEMS Pleasure			**4.7 (1.5)**	**5.1 (1.4)**	<0.001
TEMS Natural concerns			**4.7 (1.8)**	**4.4 (1.8)**	<0.001
TEMS Price			**3.9 (1.7)**	**4.2 (1.6)**	<0.001
TEMS Weight control	Eating motivations		**3.9 (1.7)**	**3.7 (1.7)**	<0.001
TEMS Need and hunger			4.9 (1.4)	4.9 (1.4)	0.254
TEMS Convenience			4.4 (1.6)	4.5 (1.5)	0.091
TEMS Affect regulation			**2.3 (1.6)**	**2.7 (1.7)**	<0.001
TEMS Habits			5.4 (1.4)	5.4 (1.3)	0.790

*Continuous variables were tested using one-way ANOVA or MANOVA test and categorical variables were tested using Chi-Squared test.
#North America was only composed by EUA, which has a limited number of participants, being not representative of this continent

'Healthier cluster' included 4% more women. Additionally, this cluster also included participants with higher schooling ($p < .001$), although no differences were found regarding confinement status, employment, income, and number of children.

The domains of eating motivations were compared between clusters using MANOVA; most of the domains differed significantly between Cluster 1 and 2 ($p < .001$; *Eta* partial squared = 0.05; power > 99%), except for Habits, Need and hunger, and Convenience ($p > .05$). The *healthier cluster* showed higher scores in the Health, Natural concerns, and Weight control domains. Price, Pleasure, Affect regulation and Liking scores were higher in the *unhealthier cluster*.

3.1.4. Food-related behaviors

Concerning food-related behaviors, "to try not to waste food" and "to be aware of products' expiration dates/shelf life" were reported as being a major concern (mean 5.7 ± 1.6 and 5.8 ± 1.5, respectively). To dedicate time to prepare meals and to plan ahead for shopping and meals were also perceived as being main behaviors, during the first lockdown period (5.3 ± 1.6 and 5.3 ± 1.6, respectively). On the other hand, on average, individuals gave lower rates for behaviors such as "to buy foods from apps or online stores" and "to consume meals prepared outside home" (mean classifications of 2.2 ± 1.8 and 2.7 ± 1.5, respectively) (Supplementary Table 1).

In terms of perceived changes during this pandemic period, an increase in the amount of purchased food was reported, as well as a preference for acquiring local products and expending more time cooking at home and trying new recipes (Supplementary Fig. 1 and Supplementary Table 1).

When clusters were compared for these parameters, it was in the unhealthier cluster that was more frequent: to buy food from Apps and/or online stores; to buy food in large quantities; to consume quick pre-cooked meals; to consume meals prepared outside home (e.g. take-away); to look for foods that provide the sensation of comfort; and to snack between meals. On the other hand, participants in this cluster perceived having a less varied/balanced diet and reported a lower involvement in meal preparation (less new dishes and new recipes) (Supplementary Table 2). Moreover, the unhealthier cluster reported higher increases in the search for comfort foods and snacking between meals, due to the pandemic, comparatively to the healthier cluster.

Among the purchase priorities, fruits and vegetables were the food items to which participants gave the higher primacy (mean classifications of 5.9 ± 1.4 and 6.0 ± 1.4, respectively), followed by cereals and eggs (mean classifications of 5.3 ± 1.5 and 5.2 ± 1.7, respectively). These were also the food items that a higher percentage of participants prioritized during the first lockdown. On the other hand, participants referred low priorities to pre-cooked foods and alcoholic beverages (mean classifications of 2.2 ± 1.5 and 2.6 ± 1.5, respectively) (Supplementary Table 1).

The priorities differed between clusters, with the healthier cluster prioritizing vegetables and the unhealthier cluster prioritizing snacks, sweets, cereals, bread, pre-cooked meals, and alcoholic beverages (Supplementary Table 2). It is interesting to see that most of these food items were perceived to increase in priority due to the pandemic (Supplementary Table 2), highlighting that the unhealthier habits of the unhealthier cluster could be potentiated by this lockdown situation.

3.2. Changes in food consumption due to the pandemic

A principal component analysis (PCA) with Varimax rotation was run to summarize data from changes in food intake and extract components. The suitability of PCA was assessed prior to analysis: the overall Kaiser-Meyer-Olkin (KMO) measure was 0.823 and the Bartlett's test of sphericity was statistically significant ($p < .001$), indicating that the data was likely factorizable. After Varimax rotation of the factors, PCA revealed

six components that explained 50% of the total variance that were retained, as described in Table 4. Additional components had only a minor contribution to variance explanation and biological meaning was difficult to interpret, and as such were not considered.

