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Identification of Natural and Artificial Colorants in Industrial Products Marketed in Senegal

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Abstract

Food colorants are widely used in the food industry to maintain or enhance product color. However, as the use of these colorants can have negative impacts on health, it is essential to analyze the risks associated with their consumption. This analysis requires, among other things, obtaining sufficient data on the presence of these colorants in foods, as well as their level of consumption. However, data on these colorants is often virtually non-existent in developing countries. The aim of this study was to determine the colorant profile of industrial products marketed in Senegal. Information on food additives was collected on 399 labels of different food product categories in shops located in Dakar. Data is recorded and processed using Excel software. Based on the Codex classification, analysis of the profile of additives identified on the labels of food samples revealed the presence of 31 colorants. The natural colorants identified are dominated by beta-carotene, widely present in beverages and dairy products, and paprika extract identified on cookies and industrial sauces. Artificial colors are dominated caramels present in several foods including bouillons, vinegars, sauces and hard candies. Secondly, there was a strong presence of the azo dye Sunset yellow FCF, widely found in samples of beverages, confectionery and cookies. The results of this case study enable us to appreciate the wide presence and diversity of colorants on the Senegalese market, and the importance of controlling them to guarantee consumer safety.

Keywords

Colorant, Artificial, Natural, Food Additives, Food Safety

1. Introduction

Over the last few decades, new processing techniques and strong demand for industrial products have led to the production of many food colorants. These substances can be of natural origin, such as saffron, anthocyanins and chlorophyll, or of artificial origin, such as indigotine, citrine red or amaranth. The food industry often uses synthetic chemistry [1] and biotechnology [2] to increase the production of these colorants. Colorants are food additives used to improve the appearance and nutritional quality of foodstuffs. However, these substances can sometimes present health risks for consumers. These risks are generally greater in the case of artificial colorants, which have been introduced to the market often because of their high stability and low economic cost [3]. In this respect, a survey has shown that, although natural colorants are the most suitable, artificial colorants are the most widely used by the food industry, as they have high stability, uniformity in the color imparted to foods, high coloring power, freedom from microbiological contamination and, what's more, relatively low production costs, [4]. However, compared with natural colorants, the use of artificial colorants is limited by the relatively greater risks associated with their consumption [5]. In fact, artificial colorants have a certain toxicity and are associated with numerous pathologies [5], which is of great concern to consumers [6]. This situation justifies the importance of food controls and inspections based on standards, whose development and constant revision require factual data for risk analysis. In addition, the public should have more information on the risks associated with consuming products containing these colorants. In fact, there is a lack of knowledge about these colorants and the negative perceptions generally attributed to food additives [7] [8]. It is in this context that this study focuses on the identification of colorants used as food additives on products marketed in Senegal. Dakar was chosen for this study because of its central position in the import, production, and distribution of industrial food products. The aim is to highlight the profile of these colorants, their uses and their potential impact on consumer health.

2. Materials and Methods

The survey was carried out using a smartphone equipped with a digital camera for photographing product labels and a computer for data recording. The samples were made up of various food products 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 [9]. 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 of collecting this information from food product labels at various randomly selected points of sale, namely neighborhood stores, mini-markets, markets and supermarkets. Data collection was carried out in Dakar, with the owners' approval, at 9 stores, 2 wholesalers, 4 petrol station minimarkets and one supermarket, to obtain a diverse range of products. The data collection process involved checking whether the product contained at least one food additive of any type, to determine both the colorant profile and the proportion of all food additives in the listed products. To this end, a photo of the ingredients and the product name on the packaging was taken to avoid duplication. This methodology is based on the identification of food additives from information on food packaging, as adopted in several studies [10]. Indeed, 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. Similarly, the General Standard on the Labeling of Prepackaged Foods specifies that the full list of ingredients is a mandatory requirement on labels [11]. Statistical data processing is carried out using Microsoft Excel (Version 2016). A qualitative approach was applied to identify the coloring profile of food products. The names of the substances on the labels and, above all, the indication of the function sought by the manufacturers made it possible to find the additives in question by referring to the table in section 3 of the Codex standard on “Class Names and the International Numbering System for Food Additives” [12]. Identified colorants were then grouped according to origin or method of synthesis into natural and artificial colorants.

