Scientific Research Publishing

Food and Nutrition Sciences, 2023, 14, 1244-1258
https://www.scirp.org/journal/fns
ISSN Online: 2157-9458
ISSN Print: 2157-944X

Profile of the Functional Categories of Food Additives in Industrial Foods Marketed in Senegal

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How to cite this paper: Kane, A., Bèye, N.F., Sow, A., Diakhaté, P.A., Ndiaye, N.Y. and Cissé, M. (2023) Profile of the Functional Categories of Food Additives in Industrial Foods Marketed in Senegal. *Food and Nutrition Sciences*, **14**, 1244-1258.
https://doi.org/10.4236/fns.2023.1412078

Received: October 13, 2023
Accepted: December 18, 2023
Published: December 21, 2023

Abstract

Food additives, whether natural or artificial substances, are widely used around the world to improve the sensory quality of products, extend their shelf life and make them more competitive. However, the abusive and uncontrolled consumption of food additives is the cause of numerous illnesses and diseases such as poisoning, allergies, diabetes and numerous cancers. So, in addition to setting up control and regulatory bodies, it is becoming essential to keep a constant watch on the presence of food additives on the market. The aim of this study is to highlight the main categories of food additives in food products frequently sold on the Senegalese market. The methodology of the study is based on the identification of food additives from the information given on the labels of food packaging. Information was collected in markets in two (2) major regions of Senegal: Dakar and Saint-Louis. The results of our study show the presence of 153 food additives on the labels of 514 samples collected. Moreover, the frequency and diversity of additives depended on the food category. On the other hand, beyond their important technological and functional roles, some additives such as aspartame and monosodium glutamate have been implicated in pathologies, and others, such as titanium dioxide, are the subject of much controversy and even withdrawal in certain legislations for their impacts deemed potentially negative on consumer health.

Keywords

Additives, Labels, Food Categories, Quality, Food Safety

1. Introduction

Food additives are chemical substances, natural or artificial, generally used to improve organoleptic qualities, stability and extend shelf life. Substances such as flavourings, preservatives and emulsifiers have been used to improve appearance, taste, texture and shelf life for hundreds of years. Food additives are used both domestically and industrially, in a wide range of food transformation processes. They are used in the production of beverages, dairy products, cereals, meat products, preserves and fats [1]. Taking into account their roles and the properties they confer on foods; food additives can be classified into groups and categories. For example, the Codex Alimentarius, an international collection of standards drawn up by the FAO and WHO, proposes a classification into 27 functional categories [2]. These include colorants such as chlorophylls, sweeteners such as saccharin, preservatives such as sodium benzoate, antioxidants such as vitamin C, and emulsifiers such as lecithins. Over the past few decades, global production of food additives has been booming, and forecasts point to further growth in the years ahead. The consumption of food additives is following the same trend, due to changing eating habits and the increasing use of industrial ingredients and foods in our daily lives. In 2020, the global food additives market was valued at 26.2 billion USD, and global consumption of food additives is expected to grow at an average annual rate of 2.4% per year, over the period 2020-2025 [3]. In the same vein, Sun and Wang (2017) suggest that there are over 25,000 food additives in use worldwide, including 600 to 1000 frequently used food additives. According to the same source, the global food additives industry is growing rapidly, by 4% to 6% a year [4].

However, while beneficial to production, processing and preservation systems, the consumption of certain additives can be highly hazardous to health. Indeed, according to several studies, food additives could cause allergies [5], cardiovascular disease [6], cancer [7], diabetes [8], obesity [9], and many other disorders. It is therefore essential for consumers and the authorities to verify their safety, to ensure that they have no undesirable effects on consumer health. To this end, standards and guidelines are drawn up by public and private bodies, and incorporated into the laws and regulations of states and countries to protect consumer health. At international level, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) is the international body responsible for assessing the safety of food additives. The results of these assessments are often used by the bodies responsible for drawing up standards, directives and regulations, such as the Codex Alimentarius in the first instance, but also the US Food and Drug Administration (FDA) and the European Food Safety Authority (EFSA). Senegal has been a member of Codex since 1964, and has put in place numerous initiatives for food control and consumer protection. As a result, the National Codex Alimentarius Committee was created in Senegal by Decree 83-1204 of November 24, 1983, and placed under the supervision of the Ministry of Health and Prevention. However, as in many developing countries, there is a lack of studies and information to facilitate the elaboration of standards and their integration into regulations. The aim of this study is to establish the food additive profile of various industrial products marketed in Senegal. This work will provide an overview of the main categories of additives present on the Senegalese market, and discuss their potential role and compliance based on research data and current regulations.

