



Research article

Exploring tea and herbal infusions consumption patterns and behaviours: The case of Portuguese consumers

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ARTICLE INFO

Keywords:

Tea and herbal infusions
Consumption survey
Preferences
Socio-demographic factors
Consumer behaviors
Safe consumption

ABSTRACT

Consumption of tea and herbal infusions (THIs) have a long history in traditional medicine and cultural practices. The health-promoting benefits attributed to THIs are considered influential factors in consumer choices. However, there is limited data on consumer choices and attitudes that might interfere with the positive effects associated with THIs consumption.

The aim of this study was to investigate the consumption pattern and behavior of THIs consumers in Portugal, assessing the influence of socio-demographic factors on the selection of THIs products and consumer practices related to these beverages.

An online survey was conducted, and from the collected data, 720 responses met the aim of the study and were further analyzed. Most of the respondents were female, 74.4%, belonging to the 40–60 age group (40.6%) and were medium consumers of THIs (47.2%). Green tea was the most consumed type among participants, and its consumption was associated not only with age but also with the pattern of THIs consumption. Despite that, participants preferred herbal infusions, with citronella, chamomile, and lemon verbena being the most consumed types. For certain types of herbal infusions, consumption was associated with age, while other types were preferred by moderate or heavy consumers. Most participants purchased THIs in supermarkets, registered trademark and brand stores, in the form of THIs bag. Light consumers use only bag, while medium/heavy consumers indicated the use of other forms. Almost half of the respondents admitted to not reading the information on product labels before consumption and using THIs after the expiry date, while only one-third of them declared paying attention to the label instructions.

This study revealed the impact of socio-demographic factors as age on the consumption patterns and preferences of THIs of consumers. Of concern is the neglect of label usage among Portuguese consumers. This emphasizes the urgency of implementing interventions to guide proper label use and promote good consumption practices to ensure the quality of THIs products.

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<https://doi.org/10.1016/j.heliyon.2024.e28779>

Received 2 February 2024; Received in revised form 14 March 2024; Accepted 25 March 2024

Available online 27 March 2024

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1. Introduction

Tea and herbal infusions (THIs) have a long history in traditional medicine and cultural practices, remaining one of the most consumed beverages around the world [1]. The high consumer demand for THIs strongly influences the global market, projecting an increase in tea production, particularly pronounced for green tea [2]. In parallel to teas, there is an increasing popularity of herbal infusions in different markets in Europe [3–5]. The high demand can be attributed to the natural bioactive molecules in THIs and consumers' perception of their recognized health benefits [6,7]. Meanwhile, the true health value attributed to THIs beverages can be compromised at various stages and, ultimately, by certain consumer behaviors or practices [8–11]. Nevertheless, data on consumer attitudes and practices regarding beverage preparation are still limited. Further, less is known on the consumption behaviors that can affect the health-related properties of THIs, and even those that may pose a threat to food safety with negative health consequences.

Tea refers to an aromatic beverage prepared by cured or fresh leaves of *Camellia sinensis*. The variety of teas is linked with the genetic diversity of the *Camellia* plant, environmental factors [12] and processing methods [13,14]. The most usual types of teas are black, green and white. In the last few years, new consumer forms have been appearing in Europe as Oolong and Pu-erh tea [15,16] or different preparations such as kombucha tea [17]. Tea consumption has also been associated with protective effects by decreasing oxidative stress responses and inflammation levels, known for a pivotal role in the pathogenesis of diseases such as cardiovascular, metabolic, cancer and neurodegenerative diseases [18,19]. Herbal infusions or tisanes are another aromatic drink with therapeutic properties that is increasingly popular, rising its consumption as a daily beverage [20]. These beverages can be prepared with herbal (medicinal) plants, fruits, spices or a mixture of both. Herbal infusions may contain a range of bioactive compounds [21] that can provide a myriad of beneficial effects such as on depression [22], reproductive [23], cancer [24,25] as well as antioxidant, anti-inflammatory and anti-thrombotic [26].

Despite the popularity of THIs as functional drinks, individual choices go beyond a health interest, being also influenced by sensory and non-sensory factors [27]. Sensory attributes of THIs such as flavor can, be divided into aroma and taste, both closely related to their chemical constituents (volatile and non-volatile compounds), including flavonoids, catechins, polyphenols, alkaloids, tannins and polysaccharide [28,29]. Nevertheless, THIs consumption pattern is also highly influenced by non-sensory factors driving change in consumption trends, such as demographics, socioeconomics, cultural and environmental factors [30,31]. In general, tea consumption is a prevalent habit in Europe due to its ancestry, culture, and the link to specific diets that are characteristic of the Mediterranean region [32]. Despite these influencing factors, the association with health benefits and the affordability of the product may be causing a change in THIs consumption patterns across European countries.

The per capita tea consumption data provided in the Food Balance for each country serves as a valuable metric to identify the average consumption within a population. However, this information introduces uncertainties regarding the variability of THIs consumption, a critical data for characterizing the diverse habits of consumers. Furthermore, these databases and epidemiological studies, such as the national dietary survey of the Portuguese population, reveal gaps to differentiate between various types of tea and herbal infusions [33,34]. Another difficulty encountered for a comprehensive assessment of THIs consumption is the great diversity of products available to consumers. Recognizing that consumers may perceive plant-based beverages as safe food, it is crucial to exercise heightened caution. Indeed, as reported in the WHO recommendations, some herbal infusions are products of traditional medicine that need a rational use, as their misuse can pose health risks [20].

The consumption trends of THIs can evolve over time and be specific to each country. For example, tea beverages are more popular in Turkey, while in Germany, consumption of the fruit and herbal infusions (aromatized or not) surpasses that of tea [1,5]. Among the un-aromatized varieties, peppermint, chamomile, and fennel are the most popular choices among German consumers [5]. The per capita tea consumption in the Portuguese population is significantly lower than that in Turkey and Germany [1]. Regarding herbal infusions in Portugal, the study by Rocha et al. [35] revealed that participants' preferences were lemon balm, followed by chamomile and linden, namely among those residing in a subregion within North of Portugal. In that study, assessment of specific tea types was not included, as well as the socio-demographic factors that affect herbal infusion preferences of Portuguese. From a market research standpoint, data on the consumption trend of THIs are relevant, but will be insufficient when trying to understand how consumption choices and behaviors can impact consumer's health. It is important to overcome the gap between general population assumptions and the consumer context, especially considering that vulnerable populations may consume THIs beverages.

There is a rising concern for food safety issues related to the consumption of THIs, which may pose challenges to public health due to toxic secondary metabolites (e.g. phytates and pyrrolizidine alkaloids) [36–40], contaminants [41–44] or contamination with other plant species. For instance, a recent quality assessment of marketed herbal infusion showed that chamomile crude flowers were most likely to be adulterated by other plant materials compared to chamomile bags [45]. Furthermore, THIs quality can be lost due to consumer behavior, including in beverage preparation [46]. In these final processing step, consumer practices can negatively interfere with the beneficial health-effects of THIs, such as using an inappropriate steeping temperature that changes its chemical composition [8–10]. However, there are research gaps about the context of THIs consumers, and these insights are needed to provide evidence for bridging the real consumer context and risk assessment, contributing to consumer protection and public health management. Therefore, this study focuses on the heterogeneous preferences of consumers regarding THIs products, consumption behaviors and the attitudes adopted related to beverages.

To the best of our knowledge, this is the first study that provided a comprehensive characterization of Portuguese THIs consumers, elucidating their preferences and the influence of socio-demographic factors on the patterns of consumption. Additionally, our results shed light on the practices and behaviors undertaken in beverage preparation, providing insights into attitudes that may impact the THIs quality and safety of consumption.

2. Materials and methods

Ethical approval was obtained from the Instituto Universitário de Ciências da Saúde Research Ethics Committee prior to conducting the study (reference number: CE/IUCS/CESPU-03/23).

2.1. Design and participants

An online survey was developed on the Google® Forms platform to collect data on THIs consumption preferences and behaviors of Portuguese consumers, including consumers' knowledge of brewing instructions and self-reported practices in infusion preparation.

Participants eligible for the study were adult respondents (≥ 18 years old) and with informed consent accepted. The survey was announced on social media platforms like Facebook®, Instagram®, WhatsApp® and widely disseminated through these channels. The survey was applied between January and February 2023. A target dichotomous question (No–Yes) “Are you a THIs consumer?” was included, so that non-consumers were not compelled to complete the survey. The final sample comprised 720 individuals who completed the questionnaire (Fig. 1).

2.2. Survey

The survey was developed based on a literature review, optimized for readability and clarity, and made available in Portuguese. Several strategies were used with the aim of organizing and optimizing the construction of the survey so that the responses were reached in an efficient manner. Therefore, only questions essential to achieve the study's objectives were formulated, minimizing time-consuming for the participant. The questions asked were both open and closed-ended.

Socio-demographic data as age, gender, marital status, geographical region, education level (categorical variable) and nationality (dichotomous variable) were collected in the first section. To allow the free participation of respondents and to respect their privacy, an option “other” or “no answer” was added in each of these questions.

The main section of the survey is related to the general characterization of THIs consumption pattern, including questions on frequency, type of tea and herbal infusions consumed, place of purchase, brand, and preparation method. The option “other” was used specifically to not make the list of teas and infusions exhaustive and decrease the dropout rate and the option “no answer” to give freedom to the respondent to express or not their preference.

