Sensing Blue
The Role of Flavor Perception in Modern Blueberry Breeding

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Abstract

Food consumption - A daily necessity and primal, sensory experience. Our sensory systems have evolved greatly over time, allowing us to perceive flavor more effectively than any other organism or machine. Using sensory data from berry cultivation specialists, we will explore the sensory experience of blueberry consumption in an effort to quantify the qualitative components of the process and find patterns in flavor and quality. The goal of this research and blueberry flavor visualization is to create an analytical and comprehensive flavor data tool that will offer new insights in blueberry sensory analysis, giving consumers a richer perspective of flavor potential in blueberries and, hence, all foods. This project is designed not only for agricultural specialists but audience members of all types. The project will inform the audience of human sensory capabilities, meticulous blueberry breeding processes, and showcase the potential of objective, visual techniques leveraged to communicate what was previously thought to be nearly impossible: subjectivity. Furthermore, this project is meant to promote conscious nourishment through the momentary beauty of food consumption, and remind us to cherish the small moments during our busy, fast-paced lives.

Introduction

Food consumption - A daily necessity and primal, sensory experience. Speaking of the latter, can you remember the last time you were excited by a meal or a single bite of food? It stays with you, and can lead you to ponder, “how is my body trained to experience this”? I want us to think more about this concept by using sensory data from an agriculture business specialized in growing berries.

Blueberries have existed as a tasty, high-antioxidant snack for centuries. The advent of modern agriculture practice and transportation systems has allowed blueberries to become highly popular and accessible - now a true staple of health-food trends and a consistent member in the produce section at consumer markets worldwide. While most of us have experienced blueberries on some level, the incredible commitment to and investment in quality during blueberry development often goes overlooked.

Of the many disciplines that surround such development, sensory analysis is the first and one of the most important steps in qualitatively assessing the performance of blueberries, acting as a basis for impactful, future decisions in naturally optimizing for desirable characteristics. Sensory analysts conduct in-person tasting surveys with thoughtfully crafted questions and grading scales regarding taste, texture, and appearance to find the most desired characteristics of the blueberries, especially flavor. The results undergo fervent statistical tests to discover consumer-driven patterns of significance and thus target qualities to be selected and promoted while breeding future blueberry varieties.

The goal of this research and blueberry flavor visualization is to create an analytical and comprehensive flavor data tool that will offer new insights in berry sensory analysis. This project is designed not only for agricultural specialists focused on berry cultivation, but for audience members of any background, as they are introduced to the meticulous measures taken in analyzing blueberry flavor and shown the visual potential that can be leveraged for communication of such subjective data. Furthermore, this project is meant to open our minds to the momentary beauty of food consumption, and remind us to cherish the small moments during our busy, fast-paced lives.

What to Expect

In the first section of this paper, I will offer a background of blueberries, touching on the history, applied agricultural methods, and recent blueberry trends to highlight the context that it holds in our present day lives. Next, I will describe the human sensory system as it relates to the blueberry consumption experience, with the understanding of flavor perception as the overarching theme. Our eyes, mouth, and nose work in unison to leave a lasting impression when eating not only blueberries but all foods, and are of ultimate concern when conducting sensory analysis. In the second part of this paper, I will analyze the approach towards systems of visually representing data derived from sensory tests, first speaking about design, then data transformation and technical implementation.

Chapter 1:
History of Berries

Before we analyze the sensory system in the context of blueberry flavor perception, let's take a moment to understand the history surrounding berries, its appearance in health trends, and agricultural advancements up to this point. Berries have existed as a nutritious fruit for humans and animals since the beginning of our existence, and were first recorded by ancient Romans as possessing effective medicinal properties (11). Berries were not cultivated during those times but were growing naturally, offering a convenient and tasty snack for foraging communities before agricultural techniques were invented. The French and other Europeans were some of the first to define a system of cultivating the fruit, at first by planting them in their gardens in the fourteenth century, and in the sixteenth century, planting them in field rows (7). Serious berry cultivation accelerated particularly in California’s central valley around the late nineteenth century as strawberries were gaining popularity in the US. The strawberry was truly the pilot berry for present-day berry cultivation methods and theories, with advanced variety testing and growing experimentation to create a fruit that not only looked and tasted great, but could also be resilient in the face of fluctuating microclimates and pest infestations (8).

