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BROTH: ENHANCING MARKET OPPORTUNITIES AND

IMPROVING SUSTAINABILITY OF

MAINE FARMED SEAWEED

By

Zachary Bonelli

B.S. Johnson & Wales University, 2016

A THESIS

Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science (in Food Science and Human Nutrition)

> The Graduate School The University of Maine August 2018

Advisory Committee:

Mary Ellen Camire, Professor of Food Science and Human Nutrition, Advisor Denise Skonberg, Associate Professor of Food Science Anne Langston Bowden, Owner of Pemetic Sea Farms

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BROTH: ENHANCING MARKET OPPORTUNITIES AND IMPROVING SUSTAINABILITY OF MAINE FARMED SEAWEED

By Zachary Bonelli

Thesis Advisor: Mary Ellen Camire

An Abstract of the Thesis Presented In Partial Fulfillment of the Requirements of the Degree of Master of Science (in Food Science and Human Nutrition) August 2018

Seaweed is becoming popular across the world as consumers learn about the variety of seaweed-based products and their health benefits. Sugar kelp is one of Maine's seaweed varieties that is locally grown each year. Sugar kelp and similar species contain many useful nutrients including iodine, calcium, magnesium, iron, and vitamins A, B, C, and E. Even though the health benefits of seaweed have been proven, locally-sourced seaweed has not yet become any more popular in Maine. Part one of this study identified suitable processing steps for a sugar kelp-based broth. Part two assessed how consumers' demographics and food neophobia, as well as products' characteristics, impacted broth acceptability.

Broths were produced from fresh and frozen kelp, and several methods for flavor extraction were evaluated. An incomplete factorial design was selected for chemical and physical analyses. Fresh and frozen kelp were treated by boiling for 15 minutes or steamed for 30 minutes. The resulting broths were strained to produce clear broths. Sugar kelp was harvested on three dates in 2018 (April 20th, May 29th, and June 7th) to help understand how harvesting dates may impact broth attributes. A commercial reduced-sodium vegetable broth served as a control sample and had had the highest sodium, glutamic acid content, total solids, and viscosity. The control vegetable broth had the lowest pH and L* value for color. The broth made using fresh sugar kelp had the highest L* value. For all other chemical and physical assays, no significant differences were found between the sugar kelp broths.

Fifty-six consumers evaluated three sugar kelp broths (frozen kelp boiled for 15 minutes, frozen kelp steamed for 30 minutes, and fresh kelp steamed for 30 minutes) and the vegetable broth control. The vegetable broth control scored significantly higher than all the experimental sugar kelp broths ($p \le 0.05$) for aroma, flavor, and overall acceptability on a nine-point hedonic scale. The vegetable broth scores were approximately 7.0 (like moderately), while the experimental sugar kelp broths scored between 4 (dislike slightly), and 5 (neither like nor dislike) on the hedonic scale. All broths were liked similarly for appearance and thickness. Almost 60% of panelists were female, and all but one person had previously eaten seaweed. The most frequently-sought food label information were ingredients, nutrition facts, and geographic source of the food. The Food Neophobia Scale scores for the panel ranged from 10 to 52. The scores were then sectioned into tertiles (low, medium, and high), but no significant associations were found between Food Neophobia scores and hedonic ratings for the

broths. The low acceptability of the broths and the panelists' prior experience eating seaweed might have limited effects of the test participants' food neophobia.

Future work should focus on developing greater flavor and testing soups with other ingredients, since consumers do not usually consume broth alone. Shelf-life of broths should also be evaluated. Also, more information about the health benefits of seaweed and the economic impact of Maine farmed seaweed may help increase consumer interest in these healthful foods.

DEDICATION

This manuscript is dedicated to my supportive parents, John and Karen Bonelli,

who are always encouraging me to further myself and be the best that I can be.

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CHAPTER ONE

INTRODUCTION

Seaweed is consumed by many people around the world in a variety of forms from sushi to ice cream. Seaweed has also been able to receive high market values with the seaweed product value of the global seaweed industry reaching 10 billion dollars in 2012 (Gardener & Marriott, 2015). Seaweed's popularity has also been growing over the past few years as more consumers are finding out about the variety that seaweed products have to offer. Also, with more attention falling on fresh, locally sourced, and sustainable foods, seaweed has the chance to be a popular item, especially in the northeastern United States. Additionally, there is a need for more sources of nutrientrich and sustainable foods as the world population continues to grow with an expected almost 10 billion people by the year 2050 (United Nations, 2017). Some are calling the oceans, seas, rivers, and lakes the last unused frontier on earth, which can be utilized for a variety of opportunities.