2.2.1. Ethics considerations

On the first page of the survey, the objectives of the study were clearly explained, and the contacts of the researchers were made available. Before starting, all participants had to read and complete an informed consent form according to the Ethical Principles for Medical Research involving human subjects expressed in the Declaration of Helsinki and the national legislation. No identifiable information was collected.

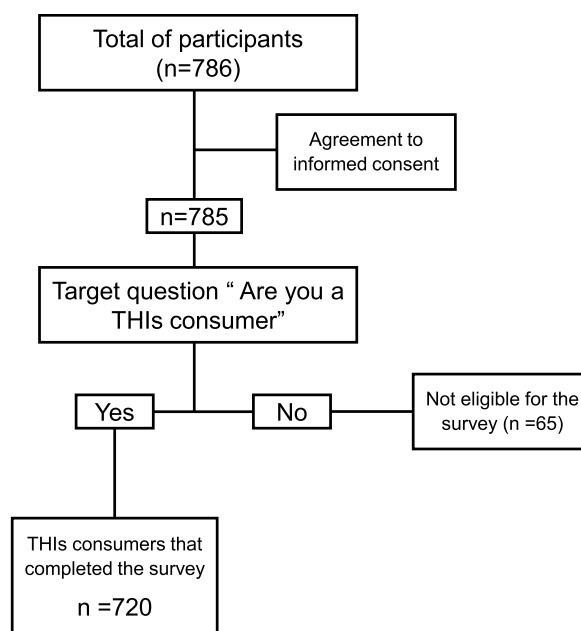


Fig. 1. Selection of participants.

2.2.2. Socio-demographic variables

The age variable of participants was first defined for five categories: 18–29, 30–39, 40–60, 61–74 and 75 or more. This stratification was adjusted after the questionnaire for elderly respondents who were aggregated into one category “61 or more”.

The gender was questioned through a closed-ended question which included the option “other”. Nationality data was collected through a closed-ended question which included the options “Portuguese”, “no answer” and “other”. Marital status was inquired through a single-selection question which included the options: “single”, “divorced”, “widowed”, and “married/relationship”.

For the variable geographical area of residence, we used the seven regions according to the Nomenclature of Territorial Units for Statistical in Portugal (NUTII), namely North, Center, Lisbon metropolitan area, Alentejo, Algarve, Azores and Madeira.

The education level variable was aggregated into four categories: elementary education (basic school education), middle education (secondary school education), post-secondary (vocational and technical school education) and higher education (all college or university degrees).

2.2.3. THIs consumption patterns

The frequency of THIs consumption was estimated based on an adaptation from Rocha et al. [35], using a six-point scale: (1) “less than one cup/month”, (2) “one to three cups/month”, (3) “two to four cups/week”, (4) “one cup/day”, (5) “two to three cups/day”, and (6) “more than three cups/day”. THIs consumption variable was aggregated into three categories according to responses: “light consumers” (drink less than 1 cup/month to 1–3 cups/month); “medium consumers” (drink 2–4 cups/week to 1 cup/day) and, “heavy consumers” (drink more than one cup every day).

2.2.4. Consumer preferences for types of THIs

To mitigate bias and streamline the survey, a set of questions was designed with ordered categories that revolve around a common target question. Therefore, consumer preferences about THIs included closed-end questions, checklist questions of relative frequency and multiple-choice grids.

The respondents’ choices of THIs types were assessed using questions grouped as checklists separately for tea types (variable with 4 items) and herbal infusion types (variable with twelve items). In these checklists, consumers provided answers for each item. The relative frequency of THIs consumed was recorded on a four-point scale: (0) “never”, (1) “rarely”, (2) “sometimes”, and (3) “the most consumed”. In both cases, the option “no answer” was included to avoid misreporting.

Data regarding the place of purchase were obtained using a multiple-choice question (variable with seven items) and the relative frequency for each item. As participants did not choose the “no answer” option, the purchase location variable was adjusted to three categories: (0) “never/rarely”, (1) “sometimes”, and (2) “most common place of purchase”. Data about purchased brand was inquired through a list of options (variable with eight items) The selected list included some of the most common brands available in the Portuguese market, such as Tetley®, Tley®, Lipton®, Gorreana®, Saludem® and white-label brands.

The type of packaging was questioned through a checklist with the five options: “bag”, “loose”, “both”, “pre-prepared”, “extract”. Since the last two options exhibited very low response frequencies, they were combined into a new category labeled as “other form”. In the questions related to the type of tea and infusion most consumed and the brand most purchased, the option “other” was included with a text box to allow the participant to add options.

2.2.5. Practices and behaviors

Consumer attitudes related to THIs preparation were assessed with checklist question and its relative frequency, which included items such as: reading labels, checking the expiry date, following preparation instructions, and consuming THIs without the labels. A three-point scale was used for all items: (0) “never/rarely”, (1) “sometimes”, and (2) “usually/always”.

To prepare the beverage, consumers were asked about the type of water and the amount of THIs used in preparation (considering the recommended dose per cup). The same three-point scale was applied to evaluate the relative frequency of the type of water used by the consumer.

For THIs quantity that was habitually used in beverage preparation, a choice-list question was applied categorized as follows: (0) “neither less nor greater”, (1) “less quantity”, (2) “greater quantity” and, (3) “either less or greater”. The same type of question was used to assess the infusion preparation methods using three options: (1) “add THIs before boiling water”, (2) “add THIs after boiling water and resting for 5 min”, (3) “add THIs after boiling water and resting for 10 min”. Given that participants could choose all applicable situations in preparation of infusion, the obtained answers were then classified into four new categories, which were a combination of all three initial categories.

Following the preparation of the beverage, the consumer was asked about their usual practice, specifically whether they remove the THIs plant/bag before drinking or after consuming the drink using a dichotomous question (Yes-No). Consumers were also requested to specify their usual additions to their tea/infusion by choosing from the provided options: “nothing”, “sugar”, “honey”, “cinnamon”, or “other”.

2.3. Data analysis

All responses were explored using descriptive statistics, which included count, percentage, mean, and plots. Statistical analysis was performed using Jamovi Software (version v. 2.3.26). The data met the assumptions of the statistical tests used, including whether normality and homogeneity of variances were formally tested (Shapiro-Wilk, Kolmogorov-Smirnov and Levene’s tests).

The categorical variables, such as socio-demographic (gender, age, geographical region, and education level) and THIs

consumption groups were analyzed using log-linear regression. In addition, THIs consumption variable was examined using multinomial logistic regression to test interaction with socio-demographic variables (age groups and geographical area). Comparisons of THIs consumption groups among age groups and geographical area were carried out using Kruskal-Wallis one-way ANOVA, followed by pair-wise post hoc tests with Dwass-Steel-Critchlow-Fligner corrections.

To reduce the dimensionality of consumer choices for types of tea and herbal infusion, purchase locations, and THIs brands, Principal Component Analysis (PCA) was employed to summarize these data with a visually oriented approach. The PCA plot allowed the segmentation of the participants' choices for further analysis. For the interaction of consumption frequency of tea and herbal infusion types with THIs consumption and age groups, we employed a Generalized Linear Model, specifically a Quasi-Poisson model along with the Holm correction method. These analyses were conducted with a 95% confidence interval. To analyze the type of package used among THIs consumption groups, the Kruskal-Wallis was used. The p -values below 0.05 were considered statistically significant.

The graphics were performed using RStudio (version R 4.3.0).

3. Results

3.1. Global profile of THIs consumers

3.1.1. Socio-demographic characterization of participants

The socio-demographic profile of the respondents revealed a predominant female representation (74.4%), with 25.6% being male (Table 1). Considering the age distribution, results showed a majority in the 40–60 age group (40.6%), whereas the lowest percentage (9.2%) belonged to the age group “61 or more”. Nearly half of the participants (48.8%) were married or in a relationship and 43.5% were single. Regarding the education level, the higher percentage of the respondents had a high education level (76.9%) with significantly differences compared to other education levels. The vast majority (98.3%) of participants were Portuguese and, responses were collected from all seven regions of Portugal (NUTII). The North region had a significantly higher percentage of responses (67.9%), compared to all other regions. The Azores was the region with the lowest number of responses.

3.1.2. THIs consumption patterns

Responses of participants were categorized as light, medium, and heavy consumers, and the frequencies were determined. Then, the influence of consumer age on the consumption pattern and variations across regions in Portugal was explored. Among the total participants (Table 1), 47.2% were categorized as medium consumers of THIs, followed by the light consumers (35.0%). Only 17.8% of the consumers belong to the heavy consumers group. The THIs consumption patterns exhibited variation between participants aged 18–29 and 40–60 years ($p < 0.001$, Fig. 2), indicating an age-related association with THIs consumption patterns (Table S1). Light consumers were more likely to belong to the 18–29 age group, whereas participants aged 40–60 tended to be medium to heavy consumers ($p = 0.004$ and $p < 0.001$, respectively). Furthermore, the average frequency of THIs consumption tended to be lower in the 18–29 age group, with an increasing trend for participants older (Fig. S1). Examining the consumption patterns across NUTII regions,

Table 1

Sociodemographic characteristics and THIs consumption pattern categories of the sample population.

