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Factors associated with the consumption of voluntarily fortified foods with micronutrients by the Portuguese population

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Abstract

This study aimed to identify the sociodemographic and health-related factors associated with the consumption of voluntarily fortified foods with micronutrients (Mn-FF) by the Portuguese population, using data from the *National Food, Nutrition and Physical Activity Survey* (*IAN-AF 2015–2016*). Food consumption, sociodemographic and other health-related factors, and physical activity data were computerised using the You Eat & Move e-platform. Foods consumed by participants and labelled foods reported as consumed were included in the database. Mn-FF were considered all foods containing added micronutrients legally authorised, and MN-FF users were those who consumed at least one Mn-FF on at least one of the dietary recall days.

Approximately 57% of the population consumed at least one Mn-FF. Children and adolescents consumed significantly more Mn-FF than older age groups. The primary contributors to Mn-FF consumption were breakfast cereals and fat spreads. Being a child (female OR 2.07 [95% CI: 1.52, 2.83]; male OR 4.80 [95% CI: 3.23, 7.14]) or adolescent (female OR 1.62 [95% CI: 1.78, 2.22]; male OR 4.59 [95% CI: 3.26, 6.47]), having a higher level of education (female OR 1.52 [95% CI: 1.17, 1.99]; male OR 1.85 [95% CI: 1.42, 2.42]) and engaging in regular physical activity (female OR 1.31 [95% CI: 1.09, 1.58]; male OR 1.36 [95% CI: 1.11, 1.68]) were factors positively associated with Mn-FF consumption. Conversely, obesity (female OR 0.76 [95% CI: 0.60, 0.96]), living in predominantly rural areas (male OR 0.70 [95% CI: 0.49, 0.91]) and eating fewer mid-meals per day (female OR 0.60 [95% CI: 0.48, 0.76]; male OR 0.64 [95% CI: 0.49, 0.84]) were associated with lower Mn-FF consumption.

Younger age, higher education and physical activity practice were positively associated with Mn-FF consumption. These findings provide important insights on priority factors to be considered when deciding on nutrient fortification policies from both public health and food industry perspectives.

KEYWORDS
fortification with minerals, fortification with vitamins, fortified food drivers, *IAN-AF 2015–2016*, micronutrients, voluntary food fortification

INTRODUCTION

Vitamins and minerals are vital to humans since they play an essential role in various body functions and are necessary for maintaining overall health and well-being. Micronutrients are needed for adequate growth and development, help the body produce energy, repair tissues and support a healthy immune system, among other functions. Deficiencies through inadequate intake or absorption of micronutrients can have serious consequences, including illness and even death. Whilst not resulting in such over-clinical symptoms, inadequacies can lead to general symptoms such as fatigue, reduced ability to fight infections, impaired cognitive function, memory and mood. They can also impact the risk of chronic diseases such as cardiovascular disease, osteoporosis and age-related eye disease (Mannar & Wesley, 2017). In Portugal, the *National Food, Nutrition and Physical Activity Survey* (*IAN-AF 2015–2016*) revealed a high prevalence of inadequate intake of some micronutrients, such as calcium and folates, particularly among older people (60.2% and 69.0% below average requirements for calcium and for folates, respectively) (Lopes, Torres, Oliveira, Severo, Alarcão, et al., 2018; Lopes, Torres, Oliveira, Severo, Guiomar, et al., 2018). The intake of vitamins A, B6, C and B2 also reported a prevalence of inadequate intake between 14% and 40% (Lopes, Torres, Oliveira, Severo, Alarcão, et al., 2018; Lopes, Torres, Oliveira, Severo, Guiomar, et al., 2018).

Food fortification is one of the strategies for addressing micronutrient inadequacies in the population (Dwyer et al., 2015). It is defined as the procedure of intentionally increasing the micronutrient content of foods to improve the nutritional quality of the food supply and provide a public health benefit with minimal health risk. Thus, fortification consists of adding one or more micronutrients to foods that do not normally contain them or increasing the content of those already present in foods. Food fortification can be mandatory or voluntary (Allen, 2006). Mandatory fortification refers to the process in which government authorities require the addition of specific nutrients to certain foods. This is usually legislated and enforced by national health policies, targeting nutrients that are identified as deficient in the general population or in specific high-risk groups (Ottaway, 2008). Voluntary fortification, also known as market-driven fortification, means that food manufacturers voluntarily add nutrients to foods, often to increase their nutritional value or to differentiate them from similar products on the market (Mannar & Wesley, 2017). In developed countries, voluntary fortification is often profit-driven, since it can be used as a marketing tool to attract health-conscious consumers (Mannar & Wesley, 2017; Ottaway, 2008). This type of food fortification can provide consumers with various micronutrient sources, helping them meet their daily requirements. However, this practice also raises concerns not only about the promotion of healthy eating, since food manufacturers may use fortification to market unhealthy foods but also regarding possible risks associated with excessive micronutrient intake (De Jong et al., 2022).

Mandatory fortification of commonly consumed foods has been implemented in 143 countries (Global Fortification DATA EXCHANGE, 2023). In Portugal, mandatory fortification has not been implemented. However, there is a diverse range of voluntary fortified foods with micronutrients (Mn-FF) available in the market, for example, ready-to-eat cereals with added B-complex vitamins and iron, salt with added iodine, soft drinks with added vitamins A, C and E, and plant-based spreads with added vitamins A and D (Mannar & Wesley, 2017; Ottaway, 2008).

In Europe, voluntary food fortification is regulated by the European Regulation (EC) No. 1925/2006 (European Commission (EC), 2006). For fortified foods to claim health benefits, the final food product must contain at least 15% of the Nutrient Reference Values per 100 g or 100 mL for products other than beverages or 7.5% per 100 mL for beverages (EC, 2011).

The global fortified food market has been continuously growing. A report by Future Market Insights (FMI) estimated that the global fortified food market is expected to reach a value of USD 140.608 million in 2023 and is projected to reach USD 257.715 million by 2033, growing at a compound annual growth rate of 6.2% during the forecast period (2023–2033). This growth is attributed to rising chronic diseases, an ageing population and increased health awareness among consumers in industrialised economies (FMI, 2022).

Despite the worldwide growth of this market, more research is needed to understand the consumer profile of fortified foods in Europe, including Portugal. Food consumption is influenced by many factors, including social, economic, cultural, environmental, educational, health-related and physiological elements (Chen & Antonelli, 2020), that may also be associated with Mn-FF food consumption.

With a deeper understanding of the determinants of Mn-FF consumption, health organisations, public health professionals, nutritionists and other health professionals can provide more accurate information about these foods, address misunderstandings or misconceptions consumers might have, educate about adequate consumption and prevent overconsumption. This can lead to a more informed and educated public that can make better decisions about their dietary choices and improve their overall health and wellbeing (De Jong et al., 2022).