There are three major types of edible seaweed including; Rhodophyta (red), Chlorophyta (green) and Phaeophyta (brown). They each grow in different depths of the water. Seaweeds are currently being collected by wild harvest and aquaculture. Wild harvest occurs all over the globe where there is usable coastline, whereas aquaculture can be done in more locations as there is not a body of water required for the seaweed to grow. Aquaculture can take place in the sea or in tanks on land where a variety of conditions are controlled throughout the growing process. Even though there are over

250 species of seaweed found in the Gulf of Maine, the seaweed harvesting season only lasts from early winter to late spring (Lüning & Mortensen, 2015; Maine Sea Grant, 2018).

Sugar kelp (*Saccharina latissima*) grows exceptionally well in the northern Atlantic Ocean due to the cooler temperature and fewer hours of sunlight exposure. Sugar kelp is a brown seaweed that is part of the kelp family. The *Saccharina* genus is the second largest produced aquaculturally around the world with over five million metric tons produced in 2011 (Abreu, Pereira, & Sassi, 2015). Sugar kelp contains iodine, calcium, magnesium, iron, and vitamins A, B, C and E (Wells, Potin, Craigie, Raven, Merchant, Helliwell, Smith, Camire, & Brawley, 2017). *S. laminaria* and other kelps are a natural source of monosodium glutamate making it desirable to certain product developers (Abreu et al., 2015).

Dashi, the traditional Japanese broth, is most commonly made using kombu (*Saccharina japonica*) and has an umami flavor. Umami is a category of taste that is most commonly associated with glutamate, an ester of glutamic acid, which is an amino acid naturally present in a free state in most foods. When proteins are broken down, one byproduct that naturally occurs is monosodium glutamate (MSG). Sugar kelp can contain anywhere from 1.3 to 10.8% of glutamic acid based on total protein depending on the time of the season that it was harvested, with the latter part of the season resulting in lower percentages (Marinho et al., 2015).

Broth is a common food ingredient found in most commercial kitchens around the world. Broth can be a very versatile ingredient and used in many things from soups, sauces, and cooking liquid for grains or meats. The words broth and stock are usually used interchangeably, but stock is often made using the bony parts of animals while broth is often made using the meat of animals or vegetables (Campbell's - Swanson., 2017). Broth is usually made in-house at most restaurants as a way to save money by using by-products of meat and vegetables. The sugar kelp broth made for this study used fresh and previously frozen sugar kelp but used both the blade and stipe. Creating a broth allows proteins, free amino acids, and minerals to be extracted resulting in a translucent liquid without any solid vegetables or meat.

Seaweed is also known for its many health benefits including reducing incidences of chronic diseases (Brown et al., 2014). High consumption of seaweed in Japanese adults may assist in reducing risk factors for cardiovascular disease such as blood pressure, stroke risk factors, and levels of cholesterol (Brown et al., 2014). Another significant health benefit from seaweed is its iodine content, which can help maintain a healthy thyroid if one's diet is lacking iodine. However, this nutrient can also have adverse effects as too much iodine can cause thyroid problems such as inflammation, fatigue, and muscle weakness (Hedman, Djarv, Strang, & Lundgen, 2017). Seaweeds are also being used as both a source of antioxidant and antimicrobial activity in food products (Gupta & Abu-Ghannam, 2011).

As new and novel food products continue to flood the marketplace, there is one group of consumers who may have a hesitation towards consuming them. These

consumers may be called food neophobic or those who show a negative attitude towards certain foods (Nordin et al., 2004). This behavior is much different from being a picky eater; some people who are food neophobic may not be able to get the nutrients they need due to lack of variety in their diets. However, seaweed is becoming known less like an exotic or novel food and starting to become more of a familiar food ingredient. Still, there are many new and innovative ways that seaweed is being brought in to western cuisines including baked goods, alcoholic beverages, and even chocolate (Abreu et al., 2015), making seaweed a product that can be enjoyed by many people and for many years to come.