For interpretation purposes, by examining Table 4 it can be assumed that for Component 1, the higher the component, the higher the increase in the consumption of cakes and cookies, chocolate, sweet snacks, salty snacks, and processed foods; for Component 2, the higher the component, the higher the increase in the frequency of wine, beer and spirits; Component 3 is related to increases in fish, vegetable, fresh fruit, olive oil, pulses, and nuts intake; Component 4 is related to increases in cereals, bread, breakfast cereal, butter, olive oil, and pulses; Component 5 is related to increases in milk, eggs, vegetable, potato, bread, butter, and tea or coffee; and Component 6 is related to increases in the intake of red meat, white meat, and fish.

Considering the different patterns of changes obtained, the component loadings generated from PCA that summarized the changes in food ingestion were compared between clusters (*healthier* × *unhealthier diet*) and between countries using MANOVA.

Comparing the Cluster 'Healthier diet' and Cluster 'Unhealthier diet', significant differences were observed in Components 1 (sugary/processed snacks), 4 (cereals and fats), and 5 (milk, eggs, butter, bread and potato) with a medium effect size and Cluster 'Unhealthier diet' showing the higher coefficients (thus, an increased frequency of consumption, comparatively to the pre-pandemic period) of foods related to these components (Fig. 1A, B, and C) (MANOVA; $p < 0.001$; *Eta* partial squared = 0.06; power > 99%).

The components were also compared between sexes, and a significant difference was found in Components 1, 2, and 5: women increased the intake of cakes and cookies, chocolate, sweet snacks, salty snacks, and processed foods (Component 1), as well as of milk, eggs, vegetables, potatos, bread, butter, and tea or coffee (Component 5), while men increased the consumption of alcoholic drinks (Component 2) (MANOVA; $p < .001$). A positive correlation between age and Component 2 was observed, that is, the higher the age, the higher the consumption of wine, beer and spirits during the pandemic ($r = 0.19$; $p < .001$); and a negative correlation was found between age and Components 3 and 5, that is, the higher the age, the lower the intake of fish, vegetables, fresh fruit, olive oil, pulses, and nuts (Component 3) and milk, eggs, vegetable, potato, bread, butter, and tea or coffee (Component 5).

Table 4
Component loadings of changes in food intake patterns obtained by principal component analysis with Varimax rotation.

	Component					
	1	2	3	4	5	6
% Cumulative variance explained by components	*17*	*26*	*34*	*39*	*44*	*50*
f1_a_Milk					0.394	
f2_a_RedMeat						0.694
f3_a_WhiteMeat						0.771
f4_a_Fish			0.386			0.458
f5_a_Eggs					0.528	
f6_a_Vegetable			0.682		0.310	
f7_a_potato					0.565	
f8_a_cereals				0.644		
f9_a_Bread				0.478	0.345	
f10_a_BreakfastCereal				0.532		
f11_a_FreshFruit			0.666			
f12_a_ButterMarg				0.510	0.350	
f13_a_OliveOil			0.469	0.344		
f14_a_Pulses			0.492	0.388		
f15_a_Nuts			0.598			
f16_a_CakesCookies	0.658					
f17_a_Chocolate	0.763					
f18_a_sweetSnack	0.743					
f19_a_SaltySnack	0.726					
f20_a_Processed	0.474					
f21_a_Wine		0.776				
f22_a_Beer		0.828				
f23_a_Spirits		0.828				
f24_a_TeaCoffee					0.483	

Coefficients equal or<0.30 are omitted.

4. Discussion

To the best of our knowledge, this is the first study involving countries from different continents that evaluated the food-related behaviors and eating motivations in the context of the first lockdown of the COVID-19 pandemic. Global trends of change with the pandemic were observed, as well as differences in the eating motivations and demographic characteristics between clusters of individuals with "healthier" and "unhealthier" dietary patterns.

The majority of participants came from medium to high socioeconomic groups, with a very limited number of people with low education level, which limits the generalization of our results, as these are factors that can influence different parameters of food related behavior, such as searching for convenience products (McGowan et al., 2016), health and natural concerns (Dijkstra, Neter, Brouwer, Huisman, & Visser, 2014), or cooking habits (Mills, White, et al., 2017). Moreover, the different countries participating in the study differed in demographic characteristics, which can also influence food-related behavior variables and diet quality, considering that living status appears to influence dietary habits (Kobayashi, Asakura, Suga, & Sasaki, 2017). Furthermore, the included countries also differed in the number of cases and severity of symptoms/consequences of COVID. Despite these limitations and although the participation of the different countries may be a source of variability, this study has the strength of allowing a global picture of motivational and demographic factors affecting healthier or unhealthier behaviors. This can be a complement to studies focused on one population, with defined characteristics, allowing to have information at a macro scale.

