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Food additives in Latin America: a descriptive analysis of the packaged food supply in five countries

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Abstract

Background Latin America is distinguished by diverse regulatory frameworks and evolving dietary patterns, including the weakening of traditional diets and the increasing consumption of ultra-processed foods (UPFs). Predominantly produced by transnational corporations, UPFs rely heavily on food additives to achieve desirable sensory properties (e.g., flavor, color), ensure food safety, and extend shelf life. Over the past decade, research has increasingly shown that higher consumption of UPFs is associated with poor health outcomes, and food additives have emerged as a potential mechanism underlying this association. However, few studies have systematically analyzed the presence of food additives in the food supply. This study aimed to assess the distribution and patterns of food additives in packaged foods from five Latin American countries.

Methods Data were obtained from packaged foods and beverages sold in supermarkets in Brazil (2017; $n=9{,}673$), Mexico (2017; $n=15{,}846$), Chile (2018; $n=13{,}913$), Colombia (2018; $n=8{,}282$), and Ecuador (2019; $n=2{,}083$). We used the list of ingredients to search for food additives described in the Codex Alimentarius. We assessed the prevalence of specific food additives, categorized their functional classes, and applied exploratory factor analysis to identify patterns of food additive use, overall and in each country.

Results Food additives were present in over 75% of the studied products, ranging from 76.1% in Colombia to 84.0% in Ecuador. Food categories with the highest prevalence of additives (> 90%) included confectionery, dairy products, bakery items, and meat products. Most products contained two or more additives (64.3%); nearly 10% contained ten or more. We observed consistent results on the most used additives (i.e., flavorings, citric acid, phosphates, and lecithin) and patterns of food additives used across countries, although differences were observed in the use of specific additives, particularly low-calorie sweeteners and colorings.

Conclusion Food additives are widely used in the packaged food supply of Latin American countries, and variations in the use of specific food additives likely reflect differences in regulatory frameworks, industry practices, and consumer preferences across countries. Given the increasing concern about the potential health effects of food additives, there is an urgent need to strengthen monitoring efforts and further investigate population-level exposures and associated health outcomes.

Keywords Food additives, Latin America, Food labeling, Food composition, Nutrition policy

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Background

Global shifts in food systems have led to changes in dietary patterns, with increased availability and consumption of ultra-processed foods (UPFs). These products have become dominant in the food supply of high-income countries such as the United States and the United Kingdom and are increasingly sold worldwide [1]. In Latin American countries, there has been a reduction in the consumption of traditional foods [2], and UPFs already represent between 20 and 30% of total energy intake, according to national analyses conducted in Brazil, Chile, and Mexico [3–5]. UPFs are predominantly produced by transnational corporations using industrial formulations that frequently contain little to no whole foods and are based on inexpensive ingredients such as refined flour, added sugars, and fats. To produce palatable and convenient products, the food industry relies on food additives to achieve desirable sensory properties (e.g., flavor, color), extend shelf life, and ensure food safety [6]. Recent evidence has associated higher UPF consumption with numerous adverse health outcomes, including obesity, cardiovascular disease, metabolic disorders, and mortality [7]; and food additives are discussed as a potential mechanism to explain these associations [8].

A food additive is defined as any substance, not usually consumed as a food or used as an ingredient, that is intentionally added to the food for a technological purpose [9]. They have long been used for a variety of purposes, such as extending shelf life and enhancing food flavor and appearance. The ones that modify the sensorial characteristics of foods, such as texture, flavor, and shelf life, can be considered markers of UPFs [10]. Currently, a large number of food additives are available for use by the food industry [11]. The Codex Alimentarius lists more than 300 food additives used in foods, which can assume one or more from 27 functional classes (e.g., antioxidants, emulsifiers, low-calorie sweeteners, etc.) [9]. Although the Codex Alimentarius is a collection of international food standards that provide general guidance, its adoption is voluntary, and it does not have regulatory authority. Each country or region establishes its own regulations, leading to variations in rules worldwide.

In the Latin American region, most countries have their own regulatory system, as is the case of Mexico, Brazil, and Argentina [12]. However, efforts to harmonize international standards for food additives are underway. In South America, the Southern Common Market - MERCOSUR has created a harmonized list of authorized additives for trade between member countries. In the United States, the Food and Drug Administration (FDA) regulates food additives under the Federal Food, Drug, and Cosmetic Act. In the European Union, the European Commission (EC), guided by the European Food Safety Authority (EFSA), sets rules on permitted additives and their conditions of use [13, 14]. While procedures for approving food additives are often similar, regulatory differences can occur. For example, the EC re-evaluated all additives authorized before 2009 [15], which resulted in the ban on titanium dioxide in 2022 [16]. However, in 2023, the WHO/FAO Joint Expert Committee on Food Additives (JECFA) reviewed its safety and found no new evidence warranting concern [17].

Food labeling requirements for additives also vary across countries. The Codex Alimentarius recommends that food additives be listed on labels using either their specific names or the International Numbering System for Food Additives (INS), along with their functional class [18]. The EU employs analogous rules but refers to the INS as an E number (i.e., the same number, but only for food additives approved by the EC). In Brazil and Colombia, the principal functional class of the additive must be declared in the list of ingredients [19, 20]; however, Chilean regulation does not require declaring functional classes [21], which poses an additional challenge for consumers to understand the type of food additives added in products.

Additionally, the amounts of food additives used in food products are generally not disclosed, with some exceptions, such as the requirement in Chile to declare the amounts of low-calorie sweeteners [21]. This lack of transparency makes it challenging to assess population-level consumption and comprehend potential health implications. Regulatory bodies primarily assess toxicity, teratogenicity, allergenicity, and carcinogenicity derived from animal or in vitro models when evaluating the safety of additives, and studies on health effects in humans are often limited or unavailable [22–25]. However, current evidence has linked certain additives, especially those found in UPFs, to adverse health outcomes. For example, artificial sweeteners have been associated with the incidence of obesity and changes in the gut microbiome [26, 27]; emulsifiers are linked to changes in gut microbiota and increased inflammation [28, 29], and certain colorings have been related to behavioral issues in children [30]. Thus, there is increasing concern of the potential health impact of food additives particularly on packaged foods.

Given the lack of information on the use of food additives in packaged foods and beverages, our study aimed to assess the distributions and patterns of usage of food additives in the Latin American countries' food supply.

Methods

This cross-sectional study was based on secondary data analysis of previously collected food composition datasets from packaged foods and beverages sold in five Latin

American countries (Brazil, Chile, Colombia, Ecuador, and Mexico) between 2017 and 2019.

Data collection

In each country, independent studies were conducted based on the methodology proposed by the International Network for Food and Obesity/Non-communicable Diseases Research, Monitoring and Action Support (INFORMAS) in the module of Food Composition [31].

In Brazil (2017), Mexico (2017), Chile (2018), and Colombia (2018), data collection was aimed at capturing information on all packaged foods and beverages available in supermarkets. A research team took photographs of all package sides and entered the data on the online platform REDCap (Research Electronic Data Capture) [32–35]. On the other hand, data collection in Ecuador (2019) was focused only on processed and ultra-processed foods and beverages, with data input into Microsoft Excel [36]. For all countries, we extracted information on product descriptions, barcodes, and lists of ingredients. We excluded products that lack a list of ingredients, such as packaged grains, bottled waters, and other products that are not required to declare ingredients, or products for which the list of ingredients was missing, unreadable in the photograph, or otherwise unavailable. We also excluded products with more than two unreadable ingredients, which were flagged with placeholder codes (e.g., −888 or −999), as in the case of entries such as "sugar, cocoa butter, chocolate, −999, lactose, milkfat, −888, artificial flavors". In addition, duplicate products were removed based on barcode and product description matches (i.e., the same product entered more than once within a country's dataset). A summary of data collection for each country is available in Supplementary Table 1.

Identification of food additives

We conducted a comprehensive search for food additives listed in the Codex General Standard for Food Additives (GSFA), updated up to the 46th Session of the Codex Alimentarius Commission (2023) [37]. The lists of ingredients were searched for standardized Codex names, synonyms, and International Numbering System (INS) codes using a fuzzy automated search strategy developed by the authors in the software R.

We treated food additives that are part of a food additive group defined by the Codex Alimentarius as a single additive. Because these additives share common properties, they are evaluated jointly by the JECFA and usually declared as a group on the food label, making it difficult to identify each group member separately. For instance, cyclamates include INS 952i, 952ii, and 952iv.

