LUISS

Department of Business and Management

Course of Marketing: Market Relationship & Consumer Engagement

Creating Consumer Awareness to Food Additives via A Modified Traffic Light Food Labeling System

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Academic Year 2023/2024

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Chapter 1: Introduction

INTRODUCTION

As consumer trends shift, the American public are paying more attention to what they are putting in their body and have a stronger focus on healthier eating. However, according to a PEW research report, although attention of consumers is focused on healthy eating, behavioral implementation of these practices is lacking (Funk & Funk, 2024). While healthy eating is the goal, the term is subjective in nature and without a full understanding one has no way to know and then implement what healthy eating is. A healthy diet, and healthy eating today means cutting back on food items with high fat, sodium, and sugar content (Grimmelt et al., 2022) and including a mix of fresh fruits, vegetables and wholegrains.

Food items with high fat, sodium, and sugar content, also known as processed foods, are becoming increasingly produced and has led to a drastic shift in dietary patterns and consumption lifestyles (World Health Organization: WHO, 2020). This change in consumption patterns can be attributed to the uptick in obesity and overweight individuals in the U.S, where nearly 1 in 3 adults are overweight and 2 in 5 are obese (*Overweight &Amp;Amp; Obesity Statistics*, 2024). It can also be attributed to the heightened risk for many health problems, including heart disease, types of cancer, diabetes, etc.

With consumption levels of processed food heightened, it is pivotal to note the majority of these food items contain an abundance of food additives, which are utilized to improve the overall appearance, shelf life, and consistency of food products ("Food Toxicology," 2016). However, according to the International Food Information Council's Food and Health Safety report, 34% of respondents found food additives and ingredients including caffeine, MSG, flavors, colors, preservatives etc. as their top issue regarding food safety (International Food Information Council, 2022). This furthers the evidence of a shift in consumer trends, and expanding the need for change regarding how consumers decipher between processed food items.

We are presently seeing a monumental shift in food additive policy in prominent food producing sectors within the United States. Fast food restaurants are one of the main sectors in the U.S. that contribute to an unhealthy diet and offer foods with high contents of additives and preservatives. Burger King, a prominent international fast food chain, has begun to change this narrative with its campaign "Beauty of No Artificial Preservatives". The campaign illustrates their initiative of eliminating harmful food additives in their products by advertising a spoiled burger, a natural phenomenon that occurs a few days after no consumption. This ensures to the public that there are no additives preserving shelf life or product appeal in this campaign. Burger King has acknowledged the shift of health-conscious consumers, and created a marketing campaign to depict a healthy and unaltered burger (Lithos & LithosPOS, 2024).

In a policy setting, some states are beginning to understand the importance of knowing what we put in our body and the health effects they may cause, and take action. The first administrative body within the United States of America to take strict action regarding harmful additives is the state of California. Gavin Newsom, the Governor of California, has passed a law that bans harmful food additives, including a popular food color additive, red dye number 3. The California Food Safety Act, Assembly Bill 418, prohibits the sale, manufacture, or distribution of the food dye, along with 3 other chemical food additives including potassium bromate, brominated vegetable oil and propylparaben (Hernandez, 2023).

It is pivotal to continue to research and explore effective approaches to ensure the consuming body has accurate and transparent information regarding food additives, allowing for the execution of autonomous decision making with respect to healthy eating. A tool that assists consumers with healthier dietary choices is the Nutrition Facts label found on the back of almost all packaged foods in the United States (Christoph et al., 2018). Nutrition Facts are regulated by the Food and Drug Administration and have been required since the legislation passed the Nutritional Labeling and Education Act of 1990 (Pintauro, 2018). In recent years there has been a push to make labels easier to understand with regards to both formatting and content (*Food Labeling: Revision of the Nutrition and Supplement Facts Labels. Final Rule*, 2016).

Two types of food labels, front of pack and back of pack, are present on food packaging. Front of pack labels are designed to attract the attention of consumers, while back of pack labels are present as an informative guideline for ingredients and nutrients present in the food item. In this research we will focus predominantly on front of pack labels, and more specifically that which follows a traffic light system.

The traffic light label system presents nutrient information in a way that illustrates a range of nutrient categories with corresponding colors. Traditionally, the four categories are fat, saturated fat, sugar, and salt levels in a product. The corresponding colors are “red” indicating a high level of that nutrient, “orange” indicating a medium level, and “green” indicating a low level of nutrient (Sacks et al., 2009). While there is ample research on traffic light food labels, mostly residing in the United Kingdom and Ecuador, continued research is needed for the United States.

While traditional food traffic labels focus on nutrition facts, my research focuses on the effectiveness of using a modified traffic light food labeling system in increasing consumer awareness of food additives. While the traditional system focuses on nutritional content—such as fat, sugar, and salt—this research will assess how well it can communicate the presence of additives in common food products. To what extent a modified traffic light food labeling system, designed to communicate the safety of food additives, improves consumer awareness and influences healthier purchasing decisions compared to traditional nutrition labels in the U.S. will be explored through this research.

My literature review will give a comprehensive background on common food additives, their history, and their present cause for concern, while also touching upon governing bodies surrounding the food additive and food label landscape. Then I will explore U.S. consumer perceptions on food additives and the concept of traffic light labels. Finally, I will explore the effectiveness of a modified traffic light food labeling system to a traditional nutrition food labeling system in the context of popular packaged food items in the U.S.

The findings of this research will contribute to ongoing efforts in assisting the American public with making more well-informed and healthy food choices, while also raising awareness about the presence of food additives in our everyday food.

Chapter 2: Literature Review

COMMON FOOD ADDITIVES

The Food and Drug Administration (FDA) defines a food additive as "any substance in which the intended use may, directly or indirectly, affect the characteristic of any food – including any substance used in producing, manufacturing, packing, processing, preparing, treating, packaging, transporting, or holding food" according to Section 201(s) of the Food, Drug, and Cosmetic Act (Program, 2018). It is important to note that these ingredients are typically not consumed as food by themselves, nor are they used as typical ingredients in foods, and that they are substances added to food for the purpose of improving color and quality perceptions, flavor, freshness, or for preservation purposes (Abedi-Firoozjah & Tavassoli, 2024). Common food additives in the scope of this research can be categorized as a coloring additive, a flavoring additive, or a preservative additive.

Color Additives:

Adding color to foods is a long standing custom that dates back to the early Indus Valley civilizations in 3500 BC and became common practice around 1500 BC when natural extracts and wine were supplemented to enhance the appeal and appearance of some food items (Unesco, 2008). The use of artificial food colors in modern practice didn't emerge until 1856, when Sir William Henry Perk discovered the first synthetic organic dye, mauve, marking significant shifts in the world of food color technology (Science History Institute, 2024). 50 years later, the first policy addressing concerns with adulterated foods, including that of artificial colors, was enacted in the 1906 Pure Food and Drug Act. Later the 1938 Food, Drug, and Cosmetic Act established the regulatory framework for food additives that remains in place today.

The presence of color additives in food products serves several purposes. They provide uniformity and consistency in color presentation, compensate for potential color loss during food processing, and impart vibrancy to bland or colorless foods (Program, 2023 & Frick, 2003). Additionally, color additives propose a significant influence over consumers sensory experiences with food, specifically in terms of taste, attraction, perception, and quality (Lehto et al., 2017; Program, 2023; Burrows, 2009).

Color is a critical attribute as it pertains to consumer preferences, selections, and desires of food items (Su & Wang, 2024) and research shows that our experience of taste and flavor is largely determined by our created expectations prior to consumption (Shankar et al., 2010), and thus color creates a psychological expectation that is difficult to overturn (Shankar et al., 2010). Color associations can be argued to be a combination of evolutionary practices and cultural norms. From an evolutionary perspective, animals and human beings alike understand food condition according to its color, a practice dating back to homo sapiens evolution 3 million years ago (Luca et al., 2010). Thus, one could argue that our preference for brighter colored food is credited to our evolutionary adaptation. The color pigmentation of food items like certain meats, fruits, and vegetables can indicate ripeness, while dull and grey items often signal spoil and harm (Luca et al., 2010).

As defined by the Food and Drug Administration, a color additive is any dye, pigment, or substance that can impart color to a consumable product, pharmaceutical, cosmetic, or even the human body (Program, 2023). Color additives fall into two categories: natural sources, which are exempt from certification, and synthetic or artificial sources, which require batch certification. This distinction highlights the difference between substances that are naturally occurring, and those that are chemically synthesized ("Encyclopedia of Food Chemistry," 2019).

Presently in the United States, the FDA has approved nine synthetic food colors additives, all of which require batch certification. Below is an overview of these certified color additives.

Require Batch Certification:

1. **FD&C Blue No. 1**: Also known as Brilliant Blue FCF disodium is an additive known for its coloring agents, which is commonly used in processed foods, pharmaceuticals, dietary supplements, and cosmetics (Shahmohammadi et al., 2016).
2. **FD&C Blue No. 2**: Referred to as Indigo Carmine or indigotine, its molecular formula is C12H19N3O5. It is used in desserts, baked goods, snacks, and dairy products, as well as in medical diagnostics and pharmaceutical formulations ("Food Chemistry," 2021).
3. **FD&C Green No. 3**: Known as Fast Green FCF, this additive is turquoise in color and used in vegetables, jellies, sauces, and baked goods (Pereira et al., 2024).

4. **Orange B**: Once used in sausage casings, Orange B is no longer in use in the United States and has not been certified for the past decade (*Synthetic Food Dyes: A Rainbow of Risks*, 2024 & Arnold et al., 2012).
5. **Citrus Red No. 2**: This color additive is used to dye the skin of oranges but is only allowed for oranges consumed as fresh produce (*Synthetic Food Dyes: A Rainbow of Risks*, 2024).
6. **FD&C Red No. 3**: Known as erythrosine, this pink dye is used in candy, ice pops, and cake-decorating gels. While its use in food and ingested medications remains unrestricted, its application in cosmetics and topical drugs is prohibited (Garg, 2024).
7. **FD&C Red No. 40**: Also called Allura Red AC, this is one of the most widely used synthetic food dyes, found in food, drugs, cosmetics, and even tattoo ink (Oplatowska-Stachowiak & Elliott, 2016).
8. **FD&C Yellow No. 5**: Known as Tartrazine, this dye is used in food products, cosmetics, and pesticides (Oplatowska-Stachowiak & Elliott, 2016).
9. **FD&C Yellow No. 6**: Also called Sunset Yellow FCF, this dye is used in gelatin, frozen desserts, carbonated beverages, and bakery products (Oplatowska-Stachowiak & Elliott, 2016).

Exempt from Batch Certification

It is relevant to point out that colorants exempt from certification frequently originate from plant, mineral, insect, or other naturally occurring origins, embodying naturalness, however not all exempt colors stem strictly from nature (Program, 2023). In the US regulatory framework, there isn't a distinct category for "natural" color additives. Instead, regulations classify color additives simply as either subject to certification or exempt from certification, without differentiation based on their origin as natural or synthetic (*21 CFR Part 170 -- Food Additives*, n.d.). You can view the list of colors that are exempt from batch certification in the charts section labeled table 3.0.

Flavor Additives:

Flavor additive practices can be distinguished throughout history by various cultures and for a plethora of reasons (Wang et al., 2023). The British Museum of History credits the Assyrian Empire, an early Mesopotamian civilization, with the earliest mentioned herb on record as sesame, where it was used as a source to enhance flavor to food, wine, and oil (Parry, 1955). Flavor enhancement through an additive substance is also described in the Holy Bible's Old Testament where it can be noted that spices from the "traffics of the spice merchants" were "employed to make food more palatable" (Parry, 1955). Fast forward to the 1850s, where the first synthetic substance used to flavor candy was created, not from the extract of a fruit, but in a lab and using the chemical compound amyl acetate (Berenstein, 2018). From this discovery, we continue to add and enhance a variety of food items with synthetic food flavoring, spanning from refreshments, confections and jellies, to pasties, syrups and sauces (Berenstein, 2018).

Flavor additives are any substances added to supplement, enhance, or modify the original taste or aroma of food items (*CFR - Code of Federal Regulations Title 21*, n.d). Flavor itself is a multisensory experience of the gustatory, olfactory, and somatosensory systems (Small, 2012), where flavor of a food can only be determined when taste and smell are present (Institute for

Quality and Efficiency in Health Care (IQWiG), 2023) and combined with our individual experiences with food and food products (Myers, 2018).

Flavoring agents are chemicals that impart flavors or fragrances and are added to food to modify its aroma or taste. It is important to note these are the most common type of additives used in foods and have hundreds of variations (World Health Organization: WHO, 2023). The U.S. Food and Drug Administration, FDA, regulates the use of flavorings in food products through the Code of Federal Regulations, CFR, Title 21, Part 101.22. The regulatory agent states that all flavorings used in food products must be safe for consumption and properly labeled (*CFR - Code of Federal Regulations Title 21*, n.d.) According to the FDA, a flavoring additive can be defined as “any substance with the function of imparting flavor, which is used or intended for use in imparting flavor to a food, including any substance that functions in this manner as a result of an interaction with other substances” (*CFR - Code of Federal Regulations Title 21*, n.d.).

Artificial Flavor:

The term artificial flavor, or artificial flavoring is defined by any substance, the function of which is to impart flavor, which is not derived from a spice, fruit or fruit juice, vegetable or vegetable juice, edible yeast, herb, bark, bud, root, leaf or similar plant material, meat, fish, poultry, eggs, dairy products, or fermentation products thereof as defined by the Food and Drug Administration classified in the Code of Regulations Title 21 Section 101.22 (*CFR - Code of Federal Regulations Title 21*, n.d.). Those which constitute an artificial flavor additive can be summarized by the charts proceeding the reference page and titled by Table 4.1-7 which are reflective of substances characterized under SS 172.515 and Table 5.1 which are reflective of substances categorized under section CFR 182.60.

Natural Flavor:

As in opposition, the term natural flavor or natural flavoring means the essential oil, oleoresin, essence or extractive, protein hydrolysate, distillate, or any product of roasting, heating or enzymolysis, which contains the flavoring constituents derived from a spice, fruit or fruit juice, vegetable or vegetable juice, edible yeast, herb, bark, bud, root, leaf or similar plant material, meat, fish, poultry, eggs, dairy products, or fermentation products (*CFR - Code of Federal Regulations Title 21*, n.d.). Those which constitute a natural flavor additive can be summarized by the charts proceeding the reference page and titled by Table 6.1 -reflective of substances characterized under section CFR 182.10; Table 7.1-3 – characterized by substances classified under CFR 182.20; Table 8.1-2 – defining substances under CFR 182.40; Table 9.1 reflecting substances under CFR 182.50; Table 10.1-2 – analyzing the natural substances under S172.510.

Flavor Additive Health Implications:

<u>Brominated Vegetable Oil</u>

Brominated Vegetable Oil is a food additive and emulsifier which is used to stabilize and prevent the citrus flavors from separating in soft drinks and other beverages. Currently, it is authorized for its usage in small amounts, but is not approved to exceed 15 parts per million (Hetter, 2023). Brominated Vegetable Oil, or BVO, was previously listed under the "generally recognized as safe" list, and has since been removed. For now, until the ban gains approval, its usage is limited. Although popular soft drink companies like PepsiCo and Coca-Cola have removed BVO from their products due to on-going concern, it is still used and found in smaller store and discount store-brand soft drinks (Hetter, 2023). The consumption of BVO has shown heart, kidney, and liver damage in pigs (Farber et al., 1976); accumulations of sodium benzoate's derivatives in the heart, liver, fat, and has led to changes in the thyroid and thyroid cells of rats (Farber et al., 1976).

Artificial Sweeteners:

Artificial sweeteners are food additives which mimic the effect of sugar on taste, known as sugar substitutes (Chattopadhyay et al., 2011). Prominent sugar additives in the United States are Aspartame, Acesulfame-K, Neotame, Saccharin, Sucralose, Cyclamate and Alitame. These provide a low calorie high sweetness ratio to consumers (Chattopadhyay et al., 2011). These sugar additives are generally found in sugar packets, soft drinks, candy items, and low calorie food items. The acceptable daily intake of these sweeteners vary from 2mg/kg per day (Neotame) to 50mg/kg a day (Aspartame) (Chattopadhyay et al., 2011). It is important to note that portion sizes have dramatically increased in the last few decades, which has aided to an increase in consumption of many unhealthy food products (Dobson & Gerstner, 2010). The daily limit is arguably impossible to achieve with supersize and gulp size sodas, coupled with other items of aspartame like sugar packets and other artificially sweetened foods. (Chattopadhyay et al., 2011 & Dobson & Gerstner, 2010). As per the World Health Organization, long term usage of artificial sweeteners are linked to an increased risk of type 2 diabetes and cardiovascular diseases (World Health Organization, 2023), as well as the Internation Agency for Research on

Cancer indicating that some artificial sweeteners (Aspartame) can be classified as “possibly carcinogenic to humans” (Marques et al., 2019).

Preservative Additives:

Food preservation methods, both chemical and naturally occurring, have been commonplace for over 8,000 years (Institute for Quality and Efficiency in Health Care (IQWiG), 2023). The ancient Egyptians were among the first to conceptualize the preservation possibilities of salt. Using this knowledge they would draw the bacteria-causing moisture out of foods, then dry the food, ensuring an effective meat storing process without the use of a refrigerator (Henney et al., 2010 & Kamel & Ahmed, 2022). Similar to the ancient relevance of color and flavor additives, food preservatives date back to the time of ancient civilizations (Sen, 2022).

In the ancient Roman empire, sheep and goats were used for meat and sacrificial purposes, and they were known for salting their meat for consumption (Graff, 2017). Forward to more modern times, French confectioner Nicolas Appert discovered the preservation properties of food in airtight glass jars and bottles in 1809 (Christensen, 2023), yet the implications of scientific principles and biological laws weren’t fully understood until Chemist Louis Pasteur coined the term pasteurization in 1865. As the next 100 years progressed, knowledge and innovation regarding bacteria continued, and the first chemical preservations - salicylic acid and benzoic acid- were studied for their inhabitation of bacteria growth (Hugo, 1995).

The need to preserve food for future use is still prevalent in our life in order to maintain the integrity of food products (Msagati, 2012) , improve the quality of food, and preserve food from different types of bacteria or fungi (Sen, 2021). Chemical preservative agents assist with both the deceleration and prevention of bacteria, mold, and yeast growth in food, and contribute to the avoidance of toxin development and spoilage. Chemical preservative agents are defined as any chemical that, when added to food, tends to prevent or retard deterioration thereof. Common salt, sugars, vinegars, spices, oils extracted from spices, and chemicals applied for insecticidal or herbicidal properties are not considered chemical preservative agents (*CFR - Code of Federal Regulations Title 21*, n.d.).

Preservative classification can be split into two class groups: Class I and Class II. Class I preservatives can be characterized by common salt, sugar, dextrose, glucose, spices, vinegar, acetic acid, edible vegetable oils, and honey (Khuntia et al., 2020). Class II preservatives include compounds that are chemically synthesized, such as elements like benzoic acid, sulphureous acids, nitrates of sodium or potassium, nisin, sodium and calcium propionate (Khuntia et al., 2020). Class II can further be classified into three subgroups: antimicrobial agents, antioxidants, and chelating reagents.

Antimicrobial agents – yeast, mold, bacteria - are often used to prevent the development, action, and presence of microorganisms by reducing moisture levels and increasing acidity, thus creating an environment which inhibits growth (Khuntia et al., 2020).

Antioxidants and other antimicrobials help in the preservation process of food through the control of atmospheric oxidation, which prevents the breakdown and reaction with free radicals (Khuntia et al., 2020).

Chelating agents help to bind with metals, which in turn prevents the natural ripening and oxidation process from occurring (Khuntia et al., 2020).

Presently, there are 20 approved chemical preservatives as recognized by the FDA and can be classified as follows: ascorbic acid, erythorbic acid, sorbic acid, thiodipropionic acid, ascorbyl palmitate, butylated hydroxytoluene, calcium ascorbate, calcium sorbate, dilauryl thiodipropionate, potassium bisulfite, potassium metabisulfite, potassium sorbate, sodium ascorbate, sodium bisulfite, sodium metabisulfite, sodium sorbate, sodium sulfite, sulfur dioxide, and tocopherols (*21 CFR Part 182 Subpart D -- Chemical Preservatives*, n.d.).

Preservative Additive Health Implications:

<u>Sodium Benzoate</u>

Sodium benzoate, the salt of benzoic acid, is a widely used food preservative and microbial substance, used in various food products, fruit juices, carbonated drinks, and cosmetics (Zengin et al., 2011), however soft drinks are the predominant dietary source (Tfouni & Toledo, 2002). Sodium benzoate inhibits the growth of bacteria, yeast and mold, and was the first food preservative to be approved by the Food and Drug Administration. It is pivotal to note that these preservatives are listed under the "generally regarded as safe" or GRAS agents by the FDA (Lennerz et al., 2015). Presently, acceptable daily intakes made by the World Health Organization of sodium benzoate reside at 5mg/kg or 0-2.27mg/lb of body weight per day (Nair, 2001). Furthermore, the FDA caps the maximum level in food to be at 0.1% presence (*21 CFR 184.1733 -- Sodium Benzoate.*, n.d.). One must consider that the above mentioned daily intake would require mathematical attention and expertise, as well as great attention to detail with regards to food packaging and labeling. This will further be extended upon later in the research. Sodium benzoate is a perfect example of the importance of updated nutrition labels when pertaining to food additives.

There are a few causes of concern in regards to sodium benzoate. Most notably, it is known for its harmful reaction with ascorbic acid (Vitamin C). When both sodium benzoate and ascorbic acid are present and exposed to heat and sunlight, the formation of benzene occurs (Program, 2022). Benzene is a carcinogen which is associated with blood disorders and leukemia (*Benzene - Cancer-Causing Substances*, 2024). Potassium bromate is an oxidizing agent that is used for its quick, efficient, and economical oxidation process in bread and other baked goods (Shanmugavel et al., 2020). Potassium bromate is a colorless and odorless powder or crystal. The FDA presently allows for 75mg/kg as a daily limit intake on potassium bromate (Nkwatoh et al., 2023). Explained further, this means that 75 milligrams per 1 kilogram of flour, or in U.S. metrics, 1 teaspoon of potassium bromate per 800 cups of flour (*Center for Research on Ingredient Safety*, 2023). Potassium bromate has been classified as a human carcinogen under the classification of many governing bodies (Shanmugavel et al., 2020).. Furthermore, potassium bromate has been linked to toxicity in the liver, bone and blood, cardiac, and kidney regions in mice (Shanmugavel et al., 2020).

NUTRITION LABELS

Nutrition labeling has a purpose of providing consumers in purchasing settings with information about the food product, allowing for consumers to practice autonomous choice in nutritional food selection (Grunert & Wills, 2007). Consumers often understand key and simple terms respective to that of food labeling, but with higher complexity of information that understanding begins to fall. In numerous studies, consumers indicated that informational aids with regard to food items are a useful tool (Grunert & Wills, 2007). The relationship between front of pack and back of pack is important in that back of pack complex information, can arguably be summarized and simplified to create a clear and concise front of pack label, that assists consumers with their overall decision making process (Grunert & Wills, 2007).

Nutrition Facts Label:

Nutrition Facts labels allow consumers to make informed decisions about their food consumption (Roberto & Khandpur, 2014) . The front, back and sides of packaging is often filled with information informing the consumer what the item contains and provides guidance in selecting healthier options (*Understanding Food Labels*, 2024). Nutrition Facts labels have been required on packaged foods in the United States since the Nutritional Labeling and Education Act of 1994 (Christoph et al., 2018 & *H.R.3562 - 101st Congress (1989-1990): Nutrition Labeling And Education Act of 1990*, n.d.). According to the Nutrition Labeling and Education Act (NLEA), a 'Nutrition Facts' label must be displayed and easily identify health related information such as calories, saturated fats, cholesterol, and sodium (Variyam, 2007). Unfortunately, the array of numbers, percentages, and complex-sounding ingredients on these labels often causes confusion to the observer (*Understanding Food Labels*, 2024) Food labels can be characterized as front of pack (FOP) labels and back of pack (BOP) labels.

Back of Pack:

Back of pack labels provide a key source of nutritional information to consumers, however they lack aesthetic appeal. These labels include four main categories: Serving Information, Calories, Nutrients, and Daily Value Percentages.

Serving Size:

Serving information includes both the servings per container/package and the serving size. Serving sizes are provided in units such as cups or pieces, and then followed by a metric amount, typically in grams. Although the serving size is often thought to be a recommendation of how much you should eat or drink, it is actually a reflection of the amount people typically consume (Program, 2024).

Calorie:

Calories are also a prominent factor to be considered on back of pack nutritional labels. A calorie is a unit of energy often used to express the nutritional value of foods. In labeling food products in the United States, a calorie refers to that of a kilocalorie. Thus, 1 food calorie equals 1 kcal, or the amount of energy needed to raise 1kg water by 1 degree of Celsius (Buchholz & Schoeller, 2004). 2,000 calories per day is a typical baseline for consumption amount, however intake can be higher or lower depending on your age, sex, height, weight, physical activity, etc. (Program, 2024).

Nutrients:

Another main component to the BOP nutrition facts label is the list of key nutrients that have an impact on your health. This includes items like total fat content, cholesterol, sodium, total carbohydrate index, protein composition, as well as key vitamins and minerals. Per the FDA, consumers should limit their intake of items high in Saturated Fat, Sodium, and Added Sugar, while striving to increase their intake of dietary fiber, Vitamin D, Calcium, Iron, and Potassium (Program, 2024).

Percent Daily Value:

The Percent Daily Value (%DV) is coupled with each listed nutrient, and informs the consumer of the percentage each nutrient accounts for in a standard 2,000 calories per day diet. A value of less than 5% is considered low, while a value exceeding 20% is considered high (Program, 2024).

Front of Pack:

Front of pack labels on the other hand, offer little nutritional information, however because of their location, these labels are often more noticeable. These labels allow for quick decision making about nutritional content of an item because of the simple, recognizable and interpretable format (Kanter et al., 2018). These labels often offer detail specific nutrients, with noticeable text, symbols, color or logos that promote specific attributes (i.e. hearth health, vegan, gluten free, etc.). (Becker et al., 2015 & Hodgkins et al., 2012). Standardization of front of pack systems has yet to be regulated, despite their popularity. Without cohesive guidance, front of pack formats are often found to be confusing, misleading, and offer manipulative information (Hawley, 2012). Some common front of pack labeling includes health logos, traffic light labeling, and warning labels.

The introduction of front-of-pack (FOP) labeling systems, such as the modified traffic light labeling system I propose, aims to combat the issue of confusing information by providing a more intuitive method for consumers to assess the nutritional quality and safety of food products. In this research, we will focus our attention on a modification of the traffic light system, as it pertains to food additives and their relative cause of concern to consumers. The traffic light system coined its name due to its color scheme usage which describes nutrient content in respect to its level of healthfulness. The traffic light system uses red, yellow, and green indicators to alert customers to the level of fat, sugar, and salt in foods (Office of the Commissioner, 2018), reflected in the images below.

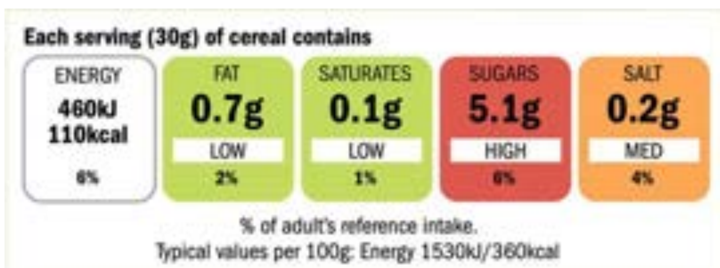


Table 1. Traditional Traffic Light Labeling Sysem, Example 1 (Adapted from World Cancer Research Fund, 2023).

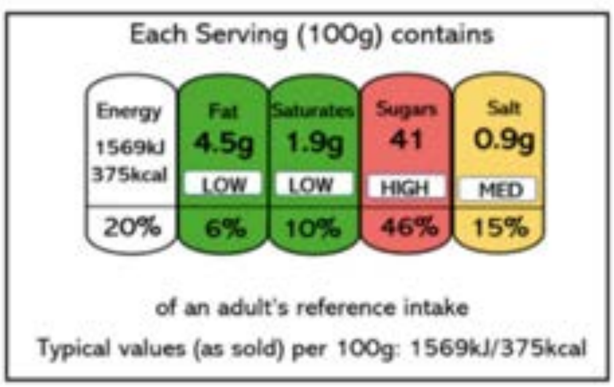


Table 2. Traditional Traffic Light Labeling System, Example 2 (Adapted from Razavi & Xue, 2023).

Numerous studies illustrate that color coded traffic light systems are easily understood by consumers (Becker et al., 2015). While many traffic light systems focus on food nutrients, more specifically the levels of fat, saturated fat, sugar and salt in foods, the focus of this research is to determine if a traffic light system will be effective in the overall consumer understanding of the food additives present in their consumable item.

A significant body of evidence supports the real-world impact of the traffic light system in improving consumer behavior and public health outcomes. For example, a study by Sacks et al. (2009) demonstrated that traffic light labeling helped consumers quickly identify healthier food options, leading to better-informed purchasing decisions. Similarly, studies done by Machín et al. (2017) extend upon nutrition labels portrayal of three important items, motivation, ability, and triggers, and how these effect consumer behavior. The argument here is by emphasizing one of these elements, you can then in turn change the way in which they are perceived (Machín et al., 2017). Machin argues that by using an effective front of pack food label, which highlights the high content of a nutrient that has been linked to negative health conditions, you can in turn increase consumer awareness of unhealthy products and encourage healthier alternatives by using the element of motivation (Machín et al., 2017). In light of my research, the same principles apply. Using the modified traffic light label as a front of pack label, which highlights the level of concern for each food additive ingredient present in a food item, will ideally increase awareness of unhealthy products with cautious food additive elements, and assist consumers with selecting items with less additives present.

While the use of traditional traffic light labels are effective in aiding consumers to healthier decisions with regards to nutritional facts, it is my goal to take this effectiveness and relay it to a more important surfacing issue in that of food additives, and their prominence and ambiguity in US food items.

REGULATION PRACTICES

Food Additive Regulation:

In the United States, the U.S. Food and Drug Administration (FDA) is a scientific, regulatory and public health agency that oversees food products, human and animal drugs, cosmetics, animal feed, etc. (Office of the Commissioner, 2018). The FDA as we know it today dates back to 1906 with the passage of the Federal Food and Drugs Act, which is known for its prohibition of the manufacturing, sale, or transportation of any food, drug, medication, or liquor which is misbranded or poisonous (*The Food and Drug Administration: The Continued History of Drug Advertising | Weill Cornell Medicine Samuel J. Wood Library*, n.d.). This act is credited with the first federal law to address product adulteration, production, distribution, as well as the marketing of food and beverages (Barkan, 1984).

While the 1906 act was a pivotal stepping stone in food regulation practices in the United States, this initiative was flawed with its presumption that food was deemed safe until proven otherwise. This changed with the introduction of the 1958 Food Additives Amendment and the 1960 Color Additives Amendment, which required the FDA to approve food safety prior to consumption and usage. Presently, “food additives” covers 400 of the approximate 2,600 substances intentionally added to foods (National Academies Press (US), 1982). Not included in this criteria are the 500 or so food ingredients termed “Generally Recognized as Safe”, or GRAS.

GRAS:

GRAS, or generally recognized as safe, was a response to the Food Additives Amendment, and created an entire class of substances that are excluded from the food additive definition, which then avoids its mandated premarket approval process (Burdock & Carabin, 2004). GRAS designation is applied when a group of qualified experts agree that a product is known to be safe when used as intended. A clear history of use before 1958 or an assessment of safety must be present to assign this label to a substance (Frestedt, 2018). The FDA is not required to review GRAS substances, such as spices and preservatives, and therefore food manufacturers may determine a substance as GRAS without the FDA's approval or knowledge (*Food Safety:(GRAS)*, 2010).

Delaney Clause:

Another important piece of legislation regarding the regulation of food additives is the Delaney Clause. The Delaney Clause is a clause of the Federal Food, Drug and Cosmetic Act of 1958 and addresses concerns that potentially cancer causing, harmful chemicals were present in foods. (Krishan et al., 2021). There are three Delaney Clauses in the FFDCA, one that applies to food additives, one that applies to color additives, and one that applies to animal drugs (Krishan et al., 2021). The Delaney Clause's vague definition and interpretation, coupled with ongoing advancements in technology and cancer research, make this clause an on-going contention in the world of food additives (Krishan et al., 2021).

Label Regulations:

The late 1960s saw the first legislation changes to nutrition labeling. Prior to this, nutrition labeling was typically voluntary or non-existent (Dumoitier et al., 2019). The Nutrition Labeling and Education Act of 1990 (NLEA), created by the Food and Drug Administration, was the first regulatory practice to communicate present nutrients in packaged foods and allow for consumers to make informed and healthy decisions pertaining to consumption (Dumoitier et al., 2019).

PROCESSED FOODS

Ultra-processed foods and food additives exist everywhere in the modern human diet (Whelan et al., 2024). It is important to note that almost all foods are processed to some extent, for a variety of purposes.

Minimally Processed Foods:

Minimally processed foods, which fall under the category of unprocessed foods, undergo industrial processes such as drying, crushing, grinding, roasting, boiling, pasteurization, refrigeration, freezing, and vacuum packaging. These methods aim to extend the shelf life and facilitate the storage and preparation of various foods, without adding salt, sugar, oils, fats, or other substances (Monteiro et al., 2019). Culinary ingredients derived from minimally processed foods or natural sources, including oils, fats, sugar, and salt, are obtained through processes like pressing, centrifuging, refining, extracting, or mining. These ingredients are used in preparing, seasoning, and cooking foods (Monteiro et al., 2019).

Processed Foods:

Processed foods are created by adding salt, sugar, or other substances to minimally processed foods or culinary ingredients. Preservation techniques such as canning, bottling, and non-alcoholic fermentation (used in products like bread and cheese) are utilized to improve durability and sensory qualities (Monteiro et al., 2019).

Ultra Processed Foods:

Then we have ultra processed foods. These foods are formulations of several ingredients which include salt, sugar, oils, and fats as well as substances not used in culinary preparations such as color, flavor and emulsifier additives (Monteiro et al., 2019) to imitate sensory qualities or to disguise undesirables of the final product (Ares et al., 2016). Ingredients characteristic of an ultra-processed food are those in which you would not find in a kitchen, or have no or rare culinary use (Monteiro et al., 2019). Processes and ingredients used for the manufacturing of ultra-processed foods are designed to be highly profitable products which contain low-cost ingredients and a long shelf life (Monteiro et al., 2019).

Chapter 3: Research

RESEARCH

Through the foundational research, it is evident that navigating the world of food additives and present food labeling systems is complex, and future research needs to be conducted to assist consumers in making informed decisions about the products they purchase, and in turn, consume.