Chapter 2:
Berries in Agriculture
2.1 Berry Growing Advancements

Berry growing industries have now popularized not only the strawberry but the blueberry, raspberry, and blackberry as well, expanding the flavor possibilities coming from a single vein of agricultural focus. Progression in modern agriculture as a result of increased demand for highly flavorful and nutritious produce has created an incredibly vast consumer market for berries. Agriculture's adaptation to this demand did not happen overnight, but took centuries of research, trial and error, and luck. One of the most important aspects of this development was the accelerative process of selective breeding to create the most hardy and desirable berry strains. Selective breeding is a process of mating two plant varieties with different types of favorable traits to produce a new, hybrid variety that possesses these traits.(5) For example, one blueberry variety has amazing flavor and texture but is too small, while another blueberry variety has a desirable size and strong resistance to pests, but average flavor qualities. The male flower from one blueberry bush would be used to pollinate the female flower of the other blueberry bush, creating a new variety that is a combination of the two. Multiple seedlings of the new variety will be produced and each will have varying levels of the desired characteristics. All seedlings will be propagated, and when these new plants fruit, breeders can analyze which of the new varieties is producing the targeted, favorable qualities of the parent varieties, and promote the growth of that exact plant within the new variety. One can imagine that when this process is repeated over hundreds of years, a highly desirable berry has evolved.(5)

2.2 GMO vs. Selective Breeding

Selective breeding, seen as a modern agricultural practice, is often bundled into the negative light that GMOs generate. Selective breeding produces fruit of incredible quality, so impressive that some assume it is a GMO, but they are clearly separate methods, as a GMO is defined as having physically, human-altered genetic structures, while selective breeding does not. Surrounding all growing methods, especially any deviation from a hands-off, natural method, there exists debates about what is most effective and, generally, what methods are acceptable on a moral level. In the past decade, we have come to know the term GMO, mostly as it relates to agricultural practice. From one perspective, GMO methods can be seen as an immoral, invasive, biotechnical breeding approach that alters genes in a plant to produce varieties with the most favorable traits possible. This usually occurs in efforts to maximize profitability as much as possible, often to the detriment of the environment. From another perspective, GMOs have saved the earth from hunger as more plants are able to produce higher, more nutritious yields and withstand environments otherwise unsuitable for growing. There are many differing views of the pros and cons. When focusing on the negative, the most understood, direct downside of GMOs so far is its direct and indirect impact on the environment due to higher herbicide use.

When super-scale agricultural conglomerates sell their GMO plant seeds to contract farmers, they sell their branded herbicide along with it. The crops are genetically resistant to the herbicide, so when the contract farmers douse their fields in herbicide, the crops are not hindered and the farmers increase profitability. However, the herbicide contains toxic chemicals that react with the environment in multiple ways, especially when the herbicide is over-sprayed, as prescribed. The chemicals seep into the topsoil and eventually local waterways and groundwater. This negatively impacts the ecosystem health and water quality, which can then place an imbalance on larger-scale water systems and ecosystems. Secondly, the herbicide creates a super weed that becomes resistant to the original herbicide and grows rampant in the fields. If the super weed is able to reach neighboring farms that do not grow GMOs or use herbicide, that farmer's crop becomes constricted by superweeds and will perish. These are some of the existing, extreme cases of GMOs negative effects, but of course, there are many positive aspects to GMOs. Regardless of the effects, it must be noted that selective breeding is separate from GMOs in that there is no physical manipulation of genetics, just a calculated pairing of different varieties and a highly selective process of promoting individuals within a new variety.

Chapter 3
Berries in Health Trends

Of all the berry types available today, blueberries have surged to the top as the most popular in food trends (3). The blueberry's increase in popularity occurred in the early 1990s after food science researchers found that high levels of free radicals in the human body often result in cancer and other diseases. Our bodies naturally produce free radicals during exercise and when we turn food into energy, but levels can reach higher amounts when exposed to sunlight, cigarette smoke, or air pollution, for example. The solution is antioxidants, which is not just a single entity but can be either solitary or combined vitamins or organic molecules that offer electrons to the free radicals that ravage the healthy electrons of our body. Although our bodies create their own antioxidants to battle the free radicals, sometimes there are too many to be neutralized on our own. Thus, after this research in the 90s, foods with antioxidants were recommended to counter the free radicals in our body, and blueberries ranked as some of the highest in containing antioxidant properties (2).