3. Results and Discussion

3.1. Frequency of Colorants in Collected Products

A total of 399 food packaging labels recording the presence of a colorant were evaluated during our investigations. The various products concerned belonged to 15 food categories according to the Codex Alimentarius classification [9]. They include beverages (18.5%; N = 74), broths, soups and sauces (18.3%; N = 73), fruits and vegetables (10.8%; N = 43), confectionery (10.2%; N = 40), bakery products (8.5%; N = 34), cereals and cereal-based products (7.5% ; N = 30), milk and dairy products (6.3%; N = 25), meat and meat products (6%; N = 24), infant formula (3.3%; N = 13), ready meals (2.2%; N = 9), ice cream (2%; N = 8), syrups (1.3%; N = 5) and canned fish (0.7%; N = 3). The results revealed the presence of 32 different colorants. These were distributed very variably across the different food categories (**Figure 1**).

Beverages are the food category with the most colorants. Sixteen different colorants were identified. In this food category, up to seven different colorants were observed in soft drinks, and three in both fruit juices and powdered drinks. In nectars, concentrates and other beverages, one or two types of colorants may be encountered. Sauces and cookies come in second place, with six and seven colorants respectively identified on the labels of these food products Broths and syrups can record the presence of 3 and 4 different types of colorants respectively. On the other hand, some food products, such as fish and infant formula, were

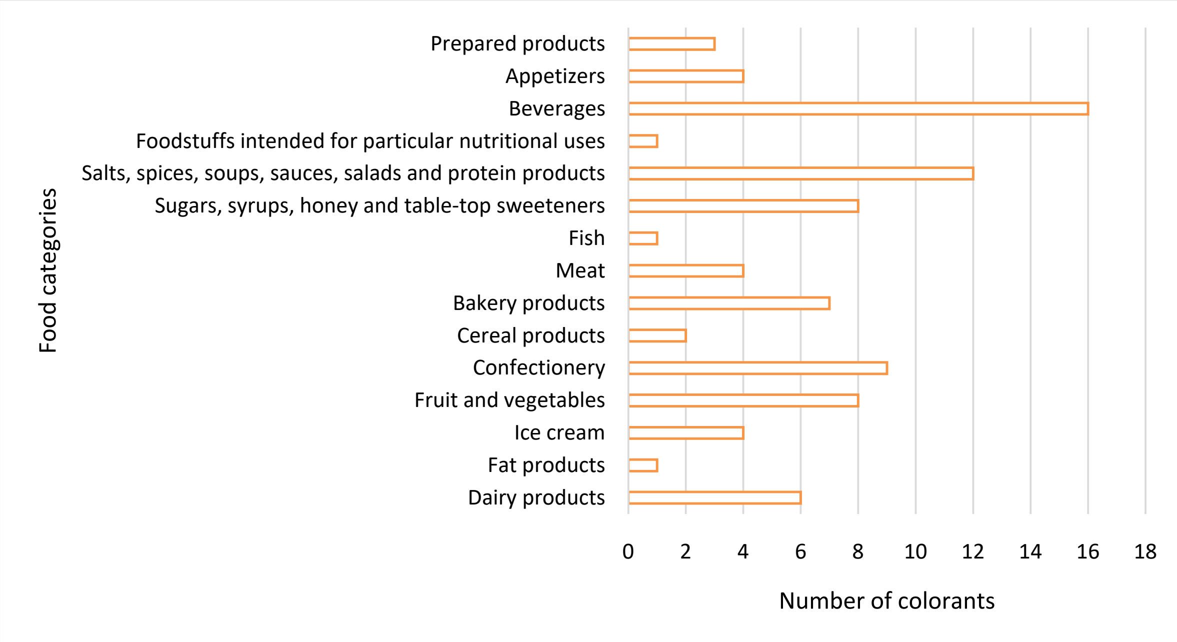

Figure 1. Number of color additives found in different food categories.

found to contain just one colorant. What's more, certain substances that can be used as colorants are sometimes assigned other functions by manufacturers. This is the case with sodium nitrates and nitrites, present on the labels of certain products, which act as preservatives. However, in the case of a food additive fulfilling several functions, the general standard on food additives stipulates that it is the responsibility of the manufacturer to specify the intended function on the label [9]. On other samples taken from the market, we noted the absence of colorants on the labels, sometimes with the words "no colorants added". This was the case with the egg products we encountered, where no colorants were identified. The survey also revealed the presence of 15 natural colorants and 16 artificial colorants on all the food products surveyed. However, artificial colorants are the most common on these products. In fact, of the 399 products concerned, artificial colorants appeared on 121 labels, while natural colorants were found on only 98 food labels. This trend is also noted in a number of studies which point to the strong presence of artificial colorants on food products at market level [13].