2. Materials and Methods

Samples are made up of empty packaging or packaging containing foodstuffs. Samples were collected from markets, supermarkets and stores in the regions of Dakar (Senegal's capital) and Saint-Louis (northern Senegal). These two areas were targeted because of their high population density and the diversity of food products sold. A batch of 514 samples was taken from various sales outlets located in several markets and supermarkets in these two regions. These samples were composed of industrial products frequently marketed in Senegal and belonging to the 16 food categories (**Table 1**) defined by Codex in the General Standard for Food Additives [10]. Sampling involved the types of industrial products most frequently found on the Senegalese market.

Table 1. Food category classifications according to the Codex Alimentarius [10].

Food categories	Foods concerned
01.0	Dairy products and analogues, excluding products of food category 02.0
02.0	Fats and oils, and fat emulsions
03.0	Edible ices, including sherbet and sorbet
04.0	Fruits and vegetables (including mushrooms and fungi, roots and tubers, pulses and legumes, and aloe vera), seaweeds, and nuts and seeds
05.0	Confectionery
06.0	Cereals and cereal products, derived from cereal grains, from roots and tubers, pulses, legumes and pith or soft core of palm tree, excluding bakery wares of food category 07.0
07.0	Bakery wares
08.0	Meat and meat products, including poultry and game
09.0	Fish and fish products, including molluscs, crustaceans, and echinoderms
10.0	Eggs and egg products
11.0	Sweeteners, including honey
12.0	Salts, spices, soups, sauces, salads and protein products
13.0	Foodstuffs intended for particular nutritional uses
14.0	Beverages, excluding dairy products
15.0	Ready-to-eat savouries
16.0	Prepared foods

The methodology of the study is based on the identification of food additives from information on food packaging, as adopted in several studies [11] [12]. The names of the substances on the labels enable the additives in question to be identified by reference to the table in section 3 of the Codex standard on "Class Names and the International Numbering System for Food Additives" [2]. Standards and regulations governing the development of food products require information that objectively informs the consumer about food additives. Regulation (EU) No. 1169/2011 of the European Parliament on the provision of food information to consumers was published in the Official Journal of the European Union on November 22, 2011. In addition, Codex, through its various committees, has drawn up a series of standards and guidelines on food labelling. These include the General Standard for the Labelling of Food Additives sold as such [13], the General Guidelines for Claims [14] and the Guidelines for Nutrition Labelling [15]. The additives listed on food packaging are recorded in an Excel table (version 2016). The information is then transferred to Sphinx Plus software (Version 5 Tuite) for statistical processing of the data collected.

3. Results and Discussion

A batch of 514 products was collected during surveys at various food retail outlets. These products belonged to 15 food categories (**Table 2**) according to the Codex classification [10]. Products on which the presence of additives was indicated were dominated by category C14 containing beverages (19%; N = 98), category 12 with particularly bouillons, condiments, mayonnaises, mustards, sauces, dressings and vinaigrettes (16%; N = 81), category 5 with various confectionery products (15% of the batch) and category 4 with particularly canned fruit and vegetables, mushrooms and purées (11%; N = 58).

Analysis of the packaging labels of the food products collected in the shops revealed the presence of 153 different food additives, distributed very variably across the 514 samples. Overall, according to the Codex classification, 15 functional categories of additives were found on the food products collected (**Figure 1**). Among these, the most frequently encountered were antioxidants, colorants and emulsifiers, which accounted for 19.7%, 15.1% and 11.8% respectively of the additives identified in all samples. The least common categories are foaming agents (0.2%) and coating agents (0.1%).

