Food Control 135 (2022) 108808

Contents lists available at ScienceDirect

Food Control

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

Risk perception of food chemicals and technologies in the Midwest of Brazil: A population-based cross-sectional survey

Peter Rembischevski [a,b], Victoria Baggi de Mendonça Lauria [a], Luiza Ismael da Silva Mota [a], Eloisa Dutra Caldas [a,*]

[a] Laboratory of Toxicology, Department of Pharmacy, Faculty of Health Sciences University of Brasilia, Darcy Ribeiro Campus, Brasília, DF, 70910-900, Brazil
[b] Brazilian Health Regulatory Agency (Anvisa), SIA, Trecho 05, Área Especial 57, Brasília, DF, 71205-050, Brazil

ARTICLE INFO

Keywords:
Risk perception
Chemicals in food
Food technologies
Brazil

ABSTRACT

This cross-sectional study aimed to assess the risk perception of three different population groups in the Federal District, Midwest Brazil, regarding chemical and technological risks related to food. An objective questionnaire was applied from May 2018 to January 2020 to 1,000 individuals in supermarkets, universities (only students) and hospitals/clinics. Risk perception was assessed through five general questions, and the degree of worry regarding 11 food-related hazards measured by a three-point scale (low, medium and high). The impact of belonging to a group and of sociodemographic variables on the worry level was assessed by multinomial logistic regression and expressed as Odds Ratio (OR). Over 80% of the participants had high or medium worry level about the presence of chemicals in food, hospital/clinic group having significantly higher level than the university group. Heavy metals had a significant higher worry score than all other hazards (2.76 ± 0.55) and was the only hazard that was not impacted by the group or any sociodemographic variable. Nanotechnology had a significantly lower score than all others hazards and, along with mycotoxins, was the most unfamiliar term to the respondents. In the adjusted multinomial model, older individuals, those interviewed in hospital/clinic, and women showed significantly greater risk perception to most hazards. Income and education exerted less effect, except for the technologies, which significantly caused more worry among individuals with lower income and/or education. The results of this study can help government authorities in the implementation of effective risk communication strategies aimed at different population segments.

1. Introduction

Risk is omnipresent in human life, and the way in which it is perceived cannot be isolated from the observer, as, in the constructivist view, risk does not exist by itself, but is mentally constructed (Hampel, 2006). Although the technical (objective) knowledge of risk provided by experts is important, individuals' and social groups' perceptions regarding different risks involve more complex aspects, being shaped by social, cultural and psychological factors, which together form what is known as values, ideologies, or worldviews (Hansen et al., 2003; Hansson, 2010; Renn, 2008).

Among the approaches to studying a population's risk perception, one of the most important is the psychometric paradigm, which was developed to verify how people perceive technological risks in relation to its benefits, considering social and psychological contexts, seeking to answer the primary question: "How safe is safe enough?" (Fischhoff et al., 2000). Individuals perceive situations as safe or risky depending on the context of the risk, such as whether it is voluntary or imposed, known or not, dreadful or not, whether it is perceived as controllable by individuals or whether the information comes from sources considered reliable (Visschers & Siegrist, 2018). Furthermore, information acquisition and processing also play a role in risk perception (Verbeke, 2005). The inverse relationship between perception of risks and benefits of a given activity or technology is also well established, which has been attributed to the associated affect heuristic (Slovic et al., 2007).

Food is essential for the development of organisms and maintenance of life; health promotion and disease prevention through healthy diets are recognized as crucial in the contemporary world, and the public has been increasingly demanding for high quality and safe food (EC, 2014). Furthermore, the act of eating has a strong social connotation, closely related to the family unit, religious festivities, and other forms of integration (Kaptan et al., 2018; Frewer et al., 2016). Risk perception in

* Corresponding author.
E-mail address: eloisa@unb.br (E.D. Caldas).

https://doi.org/10.1016/j.foodcont.2022.108808
Received 26 June 2021; Received in revised form 2 December 2021; Accepted 2 January 2022
Available online 4 January 2022

relation to food acts through cognitive mechanisms that may be different from non-food risks (Kaptan et al., 2018), and some determinants are particularly important in shaping people's reactions to dietary risks. For example, foods of technological origin evoke a greater risk perception than natural foods (Frewer et al., 2016), and microbiological hazards tend to cause less worry than chemical hazards (Kher et al., 2013). Individuals tend to perceive they have a low control over technological and chemical hazards, which are not of natural origin and are associated with fearful long-term effects (Dickson-Spillmann et al., 2011; Jansen et al., 2020; Siegrist & Sütterlin, 2014). Some authors attribute this feeling of aversion or irrational fear to chemical substances as chemophobia, which affects a large part of the population in the modern world and whose reach goes beyond the food issue (Jansen et al., 2020; Saleh et al., 2019; 2021). Similarly, resistance to new food technologies has been called food neophobia (Siegrist & Hartmann, 2020).

Knowledge of how consumers perceive the different risks they are exposed to in their food and how this influences their consumption decisions is important to design efficient government risk management and communication strategies (Charlebois & Summan, 2015). Studies to measure perceptions of dietary risks of a population have been described in literature, using different models and score formats, with the objective of devising strategies for their effective communication and management (Danelon & Salay, 2012; Komoto et al., 2016; Omari et al., 2018). Knowledge of the impact of sociodemographic factors on risk perception has the potential to direct risk communication to particular segments of the population (Ellis & Tucker, 2009). Understanding risk perception is crucial for government authorities to identify gaps in their risk communication strategies, using appropriated language to the target populations. A good risk communication would indeed help consumers to make good dietary choices, based on sound and clear information.

This study aimed to assess the risk perception by populational groups that were interviewed at three different environments (university, hospital/clinic, and supermarket), regarding the risks arising from the exposure to 11 different hazards related to food, including chemical substances (such as pesticides, food additives, and heavy metals) and certain technologies involved in its production (genetic modified food, animal cloning, and nanotechnology). The study raised mainly two questions to be answered: Does belonging to one of the groups impact risk perception? Are the sociodemographic factors predictive of the questions asked?

The risk perception was assessed through the level of worry of the participants. Indeed, affective risk perception refers to the valence (positive-negative) and arousal (high-low) of feelings associated with the threat and is typically measured by reports of worry, anxiety, or fear (Ferrer et al., 2018). In line to this view, Rosati and Saba (2004) found a strong association between worry and perception of personal risk.

To the best of our knowledge, this is the first study conducted in Brazil that evaluated the risk perception of such a large range of food hazards, and the first that evaluated whether the interview environment can impact risk perception.

2. Materials and methods

2.1. Study population

The study was conducted in the Federal District, Midwest of Brazil, from May 2018 to December 2019. The Federal District is where Brasilia is located, the country's capital. The city was founded in the second half of the last century and the region gathers people from all over the country. In 2018, Federal District's estimated population was about 2.9 million people, distributed in Brasília and 30 administrative cities, including Taguatinga and Ceilândia. The three cities make up 30% of the total Federal District population (CODEPLAN, 2020).

An objective questionnaire was applied to 1,000 individuals who were in three different environments at the time of the study: 1) Medium and large supermarkets, located in Brasília, Ceilândia, Taguatinga, and Vicente Pires (N = 400); 2) Students in public and private universities (Brasília and Ceilândia campuses of the University of Brasília, a public university, and four private universities located in Brasília and Taguatinga; N = 300); and 3) Public hospitals (University Hospital of Brasília and Regional Hospital of Taguatinga, N = 200) and private clinics (neurology, ophthalmology, angiology, and nephrology; N = 100).