3.2. Natural Colorants Identified

The 15 natural colorants identified in all the food samples surveyed are listed in **Table 1**.

This group of colorants is dominated by beta-carotene and paprika extract, but also includes the strong presence of turmeric, carmine and lutein. β-carotene (E160a(i)) is found in 7 food categories. This colorant is found in fruit juices, margarines, flavored milks, fruit concentrates and juices, cookies, milk powder, yogurt, mayonnaise, salad dressings, sauces, cereals and butter. It's a natural

Table 1. Natural colorant additives identified in food products label sold on the Senegalese market.

	Natural colorants	Number of appearances	Main foods concerned
1	Anthocyanines (E163)	1	Soft drinks
2	Carotenes, beta-, synthetic (E160a(i))	32	Fruit juice; Margarine; Flavored milk
3	Titanium dioxide (E171)	5	Powdered beverage; Sweetened beverage
4	Carmine (E120)	7	Cookie; Soft drink
5	Carotenal, beta-apo-8'- (E160e)	3	Juice concentrate; Soft drink
6	Chlorophyllins, copper complexes, potassium and sodium salts (E141(ii))	2	Milk powder
7	Turmeric (E100ii)	10	Prepared dish; Mustard; Mayonnaise; Mashed potatoes
8	Paprika extract (E160c(ii))	17	Potato; Sauce
9	Annatto extracts, bixin-based (E160b(i))	1	Flavored milk
10	Annatto extracts, norbixin-based (E160b(ii))	4	Potato; Sauce
11	Lutein (E161b)	7	Canned fish; Vinaigrette
12	Paprika oleoresin (E160c(i))	1	Potatoes
13	Iron oxides (E172)	2	Cookie; Infant formula
14	Riboflavin (E101)	4	Soft drink; Powdered drink
15	Beet red (E162)	2	Cookie; Processed meat
	TOTAL	**98**	-

pigment belonging to a group of over 600 compounds known as carotenoids. Generally derived from synthesis, β-carotene is recently being produced in biotechnology, as bioactive compounds of natural origin reveal higher bioaccessibility and greater consumer confidence in the market [14]. Beyond contributing to food coloring, β-carotene is sought after for its many health benefits such as reducing the risk of heart disease and certain types of cancer, improving the immune system and protecting against age-related macular degeneration, the leading cause of irreversible blindness in adults [15]. Paprika extract (E160c(ii)) comes in second place, appearing in several food categories, including sample labels for potato snacks, industrial sauces and ready meals. This colorant comes from the fruit pods or seeds of the red bell pepper plant known as Capsicum annuum. The two pigments responsible for its red color are capsanthein and capsorubin. Used as a natural colorant in foods such as chocolate, in which it enhances color stability and greatly improves bioavailability in the body, with especially strong antioxidant activity [16]. However, paprika extract is highly indexed in adulteration in the coloration of products such as spices and red beet [17] [18]. Turmeric (E100ii) is found in 4 food categories, and in particular in samples of ready-made meals and mustards. Turmeric, also known as turmeric, is a yellow polyphenolic pigment from the rhizome of *Curcuma longa L.* (turmeric), and has been used for centuries for culinary and food coloring purposes, and as an ingredient in various medicinal preparations in Asia [19]. This dye contains curcuminoids and offers health benefits such as induction of endogenous antioxidant defense mechanisms in organisms, anti-inflammatory effects and modulation of gene expression and epigenetic mechanisms [20]. This natural pigment is also heat-stable, making it a good alternative to artificial dyes such as eosin [21]. Carmine (E120), a deep red colorant, is found in 6 food categories. This additive can be found on the labels of samples of cookies, soft drinks, fruit juices, flavored and condensed milk, ice cream and ready-made meals. Carmine is a natural pigment extracted from the cochineal plant and used worldwide to color foods of animal or vegetable origin, such as yoghurt. Although considered safe for human health, carmine can sometimes cause allergic reactions [22]. Carmine (E120) can be fraudulently replaced by Ponceau 4R or 4-amino-carminic acid [23], hence the importance of food control. Luteins (E161b) are found in canned fish and salad dressings, condiments, mayonnaise, sauces, salad dressings, potato snacks and canned fish. This natural xanthophyll pigment is recommended for the prevention of cancer, cardiovascular disease and retinal degeneration [24]. In addition, luteins are said to have enormous potential for combating neurological disorders, eye disease, cardiac complications, microbial infections, skin irritation and bone decay [25]. Annatto extracts, colorants of plant origin, are also found in food products. These include norbixin-based annatto extract (E160b(ii)) found on potatoes and bixin-based annatto extract (E160b(i)) observed on flavored milk. Bixin and norbixin are the main components of annatto colorants, which impart a red to yellow hue to food products. [26]. Furthermore, annatto is one of the most sought after natural colorants in the food industry due to its availability, affordability and viability [26]. These investigations also revealed the presence on the market of titanium dioxide (E102). This highly controversial mineral colorant is found on the labels of samples of instant powdered drinks, sweetened drinks, soft drinks, fruit juices, chewing gum, potato chips, syrup and edible ice. Titanium dioxide (TiO_2) is a chemical substance used as an additive and a material highly prized in industry for its chemical inertness, high availability and relatively low cost [27]. TiO_2, on the other hand, is a highly controversial food coloring agent, said to be responsible for numerous health problems [27]. After several assessments by the European Food Safety Authority (EFSA), its use as a food additive has been banned in the European Union, effective 2021. Indeed, on the basis of all available evidence, a risk of genotoxicity could not be excluded and, given the many uncertainties, the scientific panel concluded that titanium dioxide can no longer be considered safe when used as a food additive [28].