In addition to Codex-defined groups, we created ten additional additive groups based on the use of generic names instead of specific ones in our database. For example, according to the Codex, there are four different specific additives for caramel color (INS 150a, 150b, 150c, 150 d), but they were commonly described only with the expression "caramel color" in the lists of ingredients, which does not allow for the identification of the specific additive. These additional groups defined by the authors allowed us to consistently identify food additives even when specific identifiers were missing. We also considered flavorings as a food additive group. Flavorings comprise over 2,500 substances used to impart aroma or taste [38, 39]; they are not listed in the GSFA and are typically reported on the list of ingredients using generic terms such as natural flavor or artificial flavor [9, 39, 40]. Given their widespread use and functional relevance in UPFs, we decided to include them in the analysis.

Both Codex-defined groups and author-defined additive groups were treated as individual additives in our analysis and were displayed in uppercase letters in our results (Supplementary Table 2).

We included all functional classes recognized by the Codex Alimentarius, covering a broad spectrum of uses: acidity regulators, anticaking agents, antifoaming agents, antioxidants, bleaching agents, bulking agents, carbonating agents, carriers, coloring agents, color retention agents, emulsifiers, emulsifying salts, firming agents, flavor enhancers, flour treatment agents, foaming agents, gelling agents, glazing agents, humectants, packaging gases, preservatives, propellants, raising agents, sequestrants, stabilizers, low-calorie sweeteners, and thickeners. Since some countries mandate the declaration of additive functions on ingredient labels while others do not, we did not search for functional classes on labels. Instead, we identified additives directly from the list of ingredients and assigned all possible functional classes according to the Codex definitions [37], using a standardized method across all countries.

Our search included all substances that can function as food additives, including vitamins and minerals that can also be used for fortification (e.g., riboflavin, calcium carbonate). However, these substances are only considered food additives when added for a technological purpose (e.g., coloring), and not when used to enhance the nutritional value of foods [9].

Food categories

We initially considered the 16 food categories from the Codex GSFA: 1) dairy products; 2) fats and oils, and fat emulsions; 3) edible ices, including sorbet; 4) fruits and vegetables; 5) confectionery; 6) cereals, roots, tubers, pulses, legumes and their products; 7) bakery products;

8) meat and meat products; 9) fish and fish products; 10) eggs and egg products; 11) sweeteners; 12) salts, spices, soups, and sauces; 13) foodstuffs for particular nutritional uses; 14) beverages; 15) ready-to-eat savories; 16) prepared foods [41]. We found only a few products in the categories edible ice ($n = 167$; 0.3%), eggs ($n = 7$; 0.01%), and foodstuffs for particular nutritional uses ($n = 105$; 0.2%), then we decided to exclude those products and present the results in 13 food categories—detailed information on the foods and beverages included in each of the food categories is available in Supplementary Table 3.

Statistical analysis

For each country and the overall sample, we described the frequency of food items by food category and by the number of different additives. Additionally, we presented the most frequently occurring food additives (> 1% of items) and the use of functional classes through heat maps, both overall and by country.

We used exploratory factor analysis to identify factors or patterns of food additives. This method facilitates the interpretation of complex data structures by reducing a large number of variables to a small set of factors [42]. A separate analysis was conducted for each country, including food additives found in more than 1% of its products. For the overall sample, all food additives included in the country-specific analyses were considered, even if they were not present in more than 1% of the overall sample. Sample adequacy was assessed using the Kaiser–Meyer–Olkin measure (≥ 0.70) and the Bartlett test of sphericity ($p < 0.001$). Factor extraction was performed using the principal component method with orthogonal rotation, which minimizes the correlation between factors and maximizes the variance explained by each factor [42]. To determine the number of factors to retain, we examined scree plots, which suggested retaining 6 to 8 factors. Based on graphical analysis and model interpretability, we retained 6 factors for each country and 8 factors for the overall sample. For each pattern, we reported the variance and the proportion of variance explained. Food additives with a factor loading > 0.3 were considered in the pattern description [43]. Using the regression scoring method, we predicted factor scores for products within each pattern and described the average scores by food categories. Higher factor scores indicate a stronger association between the food and the pattern.

As a sensitivity analysis, we conducted descriptive analyses excluding products without added sugar, sodium, fat, or additives. This approach was intended to obtain more comparable samples from all countries, considering that Ecuadorian data collection only included processed and ultra-processed foods.

All data analyses were conducted using R version 4.2.2 and Stata v. 18.0.

Results

A total of 49,797 food and beverage products from five countries were included in this analysis. The number of products per country ranged from 2,083 in Ecuador to 15,846 in Mexico. Overall, the most common food categories were dairy products (13.5%), followed by bakery goods (12.2%), and fruits and vegetables (11.7%). Most countries exhibited a similar distribution of food categories, except for Ecuador, where a higher proportion of confectionery (15.7% vs. 10.9% overall) and bakery goods (20.5% vs. 12.2% overall) were found. In Ecuador, some food categories were also comprised of only a few items, including fats and oils ($n = 23$), sweeteners ($n = 20$), and prepared foods ($n = 9$) (Table 1).

Across countries, food additives were present in 77.7% of the foods and beverages products with little variation across countries (from 76.1% in Colombia to 84.0% in Ecuador). Presence of food additives was more frequent in confectionery (93.8%), dairy products (90.6%), bakery products (90.2%), and meat and meat products (90.2%). We observed small differences across countries for confectionery (from 92.5% in Ecuador to 96.8% in Mexico) and bakery products (from 90.2% in Brazil to 93.5% in Colombia), while larger differences for dairy products (from 81.9% in Colombia to 91.6% in Ecuador), and for meat and meat products (from 81.9% in Mexico to 98.4% in Ecuador) (Table 2).

A combination of two or more different food additives was frequent and found in 64.3% of products overall. Only 13.4% of products presented one food additive, varying from 12.0% in Chile to 14.4% in Mexico. About a third of items presented five or more food additives, and almost 10% presented ten or more. Chile and Colombia had the highest (12.0%) and lowest (5.9%) proportions of foods with ten or more additives, respectively (Fig. 1).

Table 3 presents the most frequently used food additives illustrated through a heat map. A gradient color scale was utilized, with the highest frequencies indicated in red and the lowest frequencies indicated in blue. The additives were sorted by their overall frequency. The overall distribution was consistent across countries, as evidenced by the prevalence of red tones at the top and blue tones at the bottom across countries. However, regional differences were also identified. In all countries, flavorings, citric acid, phosphates, lecithin, and sorbates were among the most commonly identified food additives. In contrast, cyclamate and saccharin were present in about 3% of Brazilian products but were virtually absent in other countries. In Mexico, tartrazine (INS 102) and allura red (INS 129) were more frequently identified,

Table 1 Frequency (n and %) of food products included by country and food category

Food category	Overall		Brazil (2017)		Mexico (2017)		Chile (2018)		Colombia (2018)		Ecuador (2019)	
	n	%	n	%	n	%	n	%	n	%	n	%
Dairy products	6,699	13.5	1,571	16.2	1,518	9.6	1,948	14.0	1,399	16.9	263	12.6
Bakery products	6,088	12.2	1,311	13.6	1,786	11.3	1,635	11.8	930	11.2	426	20.5
Fruits and vegetables	5,815	11.7	1,028	10.6	2,226	14.0	1,654	11.9	756	9.1	151	7.2
Confectionery	5,440	10.9	919	9.5	1,859	11.7	1,626	11.7	710	8.6	326	15.7
Cereals, roots, tubers, pulses, and legumes products	5,408	10.9	1,021	10.6	1,809	11.4	1,358	9.8	1,058	12.8	162	7.8
Beverages	5,365	10.8	897	9.3	2,062	13.0	1,541	11.1	650	7.8	215	10.3
Salts, spices, soups, and sauces	4,801	9.6	824	8.5	1,654	10.4	1,357	9.8	779	9.4	187	9.0
Meat and meat products	2,741	5.5	646	6.7	653	4.1	786	5.6	593	7.2	63	3.0
Ready-to-eat savories	2,294	4.6	316	3.3	816	5.1	564	4.1	460	5.6	138	6.6
Prepared foods	1,663	3.3	594	6.1	358	2.3	507	3.6	195	2.4	9	0.4
Fish and fish products	1,484	3.0	211	2.2	471	3.0	456	3.3	246	3.0	100	4.8
Fat and oils	1,286	2.6	264	2.7	393	2.5	299	2.1	307	3.7	23	1.1
Sweeteners	713	1.4	71	0.7	241	1.5	182	1.3	199	2.4	20	1.0
Total	49,797	100.0	9,673	100.0	15,846	100.0	13,913	100.0	8,282	100.0	2,083	100.0

Note: Food categories are listed in descending order of overall frequency

Table 2 Frequency (n and %) of food products with at least one food additive by country and food category