		Number (N = 720)	Percentage (%)	Test statistic (p - value)
Gender	Female	536	74.4	
	Male	184	25.6	$p < 0.001$
Age group (years)	18–29	242	33.6	$p = 0.031$
	30–39	120	16.7	$p < 0.001$
	40–60	292	40.6	
	more 61	66	9.2	$p < 0.001$
Marital status	Married/relationship	351	48.8	
	Single	313	43.5	
Education level	Higher	554	76.9	
	Secondary	116	16.1	$p < 0.001$
	Post- secondary	28	3.9	$p < 0.001$
	Elementar	21	2.9	$p < 0.001$
Geographical region (NUTII)	North	489	67.9	
	Center	105	14.6	$p < 0.001$
	Lisbon MA	66	9.2	$p < 0.001$
	Alentejo	24	3.3	$p < 0.001$
	Algarve	13	1.8	$p < 0.001$
	Madeira	12	1.7	$p < 0.001$
	Azores	11	1.5	$p < 0.001$
				$p < 0.001$
THIs consumption pattern	Light consumers	252	35.0	$p < 0.001$
	Medium consumers	340	47.2	
	Heavy consumers	128	17.8	$p < 0.001$

Respondents were divided into three THIs consumption groups: light (drink ≤ 3 cups/month), medium (drink ≥ 2 cups/week to ≤ 1 cup/day) and heavy (≥ 2 cups/day) consumers. Log-Linear Regression using as reference level of female (Gender), 40–60 (Age group), North (Geographical region), Higher (Education) and, Medium consumers (THIs consumption) for p -values.

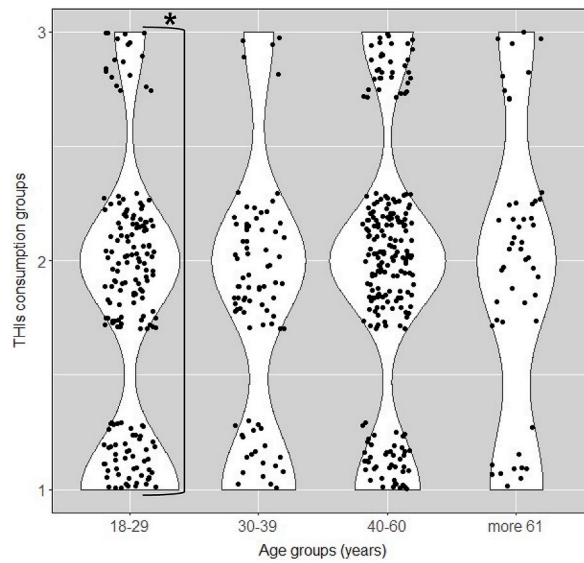


Fig. 2. THIs consumption pattern by age groups (years). Category scale of THIs consumption: (1) light consumers, (2) medium consumers and (3) heavy consumers. Kruskal-Wallis one-way ANOVA test: * $p < 0.001$ compared to 40–60 age group.

medium consumers predominated in all Portuguese regions. In multinomial logistic regression analysis using the North region as the reference level, there was no observed association between THIs consumption pattern and geographical area of residence of participants (Table S1).

3.2. Consumer choices

3.2.1. Type of tea

To unveil the patterns of THIs consumers and their preferences for the four types of tea (black, green, white, and oolong teas), PCA was employed for segmenting participants based on their choices (as depicted in Fig. 3A). From these beverages, green and black teas emerged as the most preferred choices among the respondents. Out of the total number of participants (Table S2), 18.8% indicated green tea as their most consumed beverage, followed by black tea (13.8%), whereas white and oolong teas were preferred by a smaller percentage of respondents. The results also showed that a higher percentage of medium consumers (10.4%) declared green tea as their most consumed type of tea, followed by black tea (7.1%) as the second choice.

Green tea, besides being the most frequently mentioned tea type among consumers (Fig. 3B), the frequency of its consumption also exhibited an association with the pattern of THIs consumption ($p = 0.003$) and the age of consumers ($p = 0.034$, Table S3). Indeed, the mean frequency of green tea consumption was higher in medium consumers than in light consumers ($p = 0.003$, Fig. 3B). This tea type was significantly more popular among younger consumers aged 18–30 years when compared to those in the 40–60 age group ($p =$

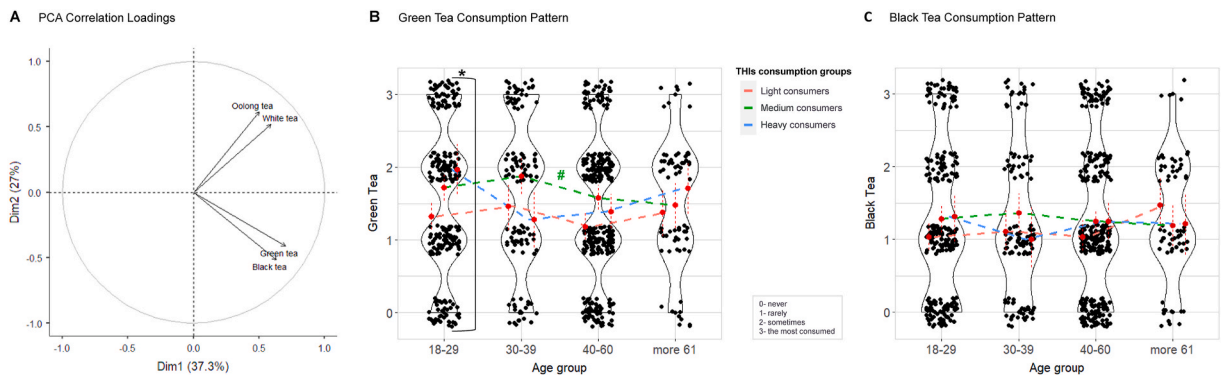


Fig. 3. Consumer’s choices of tea types and consumption patterns. (A) Correlation loadings from the first principal components of PCA on tea types. (B) Green tea and (C) black tea consumption frequency adjusted for THIs consumption pattern and age groups. The red dots represent mean, and the colored dashed lines represent tea type consumption trend of THIs consumption groups. p -values from Holm test of Generalized Linear Model analyzes: # $p = 0.003$ compared to light consumers (red line); * $p = 0.02$ compared to 40–60 age group. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

0.02). In contrast, black tea consumption exhibited consistency across both THIs consumption groups and age groups (Fig. 3C). For other tea types, results showed a positive association between the consumption of white and oolong teas and THIs groups ($p = 0.001$ and $p = 0.026$, respectively), with a tendency to increase among heavy consumers, but no association with age groups (Table S3).

3.2.2. Type of herbal infusions

To identify the consumption patterns among THIs consumers for various types of herbal infusions, the PCA was initially applied to gain a comprehensive understanding of consumer trends (Fig. 4A). Among all types of herbal infusions, consumers tended to choose chamomile, citronella, lemon verbena and linden. The most consumed herbal infusions among all respondents were citronella (41.8%), chamomile (34.4%), and 26.6% for lemon verbena infusion (Table S4). The consumption of citronella and chamomile infusions exhibited similar patterns across light, medium, and heavy consumers (Fig. 4). However, there was a relationship with the age groups ($p = 0.047$, Table S5), it is noteworthy that young consumers (aged 18–29) showed a significant preference for citronella and chamomile infusions. In detail, those aged 18–29 showed a significant preference for citronella than the 40–60 age group ($p = 0.038$, Fig. 4B). Also, the mean of chamomile infusion consumption was significantly higher among young consumers (Fig. 4C) surpassing both the 40–60 age and more 61 years old groups ($p = 0.009$ and $p = 0.012$, respectively). Nevertheless, no differences were found for THIs consumption pattern.

As for lemon verbena infusion, consumption frequency was influenced by THIs consumption pattern groups (as detailed in Table S5), but no differences were observed among age groups. It was observed that among medium consumers, individuals in the