A study on consumer attitudes towards edible seaweeds in the eastern United States carried out in 2016 showed that consumers who were surveyed wanted lowcalorie seaweed products that provide some health benefit (Banus, 2017). This data also revealed that 9.1% of those surveyed had eaten seaweed soup previously, making it the 4th most common preparation method (Banus, 2017). This thesis project created a seaweed-based broth/soup using locally-sourced Maine-farmed sugar kelp that would help seaweed farmers create more market opportunities and develop more foods using local Maine ingredients. If the farmed seaweed sub-sector is to grow in the state of Maine, there is a need for more research on consumer acceptance of locally-sourced seaweed products. The second part of this research project assessed consumer acceptance of sugar kelp broth utilizing the nine-point hedonic scale to rate the acceptability of appearance, aroma, flavor, and thickness and overall acceptability.

CHAPTER TWO

LITERATURE REVIEW

2.1 Seaweed Production

There are many different varieties of seaweed in the oceans. However, only some are edible and consumed by humans. Seaweeds all fall into three divisions -Rhodophyta (red), Chlorophyta (green) and Phaeophyta (brown). The difference between the three divisions stems from pigments, storage products, structural cell wall, and intercellular mucilage. Seaweeds contain photosynthetic pigments, like chlorophyll in terrestrial plants, which utilize sunlight to attain food and oxygen from water and carbon dioxide (Hu & Fraser, 2016). In seaweed farms, seaweed seeds usually are purchased on a large spool of line with the seeds attached. This line is then attached to a rope which is placed between two moorings and lowered to different depths based on the type of seaweed being produced (Satria, Muthohharoh, Suncoko, & Muflikhati 2017). The basic structure of a seaweed is made up of four major parts: the holdfast which is similar to a root-like portion, the stipe which is analogous to a stem-like portion, the blade which functions like a leaf would in terrestrial plants, and the pneumatocyst or float, which is a gas-filled bladder that usually contains carbon dioxide (Figure 2.1). The whole plant is called the thallus (Hu & Fraser, 2016). Seaweeds grow faster than terrestrial plants allowing them to be produced more rapidly (De San, 2012). This factor makes seaweeds a crop of interest for not only farmers but also consumers.

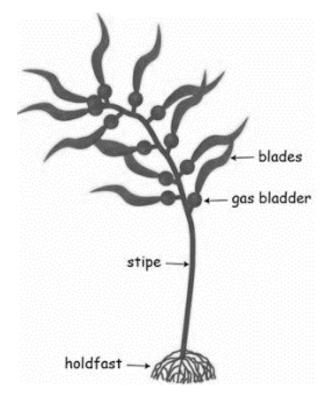


Figure 2.1 Basic Seaweed Structure (Surf Science, 2018)

Seaweeds are obtained through wild harvest or aquaculture. Wild harvesting occurs over the world where there is useable coastline. Individually, there are over 250 species of seaweeds that are indigenous to the Gulf of Maine region (Maine Sea Grant, 2018). Many factors go into finding an appropriate location for seaweed farming. Location is vital; finding a spot where there is good water movement or water turnover often is essential (De San, 2012). Farmers also want a location that is sheltered from the wind and waves. This criterion especially becomes important during inclement weather. De San (2012) also suggested that farmers should avoid choosing an area near the mouth of a river or stream as those sites may be inclined to much freshwater runoff. The salinity of the water is also something farmers should consider depending on the different types of seaweeds they are growing (De San, 2012). Temperature and water depth are other elements that are important to seaweed harvesting. De San (2012) also urged farmers to look for locations where the particular type of seaweed they want to grow is native. Specifically, for growing kelp, the water should be between 5 and 15°C and have a pH between 7.0 and 9.0 for the best growing potential (Flavin, Flavin, & Flahvie, 2013). Aquaculture can be completed in the sea or a tank; both are harvested in a contained area where many variables are controlled. For over the past decade, more seaweed has been harvested through aquaculture than wild harvesting (FAO, 2016). The nations that make the most significant contribution to seaweed harvesting includes China, Indonesia, India, Viet Nam, and the Philippines (FAO, 2016) (Figure 2.2).

| Major Producers | Total Aquaculture Production (Thousand Tonnes) |
|-----------------|--|
| | |
| China | 58,795.3 |
| Indonesia | 14,330.9 |
| India | 4,884.0 |
| Viet Nam | 3,411.4 |
| Philippines | 2,337.6 |