Food category	Overall		Brazil (2017)		Mexico (2017)		Chile (2018)		Colombia (2018)		Ecuador (2019)	
	n	%	n	%	n	%	n	%	n	%	n	%
Confectionery	5,189	95.4	862	93.8	1,799	96.8	1,562	96.1	657	92.5	309	94.8
Bakery products	5,603	92.0	1,183	90.2	1,640	91.8	1,521	93.0	870	93.5	389	91.3
Meat and meat products	2,391	87.2	583	90.2	535	81.9	661	84.1	550	92.7	62	98.4
Dairy products	5,825	87.0	1,423	90.6	1,261	83.1	1,754	90.0	1,146	81.9	241	91.6
Salts, spices, soups, and sauces	3,968	82.6	691	83.9	1,362	82.3	1,064	78.4	681	87.4	170	90.9
Beverages	4,398	82.0	779	86.8	1,745	84.6	1,114	72.3	553	85.1	207	96.3
Prepared foods	1,289	77.5	458	77.1	278	77.7	408	80.5	140	71.8	5	55.6
Ready-to-eat savories	1,516	66.1	245	77.5	581	71.2	339	60.1	282	61.3	69	50.0
Cereals, roots, tubers, pulses, and legumes products	3,496	64.6	671	65.7	1,300	71.9	817	60.2	579	54.7	129	79.6
Fruits and vegetables	3,342	57.5	528	51.4	1,242	55.8	1,035	62.6	428	56.6	109	72.2
Sweeteners	405	56.8	48	67.6	143	59.3	103	56.6	91	45.7	20	100.0
Fat and oils	718	55.8	104	39.4	228	58.0	154	51.5	219	71.3	13	56.5
Fish and fish products	569	38.3	92	43.6	183	38.9	159	34.9	109	44.3	26	26.0
Total	38,709	77.7	7,667	79.3	12,297	77.6	10,691	76.8	6,305	76.1	1,749	84.0

Note: Food categories are listed in descending order of overall frequency

while carmines (INS 120) and carotenes were less prevalent than in the overall sample. Monosodium glutamate (INS 621) was more commonly used in Brazil than in other countries, with a prevalence of 11.6% compared to 7.2% overall and 5.5% in Colombia. Riboflavin was notably prevalent in Ecuador (8.9%) and Mexico (7.5%) but was found in only 1% of products in Brazil.

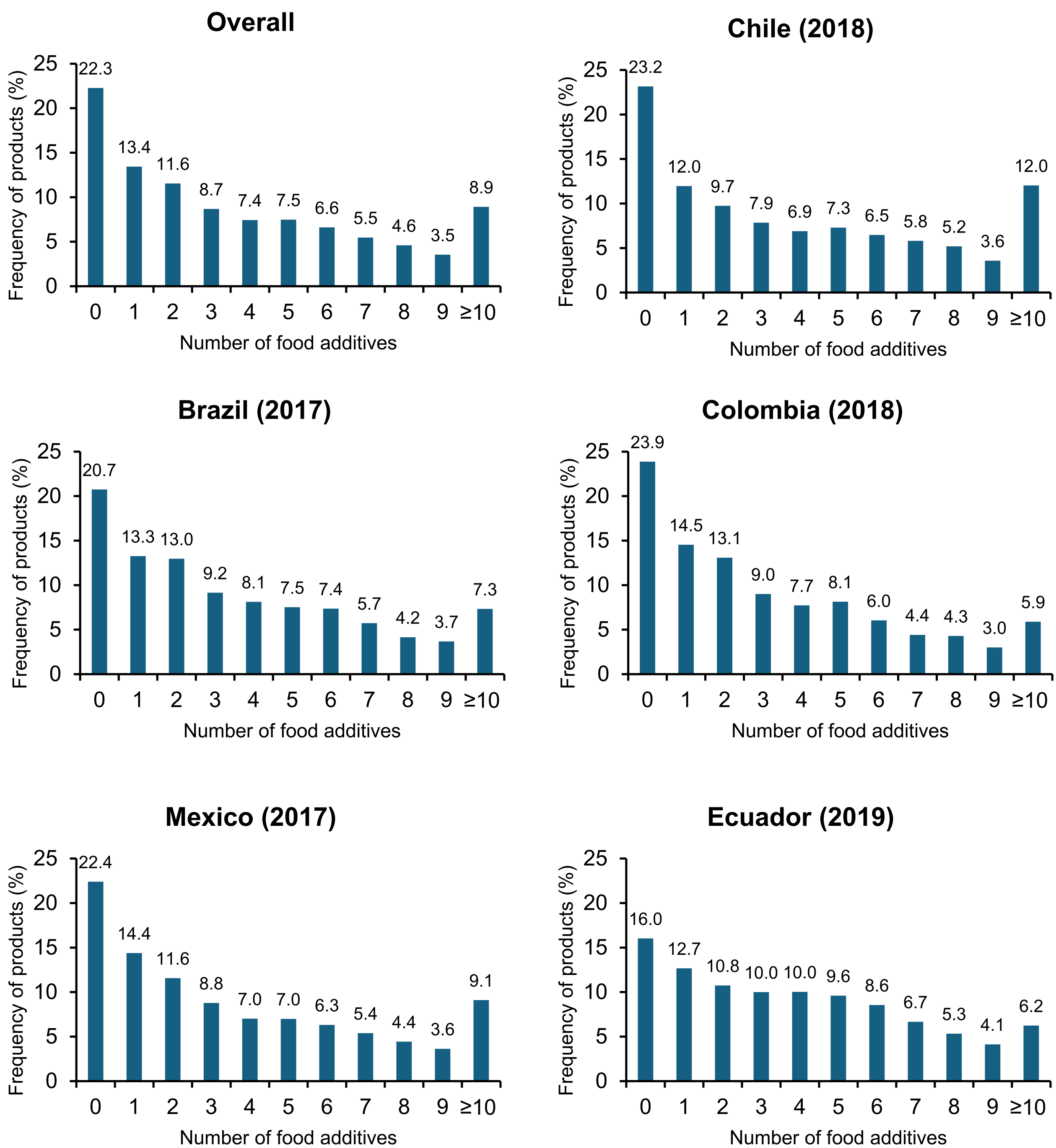

Fig. 1 Frequency (%) of food products according to the number of food additives by country

Table 4 presents food additive patterns identified overall and for each country. Similar patterns were highlighted with similar colors, revealing consistent patterns across countries. All countries exhibited a pattern that included additives such as nitrites and/or nitrates combined with flavor enhancers like monosodium glutamate, predominantly found in processed meats. Another typical pattern identified included low-calorie sweeteners, colorings, and flavorings used in confectionery and beverages. A pattern involving raising agents, emulsifiers, and flavorings, predominantly used in bakery products, was also observed across countries. Additionally, a broader pattern of preservatives was identified across a wide range of food categories, including salt, spices,

Table 3 Frequency (%) of products containing the most used food additives (>1% of items) overall and by countries