Convenience sampling was used, i.e., individuals were approached at random in the three environments until the pre-established number of interviewees for each segment was reached. Individuals under 18 years old, illiterate, and with any serious intellectual or physical impairment were excluded. The study was approved by the Ethical Committee of the Faculty of Health Sciences, University of Brasilia (71667117.5.0000.0030), and participants signed the Informed Consent form.

2.2. Objective questionnaire

The questionnaire answered by participants contains objective questions with information on sociodemographic characteristics (gender, age, marital status, place of residence, family income, and education level (Table 1). Most participants were women (57.8%), with a significant difference between individuals interviewed in the supermarket and those in hospitals/clinics ($p < 0.05$). Almost half of the participants were between 18 and 30 years old, mainly due to the contribution of the university segment (94.3% in this age group), with a significant difference in the mean age between the three groups ($p < 0.05$). About 50% of the population had a household income between 2 and 10 MW, with the highest percentage of individuals with lower income found among those interviewed in hospitals/clinics (18.9%). Most of the population had incomplete/complete college education, and about 15% of those in hospital/clinic had incomplete/complete primary school. More than half of the participants were single, but 56.8% of the hospital/clinic group were married. About 25% lived in Brasilia, but most lived in other cities of the Federal District (55.9%); about 12% lived in cities around the Federal District (metropolitan area).

In addition to the sociodemographic questions, the questionnaire contains 23 questions that address risk perception issues, which is the focus of the present paper, food consumption behavior, and trust in information sources related to food risks, which are not discussed here.

Five general objective questions about risk perception are: 1) What is your level of worry regarding the presence of chemicals in food? 2) When was the last time you've read or heard the food can be harmful to health due to the presence of chemicals? 3) Do you think the presence of pesticides in food can cause: cancer, hormonal effects, reproductive effects, affect the brain, headache, nausea, or other effects? 4) Have you ever had any symptoms or disease believed to be related to pesticides or other chemicals in food? and 5) When was the last time you've read or heard about genetically modified (GM) food being harmful to health?

Additionally, public worry about 11 food hazards (salt, sugar, pesticides, food additives, heavy metals, mycotoxins (including aflatoxins), hormones/antibiotics, substances present in packing material), and food related technologies (GM food, animal cloning, and nanotechnology) were assessed by a three-point scale: 1 = Slightly/not worried at all; 2 = Moderately worried and 3 = Very worried. This simpler scale was used to facilitate the completion of the questionnaire by individuals with lower educational level, a need that was identified during the questionnaire pre-testing process. The chemical hazards were selected based on their toxicological importance, their wide use and/or presence in foods. Among the technologies, GM food is largely produced around the world, and nanotechnology and animal cloning can be considered emerging food technologies. The unfamiliarity with a hazard was indirectly assessed in the same question when the participant responded "I do not know".

The questionnaire was previously pre-tested with a group of individuals with a similar profile of the study participants, for final

Table 1
Sociodemographic characteristics of the study population interviewed in three different environments in the Federal District.

	Total N = 1000 n (%)	Hospital/clinic N = 300 n (%)	Supermarket N = 400 n (%)	University N = 300 n (%)
Gender				
Female	573 (57.8)	187 (62.5)	212 (53.7)	174 (58.6)
Male	414 (41.8)	112 (37.5)	181 (45.8)	121(40.7)
Others	4 (0.4)	0 (0)	2 (0.51)	2 (0.67)
No response	10 (1)	2 (0.66)	5 (1.25)	3 (1)
Age, years				
18–30	462 (46.7)	53 (18.8)	128 (32.2)	281 (94.3)
31–49	310 (31.3)	123 (41.7)	176 (44.3)	11 (3.7)
50–65	182 (18.4)	96 (32.5)	80 (20.2)	6 (2.0)
> 65	36 (3.6)	23 (7.8)	13 (3.27)	0 (0)
No response	11 (1.1)	6 (2.0)	3 (0.75)	2 (0.67)
Family income, MW				
Up to 1	95 (9.7)	55 (18.9)	28 (7.24)	12 (4.0)
> 1 to 2	186 (18.6)	70 (24.0)	73 (18.9)	43 (14.5)
> 2 to 5	254 (26.0)	72 (24.7)	108 (27.9)	74 (24.9)
> 5 to 10	238 (23.8)	52 (17.9)	99 (25.6)	87 (29.3)
> 10	202 (20.2)	42 (14.4)	79 (20.4)	81 (27.3)
No response	26 (2.6)	10 (3.3)	13 (13.2)	3 (1)
Education				
Primary school, incomplete	48 (4.8)	33 (11.0)	15 (3.8)	0 (0)
Primary school	28 (2.8)	13 (4.3)	14 (3.5)	1 (0.33)
High school, incomplete	31 (3.1)	18 (6.0)	13 (3.3)	0 (0)
High school	188 (18.8)	94 (31.2)	75 (18.8)	19 (6.3)
College, incomplete	354 (35.4)	34 (11.3)	75 (18.8)	245 (81.7)
College	201 (20.1)	57 (18.9)	122 (30.5)	22 (7.3)
Graduate school	151 (15.1)	52 (17.3)	86 (21.5)	13 (4.3)
Marital status				
Single	511 (51.1)	88 (29.9)	154 (39.5)	269 (90.0)
Married	382 (38.2)	167 (56.8)	189 (48.5)	26 (8.7)
Divorced	73 (7.3)	28 (9.5)	42 (10.8)	3 (1.0)
Widow	17 (1.7)	11 (3.7)	5 (1.3)	1 (0.33)
No response	18 (1.8)	7 (2.3)	10 (2.5)	1 (0.33)
Residence				
Other cities	559 (55.9)	175 (61.6)	216 (59.2)	168 (59.2)
Brasilia	255 (25.5)	56 (19.7)	116 (31.8)	83 (29.2)
Metropolitan area	119 (11.9)	53 (18.7)	33 (9.0)	33 (11.6)
No response	68 (6.8)	17 (5.6)	35 (8.8)	16 (5.3)

MW = minimal wage, which corresponded to about US$250 at the time of the study.

adjustments of the questions and answer options (improve understanding and eliminating redundancies). Reliability (internal consistency) was assessed by calculating the Cronbach's alpha in the IBM SPSS Statistics V.28, which gave an acceptable value of 0.82. Although it was designed for interviewees to fill out on their own, some participants preferred the researcher to administer the questionnaire orally. In the questionnaire, the word *agrotóxico* (a neologism which can be translated to agritoxic) was used in all questions related to this hazard, as it is the legal term used in Brazil for products used to control agricultural pests (Law No. 7.802/1989). In this paper, the term *agrotóxico* was replaced by pesticide, except in the comparison between risk perception and unfamiliarity with the different terms used to refer to these products in Brazil.

2.3. Statistical analysis

Data from the questionnaires were inserted in the Epi Info™ 7.2.2.6, a public domain software designed for database construction that was developed by the US Center for Disease Control. Statistical analysis was performed in the IBM SPSS Statistics V.28. Multinomial logistic regression analyses were performed to test the impact (main effects) of belonging to a group and sociodemographic parameters (gender, age, income, and education) on dependent variables (risk perception). First, the impact of each parameter was tested separately (bivariate analysis), and those that showed significance were included in the adjusted model (multivariate analysis). Results are given in odds ratio (OR [lower level-upper level at 95% confidence], *p*). All the models passed the multicollinearity test, with variance inflation factor (VIF) lower than 4 and tolerance higher than 0.1, meaning that no variable is overlapping. The goodness of fit (Pearson's chi-squared test in SPSS) of all models gave $p \geq 0.05$, indicating that the adjusted model explained the observed data well.