3.3. Artificial Colorants Identified

In addition to natural colorants, the investigations also revealed the presence of 16 artificial colorants on the food labels surveyed (**Table 2**).

Caramels (E150) are the most common colorants found in the various food products sold in retail outlets. What's more, these colorants are widely distributed in food products. In fact, they were identified in all 9 food categories surveyed.

Table 2. Artificial colorant additives identified on the labels of food products sold in shops in Senegal.

	Artificial colorants	Number of appearances	Main foods concerned
1	Amaranth (E123)	1	Chewing gum
2	Brilliant blue FCF (E133)	5	Chewing gum; Syrup
3	Patent blue V (E131)	1	Syrup
4	Caramel I—plain caramel (E150a)	33	Broth; Soft drink; Vinegar
5	Caramel III—ammonia caramel (E150c)	1	Broth
6	Caramel IV—sulfite ammonia caramel (E150d)	19	Broth; Soft drink
7	Indigotine (Indigo carmine) (E132)	1	Soft drinks
8	Azorubine (Carmoisine) (E122)	6	Syrup; Soft confectionery
9	Carthamus yellow (E105)	1	Soft drinks
10	Quinoline yellow (E104)	2	Fruit juices; Soft drinks
11	Sunset yellow FCF (E110)	20	Soft drinks; Fruit juices;
12	Ponceau 6R	1	Potatoes;
13	Allura red AC (E129)	4	Chewing gum; Syrup
14	Tartrazine (E102)	16	Chewing gum; Syrup; Soft drink
15	Fast Green FCF (E143)	1	Chewing gum
16	Ponceau 4R (Cochenille rouge A) (E124)	9	Vegetable concentrate; Liquid milk
	TOTAL	121	-