Food additive	Overall	Brazil (2017)	Mexico (2017)	Chile (2018)	Colombia (2018)	Ecuador (2019)
FLAVORINGS	47.5	48.3	46.3	50.0	43.2	54.1
330-Citric acid	26.3	25.2	27.8	26.8	23.2	28.6
PHOSPHATES	17.7	20.0	14.7	20.2	16.4	17.3
LECITHIN	16.6	15.0	17.7	18.0	13.1	18.7
SORBATES	16.2	17.6	12.5	18.9	17.3	16.2
500ii-Sodium bicarbonate	9.5	11.2	8.7	10.0	6.7	15.4
BENZOATES	9.4	5.2	11.3	9.2	10.9	9.8
MODIFIED STARCHES	9.4	10.2	10.4	9.1	7.8	7.1
471-Mono- and diglycerides of fatty acids	8.9	8.2	8.1	10.1	8.7	10.0
415-Xanthan gum	8.2	9.7	7.7	8.5	6.8	9.2
300-L-Ascorbic acid	7.3	6.8	6.7	7.8	8.0	9.1
CARAMEL COLORS	7.3	7.5	7.3	7.8	6.6	6.0
621-L-Glutamate monosodium	7.2	11.6	6.2	6.4	5.5	6.8
955-Sucralose	7.1	4.8	6.0	10.5	6.3	7.4
102-Tartrazine	6.4	3.2	10.0	6.5	3.3	5.6
407-Carrageenan	6.0	4.8	4.6	8.3	5.4	8.9
331i-Sodium dihydrogen citrate	5.9	6.4	5.9	5.2	6.1	6.3
129-Allura red AC	5.8	1.6	10.4	4.9	3.0	8.3
412-Guar gum	5.5	7.1	4.0	7.3	3.7	5.3
ANNATO EXTRACTS	5.3	8.3	3.7	5.5	4.9	3.3
110-Sunset yellow FCF	5.0	3.4	7.3	5.1	2.4	4.8
RIBOFLAVINS	4.8	1.0	7.5	4.1	4.0	8.9
440-Pectins	4.5	3.9	4.8	4.1	5.5	4.1
466-Sodium carboxymethyl cellulose	4.5	4.8	3.3	5.0	5.4	5.2
950-Potassium acesulfame	4.3	4.3	4.8	4.5	3.2	3.5
133-Brilliant blue FCF	4.2	1.6	6.8	3.9	2.5	6.3
509-Calcium chloride	4.1	4.7	2.9	4.8	4.7	2.4
270-Lactic acid (L-, D- and DL-)	3.8	5.6	3.1	3.5	3.3	4.1
120-Carmines	3.7	5.7	2.0	4.4	3.1	4.5
CELLULOSE	3.7	1.1	3.4	5.8	3.7	4.8
551-Silicon dioxide	3.5	3.3	3.8	4.1	2.6	3.1
316-Sodium erythorbate	3.4	4.8	2.0	3.7	4.1	2.8
NITRITES	3.3	3.9	2.5	3.0	5.1	3.1
319-Tertiary butylhydroquinone (TBHQ)	3.2	1.0	4.2	3.9	3.4	0.7
CAROTENOIDS	3.2	3.2	2.1	4.2	4.2	1.8
282-Calcium propionate	3.1	4.9	1.0	3.9	3.8	3.4
STEVIOL GLYCOSIDES	2.9	0.8	2.9	4.5	2.6	4.2
321-Butylated hydroxytoluene (BHT)	2.8	1.2	2.2	3.8	4.4	2.0
503ii-Ammonium bicarbonate	2.8	4.6	2.3	3.1	0.7	5.3
951-Aspartame	2.8	2.9	2.7	3.2	2.1	3.0
171-Titanium dioxide	2.7	2.4	2.8	3.3	1.6	3.6
290-Carbon dioxide	2.6	1.5	2.8	3.1	2.6	2.8
ETHYLENE DIAMINO TETRA ACETATES	2.6	2.0	2.9	2.5	2.9	3.4

Table 3 (continued)

Food additive	Overall	Brazil (2017)	Mexico (2017)	Chile (2018)	Colombia (2018)	Ecuador (2019)
TOCOPHEROL	2.4	1.4	3.9	1.8	1.9	2.3
SULPHITE	2.3	3.6	1.8	2.6	1.4	2.1
410-Locust bean gum	2.1	2.2	2.4	2.0	1.6	2.6
422-Glycerol	2.1	2.0	2.3	2.1	1.4	3.0
631-5'-Disodium inosinate	2.1	2.7	2.8	1.5	1.1	1.3
STEAROYL LACTYLATES	2.1	2.5	1.9	2.2	1.5	3.2
160cii-Paprika extract	1.9	2.1	2.4	1.1	2.2	1.3
296-DL-Malic acid	1.9	0.7	3.1	1.3	1.8	3.5
627-5'-Disodium guanylate	1.9	1.6	2.5	1.8	1.3	0.7
508-Potassium chloride	1.8	1.3	1.1	3.1	1.7	0.6
414-Gum arabic	1.7	0.9	2.2	2.2	1.1	1.6
476-Polyglycerol esters of interesterified ricinoleic acid	1.7	2.0	1.1	2.5	0.9	2.9
NITRATES	1.7	3.2	0.8	1.8	1.9	0.2
1200-Polydextrose	1.6	2.2	0.7	2.8	0.8	1.4
320-Butylated hydroxyanisole (BHA)	1.5	0.4	1.4	2.5	1.7	0.0
ASCORBYL ESTERES	1.5	0.2	1.7	2.8	0.7	0.7
POLYSORBATES	1.4	1.9	1.2	1.5	1.0	1.2
1520-Propylene glycol	1.3	1.5	1.6	1.5	0.4	0.9
260-Acetic Acid, glacial	1.3	0.5	1.8	0.4	1.9	3.3
420i-Sorbitol	1.2	1.1	1.6	0.9	1.1	1.3
170i-Calcium carbonate	1.1	0.9	1.8	0.6	0.8	0.8
401-Sodium alginate	1.1	0.7	1.2	1.5	0.6	0.9
122-Azorubine	1.0	0.3	0.7	1.9	0.9	0.2
123-Amaranth	1.0	1.7	1.8	0.0	0.4	0.5
332ii-Tripotassium citrate	1.0	0.5	1.1	1.6	0.4	0.2
297-Fumaric acid	0.9	1.0	0.8	0.8	1.3	1.1
406-Agar	0.9	0.3	0.5	2.4	0.1	0.0
GLYCEROL ESTERS	0.9	1.5	1.0	0.7	0.6	1.2
310-Propyl gallate	0.8	0.0	0.1	2.8	0.1	0.2
262ii-Sodium diacetate	0.7	0.0	1.0	0.8	0.6	0.9
301-Sodium ascorbate	0.7	0.2	1.3	0.2	0.9	0.3
900a-Polydimethylsiloxane	0.7	0.5	0.1	1.8	0.4	0.4
903-Carnauba wax	0.7	0.5	0.8	0.7	0.6	1.4
CYCLAMATES	0.7	3.0	0.0	0.5	0.0	0.0
132-Indigotine	0.6	0.2	0.5	1.2	0.1	0.3
325-Sodium lactate	0.6	1.6	0.7	0.1	0.4	0.8
327-Calcium lactate	0.6	1.0	0.5	0.3	0.6	0.5
SACCHARINS	0.6	2.5	0.0	0.4	0.1	0.3
124-Ponceau 4R	0.5	0.6	0.1	0.7	1.2	0.0
127-Erythrosine	0.5	0.2	1.1	0.1	0.8	0.2
331iii-Trisodium citrate	0.5	0.9	0.0	0.5	0.6	1.2
418-Gellan gum	0.5	0.4	0.6	0.5	0.7	1.0
965ii-Maltitol syrup	0.5	0.2	0.4	1.1	0.2	0.4

Note: Groups of additives are indicated using capitalized letters

Table 4 Patterns of food additives retained for each country

Food additive pattern [a]	Food additives (factor loadings) [b]	Food categories (average factor score) [c]
Overall		
Colorants and glazing agents mostly used in confectionery Variance: 3.1 Variance explained: 3.6% Cumulative variance explained: 3.6%	133-Brilliant blue FCF (0.72), 102-Tartrazine (0.71), 129-Allura red AC (0.68), 110-Sunset yellow FCF (0.63), 903-Carnauba wax (0.44), 171-Titanium dioxide (0.4), 132-Indigotine (0.34), 414-Gum arabic (0.34)	Confectionery (1.01) Ready-to-eat snacks (0.20) Beverages (0.12)
Raising agents, emulsifiers and flavorings mostly used in bakery products Variance: 2.9 Variance explained: 3.3% Cumulative variance explained: 6.9%	LECITHIN (0.65), 500ii-Sodium bicarbonate (0.59), 503ii-Ammonium bicarbonate (0.51), ASCORBYL ESTERED (0.42), STEAROYL LACTYLATES (0.38), FLAVORINGS (0.38), 471-Mono- and diglycerides of fatty acids (0.38), TOCOPHEROL (0.34), PHOSPHATES (0.34), 319-Tertiary butylhydroquinone (TBHQ) (0.31), 422-Glycerol (0.3)	Bakery products (1.4) Confectionery (0.26) Cereals, roots and tubers, pulses, and legumes products (0.15)
Preservatives and acidity regulators used in a variety of categories Variance: 2.7 Variance explained: 3.2% Cumulative variance explained: 10.1%	SORBATES (0.68), BENZOATES (0.58), ETHYLENE DIAMINO TETRA ACETATES (0.51), 330-Citric acid (0.48), 415-Xanthan gum (0.47), MODIFIED STARCHES (0.41), CAROTENOIDS (0.33)	Salt, spices, soups and sauces (0.55) Beverages (0.39) Prepared foods (0.28)
Stabilizers and thickeners mostly used in dairy products Variance: 2.7 Variance explained: 3.2% Cumulative variance explained: 13.3%	466-Sodium carboxymethyl cellulose (0.68), CELLULOSE (0.65), 407-Carrageenan (0.56), 412-Guar gum (0.54), 471-Mono- and diglycerides of fatty acids (0.52), 410-Locust bean gum (0.44), POLYSORBATES (0.33)	Dairy products (0.71) Bakery products (0.16) Prepared foods (0.15)
Flavor enhancers, color retention agent and preservatives mostly used in meat and meat products Variance: 2.7 Variance explained: 3.1% Cumulative variance explained: 16.4%	NITRITES (0.84), 316-Sodium Erythorbate (0.8), 120-Carmines (0.47), NITRATES (0.47), 325-Sodium Lactate (0.46), PHOSPHATES (0.44), 262ii-Sodium diacetate (0.37), 621-L-Glutamate monosodium (0.31)	Meat and meat products (2.9) Prepared foods (0.30) Dairy products (-0.00)
Flavor enhancers and anti-caking agents mostly used in snacks and salt, spices, soups and sauces Variance: 2.6 Variance explained: 3.0% Cumulative variance explained: 19.4%	631-5'-Disodium inosinate (0.83), 627-5'-Disodium guanylate (0.79), 621-L-Glutamate monosodium (0.65), 551-Silicon dioxide (0.51)	Ready-to-eat snacks (0.90) Salt, spices, soups and sauces (0.73) Prepared foods (0.62)
Low-calorie sweeteners and acid regulator mosty used in beverages Variance: 2.5 Variance explained: 2.9% Cumulative variance explained: 22.3%	CYCLAMATES (0.83), SACCHARINS (0.81), 951-Aspartame (0.56), 950-Potassium acesulfame (0.46), 297-Fumaric acid (0.36)	Beverages (0.61) Sweeteners (0.12) Bakery products (-0.00)

