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Sweetener and Flavor Enhancer Food Additives in Industrial Food Products Marketed in Dakar: Frequency and Diversity

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Abstract

Sweeteners and flavor enhancers are food additives widely used in industry, respectively, to add sweetness and flavor to foods. However, the presence of these substances is often criticized by consumers for their effects on health. What's more, some scientific studies link these substances to certain pathologies. To guarantee food safety, competent authorities should have food standards based on risk analysis using consistent, reliable data. However, in developing countries, such data is often weak or non-existent. The aim of this study is therefore to carry out a pilot survey to establish the profile of sweeteners and flavour enhancers present in industrial food products marketed in Senegal. The methodology consisted of sampling various food products sold on the Senegalese market, based on analysis of labels containing information on ingredients, including additives. The investigation involved nine stores, one supermarket and 5 mini-markets in Dakar. The results showed the presence of 6 taste enhancers in food products, the most frequent being sodium L-monoglutamate (E621), inosinate (E631) and disodium guanylate (E627). Solid broths are the foodstuffs with the highest number of taste exhalters. As for sweeteners, 12 substances were identified, the most frequent being acesulfame potassium (E950), aspartame (E951), sucralose (E955) and saccharin (E954). Given the potential health risks associated with the consumption of these food additives, their control and monitoring on the market should be a priority for the competent authorities.

Keywords

Exhalter, Sugar, Acesulfame Potassium, Sodium Monoglutame, Artificial, Health Risk

1. Introduction

Taste and aroma are among the key factors to be exploited in the development of new food products to increase consumers' acceptance [1]. Taste is defined as the sensory ability to respond to dissolved molecules and ions, known as sapid agents [2]. The main five different primary taste qualities experienced by humans are: sweet, umami, bitter, salty and acidic [3]. Flavors are volatile compounds naturally released by foods [4] or produced during various processing operations such as cooking [5] and fermentation [6]. However, in the modern food industry, food additives are often used not only to reduce production costs, but also to improve taste with sweeteners and enhance flavour with flavour enhancers. Most of the sweeteners used have the advantage of providing the sensation of sugar without increasing the calorie intake [7]. These sweeteners therefore help to reduce the risk of dietary diseases such as obesity [8], as well as preventing certain illnesses such as tooth decay [9]. For people with diabetes or obesity, certain synthetic sweeteners such as saccharin, aspartame and steviol glycosides, which are not metabolized by the body, are used as alternatives to sucrose [10]. In addition, synthetic sweeteners in particular have the advantage of being more stable during processing, as well as being cheaper to buy. Flavor enhancers act to reinforce both the smell and the taste of food products, and are used extensively in industrial food manufacturing. However, for both sweeteners and flavor enhancers, potential safety risks have been suggested by scientific studies. Indeed, although the results are disputed [5], sweeteners have been associated with numerous pathologies such as lymphomas, leukemias, bladder and brain cancers, chronic fatigue syndrome, Parkinson's disease, Alzheimer's disease, multiple sclerosis, autism and systemic lupus [11]. For these reasons, many synthetic sweeteners such as aspartame, saccharin and sucralose have become less and less popular [12]. Faced with this demand, the modern food industry is increasingly offering consumers alternative natural sweeteners that have the advantage of being beneficial to health [13]. Similarly, the presence of flavor enhancers in food products raises concerns among consumers [14] [15] and numerous controversies as to their harmful effects on human health [16]. The consumption of sodium monoglutamate has been associated with genotoxic effects [17]. So many studies have been carried out by health authorities to assess consumption levels, analyze risks and establish regulations concerning the use of sweeteners and flavor enhancers. Examples include work on the safety and regulation of low-calorie sweeteners in the United States [18], and analysis of the safety aspects of authorized sweeteners in the European Union by EFSA [19].

This raises the need for regulation by health authorities and constant re-evaluation to ensure the safety of these food additives [20]. This presupposes good organization and detailed information on the presence and frequency of these substances in everyday consumer products. However, in many countries, health safety regulation is a weakness [21] with challenges to overcome particulary to Sub-Sahara Africa [22]. What's more, in developing countries such as Senegal, basic data contributing to risk analysis are not widely available in the scientific literature. The aim of this study is to determine the profile of sweeteners and flavor enhancers in various industrial food products sold on the markets of Dakar.