From a food industry perspective, this knowledge enables the identification of target markets and the tailoring or reformulating of food products to meet specific consumer needs and preferences (Buttriss, 2013; McConnon et al., 2002; Nan et al., 2017).

The current study aims to identify, for the first time in Portugal, the sociodemographic and health-related factors associated with the consumption of voluntary Mn-FF in the Portuguese population using data from the *IAN-AF 2015–2016*. By comprehensively understanding the factors that shape Mn-FF consumption, we aim to contribute to the ongoing discourse on nutrition, paving the way for informed policies and empowering individuals to make healthier dietary decisions.

MATERIALS AND METHODS

Food consumption data

Data on food consumption by the Portuguese population were collected as part of the *IAN-AF 2015–2016*. The design and methodology of the *IAN-AF 2015–2016* are described elsewhere (Lopes, Torres, Oliveira, Severo, Alarcão, et al., 2018; Lopes, Torres, Oliveira, Severo, Guiomar, et al., 2018). Briefly, among other dimensions, this survey investigated the dietary and nutritional intake of a representative sample of the Portuguese population aged between 3 months and 84 years ($n = 5811$: 2793 males and 3018 females). The sampling method was a complex, multistage probability sampling design that used the National Health Registry to select a sample representative of the Portuguese population from national territory, including the Autonomous Regions of Madeira and Azores. Exclusion criteria for participating were living in collective residences or institutions, living in Portugal for less than 1 year (except for infants), being a non-Portuguese speaker and presenting diminished physical or cognitive abilities that hamper participation (Lopes et al., 2017; Lopes, Torres, Oliveira, Severo, Alarcão, et al., 2018; Lopes, Torres, Oliveira, Severo, Guiomar, et al., 2018).

In the present analysis, only individuals over 3 years old were considered ($n = 5005$), as infants and toddlers present unique dietary patterns, which may include the consumption of fortified food products governed by specific legislation, as described below.

Dietary intake was obtained by two non-consecutive days of food diaries for children (<10 years old) and two non-consecutive 24-h recalls for the older age groups, with a time interval between 8 and 15 days, for 12 months to minimise seasonal variability. Trained nutritionists conducted the interviews using a validated electronic platform (You Eat & Move) based on client–server architecture to manage the fieldwork and assist in the data collection (Goios et al., 2020). This platform was designed to collect information about food intake and sociodemographic, general health, anthropometric and physical activity data following the EU-Menu project guidelines from the European Food Safety Authority (EFSA, 2014; Lopes, Torres, Oliveira, Severo, Alarcão, et al., 2018; Lopes, Torres, Oliveira, Severo, Guiomar, et al., 2018).

Dietary intake, including the quantification of foods, recipes and supplements, was collected for all participants using this e-platform (eAT24 module), which was synchronised with nutritional composition data of foods and recipes and considered the FoodEx2 classification system (EFSA, 2011; Lopes, Torres, Oliveira, Severo, Alarcão, et al., 2018; Lopes, Torres, Oliveira, Severo, Guiomar, et al., 2018).

Food labels database

Participants were asked to describe all food items consumed, including their respective commercial brands. If a food did not have a brand associated (e.g., fresh foods) or if the participant did not remember, the brand was categorised as "not applicable" or "missing information." Afterwards, a dataset was created that included label information on the ingredients and nutrient content (per 100 g) of each food-brand-characteristic ingredient combination.

The label information was collected from February to November 2018 through an online search to obtain each food product's ingredients and nutrient information. The official website of each product was the primary source of information. If needed, label information was collected through the websites of food retail chains. When the information about a particular food brand was unavailable online, several retail stores in the northern region of Portugal were visited to collect the necessary information from the products' labels.

All information on ingredients and allergens was collected. Each time a product's label indicated compound ingredients (e.g., fortified wheat flour [wheat flour, calcium carbonate, iron, thiamine]), all sub-ingredients were identified and included in the database. If the nutrient content was only provided per serving size, this information was recorded and converted to 100 g. Finally, the databases were reviewed, spelling or typographical errors were corrected, and terminology for some food ingredients was standardised. The final food label database includes 6510 food labels for which ingredients and nutrition label information were captured.

Definition and identification of voluntarily fortified foods with micronutrients

Since fortification is not allowed for alcoholic beverages and unprocessed foods (EC, 2006), only processed foods that underwent mechanical or chemical operations to modify or preserve their original structure were qualified to be Mn-FF. Food intended for specialised nutrition, namely foods for infants and young children, foods for calorie-restricted diets, dietary foods

for specific medicinal purposes and food supplements, was not considered voluntarily fortified since they are covered by specific legislation (DL, 2008; EC, 2013, 2016a, 2016b, 2017).

Mn-FF were considered as all those foods that contained any micronutrient (vitamins and/or minerals) allowed to be added to food by Regulation (EC) No. 1925/2006 in the ingredient list and, simultaneously, in the label's nutritional declaration to ensure that food products were effectively fortified, regardless of whether certain micronutrients were naturally present. The manufacturers must provide the overall content (naturally occurring and added) of the fortified nutrient on the food label. Since the amount of salt present in a food product must be included in the nutritional declaration – regardless of whether it is intrinsic to the food or added (EC, 2011) – sodium was excluded from our analysis. Considering all the mentioned criteria, 911 Mn-FF were identified, belonging to different food groups of *IAN-AF 2015–2016*: fruits, vegetables and legumes; dairy; cereals, cereal products and starchy tubers; meat, fish and eggs; sweets, cakes and biscuits; non-alcoholic beverages; and milk, milk product substitutes and table salt (Pimenta-Martins et al., 2022).

In the current study, the micronutrients that were present in the identified Mn-FF and analysed included vitamins A, D, E, K, B1 (thiamine), B2 (riboflavin), B6 (pyridoxine), B12 (cobalamin), C, folic acid (B9), niacin (B3) and pantothenic acid (B5), and minerals calcium, iron, phosphorus, iodine and magnesium. Users of Mn-FF were identified as those consuming at least one voluntary fortified food product on at least one of the recall days.

Assessment of non-dietary variables – Associated factors

Data on sociodemographic characteristics, health history, health behaviours and food security from *IAN-AF 2015–2016* participants were considered in the present study. The sociodemographic variables used included sex (male; female), age group (children: 3–9 years old; adolescents: 10–17 years old; adults: 18–64 years old; and older adults: 65–84 years old), highest educational level completed by the participants, in the case of adults and older adults, or by the parents' when participants were children or adolescents (None, 1st and 2nd cycle of the primary education: <6 school years; 3rd cycle of primary education and high school: 6–12 school years; Higher education: >12 school years) and degree of urbanisation, given by the individuals' residence parish, according to the Portuguese National Statistics' Institute classification (predominantly urban; moderately urban; predominantly rural) (INE, 2014).