Furthermore, the results show that the distribution of additives is a function of food category (**Figure 2**). The foods containing the most additives belong to categories 03.0 and 14.0, with an average of 5 additives per food. For example, 11 additives were found on the labels of strawberry jam ice cream. Another 14 additives were found on a powdered drink, and even 15 on a fruit juice. The third food category with the highest number of additives is category 07.0, with an average of almost 4.5 additives per food. In this category, the presence of 12 additives on a cookie packaging was noted. Categories 15.0, 04.0 and 13.0 have the lowest number of additives, with an average of around 2 per food. In these latter categories, the maximum number of additives identified in a food was 6 in a wheat-based infant formula and a potato chip.

Table 2. Categories of food sold in Dakar and Saint-Louis containing at least one additive.

Food categories	Collected samples	Number of samples (N)
01.0	Liquid milk, Cheese, powdered milk, flavoured milk, condensed milk	42
02.0	Butter, margarine	13
03.0	Edible ice	8
04.0	Canned fruit, mushrooms, jams, canned vegetables, mashed potatoes	58
05.0	Chocolate, hard candy, soft candy, spreads, chewing gum	78
06.0	Cereals, dessert, wheat cake	32
07.0	Cookie, cake	39
08.0	Processed chicken, processed meat, processed poultry	24
09.0	Canned fish	3
11.0	Syrup	5
12.0	Bouillon cube, condiment, mayonnaise, mustard, sauce, vinegar, vinaigrette	81
13.0	Preparations for infants	13
14.0	Soft drinks, hot drinks, sweet drinks, vegetable concentrates, fruit juice concentrates, fruit nectars	98
15.0	Potato chips, cornmeal chips	11
16.0	Prepared dishes	9
-	TOTAL	514

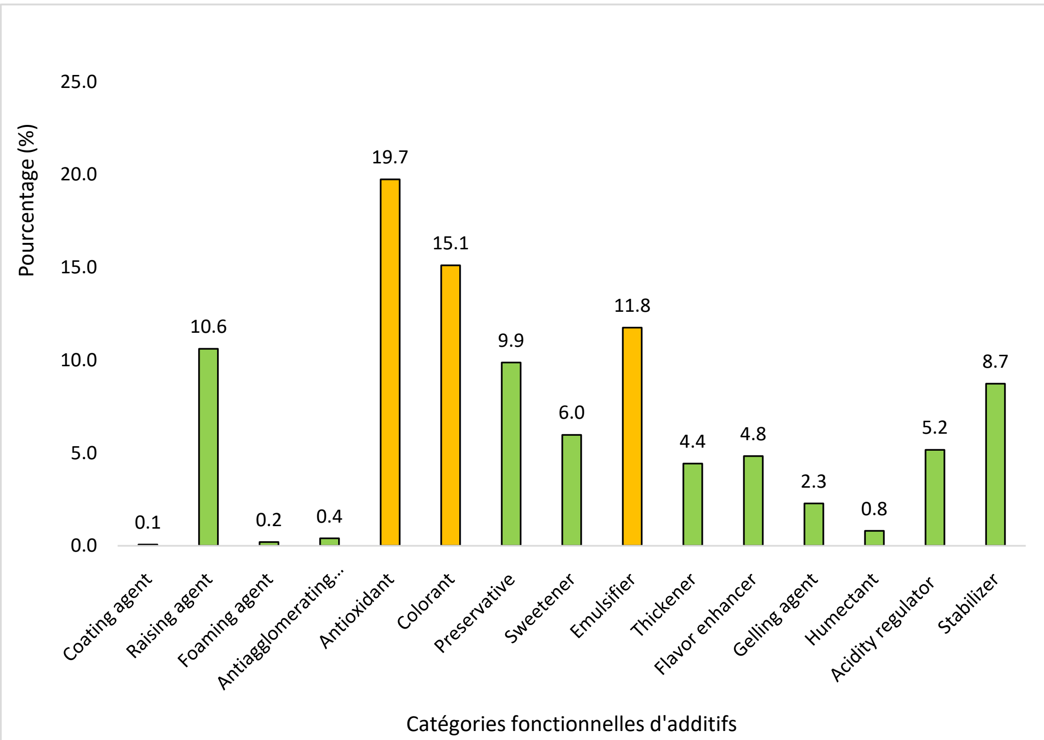

Figure 1. Functional categories of additives identified on the labels of food products collected from markets in Senegal.