2. Materials and Methods

The field studies took place between October and December 2022, with a team of Master's students trained in the survey method. The samples were made up of various industrial foodstuffs covering most of the food products commonly distributed on the national market. These samples were grouped into 16 food categories based on the Codex classification of foods [23]. The number of samples for each category depended on the availability of the products concerned on the market and the presence of additive information. The approach consisted in collecting this information from food product labels at various points of sale in the city of Dakar (capital of Senegal) in order to obtain a diversified range of products. These business locations include nine local stores, four mini-markets, two markets and one supermarket. The data collection process involved checking whether the product contained at least one food additive of any type, in order to determine the presence of sweetners ans flavor enhancers and the proportion of all food additives in the listed products.

The methodology is based on a qualitative analysis through the identification of food additives from information on food packaging labels, as adopted in several studies [24] [25]. The survey was carried out using a smartphone equipped with a quality camera for photographing product labels and a computer for data recording. Photos of the ingredients on the packaging and the name of the product are taken so as not to list it more than once, and to avoid duplication. The names of the ingredients 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 International Numbering System for Food Additives" [26]. Elsewhere, standards and regulations governing the development of food products require information that objectively informs consumers 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, the Codex Alimentarius Commission, through its various bodies, has drawn up a series of standards and guidelines on food labelling, including the General Standard for the Labelling of Food Additives sold as such [27], the General Guidelines on Claims [28] and the

Guidelines on Nutrition Labelling [29]. The additives listed on food packaging are collected and entered into the Excel spreadsheet (version 2016) for statistical processing of the data collected. These investigations were carried out with the agreement of the owners, in compliance with confidentiality and ethical rules.

3. Results

A total of 421 food packaging labels were assessed during our investigations. The collection concerned various food products belonging to 8 food categories. These were fruit and vegetables (13.8%; N = 58), confectionery (18.5%; N = 78), cereals (7.6%; N = 32), bakery products (9.3%; N = 39), meat, meat products and poultry (5.7%; N = 24), broths, soups and sauces (19.2%; N = 81), drinks (23.3%; N = 98) and savoury snacks (2.6%; N = 11).

The results of this study reveal the presence of sweeteners and flavor enhancers alone or mixed in several food categories (**Figure 1**). In cereals, bakery products and beverages, only sweeteners were found. Conversely, in categories 04.0 (fruit and vegetables), 08.0 (meat, poultry, etc.) and 14.0 (savoury snacks), only flavour enhancers were found. In the other food categories collected, sweeteners and flavor enhancers are associated with varying proportions according to product type.

3.1. Identified Flavor Enhancer Additives

Overall, flavor enhancers and sweeteners account for an average of 5% and 6% respectively of identified food additives, out of all the food products collected (**Figure 1**).