Before the popularization of antioxidant foods, blueberries were “something you put in a pie”(3) or a “side act for salads”(3). After the antioxidant craze, blueberry growers, with the help of food science studies and nutritional food marketing, found themselves with another angle to support their product and saw an immediate increase in demand. As blueberries shifted to the limelight of late twentieth century health foods, there were other large scale trends in health that were just beginning, which propelled and cemented the blueberry as a permanent feature of health foods. After the antioxidant craze, the “superfood” term was coined, and blueberries were automatically joined to the superfood group with their previous attention as an antioxidant. Today, one can find blueberries in everything from breakfast bowls to fruit smoothies, marketed with some form of a healthy connotation. However, blueberries are not just special for their health benefits, but their flavor quality. Many measures have been taken to produce blueberries of the greatest flavor possible, so let us analyze how we experience such flavor.

Chapter 4
Sensory Analysis
4.1 Sensory Introduction

To understand the perfect balance of texture, taste and appearance in a blueberry, we must first understand the human sensory systems and how it allows us to perceive flavor. Our sensory system is made up of tools used to generate “an internal representation of the outside world.”(4) We are able to interpret chemical and physical qualities of our environment, translate and transport messages to our brain through the central nervous system, and, finally, create an emotional and physical reaction to the information perceived. In the early evolutionary stages of humans, this reaction was used for our survival, as we were able to determine instinctually and from gathered experience whether something was good or bad, dangerous or safe. Those primitive methods of sensory survival have advanced not only to be interpretable as those simple, binary reactions, but have become fine-tuned as our individual, human preferences in any type of experience. And this is the beauty of the human. No one is exactly the same or reacts the same to a certain experience. As it relates to flavor perception and gastronomical satisfaction, the modern human sensory system creates a marvelous complexity of subjectiveness and individuality that I will analyze below through the senses in our eyes, mouth, and nose.

4.2 Eyes and Expectation

Using vision to understand our food is one of the first interactions we have in the process of food consumption. In these situations, we judge if we want to consume a food or not, and sometimes we even ponder how good the food will taste based on its appearance. We are setting positive or negative expectations as we take a momentary but highly crucial and instinctual glance at the food prior to eating. Our pupils, irises, retinas and brain are an incredible system that can analyze very minute details in the texture and color of our environment, especially when we hold up food items close to our eyes. We possess information and experiences in our brains that relate our visual perception to what we have seen in the past and what we have learned as comparatively regular or irregular in appearance. For example, if we see a green banana, we know from experience or learned knowledge that eating green bananas is not a pleasurable experience, and that we should wait until the banana is yellow and ripe before consumption. And even more subtle than the ripe or unripe dilemma, seeing a food color in general that is appealing and reminiscent of other experiences will also affect your flavor perception of the food, triggering the emotions associated with those experiences.

4.3 Taste Perception and Transduction

The sense of taste in our mouths is another important aspect of flavor perception, as it transforms products of the external world to digestible matter. During this transition point from external to internal, we use the tongue in our mouths to sense the taste and touch (mouth feel) of potentially ingestible food for our bodies. As food spreads across our tongue, receptors pass messages to the brain, giving us an understanding of whether the food is safe to eat and, furthermore, what the food is generally composed of. The tongue is able to sense five distinct tastes: sweet, sour, salt, bitter, and umami. "Sweet taste permits the identification of energy-rich nutrients, umami allows the recognition of amino acids, salt taste ensures the proper dietary electrolyte balance, and sour and bitter warn against the intake of potentially noxious and/or poisonous chemicals."(4) These tastes are all sensed and transduced to the brain by taste receptor cells (TRCs) that are located in various papillae along the tongue's surface. Contrary to common belief, the tongue "taste map" is not a true anatomical phenomenon. In reality, each TRC is able to sense any of the tastes no matter its physical location on the tongue. Collectively, the TRCs start to build a perception of flavor during a consumption experience.