This thesis aims to assess whether a modified traffic light system could be effective in guiding consumer choices regarding common food additives found in processed food items. Traditional traffic light labeling systems typically categorize nutrients such as fats, sugars, and sodium with corresponding colors (red, yellow, green) to reflect healthfulness. However, this research will adapt the traffic light system by expanding the color depth from only 3 colors (red, yellow, and green) to 5 (red, orange, yellow, light green, and dark green). Additionally, the color coding context will no longer reflect red as high level, yellow as moderate level, and green as good level. Instead, the system will expand into how harmful or safe an item is.

The proposed traffic light system would be characterized by a five-level rating scale, adapted from the Center for Science in the Public Interest's Chemical Cuisine Additive Safety Ratings (*CSPI’s Food Additive Safety Ratings*, 2024):

- **Safe**: Indicated by bright green, meaning the additive poses little to no health risk to consumers.
- **Cut Back**: Represented by soft green, indicating the additive is not toxic but should be consumed in moderation due to potential nutritional concerns.
- **Certain People Should Avoid**: Indicated by yellow, suggesting the additive may trigger allergic reactions, intolerances, or other issues for specific groups.
- **Caution**: Represented by orange, meaning the additive may pose risks and requires further testing and research. It is recommended to avoid products with these substances.
- **Avoid**: Marked by red, indicating the additive is unsafe at typical consumption levels or poorly researched. Consumers should avoid buying products with these ingredients.

The Center for Science in the Public Interest has identified 140 chemical additives, listing their names, purposes, and associated health concerns (*CSPI's Food Additive Safety Ratings*, 2024). These will be used as the foundation for categorizing additives within the traffic light system.

The central research question guiding this study is speculation on whether or not a traffic light food labeling system that effectively communicates the presence and risk level of food additives can improve consumer understanding of additives in a food item and in turn influence healthier food selections. By focusing on whether this adapted traffic light system can enhance consumer awareness of additives and influence healthier food choices, this research aims to contribute to ongoing efforts to increase effectivity in marketing food items and improve public health through better food labeling transparency.

Methods

This study utilized a quantitative survey methodology to assess the impact of a modified traffic light labeling system, centered on food additives, on consumer preferences for packaged food items, specifically soda and candy brands. The survey aimed to collect data on how different labeling systems (traditional and traffic light) influence consumer decision-making, with a particular emphasis on ingredients and food additives.

Participants

The target population for this research was adults over the age of 18 residing in the United States. This group was selected due to the limited existing data on their purchasing preferences, specifically regarding the use of traffic light food labels, both in a traditional context and with the added focus on food additives in this study's modified approach. Additionally, this population represents individuals responsible for their own consumption habits, making them a suitable reflection of purchase behavior within the U.S.

The initial sample included 212 respondents. However, after cleaning the data for incomplete responses, non-U.S. residents, and duplicate records, the final sample consisted of 138 valid responses.

The majority of respondents (75.4%, or 104 out of 138) identified as female, with males accounting for 22.46% (31 out of 138), and 2.17% (3 out of 138) identifying as a third gender. The age range of respondents varied, with the largest group (59.4%) falling between 25 and 32 years old. Other age groups represented included 18-24, 33-44, 45-54, and 55+, though these categories had fewer respondents. The estimated average age of participants, based on the provided age ranges, is approximately 27.55 years.

In terms of racial demographics, the sample was relatively homogeneous, with White respondents making up 89.1% (123 out of 138). Other racial identities included Black or African American (3.6%), Asian (4.3%), American Indian (<1%), and Other (2.2%).

Regarding education, 55.1% (76 out of 138) of respondents had completed a Bachelor's degree, followed by 25.4% with a Master's degree, 4.3% with a Doctorate, 3.6% with an Associate's degree, and 11.6% with only a high school education.

Finally, the geographic distribution of respondents was largely concentrated in New York, with 77.5% (107 out of 138) residing in the state. Other states represented included California and Colorado (2.9% each), Minnesota (1.4%), and Texas, North Carolina, Pennsylvania, Illinois, Massachusetts, Maryland, Oregon, and Connecticut, each with one respondent.

Survey

Participants were encouraged to complete the survey at their convenience. The only prior information given was that the survey was part of a master's thesis and would take approximately five minutes to complete. They were assigned to all conditions and questions in the same order.

The survey was divided into four sections. The first section focused on respondents' habits, opinions, and behaviors regarding food additives and nutrition labels as currently found in the U.S. The second section aimed to gauge consumers' awareness of, and appeal toward, a traffic light label system. The final two sections presented practical examples comparing traditional and traffic light labels, using popular soda and candy brands in the U.S.

The survey employed several question formats, including multiple choice, Likert scale responses, open-ended, and non-binary questions. Most questions were multiple choice, as the responses were categorical with limited options (e.g., "Very important," "Unhealthy," "Sometimes"). Likert scale questions, such as Q1 ("How important is the labeling of food additives?"), were used to measure the intensity of respondents' opinions, with classifications ranging from "Slightly important" to "Extremely important." This allowed for clear insights into respondents' preferences, attitudes, and concerns.

The first set of questions explored participants' health perceptions and nutritional awareness. When asked how important a healthy diet is, the most common responses were "Very important" (53.6%) and "Extremely important" (37.0%). This reflects a high level of health consciousness among participants. In a follow-up question, respondents were asked how healthy they perceive the average American diet to be. Most categorized it as "Unhealthy" (61.6%) or "Very Unhealthy" (27.5%), indicating their awareness of dietary issues in the U.S. When asked to identify the unhealthiest aspect of the American diet, 67.9% cited the "high consumption of processed foods," followed by concerns about artificial additives and preservatives (10.9%). This suggests that many respondents see a direct link between processed foods and diet-related health issues, along with concerns about the long-term impact of food additives.

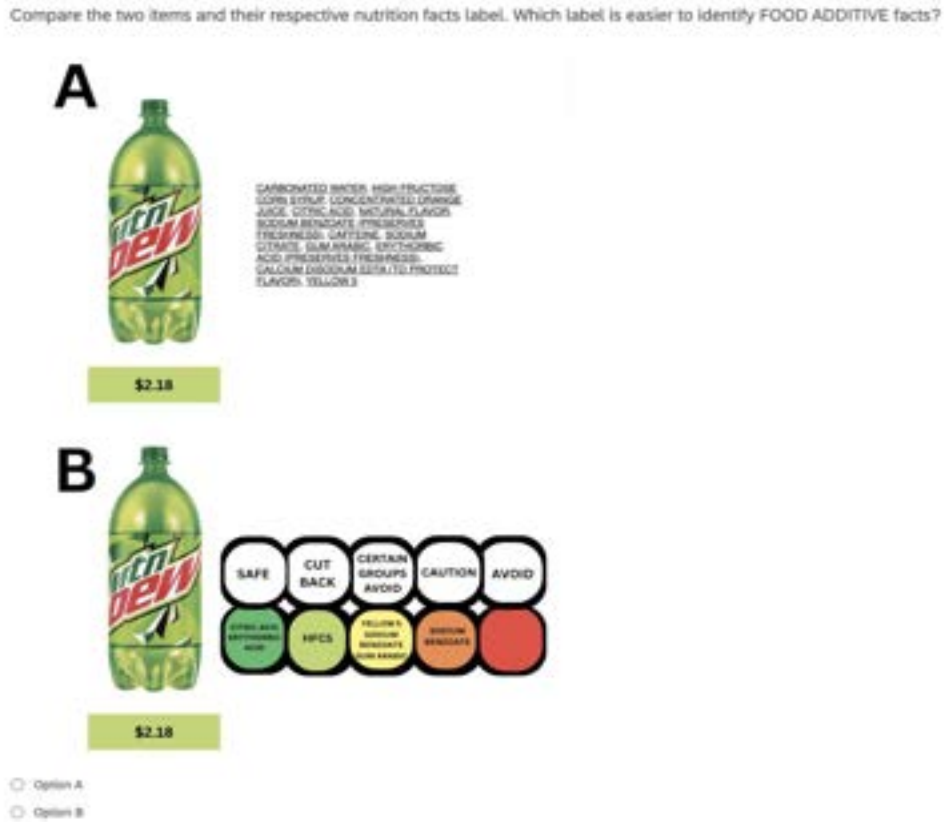
Besides diet and overall health, a collection of survey questions aimed to understand the behavioral background of respondents regarding food labels. In terms of behavior, respondents were asked how often they check the nutrition facts label when purchasing packaged food. Many reported doing so "Most of the time" (32.6%) or "About half the time" (25.4%). This suggests that while consumers are aware of the importance of checking labels, it may not be a consistent habit for everyone, possibly due to external factors like time constraints or a lack of trust in label clarity. When asked about their concerns regarding harmful additives, most respondents expressed being either "Concerned" (50.0%) or "Very Concerned" (21.0%), indicating a high level of concern about the presence of additives in food.

Another set of questions focused on the respondents' appeal toward traffic light labels. When asked to rate the effectiveness of traffic light labels in helping make healthier food choices, the majority selected "Effective" and "Very Effective." Similar ratings were given for the labels' ability to display clear, easily understood information. Additionally, 52.2% of respondents were "Very Interested" and 20.3% were "Extremely Interested" in seeing the traffic light labeling system implemented on more packaged goods. These trends suggest that traffic light labels are a powerful tool for influencing consumer behavior and that there is demand for wider implementation of such labels.

Label Comparisons:

Following the exploratory data, the survey featured two key sections: one comparing a traditional nutrition label with a traffic light nutrition label, and another focused primarily on the traffic light labeling system's effectiveness using popular U.S. packaged food items.

For the traditional nutrition label comparison, participants were first presented with two images of a popular soda brand, Mountain Dew. Next to the soda, where both price and brand remained constant, a traditional food additive label was included (Option A) and the proposed traffic light food labeling system for food additives (Option B). See Figure below.



This section aimed to evaluate the effectiveness of two food labeling systems—traditional nutrition labels and traffic light nutrition labels—in communicating the presence of food additives. Based on the existing literature, which suggests that color-coded labeling systems such as traffic light labels are more intuitive and easier for consumers to interpret (Balcombe et al., 2010; Cecchini & Warin, 2016), it was hypothesized that the traffic light label would be perceived as more effective in conveying information about food additives compared to the traditional label. The hypothesis for this is as follows:

(H_0): There is no difference in perceived effectiveness between the traffic light label and the traditional label in communicating food additives.

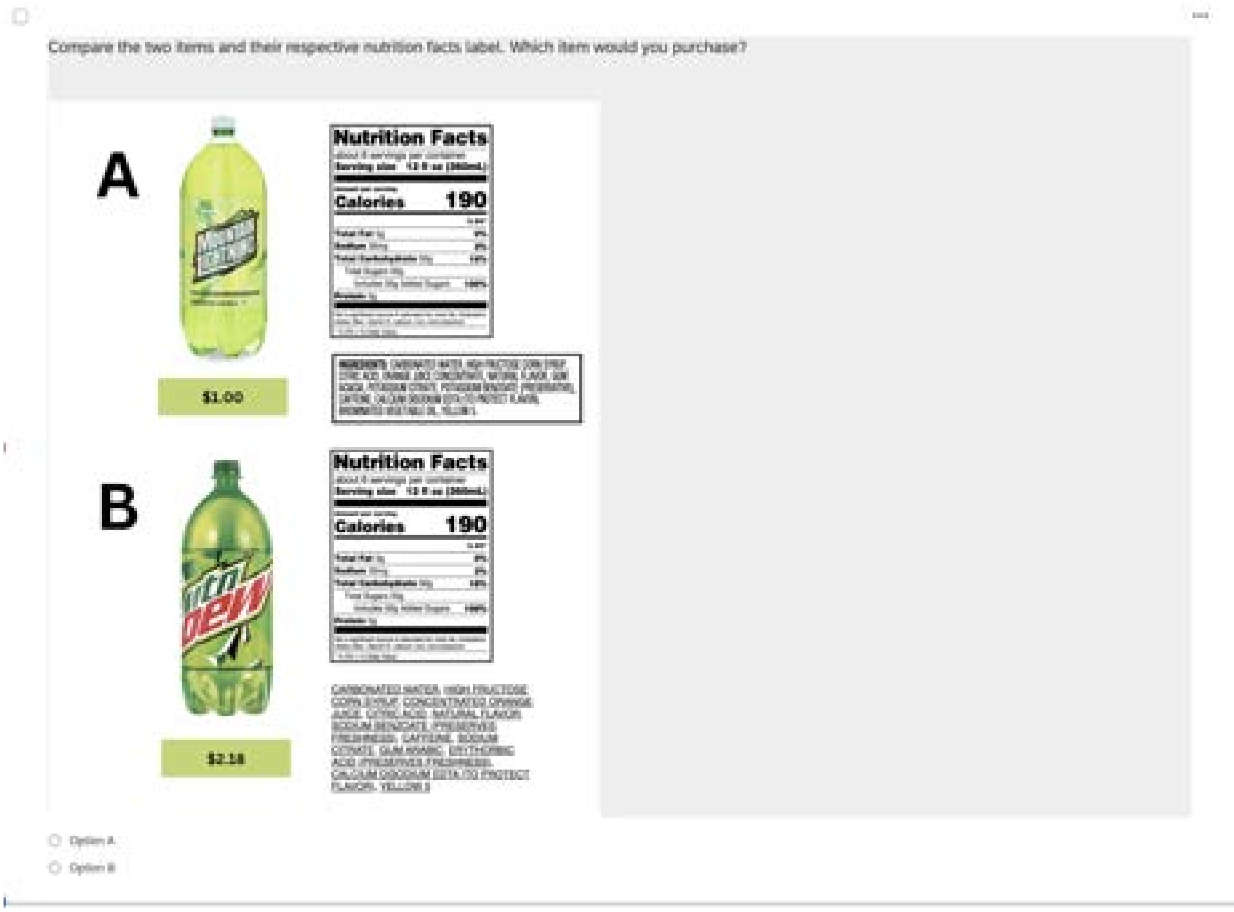
(H_1): There is a significant difference in perceived effectiveness between the traffic light label and the traditional label in communicating food additives.

To assess whether there was a significant difference in the perceived effectiveness of the two food labeling systems (traditional vs. traffic light) in communicating food additives, a chi-square goodness-of-fit test was used. This test was selected because it is designed to compare observed frequencies with expected frequencies under the assumption of no preference between the two labels.

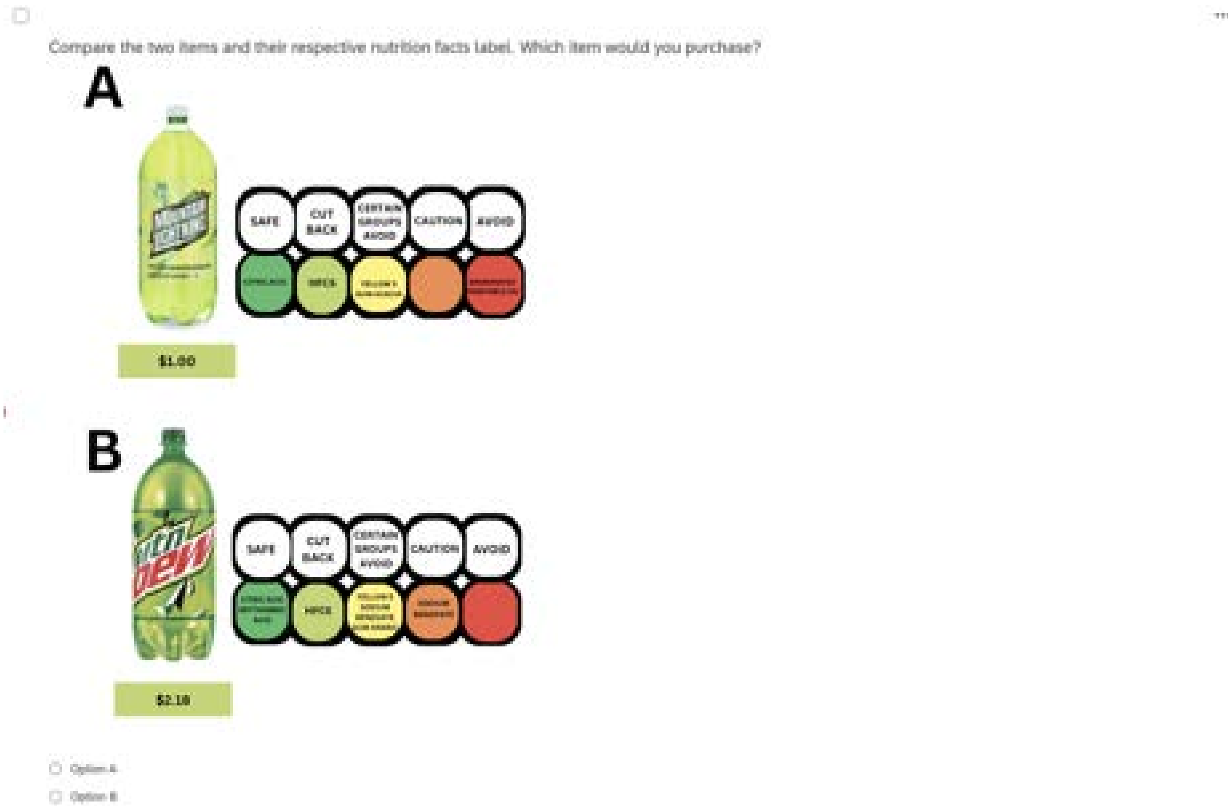
The second main section focused primarily on the traffic light labeling system, a visual representation using colors to indicate the levels of nutrients or additives. This section involved comparing traditional food labels for two prominent soda items, then again with two popular candy brands.

For the soda, the brands used in the study were Mountain Lightning (Option A), a generic, lower-cost soda brand, and Mountain Dew (Option B), a well-known national soda brand. These sodas were chosen due to their similar flavor profiles but contrasting market positions, allowing the study to investigate whether labeling systems could shift consumer preferences between an economy brand and a more recognizable brand.

The first part of the survey presented respondents with the traditional nutrition labels for both soda brands, including information on calories, sugar content, fat, sodium, and other relevant nutrients as mandated by the FDA. Respondents were asked to select which soda they would purchase based on the traditional label information. See image below.



The second part of the survey introduced the traffic light food labeling system, which uses shades of green, yellow, and red to signify the level of concern from safe to avoid. This labeling system was used to visually convey the relative healthiness of each soda option. Respondents were then asked to select their preferred soda based on the traffic light labels.



To determine whether the proportions of respondents choosing Mountain Lightning (Option A) versus Mountain Dew (Option B) differed significantly between the two labeling conditions, a chi-squared test for independence was performed. This test compares the observed frequencies in each group (traditional label vs. traffic light label) to see if the distribution of preferences is significantly different from the expected frequencies under the null hypothesis. The hypothesis for these can be reflected below:

H_0: The traffic light labeling system does not significantly influence the choice of soda.

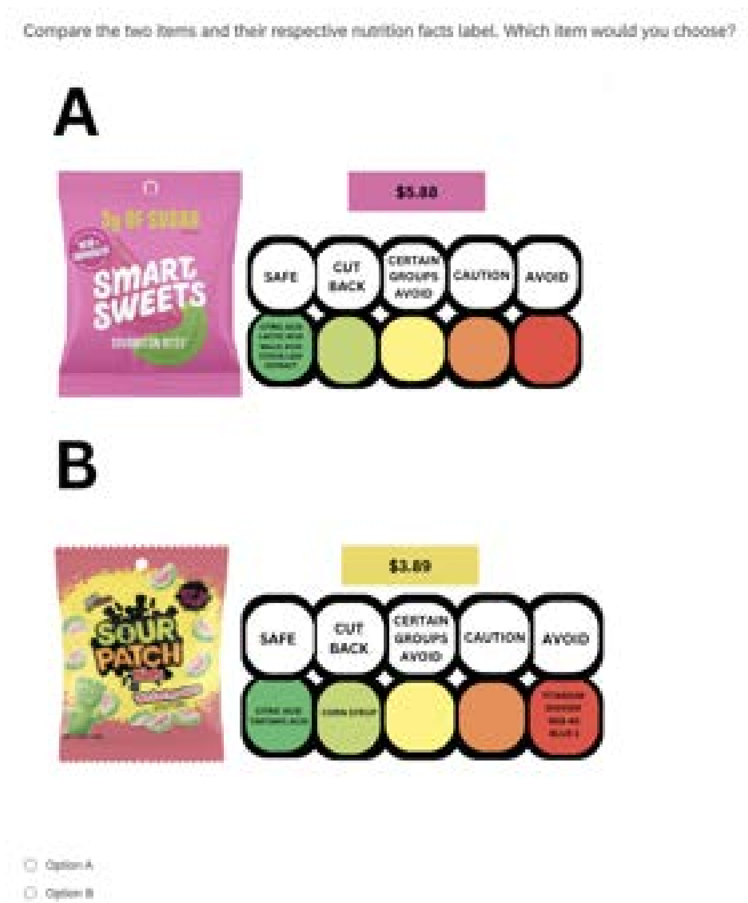
H_1: The traffic light labeling system significantly influences the choice of soda.

This process was then repeated for the candy brands. The two candy brands selected for the study were Smart Sweets (Option A), a low-sugar candy marketed as a healthier option, and

Sour Patch Kids (Option B), a traditional candy with higher sugar content. These brands were chosen because they represent contrasting nutritional profiles, making them ideal for assessing the potential impact of different labeling systems on consumer purchasing behavior.

Again, the first part of the survey presented respondents with the traditional nutrition labels for both the candy brands and were formatted in the standard table format commonly seen on food packaging. See table below.

In the second condition, participants were presented with the same two candy brands, but the nutritional information was displayed using the traffic light label for food additives. For each labeling system, respondents were asked to indicate which candy (Smart Sweets or Sour Patch) they would prefer to purchase.



To determine whether the proportions of respondents choosing Smart Sweets (Option A) versus Sour Patch (Option B) differed significantly between the two labeling conditions, a chi-squared test for independence was performed. This test compares the observed frequencies in each group (traditional label vs. traffic light label) to see if the distribution of preferences is significantly different from the expected frequencies under the null hypothesis. The hypothesis for these are as follows:

H_0: The traffic light labeling system does not significantly influence the choice of candy

H_1: The traffic light labeling system significantly influences the choice of candy

Chapter 4: Results

Traditional vs. Traffic light

A chi-square goodness-of-fit was conducted to evaluate whether there was a significant difference in respondents' perceptions of the effectiveness of two types of food labels—traditional and traffic light—in communicating food additives. Out of the 138 respondents, 128 selected the traffic light label as more effective, while only 10 selected the traditional label.

To test the hypothesis that there is a difference in perceived effectiveness between the traffic light label and the traditional label in communicating food additives, we compared the observed values to the expected values under the assumption that there would be no preference between the two labels (i.e., the responses would be equally split between the two). Our observed values included a traffic light label (128) and a traditional label (10). Given n = 138, the expected values, assuming there was no preference between the labels, is 69.

The chi-square statistic was then calculated using the following formula:

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

In the formula, O_i is the observed value, while E_i is the expected value.

For the traffic light label, the following formula reflects the chi-square value:

$$\frac{(128-69)^2}{69} = \frac{(59)^2}{69} = \frac{3481}{69} = 50.45$$

For the traditional food label, the following reflects the chi-square value:

$$\frac{(10-69)^2}{69} = \frac{(-59)^2}{69} = \frac{3481}{69} = 50.45$$

Thus, the total chi-square value would then be 100.90, because 50.45+50.45 = 100.90.

Furthermore, with one degree of freedom, the corresponding p-value was $p < 9.68 \times 10^{-24}$. Given that the p-value is significantly smaller than the conventional significance level $p < 0.05$, the null hypothesis was rejected:

H_0: There is no difference in perceived effectiveness between the traffic light label and the traditional label in communicating food additives.

This in turn, provides strong evidence to accept the alternate hypothesis:

(H_1): There is a significant difference in perceived effectiveness between the traffic light label and the traditional label in communicating food additives.

The results of this study provide strong evidence that the modified traffic light food labeling system is significantly more effective than the traditional label in communicating the presence of food additives. The overwhelming preference for the traffic light label (128 out of 138 respondents) over the traditional label (10 respondents) was significant, as indicated by the chi-square test ($\chi^2 = 100.90$, $p < 0.001$). These findings reject the null hypothesis and support the alternative hypothesis, which combined with the survey question results, suggest that the traffic light label would be perceived as more effective in conveying information about food additives.

The findings suggest that color-coded systems such as the traffic light label can play an important role in enhancing consumer understanding of nutritional content and food additives, particularly for individuals who may lack detailed nutritional knowledge. This could have significant implications for public health, as more intuitive labeling systems may encourage healthier food choices and reduce the consumption of products with undesirable additives.

Consumer Preference, Soda:

A chi squared test for independence was conducted to evaluate whether the labeling system (traditional vs. traffic light label) significantly affected consumer preference between two soda brands: Mountain Lighting (Option A) and Mountain Dew (Option B). A contingency table included below summarizes the observed frequencies of soda choices under each labeling condition.

	Mountain Lighting (Option A)	Mountain Dew (Option B)	Total
Traditional Label	75	62	137
Traffic-Light Label	38	98	136
Total	113	160	273

After organizing the data into a contingency, it was then important to calculate the expected frequencies. The expected frequency for each cell in the table is calculated using the following formula:

$$\text{Expected Frequency} = \frac{(\text{Row Total}) \times (\text{Column Total})}{\text{Grand Total}}$$

These calculations can be reflected into the expected contingency table, Figure xx.

	Mountain Lighting (Option A)	Mountain Dew (Option B)	Total
Traditional Label	55.67	80.33	137
Traffic-Light Label	56.33	79.67	136
Total	113	160	273

The chi-squared statistic was then calculated using the following formula:

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

For the Traditional Label (Option A):

$$\chi^2 = \frac{(75 - 56.67)^2}{56.67} = 5.88$$

For the Traditional Label (Option B):

$$\chi^2 = \frac{(62 - 80.33)^2}{80.33} = 4.20$$

For the traffic-light Label (Option A):

$$\chi^2 = \frac{(38 - 56.33)^2}{56.33} = 6.36$$

For the traffic -Light Label (Option B):

$$\chi^2 = \frac{(98 - 79.67)^2}{79.67} = 4.05$$

Thus, the chi-squared statistic was calculated as 20.49 with 1 degree of freedom. The corresponding p-value was 1.23 x 10^{-5}. Given that the p-value is much smaller than the significance level of 0.05, we reject the null hypothesis:

(H_0): The traffic light labeling system does not significantly influence the choice of soda

Concluding that the traffic light labeling system did significantly influence respondents' soda choice within the sample set.

These results suggest that when presented with the traffic light labeling system, consumers were more likely to choose Mountain Dew over Mountain Lightning, whereas under the traditional labeling system, preferences were more evenly split between the two soda brands. This significant shift in soda preference suggests that the traffic light labeling system is effective in portraying food additives and influencing consumer behavior. While more research is needed to confirm, one can theorize that the traffic light label better displayed the undesirable additive of Brominated Vegetable Oil, which was categorized in the red 'Avoid' section. Thus, the results not only provide evidence that the traffic light label significantly influences the choice of soda, but also provide the potential implication that this labeling system drives consumers to make more health-conscious decisions.

Consumer Preference, Candy:

A chi-squared test for independence was conducted to examine the effect of labeling systems (traditional nutrition label vs. traffic light label) on consumer preferences between two candy brands: Smart Sweets (Option A) and Sour Patch (Option B). Table 1 presents the observed frequencies of candy choices under each labeling condition.

	Smart Sweets (Option A)	Sour Patch (Option B)	Total
Traditional Label	87	51	138
Traffic -Light Label	119	19	138
Total	206	70	276

The expected frequencies, calculated under the null hypothesis that the labeling system has no impact on candy choice, are also provided in Table 2. These values were computed based on the marginal totals from the contingency table.

	Smart Sweets (Option A)	Sour Patch (Option B)	Total
Traditional Label	103	35	138
Traffic -Light Label	103	35	138
Total	206	70	276

The chi-squared statistic was then implemented using the following formula:

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

For the Traditional Label (Option A):

$$\chi^2 = \frac{(87 - 103.13)^2}{103.13} = 2.66$$

For the Traditional Label (Option B):

$$\chi^2 = \frac{(51 - 34.87)^2}{34.87} = 7.47$$

For the Traffic-light Label (Option A):

$$\chi^2 = \frac{(119 - 103.13)^2}{103.13} = 2.45$$

For the Traffic-Light Label (Option B):

$$\chi^2 = \frac{(19 - 34.87)^2}{34.87} = 7.32$$

The chi-squared test revealed a significant difference in consumer choices between the two labeling conditions, $x^2(1, N = 276) = 18.39, p < 0.0001$. The calculated chi-squared statistic was well above the critical value of 3.841 at the 0.05 significance level, allowing for rejection of the null hypothesis. The corresponding p-value of 0.000018 further confirms that the probability of observing such a difference by chance is exceedingly small.

The results of this test propose that when presented with the traffic light label, consumers were more likely to choose Smart Sweets over Sour Patch, whereas under the traditional nutritional labeling system, preferences were more evenly distributed between the two. This change in consumer preference between the two highlights the effectiveness of the traffic light labeling system with regard to the presence of food additives and influencing consumer decisions. While further research is needed, one could argue that the traffic light labeling system is effective, even in the terms of recognizable and prominent brands, such as Sour Patch. Furthermore, the labeling system impacts both consumer choice and can offer a guide to consumers when making informed decisions with health and snack purchasing.

Soda and Demographics

To further understand the data, a logistic regression was performed to investigate the relationship between respondents' age range, gender, and education level and changes in the soda preference based on the two labeling systems. To do this, an additional column was added to the dataset which reflected our dependent variable. This variable, called soda_change, was then coded where 1 indicated a change in soda preference, while 0 meant no change in preference. Demographic data, such as age range, gender, and education level would then be classified as our independent variables. The groups within each of these demographics have sufficient representation in the survey. While ethnicity data was collected, ethnicity was not included as an independent variable due to the fact that 90% of respondents identified as 'White' and therefore non-White ethnic groups may be under-represented, significantly lowering the model's ability to detect accurate differences between ethnic groups.

The logistic regression can be reflected by the function below

$$P(Y=1|X)=\frac{1}{1+e^{-(\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta_nX_n)}}$$

where *P(Y = 1|X)* is the probability of a change in soda preference. X_1, X_2, X_n are reflective of our independent variables, while β_0, β_1, β_n are the coefficients estimated by the model. The logistic regression was fit using the Maximum Likelihood Estimation (MLE) method, which finds the coefficients that maximize the likelihood of observing the given data.

The logistic regression, using soda_change as the dependent variable and gender, age range, and education as independent variables, yields a pseudo r-squared value of 0.003423, a log-likelihood value of -94.154, and a LLR p-value of 0.8857. These values inform us that the model explains very little variation in soda preference change, is a poor fit, and isn't statistically significant.

The logistic regression also yields the following coefficients and p-values for the intercept and independent variables: a coefficient of -0.1874 and a p-value of 0.6 for the intercept; a coefficient of -0.2561 and a p-value of 0.477 for the independent variable, Gender; a coefficient of -0.0479 and a p-value of 0.779 for the independent variable, Age; a coefficient of 0.0228 and a p-value of 0.858 for the independent variable, Education. The high p-values of each independent variable coefficient implies that none of these variables have a significant relationship with the dependent variable.

This logistic regression model shows that gender, age, and education do not significantly predict soda choice changes in this dataset. The model explains very little variation, and no variable is statistically significant.

Candy and Demographics

In a similar fashion, a logistic regression was performed to investigate the relationship between respondents' age range, gender, and education level and changes in the candy preference based on the two labeling systems. Again, an additional column was added to the dataset which reflected our dependent variable. This variable, called candy_change, was then coded where 1 indicated a change in candy preference, while 0 meant no change in preference. The same demographic data of age range, gender, and education level would then be classified as our independent variables.

The logistic regression can be reflected by the function below

$$P(Y = 1|X) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n)}}$$

where $P(Y = 1|X)$ is the probability of a change in candy preference. X_1, X_2, X_n are reflective of our independent variables, while β_0, β_1, β_n are the coefficients estimated by the model. The logistic regression was fit using the Maximum Likelihood Estimation (MLE) method, which finds the coefficients that maximize the likelihood of observing the given data.

The logistic regression, using candy_change as the dependent variable and gender, age range, and education as independent variables, yields a pseudo r-squared value of 0.03076, a log-likelihood value of -76.771, and a LLR p-value of 0.1814. These values inform us that the model explains very little variation in candy preference change, is a poor fit, and isn't statistically significant.

The logistic regression also yields the following coefficients and p-values for the intercept and independent variables: a coefficient of -1.7232 and a p-value < 0.001 for the intercept; a coefficient of 0.5963 and a p-value of 0.112 for the independent variable, Gender; a coefficient of 0.0941 and a p-value of 0.616 for the independent variable, Age; a coefficient of 0.1892 and a p-value of 0.185 for the independent variable, Education. The high p-values of each independent variable coefficient implies that none of these variables have a significant relationship with the dependent variable. Interestingly, the intercept coefficient is negative and statistically significant. This suggests that when all independent variables are set at their reference level, a change in candy preference based on the two different labeling systems is **not** likely to occur. The reference levels for gender, age range, and education were Male, 18-24, and High School Diploma, respectively.

Similar to soda, this logistic regression model shows that gender, age, and education independently do not significantly predict candy choice changes in this dataset. The model explains very little variation, and no variable is statistically significant.

Chapter 5: Discussion

DISCUSSION

Traffic light vs. Traditional

The findings from the studies presented in the last section offer important insights into how a modified traffic light labeling system for food additives, compared to the traditional nutritional fact labeling, can influence consumer decision making. The studies demonstrated that these newly adapted labels are significantly more effective at communicating food additives than traditional labeling practices, while also providing evidence that the labels impact consumer decision making in a practical setting.

The overwhelming preference for the traffic light label (128 out of 138 respondents) over the traditional label (10 respondents) was highly significant, as indicated by the chi-square test ($\chi^2 = 100.90$, $p < 0.001$). These findings reject the null hypothesis and support the alternative hypothesis, which posited that the traffic light label would be perceived as more effective in conveying information about food additives.

Candy: Smart Sweets vs. Sour Patch

The chi-squared test for independence revealed that the traffic light food additive labeling system significantly influenced the choice between Smart Sweets (Option A) and Sour Patch (Option B). Under the traditional nutrition label, 87 respondents chose Smart Sweets, while 51 opted for Sour Patch. However, when presented with the traffic light labeling system that highlighted food additives, 119 respondents selected Smart Sweets, and only 19 chose Sour

Patch. The p-value of 0.000018 from the chi-squared test confirms a statistically significant shift in consumer preference.

This shift suggests that consumers were influenced by the color-coded warnings on the additives used in Sour Patch, particularly those additives flagged with cautionary (yellow and orange) or avoid (red) labels. In contrast, Smart Sweets, which was primarily labeled with green (safe) for additives such as citric acid and stevia leaf extract, was perceived as the safer, healthier option. These results are consistent with previous findings that suggest simplified labeling systems can improve consumer understanding of complex ingredient information, thereby promoting healthier choices (Hersey et al., 2013). The focus on additives rather than broad nutritional content may have made health-related risks more tangible to consumers.