The parameters age, education, and family income were categorized. Age: up to 24 years, from 25 to 49 years, and 50 years and older; education: up to high school and college or more; family income: up to five minimum wage (MW) and above five MW. In some analyses, age was also considered as a continuous variable.

Differences in the sociodemographic variables between groups were assessed by one-way analysis of variance (ANOVA) followed by Tukey

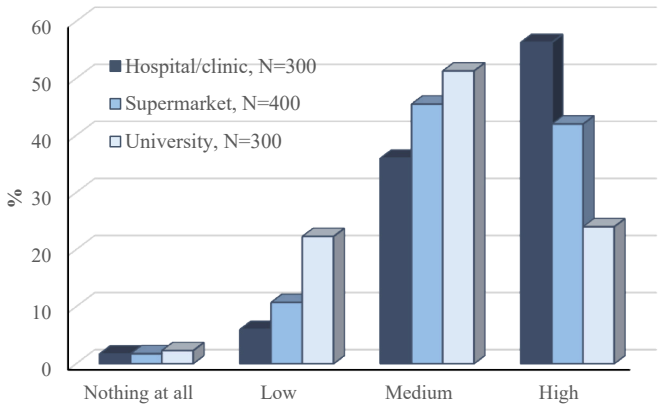

Fig. 1. Level of population worry regarding the presence of chemicals in food.

Table 2
Multinomial regression analysis for the worry over chemicals in food, according to population group and sociodemographic characteristics.

		Bivariate model	Multivariate model
Independent variable		OR [LL-UP], *p*	OR [LL-UP], *p*
High (Ref. Low)			
Group; University (ref)	Hospital/Clinic	7.51 [4.36–12.9],**< 0.001**	4.15 [1.95–8.83],**< 0.001**
	Supermarket	3.45 [2.20–5.43],**< 0.001**	2.19 [1.18–4.06], **0.013**
Age range (years); Up to 24 (ref)	50 and over	7.09 [3.92–12.8],**< 0.001**	3.33 [1.56–7.13],**0.002**
	25 to 49	3.58 [2.31–5.53],**< 0.001**	1.85 [1.02–3.35],**0.042**
Gender; Male (ref)	Female	2.31 [1.57–3.40],**< 0.001**	2.57 [1.70–3.87],**< 0.001**
Income (MW); >5 (ref)	Up to 5	1.30 [0.887–1.91],0.18	–
Education; College or higher (ref)	Up to high school	1.79 [1.16–2.77],**0.008**	0.857 [0.496–1.48],0.58
High (Ref. Medium)			
Group; University (ref)	Hospital/Clinic	3.33 [2.30–4.82],**< 0.001**	1.70 [1.01–2.86],**0.046**
	Supermarket	1.97 [1.39–2.80],**< 0.001**	1.14 [0.719–1.82],0.57
Age range (years); Up to 24 (ref)	50 and over	3.93 [2.67–5.78],**< 0.001**	3.25 [1.95–5.42],**< 0.001**
	25 to 49	2.35 [1.69–3.26],**< 0.001**	1.89 [1.23–2.92],**< 0.004**
Gender; Male (ref)	Female	1.62 [2.22–2.14],**< 0.001**	1.67 [1.24–2.24],**< 0.001**
Income (MW); >5 (ref)	Up to 5	1.50 [1.14–1.98],**< 0.004**	1.45 [1.04–2.02],**0.028**
Education; College or higher (ref)	Up to high school	1.53 [1.14–2.05],**< 0.005**	0.910 [0.627–1.32],0.620

OR = odds ratio [lower level-upper level at 95% confidence]; MW = minimal wage.

(Table 1). The difference in worry scores of the total population in relation to the 11 food hazards were assessed by non-parametric Kruskal-Wallis followed by Dunn's test, given the non-normality behavior previously indicated by the Kolmogorov-Smirnov test. In all cases, the results were considered significant when p was <0.05.

3. Results

3.1. Food-related risk perception

Most interviewees (85.3%) showed a high or medium worry level regarding the presence of chemical substances in food, with the hospital/clinic group showing the highest percentage of high worry level among the groups (56%; Fig. 1). In bivariate analysis, worry level was impacted by the group and the sociodemographic variables (Table 2). In the adjusted model, the significant difference between high and low/no worry levels was maintained for the three groups (OR = 4.15 for hospital/clinic compared to university), for age (OR = 3.33 for individuals over 50 compared to those up to 24 years) and for women (OR = 2.73) (Table 2). When age was assessed as a continuous variable, the positive association was confirmed, with an OR = 2.0 observed for each mean increment of 20 years ($p < 0.001$). When comparing high vs medium worry level, high income had a negative impact on worry level (Table 2).

About half of interviewees (47–51%) reported having heard in the last 7 days that food can be harmful to health due to the presence of chemical substances, 26% (25–29%) have heard about it in the last 30 days and about 7% (6–9%) stated they did not remember or had never heard of it. Only income and education impacted this variable in the bivariate analysis. Individuals with lower income reported hearing less about it in the last 30 days (OR = 0.565 [0.340–0.940], $p = 0.028$) and in the last year (OR = 0.422 [0.228–0.781], $p = 0.006$). A similar result was observed with individuals with less education (OR = 0.535 [0.331–8.865], $p = 0.011$ and OR = 0.388 [0.205–0.735], $p = 0.004$, respectively). The significance was lost in the multivariate analysis.

3.2. Different hazard-related risk perception

Fig. 2 shows the average of interviewees' worry scores for potential risks of eight chemical agents and three food technologies on a 3-point scale (low = 1; medium = 2; high = 3). Heavy metals had a significantly higher mean score (2.76 ± 0.55), followed by pesticides (2.62 ± 0.61), and nanotechnology had a significantly lower mean score than

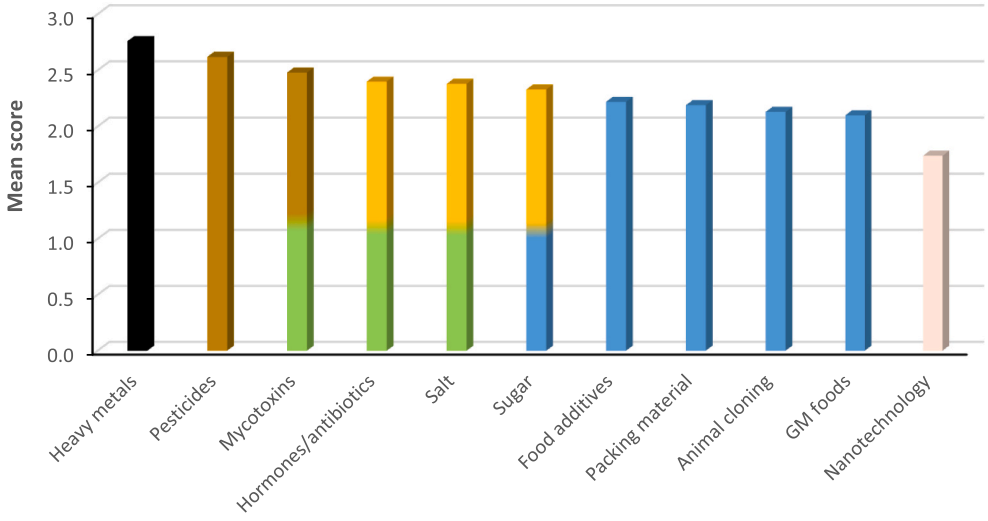

Fig. 2. Scores of worries of study population for selected food hazards. Different colors correspond to significantly different mean scores ($p < 0.05$). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 3
Multinomial regression analysis for pesticides worry by populational group and sociodemographic characteristics.