Once a human has decided whether or not to continue consuming a piece of food past the tasting stage, the deeper sensory experience begins as other senses are incorporated. Now the tongue, using touch from the somatosensory system, is able to sense the more nuanced, physical qualities of the food being consumed. The somatosensory system can be found throughout one's body in our muscles, joints, and skin and allows sensations like pressure, pain, and temperature, giving us a general understanding of touch. This sense is especially acute on our tongue, where we can translate texture sensations like warm and velvety, or dry and crunchy.(10) With a combination of mouth feel and the initial taste sense, one can start to build layers of flavor and realize the experience that is occuring in the mouth.

4.4 Orthonasal, Retronasal, and Olfaction

One can conclude that almost all of the focus is in our mouths at this point in the consumption experience. It is true, because as humans, we are inherently experiencing an intense moment when deciding whether or not something is safe to eat, or we are so hungry that we are completely overwhelmed by the joy of consumption. However, our mouths actually distract us from what creates the majority of flavor perception - our sense of smell. The nose is a sensory organ that has also adapted in different ways from our early existence as humans. At one point in history, we were on all four legs, close to the ground, and having to use our orthonasal, "sniffing" sense to detect our environment. This sense continues today in other mammals like dogs and bears that have incredible orthonasal sensory capabilities. As humans moved from four legs to two legs, we relieved the need to have an acute sense of orthonasal smell, and our eyes adapted to be the primary source of environmental awareness and synthesis (9). When this evolution and adaptation was occuring, our keen sense of smell transitioned from orthonasal smell to retronasal smell, which originates from our mouths through the back-end of our nasal cavity. The sense of retronasal smell is a defining characteristic of the modern human.

When a piece of edible matter enters the mouth, the retronasal sense engages almost immediately. As one chews food and breathes, small whiffs of the food are transported from the back of the mouth up to the retronasal passage as a primer. When the food is swallowed, a natural exhale allows a more intense experience of the food's odor retronasally, where hundreds of volatile compounds can be translated and visualized. This moment in consumption is when one experiencing food will have the most wholesome understanding of the food's flavor.(9) And a major component of this sensation is not just the retronasal travel of volatile compounds, but the reception of this information at the olfactory epithelium. Olfaction is the sensory organ that connects our sense of smell and flavor to the brain and, since our retronasal passageways are adapted to maximize smell in this direction, we have an amazing ability to sense flavor as such.

In this way, the combination of the eyes, mouth, and nose are essential in a comprehensive flavor experience, and quite remarkable in complexity. These combined factors are the foundation for sensory analysis of blueberry flavor, which will be described below.

Chapter 5
Survey Methods
5.1 Berry Surveys and Implementation of Findings

Even if an agriculture company has far-reaching financial capabilities and cutting edge technology for product development, it doesn't mean much if the consumer does not have any input in terms of the flavor quality. Therefore, it is essential to conduct consumer surveys often and with new and varying products to understand which are desired most and why. This drives intense and extensive research at the intersection of psychology and sensory analysis, in order to think of the best questions to ask, how to phrase them, what sort of scale to use, and so forth. As these proprietary tests evolve, their outcomes hone direct, nearly unbiased input from consumers that can be statistically analyzed to highlight patterns of significance. Such flavor patterns are then interpreted to be results of various volatile compounds that would potentially create that exact flavor in a fruit. However, the extent of the research and flavor promotion in blueberries doesn't stop there.

Blueberry varieties, either recent or one that has spanned generations, are genetically screened for the existence of genes that match the described flavor qualities. The varieties that possess the highest quantities or perfect balance between multiple volatile compounds are selected from the hundreds of other varieties that do not have the same concentration. Once chosen by the geneticist and confirmed with the sensory analysts, the few varietal individuals are activated by the breeding group and therefore commit the plants to the years of growth before the first fruit arrives for testing. This step in the process allows blueberry growers to restrain from using resources and extra time to manage varieties that will end up not having the desired characteristics, and focus efforts on those that do.

As the new blueberry varieties establish their roots and vegetative structures over the season, their fruit is harvested and again tested by the sensory team and other growers to further isolate the desired berry flavor qualities, focusing on varieties they think will be significant to test in a future survey. Once decided, another survey is organized, gathering information and combining with internal tests to communicate the most desired traits from the consumer sample population.