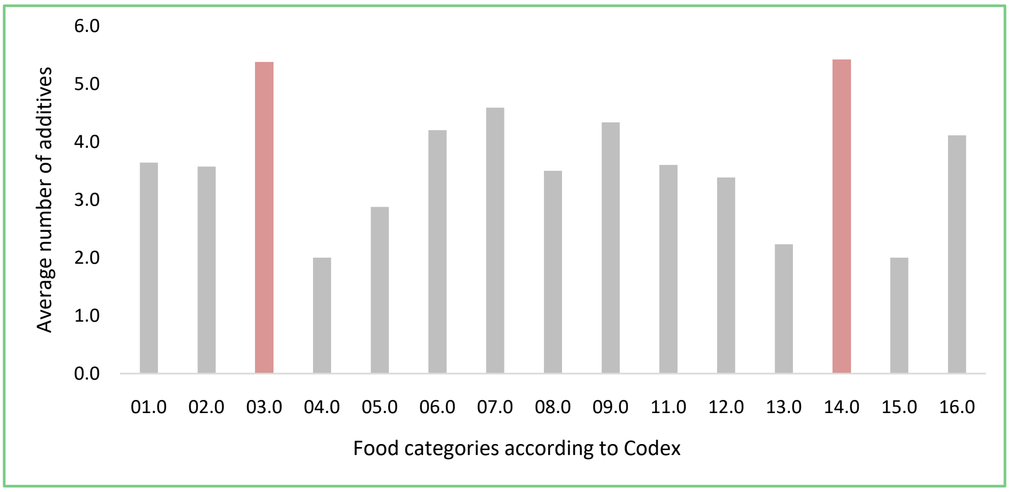

Figure 2. Average number of additives identified in the different food categories according to the classification based on the General Standard for Food Additives.

Analysis of the results has enabled us to draw up a profile of the functional categories of additives most frequently found in the various food categories identified on the markets (**Table 3**).

In food category 01.0 containing milk and dairy products, the main additives are acidity regulators, notably calcium phosphate (E341), and stabilizers, dominated by carrageenan (E407). In this category, colorants such as carminic acid (E120) and emulsifiers such as lecithin (E322) were found in condensed milk and milk powder respectively. Food category 02.0 fats is characterized by the high presence of emulsifiers such as mono- and di-glycerides of fatty acids (E471) and antioxidants, led by citric acid (E330). In these fat samples, we also find colorants such as beta-carotene (E160a(i)) on a butter, preservatives such as potassium sorbate (E202) on a margarine and stabilizers such as guar gum (E412) on a mayonnaise. Food category 03.0 is dominated by stabilizers such as guar gum, and emulsifiers such as mono- and di-glycerides of fatty acids (E471). Antioxidants such as tocopherols (E307) and gelling agents such as pectins (E440) are also found in edible ices. Food category 04.0 is largely dominated by antioxidants, with citric acid (E330) featuring prominently in fruit and vegetable samples. . Preservatives come in second place, with lactic acid (E270) particularly prevalent in fruit and vegetable samples, and canned fish. This category also records the presence of pectins (gelling agent) on jam samples. Food category 05.0 (confectionery) is dominated by emulsifiers, most notably lecithins (E322) found on chocolates and spreads, and colorants, particularly Brilliant Blue FCF (E133) in chewing gums. This food category also records the presence of leavening agents such as ammonium carbonate (E503) and antioxidants such as dipotassium phosphate (E340(ii)) on chocolate packaging. In food category 06.0, the dominant additives are leavening agents, notably sodium carbonate (E500(i)), and emulsifiers, mainly lecithins (E300), found in samples of cereals and cereal-based desserts. Also in this group, the presence of antioxidants such as butylhydroquinone (E319) was noted on cereals. In food category 07.0 (bakery

Table 3. Frequency and variability of additives in food categories surveyed at retail outlets in Senegal.