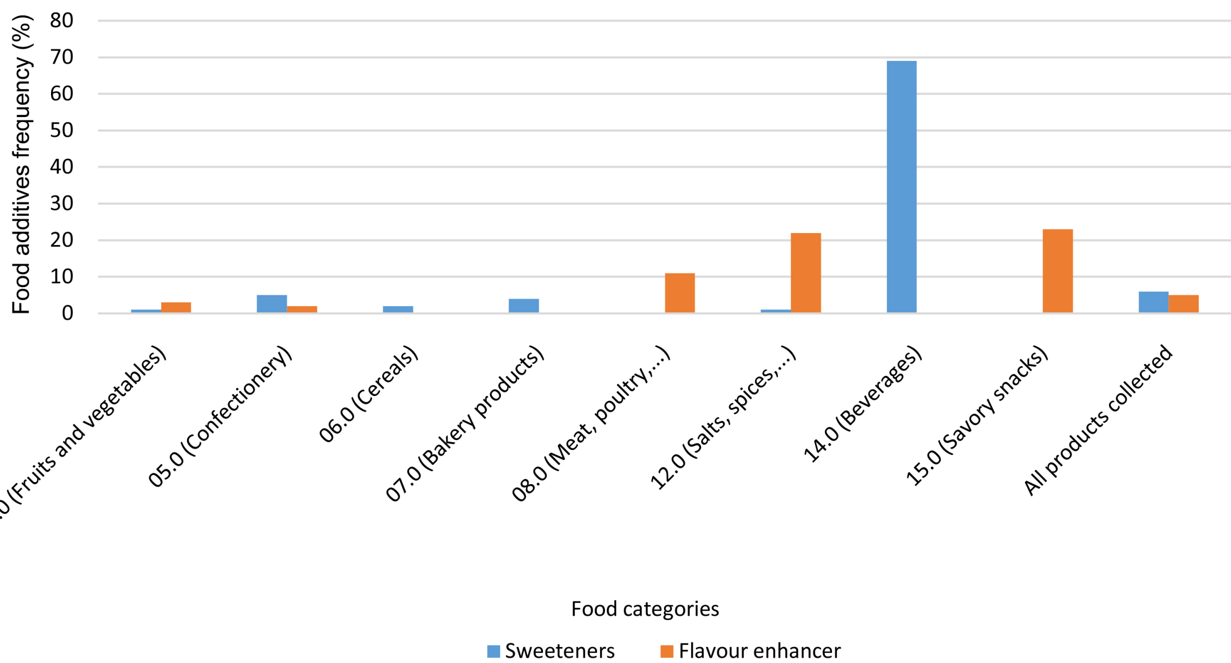

Figure 1. Frequency of sweetener and flavor enhancer additives identified in the various food categories surveyed.

The presence of 5 types of flavor enhancers was noted on the labels of the industrial products collected (**Figure 2**). These included monosodium glutamate (E621), disodium guanylate (E627), inosinate (E631), disodium ribonucleotides, 5'-(E635) and magnesium sulfate (E518).

The use of flavor enhancers has been observed in various types of food products, albeit with varying frequency (**Table 1**). Monosodium glutamate, which accounts for 46% of flavour enhancers identified, is used as an ingredient in the manufacture of meats and meat products, potato chips, sauces and particularly bouillon cubes. Disodium guanylate and inosinate come in second place, with 23% and 9% respectively. These last two food additives are found in mayonnaises, potato chips, sauces and bouillon cubes. Disodium 5' ribonucleotides are only identified on 3 food products: a mayonnaise, a potato chip and a bouillon cube. Magnesium sulfate was only found on one chocolate label. In this study, we noted the simultaneous presence of different flavor enhancers in certain food products. In fact, 78% of broths contained the monosodium glutamate/inosinate/disodium guanylate combination. Other combinations of 2 to 3 flavor enhancers are also found on products such as sauces, potato French fries and mayonnaises.

Table 1. Presence of flavour enhancer additives identified in food products sold in retail outlets in Dakar.

Flavour enhancers	Food products concerned
Monosodium glutamate (E621)	Broth cube Potato chips Corn semolina chips Processed chicken Processed poultry Processed meat Sauce
Disodium guanylate (E627)	Broth cube Mayonnaise Potato chips Sauce
Inosinate (E631)	Broth cube Mayonnaise Potato chips Sauce
Disodium 5'-ribonucleotides (E635)	Mayonnaise Broth cube Potato chips
Magnesium sulfate (E518)	Chocolate