5.2 Berry Survey Methods

XXXX is an internationally recognized berry brand, beginning with strawberry specialization in the California central valley in 1872 and now dominates the berry market of all berry types. Since its conception, XXXX has deeply invested in its research and development department, pushing the standards higher and higher in terms of what can be achieved in growing methods and berry quality. In recent years, XXXX has created an entire department focused on sensory analysis of its berries. This is the team that creates and conducts the in-depth consumer surveys as mentioned previously. The data for this project is derived from a XXXX blueberry survey.

The survey for a XXXX blueberry is extensive, and primarily focuses on flavor and other senses that indirectly affect the overall perception of flavor. Before the survey is conducted, there are many steps taken to organize the breadth of variables involved in this type of statistical study. Firstly, the sample population is selected with the goal of mimicking the real world population of berry consumers. Consumers can sign up to be a survey member on the XXXX website, and other members are selected at random. Ideally, there will be a good mix of neutral berry consumers and excited berry consumers, so there is a feeling of what each is expecting in a berry.

In the blueberry survey of concern, the sample population was about one hundred people, varying in age in gender. As mentioned in the sensory chapter, the participants start out looking at the overall appearance of the blueberry, marking reactions on a particular rating scale. The primary appearance variables are color and size. Following appearance grading is the actual tasting of the berry and the analysis of such. This includes overall taste as well as sweetness, tartness, and even more nuanced flavor levels such as floral or earthy. After the taste comes texture grading like crispness or juiciness, and, finally, a hand-written comment section regarding positive and negative aspects of the blueberry overall.

5.3 Survey Outcomes

The nuanced flavor group ratings are of primary interest and motivation for the technical development of the flavor analysis tool in this study. Flavor descriptions at these levels allow for an amazing opportunity to analyze flavor, and it makes available the ability to understand the beautiful complexity of volatile compounds that we experience through flavor perception in our bodies. As in wine, many existing and defined flavor descriptors are used to describe flavor perception. As berries grow and develop to offer higher and higher levels of flavor quality, berries begin to coincide with wine and other intense flavor experiences in that they are able to be described by an impressive list of adjectives and flavor specifications related to other naturally existing volatile compounds. Blueberries don’t just taste like blueberries - other fruit flavors can be used to describe blueberries as well. Achieving this level of flavor quality is a long term goal of the sensory team, which will be advanced through this project and its thoughtful choices in data visualization design.

Chapter 6
Data Visualization
6.1 Design conceptualization

One of the challenges in the sensory discipline at-large is communicating the results of highly subjective qualitative data in a clear and concise, quantitative manner. Currently, presentation slides and rudimentary graphical techniques have been employed to visualize these surveys. However, such complex data demands visualization methods of higher fidelity and increased efficiency of cognitive synthesis. The approach to design, data, and technical implementation is key in expressing this type of story, and can change drastically depending on the specific goals of visualization. Below, the approach for the specific case of blueberry taste survey data will be discussed.

Before designing ever begins, in-depth concept development must occur. Three weeks were spent deciding on the best way to present this topic, and most of that time was finding the storyline that was the most informative while still being true to one's own intention. Mind maps and studio discussions narrowed the topic to its roots: studying the subjectivity and quantifiability of flavor perception. As this concept progressed further, the addition of sensory data from the blueberry taste test made this concept realizable. With these pieces in place, I was able to start putting ideas in visual format to begin figuring out the best way to tell this story and visualize the data.

The first iteration of the storytelling design process was two sets of wireframes, each showcasing a different approach to the primary topic in order to practice thinking of application in multiple directions. The first of the two wireframes, "Season's Finest" is a focus on the process and cycle of breeding blueberries, giving a context of this process, moving into a bar graph tool for comparing blueberry qualities and, finally, a flavor wheel expressing the complexities of blueberry flavor through interaction and filtering options. The UI/UX for the first wireframe was clean and directed, with scrolling arrows and clear flow throughout. The aesthetics were minimal and muted with thoughtful visual hierarchies, fonts, and colors. Scrollytelling begins the journey through the webpage, ending in the interactive tools at the bottom. The second wireframe of the set, "Sensing Berries" was a more experimental approach to the concept, focusing more on illustrations describing the sensory system, a word cloud of written flavor descriptions, and an interactive spider chart to explore and compare flavor performance. The theme of this wireframe is quite different from the first, expressing more of a laboratory/anatomical feel, which was an exciting direction compared to the first. However, the general flow of the visualization was the same, with context through scrollytelling and then visuals and tools to offer more insights on the subject. This framework and progression is most effective because it informs the user at the outset, and once they are captivated by the information, they can elaborate on what was learned by exploring the interactive tool at the end.