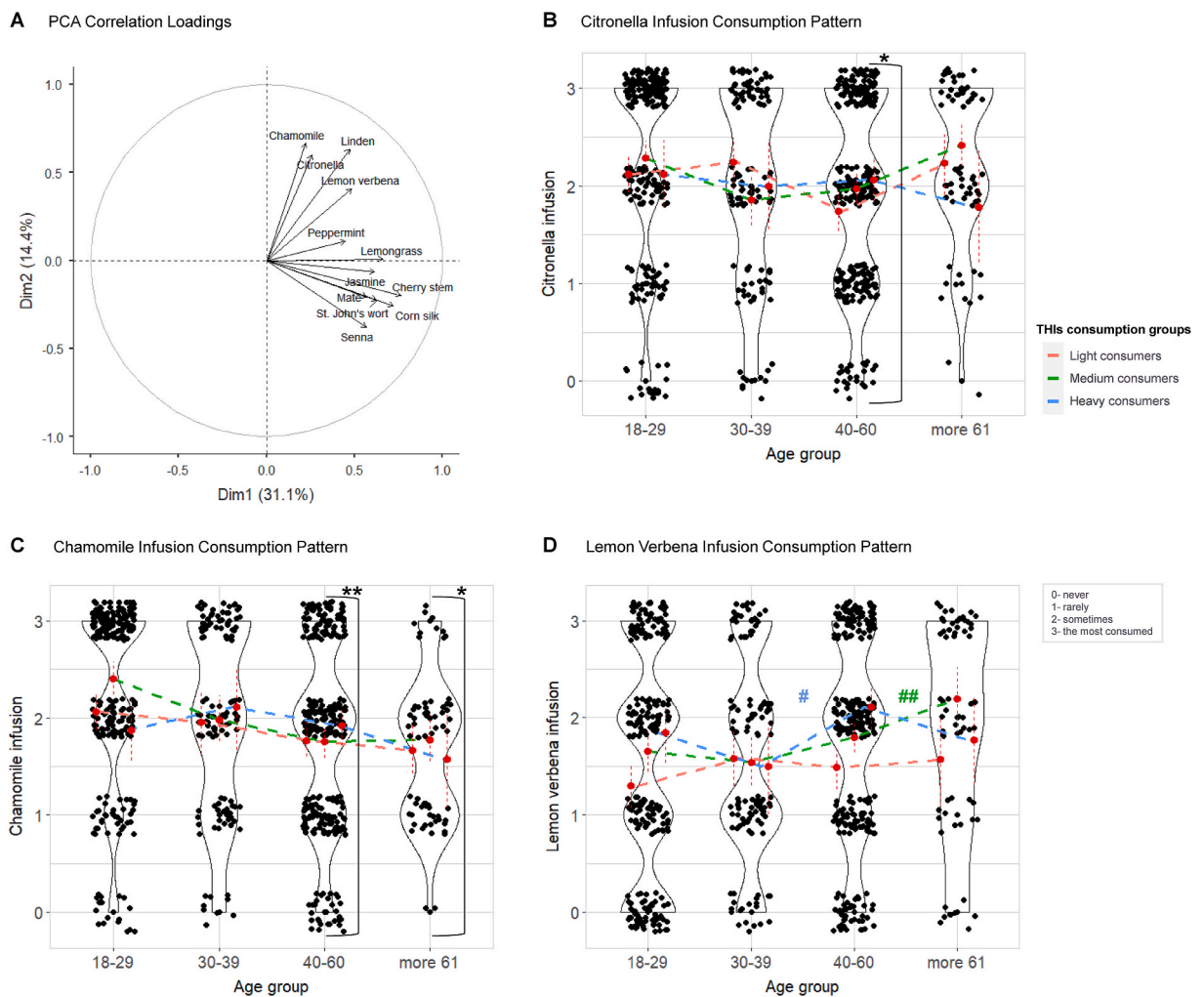


Fig. 4. Consumer's choices of herbal infusion types and consumption patterns. (A) Correlation loadings from the first principal components of PCA on herbal infusion types. (B) Citronella, (C) chamomile and (D) lemon verbena infusions consumption adjusted for THIs consumption and age groups. The red dots represent mean, and the colored dashed line represents consumption trend of THIs consumption groups. p -values for Holm test from Generalized Linear Model analyzes: * $p < 0.05$, ** $p = 0.009$, compared to 18–29 age group; # $p < 0.05$, ## $p = 0.009$, (represented by blue and green lines respectively) compared to light consumers. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

30–39 age group tended to consume it less frequently in comparison to consumers in older age groups (Fig. 4D). The mean consumption frequency of lemon verbena infusion was lower in light consumers compared to medium and heavy consumers ($p = 0.009$ and $p = 0.041$, respectively). The consumption of peppermint and lemongrass infusions was more frequent among heavy consumers of older age, whereas these herbal infusions were less popular among young participants (Table S5). Individuals in the 30–39 age group showed a higher mean frequency consumption of peppermint and lemongrass infusions than those in the 18–29 age group ($p = 0.006$ and $p = 0.005$, respectively). Despite the smaller percentage of respondents choosing herbal infusions such as jasmine and St. John's wort, the results showed that the consumption of these infusions was higher among older consumers.

The 'other' option was utilized by participants to include different types of THIs, and their preferences encompassed spice infusions like ginger, fennel, and anise, as well as fruit infusions (e.g. red berries) and hibiscus.

3.2.3. Place of THIs purchase, brands and packaging choices

To uncover the preferred places of purchase and the brands most frequently chosen by THIs consumers, PCA was employed to identify trends among the participants (Fig. 5A). THIs products are predominantly purchased by consumers in supermarkets (85.3%), with food markets coming in second at 10.4%, followed by tea shops at 4.6% (Fig. 5B). Among the most selected brands, Lipton® led with 70.3%, followed by Tetley® at 65.6%, and white-label brands with 49.6% (Fig. 5C). Some participants used the "other" option to add different brands of THIs, including Yogi®, Pukka® and Dom Duarte®. For the THIs product format, most respondents expressed a preference for bags (51.8%), 42.6% choose both bags and loose leaf, and 5.6% opted for loose leaf (Fig. 5D). A small proportion of participants reported consuming THIs in other formats (3.8% as ice-tea and 0.7% as extracts). The exclusive use of THIs bags was more common among light consumers than medium and heavy consumers ($p < 0.001$, Fig. 5E).

3.3. Consumer practices and behavior in THIs preparation

3.3.1. Practices in beverage preparation

The practices of THIs consumers in beverage preparation are shown in Fig. 6. The majority of participants reported frequently using tap water (80.2%), with 12.5% opting for bottled water (Fig. 6A). Regarding the amount of product used to prepare the beverage, most THIs consumers reported using the recommended dose as stated on the package, although 23.0% indicated using a smaller quantity, and 14.2% used a larger amount. Most of the respondents reported adding the plant leaves or bag to boiled water and steeping for 5 min (52.2%) (Fig. 6C) and then removing the leaf or bag before drinking (59.6%) (Fig. 6D). Despite this, a substantial number of respondents still reported boiling the leaves (21.3%) and, 14.7% of participants opted to keep the leaf or bag in the beverage while consuming.

3.3.2. Consumer behaviors

Regarding consumer attitudes related to THIs consumption (Fig. 7), it is noteworthy that 49.5% of the respondents declared not reading the information on product label before consumption, and 44.6% use THIs products after the expiry date. Only 29.5% of

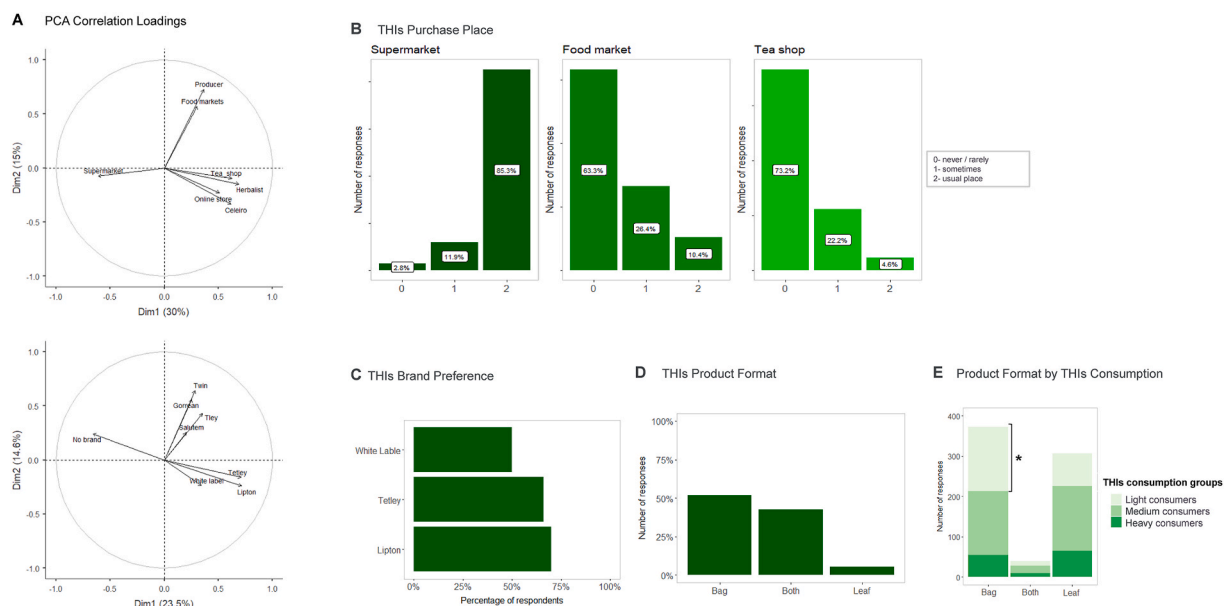


Fig. 5. Consumers choices of the THIs purchase place, brand, and packet. (A) Correlation loadings from the first principal components of PCA on purchase place (top) and brands (bottom). (B) Frequency of THIs purchase place of the consumers. (D) THIs product format choice. (E) Product format choice by THIs consumption groups. Kruskal-Wallis one-way ANOVA test: $*p < 0.001$ compared to medium and heavy consumers.