Concerning health history, the following variables were included: having a previous diagnosis of chronic disease (yes; no) and body mass index (BMI), calculated through objectively measured weight and height using standardised procedures (The International Society for the Advancement of Kinanthropometry, 2011). BMI categorisation followed the World Health Organization (WHO) cut-offs for adults: (under/normal weight: <18.5–24.9 kg/m^2; overweight: 25.0–29.9 kg/m^2; and obese: ≥30.0 kg/m^2) (WHO, 2000) and, for children, it was based on the child age- and sex-specific BMI *Z*-score, estimated according to WHO criteria (WHO, 2006) (overweight: BMI *Z*-score >1 standard deviation; obesity: BMI *Z*-score >2 standard deviations [children older than 5 years old] or >3 standard deviations [children under 5 years old]).

The variables related to health behaviours considered were the leisure-time physical activity/sports practice, where participants were asked whether they usually practised any scheduled and regular sports activity, excluding physical education lessons (yes; no) and the number of mid-meals eaten per day (<2 snacks, 2 snacks, ≥3 snacks).

Lastly, the food insecurity variable was also included (security; insecurity), obtained through a Portuguese-adapted version of the questionnaire of the measure of household food security developed by Cornell/Radimer (Alarcão et al., 2020; Radimer et al., 1990) widely applied in the evaluation and monitoring of public food assistance programmes (Bickel et al., 2000).

Statistical analysis

Missing data in the reported food item brands was addressed through multiple imputations. To ensure the national representativity of the sample, the Naïve Bayes algorithm, considering sex, age, geographical region (NUTS II) and food group, was used to calculate the estimates according to the complex sampling design. The number of imputations was set as $m = 5$, which resulted in five different imputed datasets.

The prevalence of individuals consuming at least one food fortified with micronutrients (overall), vitamins and minerals by the Portuguese population and the contribution of each food group to the total consumption of Mn-FF were estimated by sex and age group. The contribution of food groups to Mn-FF consumption was calculated as the ratio between the number of fortified food items consumed within each food group and the total number of fortified foods consumed.

To investigate the socio-economic, health-related and behavioural factors associated with consuming at least one voluntary fortified food, logistic regression models were used to calculate the adjusted odds ratio (OR) and the respective 95% confidence intervals (95% CI) of consuming fortified foods. Two adjusted models were applied including different variables as possible confounders: Model 1 – adjusted for total energy intake

(average values of the two evaluation days were used), age group and educational level, and Model 2 – Model 1 plus BMI. Since significant interaction was found between sex and age group for the consumption of fortified foods (p-value < 0.001), all analyses were stratified by sex.

All analyses described were conducted in R software version 3.4.1 for Windows (R Core Team, 2018), and a significance level of $\alpha = 0.05$ was assumed for all analyses.

RESULTS

Table 1 presents the prevalence of individuals in the Portuguese population consuming at least one food fortified with micronutrients (overall), vitamins and minerals.

The data for the prevalence of consumption of foods fortified with specific vitamins and minerals considered in the present study (Tables 2 and 3) show that, overall, the prevalence of consumption of Mn-FF with vitamin D (39.2%), A (27.0%), B2 (23.2%), folic acid (22.1%) and vitamin B6 (22.0%), iron (24.2%) and calcium (23.7%) was higher than the prevalence of consumption of foods fortified with the remaining micronutrients considered.

Among females, children exhibited the highest prevalence of consumption of Mn-FF containing vitamins D (59.5%), B1 (47.3%) and pantothenic acid (46.7%), as well as the mineral calcium (45.6%). In comparison, older adults showed the lowest prevalence of consumption of Mn-FF containing each of these micronutrients, except for foods fortified with pantothenic acid, for which consumption was lower among adults. Adolescents exhibited the highest prevalence of consumption of Mn-FF containing vitamins B6 (50%), B2 (49.7%), folic acid (48.7%) and niacin (48.1%), as well as the mineral iron (51.1%).

In males, adolescents showed the highest prevalence of consumption of Mn-FF with vitamins D (64.8%), B2 (53.5%), niacin (53.2%), folic acid (53.1%), B6 (52.6%), B1 (51.9%) and pantothenic acid (51.2%), and with calcium (44.7%) and iron (51.2%). Children had the highest consumption of Mn-FF with vitamin B12 (29.5%).

Regarding the contribution of food subgroups to Mn-FF consumption and regardless of sex, breakfast cereals and fat spreads were the main representative food subgroups (Table 4). Unlike children (female 47.2%; male 43.2%) and adolescents (female 49.9%; male 54.6%) who consumed more Mn-FF from the breakfast cereals subgroup, the fat spreads subgroup was the leading supplier of Mn-FF for adults (female 35.4%; male 35.9%) and older adults (female 46.7%; male 46.8%). Among males, the contribution of breakfast cereals consumption was highest among adolescents (54.6%), followed by children (43.2%), adults (27.2%) and older adults (17.3%), with statistically significant differences between age groups. For females, the contribution of this food subgroup was also significantly higher for the younger groups compared with the older age groups. On the contrary, for both females and males, the contribution of fat spreads to the consumption of Mn-FF was significantly higher for adults (female 35.4%; male 35.9%) compared to children and adolescents. The contribution from this subgroup was also significantly greater in older adults (female 46.7%; male 46.8%).

TABLE 1 Prevalence (%) of individuals consuming foods fortified with micronutrients, vitamins and minerals in the Portuguese population (stratified by sex and age group and weighted for the Portuguese population).

	Fortified with micronutrients (overall)	Fortified with vitamins	Fortified with minerals
Total	56.8	52.4	34.4
Female			
Children	75.1	72.9	57.5
Adolescents	65.3	64.1	56.6
Adults	57.6	53.5	33.1
Older adults	53.2	49.3	25.9
p-Value	<0.001	<0.001	<0.001
Male			
Children	79.0	75.9	61.7
Adolescents	77.2	75.0	58.1
Adults	52.8	46.0	31.8
Older adults	39.3	37.2	18.9
p-Value	<0.001	<0.001	<0.001

Note: Age range categories and sample sizes: Children – 3 to 9 years old ($n = 262$); adolescents – 10 to 17 years old ($n = 319$); adults: 18 to 64 years old ($n = 1674$); and older adults: 65 to 84 years old ($n = 358$).

TABLE 2 Prevalence (%) of individuals consuming at least one fortified food containing the different vitamins considered in the present analysis, (stratified by sex and age group and weighted for the Portuguese population).