Table 4 (continued)

Food additive pattern [a]	Food additives (factor loadings) [b]	Food categories (average factor score) [c]
Low-calorie sweeteners and acid regulator mosty used in beverages Variance: 2.3 Variance explained: 2.7% Cumulative variance explained: 25.0%	955-Sucralose (0.59), 950-Potassium acesulfame (0.54), 951-Aspartame (0.41), 1200-Polydextrose (0.35), STEVIOL (0.33), 965ii-Maltitol syrup (0.33), 331i-Sodium dihydrogen citrate (0.3)	Beverages (1.02) Sweeteners (0.26) Confectionery (0.22)
Brazil (2017)		
Low-calorie sweeteners and colorants mostly used in beverages Variance: 4.8 Variance explained: 7.5% Cumulative variance explained: 7.5%	951-Aspartame (0.84), CYCLAMATES (0.8), SACCHARINS (0.78), 950-Potassium acesulfame (0.74), 102-Tartrazine (0.58), 171-Titanium dioxide (0.58), 110-Sunset yellow FCF (0.56), 331i-Sodium dihydrogen citrate (0.52), 297-Fumaric acid (0.47), 123-Amaranth (0.43), 133-Brilliant blue FCF (0.32)	Beverages (1.14) Confectionery (0.56) Sweeteners (0.46)
Flavor enhancers, color retention agent and preservatives mostly used in meat and meat products Variance: 3.2 Variance explained: 5.2% Cumulative variance explained: 12.6%	316-Sodium Erythorbate (0.87), NITRITES (0.85), NITRATES (0.72), 325-Sodium Lactate (0.7), 120-Carmines (0.48), PHOSPHATES (0.43), 621-L-Glutamate monosodium (0.42)	Meat and meat products (2.85) Dairy products (-0.04) Fish and fishery products (-0.09)
Preservatives, emulsifiers and flavorings used in a variety of categories Variance: 3.0 Variance explained: 4.8% Cumulative variance explained: 17.4%	SORBATES (0.61), 330-Citric acid (0.55), 415-Xanthan gum (0.53), ETHYLENE DIAMINO TETRA ACETATES (0.52), MODIFIED STARCHES (0.51), 412-Guar gum (0.38), FLAVORINGS (0.35), 319-Tertiary Butylhydroquinone (TBHQ) (0.33), BENZOATES(0.33), 955-Sucralose (0.32), 466-Sodium carboxymethyl cellulose (0.31), 321-Butylated Hydroxytoluene (BHT) (0.3)	Dairy products (0.52) Beverages (0.37) Salt, spices, soups and sauces (0.36)
Flavor enhancers and colorants mostly used in ready-to-eat snacks Variance: 2.9 Variance explained: 4.6% Cumulative variance explained: 22.0%	631-5'-Disodium inosinate (0.85), 627-5'-Disodium guanylate (0.8), 551-Silicon dioxide (0.68), 621-L-Glutamate monosodium (0.6), 508-Potassium chloride (0.47), CARAMEL COLORS(0.31)	Ready-to-eat snacks (1.28) Prepared foods (0.81) Salt, spices, soups and sauces (0.62)
Raising agent, emulsifiers and flavorings mostly used in bakery products Variance: 2.9 Variance explained: 4.5% Cumulative variance explained: 26.5%	LECITHIN (0.75), 500ii-Sodium bicarbonate (0.73), 503ii-Ammonium bicarbonate (0.7), FLAVORINGS (0.47), 471-Mono- and diglycerides of fatty acids (0.39), GLYCEROL ESTERS (0.38), PHOSPHATES (0.36), 422-Glycerol (0.32), 1200-Polydextrose (0.31), 476-Polyglycerol esters of interesterified ricinoleic acid (0.3)	Bakery products (1.36) Confectionery (0.41) Cereals, roots and tubers, pulses, and legumes products (-0.01)
Flour treatment agent and emulsifiers mostly used in bakery products Variance: 2.5 Variance explained: 3.9% Cumulative variance explained: 30.4%	STEAROYL LACTYLATES (0.71), POLYSORBATES (0.64), 327-Calcium Lactate (0.62), 282-Calcium Propionate (0.54), 471-Mono- and diglycerides of fatty acids (0.47), 300-L-Ascorbic acid (0.34), GLYCEROL ESTERS (0.32)	Bakery products (0.74) Dairy products (0.18) Prepared foods (0.11)

Table 4 (continued)

Food additive pattern [a]	Food additives (factor loadings) [b]	Food categories (average factor score) [c]
Mexico (2017)		
Low-calorie sweeteners, colorants and flavorings mostly used in confectionery and beverages Variance: 3.5 Variance explained: 5.1% Cumulative variance explained: 5.1%	133-Brilliant blue FCF (0.63), 102-Tartrazine (0.63), 129-Allura Red AC (0.62), 110-Sunset yellow FCF (0.56), 951-Aspartame (0.52), 950-Potassium acesulfame (0.52), FLAVORINGS (0.45), 171-Titanium dioxide (0.41), 330-Citric acid (0.39), 296-DL-Malic acid (0.34), 331i-Sodium dihydrogen citrate (0.33), 414-Gum arabic (0.32)	Confectionery (0.90) Beverages (0.63) Ready-to-eat snacks (0.21)
Stabilizers and thickeners used in a variety of categories Variance: 3.1 Variance explained: 4.4% Cumulative variance explained: 9.5%	466-Sodium carboxymethyl cellulose (0.68), CELLULOSE (0.65), 471-Mono- and diglycerides of fatty acids (0.61), 412-Guar gum (0.54), 407-Carrageenan (0.49), 410-Locust bean gum (0.45), 415-Xanthan gum (0.33), POLYSORBATES (0.32), 1520-Propylene glycol (0.31)	Dairy products (0.66) Prepared foods (0.64) Bakery products (0.48)
Raising agent, flour treatment agent, and emulsifiers mostly used in bakery products Variance: 3.0 Variance explained: 4.4% Cumulative variance explained: 13.9%	ASCORBYL ESTERED (0.76), TOCOPHEROL (0.65), STEAROYL LACTYLATES (0.63), 319-Tertiary Butylhydroquinone (TBHQ) (0.56), LECITHIN (0.49), 1520-Propylene glycol (0.39), 500ii-Sodium bicarbonate (0.3), 321-Butylated Hydroxytoluene (BHT) (0.3), CARAMEL COLORS (0.3)	Bakery products (1.16) Cereals, roots and tubers, pulses, and legumes products (0.23) Confectionery (-0.02)
Flavor enhancers and colorants mostly used in ready-to-eat snacks Variance: 2.8 Variance explained: 4.1% Cumulative variance explained: 18.0%	631-5'-Disodium inosinate (0.8), 627-5'-Disodium guanylate (0.76), 621-L-Glutamate monosodium (0.68), 160cii-Paprika extract (0.34)	Ready-to-eat snacks (1.24) Salt, spices, soups and sauces (0.82) Prepared foods (0.35)
Preservatives used in a variety of categories Variance: 2.6 Variance explained: 3.7% Cumulative variance explained: 21.7%	SORBATES (0.67), BENZOATES (0.66), ETHYLENE DIAMINO TETRA ACETATES (0.52), 330-Citric acid (0.43), 415-Xanthan gum (0.42)	Beverages (0.69) Prepared foods (0.53) Salt, spices, soups and sauces (0.50)
Color retention agent and preservatives mostly used in meat and meat products Variance: 2.5 Variance explained: 3.6% Cumulative variance explained: 25.3%	NITRITES (0.77), 316-Sodium Erythorbate (0.73), 120-Carmines (0.59), PHOSPHATES (0.5), 262ii-Sodium diacetate (0.43), 407-Carrageenan (0.34), 301-Sodium ascorbate (0.33), 508-Potassium chloride (0.31)	Meat and meat products (2.71) Prepared foods (0.94) Dairy products (0.05)
Chile (2018)		
Preservatives and acidity regulators used a variety of categories Variance: 3.3 Variance explained: 4.7% Cumulative variance explained: 4.7%	SORBATES (0.69), BENZOATES (0.56), 330-Citric acid (0.52), 415-Xanthan gum (0.52), MODIFIED STARCHES (0.42), ETHYLENE DIAMINO TETRA ACETATES (0.42), 440-Pectins (0.41), CAROTENOIDS (0.38), FLAVORINGS (0.34), 300-L-Ascorbic acid (0.34), 310-Propyl Gallate (0.33), 955-Sucralose (0.31), 900a-Polydimethylsiloxane (0.31)	Salt, spices, soups and sauces (0.49) Prepared foods (0.29) Beverages (0.25)