Independent variable		Bivariate model	Multivariate model
		OR [LL-UP], *p*	OR [LL-UP], *p*
High (Ref. Low)			
Group; University (ref)	Hospital/Clinic	5.23 [2.52–10.8], **< 0.001**	2.84 [1.04–7.80],**0.042**
	Supermarket	2.73 [1.55–4.81], **< 0.001**	1.60 [0.752–3.42],0.22
Age range (years); Up to 24 (ref)	50 and over	6.44 [2.67–15.6], **< 0.001**	3.71 [1.29–10.7],**0.015**
	25 to 49	3.04 [1.74–5.32], **< 0.001**	1.89 [0.893–4.00],0.096
Gender; Male (ref)	Female	0.554 [0.334–0.917], **0.022**	1.95 [1.16–3.28],**0.012**
Income (MW); >5 (ref)	Up to 5	1.35 [0.811–2.24], 0.250	–
Education; College or higher (ref)	Up to high school	1.78 [0.969–3.28], 0.063	–
High (Ref. Medium)			
Group; University (ref)	Hospital/Clinic	3.25 [2.15–4.90], **< 0.001**	1.85 [1.04–3.27], **0.035**
	Supermarket	1.84 [1.30–2.62], **< 0.001**	1.20 [0.750–1.92], 0.45
Age range (years); Up to 24 (ref)	50 and over	3.83 [2.42–6.10], **< 0.001**	2.80 [1.57–4.98], **< 0.001**
	25 to 49	2.06 [1.47–2.89], **< 0.001**	1.59 [1.01–2.49], **0.045**
Gender; Male (ref)	Female	1.56 [2.13–1.15], **0.004**	1.62 [1.18–2.22], **0.003**
Income (MW); >5 (ref	Up to 5	1.25 [0.918–1.69], 0.16	–
Education; College or higher (ref)	Up to high school	1.67 [1.17–2.39], **0.005**	1.06 [0.714–1.58], 0.76

OR = odds ratio [lower level-upper level at 95% confidence]; MW = minimal wage.

the other assessed items (1.74 ± 0.81).

In multinomial regression, group and sociodemographic variables did not significantly affect risk perception to heavy metals ($p > 0.05$). Worry with mycotoxins was significantly impacted only by age category, with individuals over 24 years of age having a higher worry level than younger individuals, with a greater chance for those over 49 years (OR = 3.05 [1.46–6.34]; $p = 0.003$). When age was assessed as a continuous variable, an OR = 1.59 was observed for each mean increment of 20 years ($p = 0.001$).

3.2.1. Pesticides

Table 3 presents the results of multinomial analyses for pesticides. In bivariate analysis, worry (high *vs* low) was significantly different between groups, higher for individuals over 24 years of age and for women, with no impact of education and income. In the adjusted model, the hospital/clinic had significantly higher worry level than the university group (OR = 2.84), individuals over 50 years more than those up to 24 years (OR = 3.71), and women remained still more than men (OR = 1.95). This trend was followed when comparing high *vs* medium worry level (Table 3).

In this same question, in addition to the legal term *agrotóxico*, the terms *pesticida* (pesticide) and *defensivo agrícola* (plant protection product, PPP) were also assessed. There was no significant difference between the scores of the terms *agrotóxico* (2.62 ± 0.61) and *pesticida* (2.63 ± 0.63), but worry regarding *defensivo agrícola* was significantly lower (2.44 ± 0.72).

Between 80 and to 84% of the interviewees believe that the presence of pesticides in food can cause cancer, 59–69% headaches, malaise, nausea, and hormonal effects, and only 0.9% of all interviewees did not associate these substances with any health effects. When asked if they had already suffered any symptoms or had any disease that they believed could have been caused by the presence of pesticides or chemical contaminants in food, between 15.3% (university) and 24.6% (hospital/clinic) reported believing that this occurred at least once, with a significant difference only between these two groups ($p < 0.01$).

Table 4
Multinomial regression analysis for genetically modified foods worry by populational group and sociodemographic characteristics.

Independent variable		Bivariate model	Multivariate model
		OR [LL-UP], *p*	OR [LL-UP], *p*
High (Ref. Low)			
Group; University (ref)	Hospital/Clinic	4.63 [2.83–7.55],**< 0.001**	3.20 [1.61–6.36],**< 0.001**
	Supermarket	2.10 [1.39–3.19],**< 0.001**	1.60 [0.898–2.86],0.11
Age range (years); Up to 24 (ref)	50 and over	3.04 [1.85–4.98],**< 0.001**	1.67 [0.849–3.28],0.14
	25 to 49	2.41 [1.61–3.60],**< 0.001**	1.36 [0.771–2.38],0.29
Gender; Male (ref)	Female	2.14 [1.49–3.06],**< 0.001**	2.14 [1.46–3.13],**< 0.001**
Income (MW); >5 (ref)	Up to 5	1.52 [1.07–2.18],**0.020**	1.33 [0.875–2.01],0.18
Education; College or higher (ref)	Up to high school	1.85 [1.21–2.81],**0.004**	1.06 [0.634–1.78],0.82
High (Ref. Medium)			
Group; University (ref)	Hospital/Clinic	1.90 [1.24–2.91],**0.003**	1.61 [0.879–2.94],0.12
	Supermarket	1.50 [0.999–2.24],0.050	–
Age range (years); Up to 24 (ref)	50 and over	1.76 [1.13–2.76],**0.013**	1.33 [0.730–2.43],0.35
	25 to 49	1.54 [1.05–2.25],**0.026**	1.14 [0.682–1.92],0.61
Gender; Male (ref)	Female	1.39 [0.991–1.95],0.056	–
Income (MW); >5 (ref)	Up to 5	1.14 [0.822–1.59],0.425	–
Education; College or higher (ref)	Up to high school	1.28 [0.888–1.85],0.185	–

OR = odds ratio [lower level-upper level at 95% confidence]; MW = minimal wage.

3.2.2. Hormones/antibiotics, salt, sugar, food additives, and packing material

The results of multinomial regressions are shown in Tables S1–S5 (Supplementary Material). In bivariate analysis, worry levels for these hazards were significantly different between groups (with more worry among the individuals in hospital/clinic and supermarket groups), and older individuals (high *vs* low worry). Gender only impacted the worry level with hormones/antibiotics (Table S1) and food additives (Table S4) and education with salt (Table S2). Income had no impact on the worry level of any of these hazards.

In the adjusted model, only gender (OR = 1.59 for women) and age group, especially over 50 years (OR = 2.63), had an impact on the high worry level with hormones/antibiotics (Table S1). Only age had a significant impact on the worry with salt and sugar, with individuals over 24 years old reporting a higher worry level than the younger ones, especially in the age group from 50 years onwards (OR = 3.28 and 4.71 for salt and sugar, respectively; Tables S2 and S3).

The group, gender, and age group maintained the impact on the worry level with food additives in the adjusted model (Table S4). Individuals in hospitals/clinics and supermarkets (OR = 2.04 and 1.99, respectively), women (OR = 1.91), and older individuals, mainly in the range between 25 and 49 years (OR = 2.21), showed a higher worry level compared to a low worry level for this hazard.

Only the age group between 25 and 49 years had a higher worry level (*vs* lower worry) related to packing (OR = 2.05), a significance that was lost when comparing high *vs* medium worry (Table S5).

3.2.3. GM food

Group and all sociodemographic parameters impacted the worry levels regarding GM food (high *vs* low worry), however, in the adjusted model, only group and gender maintained a significant impact (Table 4). The hospital/clinic had more worries than the university group (OR = 3.20), and women had more worries than men (OR = 2.14). No significance was found in the adjusted model for any parameter when comparing high *vs* medium worry level (Table 4).