	Vitamin A	Vitamin B12	Vitamin B1	Vitamin B2	Niacin	Pantothenic acid	Vitamin B6	Biotin	Folic acid	Vitamin C	Vitamin D	Vitamin E	Vitamin K
Total	27.0	16.7	21.7	23.2	21.3	18.2	22.0	3.1	22.1	14.8	39.2	10.7	1.9
Female													
Children	28.9	29.3	47.3	48.9	46.7	46.7	49.9	3.5	47.5	22.2	59.5	9.7	1.6
Adolescents	21.8	24.2	43.9	49.7	48.1	44.1	50.0	7.0	48.7	17.6	54.1	13.3	5.2
Adults	27.8	17.5	21.2	20.6	18.1	12.9	18.9	2.2	19.7	15.1	36.7	12.9	0.9
Older adults	33.1	15.9	15.5	18.9	15.1	13.7	16.5	5.4	15.1	15.3	36.5	12.1	5.8
p-Value	0.296	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	0.276	<0.001	0.171	<0.001	1.000	0.422
Male													
Children	28.3	29.5	50.6	49.6	47.5	45.4	48.9	2.1	48.6	30.9	63.3	12.3	0.8
Adolescents	30.6	25.3	51.9	53.5	53.2	51.2	52.6	3.1	53.1	23.0	64.8	7.7	2.7
Adults	26.5	14.3	16.8	18.3	17.2	14.5	17.7	2.8	18.2	12.1	33.6	9.5	1.7
Older adults	24.9	10.3	8.4	10.4	8.1	6.7	9.0	3.9	8.4	5.6	30.2	8.8	1.5
p-Value	0.617	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.883	<0.001	0.004	<0.001	0.689	0.844

Note: Age range categories and sample sizes: Children – 3 to 9 years old ($n = 262$); adolescents – 10 to 17 years old ($n = 319$); adults: 18 to 64 years old ($n = 1674$); and older adults: 65 to 84 years old ($n = 358$).

	Calcium	Iron	Phosphorus	Iodine	Magnesium
Total	23.7	24.2	3.9	1.7	6.9
Female					
Children	45.6	42.2	5.4	1.6	6.1
Adolescents	41.0	51.1	6.2	5.2	8.9
Adults	19.5	23.3	3.4	0.9	8.4
Older adults	19.0	17.8	6.6	5.1	5.9
p-value	<0.001	<0.001	0.440	0.325	0.902
Male					
Children	35.6	50.4	4.3	0.1	6.4
Adolescents	44.7	51.2	6.4	2.6	2.3
Adults	22.3	20.5	3.3	1.6	6.4
Older adults	14.7	9.5	4.4	1.5	5.6
p-value	<0.001	<0.001	0.304	0.864	0.843

Note: Age range categories and sample sizes: Children – 3 to 9 years old ($n = 262$); adolescents – 10 to 17 years old ($n = 319$); adults: 18 to 64 years old ($n = 1674$); and older adults: 65 to 84 years old ($n = 358$).

TABLE 3 Prevalence (%) of individuals consuming at least one fortified food with the different minerals considered in the present analysis (stratified by sex and age group and weighted for the Portuguese population).

After breakfast cereals and fat spreads, cheese was the subgroup that most contributed to Mn-FF consumption in children (female 11.9%; male 11.4%) and male adults (9.5%). The dairy substitutes subgroup was the third largest contributor to Mn-FF consumption in adult women (10.7%) and older men (10.3%). The consumption of Mn-FF belonging to this subgroup by older women (6.7%) and adult men (7.2%) was also significantly higher than that of children and adolescents of both sexes, age groups in which the contribution of dairy substitutes had low relevance. The contribution of the yogurt and fermented milk subgroup was significantly higher in older women (5.9%) compared to the other age groups; in contrast, the contribution of this subgroup was significantly lower for the male adolescents (0.6%).

Regarding the consumption of foods fortified with vitamins (V-FF) (Table S1), the observed trends were like those reported above – breakfast cereals and fat spreads were the main vehicles for vitamins consumption. Concerning the consumption of foods fortified with minerals (M-FF) (Table S2), breakfast cereals and cheese subgroups were the main contributors for most age groups of both sexes, except for female adults who consumed more M-FF from the dairy substitutes' food subgroup.

Table 5 refers to the associations between the consumption of at least one Mn-FF, one V-FF and one M-FF and socio-economic, health-related and behavioural factors stratified by sex. Only the adjusted models for the variable's total energy intake, level of education and age group are included, given the absence of a confounding effect of BMI on the studied factors.

For both females and males, being a child or an adolescent, having a higher level of education (>12 years) and practising physical activity regularly were significantly associated with higher odds of being a consumer of Mn-FF. Among females, those with obesity and those who consumed two or fewer snacks per day were less likely to be Mn-FF consumers. Among men, living in predominantly rural areas and eating less than two snacks per day were factors significantly associated with a lower likelihood of being Mn-FF consumers; on the contrary, having the third cycle of primary education or high school (6–12 years) was associated with higher odds of being a Mn-FF consumer.

The associations between consuming at least one V-FF or M-FF followed the same trend as those reported for Mn-FF consumption, although some differences were observed. Previous chronic disease diagnosis among men was associated with higher odds of consuming V-FF. For both females and males, higher education levels (6–12 years and >12 years) were significantly associated with M-FF consumption. In contrast, having obesity and having fewer than two snacks per day were associated with lower odds of consuming M-FF. The degree of urbanisation was not associated with the consumption of M-FF.

No associations were observed between the variable food insecurity and the consumption of Mn-FF.

DISCUSSION

The use of Mn-FF is one of the strategies to minimise micronutrient deficiencies in nutritional health policies (Allen, 2006). However, to our knowledge, there are no published data on Mn-FF consumption in Portugal nor on the sociodemographic and health-related factors associated with their consumption. This knowledge is necessary from a public health perspective and for the food industry sector, allowing the creation/reformulation of fortified products aligned with consumer needs, preferences and behaviours.

TABLE 4 Contribution (%) of different food groups to the consumption of fortified foods with micronutrients, stratified by age group and sex and weighted for the Portuguese population. Mean and confidence interval 95%.