Soda: Mountain Lightning vs. Mountain Dew

Similarly, the traffic light food additive label significantly influenced the soda choices. Under the traditional nutrition label, 75 respondents chose Mountain Lightning, while 62 chose Mountain Dew. However, under the traffic light label, only 38 respondents selected Mountain Lightning, while 98 favored Mountain Dew. The p-value of 0.0000123 from the chi-squared test indicates a strong statistical significance, suggesting that the traffic light food additive labels had a considerable impact on consumer preference.

Interestingly, Mountain Lightning contains Brominated Vegetable Oil (BVO), which was flagged in red under the traffic light system as an additive to avoid. This likely played a role in the reduced preference for Mountain Lightning when the traffic light label was used, as consumers were steered away from the product due to the presence of this additive. In contrast, Mountain Dew does not contain BVO, and while it includes other additives like sodium benzoate (flagged in orange), the absence of a "red flag" additive may have made it more appealing under the traffic light label system.

This suggests that consumers may be particularly sensitive to red warnings (additives to avoid) when making their purchasing decisions. The significant drop in preference for Mountain Lightning under the traffic light label highlights the effectiveness of such a label in communicating safety concerns about specific food additives.

Demographics and Candy / Soda

The key takeaway from the regression model analysis for both soda and candy is that the results indicate all demographic groups surveyed may be influenced by the modified traffic light labeling system equally. In other words, a female and male will react in similar ways when exposed to the traffic light label. The female and male could both be equally likely to change their preference from Mountain Lightning to Mountain Dew, and from Sour Patch to Smart Sweets when presented with the traffic light label compared to the traditional label, for example. Likewise, people in their forties are just as likely to change their preferences as people in their twenties, and those with Master's degrees operate no differently than those with a High School diploma. This is a positive sign, as it suggests the effectiveness of the traffic light labeling system is not exclusive to specific demographic groups, and instead has the ability to influence consumer behavior across diverse backgrounds.

Implications / Further Research

Although the results of this study indicate that a traffic light food additive labeling system can be a powerful tool for informing consumers about the safety of ingredients in packaged food items, further research is needed to conclude its effectiveness. In this study involving consumer choices of soda, when provided the choice between Mountain Lightning or Mountain Dew when only being exposed to the original nutrition facts label, 75 chose Mountain Lightning and 62 chose Mountain Dew. In this question, price was included where Mountain Lightning cost $1.00 and Mountain Dew cost $2.18. One could argue that the higher selection of Mountain Lighting could be attributed to the lower price, although the survey did not distinguish this.

Once the traffic light labels were introduced, 38 participants chose Mountain Lightning and 98 chose Mountain Dew. With the change in selection from the nutrition label to the traffic label, one could make the argument that people are willing to spend more for a food item that has less harmful food additives present in the traffic-light food additive label. Further research would need to be explored to test this implication.

In this research, brand names were explicitly used and defined in the survey questions. According to research by Grewal, Krishnan, Baker, and Borin (1998), the knowledge of brand name helps increase perceptions of quality and oftentimes a consumer has a favorable brand when shopping. With this in mind, it is possible that consumers selected their answers to the survey questions reflective of their personal attachments to the food items, vs the nutritional and food additive information displayed. For future research, it may be advisable to take this into consideration and conduct a blind survey, where brand names are excluded when asking participants to choose a selection.

Policy makers often make the argument that a consumer's health and choices are dependent on their own decisions, ignoring the facts that nutrition and food additive labels are often difficult to decipher (Grimmelt et al., 2022). The aim of this research was to offer an alternative tool to consumers to be able to make health conscious decisions regarding packaged food effectively. While the modified traffic light food labeling system for food additives was introduced to address these concerns, it is important to recognize that too much information may cause an aversive effect. Therefore, future implications may want to consider how many additives per color does a consumer find helpful, as well as find harmful to their purchasing decisions.

In terms of marketing, brands that use fewer harmful additives may use this modified traffic light food labeling system to create an effective competitive advantage and distinguish themselves from their competitors. The labeling system can become an effective marketing tool for brands of food products who would like to emphasize the safety, and the quality of their products. This in turn would assist producers in their ability to attract target consumers, those who are health conscious and care about the quality of their food. Products like those of the smart sweet candy example would benefit from the usage of this modified traffic light labeling system.

In the same breath, if the modified traffic food labeling system became a trusted and well respected tool for consumers with regards to food safety, companies failing to comply may lose market share, popularity and a loyal customer base. As consumers gravitate toward brands offering the transparency of the modified traffic light labeling system, companies who don't face severe consequences.

Furthermore, the success of the proposed traffic light labeling system can be attributed to influencing consumer behavior. An uptick in changed behavior and consumer demand may inspire a larger and more widespread adoption of the method, which could lead to those of government regulating bodies or prominent industry leaders. We have already seen this pattern with the discontinuance of usage of brominated vegetable oil, and top industry leaders Coke and Pepsi. This would then have the potential to shift the overall marketing dynamics and set new industry standards for food labeling, and perhaps in turn food additive usage overall.

Limitations:

While the research at hand is a stepping stone to the implication and usage of traffic light food labeling systems with the United States, a few limitations presented themselves through the research. It is important to note that this study was conducted in a controlled, survey-based environment, which may not have fully captured the complexity of a real-world purchasing scenario. In actual shopping context, consumers may be influenced by additional factors such as availability, price, convenience, brand loyalty, or social influences, which were not accounted for in this research. The study's findings may overestimate the impact of the traffic light labeling system because participants were asked to focus specifically on the label information without the distractions of a real-world setting.

Another limitation to be considered is the demographics of the research and survey data. The sample size, although statistically adequate for chi-squared testing, may not be an accurate representation of the broader population of the American people. In this research, the majority of responses came from women of white descent who were adequately educated and living in New York State. In the United States, there is a very large range of people in terms of gender classification, race, education status, and location that may not have been appropriately reflected in this research. In addition, demographic consideration of income was not accounted for, which may have an effect on consumer spending habits which relates to this research.

The traffic light labeling system in this study focused on food additives rather than nutritional information (e.g., calories, sugar, fat). While this was intentional, it may limit the applicability of findings to labeling systems that aim to convey broader nutritional information. Some consumers may prioritize calorie or sugar content over the presence of certain additives, as briefly considered in the survey.

For future research, it would be advantageous to explore this research further with an improved surveying system. In the survey presented in this research, all participants were exposed to all survey conditions, which may have posed biases to the questions. Continued research could conduct a survey where participants are segmented, some getting the control condition of the regular nutrition facts labels, others getting the scenario regarding soda, and others with the candy. In this way, the data could more effectively be compared without biases.

With more resources, further research could illustrate the effectiveness of the label when physically fixated on the product, as well as in a purchasing environment. In present research, the label was only presented next to a product, not on it and displayed in a virtual setting. With more time and resources, seeing how effective the food additive labeling system is in a real world scenario could offer a further exploratory framework.

Tables and Charts

Table 1–A list of common exempt colors and their FDA[a] and INS[b] numbers.

Natural colorant	FDA	E number
Curcumin	73.600	100
Tumeric Oleoresin	73.650	None
Riboflavin	73.450	101(i)
Carmine/Cochineal	73.100	120
Chlorophylls	None	140i to ii
K-Cu-chlorophyll	None	141ii
Na-Cu-chlorophyll	73.125	141ii
Cu-chlorophylls	None	141i
Caramel I	73.85	150a
Caramel II	73.85	150b
Caramel III	73.85	150c
Caramel IV	73.85	150d
Vegetable Carbon	None	153
Carotenes	None	160(a) iv
Carrot Oils	73.300	None
b-carotene	73.950	160(a)i to iii
b-apo-8′-carotenoic acid (caroteneal)	73.900	160e
Annatto-bixin	73.300	160(b)i
Annatto-norbixin	73.300	160(b)ii
Paprika	73.340	None
Paprika oleoresins	73.345	160(c)
Lycopene	73.585	160(d)I, ii, iii
Lutein	None	161(b)i
Canthaxanthin	73.750	161g
Beet red	73.40	162
Anthocyanins	None	163
Grape color extract	73.169	None
Fruit juice	73.250	None
Vegetable juice	73.260	None
Enocianin (Grape skin extract)	73.170	163ii
Saffron, crocetin, and crocin	73.500	None
Titanium dioxide	73.575	171
Iron Oxides	73.200	172
Spirulina Blue	73.530	None
Spirulina Green	None	None
Gardenia Blue	None	None
Gardenia Yellow	None	None
Gardenia Red	None	None
Monascus Red	None	None
Monascus Yellow	None	None
Carthamus Yellow	None	None
Carthamus Red	None	None
Flavoanthin	None	None
Huito (*Genipa americana*)/ Jagua	None	None

[a]Food and Drug Administration from the Federal Food, Drug, and Cosmetic Act, 21 C.F.R. §73.
[b]Intl. Numbering System (European Union) by Codex Alimentarius.

Table 3.0: Colors Exempt From Batch Certification (Adapted from *21 CFR Part 170 -- Food Additives*, n.d.)

§ 172.515 Synthetic flavoring substances and adjuvants.

Synthetic flavoring substances and adjuvants may be safely used in food in accordance with the following conditions.

(a) They are used in the minimum quantity required to produce their intended effect, and otherwise in accordance with all the principles of good manufacturing practice.

(b) They consist of one or more of the following, used alone or in combination with flavoring substances and adjuvants generally recognized as safe in food, prior-sanctioned for such use, or regulated by an appropriate section in this part.

Acetal; acetaldehyde diethyl acetal.
Acetaldehyde phenethyl propyl acetal.
Acetanisole; 4′-methoxyacetophenone.
Acetophenone; methyl phenyl ketone.
Allyl anthranilate.
Allyl butyrate.
Allyl cinnamate.
Allyl cyclohexaneacetate.
Allyl cyclohexanebutyrate.
Allyl cyclohexanehexanoate.
Allyl cyclohexaneproprionate.
Allyl cyclohexanevalerate.
Allyl disulfide.
Allyl 2-ethylbutyrate.
Allyl hexanoate; allyl caproate.
Allyl α-ionone; 1-(2,6,6-trimethyl-2-cyclo-hexene-1-yl)-1,6-heptadiene-3-one.
Allyl isothiocyanate; mustard oil.
Allyl isovalerate.
Allyl mercaptan; 2-propene-1-thiol.
Allyl nonanoate.
Allyl octanoate.
Allyl phenoxyacetate.
Allyl phenylacetate.
Allyl propionate.
Allyl sorbate; allyl 2,4-hexadienoate.
Allyl sulfide.
Allyl tiglate; allyl *trans*-2-methyl-2-butenoate.
Allyl 10-undecenoate.
Ammonium isovalerate.
Ammonium sulfide.
Amyl alcohol; pentyl alcohol.
Amyl butyrate.
α-Amylcinnamaldehyde.
α-Amylcinnamaldehyde dimethyl acetal.
α-Amylcinnamyl acetate.
α-Amylcinnamyl alcohol.
α-Amylcinnamyl formate.
α-Amylcinnamyl isovalerate.
Amyl formate.
Amyl heptanoate.
Amyl hexanoate.
Amyl octanoate.
Anisole; methoxybenzene.
Anisyl acetate.
Anisyl alcohol; *p*-methoxybenzyl alcohol.
Anisyl butyrate
Anisyl formate.
Anisyl phenylacetate.
Anisyl propionate.
Beechwood creosote.
Benzaldehyde dimethyl acetal.
Benzaldehyde glyceryl acetal; 2-phenyl-*m*-dioxan-5-ol.
Benzaldehyde propylene glycol acetal; 4-methyl-2-phenyl-*m*-dioxolane.
Benzenethiol; thiophenol.
Benzoin; 2-hydroxy-2-phenylacetophenone.
Benzophenone; diphenylketone.
Benzyl acetate.
Benzyl acetoacetate.
Benzyl alcohol.
Benzyl benzoate.
Benzyl butyl ether.
Benzyl butyrate.
Benzyl cinnamate.
Benzyl 2,3-dimethylcrotonate; benzyl methyl tiglate.
Benzyl disulfide; dibenzyl disulfide.
Benzyl ethyl ether.
Benzyl formate.

Table 4.1: Synthetic Flavor Adatitves (Adapted from 21 CFR Part 170, n.d.).

3-Benzyl-4-heptanone; benzyl dipropyl ketone.
Benzyl isobutyrate.
Benzyl isovalerate.
Benzyl mercaptan; α-toluenethiol.
Benzyl methoxyethyl acetal; acetaldehyde benzyl β-methoxyethyl acetal.
Benzyl phenylacetate.
Benzyl propionate.
Benzyl salicylate.
Birch tar oil.
Borneol; *d*-camphanol.
Bornyl acetate.
Bornyl formate.
Bornyl isovalerate.
Bornyl valerate.
β-Bourbonene; 1,2,3,3a,3bβ,4,5,6,6aβ,6bα-decahydro-1α-isopropyl-3a$_{\alpha}$-methyl-6-methylene-cyclobuta [1,2:3,4] dicyclopentene.
2-Butanol.
2-Butanone; methyl ethyl ketone.
Butter acids.
Butter esters.
Butyl acetate.
Butyl acetoacetate.
Butyl alcohol; 1-butanol.
Butyl anthranilate.
Butyl butyrate.
Butyl butyryllactate; lactic acid, butyl ester, butyrate.
α-Butylcinnamaldehyde.
Butyl cinnamate.
Butyl 2-decenoate.
Butyl ethyl malonate.
Butyl formate.
Butyl heptanoate.
Butyl hexanoate.
Butyl *p*-hydroxybenzoate.
Butyl isobutyrate.
Butyl isovalerate.
Butyl lactate.
Butyl laurate.
Butyl levulinate.
Butyl phenylacetate.
Butyl propionate.
Butyl stearate.
Butyl sulfide.
Butyl 10-undecenoate.
Butyl valerate.
Butyraldehyde.
Cadinene.
Camphene; 2,2-dimethyl-3-methylene-norbornane.
d-Camphor.
Carvacrol; 2-*p*-cymenol.
Carvacryl ethyl ether; 2-ethoxy-*p*-cymene.
Carveol; *p*-mentha-6,8-dien-2-ol.
4-Carvomenthenol; 1-*p*-menthen-4-ol; 4-terpinenol.
cis Carvone oxide; 1,6-epoxy-*p*-menth-8-en-2-one.
Carvyl acetate.
Carvyl propionate.
β-Caryophyllene.
Caryophyllene alcohol.
Caryophyllene alcohol acetate.
β-Caryophyllene oxide; 4-12,12-trimethyl-9-methylene-5-oxatricylo [8.2.0.0^{4,6}] dodecane.
Cedarwood oil alcohols.
Cedarwood oil terpenes.
1,4-Cineole.
Cinnamaldehyde ethylene glycol acetal.
Cinnamic acid.
Cinnamyl acetate.
Cinnamyl alcohol; 3-phenyl-2-propen-1-ol.
Cinnamyl benzoate.
Cinnamyl butyrate.
Cinnamyl cinnamate.
Cinnamyl formate.
Cinnamyl isobutyrate.
Cinnamyl isovalerate.
Cinnamyl phenylacetate.
Cinnamyl propionate.
Citral diethyl acetal; 3,7-dimethyl-2,6-octadienal diethyl acetal.
Citral dimethyl acetal; 3,7-dimethyl-2,6-octadienal dimethyl acetal.
Citral propylene glycol acetal.
Citronellal; 3,7-dimethyl-6-octenal; rhodinal.
Citronellol; 3,7-dimethyl-6-octen-1-ol; *d*-citronellol.
Citronelloxyacetaldehyde.
Citronellyl acetate.
Citronellyl butyrate.
Citronellyl formate.
Citronellyl isobutyrate.
Citronellyl phenylacetate.
Citronellyl propionate.
Citronellyl valerate.
p-Cresol.
Cuminaldehyde; cuminal; *p*-isopropyl benzaldehyde.
Cyclohexaneacetic acid.
Cyclohexaneethyl acetate.
Cyclohexyl acetate.
Cyclohexyl anthranilate.
Cyclohexyl butyrate.
Cyclohexyl cinnamate.
Cyclohexyl formate.
Cyclohexyl isovalerate.
Cyclohexyl propionate.
p-Cymene.
γ-Decalactone; 4-hydroxy-decanoic acid, γ-lactone.
γ-Decalactone; 5-hydroxy-decanoic acid, δ-lactone.
Decanal dimethyl acetal.
1-Decanol; decylic alcohol.
2-Decenal.
3-Decen-2-one; heptylidene acetone.
Decyl actate.
Decyl butyrate.
Decyl propionate.
Dibenzyl ether.
4,4-Dibutyl-γ-butyrolactone; 4,4-dibutyl-4-hydroxy-butyric acid, γ-lactone.
Dibutyl sebacate.
Diethyl malate.
Diethyl malonate; ethyl malonate.
Diethyl sebacate.
Diethyl succinate.
Diethyl tartrate.

Table 4.2: Synthetic Flavor Adatitves (Adapted from 21 CFR Part 170, n.d.).

2,5-Diethyltetrahydrofuran.
Dihydrocarveol; 8-*p*-menthen-2-ol; 6-methyl-3-isopropenylcyclohexanol.
Dihydrocarvone.
Dihydrocarvyl acetate.
m-Dimethoxybenzene.
p-Dimethoxybenzene; dimethyl hydroquinone.
2,4-Dimethylacetophenone.
α,α-Dimethylbenzyl isobutyrate; phenyldimethylcarbinyl isobutyrate.
2,6-Dimethyl-5-heptenal.
2,6-Dimethyl octanal; isodecylaldehyde.
3,7-Dimethyl-1-octanol; tetrahydrogeraniol.
α,α-Dimethylphenethyl acetate; benzylpropyl acetate; benzyldimethylcarbinyl acetate.
α,α-Dimethylphenethyl alcohol; dimethylbenzyl carbinol.
α,α-Dimethylphenethyl butyrate; benzyldimethylcarbinyl butyrate.
α,α-Dimethylphenethyl formate; benzyldimethylcarbinyl formate.
Dimethyl succinate.
1,3-Diphenyl-2-propanone; dibenzyl ketone.
delta-Dodecalactone; 5-hydroxydodecanoic acid, deltalactone.
γ-Dodecalactone; 4-hydroxydodecanoic acid γ-lactone.
2-Dodecenal.
Estragole.
p-Ethoxybenzaldehyde.
Ethyl acetoacetate.
Ethyl 2-acetyl-3-phenylpropionate; ethylbenzyl acetoacetate.
Ethyl aconitate, mixed esters.
Ethyl acrylate.
Ethyl p-anisate.
Ethyl anthranilate.
Ethyl benzoate.
Ethyl benzoylacetate.
α-Ethylbenzyl butyrate; α-phenylpropyl butyrate.
Ethyl brassylate; tridecanedioic acid cyclic ethylene glycol diester; cyclo 1,13-ethylenedioxytridecan-1,13-dione.
2-Ethylbutyl acetate.
2-Ethylbutyraldehyde.
2-Ethylbutyric acid.
Ethyl cinnamate.
Ethyl crotonate; *trans*-2-butenoic acid ethyl ester.
Ethyl cyclohexanepropionate.
Ethyl decanoate.
2-Ethylfuran.
Ethyl 2-furanpropionate.
4-Ethylguaiacol; 4-ethyl-2-methoxyphenol.
Ethyl heptanoate.
2-Ethyl-2-heptenal; 2-ethyl-3-butylacrolein.
Ethyl hexanoate.
Ethyl isobutyrate.
Ethyl isovalerate.
Ethyl lactate.
Ethyl laurate.
Ethyl levulinate.
Ethyl maltol; 2-ethyl-3-hydroxy-4H-pyran-4-one.
Ethyl 2-methylbutyrate.
Ethyl myristate.
Ethyl nitrite.
Ethyl nonanoate.
Ethyl 2-nonynoate; ethyl octyne carbonate.
Ethyl octanoate.
Ethyl oleate.
Ethyl phenylacetate.
Ethyl 4-phenylbutyrate.
Ethyl 3-phenylglycidate.
Ethyl 3-phenylpropionate; ethyl hydrocinnamate.
Ethyl propionate.
Ethyl pyruvate.
Ethyl salicylate.
Ethyl sorbate; ethyl 2,4-hexadienoate.
Ethyl tiglate; ethyl *trans*-2-methyl-2-butenoate.
Ethyl undecanoate.
Ethyl 10-undecenoate.
Ethyl valerate.
Eucalyptol; 1,8-epoxy-*p*-menthane; cineole.
Eugenyl acetate.
Eugenyl benzoate.
Eugenyl formate.
Eugenyl methyl ether; 4-allylveratrole; methyl eugenol.
Farnesol; 3,7,11-trimethyl-2,6,10-dodecatrien-1-ol.
d-Fenchone; *d*-1,3,3-trimethyl-2-norbornanone.
Fenchyl alcohol; 1,3,3-trimethyl-2-norbornanol.
Formic acid
(2-Furyl)-2-propanone; furyl acetone.
1-Furyl-2-propanone; furyl acetone.
Fusel oil, refined (mixed amyl alcohols).
Geranyl acetoacetate; *trans*-3,7-dimethyl-2, 6-octadien-1-yl acetoacetate.
Geranyl acetone; 6,10-dimethyl-5,9-undecadien-2-one.
Geranyl benzoate.
Geranyl butyrate.
Geranyl formate.
Geranyl hexanoate
Geranyl isobutyrate.
Geranyl isovalerate.
Geranyl phenylacetate.
Geranyl propionate.
Glucose pentaacetate.
Guaiacol; μ -methoxyphenol.
Guaiacyl acetate; μ -methoxyphenyl acetate.
Guaiacyl phenylacetate.
Guaiene; 1,4-dimethyl-7-isopropenyl-Δ9,10-octahydroazulene.
Guaiol acetate; 1,4-dimethyl-7-(α-hydroxy-isopropyl)-δ9,10-octahydroazulene acetate.
γ-Heptalactone; 4-hydroxyheptanoic acid, γ-lactone.
Heptanal; enanthaldehyde.
Heptanal dimethyl acetal.
Heptanal 1,2-glyceryl acetal.
2,3-Heptanedione; acetyl valeryl.
3-Heptanol.
2-Heptanone; methyl amyl ketone.
3-Heptanone; ethyl butyl ketone.
4-Heptanone; dipropyl ketone.

Table 4.3: Synthetic Flavor Adatitves (Adapted from 21 CFR Part 170, n.d.).

cis-4-Heptenal; cis-4-hepten-1-al.
Heptyl acetate.
Heptyl alcohol; enanthic alcohol.
Heptyl butyrate.
Heptyl cinnamate.
Heptyl formate.
Heptyl isobutyrate.
Heptyl octanoate.
1-Hexadecanol; cetyl alcohol.
ω-6-Hexadecenlactone; 16-hydroxy-6-hexadecenoic acid, ω-lactone; ambrettolide.
γ-Hexalactone; 4-hydroxyhexanoic acid, γ-lactone; tonkalide.
Hexanal; caproic aldehyde.
2,3-Hexanedione; acetyl butyryl.
Hexanoic acid; caproic acid.
2-Hexenal.
2-Hexen-1-ol.
3-Hexen-1-ol; leaf alcohol.
2-Hexen-1-yl acetate.
3-Hexenyl isovalerate.
3-Hexenyl 2-methylbutyrate.
3-Hexenyl phenylacetate; cis-3-hexenyl phenylacetate.
Hexyl acetate.
2-Hexyl-4-acetoxytetrahydrofuran.
Hexyl alcohol.
Hexyl butyrate.
α-Hexylcinnamaldehyde.
Hexyl formate.
Hexyl hexanoate.
2-Hexylidene cyclopentanone.
Hexyl isovalerate.
Hexyl 2-methylbutyrate.
Hexyl octanoate.
Hexyl phenylacetate; n-hexyl phenylacetate.
Hexyl propionate.
Hydroxycitronellal; 3,7-dimethyl-7-hydroxyoctanal.
Hydroxycitronellal diethyl acetal.
Hydroxycitronellal dimethyl acetal.
Hydroxycitronellal; 3,7-dimethyl-1,7-octanediol.
N-(4-Hydroxy-3-methoxybenzyl)-nonanamide; pelargonyl vanillylamide.
5-Hydroxy-4-octanone; butyroin.
4-(p-Hydroxyphenyl)-2-butanone; p-hydroxybenzyl acetone.
Indole.
α-Ionone; 4-(2,6,6-trimethyl-2-cyclohexen-1-yl)-3-buten-2-one.
β-Ionone; 4-(2,6,6-trimethyl-1-cyclohexen-1-yl)-3-buten-2-one.
α-Irone; 4-(2,5,6,6-tetramethyl-2-cyclohexene-1-yl)-3-buten-2-one; 6-methylionone.
Isoamyl acetate.
Isoamyl acetoacetate.
Isoamyl alcohol; isopentyl alcohol; 3-methyl-1-butanol.
Isoamyl benzoate.
Isoamyl butyrate.
Isoamyl cinnamate.
Isoamyl formate.
Isoamyl 2-furanbutyrate; α-isoamyl furfurylpropionate.
Isoamyl 2-furanpropionate; α-isoamyl furfurylacetate.
Isoamyl hexanoate.
Isoamyl isobutyrate.
Isoamyl isovalerate.
Isoamyl laurate.
Isoamyl-2-methylbutyrate; isopentyl-2-methylbutyrate.
Isoamyl nonanoate.
Isoamyl octanoate.
Isoamyl phenylacetate.
Isoamyl propionate.
Isoamyl pyruvate.
Isoamyl salicylate.
Isoborneol.
Isobornyl acetate.
Isobornyl formate.
Isobornyl isovalerate.
Isobornyl propionate.
Isobutyl acetate.
Isobutyl acetoacetate.
Isobutyl alcohol.
Isobutyl angelate; isobutyl cis-2-methyl-2-butenoate.
Isobutyl anthranilate.
Isobutyl benzoate.
Isobutyl butyrate.
Isobutyl cinnamate.
Isobutyl formate.
Isobutyl 2-furanpropionate.
Isobutyl heptanoate.
Isobutyl hexanoate.
Isobutyl isobutyrate.
α-Isobutylphenethyl alcohol; isobutyl benzyl carbinol; 4-methyl-1-phenyl-2-pentanol.
Isobutyl phenylacetate.
Isobutyl propionate.
Isobutyl salicylate.
2-Isobutylthiazole.
Isobutyraldehyde.
Isobutyric acid.
Isoeugenol; 2-methoxy-4-propenylphenol.
Isoeugenyl acetate.
Isoeugenyl benzyl ether; benzyl isoeugenol.
Isoeugenyl ethyl ether; 2-ethoxy-5-propenylanisole; ethyl isoeugenol.
Isoeugenyl formate.
Isoeugenyl methyl ether; 4-propenylveratrole; methyl isoeugenol.
Isoeugenyl phenylacetate.
Isojasmone; mixture of 2-hexylidenecyclopentanone and 2-hexyl-2-cyclopenten-1-one.
α-Isomethylionone; 4-(2,6,6-trimethyl-2-cyclohexen-1-yl)-3-methyl-3-buten-2-one; methyl γ-ionone.
Isopropyl acetate.
p-Isopropylacetophenone.
Isopropyl alcohol; isopropanol.
Isopropyl benzoate.
p-Isopropylbenzyl alcohol; cuminic alcohol; p-cymen-7-ol.
Isopropyl butyrate.
Isopropyl cinnamate.
Isopropyl formate.
Isopropyl hexanoate.
Isopropyl isobutyrate.
Isopropyl isovalerate.

Table 4.4: Synthetic Flavor Adatitves (Adapted from 21 CFR Part 170, n.d.).

p-Isopropylphenylacetaldehyde; *p*-cymen-7-carboxaldehyde.
Isopropyl phenylacetate.
3-(*p*-Isopropylphenyl)-propionaldehyde; *p*-isopropylhydrocinnamaldehyde; cuminyl acetaldehyde.
Isopropyl propionate.
Isopulegol; *p*-menth-8-en-3-ol.
Isopulegone; *p*-menth-8-en-3-one.
Isopulegyl acetate.
Isoquinoline.
Isovaleric acid.
cis-Jasmone; 3-methyl-2-(2-pentenyl)-2-cyclopenten-1-one.
Lauric aldehyde; dodecanal.
Lauryl acetate.
Lauryl alcohol; 1-dodecanol.
Lepidine; 4-methylquinoline.
Levulinic acid.
Linalool oxide; *cis*- and *trans*-2-vinyl-2-methyl-5-(1'-hydroxy-1'-methylethyl) tetrahydrofuran.
Linalyl anthranilate; 3,7-dimethyl-1,6-octadien-3-yl anthranilate.
Linalyl benzoate.
Linalyl butyrate.
Linalyl cinnamate.
Linalyl formate.
Linalyl hexanoate.
Linalyl isobutyrate.
Linalyl isovalerate.
Linalyl octanoate.
Linalyl propionate.
Maltol; 3-hydroxy-2-methyl-4H-pyran-4-one.
Menthadienol; *p*-mentha-1,8(10)-dien-9-ol.
p-Mentha-1,8-dien-7-ol; perillyl alcohol.
Menthadienyl acetate; *p*-mentha-1,8(10)-dien-9-yl acetate.
p-Menth-3-en-1-ol.
1-*p*-Menthen--9-yl acetate; *p*-menth-1-en-9-yl acetate.
Menthol; 2-isopropyl-5-methylcyclohexanol.
Menthone; *p*-menthan-3-one.
Menthyl acetate; *p*-menth-3-yl acetate.
Menthyl isovalerate; *p*-menth-3-yl isovalerate.
o-Methoxybenzaldehyde.
p-Methoxybenzaldehyde; *p*-anisaldehyde.
o-Methoxycinnamaldehyde.
2-Methoxy-4-methylphenol; 4-methylguaiacol; 2-methoxy-*p*-cresol.
4-(*p*-Methoxyphenyl)-2-butanone; anisyl acetone.
1-(4-Methoxyphenyl)-4-methyl-1-penten-3-one; methoxystyryl isopropyl ketone.
1-(*p*-Methoxyphenyl)-1-penten-3-one; α-methylanisylidene acetone; ethone.
1-(*p*-Methoxyphenyl)-2-propanone; anisylmethyl ketone; anisic ketone.
2-Methoxy-4-vinylphenol; *p*-vinylguaiacol.
Methyl acetate.
4'-Methylacetophenone; *p*-methylacetophenone; methyl *p*-tolyl ketone.
2-Methylallyl butyrate; 2-methyl-2-propenyl butyrate.
Methyl anisate.
o-Methylanisole; *o*-cresyl methyl ether.
p-Methylanisole; *p*-cresyl methyl ether; *p*-methoxytoluene.
Methyl benzoate.
Methylbenzyl acetate, mixed *o*-,*m*-,*p*-.
α-Methylbenzyl acetate; styralyl acetate.
α-Methylbenzyl alcohol; styralyl alcohol.
α-Methylbenzyl butyrate; styralyl butyrate.
α-Methylbenzyl isobutyrate; styralyl isobutyrate.
α-Methylbenzyl formate; styralyl formate.
α-Methylbenzyl propionate; styralyl propionate.
2-Methyl-3-buten-2-ol.
2-Methylbutyl isovalerate.
Methyl *p*-*tert*-butylphenylacetate.
2-Methylbutyraldehyde; methyl ethyl acetaldehyde.
3-Methylbutyraldehyde; isovaleraldehyde.
Methyl butyrate.
2-Methylbutyric acid.
α-Methylcinnamaldehyde.
p-Methylcinnamaldehyde.
Methyl cinnamate.
2-Methyl-1,3-cyclohexadiene.
Methylcyclopentenolone; 3-methylcyclopentane-1,2-dione.
Methyl disulfide; dimethyl disulfide.
Methyl ester of rosin, partially hydrogenated (as defined in §172.615); methyl dihydroabietate.
Methyl heptanoate.
2-Methylheptanoic acid.
6-Methyl-3,5-heptadien-2-one.
Methyl-5-hepten-2-ol.
6-Methyl-5-hepten-2-one.
Methyl hexanoate.
Methyl 2-hexanoate.
Methyl *p*-hydroxybenzoate; methylparaben.
Methyl α-ionone; 5-(2,6,6-trimethyl-2-cyclohexen-1-yl)-4-penten-3-one.
Methyl β-ionone; 5-(2,6,6-trimethyl-1-cyclohexen-1-yl)-4-penten-3-one.
Methyl Δ-ionone; 5-(2,6,6-trimethyl-3-cyclohexen-1-yl-)-4-penten-3-one.
Methyl isobutyrate.
2-Methyl-3-(*p*-isopropylphenyl)-propionaldehyde; α-methyl-*p*-isopropylhydrocinnamal- dehyde; cyclamen aldehyde.
Methyl isovalerate.
Methyl laurate.
Methyl mercaptan; methanethiol.
Methyl *o*-methoxybenzoate.
Methyl *N*-methylanthranilate; dimethyl anthranilate.
Methyl 2-methylbutyrate.
Methyl-3-methylthiopropionate.
Methyl 4-methylvalerate.
Methyl myristate.
Methyl β-naphthyl ketone; 2'-acetonaphthone.
Methyl nonanoate.
Methyl 2-nonenoate.
Methyl 2-nonynoate; methyloctyne carbonate.
2-Methyloctanal; methyl hexyl acetaldehyde.
Methyl octanoate.

Table 4.5: Synthetic Flavor Adatitves (Adapted from 21 CFR Part 170, n.d.).