Caramel I—plain caramel (E150a), the majority in this group, is found on the labels of samples of bouillon, soft drinks, vinegar and products such as industrial sauce and syrup. Caramel IV—sulfite ammonia caramel (E150d), is found on samples of broths and soft drinks. Caramel III—ammonia caramel (E150c), was found only on one solid broth sample. Caramel II—sulfite caramel (E150b), on the other hand, was not found on any of the products surveyed. The caramels added to these industrial products contribute to the antioxidant power of foodstuffs thanks to their melanoidin composition [29]. Currently, most international organizations and scientific institutes recognize these caramels, through the numerous scientific results of toxicokinetic, genotoxic, carcinogenic and reproductive and developmental toxicity studies, as safe for consumers if the ADIs are respected [30]. Among the artificial colorants identified, there was a strong presence of azo dyes such as Tartrazine, Sunset yellow FCF, Ponceau 4R (Cochineal Red A), Azorubine (Carmoisine), Amaranth, Brilliant blue FCF and Allura Red. Azo dyes account for almost 2/3 of artificial colorants in the food industry, and are characterized by relatively high toxicity [31]. Indeed, they are associated with conditions such as hypersensitivity and allergic reactions [32]. Sunset Yellow FCF (E110), the majority in this group, is found on the labels of soft drinks, fruit juices, sweet drinks, hard confectionery and cookies. Sunshine Yellow FCF, widely used in the food industry, can cause ADHD, symptoms including hyperactivity in children, and cancer if consumed in excess [33]. This substance may also have cytotoxic and genotoxic potential [34]. Tartrazine (E102) was found in samples of chewing gum, syrups, soft drinks, sweet drinks, potato chips, syrup and ice cream. This azo dye has the advantage of high thermal stability, at least up to 200˚C, which is of interest in industrial processing [35]. However, existing literature and accumulated evidence point to various adverse effects of tartrazine on several organs and health systems. *In vitro* studies have revealed its embryological, cytotoxic teratogenic and mutagenic effects [36]. As a result, the use of tartrazine as a food additive is highly restricted in some countries, such as France, and even banned in others, such as Tunisia and Iran [37]. Ponceau 4R or Red Cochineal A (E124) was observed in samples of vegetable concentrate, liquid milk, and syrup. This azo dye was re-evaluated by the EFSA, in view of the numerous risks it was thought to pose (allergies, hyperactivity in children). Subsequently, maximum use quantities were reduced, and the acceptable daily intake (ADI) was also lowered to 0.7 mg/kg body weight per day [38]. Its wide industrial use in many products is justified by the fact that it is an economical alternative to natural colorants such as carmine (E120), but also by its ability to compensate for color loss in food processing and preservation, cosmetics and pharmaceuticals [39]. Brilliant Blue FCF (E133) is also found on chewing gum and syrup labels. This petrochemically-derived color additive is highly soluble in water, which facilitates its use in food manufacturing processes. However, it is not without risks, as it is said to have potential genotoxic and cytotoxic effects on humans [34]. Carmoisine (E122) was identified in the syrup and soft confectionery samples. Also known as azoburine, carmoisine is an artificial colorant of petrochemical origin derived from coal tar and widely used in the food, cosmetics, pharmaceutical and textile industries. Studies have shown that long-term exposure to azoburine can cause health problems, particularly in children [40]. Foods containing azoburine must therefore be labelled "May have adverse effects on activity and attention in children". In addition, azoburine adversely affects and modifies biochemical markers in vital organs such as the liver and kidneys [40]. Ponceau Red, a synthetic organic colorant found in this study on a label of potato French fries, has been banned in Europe since January 1977 and withdrawn by Codex since 2015. Indeed, like other synthetic colorants such as Chrysoin S, Solid Yellow, Orange GGN, Scarlet GNE, Rouge Ponceau has been removed from the list of food additives for safety reasons [41].

4. Conclusion

This pilot study enabled us to observe the high presence and diversity of color additives on the labels of industrial food products distributed on the Senegalese market. Artificial colorants, dominated by azoic substances, are more frequent on the products surveyed, certainly because of their stability, their high coloring capacity and, above all, their low economic cost. Nevertheless, the presence of natural colorants such as beta-carotene, paprika extracts and turmeric has been noted in several food categories, demonstrating manufacturers' ongoing interest in these substances in line with consumer demand. Most of the colorants identified are authorized by Codex standards, provided that Good Manufacturing Practices (GMP) and maximum authorized concentrations are respected. On the other hand, some additives that are highly controversial or even banned in certain countries are still found on the Senegalese market. This underscores the importance of stepping up health and safety monitoring of industrial products sold on markets in developing countries. On the one hand, the data obtained can be used for risk analysis purposes. Secondly, they can serve as a basis for raising consumer awareness and providing information on food colorants. In addition, it would be interesting to tackle qualitative analyses to verify the accuracy of information or the existence of label fraud.

Conflicts of Interest

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

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