Food group	Food subgroup	Female				Male			
		Children	Adolescents	Adults	Older adults	Children	Adolescents	Adults	Older adults
Dairy	Yogurt and other fermented milks	3.7 (2.7, 4.6)	2.8 (2.0, 3.6)	2.7 (2.3, 3.0)	5.9 (4.6, 7.1)	3.6 (2.8, 4.5)	0.6 (0.3, 1.0)	2.9 (2.4, 3.4)	4.2 (2.9, 5.5)
	Cheese	11.9 (9.8, 13.9)	5.7 (4.3, 7.0)	5.9 (5.2, 6.5)	6.1 (4.6, 7.5)	11.4 (9.8, 13.0)	6.3 (5.3, 7.3)	9.5 (8.5, 10.4)	8.5 (6.8, 10.2)
Cereal, cereal products, starchy tubers	Bread and toasts	0.8 (0.3, 1.2)	1.7 (0.7, 2.7)	1.4 (1.1, 1.7)	2.1 (1.2, 2.9)	0.7 (0.2, 1.2)	1.0 (0.5, 1.5)	1.3 (0.8, 1.7)	3.7 (2.4, 4.9)
	Breakfast cereals	47.2 (44.8, 49.6)	49.9 (47.5, 52.3)	24.4 (23.4, 25.4)	16.7 (14.7, 18.8)	43.2 (40.9, 45.5)	54.6 (52.6, 56.6)	27.2 (25.9, 28.4)	17.3 (15.1, 19.6)
	Cereal bars	1.3 (0.7, 1.8)	5.4 (4.2, 6.5)	2.4 (2.0, 2.7)	0.7 (0.2, 1.1)	0.8 (0.4, 1.2)	2.2 (1.6, 2.8)	2.7 (2.2, 3.1)	0.4 (0.0, 0.8)
Fats and oils	Fat spreads	21.7 (19.7, 23.7)	21.4 (19.5, 23.3)	35.4 (34.3, 36.5)	46.7 (44.0, 49.5)	23.8 (21.9, 25.8)	25.8 (24.0, 27.5)	35.9 (34.5, 37.3)	46.8 (43.8, 49.8)
Sweets, cakes and biscuits	Spoon desserts	4.7 (3.5, 6.0)	3.6 (2.8, 4.5)	8.8 (8.1, 9.5)	10.1 (8.4, 11.8)	6.7 (5.5, 7.9)	2.9 (2.2, 3.7)	6.6 (5.9, 7.3)	5.0 (3.6, 6.5)
	Cakes	1.4 (0.7, 2.0)	1.9 (1.2, 2.6)	0.5 (0.3, 0.8)	0.0	1.1 (0.6, 1.7)	1.8 (1.2, 2.5)	0.6 (0.4, 0.9)	0.0
	Cookies and biscuits	6.0 (4.7, 7.2)	5.5 (4.1, 6.8)	7.6 (6.9, 8.3)	4.8 (3.6, 6.0)	6.1 (4.9, 7.2)	2.4 (1.7, 3.2)	5.8 (5.1, 6.4)	3.3 (1.9, 4.7)
Non-alcoholic beverages	Nectars	0.5 (0.1, 0.9)	0.4 (0.1, 0.7)	0.3 (0.2, 0.5)	0.0	0.2 (0, 0.5)	0.6 (0.3, 0.9)	0.5 (0.3, 0.8)	0.0
Milk and milk product substitutes	Dairy substitutes	1.0 (0.5, 1.4)	1.8 (1.2, 2.4)	10.7 (10.0, 11.4)	6.7 (5.3, 8.00)	2.4 (1.7, 3.1)	1.7 (1.2, 2.3)	7.2 (6.5, 7.9)	10.3 (8.5, 12.1)

Note: Age range categories and sample sizes: Children – 3 to 9 years old ($n = 262$); adolescents – 10 to 17 years old ($n = 319$); adults: 18 to 64 years old ($n = 1674$); and older adults: 65 to 84 years old ($n = 358$).

TABLE 5 Odds ratio (OR) and 95% CI for the associations between age group, socio-economic and behavioural characteristics, and consumption of at least one food fortified with micronutrients (overall), vitamins and minerals among female and male participants of the *IAN-AF 2015–2016*.

	At least one micronutrient-fortified food				At least one fortified food with vitamins				At least one fortified food with minerals			
	Female		Male		Female		Male		Female		Male	
	OR (95% CI)		OR (95% CI)		OR (95% CI)		OR (95% CI)		OR (95% CI)		OR (95% CI)	
	n	Model[a]	*n*	Model[a]	*n*	Model[a]	*n*	Model[a]	*n*	Model[a]	*n*	Model[a]
Age group												
Children	262	**2.07 (1.52, 2.83)**	259	**4.80 (3.23, 7.14)**	262	**2.04 (1.48, 2.82)**	259	**4.92 (3.38, 7.17)**	262	**2.53 (1.91, 3.35)**	259	**4.17 (3.05, 5.71)**
Adolescents	319	**1.62 (1.78, 2.22)**	313	**4.59 (3.26, 6.47)**	319	**1.67 (1.26, 2.22)**	313	**4.85 (3.55, 6.62)**	319	**2.58 (1.98, 3.37)**	313	**4.17 (3.17, 5.48)**
Adults	1674	Ref.	1428	Ref.	1674	Ref.	1428	Ref.	1674	Ref.	1428	Ref.
Older adults	358	1.05 (0.79, 1.40)	392	0.96 (0.74, 1.24)	358	1.04 (0.80, 1.36)	392	0.98 (0.75, 1.27)	358	0.86 (0.61, 1.19)	392	0.80 (0.58, 1.11)
Education level												
≤6 years	746	Ref.	751	Ref.	746	Ref.	751	Ref.	746	Ref.	751	Ref.
7–12 years	1123	1.21 (0.97, 1.49)	1078	**1.58 (1.27, 1.96)**	1123	1.21 (0.98, 1.51)	1078	**1.50 (1.20, 1.86)**	1123	**1.37 (1.08, 1.74)**	1078	**2.06 (1.61, 2.64)**
>12 years	737	**1.52 (1.17, 1.99)**	554	**1.85 (1.42, 2.42)**	737	**1.49 (1.43, 1.94)**	554	**1.76 (1.36, 2.29)**	737	**1.81 (1.40, 2.35)**	554	**2.51 (1.90, 3.30)**
Chronic disease												
0 – no	1604	Ref.	1560	Ref.	1604	Ref.	1560	Ref.	1604	Ref.	1560	Ref.
1 – yes	1009	1.10 (0.90, 1.34)	832	1.16 (0.95, 1.42)	1009	1.09 (0.89, 1.33)	832	**1.24 (1.01, 1.51)**	1009	0.95 (0.76, 1.20)	832	0.87 (0.70, 1.08)
Leisure-time/physical activity												
0 – no	1559	Ref.	1319	Ref.	1559	Ref.	1319	Ref.	1559	Ref.	1319	Ref.
1 – yes	999	**1.31 (1.09, 1.58)**	1056	**1.36 (1.11, 1.68)**	999	**1.27 (1.07, 1.51)**	1056	**1.32 (1.09, 1.60)**	999	**1.30 (1.08, 1.56)**	1056	**1.34 (1.07, 1.68)**
BMI class												
Normal weight	1193	Ref.	944	Ref.	1193	Ref.	944	Ref.	1193	Ref.	944	Ref.
Overweight	731	0.87 (0.71, 1.07)	881	0.93 (0.74, 1.16)	731	0.86 (0.69, 1.06)	881	0.90 (0.73, 1.11)	731	0.84 (0.68, 1.03)	881	0.80 (0.63, 1.02)
Obesity	600	**0.76 (0.60, 0.96)**	462	0.80 (0.61, 1.05)	600	**0.75 (0.60, 0.94)**	462	0.82 (0.62, 1.07)	600	**0.75 (0.58, 0.96)**	462	**0.66 (0.49, 0.89)**
Food insecurity												
Security	1770	Ref.	1678	Ref.	1770	Ref.	1678	Ref.	1770	Ref.	1678	Ref.
Insecurity	257	0.75 (0.56, 1.01)	140	0.85 (0.56, 1.29)	257	0.77 (0.57, 1.04)	140	0.88 (0.60, 1.30)	257	0.89 (0.62, 1.27)	140	0.74 (0.42, 1.30)
Degree of urbanisation												
Predominantly urban	1930	Ref.	1720	Ref.	1930	Ref.	1720	Ref.	1930	Ref.	1720	Ref.
Moderately urban	437	1.12 (0.85, 1.46)	426	1.00 (0.75, 1.34)	437	1.24 (0.95, 1.62)	426	1.02 (0.81, 1.29)	437	1.01 (0.80, 1.28)	426	0.93 (0.61, 1.40)
Predominantly rural	246	0.96 (0.69, 1.35)	246	**0.70 (0.49, 0.91)**	246	1.01 (0.76, 1.35)	246	**0.64 (0.47, 0.86)**	246	1.03 (0.72, 1.48)	246	0.82 (0.57, 1.16)
Snacks												
<2	593	**0.60 (0.48, 0.76)**	707	**0.64 (0.49, 0.84)**	593	**0.63 (0.50, 0.80)**	707	**0.70 (0.55, 0.87)**	593	**0.62 (0.47, 0.82)**	707	**0.57 (0.43, 0.77)**
2	872	**0.72 (0.59, 0.88)**	736	0.83 (0.64, 1.06)	872	**0.7 (0.61, 0.90)**	736	0.85 (0.69, 1.06)	872	0.86 (0.70, 1.05)	736	0.85 (0.65, 1.11)
≥3	1148	Ref.	949	Ref.	1148	Ref.	949	Ref.	1148	Ref.	949	Ref.