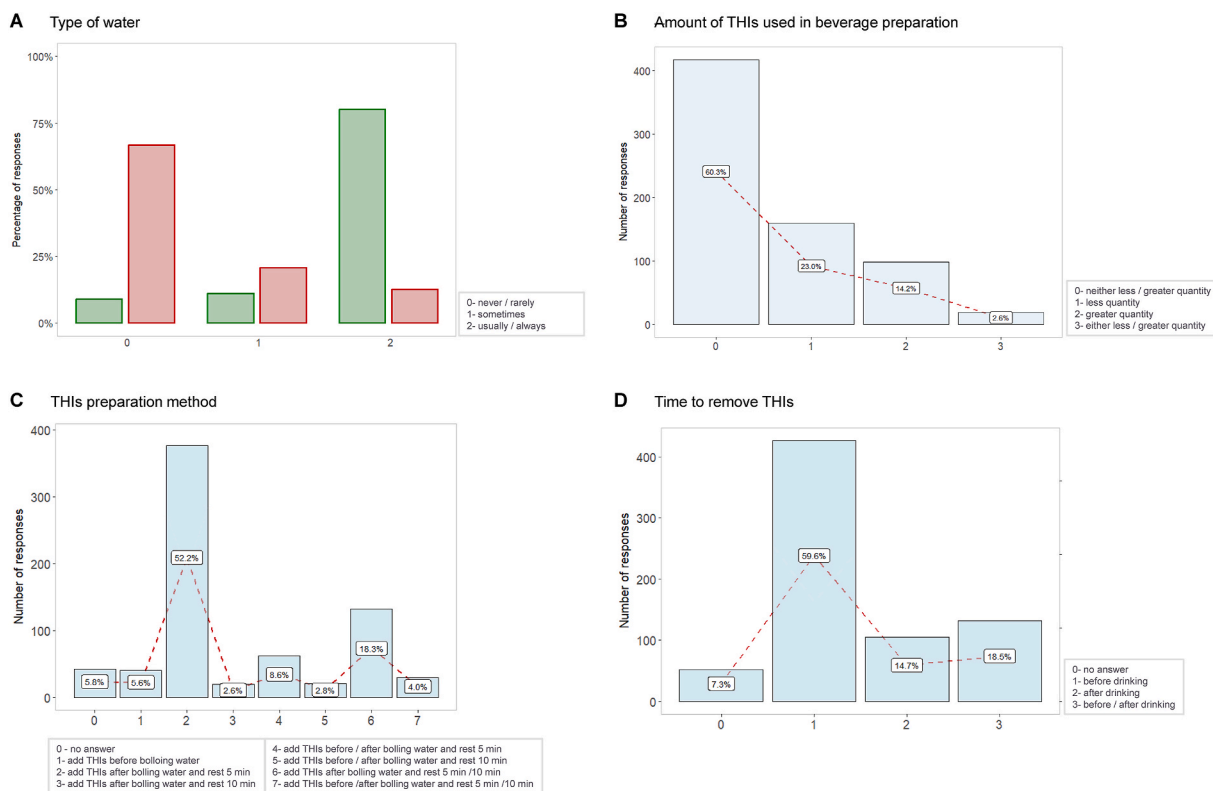


Fig. 6. Consumer practices in THIs preparation. (A) Type of water used to prepare the beverage (green bars-tap water; red bars-bottled water) and frequency of use. (B) Amount of plant or bag used to prepare the THIs, based on the recommended dose per cup. (C) THIs preparation method used. (D). Time to remove THIs after preparation. Data express as response number and percentage; the dashed line represents the trend of consumers' practices. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

participants reported consistently paying attention to the instructions and suggestions on preparation methods provided on the packaging, while the majority occasionally use them, and some individuals admitted to never following this information. As for the addition of other products (such as sweeteners) to their THIs beverage, most of the participants (70.0%) declared that they do not add any kind of product to the THIs (Fig. 8).

4. Discussion

Most participants were female, predominantly in the 40–60 age group, followed by young adults aged 18–29, living in the North region of Portugal and with a high level of education. The majority of respondents declared to be medium consumers of THIs, a consumption that ranged between two cups per week and one cup per day. The difference in gender among participants in our study can be partially explained by the tendency of females to be more concerned about healthy eating than males [47,48]. Our results revealed that socio-demographic factors as age influence the consumption pattern of THIs, aligning with findings reported for the Portuguese population in the National Food, Nutrition, and Physical Activity Survey 2015–2016 [33]. The North region of Portugal was identified as one of the NUTII regions where consumers had the highest average daily intake of THIs, as shown in a previous study [33].

A distinct consumption pattern was identified among THIs consumers, showing that young adults were predominantly light consumers and the majority of heavy consumers belonged to the 40–60 age groups. However, no variation in the consumption pattern of THIs was observed between consumers aged 40–60 and the oldest group. This can be attributed to lower response rates among the oldest participants, an occurrence also observed in other studies [49,50]. Our results highlight the importance of stratifying adult consumers to better understand the THIs consumption pattern.

Consumer choices can be influenced by various factors such as socio-demographics, traditions, health benefits, and taste, as well as drivers of consumption trends [25,27,32,51–55]. Consistent with these studies, our findings revealed that consumers' age had influence their preferences for the type of THIs beverages. Additionally, we found that consumer choices varied based on their consumption pattern, specifically between light and heavy consumers.

In the context of the four most popular types of tea, consumers identified green tea as the preferred choice, particularly among young consumers, exhibiting a higher frequency of consumption compared to those aged 40–60. Other types of tea, such as white and oolong teas, are gaining popularity in Europe, exhibiting an increasing consumption trend [14,16,56]. However, a similar pattern was

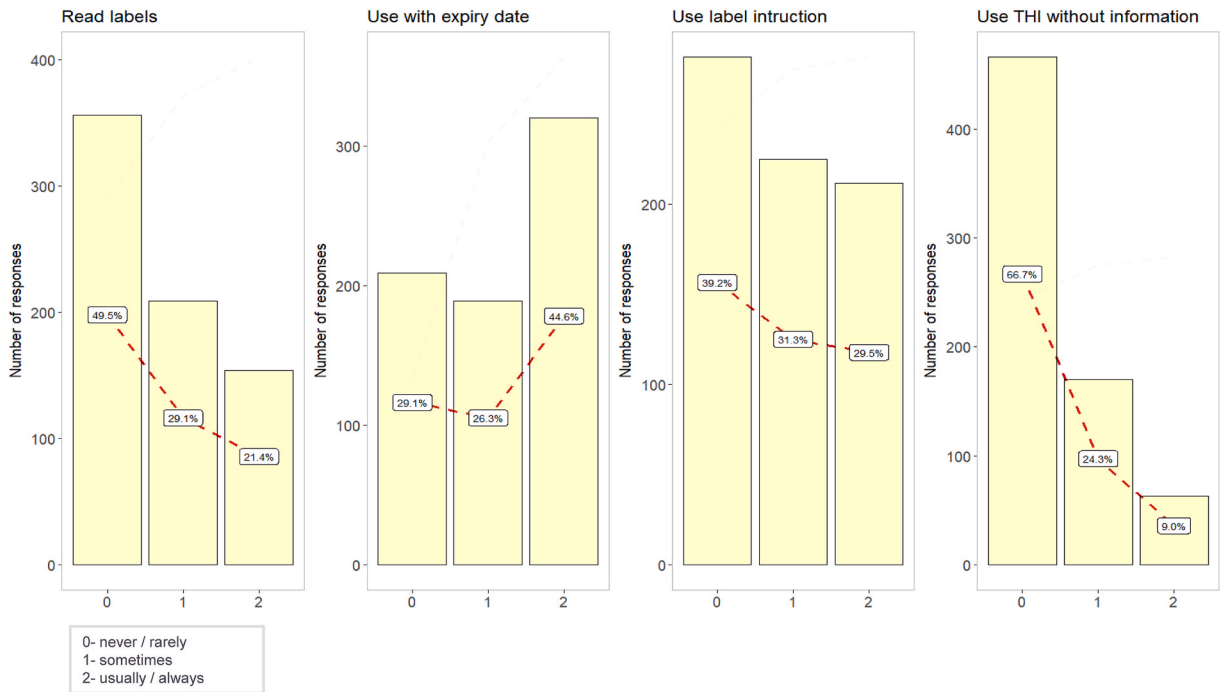


Fig. 7. Consumer attitudes related to THIs preparation. Data expressed as number and percentage of responses; dashed line represents the trend of consumers' practices.

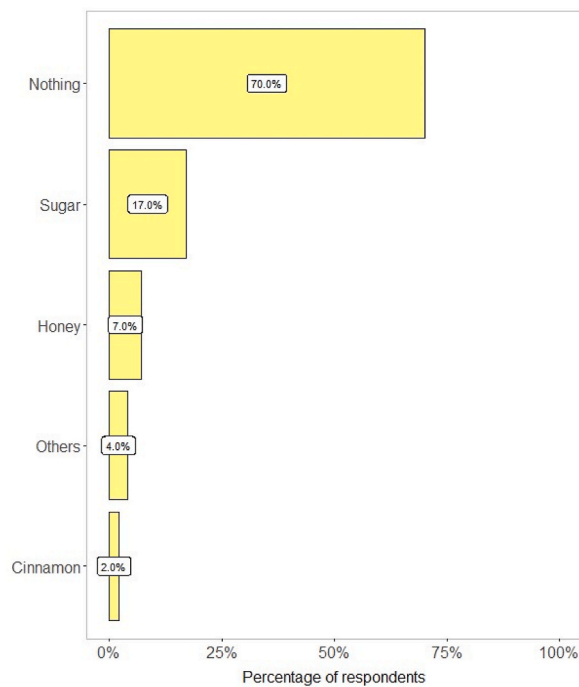


Fig. 8. Products commonly added to the consumer's THI beverage.

not confirmed for our country. Indeed, the majority of Portuguese consumers reported not knowing white and oolong teas, likely due to the absence of a strong tea culture and a preference for other THIs beverages [12,28,57]. In accordance with previous findings [35], we showed that herbal infusions were more popular among Portuguese consumers than tea beverages. This preference for herbal infusions can be explained by the diversity of herbal medicinal plants traditionally used in Portugal and the culture, as reported previously [57,

[58]. A similar close relationship between traditions and the consumption patterns of consumers was observed in other countries [4,8,59].