Methyl 2-octynoate; methyl heptine carbonate.
4-Methyl-2,3-pentanedione; acetyl isobutyryl.
4-Methyl-2-pentanone; methyl isobutyl ketone.
β-Methylphenethyl alcohol; hydratropyl alcohol.
Methyl phenylacetate.
3-Methyl-4-phenyl-3-butene-2-one.
2-Methyl-4-phenyl-2-butyl acetate; dimethylphenylethyl carbinyl acetate.
2-Methyl-4-phenyl-2-butyl isobutyrate; dimethylphenyl ethylcarbinyl isobutyrate.
3-Methyl-2-phenylbutyraldehyde; α-isopropyl phenylacetaldehyde.
Methyl 4-phenylbutyrate.
4-Methyl-1-phenyl-2-pentanone; benzyl isobutyl ketone.
Methyl 3-phenylpropionate; methyl hydrocinnamate.
Methyl propionate.
3-Methyl-5-propyl-2-cyclohexen-1-one.
Methyl sulfide.
3-Methylthiopropionaldehyde; methional.
2-Methyl-3-tolylpropionaldehyde, mixed *o*-, *m*-, *p*-.
2-Methylundecanal; methyl nonyl acetaldehyde.
Methyl 9-undecenoate.
Methyl 2-undecynoate; methyl decyne carbonate.
Methyl valerate.
2-Methylvaleric acid.
Myrcene; 7-methyl-3-methylene-1,6-octadiene.
Myristaldehyde; tetradecanal.
d-Neomenthol; 2-isopropyl-5-methylcyclohexanol.
Nerol; *cis*-3,7-dimethyl-2,6-octadien-1-ol.
Nerolidol; 3,7,11-trimethyl-1,6,10-dodecatrien-3-ol.
Neryl acetate.
Neryl butyrate.
Neryl formate.
Neryl isobutyrate.
Neryl isovalerate.
Neryl propionate.
2,6-Nonadien-1-ol.
γ-Nonalactone; 4-hydroxynonanoic acid, γ-lactone; aldehyde C-18.
Nonanal; pelargonic aldehyde.
1,3-Nonanediol acetate, mixed esters.
Nonanoic acid; pelargonic acid.
2-Nonanone; methylheptyl ketone.
3-Nonanon-1-yl acetate; 1-hydroxy-3-nonanone acetate.
Nonyl acetate.
Nonyl alcohol; 1-nonanol.
Nonyl octanoate.
Nonyl isovalerate.
Nootkatone; 5,6-dimethyl-8-isopropenylbicyclo[4,4,0]-dec-1-en-3-one.
Ocimene; *trans*-β-ocimene; 3,7-dimethyl-1,3,6-octatriene.
γ-Octalactone; 4-hydroxyoctanoic acid, γ-lactone.
Octanal; caprylaldehyde.
Octanal dimethyl acetal.
1-Octanol; octyl alcohol.
2-Octanol.
3-Octanol.
2-Octanone; methyl hexyl ketone.
3-Octanone; ethyl amyl ketone.
3-Octanon-1-ol.
1-Octen-3-ol; amyl vinyl carbinol.
1-Octen-3-yl acetate.
Octyl acetate.
3-Octyl acetate.
Octyl butyrate.
Octyl formate.
Octyl heptanoate.
Octyl isobutyrate.
Octyl isovalerate.
Octyl octanoate.
Octyl phenylacetate.
Octyl propionate.
ω-Pentadecalactone; 15-hydroxypentadecanoic acid, ω-lactone; pentadecanolide; angelica lactone.
2,3-Pentanedione; acetyl propionyl.
2-Pentanone; methyl propyl ketone.
4-Pentenoic acid.
1-Penten-3-ol.
Perillaldehyde; 4-isopropenyl-1-cyclohexene-1-carboxaldehyde;*p*-mentha-1,8-dien-7-al.
Perillyl acetate; *p*-mentha-1,8-dien-7-yl acetate.
α-Phellandrene; *p*-mentha-1,5-diene.
Phenethyl acetate.
Phenethyl alcohol; β-phenylethyl alcohol.
Phenethyl anthranilate.
Phenethyl benzoate.
Phenethyl butyrate.
Phenethyl cinnamate.
Phenethyl formate.
Phenethyl isobutyrate.
Phenethyl isovalerate.
Phenethyl 2-methylbutyrate.
Phenethyl phenylacetate.
Phenethyl propionate.
Phenethyl salicylate.
Phenethyl senecioate; phenethyl 3,3-dimethylacrylate.
Phenethyl tiglate.
Phenoxyacetic acid.
2-Phenoxyethyl isobutyrate.
Phenylacetaldehyde; α-toluic aldehyde.
Phenylacetaldehyde 2,3-butylene glycol acetal.
Phenylacetaldehyde dimethyl acetal.
Phenylacetaldehyde glyceryl acetal.
Phenylacetic acid; α-toluic acid.
4-Phenyl-2-butanol; phenylethyl methyl carbinol.
4-Phenyl-3-buten-2-ol; methyl styryl carbinol.
4-Phenyl-3-buten-2-one.
4-Phenyl-2-butyl acetate; phenylethyl methyl carbinyl acetate.
1-Phenyl-3-methyl-3-pentanol; phenylethyl methyl ethyl carbinol.
1-Phenyl-1-propanol; phenylethyl carbinol.
3-Phenyl-1-propanol; hydrocinnamyl alcohol.

Table 4.6: Synthetic Flavor Adatitves (Adapted from 21 CFR Part 170, n.d.).

2-Phenylpropionaldehyde; hydratropaldehyde.
3-Phenylpropionaldehyde; hydrocinnamaldehyde.
2-Phenylpropionalde-hyde dimethyl acetal; hydratropic aldehyde dimethyl acetal.
3-Phenylpropionic acid; hydrocinnamic acid.
3-Phenylpropyl acetate.
2-Phenylpropyl butyrate.
3-Phenylpropyl cinnamate.
3-Phenylpropyl formate.
3-Phenylpropyl hexanoate.
2-Phenylpropyl isobutyrate.
3-Phenylpropyl isobutyrate.
3-Phenylpropyl isovalerate.
3-Phenylpropyl propionate.
2-(3-Phenylpropyl)-tetrahydrofuran.
α-Pinene; 2-pinene.
β-Pinene; 2(10)-pinene.
Pine tar oil.
Pinocarveol; 2(10)-pinen-3-ol.
Piperidine.
Piperine.
d-Piperitone; *p*-menth-1-en-3-one.
Piperitenone; *p*-mentha-1,4(8)-dien-3-one.
Piperitenone oxide; 1,2-epoxy-*p*-menth-4-(8)-en-3-one.
Piperonyl acetate; heliotropyl acetate.
Piperonyl isobutyrate.
Polylimonene.
Polysorbate 20; polyoxyethylene (20) sorbitan monolaurate.
Polysorbate 60; polyoxyethylene (20) sorbitan monostereate.
Polysorbate 80; polyoxyethylene (20) sorbitan monooleate.
Potassium acetate.
Propenylguaethol; 6-ethoxy-*m*-anol.
Propionaldehyde.
Propyl acetate.
Propyl alcohol; 1-propanol.
p-Propyl anisole; dihydroanethole.
Propyl benzoate.
Propyl butyrate.
Propyl cinnamate.
Propyl disulfide.
Propyl formate.
Propyl 2-furanacrylate.
Propyl heptanoate.
Propyl hexanoate.
Propyl *p*-hydroxybenzoate; propylparaben.
3-Propylidenephthalide.
Propyl isobutyrate.
Propyl isovalerate.
Propyl mercaptan.
α-Propylphenethyl alcohol.
Propyl phenylacetate.
Propyl propionate.
Pulegone; *p*-menth-4(8)-en-3-one.
Pyridine.
Pyroligneous acid extract.
Pyruvaldehyde.
Pyruvic acid.
Rhodinol; 3,7-dimethyl-7-octen-1-ol; *l*-citronellol.
Rhodinyl acetate.
Rhodinyl butyrate.
Rhodinyl formate.
Rhodinyl isobutyrate.
Rhodinyl isovalerate.
Rhodinyl phenylacetate.
Rhodinyl propionate.
Rum ether; ethyl oxyhydrate.
Salicylaldehyde.
Santalol, α and β.
Santalyl acetate.
Santalyl phenylacetate.
Skatole.
Sorbitan monostearate.
Styrene.
Sucrose octaacetate.
α-Terpinene.
γ-Terpinene.
α-Terpineol; *p*-menth-1-en-8-ol.
β-Terpineol.
Terpinolene; *p*-menth-1,4(8)-diene.
Terpinyl acetate.
Terpinyl anthranilate.
Terpinyl butyrate.
Terpinyl cinnamate.
Terpinyl formate.
Terpinyl isobutyrate.
Terpinyl isovalerate.
Terpinyl propionate.
Tetrahydrofurfuryl acetate.
Tetrahydrofurfuryl alcohol.
Tetrahydrofurfuryl butyrate.
Tetrahydrofurfuryl propionate.
Tetrahydro-pseudo-ionone; 6,10-dimethyl-9-undecen-2-one.
Tetrahydrolinalool; 3,7-dimethyloctan-3-ol.
Tetramethyl ethylcyclohexenone; mixture of 5-ethyl-2,3,4,5-tetramethyl-2-cyclohexen-1-one and 5-ethyl-3,4,5,6-tetramethyl-2-cyclohexen-1-one.
2-Thienyl mercaptan; 2-thienylthiol.
Thymol.
Tolualdehyde glyceryl acetal, mixed *o, m, p*.
Tolualdehydes, mixed *o, m, p*.
p-Tolylacetaldehyde.
o-Tolyl acetate; *o*-cresyl acetate.
p-Tolyl acetate; *p*-cresyl acetate.
4-(*p*-Tolyl)-2-butanone; *p*-methylbenzylacetone.
p-Tolyl isobutyrate.
p-Tolyl laurate.
p-Tolyl phenylacetate.
2-(*p*-Tolyl)-propionaldehyde; *p*-methylhydratropic aldehyde.
Tributyl acetylcitrate.
2-Tridecenal.
2,3-Undecadione; acetyl nonyryl.
γ-Undecalactone; 4-hydroxyundecanoic acid γ-lactone; peach aldehyde; aldehyde C-14.
Undecenal.
2-Undecanone; methyl nonyl ketone.
9-Undecenal; undecenoic aldehyde.
10-Undecenal.
Undecen-1-ol; undecylenic alcohol.
10-Undecen-1-yl acetate.
Undecyl alcohol.
Valeraldehyde; pentanal.
Valeric acid; pentanoic acid.
Vanillin acetate; acetyl vanillin.

Table 4.7: Synthetic Flavor Adatitves (Adapted from 21 CFR Part 170, n.d.).

§ 182.60 Synthetic flavoring substances and adjuvants.

Synthetic flavoring substances and adjuvants that are generally recognized as safe for their intended use, within the meaning of section 409 of the Act, are as follows:

Acetaldehyde (ethanal).
Acetoin (acetyl methylcarbinol).
Anethole (parapropenyl anisole).
Benzaldehyde (benzoic aldehyde).
N-Butyric acid (butanoic acid).
d- or *l*-Carvone (carvol).
Cinnamaldehyde (cinnamic aldehyde).
Citral (2,6-dimethyloctadien-2,6-*al*-8, geranial, neral).
Decanal (*N*-decylaldehyde, capraldehyde, capric aldehyde, caprinaldehyde, aldehyde C-10).
Ethyl acetate.
Ethyl butyrate.
3-Methyl-3-phenyl glycidic acid ethyl ester (ethyl-methyl-phenyl-glycidate, so-called strawberry aldehyde, C-16 aldehyde).
Ethyl vanillin.
Geraniol (3,7-dimethyl-2,6 and 3,6-octadien-1-*ol*).
Geranyl acetate (geraniol acetate).
Limonene (*d*-, *l*-, and *dl*-).
Linalool (linalol, 3,7-dimethyl-1,6-octadien-3-*ol*).
Linalyl acetate (bergamol).
Methyl anthranilate (methyl-2-aminobenzoate).
Piperonal (3,4-methylenedioxy-benzaldehyde, heliotropin).
Vanillin.

[42 FR 14640, Mar. 15, 1977, as amended at 43 FR 47724, Oct. 17, 1978; 44 FR 3963, Jan. 19, 1979; 44 FR 20656, Apr. 6, 1979; 48 FR 51907, Nov. 15, 1983; 54 FR 7402, Feb. 21, 1989]

ognized as safe for their intended use, within the meaning of section 409 of the Act, are as follows:

Beef tallow.
Carboxymethylcellulose.
Coconut oil, refined.
Cornstarch.
Gelatin.
Lard.
Lard oil.
Oleic acid.
Peanut oil.
Potato starch.
Sodium acetate.
Sodium chloride.
Sodium silicate.
Sodium tripolyphosphate.
Soybean oil (hydrogenated).
Talc.
Tallow (hydrogenated).
Tallow flakes.
Tapioca starch.
Tetrasodium pyrophosphate.
Wheat starch.
Zinc chloride.

[42 FR 14640, Mar. 15, 1977, as amended at 43 FR 11698, Mar. 21, 1978; 44 FR 28323, May 15, 1979; 45 FR 6085, Jan. 25, 1980; 47 FR 27807, 27814, June 25, 1982; 48 FR 51150, Nov. 7, 1983; 48 FR 51616, Nov. 10, 1983; 48 FR 51909, Nov. 15, 1983; 48 FR 52441, 52443, 52445, 52446, Nov. 18, 1983; 51 FR 16830, May 7, 1986; 51 FR 27171, July 30, 1986; 60 FR 62208, Dec. 5, 1995]

Table 5.1: Synthetic Flavor Adatitves (Adapted from 21 CFR Part 170, n.d.).

Common name	Botanical name of plant source
Alfalfa herb and seed	Medicago sativa L.
Allspice	Pimenta officinalis Lindl.
Ambrette seed	Hibiscus abelmoschus L.
Angelica	Angelica archangelica L. or other spp. of Angelica.
Angelica root	Do.
Angelica seed	Do.
Angostura (cusparia bark)	Galipea officinalis Hancock.
Anise	Pimpinella anisum L.
Anise, star	Illicium verum Hook. f.
Balm (lemon balm)	Melissa officinalis L.
Basil, bush	Ocimum minimum L.
Basil, sweet	Ocimum basilicum L.
Bay	Laurus nobilis L.
Calendula	Calendula officinalis L.
Camomile (chamomile), English or Roman	Anthemis nobilis L.
Camomile (chamomile), German or Hungarian	Matricaria chamomilla L.
Capers	Capparis spinosa L.
Capsicum	Capsicum frutescens L. or Capsicum annuum L.
Caraway	Carum carvi L.
Caraway, black (black cumin)	Nigella sativa L.
Cardamom (cardamon)	Elettaria cardamomum Maton.
Cassia, Chinese	Cinnamomum cassia Blume.
Cassia, Padang or Batavia	Cinnamomum burmanni Blume.
Cassia, Saigon	Cinnamomum loureirii Nees.
Cayenne pepper	Capsicum frutescens L. or Capsicum annuum L.
Celery seed	Apium graveolens L.
Chervil	Anthriscus cerefolium (L.) Hoffm.
Chives	Allium schoenoprasum L.
Cinnamon, Ceylon	Cinnamomum zeylanicum Nees.
Cinnamon, Chinese	Cinnamomum cassia Blume.
Cinnamon, Saigon	Cinnamomum loureirii Nees.
Clary (clary sage)	Salvia sclarea L.
Clover	Trifolium spp.
Coriander	Coriandrum sativum L.
Cumin (cummin)	Cuminum cyminum L.
Cumin, black (black caraway)	Nigella sativa L.
Elder flowers	Sambucus canadensis L.
Fennel, common	Foeniculum vulgare Mill.
Fennel, sweet (finocchio, Florence fennel)	Foeniculum vulgare Mill. var. dulce (DC.) Alex.
Fenugreek	Trigonella foenum-graecum L.
Galanga (galangal)	Alpinia officinarum Hance.
Geranium	Pelargonium spp.
Ginger	Zingiber officinale Rosc.
Grains of paradise	Amomum melegueta Rosc.
Horehound (hoarhound)	Marrubium vulgare L.
Horseradish	Armoracia lapathifolia Gilib.
Hyssop	Hyssopus officinalis L.
Lavender	Lavandula officinalis Chaix.
Linden flowers	Tilia spp.
Mace	Myristica fragrans Houtt.
Marigold, pot	Calendula officinalis L.
Marjoram, pot	Majorana onites (L.) Benth.
Marjoram, sweet	Majorana hortensis Moench.
Mustard, black or brown	Brassica nigra (L.) Koch.
Mustard, brown	Brassica juncea (L.) Coss.
Mustard, white or yellow	Brassica hirta Moench.
Nutmeg	Myristica fragrans Houtt.
Oregano (oreganum, Mexican oregano, Mexican sage, origan).	Lippia spp.
Paprika	Capsicum annuum L.
Parsley	Petroselinum crispum (Mill.) Mansf.
Pepper, black	Piper nigrum L.
Pepper, cayenne	Capsicum frutescens L. or Capsicum annuum L.
Pepper, red	Do.
Pepper, white	Piper nigrum L.
Peppermint	Mentha piperita L.
Poppy seed	Papayer somniferum L.
Pot marigold	Calendula officinalis L.
Pot marjoram	Majorana onites (L.) Benth.
Rosemary	Rosmarinus officinalis L.
Saffron	Crocus sativus L.
Sage	Salvia officinalis L.
Sage, Greek	Salvia triloba L.
Savory, summer	Satureia hortensis L. (Satureja).

Table 6.1. Spices and other natural seasonings (Adapted from 21 CFR Part 182.10, n.d.).

Common name	Botanical name of plant source
Savory, winter	Satureia montana L. (Satureja).
Sesame	Sesamum indicum L.
Spearmint	Mentha spicata L.
Star anise	Illicium verum Hook. f.
Tarragon	Artemisia dracunculus L.
Thyme	Thymus vulgaris L.
Thyme, wild or creeping	Thymus serpyllum L.
Turmeric	Curcuma longa L.
Vanilla	Vanilla planifolia Andr. or Vanilla tahitensis J. W. Moore.
Zedoary	Curcuma zedoaria Rosc.

Table 7.1. Essential Oils (Adapted from 21 CFR Part 182.20, n.d.).

Common name	Botanical name of plant source
Alfalfa	Medicago sativa L.
Allspice	Pimenta officinalis Lindl.
Almond, bitter (free from prussic acid)	Prunus amygdalus Batsch, Prunus armeniaca L., or Prunus persica (L.) Batsch.
Ambrette (seed)	Hibiscus moschatus Moench.
Angelica root	Angelica archangelica L.
Angelica seed	Do.
Angelica stem	Do.
Angostura (cusparia bark)	Galipea officinalis Hancock.
Anise	Pimpinella anisum L.
Asafetida	Ferula assa-foetida L. and related spp. of Ferula.
Balm (lemon balm)	Melissa officinalis L.
Balsam of Peru	Myroxylon pereirae Klotzsch.
Basil	Ocimum basilicum L.
Bay leaves	Laurus nobilis L.
Bay (myrcia oil)	Pimenta racemosa (Mill.) J. W. Moore.
Bergamot (bergamot orange)	Citrus aurantium L. subsp. bergamia Wright et Arn.
Bitter almond (free from prussic acid)	Prunus amygdalus Batsch, Prunus armeniaca L., or Prunus persica (L.) Batsch.
Bois de rose	Aniba rosaeodora Ducke.
Cacao	Theobroma cacao L.
Camomile (chamomile) flowers, Hungarian	Matricaria chamomilla L.
Camomile (chamomile) flowers, Roman or English	Anthemis nobilis L.
Cananga	Cananga odorata Hook. f. and Thoms.
Capsicum	Capsicum frutescens L. and Capsicum annuum L.
Caraway	Carum carvi L.
Cardamom seed (cardamon)	Elettaria cardamomum Maton.
Carob bean	Ceratonia siliqua L.
Carrot	Daucus carota L.
Cascarilla bark	Croton eluteria Benn.
Cassia bark, Chinese	Cinnamomum cassia Blume.
Cassia bark, Padang or Batavia	Cinnamomum burmanni Blume.
Cassia bark, Saigon	Cinnamomum loureirii Nees.
Celery seed	Apium graveolens L.
Cherry, wild, bark	Prunus serotina Ehrh.
Chervil	Anthriscus cerefolium (L.) Hoffm.
Chicory	Cichorium intybus L.
Cinnamon bark, Ceylon	Cinnamomum zeylanicum Nees.
Cinnamon bark, Chinese	Cinnamomum cassia Blume.
Cinnamon bark, Saigon	Cinnamomum loureirii Nees.
Cinnamon leaf, Ceylon	Cinnamomum zeylanicum Nees.
Cinnamon leaf, Chinese	Cinnamomum cassia Blume.
Cinnamon leaf, Saigon	Cinnamomum loureirii Nees.
Citronella	Cymbopogon nardus Rendle.
Citrus peels	Citrus spp.
Clary (clary sage)	Salvia sclarea L.
Clover	Trifolium spp.
Coca (decocainized)	Erythroxylum coca Lam. and other spp. of Erythroxylum.

Table 7.2. Essential Oils (Adapted from 21 CFR Part 182.20, n.d.).

Common name	Botanical name of plant source
Coffee	Coffea spp.
Cola nut	Cola acuminata Schott and Endl., and other spp. of Cola.
Coriander	Coriandrum sativum L.
Cumin (cummin)	Cuminum cyminum L.
Curacao orange peel (orange, bitter peel)	Citrus aurantium L.
Cusparia bark	Galipea officinalis Hancock.
Dandelion	Taraxacum officinale Weber and T. laevigatum DC.
Dandelion root	Do.
Dog grass (quackgrass, triticum)	Agropyron repens (L.) Beauv.
Elder flowers	Sambucus canadensis L. and S. nigra I.
Estragole (esdragol, esdragon, tarragon)	Artemisia dracunculus L.
Estragon (tarragon)	Do.
Fennel, sweet	Foeniculum vulgare Mill.
Fenugreek	Trigonella foenum-graecum L.
Galanga (galangal)	Alpinia officinarum Hance.
Geranium	Pelargonium spp.
Geranium, East Indian	Cymbopogon martini Stapf.
Geranium, rose	Pelargonium graveolens L'Her.
Ginger	Zingiber officinale Rosc.
Grapefruit	Citrus paradisi Macf.
Guava	Psidium spp.
Hickory bark	Carya spp.
Horehound (hoarhound)	Marrubium vulgare L.
Hops	Humulus lupulus L.
Horsemint	Monarda punctata L.
Hyssop	Hyssopus officinalis L.
Immortelle	Helichrysum augustifolium DC.
Jasmine	Jasminum officinale L. and other spp. of Jasminum.
Juniper (berries)	Juniperus communis L.
Kola nut	Cola acuminata Schott and Endl., and other spp. of Cola.
Laurel berries	Laurus nobilis L.
Laurel leaves	Laurus spp.
Lavender	Lavandula officinalis Chaix.
Lavender, spike	Lavandula latifolia Vill.
Lavandin	Hybrids between Lavandula officinalis Chaix and Lavandula latifolin Vill.
Lemon	Citrus limon (L.) Burm. f.
Lemon balm (see balm).	
Lemon grass	Cymbopogon citratus DC. and Cymbopogon lexuosus Stapf.
Lemon peel	Citrus limon (L.) Burm. f.
Lime	Citrus aurantifolia Swingle.
Linden flowers	Tilia spp.
Locust bean	Ceratonia siliqua L,
Lupulin	Humulus lupulus L.
Mace	Myristica fragrans Houtt.
Mandarin	Citrus reticulata Blanco.
Marjoram, sweet	Majorana hortensis Moench.
Maté	Ilex paraguariensis St. Hil.
Melissa (see balm).	
Menthol	Mentha spp.
Menthyl acetate	Do.
Molasses (extract)	Saccarum officinarum L.
Mustard	Brassica spp.
Naringin	Citrus paradisi Macf.
Neroli, bigarade	Citrus aurantium L.
Nutmeg	Myristica fragrans Houtt.
Onion	Allium cepa L.
Orange, bitter, flowers	Citrus aurantium L.
Orange, bitter, peel	Do.
Orange leaf	Citrus sinensis (L.) Osbeck.
Orange, sweet	Do.
Orange, sweet, flowers	Do.
Orange, sweet, peel	Do.
Origanum	Origanum spp.
Palmarosa	Cymbopogon martini Stapf.
Paprika	Capsicum annuum L.
Parsley	Petroselinum crispum (Mill.) Mansf.
Pepper, black	Piper nigrum L.
Pepper, white	Do.
Peppermint	Mentha piperita L.
Peruvian balsam	Myroxylon pereirae Klotzsch.
Petitgrain	Citrus aurantium L.
Petitgrain lemon	Citrus limon (L.) Burm. f.
Petitgrain mandarin or tangerine	Citrus reticulata Blanco.
Pimenta	Pimenta officinalis Lindl.

Table 7.3. Essential Oils (Adapted from 21 CFR Part 182.20, n.d.).

Common name	Botanical name of plant source
Pimenta leaf	Pimenta officinalis Lindl.
Pipsissewa leaves	Chimaphila umbellata Nutt.
Pomegranate	Punica granatum L.
Prickly ash bark	Xanthoxylum (or Zanthoxylum) Americanum Mill. or Xanthoxylum clava-herculis L.
Rose absolute	Rosa alba L., Rosa centifolia L., Rosa damascena Mill., Rosa gallica L., and vars. of these spp.
Rose (otto of roses, attar of roses)	Do.
Rose buds	Do.
Rose flowers	Do.
Rose fruit (hips)	Do.
Rose geranium	Pelargonium graveolens L'Her.
Rose leaves	Rosa spp.
Rosemary	Rosmarinus officinalis L.
Saffron	Crocus sativus L.
Sage	Salvia officinalis L.
Sage, Greek	Salvia triloba L.
Sage, Spanish	Salvia lavandulaefolia Vahl.
St. John's bread	Ceratonia siliqua L.
Savory, summer	Satureia hortensis L.
Savory, winter	Satureia montana L.
Schinus molle	Schinus molle L.
Sloe berries (blackthorn berries)	Prunus spinosa L.
Spearmint	Mentha spicata L.
Spike lavender	Lavandula latifolia Vill.
Tamarind	Tamarindus indica L.
Tangerine	Citrus reticulata Blanco.
Tarragon	Artemisia dracunculus L.
Tea	Thea sinensis L.
Thyme	Thymus vulgaris L. and Thymus zygis var. gracilis Boiss.
Thyme, white	Do.
Thyme, wild or creeping	Thymus serpyllum L.
Triticum (see dog grass).	
Tuberose	Polianthes tuberosa L.
Turmeric	Curcuma longa L.
Vanilla	Vanilla planifolia Andr. or Vanilla tahitensis J. W. Moore.
Violet flowers	Viola odorata L.
Violet leaves	Do.
Violet leaves absolute	Do.
Wild cherry bark	Prunus serotina Ehrh.
Ylang-ylang	Cananga odorata Hook. f. and Thoms.
Zedoary bark	Curcuma zedoaria Rosc.

Table 8.1. Natural Extracts (Adapted from 21 CFR Part 182.40, n.d.).

Common name	Botanical name of plant source
Apricot kernel (persic oil)	Prunus armeniaca L.
Peach kernel (persic oil)	Prunus persica Sieb. et Zucc.
Peanut stearine	Arachis hypogaea L.
Persic oil (see apricot kernel and peach kernel).	
Quince seed	Cydonia oblonga Miller.

Table 8.2. Natural Extracts (Adapted from 21 CFR Part 182.40, n.d.).

Common name	Derivation
Ambergris	Physeter macrocephalus L.
Castoreum	Castor fiber L. and C. canadensis Kuhl.
Civet (zibeth, zibet, zibetum)	Civet cats, Viverra civetta Schreber and Viverra zibetha Schreber.
Cognac oil, white and green	Ethyl oenanthate, so-called.
Musk (Tonquin musk)	Musk deer, Moschus moschiferus L.

Table 9.1 Other Spices and Seasoningss (Adapted from 21 CFR Part 182.50, n.d.).

Common name	Scientific name	Limitations
Costus root	*Saussurea lappa* Clarke.	
Cubeb	*Piper cubeba* L. f.	
Currant, black, buds and leaves	*Ribes nigrum* L.	
Damiana leaves	*Turnera diffusa* Willd.	
Davana	*Artemisia pallens* Wall.	
Dill, Indian	*Anethum sowa* Roxb. (*Peucedanum graveolens* Benth et Hook., *Anethum graveolens* L.).	
Dittany (fraxinella) roots	*Dictamnus albus* L	Do.
Dittany of Crete	*Origanum dictamnus* L.	
Dragon's blood (dracorubin)	*Daemonorops* spp.	
Elder tree leaves	*Sambucus nigra* L	In alcoholic beverages only; not to exceed 25 p.p.m. prussic acid in the flavor
Elecampane rhizome and roots	*Inula helenium* L	In alcoholic beverages only
Elemi	*Canarium commune* L. or *C. luzonicum* Miq.	
Erigeron	*Erigeron canadensis* L.	
Eucalyptus globulus leaves	*Eucalyptus globulus* Labill.	
Fir ("pine") needles and twigs	*Abies sibirica* Ledeb., *A. alba* Mill., *A. sachalinesis* Masters or *A. mayriana* Miyabe et Kudo.	
Fir, balsam, needles and twigs	*Abies balsamea* (L.) Mill.	
Galanga, greater	*Alpinia galanga* Willd	Do.
Galbanum	*Ferula galbaniflua* Boiss. et Buhse and other *Ferula* spp.	
Gambir (catechu, pale)	*Uncaria gambir* Roxb.	
Genet flowers	*Spartium junceum* L.	
Gentian rhizome and roots	*Gentiana lutea* L.	
Gentian, stemless	*Gentiana acaulis* L	Do.
Germander, chamaedrys	*Teucrium chamaedrys* L	Do.
Germander, golden	*Teucrium polium* L	Do.
Guaiac	*Guaiacum officinale* L., *G. santum* L., *Bulnesia sarmienti* Lor.	
Guarana	*Paullinia cupana* HBK.	
Haw, black, bark	*Viburnum prunifolium* L.	
Hemlock needles and twigs	*Tsuga canadensis* (L.) Carr. or *T. heterophylla* (Raf.) Sarg.	
Hyacinth flowers	*Hyacinthus orientalis* L.	
Iceland moss	*Cetraria islandica* Ach	Do.
Imperatoria	*Peucedanum ostruthium* (L.). Koch (*Imperatoria ostruthium* L.).	
Iva	*Achillea moschata* Jacq	Do.
Labdanum	*Cistus* spp.	
Lemon-verbena	*Lippia citriodora* HBK	Do.
Linaloe wood	*Bursera delpechiana* Poiss. and other *Bursera* spp.	
Linden leaves	*Tilia* spp	Do.
Lovage	*Levisticum officinale* Koch.	
Lungmoss (lungwort)	*Sticta pulmonacea* Ach.	
Maidenhair fern	*Adiantum capillus-veneris* L	Do.
Maple, mountain	*Acer spicatum* Lam.	
Mimosa (black wattle) flowers	*Acacia decurrens* Willd. var. *dealbata*.	
Mullein flowers	*Verbascum phlomoides* L. or *V. thapsiforme* Schrad	Do.
Myrrh	*Commiphora molmol* Engl., *C. abyssinica* (Berg) Engl., or other *Commiphora* spp.	
Myrtle leaves	*Myrtus communis* L	Do.
Oak, English, wood	*Quercus robur* L	Do.
Oak, white, chips	*Quercus alba* L.	
Oak moss	*Evernia prunastri* (L.) Ach., *E. furfuracea* (L.) Mann, and other lichens.	Finished food thujone free [1]
Olibanum	*Boswellia carteri* Birdw. and other *Boswellia* spp.	
Opopanax (bisabolmyrrh)	*Opopanax chironium* Koch (true opopanax) of *Commiphora erythraea* Engl. var. *Llabrescens*.	
Orris root	*Iris germanica* L. (including its variety *florentina* Dykes) and *I. pallida* Lam.	
Pansy	*Viola tricolor* L	In alcoholic beverages only
Passion flower	*Passiflora incarnata* L.	
Patchouly	*Pogostemon cablin* Benth. and *P. heyneanus* Benth.	
Peach leaves	*Prunus persica* (L.) Batsch	In alcoholic beverages only; not to exceed 25 p.p.m. prussic acid in the flavor
Pennyroyal, American	*Hedeoma pulegioides* (L.) Pers.	
Pennyroyal, European	*Mentha pulegium* L.	

Table 10.1 Natural flavoring substances (Adapted from 21 CFR Part S172.510, n.d.).

Common name	Scientific name	Limitations
Pine, dwarf, needles and twigs	*Pinus mugo* Turra var. *pumilio* (Haenke) Zenari.	
Pine, Scotch, needles and twigs	*Pinus sylvestris* L.	
Pine, white, bark	*Pinus strobus* L	In alcoholic beverages only
Pine, white oil	*Pinus palustris* Mill., and other *Pinus* spp.	
Poplar buds	*Populus balsamifera* L. (*P. tacamahacca* Mill.), *P. candicans* Ait., or *P. nigra* L.	Do.
Quassia	*Picrasma excelsa* (Sw.) Planch, or *Quassia amara* L.	
Quebracho bark	*Aspidosperma quebracho-blanco* Schlecht, or (*Quebrachia lorentzii* (Griseb)).	*Schinopsis lorentzii* (Griseb.) Engl.
Quillaia (soapbark)	*Quillaja saponaria* Mol.	
Red saunders (red sandalwood)	*Pterocarpus san alinus* L	In alcoholic beverages only
Rhatany root	*Krameria triandra* Ruiz et Pav. or *K. argentea* Mart.	
Rhubarb, garden root	*Rheum rhaponticum* L	Do.
Rhubarb root	*Rheum officinale* Baill., *R. palmatum* L., or other spp. (excepting *R. rhaponticum* L.) or hybrids of *Rheum* grown in China.	
Roselle	*Hibiscus sabdariffa* L	Do.
Rosin (colophony)	*Pinus palustris* Mill., and other *Pinus* spp	Do.
St. Johnswort leaves, flowers, and caulis	*Hypericum perforatum* L	Hypericin-free alcohol distillate form only; in alcoholic beverages only
Sandalwood, white (yellow, or East Indian)	*Santalum album* L.	
Sandarac	*Tetraclinis articulata* (Vahl.), Mast	In alcoholic beverages only
Sarsaparilla	*Smilax aristolochiaefolia* Mill., (Mexican sarsaparilla), *S. regelii* Killip et Morton (Honduras sarsaparilla), *S. febrifuga* Kunth (Ecuadorean sarsaparilla), or undetermined *Smilax* spp. (Ecuadorean or Central American sarsaparilla).	
Sassafras leaves	*Sassafras albidum* (Nutt.) Nees	Safrole free
Senna, Alexandria	*Cassia acutifolia* Delile.	
Serpentaria (Virginia snakeroot)	*Aristolochia serpentaria* L	In alcoholic beverages only
Simaruba bark	*Simaruba amara* Aubl	Do.
Snakeroot, Canadian (wild ginger)	*Asarum canadense* L.	
Spruce needles and twigs	*Picea glauca* (Moench) Voss or *P. mariana* (Mill.) BSP.	
Storax (styrax)	*Liquidambar orientalis* Mill. or *L. styraciflua* L.	
Tagetes (marigold)	*Tagetes patula* L., *T. erecta* L., or *T. minuta* L. (*T. glandulifera* Schrank).	As oil only
Tansy	*Tanacetum vulgare* L	In alcoholic beverages only; finished alcoholic beverage thujone free [1]
Thistle, blessed (holy thistle)	*Cnicus benedictus* L	In alcoholic beverages only
Thymus capitatus (Spanish "origanum")	*Thymus capitatus* Hoffmg. et Link.	
Tolu	*Myroxylon balsamum* (L.) Harms.	
Turpentine	*Pinus palustris* Mill. and other *Pinus* spp. which yield terpene oils exclusively.	
Valerian rhizome and roots	*Valeriana officinalis* L.	
Veronica	*Veronica officinalis* L	Do.
Vervain, European	*Verbena officinalis* L	Do.
Vetiver	*Vetiveria zizanioides* Stapf	Do.
Violet, Swiss	*Viola calcarata* L.	
Walnut husks (hulls), leaves, and green nuts	*Juglans nigra* L. or *J. regia* L.	
Woodruff, sweet	*Asperula odorata* L	In alcoholic beverages only
Yarrow	*Achillea millefolium* L	In beverages only; finished beverage thujone free [1]
Yerba santa	*Eriodictyon californicum* (Hook, et Arn.) Torr.	
Yucca, Joshua-tree	*Yucca brevifolia* Engelm.	
Yucca, Mohave	*Yucca schidigera* Roezl ex Ortgies (*Y. mohavensis* Sarg.).	