Between 48% (hospital/clinic) and 64% (university) reported having read or heard in the previous 6 months that GM food can be harmful to health, about 20% have heard about it more than 6 months previously the study, and from 14% (university) and 33% (hospital/clinic) did not remember or had never heard of it. Only gender had no impact on the response (Table S6). In the adjusted model, individuals from the supermarket group (OR = 0.582), those aged 25–49 years (OR = 0.592), and those with lower education (OR = 0.541) had heard less about the topic in the previous 6 months compared to not remember/never heard (Table S6). Individuals with lower income and education had heard less about GM food when the timeframe was more than 6 months (Table S6).

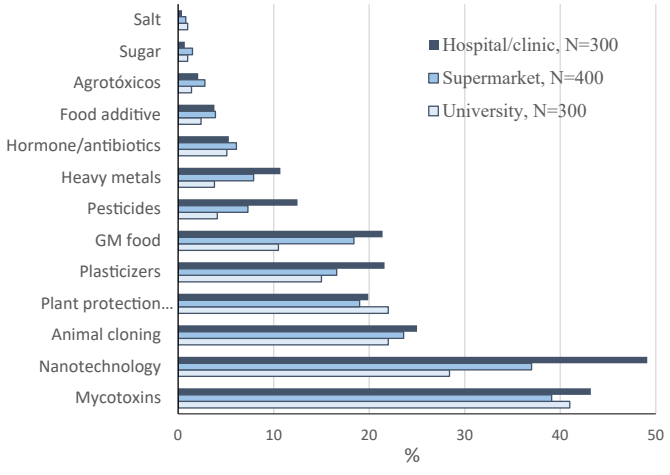

Fig. 3. Unfamiliarity of hazard terms according to the group, in % of respondents.

3.2.4. Animal cloning and nanotechnology

Group and the sociodemographic parameters impacted the worry regarding cloning (Table S7) and nanotechnology (Table S8) in the bivariate analysis, except for gender on nanotechnology. In the adjusted model, group, income and gender impacted significantly cloning worry level, with higher levels for hospital/clinic and supermarket groups (OR = 3.29 and 2.39, respectively), women and low income individuals compared to low worry level (OR = 2.01; Table S7). Group and age range maintained the impact on the worry level with nanotechnology in the adjusted model, with individuals in hospital/clinic and supermarket groups and those 50 years and over having higher worry compared to low (Table S8). For both hazards, the group maintained the impact in the high *vs* medium worry comparison, and education impacted animal cloning worry (Tables S7 and S8).

3.2.5. Unfamiliarity with the hazards

Fig. 3 shows the levels of unfamiliarity with the hazards included in the study, which was indirectly assessed when the participants responded "I do not know" when asked about the worry level. Salt and sugar had the lowest unfamiliarity levels (0.4–1%), while mycotoxins (39–43%), nanotechnology (28–49%) and animal cloning (22–25%) the highest. For most hazards, the unfamiliarity with the terms were similar among the groups, the main exceptions being nanotechnology and GM foods, with individuals interviewed in hospital/clinic recognizing these terms less than the other groups, mainly the university group (Fig. 3). Among the terms to describe the products used to control agricultural pests, the legal term *agrotóxico* was the most familiar to the interviewees (1.4–2.8% of unfamiliarity) and PPP the least (19–22% of unfamiliarity).

4. Discussion

In this study, risk perception of chemical substances present in food and technologies involved in food production was assessed through worry levels in three subpopulations divided according to where they were at the time of the study - supermarket, university (only students), and hospital or clinic. Individuals in hospital/clinic had lower family income and education, which was expected, since most were interviewed in two public hospitals that mainly assist the lower-income population of the region.

The fact that 75% of the interviewees had read or heard in the previous 30 days about health risks due to the presence of chemical substances in food, combined with high or average worry levels reported by 85% of interviewees, supports the Social Amplification/Attenuation of Risk Framework (SARF) confirming that social communication contributes decisively to risk perception, the role of the media and interest groups being significant in this regard (Pidgeon et al., 2003, p. 449). Older individuals and women were more likely to be worried about the presence of chemical substances in food, which corroborates other studies on the topic that put gender and age as predictive factors for food-related risk perception (Dosman et al., 2001; Dickson-Spillmann et al., 2011). Ellis and Tucker (2009) also included education as a consistent demographic predictor for risk perception related to food, which in this study mostly affected the risk perception to food technologies. Individuals from the hospital/clinic group showed greater worry level with the presence of chemical substances in food, even when adjusted for age and education, which indicates that being in the hospital environment can have an important impact on risk perception.

A greater worry level with heavy metals and pesticides and a lower worry level with technologies was found among the participants, a pattern that showed similarities and differences with studies conducted in other countries. The last Eurobarometer survey of food risks ranked the highest worry level for residues of antibiotics, hormones, or steroids in meat, followed by pesticide residues in food and environmental

pollutants, which may include heavy metals, although not explicitly described (EC, 2019). The survey also indicated that Europeans were currently less worried about GM foods than in the previous survey (EC, 2010). In Ghana, interviewees showed a similar worry regarding pesticides and substances present in food packing, lower than food additives; aflatoxins exerted the lowest worry level among all the hazards listed, along with food produced near mining sites, a reference to heavy metals (Omari et al., 2018).

The university group (only students) was less worried about pesticides than the hospital/clinic one, even when the model was adjusted for age group, probably because they receive more technical and less stigmatized information on the topic at the university. Worry with pesticides increased significantly with age and was higher among women. In Brazil, there is a proliferation of interest groups articulated against pesticides, advocating the complete elimination of these products in agriculture, which are referred to as poison no matter the dose (www.contraosagrotoxicos.org). Studies conducted in other countries also showed a high risk perception in relation to pesticide residues in food (Arrebola et al., 2020; Koch et al., 2017; Nguyen et al., 2020). Saleh et al. (2021) did not find a relationship between acceptance of pesticides and education, but acceptance was higher for older individuals and differed among the genders, although it is not clear in the paper which gender has a higher acceptance level. In Japan, the population worry with contaminants (including cadmium and methylmercury) and pesticides ranked first among the hazards from 2004 to 2007, but their importance decreased over the subsequent years (Abe et al., 2020).

Not surprisingly, a high percentage of interviewees associated cancer and other diseases with the presence of pesticides in food. The underlying stigma of these substances is the difficulty of dealing with fearful long-term illnesses, creating psychological mechanisms in people that blame an external, man-made agent, something to fight against, instead of accepting the disease as being impacted mainly by genetic aspects or caused by chance, which reduces the perspective of controlling the situation (Renn, 2008). When the focus of the question became the individual, less than a quarter indicated that they believed they had already experienced some health problem due to the presence of chemicals in food, a belief that is lower among younger individuals. However, about 35% responded that this may have happened, reflecting the degree of uncertainty in the population about the relationship between pesticides and chemicals in general in food and the development of diseases. The public's lack of knowledge of basic toxicology principles, including the role of dose in the manifestation of toxicological effects from chemical exposure, and how this affects the perception of chemical risk in food, has been particularly addressed in Europe (Bearth et al., 2019; Koch et al., 2017).

The greater identification of the legal and nationally recognized term *agrotóxico* (*agritoxic*) in relation to pesticides and *defensivo agrícola* (plant protection product, PPP) was expected. *Agrotóxico* is also the most used term by the national media, a decisive factor for its greater recognition by the public. This term, a neologism, was coined in the late 70s and consecrated by activists of the environmental movement in Brazil as a risk communication strategy for rural workers. The term opposed to *defensivo agrícola* in use until then, which only highlighted its positive character in protecting the crop (Rembischevski & Caldas, 2018). Indeed, *defensivo agrícola* evoked the lowest levels of worry in the present study compared to the other two terms in the three study groups.