The next step was to narrow the two options into a single visualization progression in order to find the best method in visualizing this dataset. So, with both wireframes in hand, the approaches were presented to the studio class. Much of the interest was in the flavor wheel of "Season's Finest", and the aesthetics, sensory graphics, and word cloud from "Sensing Blue". These components were of highest consideration prior to presenting, so it was great to hear feedback in support of the desired direction. After the components were prioritized, a singular wireframe was assembled and iterated upon until the final visualization, however, a few challenges altered the path of the visualization, and targeted design decisions resulted. The first of these challenges became apparent when actually receiving the data from the blueberry sensory team. There was an expectation to see a great volume of various taste descriptors, while the data only contained 10 taste descriptors and 20 other categories representing color and texture. This made it difficult to execute an engaging flavor wheel since there are usually 50 or more taste categories with multiple levels of subcategories. The dataset simply did not have this granularity. Therefore, an alternative, custom-designed, radial style was implemented to showcase the dataset as effectively as possible.

The specific radial style was an area chart, and it was chosen for multiple reasons. Objectively, radial area charts are useful in visualizing categorical data, so with the many flavor categories involved in the data, this chart style would create an intriguing visual and be useful to see all of these categories at once, especially when giving the user the power of interactivity to highlight categories and explore the detailed graphs. Another reason was that the radial area chart mimicked a splattered blueberry (when designed correctly), which offered an intuitive connection to the topic and fun hint to the user in “breaking down” the flavor profiles of each blueberry. Once the style of the radial chart was decided, the next challenge was the best way to display all of the nine blueberry flavor profiles in a seamless format. A small multiple grid layout was the first choice of implementation, with clicking on one of the charts allowing a larger view for inspection. As the small multiples concept grew closer to realization in the visualization, it became clear that the small multiples would not be able to fit on the screen as desired while keeping the categories legible. At this point a modification had to be executed in order to uphold the integrity of the UX in the visualization. The radial charts were organized in a single line sequence across the screen, without any flavor categories, and then, when clicked, a larger version of the selected radial chart would take up the majority of the screen with the flavor labels added. When hovering over categories (nodes), the remaining varieties (still in small multiple form) would show the ranking for that category as well as a circle along a line to show a visual representation of the value compared to the other varieties within that same flavor category. This became the final version of the main visualization and was the most engaging version of exploring and comparing flavor with small visual aids and number values triggered by hovering interactions and clicking.

Regarding UI and style choices, an anatomical aesthetic was intended for the scrollytelling section for two primary reasons. First, it triggers a reaction that one is learning something that is science-based, which is natural in this case with subjects like the human sensory system and plant genetics. Secondly, the detail and charm of a vintage etching is visually engaging, inviting the user to inspect each marking of the etching graphic, and this inspection is a way of thinking that will be asked of the user again at a later point in the visualization - during flavor tool exploration. With these goals of engagement in mind, the graphic style for the scrollytelling section experienced a high frequency of iterations and much consideration.

The versions of the sensory graphics in the initial wireframes were anatomical illustrations that I found on google images as placeholders until I either created my own or found a similar style. As the implementation process accelerated, it became clear that the only way to create the anatomical drawings seemed to be drawing them by hand, which was not possible in the timeframe of this project. It was disappointing to lose hope in this aesthetic style, but other styles were created and seemed promising. Single contour line drawings and other digital sketches were created in adobe illustrator to show the sensory graphics, but none of them quite matched the feeling that was desired for the work. After hours and days of trying to find the best solution, an idea surfaced that enabled the original concept of anatomical illustrations to re-enter the equation - photographic filters. It became apparent that a wide variety of illustrative filters exist online, and if there was one that provided the correct look, then the problem would be solved. Eventually, there was an etching filter on a particular web application that was able to produce the desired results. Small photoshoots with special lighting, blueberries, and other miscellaneous plants were conducted in an apartment and were eventually translated to the final anatomical feel of the graphics. These graphics are essential to engage the user at the outset, adding to the goal of creating the most effective visualization for the data and story overall.