Table 2.1 Top Five Seaweed Producers Globally (FAO, 2016)

In the United States of America, the wild harvest seaweed industry is primarily based in Maine due to the cold temperature waters that provide a suitable medium for the seaweeds to grow (Augyte, Yarish, Redmond, & Kim, 2017). Maine was the first state to commercially grow sugar kelp (*Saccharina latissima*) in 2010 (Augyte et al., 2017). Specifically, in Maine seaweed has high sales revenues with a recent study reporting 42% percent of seaweed businesses stated their gross revenue was less than \$100,000, 29% stated gross revenue between \$250,000 and \$500,000 and 28% stated gross revenue greater than \$1,000,000 (Cole, Langston & Davis, 2017). Also, Maine's seaweed industry has an estimated market value of 20 million dollars (Gardener & Marriott, 2015).

2.2 Seaweed Harvesting

Through the years there have been many ways that seaweeds have been harvested. Historically seaweeds were harvested by hand during low tide by workers (Mac Monagail, Cornish, Morrison, Araujo, & Critchley, 2017). Throughout the years, farmers have tried a variety of techniques including diving, raking, and using boats. Most farmers or wild harvesters decided which technique to use based on catch per amount of effort put in and the type of seaweed (Mac Monagail et al., 2017). Different types of seaweeds grow in a variety of ways that require different techniques for harvesting to be utilized. Specifically, it is best to harvest kelp on a cloudy day that is between 0 and 10°C to maintain the quality of the kelp (Flavin, Flavin, & Flahvie, 2013).

Wild harvesters of seaweed are usually found in small cottage-like operations on the east and west coasts of Canada as well as the United States (Redmond, Green, Yarish, Kim, & Neefus, 2014). Most kelps utilized in the US are wild harvested (Redmond et al., 2014). Some farmers directly seed wild-collected spores onto seed string, allowing for new seaweeds to be grown without any initial purchasing of seeds (Redmond et al., 2014). While wild harvesting may allow for lower initial costs, it does have its downsides including a higher risk for contamination, lack of genetic control, and the number of spores one can harvest a year may vary. The amount of seaweed that is wild-harvested has stayed consistent over the past 20 years, but with the increased demand for seaweed, seaweed farms have seen a spike in annual amount harvested (Redmond et al., 2014).

Mechanical harvesting has been successfully utilized for many years now by a variety of wild harvesters to harvest different types of seaweeds. Mechanical devices used are custom built ones that have specific purposes and increase the harvesting rate (Mac Monagail et al., 2017). One criticism that mechanical harvesting received was the potential for over-harvesting (Mac Monagail et al., 2017). Some critics thought that using mechanized harvesting devices would allow wild harvesters to remove more seaweed than expected for the annual allotment rate; this problem has already happened with a few species of seaweed on the coast of France (Mac Monagail et al., 2017). Over-harvesting caused the beds where the seaweeds were grown to become unusable for future harvesting. Over-harvesting is not only done by machines it can also be done by harvesting by hand (Seeley & Schlesinger, 2012). There have also been concerns about over-harvesting in Maine as well, as there are currently no strict penalties if the regulations are broken (Seeley & Schlesinger, 2012). Some of Maine's regulations for wild harvesters include; a length requirement before harvesting, an annual limit, and required harvester's licenses (Seeley & Schlesinger, 2012). The only

penalty in place for over-harvesting is summons and fines while other areas that harvest seaweed include much more strict penalties for wild harvesters including companies getting their license revoked (Seeley & Schlesinger, 2012). Over-harvesting is only a problem with wild harvesting as the amount of seaweed available to harvest can vary from year to year (Seeley & Schlesinger, 2012).

2.3 Sustainability

Sustainability is a term that can span many things including the environment and one's diet (Merriam-Webster, 2018). Choosing a diet that is sustainable may allow present and future generations to continue to have safe and healthy options. Sustainability also is a significant factor towards maintaining nutrition security for many generations. Seaweed species have recently seen an increase in sustainability as more industries begin to utilize them.

Many coastal regions where seaweeds are found have been able to utilize them in many different avenues. This previous niche market has now become one of the major players in the push towards sustainability with a total estimated value of 10 billion dollars per year (Rebours et al., 2014; Gómez Pinchetti & Quintana, 2016).