Regarding the consumption of herbal infusions, our results demonstrated that citronella was the most chosen, followed by chamomile and lemon verbena. However, some age-related differences were found in the consumption pattern of herbal infusions. Citronella and chamomile beverages were more consumed by young adults compared to participants aged 40–60. Meanwhile, peppermint and lemongrass were preferably chosen among consumers aged 30–39. Additionally, our results show that heavy consumers of THIs, mostly in the 40–60 age group, were those who reported a higher consumption of lemon verbena. Among the traditional medicinal plant varieties in Portugal [58], St. John's wort was chosen by a small number of THIs consumers, all belonging to the oldest age group. It is recognized that personal health is one of the most important determinants of food choices [60–62], particularly in the case of older consumers [63,64]. Corroborating these previous findings, we demonstrated a higher consumption of THIs beverages among older consumers and their distinct preferences compared to young adults.

Consumer behaviors regarding purchase decision are influenced by various non-sensory factors, convenience, price or brand identification [55,62,65]. As previously reported [35], we observed that supermarkets were the main purchasing establishment for acquiring THIs products. This can be explained by the convenience for consumers [62], as they can buy groceries and find a diverse selection of THIs in the same place [63,64]. Concerning brands, Lipton®, Tetley®, and white-label brands were the most common choices, which may reflect both brand identification, as in the case of Lipton® and Tetley®, and consumers' potential acceptance of the quality of white-label brands relative to their price [65]. For THIs packet format, the bag emerged as the most popular choice, especially among light consumers, probably due to the reduced effort and time required when using bags.

Taken together, our findings suggest that THIs consumption pattern and the related consumption behaviors may be driven by complex interactions between sensory and non-sensory factors, aligning with other studies [62,65].

The quality of tea and herbal infusions can be affected by the consumer attitudes in preparation of beverages, including brewing temperature, infusion time and water proportion to THIs product [8,35,46]. For practices in THIs preparation, the majority of participants declared using tap water for brewing, following the recommended steeping time, and removing the THIs product before drinking. These practices can provide an efficient extraction of the bioactive compounds [66]. Nevertheless, we also identified attitudes that may interfere with beverage quality and potentially compromise the safety of consumers. These include using a higher quantity of THIs product than the recommended dose, using products past their expiration date or utilizing items lacking proper labeling.

It has been considered that education level can influence food-related behaviors, and individuals with higher education tend to be more concerned about health benefits and food safety [35,67]. In line with another study [55], we could not find this association, probably due to the underrepresentation of individuals with lower educational levels. Nonetheless, our identification of some attitudes adopted by consumers is concerning in a food safety context.

Studies focused on the health benefits related to THIs consumption pointed to its positive effects on chronic disease prevention, reduced cardiovascular risk, as well as relaxing effects that contribute to maintaining mental health [6,7,26,34]. However, uncertainties exist regarding the long-term safety of using medicinal plants due to the lack of strong support from toxicological studies [68]. Furthermore, there are potential risks stemming from excessive consumption due to the possible interference of bioactive components of THIs with fundamental biological parameters [39,69] that consumers should be aware of. Moreover, greater attention should be given to herb-drug/pharmaceuticals interactions [58,70], particularly for elderly or individuals with underlying health conditions.

While THIs are rich in bioactive compounds that positively impact health, their chemical complexity, and the risk of endogenous and exogenous contamination must be carefully considered [41,71–73]. Furthermore, ensuring the quality of THIs requires more attention to storage conditions [11], including exposure to light and humidity which could modify the chemical profile of beverages [10] as reported in the case of green tea [74]. Moreover, an incorrect beverage preparation may facilitate the extraction of toxic secondary metabolites, which can have a negative impact on vulnerable populations, favoring decline of health conditions [75]. Therefore, it is crucial to advocate for moderate consumption of THIs [39,76], improve food safety knowledge among consumers, and raise awareness about misleading information regarding 'naturalness' and health-related effects.

4.1. Limitations of the study

The current investigation was based on a non-probabilistic sampling design using an online survey. An advantage of this approach was the accessibility that allowed participation of all individuals across all regions of Portugal. One of the limitations of the study was the difficulty in collecting representative data on socio-demographic characteristics. Hence, our findings should not be generalized to the broader Portuguese population but should be interpreted within the specific context of THIs beverage consumers. The study collected a total of 720 responses (power of 0.76 and effect size of ≈ 0.1) enabling us to identify significant differences among THIs consumers. While a larger sample size would have yielded a more robust result. The lower response rates from some geographical regions limited the possibility of gaining more insights into potential regional variations in consumption patterns. As with any cross-sectional study, it provides a snapshot picture of the consumption pattern that can change over time. Nevertheless, our demonstration of consumers preferences enables us to extend previous results. Many participants were female, young adults, or older adults (40–60 years old) with a high level of education. Thus, there is a lack of representation of male consumers, those over the age of 61, and individuals with other levels of education. Consequently, the influence of gender and education level on consumer behavior was not investigated, and there was also limited insight into the behavior of consumers aged more than 61 years old. Despite this sample bias, our results align with epidemiological studies that reported higher consumption among females and a lower response rate of older

participants. Nevertheless, our study highlights associations between socio-demographic factors and THIs consumption behavior, addressing a gap in the literature. It underscores the need for deeper insight into older consumers. Future research should focus on the health risk-benefits related to THIs consumption behaviors among vulnerable populations.

5. Conclusion

Our findings have enhanced the understanding of the current patterns of THIs consumption among the Portuguese population, highlighting the influence of age on both THIs consumption and preferences. The importance lies in the need for moderation in THIs consumption, especially among older age groups with underlying health conditions. This caution is warranted due to the potential of interactions between some herbal infusions and prescribed medications. Concerning consumers' attitudes, approximately half do not read the labels and use tea after the expiration date, posing a threat to food safety. The study underscores the need for increased awareness campaigns and pedagogic interventions to improve knowledge of label use and good consumption practices. Furthermore, it is crucial for competent authorities to ensure control over production and storage conditions, thereby guaranteeing the essential quality and safety standards of THIs products for consumer protection.

CRedit authorship contribution statement

Ana Catarina Sousa: Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Inês Pádua:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Virgínia M.F. Gonçalves:** Writing – review & editing, Methodology, Conceptualization. **Cláudia Ribeiro:** Writing – review & editing, Visualization, Supervision, Methodology, Conceptualization. **Sandra Leal:** Writing – review & editing, Visualization, Project administration, Methodology, Conceptualization.

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.

Acknowledgements

This work is funded by CESPU – Cooperativa de Ensino Superior Politécnico e Universitário under the grant “SPAinT-GI2-CESPU-2022”.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.heliyon.2024.e28779>.

References

- [1] Global: Annual Tea Consumption 2012-2025 | Statista, (n.d.).
- [2] Food and Agriculture Organization of the United Nations, International Tea Market: Market Situation, Prospects and Emerging Issues, FAO Publications Catalogue, 2022, p. 2022.
- [3] S.Y. Pan, Q. Nie, H.C. Tai, X.L. Song, Y.F. Tong, L.J.F. Zhang, X.W. Wu, Z.H. Lin, Y.Y. Zhang, D.Y. Ye, Y. Zhang, X.Y. Wang, P.L. Zhu, Z.S. Chu, Z.L. Yu, C. Liang, Tea and tea drinking: China's outstanding contributions to the mankind, *Chin. Med.* 17 (2022) 27.
- [4] E.M. Tomou, E. Peppas, A. Trichopoulos, Consumption of herbal infusions/decoctions and tea in Greece: a Planeterranean perspective on the results of Hydria survey, *J. Transl. Med.* 21 (2023).
- [5] Sales of Herbal and Fruit Tea Germany, Statista, 2018 (n.d.).
- [6] S. Bag, A. Mondal, A. Majumder, A. Banik, Tea and its phytochemicals: hidden health benefits & modulation of signaling cascade by phytochemicals, *Food Chem.* 371 (2022).
- [7] F.S. Poswal, G. Russell, M. Mackonochie, E. MacLennan, E.C. Adukwu, V. Rolfe, Herbal teas and their health benefits: a scoping review, *Plant Foods Hum. Nutr.* 74 (2019) 266–276.
- [8] A. Polat, Z. Kalcioğlu, N. Müezzinoğlu, Effect of infusion time on black tea quality, mineral content and sensory properties prepared using traditional Turkish infusion method, *Int. J. Gastron. Food Sci.* 29 (2022) 100559.
- [9] F.Y. Fan, M. Shi, Y. Nie, Y. Zhao, J.H. Ye, Y.R. Liang, Differential behaviors of tea catechins under thermal processing: formation of non-enzymatic oligomers, *Food Chem.* 196 (2016) 347–354.
- [10] J. Li, S. Han, X. Mei, M. Wang, B. Han, Changes in profiles of volatile compounds and prediction of the storage year of organic green tea during the long-term storage, *Food Chem.* 437 (2024) 137831.
- [11] A. Ociecek, T. Pukszta, K. Zylka, N. Kirieieva, The influence of storage conditions on the stability of selected health-promoting properties of tea, *LWT-Food Sci. Technol.* 184 (2023) 115029.
- [12] S. Deng, Q.Q. Cao, Y. Zhu, F. Wang, J.X. Chen, H. Zhang, D. Granato, X. Liu, J.F. Yin, Y.Q. Xu, Effects of natural spring water on the sensory attributes and physicochemical properties of tea infusions, *Food Chem.* 419 (2023) 136079.
- [13] C. Wei, H. Yang, S. Wang, J. Zhao, C. Liu, L. Gao, E. Xia, Y. Lu, Y. Tai, G. She, J. Sun, H. Cao, W. Tong, Q. Gao, Y. Li, W. Deng, X. Jiang, W. Wang, Q. Chen, S. Zhang, H. Li, J. Wu, P. Wang, P. Li, C. Shi, F. Zheng, J. Jian, B. Huang, D. Shan, M. Shi, C. Fang, Y. Yue, F. Li, D. Li, S. Wei, B. Han, C. Jiang, Y. Yin, T. Xia, Z. Zhang, J.L. Bennetzen, S. Zhao, X. Wan, Draft genome sequence of *Camellia sinensis* var. *sinensis* provides insights into the evolution of the tea genome and tea quality, *Proc. Natl. Acad. Sci. U. S. A.* 115 (2018) E4151–E4158.
- [14] L. Zeng, X. Zhou, X. Su, Z. Yang, Chinese oolong tea: an aromatic beverage produced under multiple stresses, *Trends Food Sci. Technol.* 106 (2020) 242–253.