Food categories	Major additive categories	Most frequent additives
01.0	Acidity regulator (23%)	Calcium phosphate (E341)
	Stabilizer (21%)	Carrageenan (E407)
	Emulsifier (18%)	Lecithin (E322)
02.0	Emulsifier (36%)	Mono- and di-glycerides of fatty acids (E471)
	Antioxidant (28%)	Citric acid (E330)
	Colorant (16%)	Carotenes, beta-, synthetic (E160a(i))
03.0	Stabilizer (42%)	Guar gum (E412)
	Emulsifier (26%)	Mono- and di glycerides of fatty acids (E471)
04.0	Antioxidant (52%)	Citric acid (E330)
	Preservative (17%)	Lactic acid (E270)
05.0	Emulsifier (38%)	Lecithin (E322)
	Colorant (19%)	Brilliant blue FCF (E133)
06.0	Raising agent (42%)	Sodium carbonate (E500(i))
	Emulsifier (23%)	Lecithin (E322)
07.0	Raising agent (42%)	Ammonium hydrogen carbonate (E503(ii))
	Emulsifier (24%)	Lecithin (E322)
08.0	Preservative (26%)	Sodium nitrate (E250)
	Stabilizer (24%)	Triphosphate (E451)
	Antioxidant (21%)	Ascorbic acid (E300)
09.0	Stabilizer (33%)	Guar gum (E412)
	Thickener (25%)	Xanthan gum (E415)
	Colorant (17%)	Lutein (E161b)
	Preservative (17%)	Sodium metabisulfite (E223)
11.0	Colorant (36%)	Tartrazine (E102)
	Preservative (21%)	Sodium benzoate (E211)
12.0	Colorant (24%)	Caramel (E150)
	Flavour enhancer (21%)	Monosodium glutamate (E621)
	Antioxidant (18%)	Citric acid (E330)
	Preservative (15%)	Potassium sorbate (E202)
13.0	Antioxidant (41%)	Ascorbic acid (E300)
	Raising agent (31%)	Calcium carbonate (E170(i))
	Acidity regulator (24%)	Tricalcium phosphate (E341(iii))
14.0	Antioxidant (26%)	Citric acid (E330)
	Colorant (17%)	Sunset yellow FCF (E110)
	Sweetener (17%)	Acesulfame potassium (E950)
15.0	Colorant (59%)	Paprika extract (E160c(ii))
	Flavor enhancer (23%)	Monosodium glutamate (E621)
16.0	Stabilizer (32%)	Guar gum (E412)
	Colorant (19%)	Turmeric (E100(ii))
	Antioxidant (19%)	Citric acid (E330)
	Thickener (19%)	Xanthan gum (E415)

products), the main additives are leavening agents, led by ammonium hydrogen carbonate (E503(ii)) and emulsifiers such as lecithin. Antioxidants such as rosemary extract (E392) and acidity regulators such as calcium phosphate (E341) are also present in these mainly biscuit-based foods. Food category 08.0 (meat, poultry, meat products) is dominated by preservatives (26%) with sodium nitrate (E250) and stabilizers (24%) with triphosphates (E451). Antioxidants in this food group include ascorbic acid (E300), but also leavening agents, mainly diphosphates (E450). In category 09.0, made up mainly of canned fish, the main additives are stabilizers, notably guar gum (E412), and thickeners, particularly xanthan gum (E415). Lutein (E161b), a yellow colorant, and sodium metabisulfite (E223), a preservative, are also identified on cans. In food category 11.0, made up mainly of syrups, we note the presence of colorants such as tartrazine (E102) and preservatives such as sodium benzoate (E211), potassium sorbate (E202) and sorbic acid (E200). Stabilizers such as cellulose gum (E466) are also found in this food group. Food category 12.0 (salt, spice, condiment, etc.) is dominated by colorants, with a high proportion of caramels (E150), and flavor enhancers, particularly monosodium glutamate (E621), found in bouillon cubes and sauces. This food category also includes antioxidants such as EDTA (E385) in mayonnaise, and preservatives such as sulfur dioxide (E220) in vinegar. In food category 13.0 (infant formula), made up essentially of infant formula, the main additives are antioxidants (41%), with ascorbic acid (E300) in particular, and leavening agents such as calcium carbonate (E170(i)). In this food category, the only additional additives are acidity regulators, notably tricalcium phosphate (E341(iii)) and sodium citrate (E331). Food category 14 (beverages) is dominated firstly by antioxidants, notably citric acid (E330), 17 types of colorants, the most frequent being Sunshine Yellow (E110), caramel (E150), tartrazine (E102) and beta-carotene (E160a(i)). A large number of sweeteners were also present, most notably Acesulfame potassium (E950). In addition, other functional additive categories such as preservatives, stabilizers and acidity regulators were found in these beverages. In food category 15.0 (savory snacks), colorants such as paprika extract (E160c(ii)) and annatto norbixin (E160b(ii)) are the most frequent additives on labels. Flavor enhancers, mainly monosodium glutamate (E621), were found on cornmeal and potato-based snacks. Mono- and di-glycerides of fatty acids (E471), the only emulsifier identified in this group, was found on potato chip packaging. In food category 16.0 (prepared foods), the most frequent additives are stabilizers such as guar gum (E412). The other most representative additives are colorants such as turmeric (E100(ii)), antioxidants with ascorbic acid (E300) and thickeners dominated by guar gum (E412). The presence of preservatives, notably sodium metabisulfite (E223), was also noted in these prepared dishes.