Note: Age range categories: Children – 3 to 9 years old; adolescents – 10 to 17 years old; adults: 18 to 64 years old; and older adults: 65 to 84 years old.

Values highlighted in bold indicate statistically significant associations.

[a]Model – adjusted for total energy intake, age group and educational level.

Voluntary Mn-FF can be included within the concept of functional foods, which can be defined as "whole foods along with fortified, enriched or enhanced foods that have a potentially beneficial effect on health when consumed as part of a varied diet on a regular basis at effective levels" (Crowe & Francis, 2013). Based on this rationale, our discussion will be based on both Mn-FF and functional food consumption, given the overlapping characteristics and the limited scientific literature focusing specifically on fortified foods.

Our study showed that more than half of the Portuguese population consumed at least one Mn-FF, with children and adolescents having a higher consumption prevalence than adults and older adults. These results are in line with those reported by Bird et al. (2022), who, through secondary data analysis of the *UK National Diet and Nutrition Survey* (2012/2013–2013/2014, $n = 2546$, 1.5–95 years), found that 72% of the participants consumed Mn-FF and that consumption of these foods was highest among children (1–3 years old, 98%; 4–6 years old, 96%; 7–10 years old, 92.1%) and adolescents (11–14 years old: male 88%, female 78%; 14–18 years old: male 84%; female 79%) compared to older participants (19–50 years old: male 67%, female 69%; ≥51 years old: male 64%; female 67%) (Bird et al., 2022).

The higher prevalence of consumption of Mn-FF with vitamins D, B2, B6, A and folic acid and the minerals iron and calcium may be related to the fact that manufacturers often use these micronutrients to fortify a wide variety of food products. In fact, at the time that the *IAN-AF 2015–2016* was conducted in Portugal, 443, 412, 392, 380 and 124 food products of different categories fortified with vitamins B2, B6, folic acid, D and A, respectively, and 411 and 334 fortified with iron and calcium, respectively, were found in the market (Pimenta-Martins et al., 2022).

Regardless of sex and age, breakfast cereals and fat spreads were the food subgroups that contributed the most to Mn-FF consumption. In Ireland, it was found that "breakfast cereals" were the predominant category of Mn-FF, followed by beverages of different varieties, and were the most consumed type of Mn-FF by the participants of the *North/South Ireland Food Consumption Survey 1997–1999* (male 61.7%; female 63.2%) (Hannon et al., 2007). Hennessy et al. (2013) reported that "breakfast cereals" remained the fortified food category most consumed by Irish adults in the *National Adult Nutrition Survey 2008–2010* (55%), followed by "fat spreads" (30%), "bread and rolls" (25%) and "fortified milk" (15%) (Hennessy et al., 2013). On the other hand, in a Finnish study, the groups "yogurt" and "juice drinks" represented the highest amount of Mn-FF foods consumed (Hirvonen et al., 2012). A more recent study reported that within the Dutch population, the most frequently consumed Mn-FF belonged to the food groups "fats and oils," "non-alcoholic beverages" and "dairy products" (De Jong et al., 2022). The variations in eating habits and behaviours observed in different countries could be due to the influence of culture and social interactions (Monterrosa et al., 2020). For instance, in countries where breakfast cereals are integral to the morning routine, there may be a greater emphasis on fortifying these products to enhance nutrient intake and possibly add commercial value. In contrast, regions with a cultural emphasis on dairy may prioritise the fortification of yogurts and milks. Cultural preferences and social practices shape the focus of food fortification efforts, directly influencing the consumption patterns of Mn-FF across different populations (Dwyer et al., 2015).

Breakfast cereals are among the most consumed Mn-FF worldwide and are consumed by a wide range of age groups, from young children to older adults. Both breakfast cereals and fat spreads have a long history of fortification, given their formulation and technological versatility, stability and robustness (Saade & Arijaje, 2020; Smith et al., 2020). In Portugal, the results of *IAN-AF 2015–2016* also showed a widespread consumption of breakfast cereals, with adolescents having the highest consumption (20 g/day), followed by children (11 g/day), adults (9 g/day) and older adults (4 g/day) (Lopes, Torres, Oliveira, Severo, Alarcão, et al., 2018; Lopes, Torres, Oliveira, Severo, Guiomar, et al., 2018). In a previous study, we observed that many breakfast cereals and cereal bar products (67%) available on the Portuguese market were fortified with one or more micronutrients (Pimenta-Martins et al., 2022). Although the fortification of fat spreads is not mandatory in Portugal, contrary to what happens in other European countries (Saade & Arijaje, 2020; Sioen, 2013), we observed that the majority of the products (86%) available on the market were fortified with vitamins, particularly vitamins A and D (Pimenta-Martins et al., 2022). Considering the above, it cannot be ruled out that Mn-FF consumption may not always result from an intentional choice but, to some extent, a consequence of a supply led by fortified products. Also, it is plausible that attributes other than fortification itself contribute to the consumption of voluntary Mn-FF, for example, health value, sensory attributes, convenience, familiarity, availability and accessibility (Niedermaier et al., 2022; Rolls et al., 2023; Urala & Lähteenmäki, 2003).