6.2 Data transformation and structure

In order to tell the intended story from the data, the data had to be transformed into a thoughtful structure for the visualization. The data for this project was received in an excel table format with thirty-five columns and nine rows for each participant of the one hundred person survey, leading to a total of about 28,000 data points from the dataset. The first decision in transformation was to remove any dimensions that were not to be represented explicitly in the data visualization - and that dimension was the one hundred participants. It is not the goal of the data visualization to focus on the opinions of each participant, but to find patterns across all participants, so calculations were made to average the one hundred scores in each category for each blueberry variety. For example, when looking at the Kodiak variety, the unaltered dataset offered one hundred different value scores for performance on expressing a citrus taste. The one hundred scores were averaged so there would only be one value for Kodiak's performance on the citrus taste. Therefore, this reduced the data point total from 28,000 to 280, making the dataset even more manageable. However, there were multiple considerations while performing this seemingly simple averaging technique.

Each of the flavor categories are graded on a different scale. One flavor category might be rated "1-9" while another is "1-5" or "1-7". Also, some categories use a JAR (just-about-right) rating where "1" is not enough and "5" is too much, so the ideal number is really "3". Needless to say, there was enough variety in rating scales where it would not be possible to confidently compare directly between flavor category values without more in depth calculations, which was not within the scope of this project . The decision was to create a unique scale for each category depending on its values, creating more of a ranking system. This would only be comparable with other blueberry varieties within the same flavor category. Using google sheets column formulas, each value was calculated to be a decimal value based on the scale for each column. For instance, if the Kodiak variety scored a 5 out of 7 for sweetness according to participant number 26, then that value would be translated to 5/7= 0.714. (The JAR score was accounted for by turning 5s to 1s and 4s to 2s so that the values were low to high, representing a blueberry's JAR score in a certain category. I sacrificed knowing whether a blueberry was too much or too little of a certain category for JAR). After this, a score for each flavor category was averaged across all of the participants, creating the previously stated goal of single values for each variety in each flavor category, and thereby offering a natural ranking between varieties for each category. This was then exported as a .csv, translated to json, and saved in my codebase as a local file for object-oriented queries. Its small file size and computationally low impact data structure made it so a separate database was not necessary. Considering all of these data manipulation decisions, each is in an effort to support the overall data visualization concept and effective synthesis of data.

6.3 Technical Implementation

A particular implementation approach was used to continue the path to an effective, custom data visualization that honors the data at hand. The project was split into four separate components, scrollytelling phase 1, scrollytelling phase 2, interactive bar chart, and interactive radial graphs in small multiple. All of this implementation starts with the framework of vue and nuxt that provides the structure to organize each of these into standalone components that communicate with a singular central page that fluidly displays all components, images and text through DOM manipulation. Both scrollytelling phases were instituted using a scrollama package and changing various configuration parameters in nuxt. After successful installation, the sensory graphics and text descriptions for each of the three stages in the scrollama were added manually to the scrollytelling series by linking to asset folders containing the imported .png files. This was then repeated for the breeding methods scrolly but was saved as a separate component to allow for other elements to exist between the two on the main page.

Following the scrollytelling and required context for the visualization, a bar chart was implemented as a simple comparison tool and method of familiarizing the user with the blueberry variety names and breadth of flavor category options. The visualization was attributed from a bl.ocks bar chart with an accompanying dropdown selection menu. The executions of the code were studied and modified to represent the blueberry varieties along the x-axis, ranking value along the y-axis, and flavor category in the dropdown menu. One of the major visual alterations to the chart was converting the bars to circles on a line (similar to the circle and line visual on the small multiple radial charts). The blue circles were eventually replaced with .png assets of the nine individual blueberry anatomical drawings. This graph is simple but a nice introduction to the concept and allows the users to interact and see blueberries “change” in preparation for the following, more complex visualization.