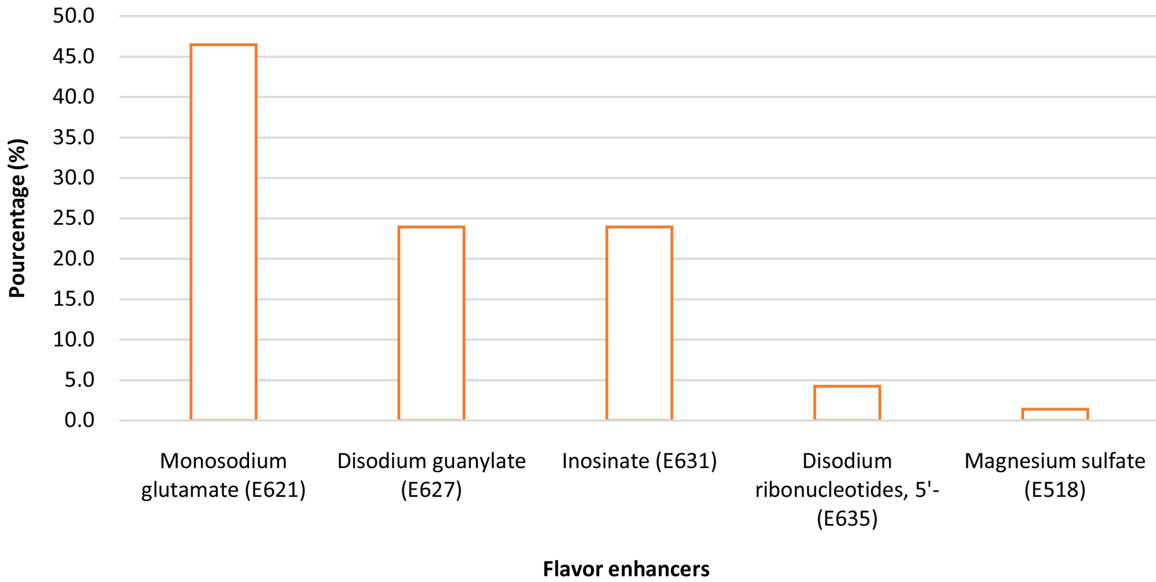

Figure 2. Flavor enhancer additives identified in food products collected from retail outlets.

3.2. Identified Sweetener Additives

The results of our work show the presence of 12 sweeteners on the labels of the industrial products collected (**Figure 3**). In terms of frequency, the four substances most frequently found on food products are acesulfame potassium (27%), sucralose (21%), aspartame (17%) and saccharin (10%). These sweeteners are followed by sorbitol (8%) and steviol glycoside (5%). Other sweeteners such as cyclamates (3%), maltitol (3%), isomalt (1%), lactitol (1%) and neohesperidine dihydrochalcone (1%) are identified on only a few products.

The use of sweeteners was noted on around fifteen different food products (**Table 2**). These identified sweeteners are classified into 2 groups according to their origin. On the one hand, we distinguish natural sweeteners made up of sorbitol, lactitol, sucralose, isomalt and steviol glycoside. Sorbitol (E420 (i)) is found in 4 food products: cookies, cereals, chocolate and hard confectionery. Isomalt (E953) is only present on one cookie sample. Sucralose (E955) is found on the widest range of products. In fact, this substance was identified on 7 food products, including beverages, an ice cream, a potato chip and a sauce. Neohesperidine dihydrochalcone (E959) is identified on the label of a fruit juice. Steviol glycoside is present in 4 samples, including drinks and sauces. Maltitol (E965 (i)) is present on cookies and a dessert. Lactitol was only identified on one cookie sample. On the other hand, we noted the presence of synthetic sweeteners made up of acesulfame, aspartame, cyclamate, saccharin and neotame. Acesulfame potassium (E950) was identified on beverage samples and a cookie. The presence of aspartame (E951) was noted on 16 samples, including beverages and a chewing gum. Cyclamate (E952) is identified on beverage powders and a fruit juice. Saccharin (E954) is identified on 3 beverage samples. Neotame (E961) is found on a sweetened beverage.

Table 2. Types of sweetener additives identified on products sold in Dakar markets.

Sweetners	Food products concerned
Sorbitol (E420 (i))	Cookie Cereal Chocolate Hard candy
Acesulfame potassium (E950)	Cookie Powdered drink Soft drink Sweetened beverage Fruit juice Fruit nectar
Aspartame (E951)	Powdered drinks Soft drinks Sweetened beverage Chewing gum Fruit juice
cyclamates (E952)	Powdered drink Powdered drink Fruit juice
Isomalt (E953)	Cookie
Saccharins (E954)	Powdered drink Soft drink Fruit juice
Sucralose (E955)	Soft drinks Sweetened beverage Ice cream Fruit juice Fruit nectar Potatoes Sauce
Neohesperidine dihydrochalcone (E959)	Fruit juice
Steviol glycosides (960)	Sauce Soft drinks Fruit nectar
Neotame (E961)	Sweet drink
Maltitol (E965 (i))	Cookie Dessert
Lactitol (E966)	Cookie