Table 10.2 Natural flavoring substances (Adapted from 21 CFR Part S172.510, n.d.).

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Chapter 1: Introduction

INTRODUCTION

As consumer trends shift, the American public are paying more attention to what they are putting in their body and have a stronger focus on healthier eating. However, according to a PEW research report, although attention of consumers is focused on healthy eating, behavioral implementation of these practices is lacking (Funk & Funk, 2024). While healthy eating is the goal, the term is subjective in nature and without a full understanding one has no way to know and then implement what healthy eating is. A healthy diet, and healthy eating today means cutting back on food items with high fat, sodium, and sugar content (Grimmelt et al., 2022) and including a mix of fresh fruits, vegetables and wholegrains.

Food items with high fat, sodium, and sugar content, also known as processed foods, are becoming increasingly produced and has led to a drastic shift in dietary patterns and consumption lifestyles (World Health Organization: WHO, 2020). This change in consumption patterns can be attributed to the uptick in obesity and overweight individuals in the U.S, where nearly 1 in 3 adults are overweight and 2 in 5 are obese (*Overweight &Amp;Amp; Obesity Statistics*, 2024). It can also be attributed to the heightened risk for many health problems, including heart disease, types of cancer, diabetes, etc.

With consumption levels of processed food heightened, it is pivotal to note the majority of these food items contain an abundance of food additives, which are utilized to improve the overall appearance, shelf life, and consistency of food products ("Food Toxicology," 2016). However, according to the International Food Information Council's Food and Health Safety report, 34% of respondents found food additives and ingredients including caffeine, MSG, flavors, colors, preservatives etc. as their top issue regarding food safety (International Food Information Council, 2022). This furthers the evidence of a shift in consumer trends, and expanding the need for change regarding how consumers decipher between processed food items.

We are presently seeing a monumental shift in food additive policy in prominent food producing sectors within the United States. Fast food restaurants are one of the main sectors in the U.S. that contribute to an unhealthy diet and offer foods with high contents of additives and preservatives. Burger King, a prominent international fast food chain, has begun to change this narrative with its campaign "Beauty of No Artificial Preservatives". The campaign illustrates their initiative of eliminating harmful food additives in their products by advertising a spoiled burger, a natural phenomenon that occurs a few days after no consumption. This ensures to the public that there are no additives preserving shelf life or product appeal in this campaign. Burger King has acknowledged the shift of health-conscious consumers, and created a marketing campaign to depict a healthy and unaltered burger (Lithos & LithosPOS, 2024).

In a policy setting, some states are beginning to understand the importance of knowing what we put in our body and the health effects they may cause, and take action. The first administrative body within the United States of America to take strict action regarding harmful additives is the state of California. Gavin Newsom, the Governor of California, has passed a law that bans harmful food additives, including a popular food color additive, red dye number 3. The California Food Safety Act, Assembly Bill 418, prohibits the sale, manufacture, or distribution of the food dye, along with 3 other chemical food additives including potassium bromate, brominated vegetable oil and propylparaben (Hernandez, 2023).

It is pivotal to continue to research and explore effective approaches to ensure the consuming body has accurate and transparent information regarding food additives, allowing for the execution of autonomous decision making with respect to healthy eating. A tool that assists consumers with healthier dietary choices is the Nutrition Facts label found on the back of almost all packaged foods in the United States (Christoph et al., 2018). Nutrition Facts are regulated by the Food and Drug Administration and have been required since the legislation passed the Nutritional Labeling and Education Act of 1990 (Pintauro, 2018). In recent years there has been a push to make labels easier to understand with regards to both formatting and content (*Food Labeling: Revision of the Nutrition and Supplement Facts Labels. Final Rule*, 2016).

Two types of food labels, front of pack and back of pack, are present on food packaging. Front of pack labels are designed to attract the attention of consumers, while back of pack labels are present as an informative guideline for ingredients and nutrients present in the food item. In this research we will focus predominantly on front of pack labels, and more specifically that which follows a traffic light system.

The traffic light label system presents nutrient information in a way that illustrates a range of nutrient categories with corresponding colors. Traditionally, the four categories are fat, saturated fat, sugar, and salt levels in a product. The corresponding colors are “red” indicating a high level of that nutrient, “orange” indicating a medium level, and “green” indicating a low level of nutrient (Sacks et al., 2009). While there is ample research on traffic light food labels, mostly residing in the United Kingdom and Ecuador, continued research is needed for the United States.

While traditional food traffic labels focus on nutrition facts, my research focuses on the effectiveness of using a modified traffic light food labeling system in increasing consumer awareness of food additives. While the traditional system focuses on nutritional content—such as fat, sugar, and salt—this research will assess how well it can communicate the presence of additives in common food products. To what extent a modified traffic light food labeling system, designed to communicate the safety of food additives, improves consumer awareness and influences healthier purchasing decisions compared to traditional nutrition labels in the U.S. will be explored through this research.

My literature review will give a comprehensive background on common food additives, their history, and their present cause for concern, while also touching upon governing bodies surrounding the food additive and food label landscape. Then I will explore U.S. consumer perceptions on food additives and the concept of traffic light labels. Finally, I will explore the effectiveness of a modified traffic light food labeling system to a traditional nutrition food labeling system in the context of popular packaged food items in the U.S.

The findings of this research will contribute to ongoing efforts in assisting the American public with making more well-informed and healthy food choices, while also raising awareness about the presence of food additives in our everyday food.

Chapter 2: Literature Review

COMMON FOOD ADDITIVES

The Food and Drug Administration (FDA) defines a food additive as “any substance in which the intended use may, directly or indirectly, affect the characteristic of any food – including any substance used in producing, manufacturing, packing, processing, preparing, treating, packaging, transporting, or holding food” according to Section 201(s) of the Food, Drug, and Cosmetic Act (Program, 2018). It is important to note that these ingredients are typically not consumed as food by themselves, nor are they used as typical ingredients in foods, and that they are substances added to food for the purpose of improving color and quality perceptions, flavor, freshness, or for preservation purposes (Abedi-Firoozjah & Tavassoli, 2024). Common food additives in the scope of this research can be categorized as a coloring additive, a flavoring additive, or a preservative additive.

Color Additives:

Adding color to foods is a long standing custom that dates back to the early Indus Valley civilizations in 3500 BC and became common practice around 1500 BC when natural extracts and wine were supplemented to enhance the appeal and appearance of some food items (Unesco, 2008). The use of artificial food colors in modern practice didn’t emerge until 1856, when Sir William Henry Perk discovered the first synthetic organic dye, mauve, marking significant shifts in the world of food color technology (Science History Institute, 2024). 50 years later, the first policy addressing concerns with adulterated foods, including that of artificial colors, was enacted in the 1906 Pure Food and Drug Act. Later the 1938 Food, Drug, and Cosmetic Act established the regulatory framework for food additives that remains in place today.

The presence of color additives in food products serves several purposes. They provide uniformity and consistency in color presentation, compensate for potential color loss during food processing, and impart vibrancy to bland or colorless foods (Program, 2023 & Frick, 2003). Additionally, color additives propose a significant influence over consumers sensory experiences with food, specifically in terms of taste, attraction, perception, and quality (Lehto et al., 2017; Program, 2023; Burrows, 2009).

Color is a critical attribute as it pertains to consumer preferences, selections, and desires of food items (Su & Wang, 2024) and research shows that our experience of taste and flavor is largely determined by our created expectations prior to consumption (Shankar et al., 2010), and thus color creates a psychological expectation that is difficult to overturn (Shankar et al., 2010). Color associations can be argued to be a combination of evolutionary practices and cultural norms. From an evolutionary perspective, animals and human beings alike understand food condition according to its color, a practice dating back to homo sapiens evolution 3 million years ago (Luca et al., 2010). Thus, one could argue that our preference for brighter colored food is credited to our evolutionary adaptation. The color pigmentation of food items like certain meats, fruits, and vegetables can indicate ripeness, while dull and grey items often signal spoil and harm (Luca et al., 2010).

As defined by the Food and Drug Administration, a color additive is any dye, pigment, or substance that can impart color to a consumable product, pharmaceutical, cosmetic, or even the human body (Program, 2023). Color additives fall into two categories: natural sources, which are exempt from certification, and synthetic or artificial sources, which require batch certification. This distinction highlights the difference between substances that are naturally occurring, and those that are chemically synthesized ("Encyclopedia of Food Chemistry," 2019).

Presently in the United States, the FDA has approved nine synthetic food colors additives, all of which require batch certification. Below is an overview of these certified color additives.

Require Batch Certification:

1. **FD&C Blue No. 1**: Also known as Brilliant Blue FCF disodium is an additive known for its coloring agents, which is commonly used in processed foods, pharmaceuticals, dietary supplements, and cosmetics (Shahmohammadi et al., 2016).
2. **FD&C Blue No. 2**: Referred to as Indigo Carmine or indigotine, its molecular formula is C12H19N3O5. It is used in desserts, baked goods, snacks, and dairy products, as well as in medical diagnostics and pharmaceutical formulations ("Food Chemistry," 2021).
3. **FD&C Green No. 3**: Known as Fast Green FCF, this additive is turquoise in color and used in vegetables, jellies, sauces, and baked goods (Pereira et al., 2024).

4. **Orange B**: Once used in sausage casings, Orange B is no longer in use in the United States and has not been certified for the past decade (*Synthetic Food Dyes: A Rainbow of Risks*, 2024 & Arnold et al., 2012).
5. **Citrus Red No. 2**: This color additive is used to dye the skin of oranges but is only allowed for oranges consumed as fresh produce (*Synthetic Food Dyes: A Rainbow of Risks*, 2024).
6. **FD&C Red No. 3**: Known as erythrosine, this pink dye is used in candy, ice pops, and cake-decorating gels. While its use in food and ingested medications remains unrestricted, its application in cosmetics and topical drugs is prohibited (Garg, 2024).
7. **FD&C Red No. 40**: Also called Allura Red AC, this is one of the most widely used synthetic food dyes, found in food, drugs, cosmetics, and even tattoo ink (Oplatowska-Stachowiak & Elliott, 2016).
8. **FD&C Yellow No. 5**: Known as Tartrazine, this dye is used in food products, cosmetics, and pesticides (Oplatowska-Stachowiak & Elliott, 2016).
9. **FD&C Yellow No. 6**: Also called Sunset Yellow FCF, this dye is used in gelatin, frozen desserts, carbonated beverages, and bakery products (Oplatowska-Stachowiak & Elliott, 2016).

Exempt from Batch Certification

It is relevant to point out that colorants exempt from certification frequently originate from plant, mineral, insect, or other naturally occurring origins, embodying naturalness, however not all exempt colors stem strictly from nature (Program, 2023). In the US regulatory framework, there isn't a distinct category for "natural" color additives. Instead, regulations classify color additives simply as either subject to certification or exempt from certification, without differentiation based on their origin as natural or synthetic (*21 CFR Part 170 -- Food Additives*, n.d.). You can view the list of colors that are exempt from batch certification in the charts section labeled table 3.0.

Flavor Additives:

Flavor additive practices can be distinguished throughout history by various cultures and for a plethora of reasons (Wang et al., 2023). The British Museum of History credits the Assyrian Empire, an early Mesopotamian civilization, with the earliest mentioned herb on record as sesame, where it was used as a source to enhance flavor to food, wine, and oil (Parry, 1955). Flavor enhancement through an additive substance is also described in the Holy Bible's Old Testament where it can be noted that spices from the "traffics of the spice merchants" were "employed to make food more palatable" (Parry, 1955). Fast forward to the 1850s, where the first synthetic substance used to flavor candy was created, not from the extract of a fruit, but in a lab and using the chemical compound amyl acetate (Berenstein, 2018). From this discovery, we continue to add and enhance a variety of food items with synthetic food flavoring, spanning from refreshments, confections and jellies, to pasties, syrups and sauces (Berenstein, 2018).

Flavor additives are any substances added to supplement, enhance, or modify the original taste or aroma of food items (*CFR - Code of Federal Regulations Title 21*, n.d). Flavor itself is a multisensory experience of the gustatory, olfactory, and somatosensory systems (Small, 2012), where flavor of a food can only be determined when taste and smell are present (Institute for

Quality and Efficiency in Health Care (IQWiG), 2023) and combined with our individual experiences with food and food products (Myers, 2018).

Flavoring agents are chemicals that impart flavors or fragrances and are added to food to modify its aroma or taste. It is important to note these are the most common type of additives used in foods and have hundreds of variations (World Health Organization: WHO, 2023). The U.S. Food and Drug Administration, FDA, regulates the use of flavorings in food products through the Code of Federal Regulations, CFR, Title 21, Part 101.22. The regulatory agent states that all flavorings used in food products must be safe for consumption and properly labeled (*CFR - Code of Federal Regulations Title 21*, n.d.) According to the FDA, a flavoring additive can be defined as “any substance with the function of imparting flavor, which is used or intended for use in imparting flavor to a food, including any substance that functions in this manner as a result of an interaction with other substances” (*CFR - Code of Federal Regulations Title 21*, n.d.).

Artificial Flavor:

The term artificial flavor, or artificial flavoring is defined by any substance, the function of which is to impart flavor, which is not derived from a spice, fruit or fruit juice, vegetable or vegetable juice, edible yeast, herb, bark, bud, root, leaf or similar plant material, meat, fish, poultry, eggs, dairy products, or fermentation products thereof as defined by the Food and Drug Administration classified in the Code of Regulations Title 21 Section 101.22 (*CFR - Code of Federal Regulations Title 21*, n.d.). Those which constitute an artificial flavor additive can be summarized by the charts proceeding the reference page and titled by Table 4.1-7 which are reflective of substances characterized under SS 172.515 and Table 5.1 which are reflective of substances categorized under section CFR 182.60.

Natural Flavor:

As in opposition, the term natural flavor or natural flavoring means the essential oil, oleoresin, essence or extractive, protein hydrolysate, distillate, or any product of roasting, heating or enzymolysis, which contains the flavoring constituents derived from a spice, fruit or fruit juice, vegetable or vegetable juice, edible yeast, herb, bark, bud, root, leaf or similar plant material, meat, fish, poultry, eggs, dairy products, or fermentation products (*CFR - Code of Federal Regulations Title 21*, n.d.). Those which constitute a natural flavor additive can be summarized by the charts proceeding the reference page and titled by Table 6.1 -reflective of substances characterized under section CFR 182.10; Table 7.1-3 – characterized by substances classified under CFR 182.20; Table 8.1-2 – defining substances under CFR 182.40; Table 9.1 reflecting substances under CFR 182.50; Table 10.1-2 – analyzing the natural substances under S172.510.

Flavor Additive Health Implications:

<u>Brominated Vegetable Oil</u>

Brominated Vegetable Oil is a food additive and emulsifier which is used to stabilize and prevent the citrus flavors from separating in soft drinks and other beverages. Currently, it is authorized for its usage in small amounts, but is not approved to exceed 15 parts per million (Hetter, 2023). Brominated Vegetable Oil, or BVO, was previously listed under the “generally recognized as safe” list, and has since been removed. For now, until the ban gains approval, its usage is limited. Although popular soft drink companies like PepsiCo and Coca-Cola have removed BVO from their products due to on-going concern, it is still used and found in smaller store and discount store-brand soft drinks (Hetter, 2023). The consumption of BVO has shown heart, kidney, and liver damage in pigs (Farber et al., 1976); accumulations of sodium benzoate's derivatives in the heart, liver, fat, and has led to changes in the thyroid and thyroid cells of rats (Farber et al., 1976).

<u>Artificial Sweeteners:</u>

Artificial sweeteners are food additives which mimic the effect of sugar on taste, known as sugar substitutes (Chattopadhyay et al., 2011). Prominent sugar additives in the United States are Aspartame, Acesulfame-K, Neotame, Saccharin, Sucralose, Cyclamate and Alitame. These provide a low calorie high sweetness ratio to consumers (Chattopadhyay et al., 2011). These sugar additives are generally found in sugar packets, soft drinks, candy items, and low calorie food items. The acceptable daily intake of these sweeteners vary from 2mg/kg per day (Neotame) to 50mg/kg a day (Aspartame) (Chattopadhyay et al., 2011). It is important to note that portion sizes have dramatically increased in the last few decades, which has aided to an increase in consumption of many unhealthy food products (Dobson & Gerstner, 2010). The daily limit is arguably impossible to achieve with supersize and gulp size sodas, coupled with other items of aspartame like sugar packets and other artificially sweetened foods. (Chattopadhyay et al., 2011 & Dobson & Gerstner, 2010). As per the World Health Organization, long term usage of artificial sweeteners are linked to an increased risk of type 2 diabetes and cardiovascular diseases (World Health Organization, 2023), as well as the Internation Agency for Research on

Cancer indicating that some artificial sweeteners (Aspartame) can be classified as “possibly carcinogenic to humans” (Marques et al., 2019).

Preservative Additives:

Food preservation methods, both chemical and naturally occurring, have been commonplace for over 8,000 years (Institute for Quality and Efficiency in Health Care (IQWiG), 2023). The ancient Egyptians were among the first to conceptualize the preservation possibilities of salt. Using this knowledge they would draw the bacteria-causing moisture out of foods, then dry the food, ensuring an effective meat storing process without the use of a refrigerator (Henney et al., 2010 & Kamel & Ahmed, 2022). Similar to the ancient relevance of color and flavor additives, food preservatives date back to the time of ancient civilizations (Sen, 2022).

In the ancient Roman empire, sheep and goats were used for meat and sacrificial purposes, and they were known for salting their meat for consumption (Graff, 2017). Forward to more modern times, French confectioner Nicolas Appert discovered the preservation properties of food in airtight glass jars and bottles in 1809 (Christensen, 2023), yet the implications of scientific principles and biological laws weren’t fully understood until Chemist Louis Pasteur coined the term pasteurization in 1865. As the next 100 years progressed, knowledge and innovation regarding bacteria continued, and the first chemical preservations - salicylic acid and benzoic acid- were studied for their inhabitation of bacteria growth (Hugo, 1995).

The need to preserve food for future use is still prevalent in our life in order to maintain the integrity of food products (Msagati, 2012) , improve the quality of food, and preserve food from different types of bacteria or fungi (Sen, 2021). Chemical preservative agents assist with both the deceleration and prevention of bacteria, mold, and yeast growth in food, and contribute to the avoidance of toxin development and spoilage. Chemical preservative agents are defined as any chemical that, when added to food, tends to prevent or retard deterioration thereof. Common salt, sugars, vinegars, spices, oils extracted from spices, and chemicals applied for insecticidal or herbicidal properties are not considered chemical preservative agents (*CFR - Code of Federal Regulations Title 21*, n.d.).

Preservative classification can be split into two class groups: Class I and Class II. Class I preservatives can be characterized by common salt, sugar, dextrose, glucose, spices, vinegar, acetic acid, edible vegetable oils, and honey (Khuntia et al., 2020). Class II preservatives include compounds that are chemically synthesized, such as elements like benzoic acid, sulphureous acids, nitrates of sodium or potassium, nisin, sodium and calcium propionate (Khuntia et al., 2020). Class II can further be classified into three subgroups: antimicrobial agents, antioxidants, and chelating reagents.

Antimicrobial agents – yeast, mold, bacteria - are often used to prevent the development, action, and presence of microorganisms by reducing moisture levels and increasing acidity, thus creating an environment which inhibits growth (Khuntia et al., 2020).

Antioxidants and other antimicrobials help in the preservation process of food through the control of atmospheric oxidation, which prevents the breakdown and reaction with free radicals (Khuntia et al., 2020).

Chelating agents help to bind with metals, which in turn prevents the natural ripening and oxidation process from occurring (Khuntia et al., 2020).

Presently, there are 20 approved chemical preservatives as recognized by the FDA and can be classified as follows: ascorbic acid, erythorbic acid, sorbic acid, thiodipropionic acid, ascorbyl palmitate, butylated hydroxytoluene, calcium ascorbate, calcium sorbate, dilauryl thiodipropionate, potassium bisulfite, potassium metabisulfite, potassium sorbate, sodium ascorbate, sodium bisulfite, sodium metabisulfite, sodium sorbate, sodium sulfite, sulfur dioxide, and tocopherols (*21 CFR Part 182 Subpart D -- Chemical Preservatives*, n.d.).

Preservative Additive Health Implications:

<u>Sodium Benzoate</u>

Sodium benzoate, the salt of benzoic acid, is a widely used food preservative and microbial substance, used in various food products, fruit juices, carbonated drinks, and cosmetics (Zengin et al., 2011), however soft drinks are the predominant dietary source (Tfouni & Toledo, 2002). Sodium benzoate inhibits the growth of bacteria, yeast and mold, and was the first food preservative to be approved by the Food and Drug Administration. It is pivotal to note that these preservatives are listed under the “generally regarded as safe” or GRAS agents by the FDA (Lennerz et al., 2015). Presently, acceptable daily intakes made by the World Health Organization of sodium benzoate reside at 5mg/kg or 0-2.27mg/lb of body weight per day (Nair, 2001). Furthermore, the FDA caps the maximum level in food to be at 0.1% presence (*21 CFR 184.1733 -- Sodium Benzoate.*, n.d.). One must consider that the above mentioned daily intake would require mathematical attention and expertise, as well as great attention to detail with regards to food packaging and labeling. This will further be extended upon later in the research. Sodium benzoate is a perfect example of the importance of updated nutrition labels when pertaining to food additives.

There are a few causes of concern in regards to sodium benzoate. Most notably, it is known for its harmful reaction with ascorbic acid (Vitamin C). When both sodium benzoate and ascorbic acid are present and exposed to heat and sunlight, the formation of benzene occurs (Program, 2022). Benzene is a carcinogen which is associated with blood disorders and leukemia (*Benzene - Cancer-Causing Substances*, 2024). Potassium bromate is an oxidizing agent that is used for its quick, efficient, and economical oxidation process in bread and other baked goods (Shanmugavel et al., 2020). Potassium bromate is a colorless and odorless powder or crystal. The FDA presently allows for 75mg/kg as a daily limit intake on potassium bromate (Nkwatoh et al., 2023). Explained further, this means that 75 milligrams per 1 kilogram of flour, or in U.S. metrics, 1 teaspoon of potassium bromate per 800 cups of flour (*Center for Research on Ingredient Safety*, 2023). Potassium bromate has been classified as a human carcinogen under the classification of many governing bodies (Shanmugavel et al., 2020).. Furthermore, potassium bromate has been linked to toxicity in the liver, bone and blood, cardiac, and kidney regions in mice (Shanmugavel et al., 2020).

NUTRITION LABELS

Nutrition labeling has a purpose of providing consumers in purchasing settings with information about the food product, allowing for consumers to practice autonomous choice in nutritional food selection (Grunert & Wills, 2007). Consumers often understand key and simple terms respective to that of food labeling, but with higher complexity of information that understanding begins to fall. In numerous studies, consumers indicated that informational aids with regard to food items are a useful tool (Grunert & Wills, 2007). The relationship between front of pack and back of pack is important in that back of pack complex information, can arguably be summarized and simplified to create a clear and concise front of pack label, that assists consumers with their overall decision making process (Grunert & Wills, 2007).

Nutrition Facts Label:

Nutrition Facts labels allow consumers to make informed decisions about their food consumption (Roberto & Khandpur, 2014) . The front, back and sides of packaging is often filled with information informing the consumer what the item contains and provides guidance in selecting healthier options (*Understanding Food Labels*, 2024). Nutrition Facts labels have been required on packaged foods in the United States since the Nutritional Labeling and Education Act of 1994 (Christoph et al., 2018 & *H.R.3562 - 101st Congress (1989-1990): Nutrition Labeling And Education Act of 1990*, n.d.). According to the Nutrition Labeling and Education Act (NLEA), a 'Nutrition Facts' label must be displayed and easily identify health related information such as calories, saturated fats, cholesterol, and sodium (Variyam, 2007). Unfortunately, the array of numbers, percentages, and complex-sounding ingredients on these labels often causes confusion to the observer (*Understanding Food Labels*, 2024) Food labels can be characterized as front of pack (FOP) labels and back of pack (BOP) labels.

Back of Pack:

Back of pack labels provide a key source of nutritional information to consumers, however they lack aesthetic appeal. These labels include four main categories: Serving Information, Calories, Nutrients, and Daily Value Percentages.

Serving Size:

Serving information includes both the servings per container/package and the serving size. Serving sizes are provided in units such as cups or pieces, and then followed by a metric amount, typically in grams. Although the serving size is often thought to be a recommendation of how much you should eat or drink, it is actually a reflection of the amount people typically consume (Program, 2024).

Calorie:

Calories are also a prominent factor to be considered on back of pack nutritional labels. A calorie is a unit of energy often used to express the nutritional value of foods. In labeling food products in the United States, a calorie refers to that of a kilocalorie. Thus, 1 food calorie equals 1 kcal, or the amount of energy needed to raise 1kg water by 1 degree of Celsius (Buchholz & Schoeller, 2004). 2,000 calories per day is a typical baseline for consumption amount, however intake can be higher or lower depending on your age, sex, height, weight, physical activity, etc. (Program, 2024).

Nutrients:

Another main component to the BOP nutrition facts label is the list of key nutrients that have an impact on your health. This includes items like total fat content, cholesterol, sodium, total carbohydrate index, protein composition, as well as key vitamins and minerals. Per the FDA, consumers should limit their intake of items high in Saturated Fat, Sodium, and Added Sugar, while striving to increase their intake of dietary fiber, Vitamin D, Calcium, Iron, and Potassium (Program, 2024).

Percent Daily Value:

The Percent Daily Value (%DV) is coupled with each listed nutrient, and informs the consumer of the percentage each nutrient accounts for in a standard 2,000 calories per day diet. A value of less than 5% is considered low, while a value exceeding 20% is considered high (Program, 2024).

Front of Pack:

Front of pack labels on the other hand, offer little nutritional information, however because of their location, these labels are often more noticeable. These labels allow for quick decision making about nutritional content of an item because of the simple, recognizable and interpretable format (Kanter et al., 2018). These labels often offer detail specific nutrients, with noticeable text, symbols, color or logos that promote specific attributes (i.e. hearth health, vegan, gluten free, etc.). (Becker et al., 2015 & Hodgkins et al., 2012). Standardization of front of pack systems has yet to be regulated, despite their popularity. Without cohesive guidance, front of pack formats are often found to be confusing, misleading, and offer manipulative information (Hawley, 2012). Some common front of pack labeling includes health logos, traffic light labeling, and warning labels.

The introduction of front-of-pack (FOP) labeling systems, such as the modified traffic light labeling system I propose, aims to combat the issue of confusing information by providing a more intuitive method for consumers to assess the nutritional quality and safety of food products. In this research, we will focus our attention on a modification of the traffic light system, as it pertains to food additives and their relative cause of concern to consumers. The traffic light system coined its name due to its color scheme usage which describes nutrient content in respect to its level of healthfulness. The traffic light system uses red, yellow, and green indicators to alert customers to the level of fat, sugar, and salt in foods (Office of the Commissioner, 2018), reflected in the images below.

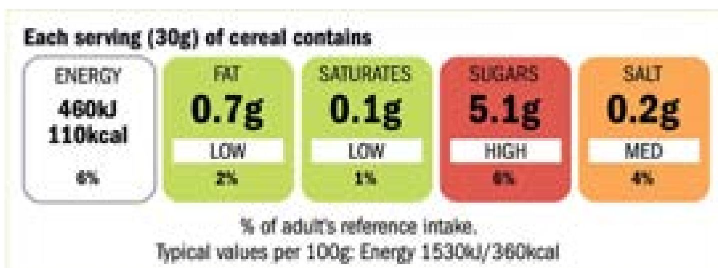


Table 1. Traditional Traffic Light Labeling Sysem, Example 1 (Adapted from World Cancer Research Fund, 2023).

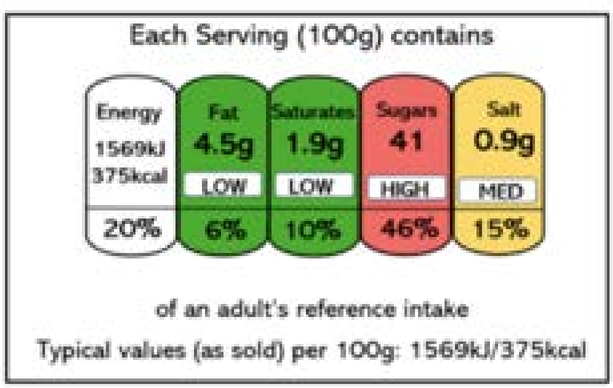


Table 2. Traditional Traffic Light Labeling System, Example 2 (Adapted from Razavi & Xue, 2023).

Numerous studies illustrate that color coded traffic light systems are easily understood by consumers (Becker et al., 2015). While many traffic light systems focus on food nutrients, more specifically the levels of fat, saturated fat, sugar and salt in foods, the focus of this research is to determine if a traffic light system will be effective in the overall consumer understanding of the food additives present in their consumable item.

A significant body of evidence supports the real-world impact of the traffic light system in improving consumer behavior and public health outcomes. For example, a study by Sacks et al. (2009) demonstrated that traffic light labeling helped consumers quickly identify healthier food options, leading to better-informed purchasing decisions. Similarly, studies done by Machín et al. (2017) extend upon nutrition labels portrayal of three important items, motivation, ability, and triggers, and how these effect consumer behavior. The argument here is by emphasizing one of these elements, you can then in turn change the way in which they are perceived (Machín et al., 2017). Machin argues that by using an effective front of pack food label, which highlights the high content of a nutrient that has been linked to negative health conditions, you can in turn increase consumer awareness of unhealthy products and encourage healthier alternatives by using the element of motivation (Machín et al., 2017). In light of my research, the same principles apply. Using the modified traffic light label as a front of pack label, which highlights the level of concern for each food additive ingredient present in a food item, will ideally increase awareness of unhealthy products with cautious food additive elements, and assist consumers with selecting items with less additives present.

While the use of traditional traffic light labels are effective in aiding consumers to healthier decisions with regards to nutritional facts, it is my goal to take this effectiveness and relay it to a more important surfacing issue in that of food additives, and their prominence and ambiguity in US food items.

REGULATION PRACTICES

Food Additive Regulation:

In the United States, the U.S. Food and Drug Administration (FDA) is a scientific, regulatory and public health agency that oversees food products, human and animal drugs, cosmetics, animal feed, etc. (Office of the Commissioner, 2018). The FDA as we know it today dates back to 1906 with the passage of the Federal Food and Drugs Act, which is known for its prohibition of the manufacturing, sale, or transportation of any food, drug, medication, or liquor which is misbranded or poisonous (*The Food and Drug Administration: The Continued History of Drug Advertising | Weill Cornell Medicine Samuel J. Wood Library*, n.d.). This act is credited with the first federal law to address product adulteration, production, distribution, as well as the marketing of food and beverages (Barkan, 1984).

While the 1906 act was a pivotal stepping stone in food regulation practices in the United States, this initiative was flawed with its presumption that food was deemed safe until proven otherwise. This changed with the introduction of the 1958 Food Additives Amendment and the 1960 Color Additives Amendment, which required the FDA to approve food safety prior to consumption and usage. Presently, "food additives" covers 400 of the approximate 2,600 substances intentionally added to foods (National Academies Press (US), 1982). Not included in this criteria are the 500 or so food ingredients termed "Generally Recognized as Safe", or GRAS.

GRAS:

GRAS, or generally recognized as safe, was a response to the Food Additives Amendment, and created an entire class of substances that are excluded from the food additive definition, which then avoids its mandated premarket approval process (Burdock & Carabin, 2004). GRAS designation is applied when a group of qualified experts agree that a product is known to be safe when used as intended. A clear history of use before 1958 or an assessment of safety must be present to assign this label to a substance (Frestedt, 2018). The FDA is not required to review GRAS substances, such as spices and preservatives, and therefore food manufacturers may determine a substance as GRAS without the FDA's approval or knowledge (*Food Safety:(GRAS)*, 2010).

Delaney Clause:

Another important piece of legislation regarding the regulation of food additives is the Delaney Clause. The Delaney Clause is a clause of the Federal Food, Drug and Cosmetic Act of 1958 and addresses concerns that potentially cancer causing, harmful chemicals were present in foods. (Krishan et al., 2021). There are three Delaney Clauses in the FFDCA, one that applies to food additives, one that applies to color additives, and one that applies to animal drugs (Krishan et al., 2021). The Delaney Clause's vague definition and interpretation, coupled with ongoing advancements in technology and cancer research, make this clause an on-going contention in the world of food additives (Krishan et al., 2021).

Label Regulations:

The late 1960s saw the first legislation changes to nutrition labeling. Prior to this, nutrition labeling was typically voluntary or non-existent (Dumoitier et al., 2019). The Nutrition Labeling and Education Act of 1990 (NLEA), created by the Food and Drug Administration, was the first regulatory practice to communicate present nutrients in packaged foods and allow for consumers to make informed and healthy decisions pertaining to consumption (Dumoitier et al., 2019).

PROCESSED FOODS

Ultra-processed foods and food additives exist everywhere in the modern human diet (Whelan et al., 2024). It is important to note that almost all foods are processed to some extent, for a variety of purposes.

Minimally Processed Foods:

Minimally processed foods, which fall under the category of unprocessed foods, undergo industrial processes such as drying, crushing, grinding, roasting, boiling, pasteurization, refrigeration, freezing, and vacuum packaging. These methods aim to extend the shelf life and facilitate the storage and preparation of various foods, without adding salt, sugar, oils, fats, or other substances (Monteiro et al., 2019). Culinary ingredients derived from minimally processed foods or natural sources, including oils, fats, sugar, and salt, are obtained through processes like pressing, centrifuging, refining, extracting, or mining. These ingredients are used in preparing, seasoning, and cooking foods (Monteiro et al., 2019).

Processed Foods:

Processed foods are created by adding salt, sugar, or other substances to minimally processed foods or culinary ingredients. Preservation techniques such as canning, bottling, and non-alcoholic fermentation (used in products like bread and cheese) are utilized to improve durability and sensory qualities (Monteiro et al., 2019).

Ultra Processed Foods:

Then we have ultra processed foods. These foods are formulations of several ingredients which include salt, sugar, oils, and fats as well as substances not used in culinary preparations such as color, flavor and emulsifier additives (Monteiro et al., 2019) to imitate sensory qualities or to disguise undesirables of the final product (Ares et al., 2016). Ingredients characteristic of an ultra-processed food are those in which you would not find in a kitchen, or have no or rare culinary use (Monteiro et al., 2019). Processes and ingredients used for the manufacturing of ultra-processed foods are designed to be highly profitable products which contain low-cost ingredients and a long shelf life (Monteiro et al., 2019).

Chapter 3: Research

RESEARCH

Through the foundational research, it is evident that navigating the world of food additives and present food labeling systems is complex, and future research needs to be conducted to assist consumers in making informed decisions about the products they purchase, and in turn, consume.