The results of our work are comparable to numerous studies on the profile of additives in foods. Indeed, investigations carried out in France using databases have shown, on the one hand, that the food categories most likely to contain food additives (in over 85% of food products) were artificially sweetened drinks, ice creams, industrial sandwiches, cookies and cakes [12]. On the other hand, this study revealed that the most frequent food additives were citric acid, lecithins and modified starches [12]. Another survey based on the analysis of 517 food product labels from the Kenitra market in Morocco showed that the most commonly encountered additives include emulsifiers with lecithins (E322), but also leavening agents, colorants with tartrazine (E102), preservatives with sodium sorbate (E202) and antioxidants with ascorbic acid (E300) [16]. The various additives identified have important technological and nutritional properties, but can sometimes have negative impacts on consumer health. Indeed, among the antioxidants, ascorbic acid, very common in the samples collected, is also currently used as a dietary supplement for its antioxidant properties and numerous health benefits [17]. EDTA or ethylene diamine tetra-acetic acid, another antioxidant found on products, is widely used in the food industry for its proven antioxidant and protective capacity, but also for its function in preserving foodstuffs against microbial deterioration. For example, this substance reduces cadmium toxicity in mustard (Brassica juncea L.) by improving metal chelation, antioxidant defense and glyoxalase systems [18]. EDTA, on the other hand, has been implicated in increasing intestinal inflammation and colorectal carcinogenesis by disrupting the intestinal epithelial barrier [19]. Tartrazine, a synthetic yellow azo dye frequently used by manufacturers, is often considered hazardous to health and is associated with diseases such as cancer. Tartrazine (E102), which is still widely available on the food market, is formally banned in many countries [20]. Sunshine Yellow FCF (E110), an azoic substance identified in foods, is highly prized by consumers, but excessive consumption could lead to attention deficit hyperactivity disorder, behavioral symptoms and even cancer [21]. As for titanium dioxide (E171), found in many beverages, ice creams and confectionery, studies have shown its widespread use in the food industry [22]. However, recent studies have shown that this colorant is suspected of being involved in the development of several tumors and cancers [23] [24]. In addition, titanium dioxide (TiO_2) has been withdrawn from the market and even banned as a food additive in the European Union [25]. Caramels, widely found on collected products, with the code E150, are one of the oldest and most widely used colorants in foods and beverages [26]. Caramels have long been used as substitutes for synthetic colorants, but also for their antioxidant properties in industries and particularly in beverage manufacture and baking [27]. With regard to emulsifiers, our results are similar to those of Cox *et al.* (2021), who reveal that the two emulsifiers commonly used in the EU food supply are lecithin (E322), found in 14% of foods, and mono- and di-glycerides of fatty acids (E471), present in 7% of foods [28]. According to the same study, over 100 emulsifying agents are known to be added to foods worldwide [28]. Furthermore, at the technological level, lecithin performs a dozen functions, notably as an emulsifier, wetting agent, viscosity reducer, mold release agent and crystallization control agent. Indeed, it is used in the production of chocolates, ice creams, mayonnaises and many other modern food processes [29] [30]. However, Chassaing *et* *al.* (2015) demonstrate the negative impact of emulsifier abuse on chronic inflammatory bowel disease and metabolic syndrome [31]. On the other hand, the authors suggest that emulsifying agents can alter the location and composition of the microbiota and lead to intestinal inflammation at the root of colitis and metabolic syndromes [32]. As far as flavor enhancers are concerned, monosodium glutamate (E621), widely found on the labels of various categories of foods collected, is by far the most commonly used flavor enhancer in the food industry [33]. On the other hand, it is a substance subject to much dispute and controversy for its possible negative impact on human health. Indeed, studies have often associated monosodium glutamate consumption with numerous pathologies, including cardiotoxicity [34], neurotoxicity and cancer [35]. On the other hand, these assertions are challenged by other researchers such as Zanfirescu *et al.