Seaweed is used in a variety of different industries with about 83% of production being used for human consumption, while the rest is used for other things including; fertilizers, animal feed, medical applications and biotechnology application (Rebours et al., 2014). One of the significant factors that may have caused seaweeds and algae have such a rise in the marketplace is due to their possible nutritional benefits (Gómez

Pinchetti & Quintana, 2016). With more seaweed species and varieties being discovered, the boom in the marketplace is not showing any signs of slowing down. This expansion also allows for more benefits when it comes to sustainability because not all algae and seaweeds are safe for human consumption but may have different uses in other areas including pharmaceuticals, cosmetics, food production, and nutraceuticals (Buschmann et al., 2017).

Algae and seaweeds have recently been included in holistic approaches to processing. This approach extracts the valuable parts but then still uses the rest of the plant for things such as feed, fuel, and fertilizer (Buschmann et al., 2017). This sustainable approach utilizes the whole plant minimizing the environmental impact and having very little waste. Seaweeds for human consumption come in a variety of forms allowing them to reach a variety of consumers. However, the main reason algae and seaweed are being seen as a sustainable food source is due to their health and nutritional benefits (Gómez Pinchetti & Quintana, 2016). There are many ways to harvest these products, but a more sustainable way is aquaculture. Open-sea cultivating requires no land to be used allowing for land to be used for other terrestrial crops (Gómez Pinchetti & Quintana., 2016). Aquaculture allows for more stable harvesting with similar results from year to year. Another factor that helps algae and seaweeds grow is planting a variety of plants from season to season to make sure that area gets exposure to different plants and growing patterns. This practice is known as biodiversity, and it is commonly used in terrestrial crops to make sure the soil does not get depleted of specific nutrients the plants may need (Buschmann et al., 2017).

Although having a nutritious and plentiful food source for the future is valuable, seaweed also helps improve sustainability by reducing the amount of carbon dioxide (CO₂) in the atmosphere (Roleda, Morris, McGraw, & Hurd, 2012). Ever since new manufacturing processes started to emerge in the 1700s and 1800s during the industrial revolution, the atmospheric CO_2 has increased (Roleda et al., 2012). Seaweed is known to remove CO₂ from the atmosphere and has removed about 30% since CO₂ has been increasing (Roleda et al., 2012). However, the ocean's pH has also dropped what is known as ocean acidification, which can have many adverse effects on marine life (Roleda et al., 2012). Seaweed may also purify water sources by absorbing nutrients, minerals, environmental toxins (Omori, Otsuka, Ishii, & Nakatani, 2012). Different genera of seaweed can absorb different amounts of nutrients, minerals, environmental toxins at varying times of the year (Omori et al., 2012). Research shows that placing large-scale tanks of different seaweeds at the mouth of river or lakes can help purify the surrounding water (Omori et al., 2012). Along with benefitting the surrounding environment, seaweed can also benefit the surrounding marine life as well by providing food and shelter (Czyrnek-Delêtre, Rocca, Agostini, Giuntoli, & Murphy, 2017). Research even suggests that farming seaweed and salmon together can be beneficial as it increases the yield of seaweed per hectare produced and can also decrease overenriching of nutrients and minerals in the water caused by fish farming (Czyrnek-Delêtre et al., 2017). When seaweed is in the wild, it can also provide shelter for marine life from predators (Hasegawa et al. 2017). Seaweed has been found as a good shelter for both sedentary and more active marine life in smaller schools (Hasegawa et al. 2017).

This feature allows for certain marine life to increase population (Hasegawa et al. 2017). It is important to note that only seaweed with yellow/brown coloring has been found to be a good shelter against possible predators (Hasegawa et al. 2017). Seventy percent of the world is covered in water, yet there are still far fewer algae and seaweed harvested every year from the oceans in comparison to terrestrial plants (Buschmann et al., 2017). Many factors that go into algae and seaweed growing and harvesting impact how much and when it can be utilized. Time of year plays a significant factor since the seaweed harvesting season has a very short window. This phenomenon is due to different ocean temperatures and nutrients available in the oceans (Buschmann et al., 2017). It is known that seaweeds have different nutritive properties at different times throughout the harvesting season. The sunniest parts of the world are covered in deserts, and with this in mind, some researchers have started hypothesizing about creating large-scale aquaculture facilities that can produce a variety of algae and seaweeds.