- [15] S. Li, C.Y. Lo, M.H. Pan, C.S. Lai, C.T. Ho, Black tea: chemical analysis and stability, *Food Funct.* 4 (2013) 10–18.
- [16] S. Wang, Y. Qiu, R.Y. Gan, F. Zhu, Chemical constituents and biological properties of Pu-erh tea, *Food Res. Int.* 154 (2022) 110899.
- [17] H. Antolak, D. Piechota, A. Kucharska, Kombucha tea-A double power of bioactive compounds from tea and symbiotic culture of bacteria and yeasts (SCOBY), *Antioxidants* 10 (2021) 1541.
- [18] T.C. Dinh, T.N. Thi Phuong, L.B. Minh, V.T. Minh Thuc, N.D. Bac, N. Van Tien, V.H. Pham, P.L. Show, Y. Tao, V.T. Nhu Ngoc, N.T. Bich Ngoc, A. Jurgoński, D. B. Thimiri Govinda Raj, P. Van Tu, V.N. Ha, J. Czarzasta, D.T. Chu, The effects of green tea on lipid metabolism and its potential applications for obesity and related metabolic disorders - an existing update, *Diabetes Metabol. Syndr.* 13 (2019) 1667–1673.
- [19] M. Wang, Y. Bai, Z. Wang, Z. Zhang, D. Liu, X. Lian, Higher tea consumption is associated with decreased risk of small vessel stroke, *Clin. Nutr.* 40 (2021) 1430–1435.
- [20] 2014-2023 WHO Traditional Medicine Strategy, 2013.
- [21] A. Gupta, N. Sanwal, M.A. Barea, S. Barua, N. Sharma, J. Olatunji, N. Prakash Nirmal, J.K. Sahu, Trends in functional beverages: functional ingredients, processing technologies, stability, health benefits, and consumer perspective, *Food Res. Int.* 170 (2023) 113046.
- [22] Y.X. Chen, C.Q. Jiang, W.S. Zhang, F. Zhu, Y.L. Jin, K.K. Cheng, T.H. Lam, L. Xu, Habitual tea consumption was associated with lower levels of depressive symptoms among older Chinese: guangzhou Biobank Cohort Study, *Nutr. Res.* 103 (2022) 59–67.
- [23] X. ren Liu, X. lin Wang, J. Zhao, C. hui Hu, N. nan Cao, H. gui Chen, B. Sun, Y. xin Wang, C. liang Xiong, J. Deng, P. Duan, Association between tea consumption and semen quality among 1385 healthy Chinese men, *Chemosphere* 303 (2022) 135140.
- [24] A.H. Al-Zalabani, A. Wesselius, E. Yi-Wen Yu, P. van den Brandt, E.J. Grant, E. White, G. Skeie, F. Liedberg, E. Weiderpass, M.P. Zeegers, Tea consumption and risk of bladder cancer in the Bladder Cancer Epidemiology and Nutritional Determinants (BLEND) Study: pooled analysis of 12 international cohort studies, *Clin. Nutr.* 41 (2022) 1122–1130.
- [25] W. Wang, Y. Yang, W. Zhang, W. Wu, Association of tea consumption and the risk of oral cancer: a meta-analysis, *Oral Oncol.* 50 (2014) 276–281.
- [26] W.H. Talib, I.A. Al-Ataby, A. Ismail Mahmood, S. Jawarneh, L.T. Al Kury, I.H. Al-Yasari, The impact of herbal infusion consumption on oxidative stress and cancer: the good, the bad, the misunderstood, *Molecules* 25 (2020) 4207.
- [27] J. Yu, K. Zhang, Y. Wang, X. Zhai, X. Wan, Flavor perception and health benefits of tea, *Adv. Food Nutr. Res.* 106 (2023) 129–218.
- [28] X. Zhai, L. Zhang, M. Granvogl, C.T. Ho, X. Wan, Flavor of tea (*Camellia sinensis*): a review on odorants and analytical techniques, *Compr. Rev. Food Sci. Food Saf.* 21 (2022) 3867–3909.
- [29] L. Zhang, Q.-Q. Cao, D. Granato, Y.-Q. Xu, C.-T. Ho, Association between chemistry and taste of tea: a review, *Trends Food Sci. Technol.* 101 (2020) 139–149.
- [30] M. Arenas-Jal, J.M. Suñé-Negre, P. Pérez-Lozano, E. García-Montoya, Trends in the food and sports nutrition industry: a review, *Crit. Rev. Food Sci. Nutr.* 60 (2020) 2405–2421.
- [31] F.G. Santeramo, D. Carlucci, B. De Devitiis, A. Seccia, A. Stasi, R. Viscecchia, G. Nardone, Emerging trends in European food, diets and food industry, *Food Res. Int.* 104 (2018) 39–47.
- [32] G.C. Román, R.E. Jackson, R. Gadhia, A.N. Román, J. Reis, Mediterranean diet: the role of long-chain ω -3 fatty acids in fish; polyphenols in fruits, vegetables, cereals, coffee, tea, cacao and wine; probiotics and vitamins in prevention of stroke, age-related cognitive decline, and Alzheimer disease, *Rev. Neurol. (Paris)* 175 (2019) 724–741.
- [33] C. Lopes, D. Torres, A. Oliveira, M. Severo, V. Alarcão, S. Guiomar, J. Mota, P. Teixeira, S. Rodrigues, L. Lobato, V. Magalhães, D. Correia, C. Carvalho, A. Pizarro, A. Marques, S. Vilela, L. Oliveira, P. Nicola, S. Soares, E. Ramos, Inquérito Alimentar Nacional e de Atividade Física, IAN-AF 2015-2016: Relatório de Resultados, 2017.
- [34] C. He, P. Ye, X. Zhang, Y. Li, Q. Li, P. Lü, C. Cai, X. Cai, Sex differences in the benefit of tea consumption: a critical summation of the epidemiological evidence, *Food Biosci.* 58 (2024) 103716.
- [35] C. Rocha, A.P. Moura, L.M. Cunha, Consumers' associations with herbal infusions and home preparation practices, *Food Qual. Prefer.* 86 (2020) 104006.
- [36] K.H. Merz, D. Schrenk, Interim relative potency factors for the toxicological risk assessment of pyrrolizidine alkaloids in food and herbal medicines, *Toxicol. Lett.* 263 (2016) 44–57.
- [37] D. Schrenk, L. Gao, G. Lin, C. Mahony, P.P.J. Mulder, A. Peijnenburg, S. Pfuhler, I.M.C.M. Rietjens, L. Rutz, B. Steinhoff, A. These, Pyrrolizidine alkaloids in food and phytomedicine: occurrence, exposure, toxicity, mechanisms, and risk assessment - a review, *Food Chem. Toxicol.* 136 (2020).
- [38] F. Widjaja, Y. Alhejji, I.M.C.M. Rietjens, Focus issue pyrrolizidine alkaloids: the role of kinetics as key determinant in toxicity of pyrrolizidine alkaloids and their N-oxides, *Planta Med.* 88 (2022) 130.
- [39] N. Pathaw, K.S. Devi, R. Sapam, J. Sanasam, S. Monteshori, S. Phurailatpam, H.C. Devi, W.T. Chanu, B. Wangkhem, N.L. Mangang, A comparative review on the anti-nutritional factors of herbal tea concoctions and their reduction strategies, *Front. Nutr.* 9 (2022) 9889664.
- [40] A.C. Sousa, C. Ribeiro, V.M.F. Gonçalves, I. Pádua, S. Leal, Chromatographic methods for detection and quantification of pyrrolizidine alkaloids in flora, herbal medicines, and food: an overview, *Crit. Rev. Anal. Chem.* (2023) 1–25.
- [41] Z. Zhuang, Z. Mi, L. Kong, Q. Wang, A.H. Schweiger, Y. Wan, H. Li, Accumulation of potentially toxic elements in Chinese tea (*Camellia sinensis*): towards source apportionment and health risk assessment, *Sci. Total Environ.* 851 (2022) 158018.
- [42] A.M. Abd El-Aty, J.H. Choi, M.M. Rahman, S.W. Kim, A. Tosun, J.H. Shim, Residues and contaminants in tea and tea infusions: a review, *Food Addit. Contam. Part A Chem Anal Control Expo Risk Assess* 31 (2014) 1794–1804.
- [43] J. Brzezicha-Cirocka, M. Grembecka, P. Szefer, Monitoring of essential and heavy metals in green tea from different geographical origins, *Environ. Monit. Assess.* 188 (2016) 183.
- [44] I. Sedova, M. Kiseleva, V. Tutelyan, Mycotoxins in tea: occurrence, methods of determination and risk evaluation, *Toxins* 10 (2018) 444.
- [45] E. Guzelmeric, P. Ristivojević, I. Vovk, D. Milojković-Opsenica, E. Yesilada, Quality assessment of marketed chamomile tea products by a validated HPTLC method combined with multivariate analysis, *J. Pharm. Biomed. Anal.* 132 (2017) 35–45.
- [46] M. Franks, P. Lawrence, A. Abbaspourrad, R. Dando, The influence of water composition on flavor and nutrient extraction in green and black tea, *Nutrients* 11 (2019) 80.
- [47] J. Wardle, A.M. Haase, A. Steptoe, M. Nillapun, K. Jonwutiwes, F. Bellisle, Gender differences in food choice: the contribution of health beliefs and dieting, *Ann. Behav. Med.* 27 (2004) 107–116.
- [48] M. Sääksjärvi, M. Holmlund, N. Tanskanen, Consumer knowledge of functional foods, *Int. Rev. Retail Distrib. Consum. Res.* 19 (2009) 135–156.
- [49] S. Bel, S. Van den Abeele, T. Lebacqz, C. Ost, L. Brocatus, C. Stiévenart, E. Teppers, J. Tafforeau, K. Cuyppers, Protocol of the Belgian food consumption survey 2014: objectives, design and methods, *Arch. Publ. Health* 74 (2016) 1–11.
- [50] C. Lopes, D. Torres, A. Oliveira, M. Severo, S. Guiomar, V. Alarcão, E. Ramos, S. Rodrigues, S. Vilela, L. Oliveira, J. Mota, P.J. Teixeira, P.J. Nicola, S. Soares, L. F. Andersen, National food, nutrition, and physical activity survey of the Portuguese general population (2015-2016): protocol for design and development, *JMIR Res. Protoc.* 7 (2018).
- [51] E. Czarniecka-Skubina, R. Korzeniowska-Ginter, M. Pielak, P. Salek, T. Owczarek, A. Kozak, Consumer choices and habits related to tea consumption by Poles, *Foods* 11 (2022) 2873.
- [52] R. Sökand, C.L. Quave, A. Pieroni, M. Pardo-de-Santayana, J. Tardío, R. Kalle, L. Luczaj, I. Svanberg, V. Kolosova, L. Aceituno-Mata, G. Menendez-Baceta, I. Kotodziejaska-Degórska, E. Piroznikow, R. Petkevicius, A. Hajdari, B. Mustafa, Plants used for making recreational tea in Europe: a review based on specific research sites, *J. Ethnobiol. Ethnomed.* 9 (2013) 58.
- [53] S. Tang, H. Fu, W. Pan, J. Zhou, M. Xu, K. Han, K. Chen, Q. Ma, L. Wu, Improving tea (*Camellia sinensis*) quality, economic income, and environmental benefits by optimizing agronomic nitrogen efficiency: a synergistic strategy, *Eur. J. Agron.* 142 (2023) 126673.
- [54] F. Wei, L. Luo, L. Zeng, Characterization of key sweet taste compounds in *Camellia nanchuanica* black tea, *LWT* 182 (2023) 114858.
- [55] D.A. Ogundijo, A.A. Tas, B.A. Onarinde, Age, an important sociodemographic determinant of factors influencing consumers' food choices and purchasing habits: an English university setting, *Front. Nutr.* 9 (2022).