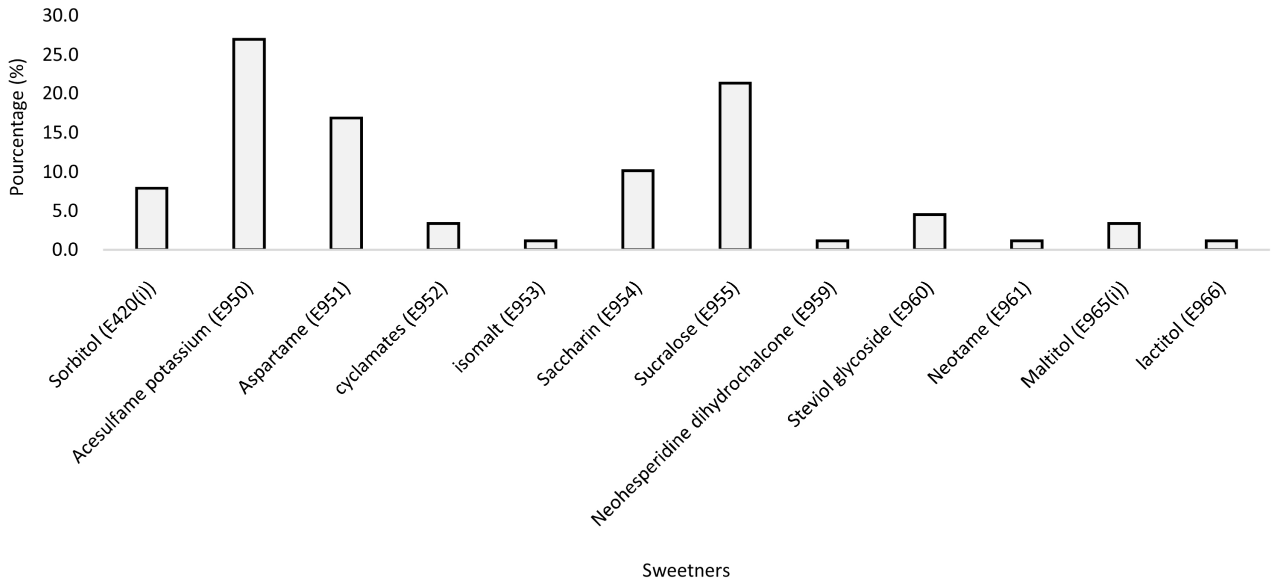

Figure 3. Sweetener additives identified in food products collected from shops.

3.3. Combination of Enhancer and Sweetener Additives

Some product labels show the simultaneous presence of food sweeteners (**Table 3**). In fact, the number of sweeteners in the same product varies from 2 to 4 in cookies, fruit nectars and juices, soft drinks and beverage powders.

4. Discussion

This study shows that all the additives listed are qualitatively considered suitable for use in foodstuffs, as they comply with the general standard for food additives [23]. As regards the flavour enhancers identified in this study, monosodium glutamate (MSG), present on various labels, is by far the most widely used substance in the food industry [30]. According to the statistics website Planétoscope, every second in the world, more than 63 kilos of MSG are produced and consumed; this corresponds to 2 million tons per year [11]. However, this substance is the subject of much dispute and controversy. Studies have often associated the administration of monosodium glutamate with numerous pathologies, including cardiotoxicity [31], hepatotoxicity [32], neurotoxicity [33], attention deficit and behavioral disorders [34] and cancer [35]. However, these claims are challenged by other researchers such as Zanfirescu *et al.* (2019), who identify 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]. According to this author, many of the negative health effects allegedly caused by monosodium glutamate have little relevance to chronic human exposure, and are uninformative because they are based on excessive dosing that does not correspond to levels normally consumed in food products. Furthermore, according to Awuchi *et al.* (2020), despite anecdotal reports of monosodium glutamate exacerbating asthma or triggering headaches,

Table 3. Association of sweetener additives in food products collected from markets.

Type of combination	Produits (nombre)	Edulcorant	N˚INS (*)
4 sweetners	Powdered drinks	Aspartame	951
		Acésulfame de potassium	950
		Cyclamates	952
		Saccharine	954
3 sweetners	Fruit juices	Dihydrochalcone de néohesperidine	959
		Sucralose	955
		Acésulfame de potassium	950
	Powdered drinks	Aspartame	951
		Cyclamates	952
		Acésulfame de potassium	950
	Soft drinks	Aspartame	951
		Acésulfame de potassium	950
		Saccharine	954
	Soft drinks	Acésulfame de potassium	950
		Glycoside de stéviol	960
		Sucralose	955
	cakes	Maltitol	965 (i)
		Lactitol	966
		Acésulfame de potassium	950
2 sweetners	cakes	Maltitol	965 (i)
		Isomalt	953
	Fruits juice	Cyclamates	952
		Saccharine	954
	Sweet drinks	Sucralose	955
		Néotame	961
	Soft drinks Fruits nectar Fruits juice	Acésulfame de potassium	950
		Sucralose	955
	Soft drinks	Sucralose	955
		Aspartame	E951
	Soft drinks Sweet drinks	Aspartame	951
		Acésulfame de potassium	950
	Soft drinks	Sucralose	955
		Aspartame	951