* (2019), who point to several methodological flaws that lead to the conclusion that these studies have limited relevance for extrapolating monosodium glutamate risk exposure to human dietary intake [36] [37]. With regard to the acidity regulators identified, a study of the use of additives in processed products in France showed that citric acid, listed on 23% of processed products, is the most frequent food additive on ingredient lists [38], with worldwide production increasing rapidly [39]. In addition to citric acid, acetic acid, benzoic acid and sodium salts of acids are some of the acidity regulators commonly used in foods [39]. The notable presence of thickeners, gelling agents and stabilizers on collected products is explained by their key technological properties. Guar gum (E412), very common on the industrial products studied, is a molecule extracted from plants and widely used in many modern food processing technologies, as well as in the cosmetics and pharmaceutical industries. What's more, this gum has important functional properties. Indeed, according to Mudgil *et al.* (2014), it is involved in the control of numerous health problems such as diabetes, bowel movements, heart disease and colon cancer [40]. Saha *et al.* (2010) reveal that the hydrocolloids most commonly used as thickeners in food products are starch, xanthan gum (E415), guar gum (E412), locust bean gum (E410), karaya gum (E416), tragacanth gum (E413), gum arabic (E414) and cellulose derivatives [41]. As far as sweeteners are concerned, the availability of aspartame, an artificial sweetener, makes it the preferred choice of sweetening agent for food manufacturers. In addition to its use as a sweetening agent, aspartame enhances and prolongs certain food and beverage flavors, particularly acidic fruit flavors [42]. In terms of health, studies have shown the potential negative effects of aspartame on health, such as the occurrence of tumors or cancers [43]. However, a reassessment of the risks associated with aspartame carried out by EFSA at the request of the European Commission concluded that "aspartame and its breakdown products are safe for the general population" [44]. The fact remains that a constant reassessment of the safety of the intense sweeteners widely used in the agri-food industry remains a necessity. For the preservation of food product spoilage, it was noted in another study that citric acid (E330), sodium benzoate (E211) and potassium sorbate (E202) are widely used worldwide as food and beverage preservatives [45]. However, sodium benzoate may react with ascorbic acid in beverages to produce benzene, a carcinogenic substance [46]. In addition, in some children, sodium benzoate may also adversely affect neurotransmission and cognitive functioning [46]. Faced with the various risks listed and growing consumer demand, alternatives aimed at reducing the use of artificial additives are currently being developed. Moreover, a number of surveys carried out in various countries have shown that consumers have a negative perception of food additives due to the potential toxicity linked above all to artificial substances [47] [48]. This attitude has a negative impact on the acceptability of foodstuffs containing artificial additives, and consequently hampers the marketing of these products. In this respect, one study suggests that a graphic label would indicate to consumers that a foodstuff contains artificial additives, and could therefore help them to make an informed purchasing decision [49]. It is in this context, for example, that experiments are being conducted to exploit the biotechnological potential of microorganisms in the production of natural pigments for food use [50]. In addition, recent research results have demonstrated the antioxidant and antimicrobial potential of several natural substances of plant, animal or microbial origin [51].

4. Conclusion

The use of food additives has become fashionable in the agri-food sector, not only for reasons of technical efficiency, but also for commercial and competitive reasons. These substances are found in virtually all industrial food products worldwide, thanks to the trade facilitated by globalization. Various categories of food additives, adopted by regulatory authorities and included in Codex Alimentarius standards, are thus highly present in industrial foods and beverages marketed in southern countries such as Senegal, the subject of our case study. However, there is still a limit to the presence of certain food additives whose negative effects on health have been scientifically proven, and some have even been banned by regulatory authorities. Controversies and contradictory debates on certain research results, as well as consumer concerns and worries, should prompt national authorities to strengthen control and monitoring systems on food additives. Alternatives are currently being tested to replace with natural substances or reduce consumption of the artificial additives most likely to present health risks for consumers.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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