- [56] Z. Ni, Y. Yang, Y. Zhang, Q. Hu, J. Lin, H. Lin, Z. Hao, Y. Wang, J. Zhou, Y. Sun, Dynamic change of the carotenoid metabolic pathway profile during oolong tea processing with supplementary LED light, *Food Res. Int.* 169 (2023) 112839.
- [57] A.M. Carvalho, R. Morales, Persistence of wild food and wild medicinal plant knowledge in a north-eastern region of Portugal, in: *Ethnobotany in the New Europe: People, Health and Wild Plant Resources*, Vol. 14, 2010, pp. 147–171.
- [58] M.S. Gão, M.L. González-Sanjosé, M.D. Rivero-Pérez, C.I. Pereira, M.E. Pintado, F.X. Malcata, Infusions of Portuguese medicinal plants: dependence of final antioxidant capacity and phenol content on extraction features, *J. Sci. Food Agric.* 87 (2007) 2638–2647.
- [59] S. Rivaroli, J. Lindenmeier, M. Hingley, R. Spadoni, Social representations of craft food products in three European countries, *Food Qual. Prefer.* 93 (2021) 104253.
- [60] L.J. Dominguez, N. Veronese, E. Baiamonte, M. Guarrera, A. Parisi, C. Ruffolo, F. Tagliaferri, M. Barbagallo, Healthy aging and dietary patterns, *Nutrients* 14 (2022) 889.
- [61] E. Giacomello, L. Toniolo, Nutrition, diet and healthy aging, *Nutrients* 14 (2021) 190.
- [62] S.R. Jaeger, Non-sensory factors in sensory science research, *Food Qual. Prefer.* 17 (2006) 132–144.
- [63] W. Verbeke, Consumer acceptance of functional foods: socio-demographic, cognitive and attitudinal determinants, *Food Qual. Prefer.* 16 (2004) 45–47.
- [64] M.N. Vella, L.M. Stratton, J. Sheeshka, A.M. Duncan, Exploration of functional food consumption in older adults in relation to food matrices, bioactive ingredients, and health, *J. Nutr. Gerontol. Geriatr.* 32 (2013) 122–144.
- [65] N. Rubio, J. Oubiña, N. Villaseñor, Brand awareness-Brand quality inference and consumer's risk perception in store brands of food products, *Food Qual. Prefer.* 32 (2013) 289–298.
- [66] C. Rocha, M. Coelho, R.C. Lima, F.M. Campos, M. Pintado, L.M. Cunha, Increasing phenolic and aromatic compounds extraction and maximizing liking of lemon verbena (*Aloysia triphylla*) infusions through the optimization of steeping temperature and time, *Food Sci. Technol. Int.* 25 (2019) 701–710.
- [67] N. Sameshima, R. Akamatsu, Influence of school education and advice received at home in the past on current food safety perceptions, *Food Qual. Prefer.* 110 (2023) 104958.
- [68] C.L. Kruger, S.W. Mann, Safety evaluation of functional ingredients, *Food Chem. Toxicol.* 41 (2003) 793–805.
- [69] M. Lazrak, K. El Kari, N.U. Stoffel, L. Elammari, A. Al-Jawaldeh, C.U. Loechl, A. Yahyane, A. Barkat, M.B. Zimmermann, H. Aguenou, Tea consumption reduces iron bioavailability from NaFeEDTA in nonanemic women and women with iron deficiency anemia: stable iron isotope studies in Morocco, *J. Nutr.* 151 (2021) 2714–2720.
- [70] R. Bahramsoltani, P. Rostamiasrabadi, Z. Shahpiri, A.M. Marques, R. Rahimi, M.H. Farzaei, *Aloysia citrodora* Paláu (Lemon verbena): a review of phytochemistry and pharmacology, *J. Ethnopharmacol.* 222 (2018) 34–51.
- [71] K. Pakshir, Z. Mirshekari, H. Nouraei, Z. Zarehshahabadi, K. Zomorodian, H. Khodadadi, A. Hadaegh, Mycotoxins detection and fungal contamination in black and green tea by HPLC-based method, *J. Toxicol.* 7 (2020), 2020.
- [72] C.Y. Peng, X.H. Zhu, R.Y. Hou, G.F. Ge, R.M. Hua, X.C. Wan, H.M. Cai, Aluminum and heavy metal accumulation in tea leaves: an interplay of environmental and plant factors and an assessment of exposure risks to consumers, *J. Food Sci.* 83 (2018) 1165–1172.
- [73] A. Zachara, D. Galkowska, L. Juszcak, Contamination of tea and tea infusion with polycyclic aromatic hydrocarbons, *Int. J. Environ. Res. Publ. Health* 15 (2017) 45.
- [74] Y. Zhang, W. Yuan, Z. Ren, J. Ning, Y. Wang, Indicator displacement assay for freshness monitoring of green tea during storage, *Food Res. Int.* 167 (2023) 112668.
- [75] I. Mädge, L. Cramer, I. Rahaus, G. Jerz, P. Winterhalter, T. Beuerle, Pyrrolizidine alkaloids in herbal teas for infants, pregnant or lactating women, *Food Chem.* 187 (2015) 491–498.
- [76] M. Younes, P. Aggett, F. Aguilar, R. Crebelli, B. Dusemund, M. Filipič, M.J. Frutos, P. Galtier, D. Gott, U. Gundert-Remy, C. Lambré, J.C. Leblanc, I.T. Lillegaard, P. Moldeus, A. Mortensen, A. Oskarsson, I. Stankovic, I. Waalkens-Berendsen, R.A. Woutersen, R.J. Andrade, C. Fortes, P. Mosesso, P. Restani, D. Arcella, F. Pizzo, C. Smeraldi, M. Wright, Scientific opinion on the safety of green tea catechins, *EFSA J.* 16 (2018) e05239.