(*): International Numbering System for food additives.

the FAO/WHO Expert Committee on Food Additives (JECFA), the American Medical Association (AMA), the European Community's Scientific Committee for Food (ECSCF) and the National Academy of Sciences (NAS) have all affirmed the safety of monosodium glutamate at normal consumption levels [37]. The Codex Alimentarius General Standard on Food Additives, on the other hand, recommends compliance with Good Manufacturing Practice (GMP), but does not set a maximum limit for monosodium glutamate [23]. Other flavour enhancers identified in the samples collected are often used in foods in combination with monosodium glutamate. In such cases, the aim is often to achieve a synergistic effect, particularly in terms of taste. For example, the characteristic taste of monosodium glutamate and 5'-ribonucleotides is called "umami". This taste has been discovered since 1908 by Japanese researcher Kikunae Ikeda [38]. Thus, disodium 5'-ribonucleotide, composed of disodium 5'-inosine (IMP) and disodium 5'-guanosine (GMP), is an important food additive always been used together with monosodium glutamate to synergistically enhance the delicate flavor [39]. This flavor can be found in foods such as meat, poultry, fish and other seafood, dairy products or vegetables [39]. Bouillon cubes collected contain a good proportion of these flavor enhancers, and are widely produced and consumed in Senegal. Furthermore, according to the ANSD, preparations for soups and bouillons accounted for 2.9% of Senegal's total foreign sales in 2021, with a value of 84.3 billion FCFA, and ranked ninth among the most exported products [36] [40]. Senegal's main customers in the same year were Mali (33.9%), the Republic of Guinea (11.6%), Niger (9.4%), Gambia (8.9%) and Nigeria (6.2%) [40].