Our results show that being a child or adolescent, having a higher level of education and being regularly physically active are positively associated with Mn-FF consumption. In Finland, Hirvonen et al. (2012) found that younger individuals were more likely to consume Mn-FF than older ones and that higher consumption of fruits and vegetables was positively associated with Mn-FF use. However, they did not find associations between Mn-FF consumption and lifestyle factors, such as physical activity or educational level, although the authors concluded that, in large samples, there could

be a positive correlation with education (Hirvonen et al., 2012).

In an Irish study, a higher level of education was also associated with Mn-FF use (Joyce et al., 2009). Other studies corroborate that education level significantly affects consumer consumption of these products. For instance, in a study conducted in Turkey to identify the determinants of functional food consumption (which included Mn-FF such as fruit juices fortified with vitamin C, milk fortified with calcium and breakfast cereals fortified with vitamins and minerals), awareness and acceptance, it was found that consumers with higher levels of education had higher consumption of these type of food products (Büyükkaragöz et al., 2014). Similarly, Çakiroğlu and Uçar (2018) found that university graduates had a higher likelihood to consume fortified foods/functional foods (Çakiroğlu & Uçar, 2018). A higher level of education is associated with a higher awareness of ingredients and, thus, a better understanding of the nutritional and biological values of Mn-FF (Bornkessel et al., 2014). In addition, higher levels of education are often seen as an indicator of higher income potential or the ability to purchase more goods and services (Zamfir et al., 2022), including Mn-FF, which can be more expensive than their conventional counterparts due to the costs of production, marketing and quality control (Fiedler et al., 2008; Sandmann et al., 2015). Other authors emphasised that the consumption of functional foods, including Mn-FF, is enhanced and increases not only with educational level but also with the presence of children in the family (Gilbert, 1998; Gulseven & Wohlgenant, 2014). Parents are generally responsible for their children's diets and play a central role in selecting the foods to which children are exposed (Baker et al., 2022). Parenting encourages a focus on nutrition, leading to the search for foods that promote children's normal growth, development and future health. Consequently, it is suggested that parents are more inclined to seek out and purchase fortified food options (Gilbert, 1998).

Moreover, women tend to have the primary role in meal planning, purchasing and preparing food for their families (Baker et al., 2022). They are more prone to buying and consuming functional foods, including Mn-FF. This may justify the positive association between being a child and exposure to Mn-FF, since health and nutrition, along with taste, are important driving forces for parents (Russell et al., 2015) when selecting their children's foods and they may see Mn-FF as healthy food choices. In the case of adolescents, they partly make their food choices. Taste, convenience and price influence adolescents' food choices. Although their level of independence increases as they grow, their autonomy is still limited, so their supporting food environment (e.g., home, school) also plays a critical role (Daly et al., 2022). Additionally, it is important to mention that, in general, children and adolescents tend to consume fortified foods more often than adults (Bird et al., 2022; Moyersoen et al., 2017), which may be because there are numerous Mn-FF designed for younger populations available on the market, such as ready-to-eat breakfast cereals, biscuits and cookies, cakes and non-alcoholic beverages (Pimenta-Martins et al., 2022; Sacco et al., 2013; Sicinska et al., 2017; Walsh et al., 2021).

Regarding physical activity, our results align with the study of Ozen et al. (2013), who found a positive association between physical activity practice and functional food consumption in a sample of inhabitants of the Balearic Islands (Ozen et al., 2013). This may suggest that physically active individuals may consume Mn-FF to promote their health and wellbeing (Landström et al., 2007). Physical activity is often associated with health consciousness, the degree of awareness of one's health and willingness to engage in health and wellness-promoting behaviours. Health consciousness has been positively related to health-promoting behaviours, including fruit and vegetable consumption and exercise, and has been identified as a predictor of preference for fortified foods (Baker et al., 2022; Crowe & Francis, 2013).

We also found that having a diagnosis of prior chronic disease was associated with a higher likelihood of consuming V-FF in men. These results suggest that men with certain chronic diseases may consume V-FF foods to improve their health status. Other studies support our findings; for example, in Sweden, Landström et al. (2007) found that consumers who had a diet-related problem (hypertension, high cholesterol or diabetes) were more likely to consume functional foods (Landström et al., 2007). In contrast, in a Polish study involving 1578 children (5–12 years) and adolescents (13–20 years), it was reported that children with chronic diseases were less likely to be consumers of Mn-FF (SicińSka et al., 2018); a possible reason for this non-consumption may be related to specific dietary needs these young individuals have that limit their food choices. Bimbo et al. (2018), using data from 250 Italian adults collected using a virtual-shelf technique, found no associations between the presence of chronic diseases and the purchase of functional foods (Bimbo et al., 2018).

We found that obesity was related to lower consumption of Mn-FF, V-FF (females) and M-FF (both sexes). Ozen et al. (2013) also found that adults with obesity from the Balearic Islands were less likely to consume functional foods (Ozen et al., 2013). However, Brečić et al. (2014) found a positive relationship between consumers' self-reported BMI and their functional food consumption, suggesting that functional foods may appeal to consumers with higher BMI who may use them to counterbalance unhealthy lifestyles (Brečić et al., 2014). On the other hand, our findings may be because individuals with higher BMI tend to underreport their food intake (Wehling & Lusher, 2019).

Magalhães et al. (2020), using data from the *IAN-AF 2015–2016* ($n = 3639$; age 18–84 years), found that participants with overweight and obesity presented higher odds of being classified as under-reporters of energy intake, which reflects the voluntary omission of food consumption episodes (Magalhães et al., 2020). These results could also be because the subjects with obesity followed a stricter weight-loss diet.

Eating ≤2 snacks per day for females and <2 snacks for males was also associated with lower odds of consumption of Mn-FF. SicińSka et al. (2018) found that children who consumed 4 meals per day were more likely to be Mn-FF consumers compared to children who ate ≤3 meals per day (SicińSka et al., 2018). In Western culture, it is common to divide the daily food intake into three standard meals – breakfast, lunch and dinner. Health professionals and nutritionists, scientific bodies and societies often recommend eating two to three intermediate meals (mid-morning, mid-afternoon and evening snacks) to improve the overall diet quality, help appetite control and contribute to better health status (Hess et al., 2016; Marangoni et al., 2019). In Portugal, snacks between main meals are part of the traditional meal pattern (Gregório et al., 2021), where, besides fruit and nuts, dairy products (e.g., milk, yogurts), non-dairy milk substitutes, cereal products (e.g., bread, ready-to-eat cereals), commercial cakes, spoon desserts (e.g., jelly), biscuits and candies and non-alcoholic beverages (e.g., fruit juices, soft drinks) are popular snack food categories. The voluntary micronutrient fortification of these products to increase their commercial value is a common practice (Pimenta-Martins et al., 2022; Renc et al., 2016; Sicińska et al., 2013). So, skipping one or more mid-meals can reduce exposure to Mn-FF.