2.4 Sugar Kelp

Saccharina latissima, more commonly referred to as sugar kelp, is a brown seaweed that is part of the kelp family. Sugar kelp got its name because it has a sweet flavor. Sugar kelp can range from an olive brown to a dark brown color (White & Keleshian, 1994). It is known to have a strong holdfast portion with a flexible blade that can be up to six feet long (White & Keleshian, 1994). Environmental factors that determine the reproduction and growth rates of sugar kelp are light intensity, temperature and availability of different nutrients, specifically nitrates, and phosphates (Parke, 1948). The favorable seasons to grow sugar kelp are winter and spring due to the

cooler ocean temperature, and fewer hours of light, which is why sugar kelp is grown in the Atlantic Ocean to help increase reproduction and growth rates (Lüning & Mortensen, 2015). Popular places sugar kelp is harvested in the Atlantic Ocean range from the high arctic down to the Iberian Peninsula including Maine and New Jersey. There are also some places in the northern Pacific Ocean including Korea and central California that grow sugar kelp. In the wild, sugar kelp is usually found secured to stones and shells from shallow areas to up to sixty feet deep. It has been known to resemble an "underwater forest." Sugar kelp is harvested in the wild by either cutting with a knife or a sickle at low tide (De San, 2012). However different harvests result in differences in the sugar kelp such as protein and alginate contents (Marinho, Holdt, & Angelidaki, 2015). Marinho et al. (2015) also found that these contents especially differ at the beginning and end of the harvesting season. Other differences have been found in water, ash, total carbohydrates, total proteins, total fatty acids, phenolics, total carotenoids, and chlorophyll contents (Vilg et al., 2015). Sugar kelp has also been found to have a high iodine content, which might be a useful discovery since the human body is usually iodine deficient from low levels of iodine in terrestrial plants and animals (Lüning & Mortensen, 2015).

Sugar kelp can also change in nutritional value during storage in seawater, which is a conventional pre-treatment process after harvesting to avoid degradation of the product (Stévant, Marfaing, Rustad, Sandbakken, Fleurence, & Chapman, 2017). Stévant et al. (2017) measured dry weight, minerals, carbohydrates, proteins, polyphenols, and fucoxanthin after short-term storage of 22 hours. The study found that sugar kelp lost

about 20% of its dry matter content, while the sodium levels increased by about 20%. The mannitol levels decreased by about 30% and glucose levels decreased by over 40% (Stévant et al., 2017). The protein content was stable through the study. The polyphenol content decreased by about 25%, and the fucoxanthin content decreased by about 30% (Stévant et al., 2017). Dry matter differences may have been caused by water uptake.

Unlike some seaweeds such as *Porphyra* (nori), sugar kelp is not commonplace in the food industry. As for product development companies, they have an issue with the sugar kelp that is wild harvested due to it having epiphytes on the blades (Lüning & Mortensen, 2015). When the plant is prepared correctly, it may be used as a straight cooked vegetable or added to soup.

More recently sugar kelp has seen increased use in product development. Such as; a dried powder in pizza dough, whole blades used in place of noodles in lasagna, fresh in a salad, and dried powder as part of a tempura batter (Griffin & Warner, 2017). Griffin & Warner (2017) reported that sugar kelp has also been found to be a good substitute for other seaweeds in recipes depending on their primary function. *Laminaria* or kelps are a natural source of monosodium glutamate making them desirable for product development (Abreu, Pereira, & Sassi, 2015).

The *Saccharina* genus is the second largest seaweed produced aquaculturally around the world (Abreu et al., 2015). Abreu et al. (2015) also reported that the *Saccharina* genus has an estimated value of 263.3 million dollars with the main producer being China. Abreu et al. (2015) investigated the nutritional value of different edible

seaweeds including sugar kelp. Abreu et al. (2015) looked at energy value(kcal), protein(g), carbohydrates(g), fats(g), fiber(g), and sodium(g) in a 6gram portion. For sugar kelp, the research reported 9.6kcal, 0.7g, 3.3g, 0.1g, 1.7g, and 0.5g, respectively. Based off the Recommended Daily Intake(RDI) values, sugar kelp's nutrients are 0.5%, 1.4%, 1.2%, 0.1%, 6.9%, and 9.0% respectively. Trace minerals and amino acids were also reported by Abreu et al. (2015). Sugar kelp and other related species were found to have contained iodine, calcium, magnesium, iron, and vitamins A, B, C, and E. As for amino acids, sugar kelp and other related species contained alanine, aspartic acid, glutamic acid, leucine, and taurine. The amount of ash present was around 30% of the total dry weight (Vilg et al., 2015). Sugar kelp contains phenolic compounds at a level 12 to 15 times higher than red algae (Tibbetts et al., 2016). Examples of phenolic compounds include flavonoids and phenolic acids. Tibbetts et al. (2016) also reported that the major metal salts calcium (Ca) and potassium (K), as well as iron (Fe), have been found to fluctuate with when the sugar kelp is harvested, while other trace minerals remain constant throughout the harvesting season.