Vegetables, fresh fruit, dairy products, olive oil and tea/black coffee were among the foods with higher consumption frequency, during the studied period. Moreover, in terms of food-related behaviors, during the first period of the pandemic, individuals reported a high concern with food waste and expiration date, and reported low levels of consumption of pre-cooked meals. Additionally, a higher priority for purchasing fresh fruits and vegetables was observed, followed by cereals and eggs. This is in line with previous research reporting a positive shift in the consumption of fruits and vegetables during the pandemic (e.g., Murphy et al., 2021). This could be seen as a positive effect of the pandemic, together with a higher disposition for home-cooking and trying new recipes (Murphy et al., 2021).

Among the changes that individuals perceived to occur, the concern with purchases and cooking planning, acquisition of larger amounts of foods, and an increase in the time and efforts dedicated to cooking, were the more evident adjustments mentioned by participants. The increase in home-cooking has been greatly reported as a consequence of the pandemic (Gerritsen et al., 2020; Murphy et al., 2021), considering the increased time-availability and the restricted access to prepared foods, as movements were restricted and restaurants were closed. Home cooking has been associated with health-benefits (Mills, Brown, Wrieden, White, & Adams, 2017; Wolfson & Bleich, 2015) and this change, alongside the considerable reduction in take-away eating, represents another positive aspect in consequence of the pandemic. Even so, attention needs to be paid to the type of meals cooked, since a recent study reported increases in home-cooking concomitant with higher fat intake during this period (Murphy et al., 2021).

Considering the frequency of the different foods consumed during the first phase of pandemic, it was possible to cluster individuals in "*healthier*" vs. "*unhealthier*" food consumption frequency. These clusters are particularly different considering the frequency of intake of palatable products, like cookies and cakes, chocolates, snacks, and processed foods. This high consumption of cakes and cookies could be a reflex of

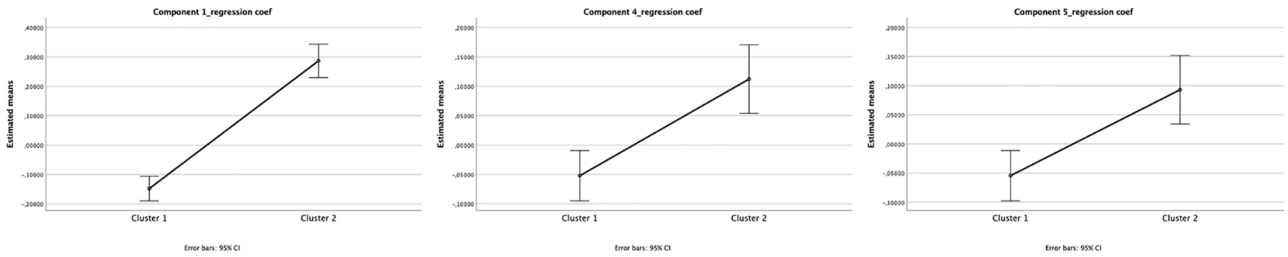

Fig. 1. Comparison of the regression coefficients from Components 1 (1A), Component 4 (1B) and Component 5 (1C) of changes in food intake patterns between Clusters 1 and 2 (MANOVA; $p < 0.0001$; Eta partial squared = 0.06; power > 99%).

the pandemic, for these individuals, in line with other studies conducted during this time (Gerritsen et al., 2020), which also report higher intake of comfort foods. The pleasurable sensations resultant from the consumption of sweet and palatable foods, have been suggested to act as a form of "self-medication", in order to deal with daily stresses (Brewerton, 2011; Fortuna, 2010), since sugar rich foods encourage serotonin production (Ma, Ratnasabapathy, & Gardiner, 2017). For instance, in Italy, a country that was particularly affected during the first wave of the pandemic, an increase in the intake of sweets, during the lockdown, was reported (Di Renzo et al., 2020).

Consumption of palatable and processed food during quarantine was also reported to increase in a study with USA population (Bin Zarah, Enriquez-Marulanda, & Andrade, 2020). The considerable hedonic value of these foods (Dallman, 2010; Liedtke et al., 2011), may justify a higher demand in periods of stress, such as the one caused by the pandemic. This relationship between hedonics and the choice of unhealthy foods is reinforced by the motivations for foods choices that are reported, where liking, pleasure and affect regulation appear as having higher influence in the choices of the "*unhealthier*" one, comparatively to the "*healthier*" one.