Males living in rural areas were less likely to consume Mn-FF and V-FF than those in urban environments. Indeed, these foods may not be as easily available in more rural areas as in urban environments. Furthermore, it is known that lower exposure to less conventional foods is associated with higher neophobia, and men are more neophobic than women (Siegrist et al., 2013); so, our results may also be because men living in rural areas have more fixed dietary habits and avoid more innovative food products, including fortified foods. As mentioned, women are more often in charge of food preparation and, as a result, may be more open to and more familiar with a broader set of foods than men (Siegrist et al., 2013).

This informative national study seeks to understand which sociodemographic and lifestyle factors are associated with the consumption of Mn-FF based on high-quality data from *IAN-AF 2015–2016*. The present work did not aim to assess the nutritional profile or the level of processing of voluntarily Mn-FF consumed by the Portuguese population. However, it is important to mention that many Mn-FF available on the market can be considered ultra-processed foods (UPF), according to the NOVA food classification system (Monteiro et al., 2018). UPF are defined as formulations of ingredients mostly of exclusive industrial use which, besides sugar, fats and oils and salt, include substances not used in culinary preparations, particularly "cosmetic" additives, such as flavour enhancers, colours, emulsifiers, sweeteners and thickeners, used to mimic sensory properties of natural and minimally processed foods and their fresh prepared dishes and meals. These foods result from a series of industrial processes, typically containing little or even no intact food, and are characteristically energy-dense, high in saturated fats, simple starches, free sugars and salt and with low fibre content, good-quality protein and bioactive compounds. Examples of UPF include soft drinks, sweet or savoury package snacks, industrial bread, margarine and other spreads, reconstituted meat products, pastries, industrial cakes, cookies and biscuits and some breakfast cereals and cereals bars (Monteiro et al., 2019). The consumption of UPF has been linked in observational studies to various negative health outcomes, including obesity, hypertension, dyslipidaemia, diabetes, cardiovascular disease, depression and cancer due to their poor nutritional profile and contribution to unhealthy dietary patterns (Jardim et al., 2021; Lane et al., 2021; Pagliai et al., 2021). Many UPFs give the misleading appearance of healthfulness through strategies such as adding dietary fibre and one or more micronutrients, replacing sugar with sweeteners or reducing sodium content (Scrinis, 2016). This allows food manufacturers to make nutritional and health claims to influence purchase behaviours and food preferences. Misleading claims on UPF, even when fortified with nutrients, can obscure their detrimental nutritional value, misleading consumers (Kroker-Lobos et al., 2022).

Regarding Portugal and other European Union countries, Regulation (EC) No. 1925/2006 (EC, 2006) states that micronutrients cannot be added to unprocessed food and alcoholic beverages; however, it does not specify which type of processed foods, including UPF, may be fortified, allowing food manufacturers the opportunity to decide which food products are most suitable for fortification regardless of their healthy/unhealthy nutritional profiles. So, UPF fortified with micronutrients might conflict with public health initiatives designed to enhance dietary quality and health outcomes (Kroker-Lobos et al., 2022). Therefore, it is imperative to invest in increasing the nutritional literacy of consumers, educating them to carefully read the food labels, emphasising the list of ingredients and the nutritional declaration, and providing them with the knowledge that will empower them to make informed food choices. Moreover, regulatory authorities should implement more stringent controls over voluntary fortification, particularly for products with unbalanced nutritional profiles, aligning fortification practices with public health

goals (Pimenta-Martins et al., 2022), recognising that fortified foods may be an important contributor to micronutrient intake, especially in some vulnerable groups (e.g., children, adolescents) (Giménez-Legarre et al., 2020; Van Den Boom et al., 2006).

The main strengths of this study are the use of individual food consumption data from a representative sample of the Portuguese population and a comprehensive analysis of commercial food brand labels, whose database has a good degree of completeness, indicating adequate coverage of label information (Pimenta-Martins et al., 2022). A limitation to note is the reliance on self-reported retrospective data for assessing dietary intake, which may introduce bias. However, the collection of food consumption data for *IAN-AF 2015–2016* adhered to the European Guidelines through the EU Menu methodology. This method is recognised as the leading approach to secure harmonised and high-quality dietary survey data across Europe (EFSA, 2014). Also, the collection of food label information and the construction of the database occurred after the food consumption assessment, which means that some foods reported as consumed may have been reformulated during this period. Therefore, it cannot be ruled out that the results may underestimate or overestimate the prevalence of consumption of Mn-FF and the contributions of food subgroups.

CONCLUSIONS

In Portugal, more than half of the population consumes Mn-FF, with children and adolescents consuming more than adults and older adults. Breakfast cereals and fat spreads are the food categories that contribute most to Mn-FF consumption. Lower age, higher education level and higher physical activity are positively associated with Mn-FF consumption. In contrast, obesity, lower frequency of snacking and living in less urbanised areas are associated with lower Mn-FF consumption.

Our findings highlight the importance of considering sociodemographic and health-related factors in the development of micronutrient fortification policies and educational programmes, ensuring that all segments of the population, including those with lower education levels, those living in less urban environments, older adults and individuals with obesity, are educated and aware of the importance of practising healthy eating and micronutrient intake for overall health. The food industry can also benefit by gaining insights into consumer behaviour, which supports developing new nutritionally balanced products tailored to consumer needs and preferences.

AUTHOR CONTRIBUTIONS

A.P.M. contributed to the development of the methodology, the analysis and interpretation of the results, and wrote the manuscript. D.C. contributed to the formal analysis and the curation of the data. C.C. was involved in data collection, formal analysis, and reviewing and editing the manuscript. C.L. and D.T. coordinated the IAN-AF 2015–2016 survey, formulating the main research questions. A.M.G contributed to the supervision of this study and the reviewing and editing of the manuscript. D.T. contributed to the development of the methodology, the supervision of this study, and the reviewing and editing of the manuscript. All authors participated in the study design, in the discussion of results, contributing to the final document.

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CONFLICT OF INTEREST STATEMENT

None.

DATA AVAILABILITY STATEMENT

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

ETHICS STATEMENT

The study was approved by the National Commission for Data Protection, the Ethical Committee of the Institute of Public Health of the University of Porto and from the Ethical Commissions of each one of the Regional Administrations of Health. Informed consent was obtained from all participants.

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