Along with its nutritional content, sugar kelp's reproductive organ size also varies throughout the harvesting season (Mouritsen, Williams, Bjerregaard, & Duelund, 2012). When sugar kelp has a larger reproductive organ, it is known as the sorus stage (Mouritsen et al., 2012). A recent study that used sugar kelp to make dashi found that sugar kelp with more of the reproductive organ resulted in less flavor and was also lighter in color (Mouritsen et al., 2012).

2.5 Umami/Glutamic Acid/Dashi

Umami is known as the fifth taste alongside sweet, sour, bitter, and salty (Yamaguchi & Ninomiya, 2000). The umami taste is associated with glutamate, an ester of glutamic acid. Glutamic acid is an amino acid naturally present in a free state in most foods. The more common name for glutamate is monosodium glutamate (MSG). When proteins are broken down one compound that naturally occurs is MSG. MSG is a traditional additive in Asian cooking. Originally MSG was obtained from kelp but now is mostly obtained from bean and cereal proteins (Yamaguchi & Ninomiya, 2000). However, since gluten has become a significant concern for many, MSG is now industrially manufactured by bacterial fermentation using Corynebacterium sp. exclusively (Choudhury & Sen Sarkar 2017). Another compound associated with the umami taste is disodium 5'-ribonucleotides, which are natural compounds found in mammals, fish, shellfish, and plants. Common ribonucleotides that provide umami flavor are 5'-inosinate, 5'- guanylate and 5'-adenylate (Yamaguchi & Ninomiya, 2000). Though both MSG and 5'-ribonucleotides themselves do not have a distinct or pleasant taste when added to certain foods or recipes, they enhance the flavor and are known to make food more palatable.

Umami was discovered in 1908 by Kikunae Ikeda, a Japanese chemist, who was unable to identify the taste quality in "dashi" or Japanese broth (Halpern, 2000). Dashi is traditionally made with dried and fermented bonito, kombu kelp, or shiitake mushrooms (Osawa, 2012). However, there are many ways dashi can be made; it depends on which part of the country where it is produced. There have also been new products that have been tried by some to create that same umami flavor found in their traditional dashi. The changes in Dashi ingredients were influenced by social changes. The amount of traditional dashi ingredients purchased annually has been on a decline since 1968 (Osawa, 2012). Dashi also can be made with a strong flavor or a bland flavor. This variation also depends on what part of the country one lived due to how readily available the ingredients were. However, umami was not an internationally accepted term as a basic taste for over another 75 years (Yamaguchi, 1998). The difference in taste from umami was just thought of as coming from MSG and not available from any other source initially (Yamaguchi, 1998).

The level of free glutamic acid in kelp is over twenty times higher than the levels in shellfish, over fifty times more than the level in chicken, and over one hundred times more than the levels in beef or pork (Yamaguchi& Ninomiya, 2000). Forty-nine percent of sugar kelp's amino acid profile is made up of glutamic and aspartic acid. Glutamic acid can range from 10.4 -16.4% with the higher end being found in early harvest from September through November and the lower end developed in the later months of harvesting from May to July (Marinho et al., 2015). Another factor that impacts the amino acid profile of sugar kelp is epiphytes. When epiphytes are not removed from the sugar kelp, it had an impact on specific amino acids including lysine, methionine, and arginine. The protein content of sugar kelp also ranged throughout the harvesting season. Specifically, between 1.3 to 10.8% dry weight with the highest concentration in November and the lowest in May through July (Marinho et al., 2015). The one factor that did not have a significant impact on the total amino acid profile was the site of

growing/harvesting. Wild harvested seaweed had no difference relating to protein content over seaweed harvested through aquaculture (Marinho et al., 2015).