This thesis aims to assess whether a modified traffic light system could be effective in guiding consumer choices regarding common food additives found in processed food items. Traditional traffic light labeling systems typically categorize nutrients such as fats, sugars, and sodium with corresponding colors (red, yellow, green) to reflect healthfulness. However, this research will adapt the traffic light system by expanding the color depth from only 3 colors (red, yellow, and green) to 5 (red, orange, yellow, light green, and dark green). Additionally, the color coding context will no longer reflect red as high level, yellow as moderate level, and green as good level. Instead, the system will expand into how harmful or safe an item is.

The proposed traffic light system would be characterized by a five-level rating scale, adapted from the Center for Science in the Public Interest's Chemical Cuisine Additive Safety Ratings (*CSPI's Food Additive Safety Ratings*, 2024):

- **Safe**: Indicated by bright green, meaning the additive poses little to no health risk to consumers.
- **Cut Back**: Represented by soft green, indicating the additive is not toxic but should be consumed in moderation due to potential nutritional concerns.
- **Certain People Should Avoid**: Indicated by yellow, suggesting the additive may trigger allergic reactions, intolerances, or other issues for specific groups.
- **Caution**: Represented by orange, meaning the additive may pose risks and requires further testing and research. It is recommended to avoid products with these substances.
- **Avoid**: Marked by red, indicating the additive is unsafe at typical consumption levels or poorly researched. Consumers should avoid buying products with these ingredients.

The Center for Science in the Public Interest has identified 140 chemical additives, listing their names, purposes, and associated health concerns (*CSPI's Food Additive Safety Ratings*, 2024). These will be used as the foundation for categorizing additives within the traffic light system.

The central research question guiding this study is speculation on whether or not a traffic light food labeling system that effectively communicates the presence and risk level of food additives can improve consumer understanding of additives in a food item and in turn influence healthier food selections. By focusing on whether this adapted traffic light system can enhance consumer awareness of additives and influence healthier food choices, this research aims to contribute to ongoing efforts to increase effectivity in marketing food items and improve public health through better food labeling transparency.

Methods

This study utilized a quantitative survey methodology to assess the impact of a modified traffic light labeling system, centered on food additives, on consumer preferences for packaged food items, specifically soda and candy brands. The survey aimed to collect data on how different labeling systems (traditional and traffic light) influence consumer decision-making, with a particular emphasis on ingredients and food additives.

Participants

The target population for this research was adults over the age of 18 residing in the United States. This group was selected due to the limited existing data on their purchasing preferences, specifically regarding the use of traffic light food labels, both in a traditional context and with the added focus on food additives in this study's modified approach. Additionally, this population represents individuals responsible for their own consumption habits, making them a suitable reflection of purchase behavior within the U.S.

The initial sample included 212 respondents. However, after cleaning the data for incomplete responses, non-U.S. residents, and duplicate records, the final sample consisted of 138 valid responses.

The majority of respondents (75.4%, or 104 out of 138) identified as female, with males accounting for 22.46% (31 out of 138), and 2.17% (3 out of 138) identifying as a third gender. The age range of respondents varied, with the largest group (59.4%) falling between 25 and 32 years old. Other age groups represented included 18-24, 33-44, 45-54, and 55+, though these categories had fewer respondents. The estimated average age of participants, based on the provided age ranges, is approximately 27.55 years.

In terms of racial demographics, the sample was relatively homogeneous, with White respondents making up 89.1% (123 out of 138). Other racial identities included Black or African American (3.6%), Asian (4.3%), American Indian (<1%), and Other (2.2%).

Regarding education, 55.1% (76 out of 138) of respondents had completed a Bachelor’s degree, followed by 25.4% with a Master’s degree, 4.3% with a Doctorate, 3.6% with an Associate’s degree, and 11.6% with only a high school education.

Finally, the geographic distribution of respondents was largely concentrated in New York, with 77.5% (107 out of 138) residing in the state. Other states represented included California and Colorado (2.9% each), Minnesota (1.4%), and Texas, North Carolina, Pennsylvania, Illinois, Massachusetts, Maryland, Oregon, and Connecticut, each with one respondent.

Survey

Participants were encouraged to complete the survey at their convenience. The only prior information given was that the survey was part of a master's thesis and would take approximately five minutes to complete. They were assigned to all conditions and questions in the same order.

The survey was divided into four sections. The first section focused on respondents' habits, opinions, and behaviors regarding food additives and nutrition labels as currently found in the U.S. The second section aimed to gauge consumers' awareness of, and appeal toward, a traffic light label system. The final two sections presented practical examples comparing traditional and traffic light labels, using popular soda and candy brands in the U.S.

The survey employed several question formats, including multiple choice, Likert scale responses, open-ended, and non-binary questions. Most questions were multiple choice, as the responses were categorical with limited options (e.g., "Very important," "Unhealthy," "Sometimes"). Likert scale questions, such as Q1 ("How important is the labeling of food additives?"), were used to measure the intensity of respondents' opinions, with classifications ranging from "Slightly important" to "Extremely important." This allowed for clear insights into respondents' preferences, attitudes, and concerns.

The first set of questions explored participants' health perceptions and nutritional awareness. When asked how important a healthy diet is, the most common responses were "Very important" (53.6%) and "Extremely important" (37.0%). This reflects a high level of health consciousness among participants. In a follow-up question, respondents were asked how healthy they perceive the average American diet to be. Most categorized it as "Unhealthy" (61.6%) or "Very Unhealthy" (27.5%), indicating their awareness of dietary issues in the U.S. When asked to identify the unhealthiest aspect of the American diet, 67.9% cited the "high consumption of processed foods," followed by concerns about artificial additives and preservatives (10.9%). This suggests that many respondents see a direct link between processed foods and diet-related health issues, along with concerns about the long-term impact of food additives.

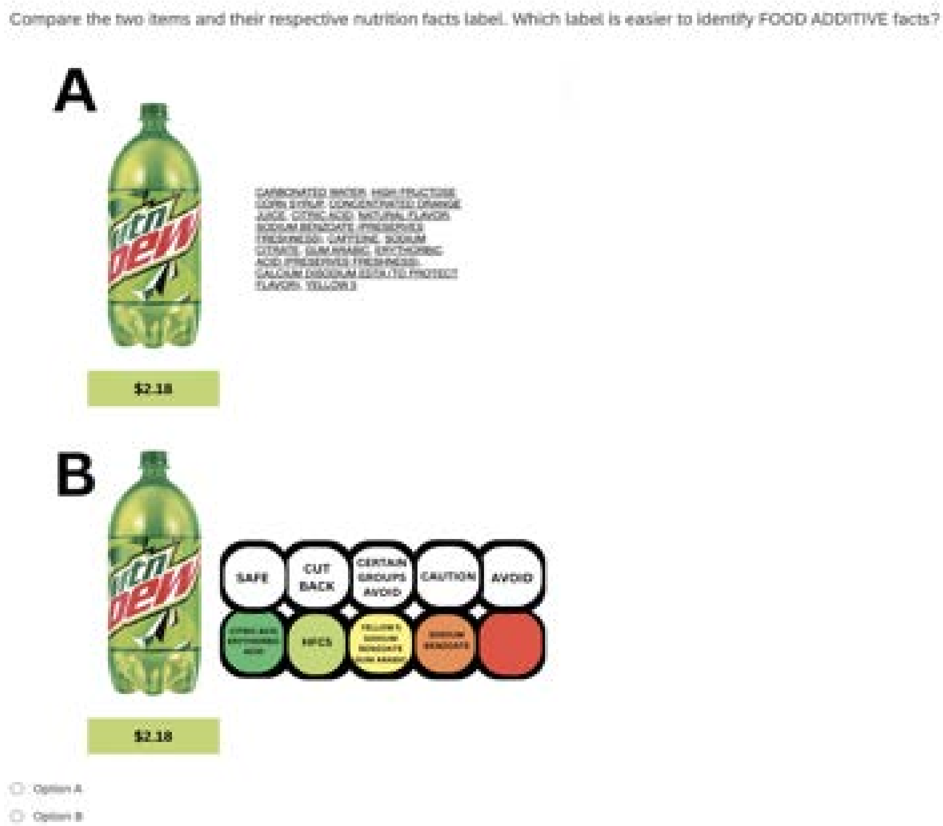
Besides diet and overall health, a collection of survey questions aimed to understand the behavioral background of respondents regarding food labels. In terms of behavior, respondents were asked how often they check the nutrition facts label when purchasing packaged food. Many reported doing so "Most of the time" (32.6%) or "About half the time" (25.4%). This suggests that while consumers are aware of the importance of checking labels, it may not be a consistent habit for everyone, possibly due to external factors like time constraints or a lack of trust in label clarity. When asked about their concerns regarding harmful additives, most respondents expressed being either "Concerned" (50.0%) or "Very Concerned" (21.0%), indicating a high level of concern about the presence of additives in food.

Another set of questions focused on the respondents' appeal toward traffic light labels. When asked to rate the effectiveness of traffic light labels in helping make healthier food choices, the majority selected "Effective" and "Very Effective." Similar ratings were given for the labels' ability to display clear, easily understood information. Additionally, 52.2% of respondents were “Very Interested” and 20.3% were “Extremely Interested” in seeing the traffic light labeling system implemented on more packaged goods. These trends suggest that traffic light labels are a powerful tool for influencing consumer behavior and that there is demand for wider implementation of such labels.

Label Comparisons:

Following the exploratory data, the survey featured two key sections: one comparing a traditional nutrition label with a traffic light nutrition label, and another focused primarily on the traffic light labeling system's effectiveness using popular U.S. packaged food items.

For the traditional nutrition label comparison, participants were first presented with two images of a popular soda brand, Mountain Dew. Next to the soda, where both price and brand remained constant, a traditional food additive label was included (Option A) and the proposed traffic light food labeling system for food additives (Option B). See Figure below.



This section aimed to evaluate the effectiveness of two food labeling systems—traditional nutrition labels and traffic light nutrition labels—in communicating the presence of food additives. Based on the existing literature, which suggests that color-coded labeling systems such as traffic light labels are more intuitive and easier for consumers to interpret (Balcombe et al., 2010; Cecchini & Warin, 2016), it was hypothesized that the traffic light label would be perceived as more effective in conveying information about food additives compared to the traditional label. The hypothesis for this is as follows:

(H_0): There is no difference in perceived effectiveness between the traffic light label and the traditional label in communicating food additives.

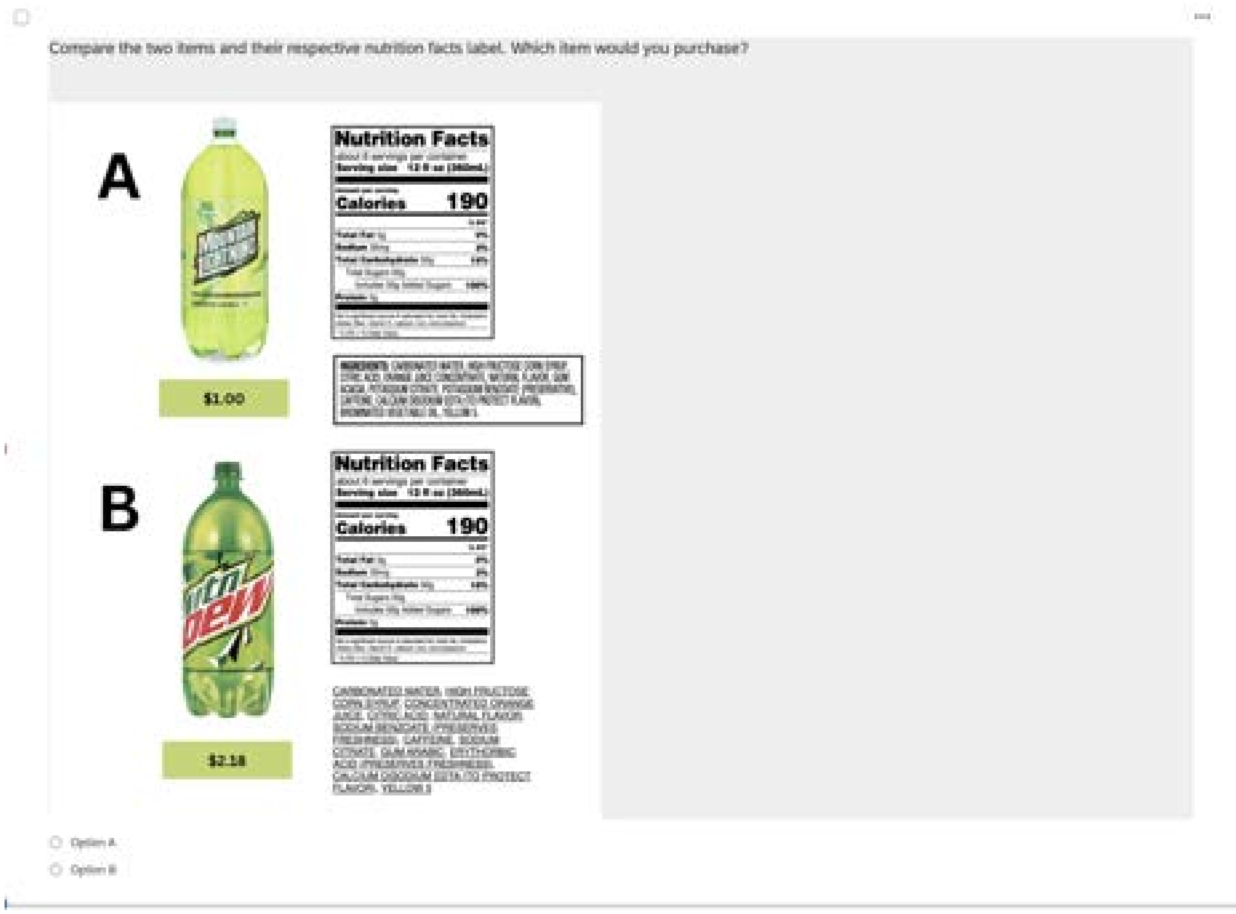
(H_1): There is a significant difference in perceived effectiveness between the traffic light label and the traditional label in communicating food additives.

To assess whether there was a significant difference in the perceived effectiveness of the two food labeling systems (traditional vs. traffic light) in communicating food additives, a chi-square goodness-of-fit test was used. This test was selected because it is designed to compare observed frequencies with expected frequencies under the assumption of no preference between the two labels.

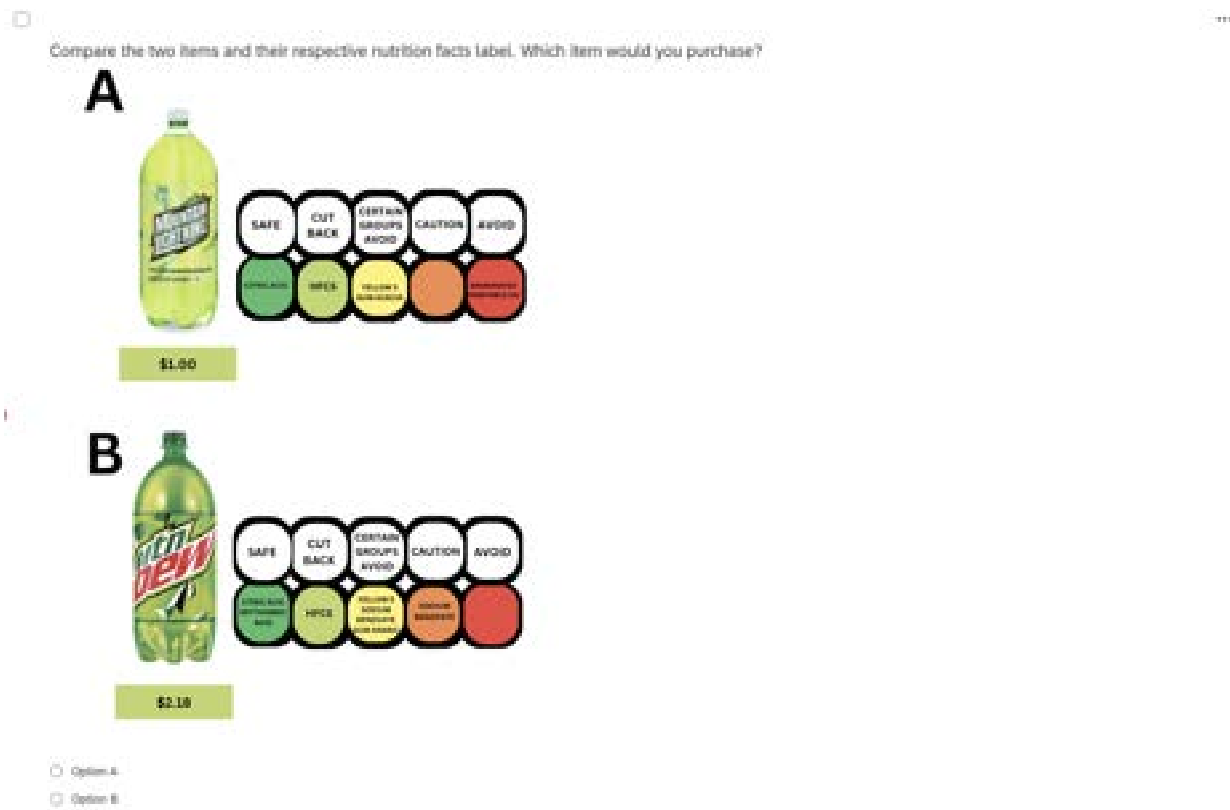
The second main section focused primarily on the traffic light labeling system, a visual representation using colors to indicate the levels of nutrients or additives. This section involved comparing traditional food labels for two prominent soda items, then again with two popular candy brands.

For the soda, the brands used in the study were Mountain Lightning (Option A), a generic, lower-cost soda brand, and Mountain Dew (Option B), a well-known national soda brand. These sodas were chosen due to their similar flavor profiles but contrasting market positions, allowing the study to investigate whether labeling systems could shift consumer preferences between an economy brand and a more recognizable brand.

The first part of the survey presented respondents with the traditional nutrition labels for both soda brands, including information on calories, sugar content, fat, sodium, and other relevant nutrients as mandated by the FDA. Respondents were asked to select which soda they would purchase based on the traditional label information. See image below.



The second part of the survey introduced the traffic light food labeling system, which uses shades of green, yellow, and red to signify the level of concern from safe to avoid. This labeling system was used to visually convey the relative healthiness of each soda option. Respondents were then asked to select their preferred soda based on the traffic light labels.



To determine whether the proportions of respondents choosing Mountain Lightning (Option A) versus Mountain Dew (Option B) differed significantly between the two labeling conditions, a chi-squared test for independence was performed. This test compares the observed frequencies in each group (traditional label vs. traffic light label) to see if the distribution of preferences is significantly different from the expected frequencies under the null hypothesis. The hypothesis for these can be reflected below:

H_0: The traffic light labeling system does not significantly influence the choice of soda.

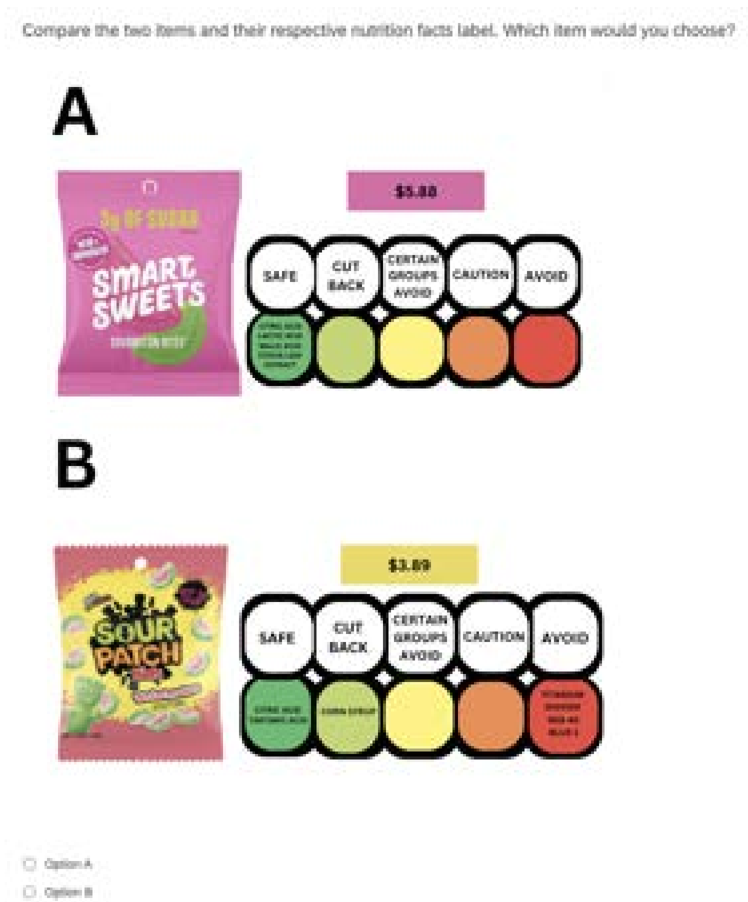
H_1: The traffic light labeling system significantly influences the choice of soda.

This process was then repeated for the candy brands. The two candy brands selected for the study were Smart Sweets (Option A), a low-sugar candy marketed as a healthier option, and

Sour Patch Kids (Option B), a traditional candy with higher sugar content. These brands were chosen because they represent contrasting nutritional profiles, making them ideal for assessing the potential impact of different labeling systems on consumer purchasing behavior.

Again, the first part of the survey presented respondents with the traditional nutrition labels for both the candy brands and were formatted in the standard table format commonly seen on food packaging. See table below.

In the second condition, participants were presented with the same two candy brands, but the nutritional information was displayed using the traffic light label for food additives. For each labeling system, respondents were asked to indicate which candy (Smart Sweets or Sour Patch) they would prefer to purchase.



To determine whether the proportions of respondents choosing Smart Sweets (Option A) versus Sour Patch (Option B) differed significantly between the two labeling conditions, a chi-squared test for independence was performed. This test compares the observed frequencies in each group (traditional label vs. traffic light label) to see if the distribution of preferences is significantly different from the expected frequencies under the null hypothesis. The hypothesis for these are as follows:

H_0: The traffic light labeling system does not significantly influence the choice of candy

H_1: The traffic light labeling system significantly influences the choice of candy

Chapter 4: Results

Traditional vs. Traffic light

A chi-square goodness-of-fit was conducted to evaluate whether there was a significant difference in respondents' perceptions of the effectiveness of two types of food labels—traditional and traffic light—in communicating food additives. Out of the 138 respondents, 128 selected the traffic light label as more effective, while only 10 selected the traditional label.

To test the hypothesis that there is a difference in perceived effectiveness between the traffic light label and the traditional label in communicating food additives, we compared the observed values to the expected values under the assumption that there would be no preference between the two labels (i.e., the responses would be equally split between the two). Our observed values included a traffic light label (128) and a traditional label (10). Given n = 138, the expected values, assuming there was no preference between the labels, is 69.

The chi-square statistic was then calculated using the following formula:

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

In the formula, O_i is the observed value, while E_i is the expected value.

For the traffic light label, the following formula reflects the chi-square value:

$$\frac{(128-69)^2}{69} = \frac{(59)^2}{69} = \frac{3481}{69} = 50.45$$

For the traditional food label, the following reflects the chi-square value:

$$\frac{(10-69)^2}{69} = \frac{(-59)^2}{69} = \frac{3481}{69} = 50.45$$

Thus, the total chi-square value would then be 100.90, because 50.45+50.45 = 100.90.

Furthermore, with one degree of freedom, the corresponding p-value was $p < 9.68 \times 10^{-24}$. Given that the p-value is significantly smaller than the conventional significance level $p < 0.05$, the null hypothesis was rejected:

H_0: There is no difference in perceived effectiveness between the traffic light label and the traditional label in communicating food additives.

This in turn, provides strong evidence to accept the alternate hypothesis:

(H_1): There is a significant difference in perceived effectiveness between the traffic light label and the traditional label in communicating food additives.

The results of this study provide strong evidence that the modified traffic light food labeling system is significantly more effective than the traditional label in communicating the presence of food additives. The overwhelming preference for the traffic light label (128 out of 138 respondents) over the traditional label (10 respondents) was significant, as indicated by the chi-square test ($\chi^2 = 100.90$, $p < 0.001$). These findings reject the null hypothesis and support the alternative hypothesis, which combined with the survey question results, suggest that the traffic light label would be perceived as more effective in conveying information about food additives.

The findings suggest that color-coded systems such as the traffic light label can play an important role in enhancing consumer understanding of nutritional content and food additives, particularly for individuals who may lack detailed nutritional knowledge. This could have significant implications for public health, as more intuitive labeling systems may encourage healthier food choices and reduce the consumption of products with undesirable additives.

Consumer Preference, Soda:

A chi squared test for independence was conducted to evaluate whether the labeling system (traditional vs. traffic light label) significantly affected consumer preference between two soda brands: Mountain Lighting (Option A) and Mountain Dew (Option B). A contingency table included below summarizes the observed frequencies of soda choices under each labeling condition.

	Mountain Lighting (Option A)	Mountain Dew (Option B)	Total
Traditional Label	75	62	137
Traffic-Light Label	38	98	136
Total	113	160	273

After organizing the data into a contingency, it was then important to calculate the expected frequencies. The expected frequency for each cell in the table is calculated using the following formula:

$$\text{Expected Frequency} = \frac{(\text{Row Total}) \times (\text{Column Total})}{\text{Grand Total}}$$

These calculations can be reflected into the expected contingency table, Figure xx.

	Mountain Lighting (Option A)	Mountain Dew (Option B)	Total
Traditional Label	55.67	80.33	137
Traffic-Light Label	56.33	79.67	136
Total	113	160	273

The chi-squared statistic was then calculated using the following formula:

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

For the Traditional Label (Option A):

$$\chi^2 = \frac{(75 - 56.67)^2}{56.67} = 5.88$$

For the Traditional Label (Option B):

$$\chi^2 = \frac{(62 - 80.33)^2}{80.33} = 4.20$$

For the traffic-light Label (Option A):

$$\chi^2 = \frac{(38 - 56.33)^2}{56.33} = 6.36$$

For the traffic -Light Label (Option B):

$$\chi^2 = \frac{(98 - 79.67)^2}{79.67} = 4.05$$

Thus, the chi-squared statistic was calculated as 20.49 with 1 degree of freedom. The corresponding p-value was 1.23 x 10^{-5}. Given that the p-value is much smaller than the significance level of 0.05, we reject the null hypothesis:

(H_0): The traffic light labeling system does not significantly influence the choice of soda

Concluding that the traffic light labeling system did significantly influence respondents' soda choice within the sample set.

These results suggest that when presented with the traffic light labeling system, consumers were more likely to choose Mountain Dew over Mountain Lightning, whereas under the traditional labeling system, preferences were more evenly split between the two soda brands. This significant shift in soda preference suggests that the traffic light labeling system is effective in portraying food additives and influencing consumer behavior. While more research is needed to confirm, one can theorize that the traffic light label better displayed the undesirable additive of

Brominated Vegetable Oil, which was categorized in the red ‘Avoid’ section. Thus, the results not only provide evidence that the traffic light label significantly influences the choice of soda, but also provide the potential implication that this labeling system drives consumers to make more health-conscious decisions.

Consumer Preference, Candy:

A chi-squared test for independence was conducted to examine the effect of labeling systems (traditional nutrition label vs. traffic light label) on consumer preferences between two candy brands: Smart Sweets (Option A) and Sour Patch (Option B). Table 1 presents the observed frequencies of candy choices under each labeling condition.

	Smart Sweets (Option A)	Sour Patch (Option B)	Total
Traditional Label	87	51	138
Traffic -Light Label	119	19	138
Total	206	70	276

The expected frequencies, calculated under the null hypothesis that the labeling system has no impact on candy choice, are also provided in Table 2. These values were computed based on the marginal totals from the contingency table.

	Smart Sweets (Option A)	Sour Patch (Option B)	Total
Traditional Label	103	35	138
Traffic -Light Label	103	35	138
Total	206	70	276

The chi-squared statistic was then implemented using the following formula:

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

For the Traditional Label (Option A):

$$\chi^2 = \frac{(87 - 103.13)^2}{103.13} = 2.66$$

For the Traditional Label (Option B):

$$\chi^2 = \frac{(51 - 34.87)^2}{34.87} = 7.47$$

For the Traffic-light Label (Option A):

$$\chi^2 = \frac{(119 - 103.13)^2}{103.13} = 2.45$$

For the Traffic-Light Label (Option B):

$$\chi^2 = \frac{(19 - 34.87)^2}{34.87} = 7.32$$

The chi-squared test revealed a significant difference in consumer choices between the two labeling conditions, $x^2(1, N = 276) = 18.39,\ p < 0.0001$. The calculated chi-squared statistic was well above the critical value of 3.841 at the 0.05 significance level, allowing for rejection of the null hypothesis. The corresponding p-value of 0.000018 further confirms that the probability of observing such a difference by chance is exceedingly small.

The results of this test propose that when presented with the traffic light label, consumers were more likely to choose Smart Sweets over Sour Patch, whereas under the traditional nutritional labeling system, preferences were more evenly distributed between the two. This change in consumer preference between the two highlights the effectiveness of the traffic light labeling system with regard to the presence of food additives and influencing consumer decisions. While further research is needed, one could argue that the traffic light labeling system is effective, even in the terms of recognizable and prominent brands, such as Sour Patch. Furthermore, the labeling system impacts both consumer choice and can offer a guide to consumers when making informed decisions with health and snack purchasing.

Soda and Demographics

To further understand the data, a logistic regression was performed to investigate the relationship between respondents' age range, gender, and education level and changes in the soda preference based on the two labeling systems. To do this, an additional column was added to the dataset which reflected our dependent variable. This variable, called soda_change, was then coded where 1 indicated a change in soda preference, while 0 meant no change in preference. Demographic data, such as age range, gender, and education level would then be classified as our independent variables. The groups within each of these demographics have sufficient representation in the survey. While ethnicity data was collected, ethnicity was not included as an independent variable due to the fact that 90% of respondents identified as 'White' and therefore non-White ethnic groups may be under-represented, significantly lowering the model's ability to detect accurate differences between ethnic groups.

The logistic regression can be reflected by the function below

$$P(Y = 1|X) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n)}}$$

where $P(Y = 1|X)$ is the probability of a change in soda preference. X_1, X_2, X_n are reflective of our independent variables, while β_0, β_1, β_n are the coefficients estimated by the model. The logistic regression was fit using the Maximum Likelihood Estimation (MLE) method, which finds the coefficients that maximize the likelihood of observing the given data.

The logistic regression, using soda_change as the dependent variable and gender, age range, and education as independent variables, yields a pseudo r-squared value of 0.003423, a log-likelihood value of -94.154, and a LLR p-value of 0.8857. These values inform us that the model explains very little variation in soda preference change, is a poor fit, and isn't statistically significant.

The logistic regression also yields the following coefficients and p-values for the intercept and independent variables: a coefficient of -0.1874 and a p-value of 0.6 for the intercept; a coefficient of -0.2561 and a p-value of 0.477 for the independent variable, Gender; a coefficient of -0.0479 and a p-value of 0.779 for the independent variable, Age; a coefficient of 0.0228 and a p-value of 0.858 for the independent variable, Education. The high p-values of each independent variable coefficient implies that none of these variables have a significant relationship with the dependent variable.

This logistic regression model shows that gender, age, and education do not significantly predict soda choice changes in this dataset. The model explains very little variation, and no variable is statistically significant.

Candy and Demographics

In a similar fashion, a logistic regression was performed to investigate the relationship between respondents' age range, gender, and education level and changes in the candy preference based on the two labeling systems. Again, an additional column was added to the dataset which reflected our dependent variable. This variable, called candy_change, was then coded where 1 indicated a change in candy preference, while 0 meant no change in preference. The same demographic data of age range, gender, and education level would then be classified as our independent variables.

The logistic regression can be reflected by the function below

$$P(Y = 1|X) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n)}}$$

where $P(Y = 1|X)$ is the probability of a change in candy preference. X_1, X_2, X_n are reflective of our independent variables, while β_0, β_1, β_n are the coefficients estimated by the model. The logistic regression was fit using the Maximum Likelihood Estimation (MLE) method, which finds the coefficients that maximize the likelihood of observing the given data.

The logistic regression, using candy_change as the dependent variable and gender, age range, and education as independent variables, yields a pseudo r-squared value of 0.03076, a log-likelihood value of -76.771, and a LLR p-value of 0.1814. These values inform us that the model explains very little variation in candy preference change, is a poor fit, and isn't statistically significant.

The logistic regression also yields the following coefficients and p-values for the intercept and independent variables: a coefficient of -1.7232 and a p-value < 0.001 for the intercept; a coefficient of 0.5963 and a p-value of 0.112 for the independent variable, Gender; a coefficient of 0.0941 and a p-value of 0.616 for the independent variable, Age; a coefficient of 0.1892 and a p-value of 0.185 for the independent variable, Education. The high p-values of each independent variable coefficient implies that none of these variables have a significant relationship with the dependent variable. Interestingly, the intercept coefficient is negative and statistically significant. This suggests that when all independent variables are set at their reference level, a change in candy preference based on the two different labeling systems is **not** likely to occur. The reference levels for gender, age range, and education were Male, 18-24, and High School Diploma, respectively.

Similar to soda, this logistic regression model shows that gender, age, and education independently do not significantly predict candy choice changes in this dataset. The model explains very little variation, and no variable is statistically significant.

Chapter 5: Discussion

DISCUSSION

Traffic light vs. Traditional

The findings from the studies presented in the last section offer important insights into how a modified traffic light labeling system for food additives, compared to the traditional nutritional fact labeling, can influence consumer decision making. The studies demonstrated that these newly adapted labels are significantly more effective at communicating food additives than traditional labeling practices, while also providing evidence that the labels impact consumer decision making in a practical setting.

The overwhelming preference for the traffic light label (128 out of 138 respondents) over the traditional label (10 respondents) was highly significant, as indicated by the chi-square test ($\chi^2 = 100.90$, $p < 0.001$). These findings reject the null hypothesis and support the alternative hypothesis, which posited that the traffic light label would be perceived as more effective in conveying information about food additives.

Candy: Smart Sweets vs. Sour Patch

The chi-squared test for independence revealed that the traffic light food additive labeling system significantly influenced the choice between Smart Sweets (Option A) and Sour Patch

(Option B). Under the traditional nutrition label, 87 respondents chose Smart Sweets, while 51 opted for Sour Patch. However, when presented with the traffic light labeling system that highlighted food additives, 119 respondents selected Smart Sweets, and only 19 chose Sour Patch. The p-value of 0.000018 from the chi-squared test confirms a statistically significant shift in consumer preference.

This shift suggests that consumers were influenced by the color-coded warnings on the additives used in Sour Patch, particularly those additives flagged with cautionary (yellow and orange) or avoid (red) labels. In contrast, Smart Sweets, which was primarily labeled with green (safe) for additives such as citric acid and stevia leaf extract, was perceived as the safer, healthier option. These results are consistent with previous findings that suggest simplified labeling systems can improve consumer understanding of complex ingredient information, thereby promoting healthier choices (Hersey et al., 2013). The focus on additives rather than broad nutritional content may have made health-related risks more tangible to consumers.