The two clusters also differed in level of education, with individuals from the "*unhealthier*" cluster having a low mean level of education than "*healthier*" cluster individuals. This goes in line with studies reporting the consumption of processed, high-salt, high-sugar and high-fat food being higher in people with lower socio-economic status and educational level (Baraldi, Martinez Steele, Canella, & Monteiro, 2018). Moreover, different studies found an association between higher levels of education and both heathier food habits (Thorpe, Milte, Crawford, & McNaughton, 2019) and lower body mass indexes (e.g., Ogden et al., 2017).

When eating motivations were considered, liking and habits were perceived to be the most influential determinants of individuals' behavior. However, these motivations appear to be different between the clusters of "*healthier*" and "*unhealthier*" individuals. The participants grouped as having "healthier" dietary patterns reported being more motivated by health, natural concerns and weight control factors, whereas the ones grouped in the "*unhealthier*" dietary pattern reported higher scores of pleasure, liking, affect regulation and price. Marty et al. (2021) found a similar link between motivations for weight control and increased nutritional quality during the pandemic in France, whereas lower dietary quality was associated with mood motives. This study also found an overall increase in mood as a driver of food choice for almost half of participants, followed by health (26%), ethical concern (21%) and natural content (19%). These results somewhat differ from those obtained in this study, with liking and habits being reported as the main eating motives during the pandemic. Although the drivers of eating motives during the pandemic are not entirely clear, one study found an association between perceived stress during lockdown and increases in choices motivated by mood, convenience, natural content, price, and familiarity (Shen, Long, Shih, & Ludy, 2020). Furthermore, emotional eating moderated the associations between perceived stress and mood, convenience, sensory appeal, price, and familiarity motives.

When looking for the characteristics that better distinguish the *healthier* and *unhealthier* clusters, the intake frequency of palatable high-sugar and/or high-salty and fatty foods was particularly relevant. As discussed earlier, these foods are linked to a higher hedonic value and, thus, are particularly sought after by individuals that tend to eat in response to negative emotions (i.e. that seek pleasure in food) (Konttinen, 2020). It is equally interesting to see that the "*unhealthier*" cluster is, simultaneously, the cluster where the changes imposed by the pandemic resulted in higher increase in consumption of palatable food, rich in sugar, salt, and fat, as well as in food-related behaviors like snacking between meals or choosing comfort foods. The identification of different clusters of *healthier* and *unhealthier* changes during lockdown echoes the idea that the disruption caused by the COVID-19 pandemic was not equal to all individuals and can be seen as both an opportunity and a threat for healthy eating, advising us to look beyond the global patterns of change to the more specific predictors of change (Vidal et al., 2021). Among these factors, sex and age can be particularly important. In the present study, a higher increase in sweet intake was observed in women, whereas men presented an increase in consumption of alcoholic drinks. When thinking of changes through a healthier pattern of food choices, a negative association with age was observed, highlighting the importance of paying special attention to younger adults.

In conclusion, the first wave of the COVID-19 pandemic brought different food-related changes, some of which were associated with differences in eating motivations. Some of these changes were negative and potentially related to the stress/anxiety felt during March-May 2020 and resulted in increases in the frequency of intake of unhealthy, highly palatable foods. Nonetheless, some of the changes in lifestyle were positive, such as the increase in vegetable and fresh fruit intake and in habits related with home-cooking. These results highlight the importance of developing strategies that prevent the increase in the consumption of palatable foods, as a source of pleasure, particularly in women and young people. On the other hand, the drastic lifestyle changes brought about by the pandemic also led to the exploration of new, positive habits, such as the intake of vegetables and food related practices such as proximity buying and cooking at home. As countries prepare to enter the post-pandemic period, it will be interesting to note whether the transient changes in eating habits and food-related behavior identified here will lead to long-lasting habits and practices.

4.1. Limitations

Due to the method of this study, based on online surveys, only people with access to technology were reached. Furthermore, despite the efforts to distribute the survey as widely as possible, the number and profile of participants that were reached is not representative of all populational groups, nor can the sample be representative for every country. As a consequence of the uneven number of participants across countries, no nation-wide comparisons were pursued. Nonetheless, this study provides a valuable contribution for understanding global changes in eating behavior and food-related behaviors during the first wave of the COVID-19 pandemic, by collecting data from 16 countries, spanning four continents.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2022.104559.

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