Less expected was the high degree of worry given to heavy metals, homogeneous among the three groups and insensitive to any sociodemographic variable. Metals are ubiquitous in nature, and would, in principle, fit the naturalness heuristic thesis (Michel & Siegrist, 2019). However, it is likely that the public perceives heavy metals as contaminants of anthropogenic origin, mainly associated with mining and metallurgy, which can, indeed, increase the contribution of metals in food.

A recent study conducted in Vietnam indicated that worries about vegetable consumption are mainly due to pesticides, heavy metals and GM foods (Ha et al., 2020). Over a third of the Vietnamese interviewed reported a reduction in vegetable consumption, especially leafy vegetables, due to the presence of pesticide residues. Heavy metals also ranked high in the Eurobarometer surveys, which used generic categories that included mercury in fish as environmental pollutant (EC, 2010; 2019). Most of health professionals participating in a survey in Spain expressed worry in relation to the exposure to heavy metals, particularly mercury and other metals in fish, followed by the presence of pesticides (Arrebola et al., 2020).

A study conducted in the UK using Principal Component Analysis (PCA) showed that nanotechnology, animal cloning, and GM food had the same risk rating (Jenkins et al., 2021). In the present study, cloning and GM food worry scores were similar, but nanotechnology raised the least worry among all hazards. The technology most recognized by the interviewees was GM food, which is in line with its greater media presence, and the fact that Brazil is one of the main producers of GM crops in the world (ISAAA, 2019).

A survey conducted with 510 individuals in the state of Rio de Janeiro, Brazil, assessed the general perception of nanotechnology, particularly its applications in food (Embrapa, 2018). Most interviewees had a neutral or positive attitude toward nanofoods, with only 15% showing aversion or neophobia. Unfamiliarity was one of the first words that came to mind when people were asked about nanotechnology. In a study conducted in Australia, risk perception to nanotechnology was greater among the general public when compared to members of the government, academia, and businesses, and that greater familiarity with the term was associated with lower risk perception (Capon et al., 2015). This inverse relationship between knowledge and risk perception was not identified in the present study, as nanotechnology was the second least recognized hazard by the study population, behind mycotoxins only. Similarly, in the Eurobarometers surveys, nanofoods were classified as causing a low worry, also being one of the items with less familiarity and/or knowledge about the risks (EC, 2010; 2019). Siegrist and Hartmann (2020) argue that transformations involved in nanotechnology are seen as physical, while chemical or biological manipulations, associated with GM foods, have a higher impact on the perception of loss of naturalness, an aspect associated with risk perception (Rozin, 2005).

The term mycotoxin, as well as *agrotóxico*, contains a terminology that can influence the ability to discern and induce a high risk perception in individuals. About 60% of interviewees were unfamiliar with the term mycotoxin (which includes aflatoxins, known genotoxic and hepatocarcinogenic compounds), probably because it is little explored by the media, as they are natural substances. It is possible that even those who were unfamiliar with it assigned a high worry level, considering that the word component "toxin" by itself implies something negative. On the other hand, nanotechnology had the lowest worry score, which can be understood to some extent by the fact that the technology component of the term is neutral or positive, as opposed to toxin (or *tóxico*), in light of the affect heuristic concept (Slovic et al., 2007).

It is worth mentioning the relative importance given to the risk arising from animal cloning (among the hospital/clinic and supermarket groups more than the university group), considering that it is still a little-known technique (the third hazard most unfamiliar in the study) and its potential risks are little discussed in society (Rudenko & Matheson, 2007). It is possible that the mere mention of the term "cloning" might bring a negative feeling in some individuals, as another example of affect heuristics (Siegrist & Sütterlin, 2014; Slovic et al., 2007) or the concept of "risk as feelings" (Loewenstein et al., 2001), for animal ethical reasons (Gamborg et al., 2009). Furthermore, the term animal cloning arouses emotions related to religiosity or spirituality of "playing God" or "tampering with nature" types, which encounter resistance (Hoogendoorn et al., 2021). In this sense, if animal cloning development increases in the country, it may occupy the cognitive space of risk perception that was reserved for GM foods two decades ago. However, animal cloning was among the items considered of greatest worry

among Eurobarometer 2010 interviewees (EC, 2010); this item was not included in the following survey (EC, 2019).

Salt and sugar were perceived with medium/high worry by a considerable fraction of interviewees, surpassing, for instance, food additives. A greater salt-and-sugar-related risk perception seems to reflect the recurrent public health campaigns carried out in the country to reduce the intake of these food components (MS, 2018). When controlled by the other variables, belonging to a group was not a determining factor for the worry with sugar and salt, which was shown to be impacted mostly by the age (individuals over 24 years old have a higher worry level).

Students at the university were less worried about the presence of hazards in food in general and in relation to some specific items, such as pesticides and technologies, when controlled by other variables in the adjusted model, including education. This somehow endorses the thesis that supplying individuals with more information can exert some positive impact on the perception dimension (Bearth et al., 2019; Saleh et al., 2019). However, some authors argue that, with controversial technologies, this impact is less observed, and the reverse effect may occur (Christiansen et al., 2017). Additionally, the assimilation of information depends on how much they agree with individuals' previous beliefs, as well as psychological and cultural aspects (McFadden & Lusk, 2015). In this regard, Xu et al. (2020) observed among Chinese consumers that the increase of information reduced risk perception to GM foods only in individuals unfamiliar with the topic. Indeed, the controversy surrounding GM foods has been decreasing over the years, as the level of information increases and its nutritional equivalence with conventional foods is confirmed (NAS, 2016).

In the present study, income/education had a significant impact on risk perception of technologies, as individuals with lower income and/or education had a higher risk perception, in line with the findings by other authors (Moerbeek & Casimir, 2005; Ellis & Tucker, 2009). Dosman et al. (2001) postulate that education can impact risk perception in conflicting ways. Individuals with higher education may have a better understanding of potential dietary risks, thus perceiving these risks as high, while individuals with less education disregard these risks, as they do not even recognize their existence. Moerbeek and Casimir (2005) called this attitude "information paradox." On the other hand, higher levels of education can provide that risks are better understood and mediated (or avoided), leading to a greater sense of control, which reduces risk perception.

Women had a greater risk perception than men for most hazards, a pattern that has also been demonstrated in other studies (Dosman et al., 2001; Omari et al., 2018), and may be mediated by factors such as ethnicity and social position (Gustafson, 1998). Age was also a strong predictor of risk perception for most hazards assessed, with a positive correlation with perception, especially after 50 years of age. Similarly, the hospital/clinic group was shown to have a greater risk perception. In both cases (being older and in a hospital/clinic environment), the greater worry with health seems to be a determinant for a greater risk perception (Ferrer & Klein, 2015).

The less sensitivity to risks by younger individuals is well established in the literature, considering that youth is a stage of life that presupposes a greater sense of invulnerability, being related to the characteristic known as optimistic bias or unrealistic optimism, when the individuals judge themselves less susceptible to risks than others (Jefferson et al., 2017), which has already been found to play a role in food area (Miles & Scaife, 2003). Indeed, a study conducted with more than 4,000 American university students showed a risky eating behavior, which is worse for men; knowledge level was weakly correlated with this behavior (Byrd-Bredbenner et al., 2008).