Soda: Mountain Lightning vs. Mountain Dew

Similarly, the traffic light food additive label significantly influenced the soda choices. Under the traditional nutrition label, 75 respondents chose Mountain Lightning, while 62 chose Mountain Dew. However, under the traffic light label, only 38 respondents selected Mountain Lightning, while 98 favored Mountain Dew. The p-value of 0.0000123 from the chi-squared test indicates a strong statistical significance, suggesting that the traffic light food additive labels had a considerable impact on consumer preference.

Interestingly, Mountain Lightning contains Brominated Vegetable Oil (BVO**)**, which was flagged in red under the traffic light system as an additive to avoid. This likely played a role in the reduced preference for Mountain Lightning when the traffic light label was used, as consumers were steered away from the product due to the presence of this additive. In contrast, Mountain Dew does not contain BVO, and while it includes other additives like sodium benzoate (flagged in orange), the absence of a "red flag" additive may have made it more appealing under the traffic light label system.

This suggests that consumers may be particularly sensitive to red warnings (additives to avoid) when making their purchasing decisions. The significant drop in preference for Mountain Lightning under the traffic light label highlights the effectiveness of such a label in communicating safety concerns about specific food additives.

Demographics and Candy / Soda

The key takeaway from the regression model analysis for both soda and candy is that the results indicate all demographic groups surveyed may be influenced by the modified traffic light labeling system equally. In other words, a female and male will react in similar ways when exposed to the traffic light label. The female and male could both be equally likely to change their preference from Mountain Lightning to Mountain Dew, and from Sour Patch to Smart Sweets when presented with the traffic light label compared to the traditional label, for example. Likewise, people in their forties are just as likely to change their preferences as people in their twenties, and those with Master's degrees operate no differently than those with a High School diploma. This is a positive sign, as it suggests the effectiveness of the traffic light labeling system is not exclusive to specific demographic groups, and instead has the ability to influence consumer behavior across diverse backgrounds.

Implications / Further Research

Although the results of this study indicate that a traffic light food additive labeling system can be a powerful tool for informing consumers about the safety of ingredients in packaged food items, further research is needed to conclude its effectiveness. In this study involving consumer choices of soda, when provided the choice between Mountain Lightning or Mountain Dew when only being exposed to the original nutrition facts label, 75 chose Mountain Lightning and 62 chose Mountain Dew. In this question, price was included where Mountain Lightning cost $1.00 and Mountain Dew cost $2.18. One could argue that the higher selection of Mountain Lighting could be attributed to the lower price, although the survey did not distinguish this.

Once the traffic light labels were introduced, 38 participants chose Mountain Lightning and 98 chose Mountain Dew. With the change in selection from the nutrition label to the traffic label, one could make the argument that people are willing to spend more for a food item that has less harmful food additives present in the traffic-light food additive label. Further research would need to be explored to test this implication.

In this research, brand names were explicitly used and defined in the survey questions. According to research by Grewal, Krishnan, Baker, and Borin (1998), the knowledge of brand name helps increase perceptions of quality and oftentimes a consumer has a favorable brand when shopping. With this in mind, it is possible that consumers selected their answers to the survey questions reflective of their personal attachments to the food items, vs the nutritional and food additive information displayed. For future research, it may be advisable to take this into consideration and conduct a blind survey, where brand names are excluded when asking participants to choose a selection.

Policy makers often make the argument that a consumer's health and choices are dependent on their own decisions, ignoring the facts that nutrition and food additive labels are often difficult to decipher (Grimmelt et al., 2022). The aim of this research was to offer an alternative tool to consumers to be able to make health conscious decisions regarding packaged food effectively. While the modified traffic light food labeling system for food additives was introduced to address these concerns, it is important to recognize that too much information may cause an aversive effect. Therefore, future implications may want to consider how many additives per color does a consumer find helpful, as well as find harmful to their purchasing decisions.

In terms of marketing, brands that use fewer harmful additives may use this modified traffic light food labeling system to create an effective competitive advantage and distinguish themselves from their competitors. The labeling system can become an effective marketing tool for brands of food products who would like to emphasize the safety, and the quality of their products. This in turn would assist producers in their ability to attract target consumers, those who are health conscious and care about the quality of their food. Products like those of the smart sweet candy example would benefit from the usage of this modified traffic light labeling system.

In the same breath, if the modified traffic food labeling system became a trusted and well respected tool for consumers with regards to food safety, companies failing to comply may lose market share, popularity and a loyal customer base. As consumers gravitate toward brands offering the transparency of the modified traffic light labeling system, companies who don't face severe consequences.

Furthermore, the success of the proposed traffic light labeling system can be attributed to influencing consumer behavior. An uptick in changed behavior and consumer demand may inspire a larger and more widespread adoption of the method, which could lead to those of government regulating bodies or prominent industry leaders. We have already seen this pattern with the discontinuance of usage of brominated vegetable oil, and top industry leaders Coke and Pepsi. This would then have the potential to shift the overall marketing dynamics and set new industry standards for food labeling, and perhaps in turn food additive usage overall.

Limitations:

While the research at hand is a stepping stone to the implication and usage of traffic light food labeling systems with the United States, a few limitations presented themselves through the research. It is important to note that this study was conducted in a controlled, survey-based environment, which may not have fully captured the complexity of a real-world purchasing scenario. In actual shopping context, consumers may be influenced by additional factors such as availability, price, convenience, brand loyalty, or social influences, which were not accounted for in this research. The study's findings may overestimate the impact of the traffic light labeling system because participants were asked to focus specifically on the label information without the distractions of a real-world setting.

Another limitation to be considered is the demographics of the research and survey data. The sample size, although statistically adequate for chi-squared testing, may not be an accurate representation of the broader population of the American people. In this research, the majority of responses came from women of white descent who were adequately educated and living in New York State. In the United States, there is a very large range of people in terms of gender classification, race, education status, and location that may not have been appropriately reflected in this research. In addition, demographic consideration of income was not accounted for, which may have an effect on consumer spending habits which relates to this research.

The traffic light labeling system in this study focused on food additives rather than nutritional information (e.g., calories, sugar, fat). While this was intentional, it may limit the applicability of findings to labeling systems that aim to convey broader nutritional information. Some consumers may prioritize calorie or sugar content over the presence of certain additives, as briefly considered in the survey.

For future research, it would be advantageous to explore this research further with an improved surveying system. In the survey presented in this research, all participants were exposed to all survey conditions, which may have posed biases to the questions. Continued research could conduct a survey where participants are segmented, some getting the control condition of the regular nutrition facts labels, others getting the scenario regarding soda, and others with the candy. In this way, the data could more effectively be compared without biases.

With more resources, further research could illustrate the effectiveness of the label when physically fixated on the product, as well as in a purchasing environment. In present research, the label was only presented next to a product, not on it and displayed in a virtual setting. With more time and resources, seeing how effective the food additive labeling system is in a real world scenario could offer a further exploratory framework.

Tables and Charts

Table 1–A list of common exempt colors and their FDA[a] and INS[b] numbers.

Natural colorant	FDA	E number
Curcumin	73.600	100
Tumeric Oleoresin	73.650	None
Riboflavin	73.450	101(i)
Carmine/Cochineal	73.100	120
Chlorophylls	None	140i to ii
K-Cu-chlorophyll	None	141ii
Na-Cu-chlorophyll	73.125	141ii
Cu-chlorophylls	None	141i
Caramel I	73.85	150a
Caramel II	73.85	150b
Caramel III	73.85	150c
Caramel IV	73.85	150d
Vegetable Carbon	None	153
Carotenes	None	160(a) iv
Carrot Oils	73.300	None
b-carotene	73.950	160(a)i to iii
b-apo-8′-carotenoic acid (caroteneal)	73.900	160e
Annatto-bixin	73.300	160(b)i
Annatto-norbixin	73.300	160(b)ii
Paprika	73.340	None
Paprika oleoresins	73.345	160(c)
Lycopene	73.585	160(d)I, ii, iii
Lutein	None	161(b)i
Canthaxanthin	73.750	161g
Beet red	73.40	162
Anthocyanins	None	163
Grape color extract	73.169	None
Fruit juice	73.250	None
Vegetable juice	73.260	None
Enocianin (Grape skin extract)	73.170	163ii
Saffron, crocetin, and crocin	73.500	None
Titanium dioxide	73.575	171
Iron Oxides	73.200	172
Spirulina Blue	73.530	None
Spirulina Green	None	None
Gardenia Blue	None	None
Gardenia Yellow	None	None
Gardenia Red	None	None
Monascus Red	None	None
Monascus Yellow	None	None
Carthamus Yellow	None	None
Carthamus Red	None	None
Flavoanthin	None	None
Huito (*Genipa americana*)/ Jagua	None	None

[a]Food and Drug Administration from the Federal Food, Drug, and Cosmetic Act, 21 C.FR §73.
[b]Intl. Numbering System (European Union) by Codex Alimentarius.

Table 3.0: Colors Exempt From Batch Certification (Adapted from *21 CFR Part 170 -- Food Additives*, n.d.)

§ 172.515 Synthetic flavoring substances and adjuvants.

Synthetic flavoring substances and adjuvants may be safely used in food in accordance with the following conditions.

(a) They are used in the minimum quantity required to produce their intended effect, and otherwise in accordance with all the principles of good manufacturing practice.

(b) They consist of one or more of the following, used alone or in combination with flavoring substances and adjuvants generally recognized as safe in food, prior-sanctioned for such use, or regulated by an appropriate section in this part.

Acetal; acetaldehyde diethyl acetal.
Acetaldehyde phenethyl propyl acetal.
Acetanisole; 4′-methoxyacetophenone.
Acetophenone; methyl phenyl ketone.
Allyl anthranilate.
Allyl butyrate.
Allyl cinnamate.
Allyl cyclohexaneacetate.
Allyl cyclohexanebutyrate.
Allyl cyclohexanehexanoate.
Allyl cyclohexaneproprionate.
Allyl cyclohexanevalerate.
Allyl disulfide.
Allyl 2-ethylbutyrate.
Allyl hexanoate; allyl caproate.
Allyl α-ionone; 1-(2,6,6-trimethyl-2-cyclo-hexene-1-yl)-1,6-heptadiene-3-one.
Allyl isothiocyanate; mustard oil.
Allyl isovalerate.
Allyl mercaptan; 2-propene-1-thiol.
Allyl nonanoate.
Allyl octanoate.
Allyl phenoxyacetate.
Allyl phenylacetate.
Allyl propionate.
Allyl sorbate; allyl 2,4-hexadienoate.
Allyl sulfide.
Allyl tiglate; allyl *trans*-2-methyl-2-butenoate.
Allyl 10-undecenoate.
Ammonium isovalerate.
Ammonium sulfide.
Amyl alcohol; pentyl alcohol.
Amyl butyrate.
α-Amylcinnamaldehyde.
α-Amylcinnamaldehyde dimethyl acetal.
α-Amylcinnamyl acetate.
α-Amylcinnamyl alcohol.
α-Amylcinnamyl formate.
α-Amylcinnamyl isovalerate.
Amyl formate.
Amyl heptanoate.
Amyl hexanoate.
Amyl octanoate.
Anisole; methoxybenzene.
Anisyl acetate.
Anisyl alcohol; *p*-methoxybenzyl alcohol.
Anisyl butyrate
Anisyl formate.
Anisyl phenylacetate.
Anisyl propionate.
Beechwood creosote.
Benzaldehyde dimethyl acetal.
Benzaldehyde glyceryl acetal; 2-phenyl-*m*-dioxan-5-ol.
Benzaldehyde propylene glycol acetal; 4-methyl-2-phenyl-*m*-dioxolane.
Benzenethiol; thiophenol.
Benzoin; 2-hydroxy-2-phenylacetophenone.
Benzophenone; diphenylketone.
Benzyl acetate.
Benzyl acetoacetate.
Benzyl alcohol.
Benzyl benzoate.
Benzyl butyl ether.
Benzyl butyrate.
Benzyl cinnamate.
Benzyl 2,3-dimethylcrotonate; benzyl methyl tiglate.
Benzyl disulfide; dibenzyl disulfide.
Benzyl ethyl ether.
Benzyl formate.

Table 4.1: Synthetic Flavor Adatitves (Adapted from 21 CFR Part 170, n.d.).

3-Benzyl-4-heptanone; benzyl dipropyl ketone.
Benzyl isobutyrate.
Benzyl isovalerate.
Benzyl mercaptan; α-toluenethiol.
Benzyl methoxyethyl acetal; acetaldehyde benzyl β-methoxyethyl acetal.
Benzyl phenylacetate.
Benzyl propionate.
Benzyl salicylate.
Birch tar oil.
Borneol; *d*-camphanol.
Bornyl acetate.
Bornyl formate.
Bornyl isovalerate.
Bornyl valerate.
β-Bourbonene; 1,2,3,3a,3bβ,4,5,6,6aβ,6bα-decahydro-lα-isopropyl-3a$_{\alpha}$-methyl-6-methylene-cyclobuta [1,2:3,4] dicyclopentene.
2-Butanol.
2-Butanone; methyl ethyl ketone.
Butter acids.
Butter esters.
Butyl acetate.
Butyl acetoacetate.
Butyl alcohol; 1-butanol.
Butyl anthranilate.
Butyl butyrate.
Butyl butyryllactate; lactic acid, butyl ester, butyrate.
α-Butylcinnamaldehyde.
Butyl cinnamate.
Butyl 2-decenoate.
Butyl ethyl malonate.
Butyl formate.
Butyl heptanoate.
Butyl hexanoate.
Butyl *p*-hydroxybenzoate.
Butyl isobutyrate.
Butyl isovalerate.
Butyl lactate.
Butyl laurate.
Butyl levulinate.
Butyl phenylacetate.
Butyl propionate.
Butyl stearate.
Butyl sulfide.
Butyl 10-undecenoate.
Butyl valerate.
Butyraldehyde.
Cadinene.
Camphene; 2,2-dimethyl-3-methylene-norbornane.
d-Camphor.
Carvacrol; 2-*p*-cymenol.
Carvacryl ethyl ether; 2-ethoxy-*p*-cymene.
Carveol; *p*-mentha-6,8-dien-2-ol.
4-Carvomenthenol; 1-*p*-menthen-4-ol; 4-terpinenol.
cis Carvone oxide; 1,6-epoxy-*p*-menth-8-en-2-one.
Carvyl acetate.
Carvyl propionate.
β-Caryophyllene.
Caryophyllene alcohol.
Caryophyllene alcohol acetate.
β-Caryophyllene oxide; 4-12,12-trimethyl-9-methylene-5-oxatricylo [8.2.0.0^{4,6}] dodecane.
Cedarwood oil alcohols.
Cedarwood oil terpenes.
1,4-Cineole.
Cinnamaldehyde ethylene glycol acetal.
Cinnamic acid.
Cinnamyl acetate.
Cinnamyl alcohol; 3-phenyl-2-propen-1-ol.
Cinnamyl benzoate.
Cinnamyl butyrate.
Cinnamyl cinnamate.
Cinnamyl formate.
Cinnamyl isobutyrate.
Cinnamyl isovalerate.
Cinnamyl phenylacetate.
Cinnamyl propionate.
Citral diethyl acetal; 3,7-dimethyl-2,6-octadienal diethyl acetal.
Citral dimethyl acetal; 3,7-dimethyl-2,6-octadienal dimethyl acetal.
Citral propylene glycol acetal.
Citronellal; 3,7-dimethyl-6-octenal; rhodinal.
Citronellol; 3,7-dimethyl-6-octen-1-ol; *d*-citronellol.
Citronelloxyacetaldehyde.
Citronellyl acetate.
Citronellyl butyrate.
Citronellyl formate.
Citronellyl isobutyrate.
Citronellyl phenylacetate.
Citronellyl propionate.
Citronellyl valerate.
p-Cresol.
Cuminaldehyde; cuminal; *p*-isopropyl benzaldehyde.
Cyclohexaneacetic acid.
Cyclohexaneethyl acetate.
Cyclohexyl acetate.
Cyclohexyl anthranilate.
Cyclohexyl butyrate.
Cyclohexyl cinnamate.
Cyclohexyl formate.
Cyclohexyl isovalerate.
Cyclohexyl propionate.
p-Cymene.
γ-Decalactone; 4-hydroxy-decanoic acid, γ-lactone.
γ-Decalactone; 5-hydroxy-decanoic acid, δ-lactone.
Decanal dimethyl acetal.
1-Decanol; decylic alcohol.
2-Decenal.
3-Decen-2-one; heptylidene acetone.
Decyl actate.
Decyl butyrate.
Decyl propionate.
Dibenzyl ether.
4,4-Dibutyl-γ-butyrolactone; 4,4-dibutyl-4-hydroxy-butyric acid, γ-lactone.
Dibutyl sebacate.
Diethyl malate.
Diethyl malonate; ethyl malonate.
Diethyl sebacate.
Diethyl succinate.
Diethyl tartrate.

Table 4.2: Synthetic Flavor Adatitves (Adapted from 21 CFR Part 170, n.d.).

2,5-Diethyltetrahydrofuran.
Dihydrocarveol; 8-*p*-menthen-2-ol; 6-methyl-3-isopropenylcyclohexanol.
Dihydrocarvone.
Dihydrocarvyl acetate.
m-Dimethoxybenzene.
p-Dimethoxybenzene; dimethyl hydroquinone.
2,4-Dimethylacetophenone.
α,α-Dimethylbenzyl isobutyrate; phenyldimethylcarbinyl isobutyrate.
2,6-Dimethyl-5-heptenal.
2,6-Dimethyl octanal; isodecylaldehyde.
3,7-Dimethyl-1-octanol; tetrahydrogeraniol.
α,α-Dimethylphenethyl acetate; benzylpropyl acetate; benzyldimethylcarbinyl acetate.
α,α-Dimethylphenethyl alcohol; dimethylbenzyl carbinol.
α,α-Dimethylphenethyl butyrate; benzyldimethylcarbinyl butyrate.
α,α-Dimethylphenethyl formate; benzyldimethylcarbinyl formate.
Dimethyl succinate.
1,3-Diphenyl-2-propanone; dibenzyl ketone.
delta-Dodecalactone; 5-hydroxydodecanoic acid, deltalactone.
γ-Dodecalactone; 4-hydroxydodecanoic acid γ-lactone.
2-Dodecenal.
Estragole.
p-Ethoxybenzaldehyde.
Ethyl acetoacetate.
Ethyl 2-acetyl-3-phenylpropionate; ethylbenzyl acetoacetate.
Ethyl aconitate, mixed esters.
Ethyl acrylate.
Ethyl *p*-anisate.
Ethyl anthranilate.
Ethyl benzoate.
Ethyl benzoylacetate.
α-Ethylbenzyl butyrate; α-phenylpropyl butyrate.
Ethyl brassylate; tridecanedioic acid cyclic ethylene glycol diester; cyclo 1,13-ethylenedioxytridecan-1,13-dione.
2-Ethylbutyl acetate.
2-Ethylbutyraldehyde.
2-Ethylbutyric acid.
Ethyl cinnamate.
Ethyl crotonate; *trans*-2-butenoic acid ethyl-ester.
Ethyl cyclohexanepropionate.
Ethyl decanoate.
2-Ethylfuran.
Ethyl 2-furanpropionate.
4-Ethylguaiacol; 4-ethyl-2-methoxyphenol.
Ethyl heptanoate.
2-Ethyl-2-heptenal; 2-ethyl-3-butylacrolein.
Ethyl hexanoate.
Ethyl isobutyrate.
Ethyl isovalerate.
Ethyl lactate.
Ethyl laurate.
Ethyl levulinate.
Ethyl maltol; 2-ethyl-3-hydroxy-4H-pyran-4-one.
Ethyl 2-methylbutyrate.
Ethyl myristate.
Ethyl nitrite.
Ethyl nonanoate.
Ethyl 2-nonynoate; ethyl octyne carbonate.
Ethyl octanoate.
Ethyl oleate.
Ethyl phenylacetate.
Ethyl 4-phenylbutyrate.
Ethyl 3-phenylglycidate.
Ethyl 3-phenylpropionate; ethyl hydrocinnamate.
Ethyl propionate.
Ethyl pyruvate.
Ethyl salicylate.
Ethyl sorbate; ethyl 2,4-hexadienoate.
Ethyl tiglate; ethyl *trans*-2-methyl-2-butenoate.
Ethyl undecanoate.
Ethyl 10-undecenoate.
Ethyl valerate.
Eucalyptol; 1,8-epoxy-*p*-menthane; cineole.
Eugenyl acetate.
Eugenyl benzoate.
Eugenyl formate.
Eugenyl methyl ether; 4-allylveratrole; methyl eugenol.
Farnesol; 3,7,11-trimethyl-2,6,10-dodecatrien-1-ol.
d-Fenchone; *d*-1,3,3-trimethyl-2-norbornanone.
Fenchyl alcohol; 1,3,3-trimethyl-2-norbornanol.
Formic acid
(2-Furyl)-2-propanone; furyl acetone.
1-Furyl-2-propanone; furyl acetone.
Fusel oil, refined (mixed amyl alcohols).
Geranyl acetoacetate; *trans*-3,7-dimethyl-2, 6-octadien-1-yl acetoacetate.
Geranyl acetone; 6,10-dimethyl-5,9-undecadien-2-one.
Geranyl benzoate.
Geranyl butyrate.
Geranyl formate.
Geranyl hexanoate
Geranyl isobutyrate.
Geranyl isovalerate.
Geranyl phenylacetate.
Geranyl propionate.
Glucose pentaacetate.
Guaiacol; μ -methoxyphenol.
Guaiacyl acetate; μ -methoxyphenyl acetate.
Guaiacyl phenylacetate.
Guaiene; 1,4-dimethyl-7-isopropenyl-Δ9,10-octahydroazulene.
Guaiol acetate; 1,4-dimethyl-7-(α-hydroxyisopropyl)-δ9,10-octahydroazulene acetate.
γ-Heptalactone; 4-hydroxyheptanoic acid, γ-lactone.
Heptanal; enanthaldehyde.
Heptanal dimethyl acetal.
Heptanal 1,2-glyceryl acetal.
2,3-Heptanedione; acetyl valeryl.
3-Heptanol.
2-Heptanone; methyl amyl ketone.
3-Heptanone; ethyl butyl ketone.
4-Heptanone; dipropyl ketone.

Table 4.3: Synthetic Flavor Adatitves (Adapted from 21 CFR Part 170, n.d.).

cis-4-Heptenal; *cis*-4-hepten-1-al.
Heptyl acetate.
Heptyl alcohol; enanthic alcohol.
Heptyl butyrate.
Heptyl cinnamate.
Heptyl formate.
Heptyl isobutyrate.
Heptyl octanoate.
1-Hexadecanol; cetyl alcohol.
ω-6-Hexadecenlactone; 16-hydroxy-6-hexadecenoic acid, ω-lactone; ambrettolide.
γ-Hexalactone; 4-hydroxyhexanoic acid, γ-lactone; tonkalide.
Hexanal; caproic aldehyde.
2,3-Hexanedione; acetyl butyryl.
Hexanoic acid; caproic acid.
2-Hexenal.
2-Hexen-1-ol.
3-Hexen-1-ol; leaf alcohol.
2-Hexen-1-yl acetate.
3-Hexenyl isovalerate.
3-Hexenyl 2-methylbutyrate.
3-Hexenyl phenylacetate; *cis*-3-hexenyl phenylacetate.
Hexyl acetate.
2-Hexyl-4-acetoxytetrahydrofuran.
Hexyl alcohol.
Hexyl butyrate.
α-Hexylcinnamaldehyde.
Hexyl formate.
Hexyl hexanoate.
2-Hexylidene cyclopentanone.
Hexyl isovalerate.
Hexyl 2-methylbutyrate.
Hexyl octanoate.
Hexyl phenylacetate; *n*-hexyl phenylacetate.
Hexyl propionate.
Hydroxycitronellal; 3,7-dimethyl-7-hydroxyoctanal.
Hydroxycitronellal diethyl acetal.
Hydroxycitronellal dimethyl acetal.
Hydroxycitronellal; 3,7-dimethyl-1,7-octanediol.
N-(4-Hydroxy-3-methoxybenzyl)-nonanamide; pelargonyl vanillylamide.
5-Hydroxy-4-octanone; butyroin.
4-(*p*-Hydroxyphenyl)-2-butanone; *p*-hydroxybenzyl acetone.
Indole.
α-Ionone; 4-(2,6,6-trimethyl-2-cyclohexen-1-yl)-3-buten-2-one.
β-Ionone; 4-(2,6,6-trimethyl-1-cyclohexen-1-yl)-3-buten-2-one.
α-Irone; 4-(2,5,6,6-tetramethyl-2-cyclohexene-1-yl)-3-buten-2-one; 6-methylionone.
Isoamyl acetate.
Isoamyl acetoacetate.
Isoamyl alcohol; isopentyl alcohol; 3-methyl-1-butanol.
Isoamyl benzoate.
Isoamyl butyrate.
Isoamyl cinnamate.
Isoamyl formate.
Isoamyl 2-furanbutyrate; α-isoamyl furfurylpropionate.
Isoamyl 2-furanpropionate; α-isoamyl furfurylacetate.
Isoamyl hexanoate.
Isoamyl isobutyrate.
Isoamyl isovalerate.
Isoamyl laurate.
Isoamyl-2-methylbutyrate; isopentyl-2-methylbutyrate.
Isoamyl nonanoate.
Isoamyl octanoate.
Isoamyl phenylacetate.
Isoamyl propionate.
Isoamyl pyruvate.
Isoamyl salicylate.
Isoborneol.
Isobornyl acetate.
Isobornyl formate.
Isobornyl isovalerate.
Isobornyl propionate.
Isobutyl acetate.
Isobutyl acetoacetate.
Isobutyl alcohol.
Isobutyl angelate; isobutyl *cis*-2-methyl-2-butenoate.
Isobutyl anthranilate.
Isobutyl benzoate.
Isobutyl butyrate.
Isobutyl cinnamate.
Isobutyl formate.
Isobutyl 2-furanpropionate.
Isobutyl heptanoate.
Isobutyl hexanoate.
Isobutyl isobutyrate.
α-Isobutylphenethyl alcohol; isobutyl benzyl carbinol; 4-methyl-1-phenyl-2-pentanol.
Isobutyl phenylacetate.
Isobutyl propionate.
Isobutyl salicylate.
2-Isobutylthiazole.
Isobutyraldehyde.
Isobutyric acid.
Isoeugenol; 2-methoxy-4-propenylphenol.
Isoeugenyl acetate.
Isoeugenyl benzyl ether; benzyl isoeugenol.
Isoeugenyl ethyl ether; 2-ethoxy-5-propenylanisole; ethyl isoeugenol.
Isoeugenyl formate.
Isoeugenyl methyl ether; 4-propenylveratrole; methyl isoeugenol.
Isoeugenyl phenylacetate.
Isojasmone; mixture of 2-hexylidenecyclopentanone and 2-hexyl-2-cyclopenten-1-one.
α-Isomethylionone; 4-(2,6,6-trimethyl-2-cyclohexen-1-yl)-3-methyl-3-buten-2-one; methyl γ-ionone.
Isopropyl acetate.
p-Isopropylacetophenone.
Isopropyl alcohol; isopropanol.
Isopropyl benzoate.
p-Isopropylbenzyl alcohol; cuminic alcohol; *p*-cymen-7-ol.
Isopropyl butyrate.
Isopropyl cinnamate.
Isopropyl formate.
Isopropyl hexanoate.
Isopropyl isobutyrate.
Isopropyl isovalerate.

Table 4.4: Synthetic Flavor Adatitves (Adapted from 21 CFR Part 170, n.d.).

p-Isopropylphenylacetaldehyde; p-cymen-7-carboxaldehyde.
Isopropyl phenylacetate.
3-(p-Isopropylphenyl)-propionaldehyde; p-isopropylhydrocinnamaldehyde; cuminyl acetaldehyde.
Isopropyl propionate.
Isopulegol; p-menth-8-en-3-ol.
Isopulegone; p-menth-8-en-3-one.
Isopulegyl acetate.
Isoquinoline.
Isovaleric acid.
cis-Jasmone; 3-methyl-2-(2-pentenyl)-2-cyclopenten-1-one.
Lauric aldehyde; dodecanal.
Lauryl acetate.
Lauryl alcohol; 1-dodecanol.
Lepidine; 4-methylquinoline.
Levulinic acid.
Linalool oxide; *cis*- and *trans*-2-vinyl-2-methyl-5-(1'-hydroxy-1'-methylethyl) tetrahydrofuran.
Linalyl anthranilate; 3,7-dimethyl-1,6-octadien-3-yl anthranilate.
Linalyl benzoate.
Linalyl butyrate.
Linalyl cinnamate.
Linalyl formate.
Linalyl hexanoate.
Linalyl isobutyrate.
Linalyl isovalerate.
Linalyl octanoate.
Linalyl propionate.
Maltol; 3-hydroxy-2-methyl-4H-pyran-4-one.
Menthadienol; p-mentha-1,8(10)-dien-9-ol.
p-Mentha-1,8-dien-7-ol; perillyl alcohol.
Menthadienyl acetate; p-mentha-1,8(10)-dien-9-yl acetate.
p-Menth-3-en-1-ol.
1-p-Menthen--9-yl acetate; p-menth-1-en-9-yl acetate.
Menthol; 2-isopropyl-5-methylcyclohexanol.
Menthone; p-menthan-3-one.
Menthyl acetate; p-menth-3-yl acetate.
Menthyl isovalerate; p-menth-3-yl isovalerate.
o-Methoxybenzaldehyde.
p-Methoxybenzaldehyde; p-anisaldehyde.
o-Methoxycinnamaldehyde.
2-Methoxy-4-methylphenol; 4-methylguaiacol; 2-methoxy-p-cresol.
4-(p-Methoxyphenyl)-2-butanone; anisyl acetone.
1-(4-Methoxyphenyl)-4-methyl-1-penten-3-one; methoxystyryl isopropyl ketone.
1-(p-Methoxyphenyl)-1-penten-3-one; α-methylanisylidene acetone; ethone.
1-(p-Methoxyphenyl)-2-propanone; anisylmethyl ketone; anisic ketone.
2-Methoxy-4-vinylphenol; p-vinylguaiacol.
Methyl acetate.
4'-Methylacetophenone; p-methylacetophenone; methyl p-tolyl ketone.
2-Methylallyl butyrate; 2-methyl-2-propenyl butyrate.
Methyl anisate.
o-Methylanisole; o-cresyl methyl ether.
p-Methylanisole; p-cresyl methyl ether; p-methoxytoluene.
Methyl benzoate.
Methylbenzyl acetate, mixed o-,m-,p-.
α-Methylbenzyl acetate; styralyl acetate.
α-Methylbenzyl alcohol; styralyl alcohol.
α-Methylbenzyl butyrate; styralyl butyrate.
α-Methylbenzyl isobutyrate; styralyl isobutyrate.
α-Methylbenzyl formate; styralyl formate.
α-Methylbenzyl propionate; styralyl propionate.
2-Methyl-3-buten-2-ol.
2-Methylbutyl isovalerate.
Methyl p-*tert*-butylphenylacetate.
2-Methylbutyraldehyde; methyl ethyl acetaldehyde.
3-Methylbutyraldehyde; isovaleraldehyde.
Methyl butyrate.
2-Methylbutyric acid.
α-Methylcinnamaldehyde.
p-Methylcinnamaldehyde.
Methyl cinnamate.
2-Methyl-1,3-cyclohexadiene.
Methylcyclopentenolone; 3-methylcyclopentane-1,2-dione.
Methyl disulfide; dimethyl disulfide.
Methyl ester of rosin, partially hydrogenated (as defined in §172.615); methyl dihydroabietate.
Methyl heptanoate.
2-Methylheptanoic acid.
6-Methyl-3,5-heptadien-2-one.
Methyl-5-hepten-2-ol.
6-Methyl-5-hepten-2-one.
Methyl hexanoate.
Methyl 2-hexanoate.
Methyl p-hydroxybenzoate; methylparaben.
Methyl α-ionone; 5-(2,6,6-trimethyl-2-cyclohexen-1-yl)-4-penten-3-one.
Methyl β-ionone; 5-(2,6,6-trimethyl-1-cyclohexen-1-yl)-4-penten-3-one.
Methyl Δ-ionone; 5-(2,6,6-trimethyl-3-cyclohexen-1-yl-)-4-penten-3-one.
Methyl isobutyrate.
2-Methyl-3-(p-isopropylphenyl)-propionaldehyde; α-methyl-p-isopropylhydrocinnamal- dehyde; cyclamen aldehyde.
Methyl isovalerate.
Methyl laurate.
Methyl mercaptan; methanethiol.
Methyl o-methoxybenzoate.
Methyl N-methylanthranilate; dimethyl anthranilate.
Methyl 2-methylbutyrate.
Methyl-3-methylthiopropionate.
Methyl 4-methylvalerate.
Methyl myristate.
Methyl β-naphthyl ketone; 2'-acetonaphthone.
Methyl nonanoate.
Methyl 2-nonenoate.
Methyl 2-nonynoate; methyloctyne carbonate.
2-Methyloctanal; methyl hexyl acetaldehyde.
Methyl octanoate.

Table 4.5: Synthetic Flavor Adatitves (Adapted from 21 CFR Part 170, n.d.).