Table 4 (continued)

Food additive pattern [a]	Food additives (factor loadings) [b]	Food categories (average factor score) [c]
Low-calorie sweeteners and colorants mostly used in confectionery Variance: 3.2 Variance explained: 4.5% Cumulative variance explained: 9.2%	102-Tartrazine (0.73), 110-Sunset yellow FCF (0.69), 133-Brilliant blue FCF (0.67), 129-Allura Red AC (0.6), 171-Titanium dioxide (0.44), 132-Indigotine (0.4), 951-Aspartame (0.37), 414-Gum arabic (0.33), 950-Potassium acesulfame (0.31)	Confectionery (0.97) Beverages (0.26) Ready-to-eat snacks (0.09)
Flavor enhancers, color retention agent and preservatives mostly used in meat and meat products Variance: 3.0 Variance explained: 4.3% Cumulative variance explained: 13.5%	621-L-Glutamate monosodium (0.75), 316-Sodium Erythorbate (0.65), NITRITES (0.6), 551-Silicon dioxide (0.53), 627-5'-Disodium guanylate (0.5), 631-5'-Disodium inosinate (0.48), PHOSPHATES (0.42), 508-Potassium chloride (0.38)	Meat and meat products (2.11) Prepared foods (0.87) Salt, spices, soups and sauces (0.38)
Stabilizers and thickeners used in a variety of categories Variance: 2.9 Variance explained: 4.2% Cumulative variance explained: 17.7%	CELLULOSE (0.62), 466-Sodium carboxymethyl cellulose (0.6), 407-Carrageenan (0.56), 471-Mono- and diglycerides of fatty acids (0.5), 412-Guar gum (0.48), POLYSORBATES (0.4), PHOSPHATES (0.33)	Dairy products (0.67) Meat and meat products (0.63) Bakery products (0.39)
Raising agent, emulsifiers and flavorings mostly used in bakery products Variance: 2.9 Variance explained: 4.2% Cumulative variance explained: 21.9%	500ii-Sodium bicarbonate (0.63), LECITHIN (0.61), 503ii-Ammonium bicarbonate (0.56), ASCORBYL ESTERED (0.4), 310-Propyl Gallate (0.38), STEAROYL LACTYLATES (0.37), FLAVORINGS (0.35), 319-Tertiary butylhydroquinone (TBHQ) (0.34), 471-Mono- and diglycerides of fatty acids (0.33), PHOSPHATES (0.31)	Bakery products (1.44) Confectionery (0.32) Cereals, roots and tubers, pulses, and legumes products (0.10)
Low-calorie sweeteners ans stabilizers mostly used in beverages Variance: 2.8 Variance explained: 4.0% Cumulative variance explained: 25.9%	950-Potassium acesulfame (0.66), 951-Aspartame (0.6), 955-Sucralose (0.56), 332ii-Tripotassium citrate (0.34), STEVIOL (0.33), 414-Gum arabic (0.31), 331i-Sodium dihydrogen citrate (0.31), 466-Sodium carboxymethyl cellulose (0.31)	Beverages (1.10) Sweeteners (0.32) Confectionery (0.06)
Colombia (2018)		
Low-calorie sweeteners, colorants and flavorings mostly used in beverages and confectionery Variance: 3.1 Variance explained: 5.1% Cumulative variance explained: 5.1%	133-Brilliant blue FCF (0.58), 951-Aspartame (0.57), 950-Potassium acesulfame (0.56), 102-Tartrazine (0.54), 129-Allura Red AC (0.53), 110-Sunset yellow FCF (0.4), 171-Titanium dioxide (0.4), 296-DL-Malic acid (0.38), FLAVORINGS (0.38), 297-Fumaric acid (0.38), 331i-Sodium dihydrogen citrate (0.34), 420i-Sorbitol (0.32)	Beverages (1.14) Confectionery (0.99) Cereals, roots and tubers, pulses, and legumes products (-0.05)
Preservatives used in a variety of categories Variance: 2.9 Variance explained: 4.9% Cumulative variance explained: 10.0%	SORBATES (0.69), BENZOATES (0.65), ETHYLENE DIAMINO TETRA ACETATES (0.57), 330-Citric acid (0.49), MODIFIED STARCHES (0.49), 415-Xanthan gum (0.47), CAROTENOIDS (0.39), 440-Pectins (0.36), 321-Butylated hydroxytoluene (BHT) (0.34)	Salt, spices, soups and sauces (0.76) Beverages (0.46) Fats and oils (0.31)

Table 4 (continued)

Food additive pattern [a]	Food additives (factor loadings) [b]	Food categories (average factor score) [c]
Stabilizers and thickeners mostly used in dairy products Variance: 2.6 Variance explained: 4.3% Cumulative variance explained: 14.3%	466-Sodium carboxymethyl cellulose (0.72), CELLULOSE (0.64), 407-Carrageenan (0.6), 412-Guar gum (0.6), 410-Locust bean gum (0.55), 471-Mono- and diglycerides of fatty acids (0.37)	Dairy products (0.58) Bakery products (0.03) Beverages (0.02)
Flavor enhancers, color retention agent and preservatives mostly used in meat and meat products Variance: 2.6 Variance explained: 4.3% Cumulative variance explained: 18.6%	NITRITES (0.84), 316-Sodium Erythorbate (0.83), PHOSPHATES (0.59), 508-Potassium chloride (0.37), 160cii-Paprika extract (0.36), 120-Carmines (0.33), 621-L-Glutamate monosodium (0.3)	Meat and meat products (2.68) Prepared foods (0.45) Fish and fishery products (-0.06)
Raising agents, emulsifiers and flavorings mostly used in bakery products Variance: 2.5 Variance explained: 4.2% Cumulative variance explained: 22.8%	471-Mono- and diglycerides of fatty acids (0.62), LECITHIN (0.62), 321-Butylated hydroxytoluene (BHT) (0.44), 500ii-Sodium bicarbonate (0.44), CAROTENOIDS (0.42), 422-Glycerol (0.38), RIBOFLAVINS (0.36), 282-Calcium propionate (0.34), FLAVORINGS (0.3), STEAROYL LACTYLATES (0.3)	Bakery products (1.21) Fats and oils (0.81) Confectionery (0.33)
Flavor enhancers and colorants mostly used in salt, spices, soups and sauces and ready-to-eat snacks Variance: 2.4 Variance explained: 4.1% Cumulative variance explained: 26.9%	627-5'-Disodium guanylate (0.81), 631-5'-Disodium inosinate (0.81), 621-L-Glutamate monosodium (0.62), 551-Silicon dioxide (0.56), CARAMEL COLORS(0.34)	Salt, spices, soups and sauces (0.84) Ready-to-eat snacks (0.46) Prepared foods (0.29)
Ecuador (2019)		
Colorants and flavorings mostly used in confectionery Variance: 3.4 Variance explained: 5.4% Cumulative variance explained: 5.4%	133-Brilliant blue FCF (0.73), 129-Allura Red AC (0.65), 102-Tartrazine (0.63), 110-Sunset yellow FCF (0.62), 903-Carnauba wax (0.56), 171-Titanium dioxide (0.53), 414-Gum arabic (0.41), FLAVORINGS (0.36), 422-Glycerol (0.34), 330-Citric acid (0.3)	Confectionery (1.09) Dairy products (-0.02) Cereals, roots and tubers, pulses, and legumes products (-0.06)
Low-calorie sweeteners and stabilizers mostly used in beverages Variance: 3.0 Variance explained: 4.8% Cumulative variance explained: 10.2%	951-Aspartame (0.72), 950-Potassium acesulfame (0.71), 551-Silicon dioxide (0.5), 331iii-Trisodium citrate (0.47), CELLULOSE (0.42), 466-Sodium carboxymethyl cellulose (0.4), 296-DL-Malic acid (0.38), 331i-Sodium dihydrogen citrate (0.38), 300-L-Ascorbic acid (0.31)	Beverages (1.47) Sweeteners (0.25) Meat and meat products (-0.02)
Raising agents, emulsifiers and flavorings mostly used in bakery products Variance: 2.9 Variance explained: 4.7% Cumulative variance explained: 14.9%	500ii-Sodium bicarbonate (0.75), 503ii-Ammonium bicarbonate (0.74), RIBOFLAVINS (0.73), 322i-LECITHIN (0.68), SULPHITE (0.4), FLAVORINGS (0.38), 476-Polyglycerol esters of interesterified ricinoleic acid (0.33)	Bakery products (1.05) Confectionery (0.06) Cereals, roots and tubers, pulses, and legumes products (-0.06)