In summary, the results of this study indicated a great risk perception to chemical hazards, particularly pesticides and heavy metals, and less to technologies (GM food, animal cloning, and nanotechnology). In general, women, older individuals, and those with lower income and education were associated with a higher risk perception, with the first two being the strongest predictors. Individuals interviewed in hospital/clinic most often showed greater worry levels than those in the university, suggesting that the interviewees' environment/context at the time of the study influences risk perception. Furthermore, interviewees showed unfamiliarity with some terms, particularly mycotoxins and nanotechnology, as well as greater familiarity of the legal term *agrotóxico* adopted in Brazil for pesticides, compared with other terms to describe these products.

The main limitations of this study are related to the answers' reliability, considering the possibilities of bias and factors such as haste or tiredness of interviewees during the questionnaire answering process. The fact that some individuals requested an oral interview, which inevitably ended up provoking a conversation between them and the interviewer, can be a bias, even though the interviewer was non-judgmental during the application of the questionnaire. Another important bias concern is the fact that people who were willing to participate in the study tend to be naturally more interested and sensitive to the topic; this presupposes an initial trend of greater worry/risk perception of food hazards than individuals who refused to participate, many of whom were not interested in the topic, consequently indicating that they are not worried about it. Other limitation concerns the unfamiliarity, which was assessed indirectly when the participant did not choose any of the three worry options about a hazard, although this could only mean that he/she cannot judge the level of worry. Finally, the use of a three-point scale to assess the hazard worries instead of the more usual five or seven-point Likert scale may have limited the calculation of the worry score, reducing the nuances that could have been detected in the analysis.

Risk perception involves subjective aspects of the human nature and could never be assessed without limitations. In addition to consider the limitations pointed out in this study to decrease the uncertainties of the outcome, further research should perform the multivariate analysis not only looking at the main effect in the model, but also possible interaction between variables as well. The relationship between familiarity with the names and the underlying risk perception also may be explored, by including these constructs altogether in the statistical model.

5. Conclusions

The results of this study corroborated with most literature findings, indicating that gender and age are strong predictors for worry levels, which is away of measuring affective risk perception about chemical and technological hazards in food. On the other hand, education and income impacted in a less predictable way. The interviewees' environment where the study was conducted also seems to influence risk perception, an issue which has not been previously investigated and deserves further research.

This is the first study on food chemical risk perception with this large scope carried out in Brazil. The results indicate the need to implement effective risk communication strategies aimed at different population segments, such as age groups, gender and socioeconomic status, which should be part of an institutional planning of government agencies responsible for ensuring food safety.

Funding

This project received financial support from the Brazilian Ministry of Justice and Public Security (MJ; TED FDD N° 58/2019).

CRediT authorship contribution statement

Peter Rembischevski: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing. Victoria B. de Mendonça Lauria: Data collection, Data Curation, Visualization; Luiza I. da Silva Mota: Data collection, Data Curation, Visualization; Eloisa Dutra Caldas:

Conceptualization; Methodology, Data Curation, Writing – review & editing, Supervision, Project administration, Funding acquisition.

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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodcont.2022.108808.

References

Abe, A., Koyama, K., Uehara, C., Hirakawa, A., & Horiguchi, I. (2020). Changes in the risk perception of food safety between 2004 and 2018. *Food Safety, 8*(4), 90–96.

Arrebola, J. P., Muñoz, A., Ferrero, S., & Larrea-Killinger, C. (2020). Perceptions and attitudes of gynecologic and pediatric professionals regarding dietary exposure to chemical pollutants. *International Journal of Environmental Research and Public Health, 17*(11), 1–14, 3946.

Bearth, A., Saleh, R., & Siegrist, M. (2019). Lay-people's knowledge about toxicology and its principles in eight European countries. *Food and Chemical Toxicology, 131*, Article 110560.

Byrd-Bredbenner, C., Abbot, J. M., Wheatley, V., Schaffner, D., Bruhn, C., & Blalock, L. (2008). Risky eating behaviors of young adults-implications for food safety education. *Journal of American Dietic Association, 108*(3), 549–552.

Capon, A., Rolfe, M., Gillespie, J., & Smith, W. (2015). Are Australians concerned about nanoparticles? A comparative analysis with established and emerging environmental health issues. *Australian & New Zealand Journal of Public Health, 39*(1), 56–62.

Charlebois, S., & Summan, A. (2015). A risk communication model for food regulatory agencies in modern society. *Trends in Food Science & Technology, 45*, 153–165.

Christiansen, A., Jonch-Clausen, K., & Kappel, K. (2017). Does controversial science call for public participation? The case of GMO skepticism. *Ethics Forum, 12*(1), 25–50.

Codeplan - Companhia de Planejamento do Distrito Federal. (2020). *Pesquisa Distrital por Amostra de Domicílio*. PDAD 2018 http://www.codeplan.df.gov.br/wp-content/uploads/2020/06/Destaques_PDAD_revisado.pdf. (Accessed 18 June 2021).

Danelon, M. S., & Salay, E. (2012). Development of a scale to measure consumer perception of the risks involved in consuming raw vegetable salad in full-service restaurants. *Appetite, 59*(3), 713–722.

Dickson-Spillmann, M., Siegrist, M., & Keller, C. (2011). Attitudes toward chemicals are associated with preference for natural food. *Food Quality and Preference, 22*(1), 149–156.

Dosman, D. M., Adamowicz, W. L., & Hrudey, S. E. (2001). Socioeconomic determinants of health- and food safety-related risk perceptions. *Risk Analysis, 21*(2), 307–318.

EC. (2010). Special eurobarometer 354: Food-related risks. https://op.europa.eu/en/publication-detail/-/publication/3352d368-8ff8-4f04-a6a6-cb890e809815. (Accessed 16 September 2021).

EC. (2014). Tomorrow's healthy society - research priorities for foods and diets. JRC Foresight Study, Final Report. https://ec.europa.eu/jrc/sites/default/files/jrc-study-tomorrow-healthly-society.pdf. (Accessed 18 September 2021).

EC. (2019). Special eurobarometer wave EB91.3: Food safety in the EU. https://www.efsa.europa.eu/sites/default/files/corporate_publications/files/Eurobarometer2019_Food-safety-in-the-EU_Full-report.pdf. (Accessed 16 September 2021).

Ellis, J. D., & Tucker, M. (2009). Factors influencing consumer perception of food hazards. *CAB Reviews Perspectives in Agriculture Veterinary Science Nutrition and Natural Resources, 4*(6), 1–8.

Embrapa. (2018). Brazilian Agricultural Research Corporation. Research evaluates how people perceive nanotechnology. https://www.embrapa.br/en/busca-de-noticias/-/noticia/38106803/research-evaluates-how-people-perceive-nanotechnology. (Accessed 16 June 2021).

Ferrer, R., & Klein, W. M. (2015). Risk perceptions and health behavior. *Current Opinion in Psychology, 5*, 85–89.

Ferrer, R. A., Klein, W., Avishai, A., Jones, K., Villegas, M., & Sheeran, P. (2018). When does risk perception predict protection motivation for health threats? A person-by-situation analysis. *PloS one, 13*(3), e0191994. https://doi.org/10.1371/journal.pone.0191994.

Fischhoff, B., Slovic, P., Lichtenstein, S., Read, S., & Combs, B. (2000). How safe is safe enough? A psychometric study of attitudes toward technological risks and benefits. In P. Slovic (Ed.), *The Perception of risk* (1st ed., p. 511) Routledge, London.

Frewer, L. J., Fischer, A. R. H., Brennan, M., Bánáti, D., Lion, R., Meertens, M., Rowe, G., Siegrist, M., Verbeke, W., & Vereijken, C. M. J. L. (2016). Risk/Benefit communication about food - a systematic review of the literature. *Critical Reviews in Food Science and Nutrition, 56*, 1728–1745.