Methyl 2-octynoate; methyl heptine carbonate.
4-Methyl-2,3-pentanedione; acetyl isobutyryl.
4-Methyl-2-pentanone; methyl isobutyl ketone.
β-Methylphenethyl alcohol; hydratropyl alcohol.
Methyl phenylacetate.
3-Methyl-4-phenyl-3-butene-2-one.
2-Methyl-4-phenyl-2-butyl acetate; dimethylphenylethyl carbinyl acetate.
2-Methyl-4-phenyl-2-butyl isobutyrate; dimethylphenyl ethylcarbinyl isobutyrate.
3-Methyl-2-phenylbutyraldehyde; α-isopropyl phenylacetaldehyde.
Methyl 4-phenylbutyrate.
4-Methyl-1-phenyl-2-pentanone; benzyl isobutyl ketone.
Methyl 3-phenylpropionate; methyl hydrocinnamate.
Methyl propionate.
3-Methyl-5-propyl-2-cyclohexen-1-one.
Methyl sulfide.
3-Methylthiopropionaldehyde; methional.
2-Methyl-3-tolylpropionaldehyde, mixed *o*-, *m*-, *p*-.
2-Methylundecanal; methyl nonyl acetaldehyde.
Methyl 9-undecenoate.
Methyl 2-undecynoate; methyl decyne carbonate.
Methyl valerate.
2-Methylvaleric acid.
Myrcene; 7-methyl-3-methylene-1,6-octadiene.
Myristaldehyde; tetradecanal.
d-Neomenthol; 2-isopropyl-5-methylcyclohexanol.
Nerol; *cis*-3,7-dimethyl-2,6-octadien-1-ol.
Nerolidol; 3,7,11-trimethyl-1,6,10-dodecatrien-3-ol.
Neryl acetate.
Neryl butyrate.
Neryl formate.
Neryl isobutyrate.
Neryl isovalerate.
Neryl propionate.
2,6-Nonadien-1-ol.
γ-Nonalactone; 4-hydroxynonanoic acid, γ-lactone; aldehyde C-18.
Nonanal; pelargonic aldehyde.
1,3-Nonanediol acetate, mixed esters.
Nonanoic acid; pelargonic acid.
2-Nonanone; methylheptyl ketone.
3-Nonanon-1-yl acetate; 1-hydroxy-3-nonanone acetate.
Nonyl acetate.
Nonyl alcohol; 1-nonanol.
Nonyl octanoate.
Nonyl isovalerate.
Nootkatone; 5,6-dimethyl-8-isopropenylbicyclo[4,4,0]-dec-1-en-3-one.
Ocimene; *trans*-β-ocimene; 3,7-dimethyl-1,3,6-octatriene.
γ-Octalactone; 4-hydroxyoctanoic acid, γ-lactone.
Octanal; caprylaldehyde.
Octanal dimethyl acetal.
1-Octanol; octyl alcohol.
2-Octanol.
3-Octanol.
2-Octanone; methyl hexyl ketone.
3-Octanone; ethyl amyl ketone.
3-Octanon-1-ol.
1-Octen-3-ol; amyl vinyl carbinol.
1-Octen-3-yl acetate.
Octyl acetate.
3-Octyl acetate.
Octyl butyrate.
Octyl formate.
Octyl heptanoate.
Octyl isobutyrate.
Octyl isovalerate.
Octyl octanoate.
Octyl phenylacetate.
Octyl propionate.
ω-Pentadecalactone; 15-hydroxypentadecanoic acid, ω-lactone; pentadecanolide; angelica lactone.
2,3-Pentanedione; acetyl propionyl.
2-Pentanone; methyl propyl ketone.
4-Pentenoic acid.
1-Penten-3-ol.
Perillaldehyde; 4-isopropenyl-1-cyclohexene-1-carboxaldehyde; *p*-mentha-1,8-dien-7-al.
Perillyl acetate; *p*-mentha-1,8-dien-7-yl acetate.
α-Phellandrene; *p*-mentha-1,5-diene.
Phenethyl acetate.
Phenethyl alcohol; β-phenylethyl alcohol.
Phenethyl anthranilate.
Phenethyl benzoate.
Phenethyl butyrate.
Phenethyl cinnamate.
Phenethyl formate.
Phenethyl isobutyrate.
Phenethyl isovalerate.
Phenethyl 2-methylbutyrate.
Phenethyl phenylacetate.
Phenethyl propionate.
Phenethyl salicylate.
Phenethyl senecioate; phenethyl 3,3-dimethylacrylate.
Phenethyl tiglate.
Phenoxyacetic acid.
2-Phenoxyethyl isobutyrate.
Phenylacetaldehyde; α-toluic aldehyde.
Phenylacetaldehyde 2,3-butylene glycol acetal.
Phenylacetaldehyde dimethyl acetal.
Phenylacetaldehyde glyceryl acetal.
Phenylacetic acid; α-toluic acid.
4-Phenyl-2-butanol; phenylethyl methyl carbinol.
4-Phenyl-3-buten-2-ol; methyl styryl carbinol.
4-Phenyl-3-buten-2-one.
4-Phenyl-2-butyl acetate; phenylethyl methyl carbinyl acetate.
1-Phenyl-3-methyl-3-pentanol; phenylethyl methyl ethyl carbinol.
1-Phenyl-1-propanol; phenylethyl carbinol.
3-Phenyl-1-propanol; hydrocinnamyl alcohol.

Table 4.6: Synthetic Flavor Adatitves (Adapted from 21 CFR Part 170, n.d.).

2-Phenylpropionaldehyde; hydratropaldehyde.
3-Phenylpropionaldehyde; hydrocinnamaldehyde.
2-Phenylpropionalde-hyde dimethyl acetal; hydratropic aldehyde dimethyl acetal.
3-Phenylpropionic acid; hydrocinnamic acid.
3-Phenylpropyl acetate.
2-Phenylpropyl butyrate.
3-Phenylpropyl cinnamate.
3-Phenylpropyl formate.
3-Phenylpropyl hexanoate.
2-Phenylpropyl isobutyrate.
3-Phenylpropyl isobutyrate.
3-Phenylpropyl isovalerate.
3-Phenylpropyl propionate.
2-(3-Phenylpropyl)-tetrahydrofuran.
α-Pinene; 2-pinene.
β-Pinene; 2(10)-pinene.
Pine tar oil.
Pinocarveol; 2(10)-pinen-3-ol.
Piperidine.
Piperine.
d-Piperitone; *p*-menth-1-en-3-one.
Piperitenone; *p*-mentha-1,4(8)-dien-3-one.
Piperitenone oxide; 1,2-epoxy-*p*-menth-4-(8)-en-3-one.
Piperonyl acetate; heliotropyl acetate.
Piperonyl isobutyrate.
Polylimonene.
Polysorbate 20; polyoxyethylene (20) sorbitan monolaurate.
Polysorbate 60; polyoxyethylene (20) sorbitan monostereate.
Polysorbate 80; polyoxyethylene (20) sorbitan monooleate.
Potassium acetate.
Propenylguaethol; 6-ethoxy-*m*-anol.
Propionaldehyde.
Propyl acetate.
Propyl alcohol; 1-propanol.
p-Propyl anisole; dihydroanethole.
Propyl benzoate.
Propyl butyrate.
Propyl cinnamate.
Propyl disulfide.
Propyl formate.
Propyl 2-furanacrylate.
Propyl heptanoate.
Propyl hexanoate.
Propyl *p*-hydroxybenzoate; propylparaben.
3-Propylidenephthalide.
Propyl isobutyrate.
Propyl isovalerate.
Propyl mercaptan.
α-Propylphenethyl alcohol.
Propyl phenylacetate.
Propyl propionate.
Pulegone; *p*-menth-4(8)-en-3-one.
Pyridine.
Pyroligneous acid extract.
Pyruvaldehyde.
Pyruvic acid.
Rhodinol; 3,7-dimethyl-7-octen-1-ol; *l*-citronellol.
Rhodinyl acetate.
Rhodinyl butyrate.
Rhodinyl formate.
Rhodinyl isobutyrate.
Rhodinyl isovalerate.
Rhodinyl phenylacetate.
Rhodinyl propionate.
Rum ether; ethyl oxyhydrate.
Salicylaldehyde.
Santalol, α and β.
Santalyl acetate.
Santalyl phenylacetate.
Skatole.
Sorbitan monostearate.
Styrene.
Sucrose octaacetate.
α-Terpinene.
γ-Terpinene.
α-Terpineol; *p*-menth-1-en-8-ol.
β-Terpineol.
Terpinolene; *p*-menth-1,4(8)-diene.
Terpinyl acetate.
Terpinyl anthranilate.
Terpinyl butyrate.
Terpinyl cinnamate.
Terpinyl formate.
Terpinyl isobutyrate.
Terpinyl isovalerate.
Terpinyl propionate.
Tetrahydrofurfuryl acetate.
Tetrahydrofurfuryl alcohol.
Tetrahydrofurfuryl butyrate.
Tetrahydrofurfuryl propionate.
Tetrahydro-pseudo-ionone; 6,10-dimethyl-9-undecen-2-one.
Tetrahydrolinalool; 3,7-dimethyloctan-3-ol.
Tetramethyl ethylcyclohexenone; mixture of 5-ethyl-2,3,4,5-tetramethyl-2-cyclohexen-1-one and 5-ethyl-3,4,5,6-tetramethyl-2-cyclohexen-1-one.
2-Thienyl mercaptan; 2-thienylthiol.
Thymol.
Tolualdehyde glyceryl acetal, mixed *o, m, p*.
Tolualdehydes, mixed *o, m, p*.
p-Tolylacetaldehyde.
o-Tolyl acetate; *o*-cresyl acetate.
p-Tolyl acetate; *p*-cresyl acetate.
4-(*p*-Tolyl)-2-butanone; *p*-methylbenzylacetone.
p-Tolyl isobutyrate.
p-Tolyl laurate.
p-Tolyl phenylacetate.
2-(*p*-Tolyl)-propionaldehyde; *p*-methylhydratropic aldehyde.
Tributyl acetylcitrate.
2-Tridecenal.
2,3-Undecadione; acetyl nonyryl.
γ-Undecalactone; 4-hydroxyundecanoic acid γ-lactone; peach aldehyde; aldehyde C-14.
Undecenal.
2-Undecanone; methyl nonyl ketone.
9-Undecenal; undecenoic aldehyde.
10-Undecenal.
Undecen-1-ol; undecylenic alcohol.
10-Undecen-1-yl acetate.
Undecyl alcohol.
Valeraldehyde; pentanal.
Valeric acid; pentanoic acid.
Vanillin acetate; acetyl vanillin.

Table 4.7: Synthetic Flavor Adatitves (Adapted from 21 CFR Part 170, n.d.).

§ 182.60 Synthetic flavoring substances and adjuvants.

Synthetic flavoring substances and adjuvants that are generally recognized as safe for their intended use, within the meaning of section 409 of the Act, are as follows:

Acetaldehyde (ethanal).
Acetoin (acetyl methylcarbinol).
Anethole (parapropenyl anisole).
Benzaldehyde (benzoic aldehyde).
N-Butyric acid (butanoic acid).
d- or *l*-Carvone (carvol).
Cinnamaldehyde (cinnamic aldehyde).
Citral (2,6-dimethyloctadien-2,6-*al*-8, geranial, neral).
Decanal (*N*-decylaldehyde, capraldehyde, capric aldehyde, caprinaldehyde, aldehyde C-10).
Ethyl acetate.
Ethyl butyrate.
3-Methyl-3-phenyl glycidic acid ethyl ester (ethyl-methyl-phenyl-glycidate, so-called strawberry aldehyde, C-16 aldehyde).
Ethyl vanillin.
Geraniol (3,7-dimethyl-2,6 and 3,6-octadien-1-*ol*).
Geranyl acetate (geraniol acetate).
Limonene (*d*-, *l*-, and *dl*-).
Linalool (linalol, 3,7-dimethyl-1,6-octadien-3-*ol*).
Linalyl acetate (bergamol).
Methyl anthranilate (methyl-2-aminobenzoate).
Piperonal (3,4-methylenedioxy-benzaldehyde, heliotropin).
Vanillin.

[42 FR 14640, Mar. 15, 1977, as amended at 43 FR 47724, Oct. 17, 1978; 44 FR 3963, Jan. 19, 1979; 44 FR 20656, Apr. 6, 1979; 48 FR 51907, Nov. 15, 1983; 54 FR 7402, Feb. 21, 1989]

ognized as safe for their intended use, within the meaning of section 409 of the Act, are as follows:

Beef tallow.
Carboxymethylcellulose.
Coconut oil, refined.
Cornstarch.
Gelatin.
Lard.
Lard oil.
Oleic acid.
Peanut oil.
Potato starch.
Sodium acetate.
Sodium chloride.
Sodium silicate.
Sodium tripolyphosphate.
Soybean oil (hydrogenated).
Talc.
Tallow (hydrogenated).
Tallow flakes.
Tapioca starch.
Tetrasodium pyrophosphate.
Wheat starch.
Zinc chloride.

[42 FR 14640, Mar. 15, 1977, as amended at 43 FR 11698, Mar. 21, 1978; 44 FR 28323, May 15, 1979; 45 FR 6085, Jan. 25, 1980; 47 FR 27807, 27814, June 25, 1982; 48 FR 51150, Nov. 7, 1983; 48 FR 51616, Nov. 10, 1983; 48 FR 51909, Nov. 15,

food packaging that are generally recognized as safe for their intended use, within the meaning of section 409 of

Table 5.1: Synthetic Flavor Adatitves (Adapted from 21 CFR Part 170, n.d.).

Common name	Botanical name of plant source
Alfalfa herb and seed	Medicago sativa L.
Allspice	Pimenta officinalis Lindl.
Ambrette seed	Hibiscus abelmoschus L.
Angelica	Angelica archangelica L. or other spp. of Angelica.
Angelica root	Do.
Angelica seed	Do.
Angostura (cusparia bark)	Galipea officinalis Hancock.
Anise	Pimpinella anisum L.
Anise, star	Illicium verum Hook. f.
Balm (lemon balm)	Melissa officinalis L.
Basil, bush	Ocimum minimum L.
Basil, sweet	Ocimum basilicum L.
Bay	Laurus nobilis L.
Calendula	Calendula officinalis L.
Camomile (chamomile), English or Roman	Anthemis nobilis L.
Camomile (chamomile), German or Hungarian	Matricaria chamomilla L.
Capers	Capparis spinosa L.
Capsicum	Capsicum frutescens L. or Capsicum annuum L.
Caraway	Carum carvi L.
Caraway, black (black cumin)	Nigella sativa L.
Cardamom (cardamon)	Elettaria cardamomum Maton.
Cassia, Chinese	Cinnamomum cassia Blume.
Cassia, Padang or Batavia	Cinnamomum burmanni Blume.
Cassia, Saigon	Cinnamomum loureirii Nees.
Cayenne pepper	Capsicum frutescens L. or Capsicum annuum L.
Celery seed	Apium graveolens L.
Chervil	Anthriscus cerefolium (L.) Hoffm.
Chives	Allium schoenoprasum L.
Cinnamon, Ceylon	Cinnamomum zeylanicum Nees.
Cinnamon, Chinese	Cinnamomum cassia Blume.
Cinnamon, Saigon	Cinnamomum loureirii Nees.
Clary (clary sage)	Salvia sclarea L.
Clover	Trifolium spp.
Coriander	Coriandrum sativum L.
Cumin (cummin)	Cuminum cyminum L.
Cumin, black (black caraway)	Nigella sativa L.
Elder flowers	Sambucus canadensis L.
Fennel, common	Foeniculum vulgare Mill.
Fennel, sweet (finocchio, Florence fennel)	Foeniculum vulgare Mill. var. dulce (DC.) Alex.
Fenugreek	Trigonella foenum-graecum L.
Galanga (galangal)	Alpinia officinarum Hance.
Geranium	Pelargonium spp.
Ginger	Zingiber officinale Rosc.
Grains of paradise	Amomum melegueta Rosc.
Horehound (hoarhound)	Marrubium vulgare L.
Horseradish	Armoracia lapathifolia Gilib.
Hyssop	Hyssopus officinalis L.
Lavender	Lavandula officinalis Chaix.
Linden flowers	Tilia spp.
Mace	Myristica fragrans Houtt.
Marigold, pot	Calendula officinalis L.
Marjoram, pot	Majorana onites (L.) Benth.
Marjoram, sweet	Majorana hortensis Moench.
Mustard, black or brown	Brassica nigra (L.) Koch.
Mustard, brown	Brassica juncea (L.) Coss.
Mustard, white or yellow	Brassica hirta Moench.
Nutmeg	Myristica fragrans Houtt.
Oregano (oreganum, Mexican oregano, Mexican sage, origan).	Lippia spp.
Paprika	Capsicum annuum L.
Parsley	Petroselinum crispum (Mill.) Mansf.
Pepper, black	Piper nigrum L.
Pepper, cayenne	Capsicum frutescens L. or Capsicum annuum L.
Pepper, red	Do.
Pepper, white	Piper nigrum L.
Peppermint	Mentha piperita L.
Poppy seed	Papayer somniferum L.
Pot marigold	Calendula officinalis L.
Pot marjoram	Majorana onites (L.) Benth.
Rosemary	Rosmarinus officinalis L.
Saffron	Crocus sativus L.
Sage	Salvia officinalis L.
Sage, Greek	Salvia triloba L.
Savory, summer	Satureia hortensis L. (Satureja).

Table 6.1. Spices and other natural seasonings (Adapted from 21 CFR Part 182.10, n.d.).

Common name	Botanical name of plant source
Savory, winter	Satureia montana L. (Satureja).
Sesame	Sesamum indicum L.
Spearmint	Mentha spicata L.
Star anise	Illicium verum Hook. f.
Tarragon	Artemisia dracunculus L.
Thyme	Thymus vulgaris L.
Thyme, wild or creeping	Thymus serpyllum L.
Turmeric	Curcuma longa L.
Vanilla	Vanilla planifolia Andr. or Vanilla tahitensis J. W. Moore.
Zedoary	Curcuma zedoaria Rosc.

Table 7.1. Essential Oils (Adapted from 21 CFR Part 182.20, n.d.).

Common name	Botanical name of plant source
Alfalfa	Medicago sativa L.
Allspice	Pimenta officinalis Lindl.
Almond, bitter (free from prussic acid)	Prunus amygdalus Batsch, Prunus armeniaca L., or Prunus persica (L.) Batsch.
Ambrette (seed)	Hibiscus moschatus Moench.
Angelica root	Angelica archangelica L.
Angelica seed	Do.
Angelica stem	Do.
Angostura (cusparia bark)	Galipea officinalis Hancock.
Anise	Pimpinella anisum L.
Asafetida	Ferula assa-foetida L. and related spp. of Ferula.
Balm (lemon balm)	Melissa officinalis L.
Balsam of Peru	Myroxylon pereirae Klotzsch.
Basil	Ocimum basilicum L.
Bay leaves	Laurus nobilis L.
Bay (myrcia oil)	Pimenta racemosa (Mill.) J. W. Moore.
Bergamot (bergamot orange)	Citrus aurantium L. subsp. bergamia Wright et Arn.
Bitter almond (free from prussic acid)	Prunus amygdalus Batsch, Prunus armeniaca L., or Prunus persica (L.) Batsch.
Bois de rose	Aniba rosaeodora Ducke.
Cacao	Theobroma cacao L.
Camomile (chamomile) flowers, Hungarian	Matricaria chamomilla L.
Camomile (chamomile) flowers, Roman or English	Anthemis nobilis L.
Cananga	Cananga odorata Hook. f. and Thoms.
Capsicum	Capsicum frutescens L. and Capsicum annuum L.
Caraway	Carum carvi L.
Cardamom seed (cardamon)	Elettaria cardamomum Maton.
Carob bean	Ceratonia siliqua L.
Carrot	Daucus carota L.
Cascarilla bark	Croton eluteria Benn.
Cassia bark, Chinese	Cinnamomum cassia Blume.
Cassia bark, Padang or Batavia	Cinnamomum burmanni Blume.
Cassia bark, Saigon	Cinnamomum loureirii Nees.
Celery seed	Apium graveolens L.
Cherry, wild, bark	Prunus serotina Ehrh.
Chervil	Anthriscus cerefolium (L.) Hoffm.
Chicory	Cichorium intybus L.
Cinnamon bark, Ceylon	Cinnamomum zeylanicum Nees.
Cinnamon bark, Chinese	Cinnamomum cassia Blume.
Cinnamon bark, Saigon	Cinnamomum loureirii Nees.
Cinnamon leaf, Ceylon	Cinnamomum zeylanicum Nees.
Cinnamon leaf, Chinese	Cinnamomum cassia Blume.
Cinnamon leaf, Saigon	Cinnamomum loureirii Nees.
Citronella	Cymbopogon nardus Rendle.
Citrus peels	Citrus spp.
Clary (clary sage)	Salvia sclarea L.
Clover	Trifolium spp.
Coca (decocainized)	Erythroxylum coca Lam. and other spp. of Erythroxylum.

Table 7.2. Essential Oils (Adapted from 21 CFR Part 182.20, n.d.).

Common name	Botanical name of plant source
Coffee	Coffea spp.
Cola nut	Cola acuminata Schott and Endl., and other spp. of Cola.
Coriander	Coriandrum sativum L.
Cumin (cummin)	Cuminum cyminum L.
Curacao orange peel (orange, bitter peel)	Citrus aurantium L.
Cusparia bark	Galipea officinalis Hancock.
Dandelion	Taraxacum officinale Weber and T. laevigatum DC.
Dandelion root	Do.
Dog grass (quackgrass, triticum)	Agropyron repens (L.) Beauv.
Elder flowers	Sambucus canadensis L. and S. nigra I.
Estragole (esdragol, esdragon, tarragon)	Artemisia dracunculus L.
Estragon (tarragon)	Do.
Fennel, sweet	Foeniculum vulgare Mill.
Fenugreek	Trigonella foenum-graecum L.
Galanga (galangal)	Alpinia officinarum Hance.
Geranium	Pelargonium spp.
Geranium, East Indian	Cymbopogon martini Stapf.
Geranium, rose	Pelargonium graveolens L'Her.
Ginger	Zingiber officinale Rosc.
Grapefruit	Citrus paradisi Macf.
Guava	Psidium spp.
Hickory bark	Carya spp.
Horehound (hoarhound)	Marrubium vulgare L.
Hops	Humulus lupulus L.
Horsemint	Monarda punctata L.
Hyssop	Hyssopus officinalis L.
Immortelle	Helichrysum augustifolium DC.
Jasmine	Jasminum officinale L. and other spp. of Jasminum.
Juniper (berries)	Juniperus communis L.
Kola nut	Cola acuminata Schott and Endl., and other spp. of Cola.
Laurel berries	Laurus nobilis L.
Laurel leaves	Laurus spp.
Lavender	Lavandula officinalis Chaix.
Lavender, spike	Lavandula latifolia Vill.
Lavandin	Hybrids between Lavandula officinalis Chaix and Lavandula latifolin Vill.
Lemon	Citrus limon (L.) Burm. f.
Lemon balm (see balm).	
Lemon grass	Cymbopogon citratus DC. and Cymbopogon lexuosus Stapf.
Lemon peel	Citrus limon (L.) Burm. f.
Lime	Citrus aurantifolia Swingle.
Linden flowers	Tilia spp.
Locust bean	Ceratonia siliqua L,
Lupulin	Humulus lupulus L.
Mace	Myristica fragrans Houtt.
Mandarin	Citrus reticulata Blanco.
Marjoram, sweet	Majorana hortensis Moench.
Maté	Ilex paraguariensis St. Hil.
Melissa (see balm).	
Menthol	Mentha spp.
Menthyl acetate	Do.
Molasses (extract)	Saccarum officinarum L.
Mustard	Brassica spp.
Naringin	Citrus paradisi Macf.
Neroli, bigarade	Citrus aurantium L.
Nutmeg	Myristica fragrans Houtt.
Onion	Allium cepa L.
Orange, bitter, flowers	Citrus aurantium L.
Orange, bitter, peel	Do.
Orange leaf	Citrus sinensis (L.) Osbeck.
Orange, sweet	Do.
Orange, sweet, flowers	Do.
Orange, sweet, peel	Do.
Origanum	Origanum spp.
Palmarosa	Cymbopogon martini Stapf.
Paprika	Capsicum annuum L.
Parsley	Petroselinum crispum (Mill.) Mansf.
Pepper, black	Piper nigrum L.
Pepper, white	Do.
Peppermint	Mentha piperita L.
Peruvian balsam	Myroxylon pereirae Klotzsch.
Petitgrain	Citrus aurantium L.
Petitgrain lemon	Citrus limon (L.) Burm. f.
Petitgrain mandarin or tangerine	Citrus reticulata Blanco.
Pimenta	Pimenta officinalis Lindl.

Table 7.3. Essential Oils (Adapted from 21 CFR Part 182.20, n.d.).

Common name	Botanical name of plant source
Pimenta leaf	Pimenta officinalis Lindl.
Pipsissewa leaves	Chimaphila umbellata Nutt.
Pomegranate	Punica granatum L.
Prickly ash bark	Xanthoxylum (or Zanthoxylum) Americanum Mill. or Xanthoxylum clava-herculis L.
Rose absolute	Rosa alba L., Rosa centifolia L., Rosa damascena Mill., Rosa gallica L., and vars. of these spp.
Rose (otto of roses, attar of roses)	Do.
Rose buds	Do.
Rose flowers	Do.
Rose fruit (hips)	Do.
Rose geranium	Pelargonium graveolens L'Her.
Rose leaves	Rosa spp.
Rosemary	Rosmarinus officinalis L.
Saffron	Crocus sativus L.
Sage	Salvia officinalis L.
Sage, Greek	Salvia triloba L.
Sage, Spanish	Salvia lavandulaefolia Vahl.
St. John's bread	Ceratonia siliqua L.
Savory, summer	Satureia hortensis L.
Savory, winter	Satureia montana L.
Schinus molle	Schinus molle L.
Sloe berries (blackthorn berries)	Prunus spinosa L.
Spearmint	Mentha spicata L.
Spike lavender	Lavandula latifolia Vill.
Tamarind	Tamarindus indica L.
Tangerine	Citrus reticulata Blanco.
Tarragon	Artemisia dracunculus L.
Tea	Thea sinensis L.
Thyme	Thymus vulgaris L. and Thymus zygis var. gracilis Boiss.
Thyme, white	Do.
Thyme, wild or creeping	Thymus serpyllum L.
Triticum (see dog grass).	
Tuberose	Polianthes tuberosa L.
Turmeric	Curcuma longa L.
Vanilla	Vanilla planifolia Andr. or Vanilla tahitensis J. W. Moore.
Violet flowers	Viola odorata L.
Violet leaves	Do.
Violet leaves absolute	Do.
Wild cherry bark	Prunus serotina Ehrh.
Ylang-ylang	Cananga odorata Hook. f. and Thoms.
Zedoary bark	Curcuma zedoaria Rosc.

Table 8.1. Natural Extracts (Adapted from 21 CFR Part 182.40, n.d.).

Common name	Botanical name of plant source
Apricot kernel (persic oil)	Prunus armeniaca L.
Peach kernel (persic oil)	Prunus persica Sieb. et Zucc.
Peanut stearine	Arachis hypogaea L.
Persic oil (see apricot kernel and peach kernel).	
Quince seed	Cydonia oblonga Miller.

Table 8.2. Natural Extracts (Adapted from 21 CFR Part 182.40, n.d.).

Common name	Derivation
Ambergris	Physeter macrocephalus L.
Castoreum	Castor fiber L. and C. canadensis Kuhl.
Civet (zibeth, zibet, zibetum)	Civet cats, Viverra civetta Schreber and Viverra zibetha Schreber.
Cognac oil, white and green	Ethyl oenanthate, so-called.
Musk (Tonquin musk)	Musk deer, Moschus moschiferus L.

Table 9.1 Other Spices and Seasoningss (Adapted from 21 CFR Part 182.50, n.d.).

Common name	Scientific name	Limitations
Costus root	*Saussurea lappa* Clarke.	
Cubeb	*Piper cubeba* L. f.	
Currant, black, buds and leaves	*Ribes nigrum* L.	
Damiana leaves	*Turnera diffusa* Willd.	
Davana	*Artemisia pallens* Wall.	
Dill, Indian	*Anethum sowa* Roxb. (*Peucedanum graveolens* Benth et Hook., *Anethum graveolens* L.).	
Dittany (fraxinella) roots	*Dictamnus albus* L	Do.
Dittany of Crete	*Origanum dictamnus* L.	
Dragon's blood (dracorubin)	*Daemonorops* spp.	
Elder tree leaves	*Sambucus nigra* L	In alcoholic beverages only; not to exceed 25 p.p.m. prussic acid in the flavor
Elecampane rhizome and roots	*Inula helenium* L	In alcoholic beverages only
Elemi	*Canarium commune* L. or *C. luzonicum* Miq.	
Erigeron	*Erigeron canadensis* L.	
Eucalyptus globulus leaves	*Eucalyptus globulus* Labill.	
Fir ("pine") needles and twigs	*Abies sibirica* Ledeb., *A. alba* Mill., *A. sachalinesis* Masters or *A. mayriana* Miyabe et Kudo.	
Fir, balsam, needles and twigs	*Abies balsamea* (L.) Mill.	
Galanga, greater	*Alpinia galanga* Willd	Do.
Galbanum	*Ferula galbaniflua* Boiss. et Buhse and other *Ferula* spp.	
Gambir (catechu, pale)	*Uncaria gambir* Roxb.	
Genet flowers	*Spartium junceum* L.	
Gentian rhizome and roots	*Gentiana lutea* L.	
Gentian, stemless	*Gentiana acaulis* L	Do.
Germander, chamaedrys	*Teucrium chamaedrys* L	Do.
Germander, golden	*Teucrium polium* L	Do.
Guaiac	*Guaiacum officinale* L., *G. santum* L., *Bulnesia sarmienti* Lor.	
Guarana	*Paullinia cupana* HBK.	
Haw, black, bark	*Viburnum prunifolium* L.	
Hemlock needles and twigs	*Tsuga canadensis* (L.) Carr. or *T. heterophylla* (Raf.) Sarg.	
Hyacinth flowers	*Hyacinthus orientalis* L.	
Iceland moss	*Cetraria islandica* Ach	Do.
Imperatoria	*Peucedanum ostruthium* (L.). Koch (*Imperatoria ostruthium* L.).	
Iva	*Achillea moschata* Jacq	Do.
Labdanum	*Cistus* spp.	
Lemon-verbena	*Lippia citriodora* HBK	Do.
Linaloe wood	*Bursera delpechiana* Poiss. and other *Bursera* spp.	
Linden leaves	*Tilia* spp	Do.
Lovage	*Levisticum officinale* Koch.	
Lungmoss (lungwort)	*Sticta pulmonacea* Ach.	
Maidenhair fern	*Adiantum capillus-veneris* L	Do.
Maple, mountain	*Acer spicatum* Lam.	
Mimosa (black wattle) flowers	*Acacia decurrens* Willd. var. *dealbata*.	
Mullein flowers	*Verbascum phlomoides* L. or *V. thapsiforme* Schrad	Do.
Myrrh	*Commiphora molmol* Engl., *C. abyssinica* (Berg) Engl., or other *Commiphora* spp.	
Myrtle leaves	*Myrtus communis* L	Do.
Oak, English, wood	*Quercus robur* L	Do.
Oak, white, chips	*Quercus alba* L.	
Oak moss	*Evernia prunastri* (L.) Ach., *E. furfuracea* (L.) Mann, and other lichens.	Finished food thujone free [1]
Olibanum	*Boswellia carteri* Birdw. and other *Boswellia* spp.	
Opopanax (bisabolmyrrh)	*Opopanax chironium* Koch (true opopanax) or *Commiphora erythraea* Engl. var. *Liabrescens*.	
Orris root	*Iris germanica* L. (including its variety *florentina* Dykes) and *I. pallida* Lam.	
Pansy	*Viola tricolor* L	In alcoholic beverages only
Passion flower	*Passiflora incarnata* L.	
Patchouly	*Pogostemon cablin* Benth. and *P. heyneanus* Benth.	
Peach leaves	*Prunus persica* (L.) Batsch	In alcoholic beverages only; not to exceed 25 p.p.m. prussic acid in the flavor
Pennyroyal, American	*Hedeoma pulegioides* (L.) Pers.	
Pennyroyal, European	*Mentha pulegium* L.	

Table 10.1 Natural flavoring substances (Adapted from 21 CFR Part S172.510, n.d.).

Common name	Scientific name	Limitations
Pine, dwarf, needles and twigs	*Pinus mugo* Turra var. *pumilio* (Haenke) Zenari.	
Pine, Scotch, needles and twigs	*Pinus sylvestris* L.	
Pine, white, bark	*Pinus strobus* L	In alcoholic beverages only
Pine, white oil	*Pinus palustris* Mill., and other *Pinus* spp.	
Poplar buds	*Populus balsamifera* L. (*P. tacamahacca* Mill.), *P. candicans* Ait., or *P. nigra* L.	Do.
Quassia	*Picrasma excelsa* (Sw.) Planch, or *Quassia amara* L.	
Quebracho bark	*Aspidosperma quebracho-blanco* Schlecht, or (*Quebrachia lorentzii* (Griseb)).	*Schinopsis lorentzii* (Griseb.) Engl.
Quillaia (soapbark)	*Quillaja saponaria* Mol.	
Red saunders (red sandalwood)	*Pterocarpus san alinus* L	In alcoholic beverages only
Rhatany root	*Krameria triandra* Ruiz et Pav. or *K. argentea* Mart.	
Rhubarb, garden root	*Rheum rhaponticum* L	Do.
Rhubarb root	*Rheum officinale* Baill., *R. palmatum* L., or other spp. (excepting *R. rhaponticum* L.) or hybrids of *Rheum* grown in China.	
Roselle	*Hibiscus sabdariffa* L	Do.
Rosin (colophony)	*Pinus palustris* Mill., and other *Pinus* spp	Do.
St. Johnswort leaves, flowers, and caulis	*Hypericum perforatum* L	Hypericin-free alcohol distillate form only; in alcoholic beverages only
Sandalwood, white (yellow, or East Indian)	*Santalum album* L.	
Sandarac	*Tetraclinis articulata* (Vahl.), Mast	In alcoholic beverages only
Sarsaparilla	*Smilax aristolochiaefolia* Mill., (Mexican sarsaparilla), *S. regelii* Killip et Morton (Honduras sarsaparilla), *S. febrifuga* Kunth (Ecuadorean sarsaparilla), or undetermined *Smilax* spp. (Ecuadorean or Central American sarsaparilla).	
Sassafras leaves	*Sassafras albidum* (Nutt.) Nees	Safrole free
Senna, Alexandria	*Cassia acutifolia* Delile.	
Serpentaria (Virginia snakeroot)	*Aristolochia serpentaria* L	In alcoholic beverages only
Simaruba bark	*Simaruba amara* Aubl	Do.
Snakeroot, Canadian (wild ginger)	*Asarum canadense* L.	
Spruce needles and twigs	*Picea glauca* (Moench) Voss or *P. mariana* (Mill.) BSP.	
Storax (styrax)	*Liquidambar orientalis* Mill. or *L. styraciflua* L.	
Tagetes (marigold)	*Tagetes patula* L., *T. erecta* L., or *T. minuta* L. (*T. glandulifera* Schrank).	As oil only
Tansy	*Tanacetum vulgare* L	In alcoholic beverages only; finished alcoholic beverage thujone free [1]
Thistle, blessed (holy thistle)	*Cnicus benedictus* L	In alcoholic beverages only
Thymus capitatus (Spanish "origanum")	*Thymus capitatus* Hoffmg. et Link.	
Tolu	*Myroxylon balsamum* (L.) Harms.	
Turpentine	*Pinus palustris* Mill. and other *Pinus* spp. which yield terpene oils exclusively.	
Valerian rhizome and roots	*Valeriana officinalis* L.	
Veronica	*Veronica officinalis* L	Do.
Vervain, European	*Verbena officinalis* L	Do.
Vetiver	*Vetiveria zizanioides* Stapf	Do.
Violet, Swiss	*Viola calcarata* L.	
Walnut husks (hulls), leaves, and green nuts	*Juglans nigra* L. or *J. regia* L.	
Woodruff, sweet	*Asperula odorata* L	In alcoholic beverages only
Yarrow	*Achillea millefolium* L	In beverages only; finished beverage thujone free [1]
Yerba santa	*Eriodictyon californicum* (Hook, et Arn.) Torr.	
Yucca, Joshua-tree	*Yucca brevifolia* Engelm.	
Yucca, Mohave	*Yucca schidigera* Roezl ex Ortgies (*Y. mohavensis* Sarg.).	

Table 10.2 Natural flavoring substances (Adapted from 21 CFR Part S172.510, n.d.).

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