Table 4 (continued)

Food additive pattern [a]	Food additives (factor loadings) [b]	Food categories (average factor score) [c]
Preservatives and acidity regulators mostly used in salt, spices, soups and sauces Variance: 2.7 Variance explained: 4.4% Cumulative variance explained: 19.3%	BENZOATES (0.68), 415-Xanthan gum (0.62), SORBATES (0.59), ETHYLENE DIAMINO TETRA ACETATES (0.58), 260-Acetic acid, glacial (0.54), 330-Citric acid (0.42), MODIFIED STARCHES (0.42), CARAMEL COLORS (0.3)	Salt, spices, soups and sauces (1.72) Fats and oils (0.33) Beverages (0.27)
Stabilizers and thickeners mostly used in dairy products Variance: 2.6 Variance explained: 4.3% Cumulative variance explained: 23.6%	407-Carrageenan (0.68), 471-Mono- and diglycerides of fatty acids (0.64), CELLULOSE (0.58), 466-Sodium carboxymethyl cellulose (0.57), 410-Locust bean gum (0.56), 412-Guar gum (0.54)	Dairy products (1.01) Beverages (0.26) Meat and meat products (0.15)
Flavor enhancers, color retention agent and preservatives mostly used in meat and meat products Variance: 2.6 Variance explained: 4.3% Cumulative variance explained: 27.9%	316-Sodium Erythorbate (0.84), NITRITES (0.83), PHOSPHATES (0.55), 621-L-Glutamate monosodium (0.5), 120-Carmines (0.41)	Meat and meat products (4.62) Ready-to-eat snacks (0.15) Fish and fishery products (-0.04)

Notes: [a]Similar food additive patterns are represented using similar colors. Factors were derived using principal components, and variances were considered after orthogonal rotation

[b] Food additives with a factor loading > 0.3 were used to describe the additive patterns. Groups of additives are indicated using capitalized letters

[c] For each pattern, we presented the three food categories with the highest factor scores. Complete results are shown in Supplementary Tables S4-S9

sauces, beverages, and prepared foods. This pattern was characterized by the presence of sorbates, benzoates, and citric acid, among other food additives. Detailed results of the factor analysis, including factor loadings for all food additives in each extracted factor, both in the overall sample and for each country, are available in Supplementary Tables S4-S9.

Table 5 shows a heat map of the use of functional classes of additives by country and overall. The highest frequencies are indicated in orange, and the lowest are marked in yellow. The overall distribution was consistent across countries, with stabilizers, emulsifiers, acidity regulators, and antioxidants being the most frequently used functional classes of additives. In contrast, packaging gases, propellants, carbonating agents, and bleaching agents were among the least used functional classes.

As a sensitivity analysis, we repeated the descriptive analyses, but excluding products without added sugar, sodium, fat, or additives (n =44,584). Overall, we found less variability across countries; the prevalence of food additives was 86.8%, ranging from 84.9% in Mexico to 88.3% in Ecuador. In this analysis, the food categories with the highest frequency of items with additives were beverages (96.6%, sixth place before), followed by confectionery (96.4%), meat and meat products (93.9%), and bakery products (93.5%). The categories with the highest variability between countries continued to be dairy products (94.5% in Ecuador vs. 83.8% in Colombia) and meat and meat products (98.4% in Ecuador vs. 85.6% in Mexico). Other results remained consistent with the main results presented in the article (Supplementary Tables S10-S12).

Discussion

This study assessed the use of food additives in packaged foods and beverages across five countries of Latin American countries: Brazil, Mexico, Chile, Colombia, and Ecuador. Food additives were present in 77.7% of products, with prevalence ranging from 76.1% in Colombia to 84.0% in Ecuador. Confectionery, dairy, bakery, and meat products consistently had the highest proportions of additives, exceeding 90% in most countries. Approximately one-third of products contained five or more additives, and nearly 10% contained ten or more. The most frequently used additives were consistent across countries, with flavorings, citric acid, phosphates, lecithin, and sorbates among the most common. However, regional differences emerged, particularly in the use of

Table 5 Frequency (%) of products containing each functional class of food additives overall and by countries

Functional class	Overall	Brazil (2017)	Mexico (2017)	Chile (2018)	Colombia (2018)	Ecuador (2019)
Stabilizer	50.6	53.3	46.4	52.7	50.2	57.1
Emulsifier	50.4	52.6	46.9	53.3	48.0	57.5
Acidity regulator	49.3	50.3	49.6	48.8	46.6	56.8
Antioxidant	48.5	46.2	50.4	49.6	44.6	53.9
Thickener	46.6	50.1	42.9	48.5	44.4	53.4
Sequestrant	44.2	44.6	43.9	44.9	42.5	46.5
Color	31.4	28.1	35.4	31.1	27.6	34.1
Color retention agent	31.0	29.5	32.0	31.1	30.5	32.9
Preservative	29.5	31.5	25.3	31.1	31.9	31.1
Humectant	27.5	29.0	23.6	31.7	25.0	30.9
Raising agent	23.4	25.7	20.8	25.1	21.3	28.2
Emulsifying salt	22.9	25.2	20.1	25.1	21.9	23.7
Glazing agent	22.7	20.8	20.6	26.0	22.9	24.7
Flavor enhancer	18.7	20.4	16.6	21.8	15.5	18.3
Anticaking agent	18.6	17.5	18.4	21.1	14.7	24.6
Bulking agent	16.1	14.7	14.2	20.3	13.5	18.8
Gelling agent	14.7	12.9	13.1	17.0	15.2	17.0
Foaming agent	13.5	14.2	12.9	14.8	11.4	15.7
Carrier	13.5	11.4	13.1	17.1	10.1	15.9
Low-calorie sweeteners	13.2	10.2	13.0	15.8	11.9	15.4
Antifoaming agent	12.6	11.7	11.5	15.0	11.4	13.2
Flour treatment agent	12.5	12.4	12.2	12.8	12.1	14.5
Firming agent	12.4	12.4	10.7	13.8	13.7	10.7
Packaging gas	2.6	1.5	2.9	3.2	2.7	2.8
Propellant	2.6	1.5	2.9	3.2	2.7	2.8
Carbonating agent	2.6	1.5	2.8	3.1	2.6	2.8
Bleaching agent	2.5	3.6	2.0	3.0	1.6	2.1

Note: We considered all functional classes that an additive can assume according to the Codex Alimentarius

low-calorie sweeteners (e.g., steviol glycosides, cyclamate, saccharin), colorings (e.g., tartrazine, allura red), and flavor enhancers (e.g., monosodium glutamate). Despite these variations, patterns of additive use were similar across countries, reflecting their functional roles in processed meats, confectionery, beverages, and bakery products. Stabilizers, emulsifiers, acidity regulators, antioxidants, and thickeners were the most frequently used functional classes.

Our results showed a higher prevalence of food additives than reported in other countries. In France, a similar study (n =126,556, year 2019) found that 53.8% of products contained at least one additive, with the highest proportions in beverages, sweets, and bakery products [44]. In the United States, an analysis of 241,688 packaged foods indicated that 64.9% of products contained at least one sensory-related food additive, mostly in sweets (89.5%), beverages (84.9%), and ready-to-eat foods (82.0%) [45]. Data from Ireland in the late 1990s (n =5,684) already reported 67% of products with food additives, with higher prevalence in diet soft drinks (100%), sausages, bacon and ham (98%), and confectionery (96%) [46].