Gamborg, C., Gjerris, M., & Sandøe, P. (2009). The ethics of animal cloning. In J. Gunning, S. Holm, & I. Kenway (Eds.), *Ethics, Law and society: Volume IV* (*1st* ed., pp. 43–54). Routledge.

Gustafson, P. E. (1998). Gender differences in risk perception: Theoretical and methodological perspectives. *Risk Analysis, 18*(6), 805–811.

Hampel, J. (2006). Different concepts of risk: A challenge for risk communication. *International Journal of Medical Microbiology, 296*(S1), 5–10.

Hansen, J., Holm, L., Frewer, L. J., Robinson, P., & Sandøea, P. (2003). Beyond the knowledge deficit: Recent research into lay and expert attitudes to food risks. *Appetite, 41*, 111–121.

Hansson, S. O. (2010). Risk: Objective or subjective, facts or values. *Journal of Risk Research, 13*(2), 231–238.

Ha, T. M., Shakur, S., & Do, K. H. P. (2020). Risk perception and its impact on vegetable consumption: A case study from Hanoi, Vietnam. *Journal of Cleaner Production, 271*, 1–10.

Hoogendoorn, G., Sütterlin, B., & Siegrist, M. (2021). Tampering with nature: A systematic review. *Risk Analysis : An Official Publication of the Society for Risk Analysis, 41*(1), 141–156.

ISAAA. International Service for the Acquisition of Agri-biotech Applications. (2019). *Pocket K No. 16: Biotech Crop Highlights in, 2019*. https://www.isaaa.org/resources/publications/pocketk/16/. (Accessed 16 June 2021).

Jansen, T., Claassen, L., van Kamp, I., & Timmermans, D. R. M. (2020). 'It is not entirely healthy.' A qualitative study into public appraisals of uncertain risks of chemical substances in food. *Public Understanding of Science, 29*(2), 139–156.

Jefferson, A., Bojana, L., & Kuzmanovic, B. (2017). What is unrealistic optimism? *Consciousness and Cognition, 50*, 3–11.

Jenkins, S. C., Harris, A. J. L., & Osman, M. (2021). What drives risk perceptions? Revisiting public perceptions of food hazards associated with production and consumption. *Journal of Risk Research* (in press).

Kaptan, G., Fischer, A. R. H., & Frewer, L. J. (2018). Extrapolating understanding of food risk perceptions to emerging food safety cases. *Journal of Risk Research, 21*(8), 996–1018.

Kher, S. V., de Jonge, J., Wentholt, M. T. A., Deliza, R., Andrade, J. C., Cnossen, H. J., Luijckx, N. B. L., & Frewer, L. J. (2013). Consumer perceptions of risks of chemical and microbiological contaminants associated with food chains: A cross-national study. *International Journal of Consumer Studies, 37*, 73–83.

Koch, S., Epp, A., Lohmann, M., & Böl, G. F. (2017). Pesticide residues in food: Attitudes, beliefs, and misconceptions among conventional and organic consumers. *Journal of Food Protection, 80*(12), 2083–2089.

Komoto, K., Okamoto, S., Hamada, M., Obana, N., Samori, M., & Imamura, T. (2016). Japanese consumer perceptions of genetically modified food: Findings from an international comparative study. *Interactive Journal of Medical Research, 5*(3), Article e23.

Loewenstein, G. F., Weber, E. U., Hsee, C. K., & Welch, N. (2001). Risk as feelings. *Psychological Bulletin, 127*(2), 267–286.

McFadden, B. R., & Lusk, J. (2015). Cognitive biases in the assimilation of scientific information on global warming and genetically modified food. *Food Policy, 54*, 35–43.

Michel, F., & Siegrist, M. (2019). How should importance of naturalness be measured? A comparison of different scales. *Appetite, 140*, 298–304.

Miles, S., & Scaife, V. (2003). Optimistic bias and food. *Nutrition Research Reviews, 16*(1), 3–19.

Moerbeek, H., & Casimir, G. (2005). Gender differences in consumers' acceptance of genetically modified foods. *International Journal of Consumer Studies, 29*(4), 308–318.

MS. Brazilian Ministry of Health. (2018). Promoção da Saúde e da Alimentação Adequada e Saudável. Redução de Sódio, Açúcar e Gordura Trans. https://aps.saude.gov.br/ape/promocaosaude/reducao. (Accessed 18 June 2021).

NAS. (2016). National Academies of Sciences, engineering, and medicine, division on earth and life studies, board on agriculture and natural resources, & committee on genetically engineered crops: Past experience and future prospects. *Genetically Engineered Crops: Experiences and Prospects*. National Academies Press (US).

Nguyen, T. V., Ha, T. M., Boulom, S., Voe, P., Heang, C., Ha, D. A., Chialue, L., Bor, B., Phommaluesa, S., & Pham, D. H. (2020). Consumers' risk perception of vegetables in Southeast Asia: Evidence from Laos, Cambodia, and Viet Nam. *APN Science Bulletin, 10*(1), 61–66.

Omari, R., Fremponga, G. K., & Arthur, W. (2018). Public perceptions and worry about food safety hazards and risks in Ghana. *Food Control, 93*, 76–82.

Pidgeon, N., Kasperson, R. E., & Slovic, P. (2003). *The social amplification of risk*. Cambridge: Cambridge University Press.

Rembischevski, P., & Caldas, E. D. (2018). Agrochemicals for pest control in Brazil: Critical analysis of the use of the term *agrotóxico* as a tool for risk communication. *Vigilância Sanitária em Debate, 6*(4), 2–12.

Renn, O. (2008). Concepts of risk: An interdisciplinary review. Part 1: Disciplinary risk concepts. *Gaia, 17*(1), 50–66.

Rosati, S., & Saba, A. (2004). The perception of risks associated with food-related hazards and the perceived reliability of sources of information. *International Journal of Food Science and Technology, 39*, 491–500.

Rozin, P. (2005). The meaning of "natural": Process more important than content. *Psychological Science, 16*(8), 652–658.

Rudenko, L., & Matheson, J. C. (2007). The US FDA and animal cloning: Risk and regulatory approach. *Theriogenology, 67*(1), 198–206.

Saleh, R., Bearth, A., & Siegrist, M. (2019). Chemophobia" today: Consumers' knowledge and perceptions of chemicals. *Risk Analysis, 39*(12), 2668–2682.

Saleh, R., Bearth, A., & Siegrist, M. (2021). How chemophobia affects public acceptance of pesticide use and biotechnology in agriculture. *Food Quality and Preference, 91*, Article 104197.

Siegrist, M., & Hartmann, C. (2020). Consumer acceptance of novel food technologies. *Nature Food, 1*, 343–350.

Siegrist, M., & Sütterlin, B. (2014). Human and nature-caused hazards: The affect heuristic causes biased decisions. *Risk Analysis, 34*(8), 1482–1494.

Slovic, P., Finucane, M. L., Peters, E., & MacGregor, D. G. (2007). The affect heuristic. *European Journal of Operational Research, 177*, 1333–1352.
Verbeke, W. (2005). Agriculture and the food industry in the information age. *European Review of Agricultural Economics, 32*(3), 347–368.
Visschers, V. H. M., & Siegrist, M. (2018). Differences in risk perception between hazards and between individuals. In M. Raue, E. Lermer, & B. Streicher (Eds.), *Psychological perspectives on risk and risk analysis*. Cham: Springer.
Xu, R., Wu, Y., & Luan, J. (2020). Consumer-perceived risks of genetically modified food in China. *Appetite, 147*, Article 104520.