As far as sweeteners are concerned, the substances found on samples of industrial food products in the Dakar markets are highly diversified. Their use depends on technological, nutritional or even economic objectives. In this sens, sorbitol, found in the products analyzed, is a bulking sweetener with a sweetening power 2 to 3 times lower than that of sucrose. Often combined with other sweeteners, sorbitol is the polyol most commonly used in the USA as a standard sweetener in many sugar-free chewing gums and medicines [41]. Used in the manufacture of food products such as confectionery, sorbitol has the advantage of a low cariogenic effect compared with table sugar [41]. Acesulfame, the sweetener most frequently found in samples, is 200 times sweeter than sucrose and is non-energetic. It is one of the most common sweeteners in foods, particularly in baked goods, frozen desserts, candies, drinks and cough drops [11]. Aspartame is a synthetic dipeptide whose sweetening power is 180 to 200 times greater than that of sucrose. It is the most widely used artificial sweetener, notably in soft and powdered drinks, beverages, medicines and personal care products [16]. Aspartame is also one of the world's most widely used artificial sweeteners, used in over 5000 food products worldwide [42]. This sweetener has proved a valuable addition to the fast-growing low-calorie food sector, enabling the formulation of "light" foods whose organoleptic properties are very similar to those of high-calorie food products [43]. The availability of aspartame makes it the sweetening agent of choice for food manufacturers. This artificial sweetener adds a highly pronounced sweetness to foods and beverages. In addition to its use as a sweetening agent, aspartame enhances and prolongs certain food and beverage flavors, particularly acidic fruit flavors [44]. In 2021, the global sweeteners market size was valued at USD 79.01 billion, and is expected to develop at a compound annual growth rate (CAGR) of 2.4% from 2022 to 2030 [45]. Cyclamate, found on various beverages and beverage powders is characterized by its high sweetening power (30 to 50 times) and low price compared with sucrose. It is widely used in the food industry in over 40 countries and regions worldwide [46]. Saccharin (1,1-dioxo-1,2-benzothiazol-3-one) is 300 times sweeter than sucrose. It is not metabolized in the body and has the advantage of being heat-stable, which facilitates its use in thermal food processing [47]. Sucralose is 600 times sweeter than sucrose, non-nutritive and highly soluble in water. According to JECFA, sucralose can be used in beverages, dairy desserts, as well as in high-temperature processed products such as cooked or fried vegetables, cooked fruits, fine bakery products and mixes, bread and everyday bakery products [48]. The neotome, not very common in the samples, is a highly potent sweetener (6000 to 10,000 times that of sucrose) offering a clean sweet taste, with a good flavor profile and consumer acceptance [49]. Steviol glycosides, identified on industrial drinks and sauces, are the secondary metabolites responsible for the sweet taste of stevia (*Stevia rebaudiana*) and are synthesized by the steviol glycoside biosynthetic pathway operating in the leaves [50]. These natural sweeteners are non-mutagenic, non-toxic, antimicrobial and do not present any remarkable side effects when consumed [50]. In the case of maltitol, its use in confectionery reduces the abundance of several bacterial species [51]. Lactitol shows beneficial effects on the composition of the intestinal microbiota in constipated patients [52] and could be a promising prebiotic candidate for patients suffering from constipation. The study also revealed a relatively high incidence of artificial sweeteners in industrial foodstuffs in Dakar markets. These sweeteners present a benefit insofar as they provide a sweet taste, increase the palatability of foods without the added sugar and resulting calories, making them an important adjunct to weight-loss and weight-loss diets [53]. On the other hand, the negative effects of these sweeteners raise many questions in the scientific community. Indeed, several studies suggest that some of these artificial sweeteners may have negative impacts on human health. In terms of health, studies have shown the potential negative effects of aspartame on health, such as its involvement in the development of tumours and cancers [42]. However, the rumors and cancer risks noted in certain animal and in vitro experiments are rejected by many epidemiologists and legislators. It is in this context that the American Cancer Society states that the results of epidemiological studies on the possible links between aspartame and cancer (including blood-related cancers) have not been consistent [54]. In addition, an EFSA risk reassessment study commissioned by the European Commission concluded that "aspartame and its breakdown products are safe for the general population" [55]. Acesulfame has been associated with increased risks of causing diseases such as diabetes and cancer [56]. However, as with aspartame, saccharin and sucralose, acesulfame potassium is authorized as a food additive by several regulatory authorities, such as the FDA in the USA [57]. In addition, a question arises concerning the potential risks associated with mixing sweeteners in food products. In this context, the results of a large-scale cohort study suggest a potential association between increased consumption of artificial sweeteners, including aspartame, acesulfame potassium and sucralose, and an increased risk of cardiovascular disease [58]. These various controversies and confusion point to a constant reassessment of the safety of intense sweeteners are widely used in the food industry. Thus, a call for data to assess genotoxicity has been launched by EFSA from June 2021 to March 2022 to submit documented information relating to the re-evaluation of acesulfame K (E 950), aspartame-acesulfame salt (E962), isomalt (E 953), sucralose (E 955), neohesperidine DC (E 959), neotame (E 961), lactitol (E 966), xylitol (E 967) and cyclamates (E 952 i, ii, iii). This call was to assess the genotoxicity of sweeteners (EFSA) from June 30, 2021 to March 31, 2022 [59]. In view of the potential health risks, a reduction in the consumption of artificial sweeteners is recommended [60]. In addition, the identification of natural sweeteners with favorable effects on body weight and metabolism could help achieve the current recommendations for restricting the consumption of simple sugars [60]. In this context, numerous studies have been initiated to find natural alternatives for both flavour enhancers [61] and sweeteners [62].

Overall, this pilot study provided a good overview of the presence and diversity of educators and taste enhancers on food labels. However, larger sample sizes and greater diversity are needed to confirm certain results statistically. In addition to possible cases of fraud, information on food labels is not sufficient to assess compliance with maximum concentrations of identified additives. In order to protect consumer health, we recommend unannounced checks based on qualitative analyses, particularly for high-risk additives.

5. Conclusion

This work has enabled us to draw up profiles of sweeteners and flavor enhancers on various food products sold on markets in Dakar. Flavor enhancers, largely dominated by monosodium glutamate, were observed on numerous products, particularly bouillon cubes. More than a dozen natural and artificial sweeteners were also found on a wide range of foods, including beverages. These two functional categories of additives are proving unavoidable in the food industry because of their contribution to taste and aroma enhancement, and consumer acceptability. However, given the many potential health risks associated with these food additives and their high presence in everyday consumer product, it would be advisable to step up their monitoring on the market. In addition, application of the precautionary principle would make it possible to anticipate the impact of these substances on public health. The results of this study could be used in consumers' informations and awareness campaigns. In addition to this study, we need to create national, accessible databases on the various food additives. This would enable them to be used for risk analysis and to reinforce food legislation.

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Conflicts of Interest

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

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