The most frequently used food additives included flavorings (47.5%), citric acid (26.3%), phosphates (17.7%), lecithin (16.6%), and sorbates (16.2%). This result was consistent across the evaluated countries and is also in line with results reported in other countries. For instance, citric acid was the most common food additive in France and Ireland (33,34). Many of the additives we listed among those most found (> 1% of products) were also listed among the 50 most found in the French study, including some with potential adverse health effects such as phosphates, lecithin, glutamate monosodium, sucralose, carrageenan, nitrites, and nitrates [44]. However, we also found notable differences between countries. For instance, the use of cyclamate and saccharin was higher in Brazil, while steviol glycosides and sucralose were more prevalent in Chile. Similarly, artificial colorings such as tartrazine and allura red were more frequently used in Mexico, whereas natural colorings like annatto and carmines were more common in Brazil. These differences may result from variations in regulatory frameworks, industrial practices, and consumer preferences. In particular, differences in national regulations, such as approval status, acceptable daily intake thresholds, and labeling requirements, may help explain the divergent use of specific additives across countries. For example, cyclamate and saccharin are the least expensive low-calorie sweeteners [47] and are usually used together to reduce the bitter-off taste and achieve a better sensorial aspect [48]. Both additives are considered safe by the JECFA and are approved for use in all Latin American countries assessed. However, cyclamate has been banned by the FDA since the late 1960s due to concerns about its potential carcinogenicity [49]. Although more recent evaluations have concluded that the evidence for cyclamate's carcinogenicity is inadequate [50], these historical concerns may have influenced its regulatory status in other countries. For instance, in Chile, the acceptable daily intake (IDA) for cyclamate is lower than that endorsed by the JECFA – which serves as the main reference in Brazilian regulation – [21, 51, 52], and the use of natural sweeteners, such as stevia, is more common in the Chilean food supply. Since our search included all substances that could be used as food additives, including some vitamins and minerals, some of the differences may reflect fortification policies or practices. Riboflavin is the most notable example; it was found in around 5% of products, ranging from 1% in Brazil to 9% in Ecuador. The addition of micronutrients to UPFs is a common practice in the food industry that contributes to consumer misperceptions of the nutritional quality and healthfulness of these products. It is important to address the regulation of UPF fortification and control the use of health claims displayed on food packages to avoid contradictory messages to the population [53].

While there are specific differences, the overall distribution of the most frequently used functional classes of additives was consistent across countries, with stabilizers, emulsifiers, acidity regulators, and antioxidants being the most prevalent. Consistent food additive patterns were also observed across countries, aligning with findings from other studies on additives'industrial and sensory functions in specific food categories. We found nitrites, nitrates, and flavor enhancers in a pattern associated with processed meats. Nitrites and nitrates can serve as preservatives and color retention agents and are used in processed meats globally to prevent microbial growth, particularly Clostridium botulinum, while contributing to the characteristic pink color of cured meats [54]. Flavor enhancers such as monosodium glutamate are frequently added to processed meats to enhance umami flavor [55]. In confectionery, the prevalence of low-calorie sweeteners and colorings can reflect the category's reliance on additives to achieve bright, appealing visuals and sweet taste profiles. In the United States, artificial food colorings were among the most common additives in candies and sweets [56]. The association of low-calorie sweeteners with beverages is also well-documented. Studies in several countries have identified these additives as key components in different beverages, such as soft and dairy-based drinks [57–59].

The widespread use of food additives in Latin American packaged foods raises concerns regarding potential adverse health effects associated with these substances and the growing reliance on UPF [1]. Several of the most frequently used additives have been linked to metabolic or inflammatory alterations. For instance, phosphates added as food additives with preservative function are highly absorbed in the intestine, and elevated levels have been associated with increased risk of vascular calcification and mortality in animal models and epidemiological studies [60]. Benzoate and sorbates salts, which are also commonly used as preservatives, have been associated with type 2 diabetes and a negative influence on the neurochemistry of the brain in susceptible individuals [61]. Some emulsifiers, such as polysorbates, carboxymethyl cellulose, and carrageenan, have been implicated in microbiota alterations and gastrointestinal inflammation in multiple in vitro and animal studies [28, 29], and have recently been associated with a higher risk of type 2 diabetes [62], cardiovascular disease [63], and cancer [63] in a large French cohort study. Future studies should confirm or exclude these potential associations.

Currently, a large body of evidence has associated higher consumption of UPF with multiple diet-related diseases [7]. Many possible mechanisms have been debated to explain the harmful effects of UPF, including nutritional imbalances, changes in the food matrix, and the presence of food additives [7, 8]. However, more studies are needed to elucidate these mechanisms. Still, policies targeting these products are under active discussion. An approach that relies on the list of ingredients to identify proxies of UPF, especially food additives used to alter sensorial characteristics of foods, such as emulsifiers, low-calorie sweeteners, coloring, and flavorings, has been debated [64–66]. Current front-of-package nutrition labeling policies in Latin America, such as those implemented in Chile and Brazil, focus on nutrients of public health concern and may encourage manufacturers to modify product formulations to avoid high-sugar, high-sodium, or high-saturated-fat labels. However, this practice may also result in unintended consequences, such as increased use of food additives [67]. In Chile, the food industry reformulated its products after the implementation of the food law and added sugar was partially replaced with low-calorie sweeteners, especially in beverages [59]. Similarly, sodium reductions could be accompanied by higher use of food additives such as potassium chloride, monosodium glutamate, and disodium inosinate [68, 69], and the reduction of saturated fats might be achieved through the use of emulsifiers like lecithin and stabilizers such as carrageenan [70]. However, these replacements have not been systematically reported; thus, further research is needed to determine the extent to which front-of-package nutrition labeling has influenced additive use. In addition, future studies should examine how labeling reforms that increase transparency about additives could support informed consumer choices. For example, Mexico's front-of-package label for low-calorie sweeteners has been associated with increased awareness and reduced willingness to purchase products containing these additives [71]. Other studies have reported consumer health-related concerns or uncertainty regarding food additives [72, 73]. Given the limited transparency currently observed in food labeling of food additives, a minimum and urgent step is to require, through regulation, that all food additives be declared in a standardized format, including their functional class, standardized name as defined by the Codex Alimentarius, and INS number. This would ensure clarity, support informed consumer decisions, and facilitate scientific research on the topic.

This study has some limitations that need to be considered. First, the methods for data collection were not uniform across the countries. Particularly, food collection was focused on processed and ultra-processed foods in Ecuador. However, we conducted a sensitivity analysis that excluded all products without added sugar, fat, sodium or additives to make the sample more similar between countries, and the results remained consistent. Second, relying on food labels may underestimate the prevalence of additives due to incomplete disclosure or inconsistent labeling practices [74], which could also result in differential misclassification due to variability in ingredient label accuracy between countries. Additionally, the available information did not allow us to estimate the amounts of food additives used in food products because this information is not required in any country. Despite these limitations, this study has several strengths. The inclusion of data from multiple countries and food categories provides a comprehensive overview of additive prevalence in Latin America, making it one of the few studies to compare additive patterns across such a diverse region systematically. The large dataset enhances the reliability of findings, while the integration of Codex Alimentarius guidelines situates the results within an international regulatory context and provides a baseline for future evaluations of the use of food additives.

This study highlights the widespread use of food additives in packaged foods and beverages across Latin America. Despite cross-country differences in the use of specific food additives, we found a high prevalence of products containing five or more additives in all countries, as well as consistent patterns of food additives and use of functional classes. These findings underscore the urgent need to harmonize food additive labeling regulations and to advance policies aimed at reducing the food supply's reliance on food additives, particularly those associated with ultra-processing, to mitigate their potential implications for public health. Such efforts are particularly important in the context of reformulation initiatives and the broader goal of promoting a healthier food environment based on traditional food practices in the Region.

Supplementary Information

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Supplementary Material 1.

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Authors' contributions
Conceptualization (CZ, CC), data curation (CZ), formal analysis (CZ, SA), funding acquisition (CC, ACD, MM-P, VA-U, LT-M), methodology (CZ, MG, SA), supervision (CC), validation, writing – original draft (CZ, MG), and writing– review & editing (CZ, MG, SA, ACD, DC, MM-P, VA-U, LT-M, MR, CC).

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

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Not applicable.

Consent for publication
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Competing interests
The authors declare no competing interests.

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