The radial chart with small multiples was by far the most intense implementation. The basis of this design was attributed from a radar chart by Nadie Bremmer on bl.ocks. It was very well documented and provided utmost customization. The data was fed into the visualization and, after some parameter alterations, the data abstractions (berry splats) became a visual entity. The only issue is that they were all layered on a single radial coordinate system while the goal was to break up the area charts to have their own displays in small multiple form. With some help from my classmate Neil, we were able to break up the single chart into multiple charts by drawing a new display for each blueberry variety while iterating over the dataset. After this major step was complete, a series of interactions were created with both clicking and hover functionalities. On clicking an area abstraction, the selected area increased to a particular size, showed circular nodes at each intersection with the chart categories, and became filled with an opaque blue. On hover over a node, the ranking for that flavor category is displayed while that flavor category is also highlighted, and rankings for the other small multiples across the top also display along with circle-on-line visual cue. All of this is reset when the enlarged area is clicked on again. These commands are all controlled by a long list of d3 on click actions, and an if statement that gives an id to what is turned on, and if it is clicked again, it has an id of “off” and resets to the original state. The hover events are controlled by a separate long list of commands with d3 mouseover. These purposeful interactivity choices further promote the ease of learning and exploration throughout the main data visualization tool.

Conclusion

The blueberry has a rich cultural and agricultural history that makes it poised to be a worthy subject for analysis. When reaching further to find what comprises a blueberry (physically and theoretically), there exists a vast array of topics, and, among them, flavor is of particular interest with its qualitative and subjective nature. Understanding blueberry flavor requires breaking down the subjectivity into an objective format, which was provided by the dataset and the work that went into measuring human sensory system reactions to different varieties of blueberries. Following quantification, a detailed visual and technical approach was executed to communicate the data as effectively as possible with the methods described in this paper. From this visualization, Blueberry growers and general audience members can understand the systems and specifics that are involved in blueberry flavor. From one perspective, a user with agricultural experience would be able to better analyze flavor and make decisions in breeding, and from another, a user will learn about what goes into blueberry development and at least garner an appreciation for the next blueberry consumption experience.

References

1. Abasolo, Carolina. “History of Antioxidants in Food.” BTSA. Carolina Abasolo https://www.btsa.com/wp-content/uploads/2016/11/logo-blanco.png, January 25, 2019. https://www.btsa.com/en/history-antioxidants-food/.

2. “Antioxidants.” The Nutrition Source, November 14, 2019. https://www.hsph.harvard.edu/nutritionsource/antioxidants/.

3. Bierend, Doug. “How Blueberries Became a Superfood.” Outside Online. Outside Magazine, April 23, 2019. https://www.outsideonline.com/2391754/blueberries-superfood-benefits.

4. Chandrashekar, Jayaram, Mark A. Hoon, Nicholas J. P. Ryba, and Charles S. Zuker. “The Receptors and Cells for Mammalian Taste.” Nature News. Nature Publishing Group, November 15, 2006. https://www.nature.com/articles/nature05401.

5. “Driscoll's Joy Maker's.” Driscoll's. Accessed March 18, 2020. https://www.driscolls.com/about/joy-makers.

6. “GMO Foods: What You Need to Know - Consumer Reports.” GMO Foods: What You Need to Know - Consumer Reports. Accessed March 18, 2020. https://www.consumerreports.org/cro/magazine/2015/02/gmo-foods-what-you-need-to-know/index.htm.

7. Kiple, Kenneth F. *The Cambridge World History of Food*. Cambridge: Cambridge Univ. Press, 2001.

8. “Our Heritage.” Driscoll's. Accessed March 18, 2020. https://www.driscolls.com/about/heritage.

9. Shepherd, Gordon M. *Neurogastronomy: How the Brain Creates Flavor and Why It Matters*. New York: Columbia University Press, 2013.

10. Spence, Charles. “Multisensory Flavor Perception.” *Multisensory Perception*, 2020, 221–37. https://doi.org/10.1016/b978-0-12-812492-5.00010-3.

11. Staub, Jack E. *75 Remarkable Fruits for Your Garden*. Layton, UT: Gibbs Smith, 2008.