Other food items that have high levels of free glutamate include; parmesan cheese, nori, fish sauce, soy sauce, and yeast extracts such as Vegemite (Osawa, 2012). Although a variety of foods contain the appropriate constituents to provide the umami flavor, the umami is difficult to define. In Japanese dictionaries, umami is defined as one of three things: a delicious taste and its level of deliciousness, a skillful thing to relish especially in relation to techniques in art, and profit which is easily gained in business (Osawa, 2012). Though only the first two have to do with food, it is still easy to identify why it has been so hard for consumers to understand what umami is. Most chefs will say that umami is defined as meaty and savory tastes. A recent study that used local Nordic seaweed to create seaweed-based soups found that their seaweed-based soups had glutamic acid levels between 22 and 145 mg/100g, and they used sous-vide as their method of cooking to extract seaweed flavor and glutamic acid (Mouritsen et al., 2012).

Although umami has been an interest of food lovers many over the years, there has much controversy about how certain foods obtain these desired tastes. MSG has had an infamous long life in the spotlight. Many have questioned its safety for food use since it has been linked to multiple reactions known as MSG symptom complex. MSG symptom complex is reported as an adverse reaction to food containing MSG. Some of the common symptoms include; headache, flushing, sweating, facial pressure or tightness, numbness, tingling or burning in the face or neck, heart palpitations, chest pain, nausea, and weakness (Zeratsky, 2015). Though these symptoms were reported by

many after consuming MSG, researchers have found no conclusive verification that MSG is linked to these symptoms. Since there was no link, the US Food & Drug Administration (FDA) has classified MSG as a "generally recognized as safe" or GRAS additive. GRAS additives became commonplace after the Federal Food, Drug, and Cosmetic Act in 1938. This act defined food additives and stated that all food additives are subject to premarket review and final approval by the FDA unless generally recognized as safe (FDA, 2018). A food additive can receive GRAS status through scientific methods or if the food additive was used in foods before 1958 (FDA, 2018). For acceptance through scientific procedures, one must gather sound scientific evidence through published scientific work and an application process is required (FDA, 2018). Even though MSG is a GRAS food additive, the FDA requires for it to be labeled on any product containing MSG.

Umami has recently been found to increase oral and overall health. Taste dysfunction can be a common occurrence in older adults. This problem causes older adults to lose their appetite resulting in unhealthy weight loss and negative impacts on their overall health (Sasano et al., 2014). However, the umami taste has been linked to increased salivary secretion which also is linked to oral function and taste sensation (Sasano et al., 2014).

2.6 Health Benefits of Seaweed Consumption

Consuming seaweed regularly in a diet has been shown to reduce the incidences of chronic diseases (Brown et al., 2014). Some of the diseases reduced by including

seaweed in a diet deal with the heart, the blood, and some cancers (Brown et al., 2014). The majority of these studies compared Japanese diets and western diets. Japanese diets are notably higher in seaweed consumption, as Japan is the largest consumer of seaweed globally. Having a low lipid content and a high mineral content algae and seaweeds are excellent sources of multiple nutrients that are important to the body (Gómez Pinchetti & Quintana, 2016). Another health issue that was studied included bone maintenance, because the thyroid can be inhibited by high iodine consumption (Brown et al., 2014). Some kelps and kelp supplements may be considered iodine-rich and may cause health-related issues with the thyroid and bone maintenance. Another study that focused on fruit and vegetable intake showed that general fruit and vegetable consumption could prevent chronic diseases (Septembre-Malaterre, Remize, & Poucheret, 2018). This study also found that low fruit and vegetable intake is one of the top ten reasons for increased mortality (Septembre-Malaterre et al., 2018).

Seaweed consumption has been linked to decreased cardiovascular disease in Japanese adults (Brown et al., 2014). It has been reported that high seaweed consumption may assist in reducing risk factors for cardiovascular disease such as high blood pressure, stroke risk factors, reduced levels of cholesterol, and lipid peroxidation (Brown et al., 2014). Alginate is found in brown seaweeds and is utilized as a marine source of fiber found in the cell walls. When consumed by humans, alginate may suppress one's appetite, reduce blood glucose levels, and help with weight maintenance. This polysaccharide has only been tested in short-term studies, and more long-term human studies will need to be performed to have conclusive evidence of

alginate's beneficial properties (Brown et al., 2014). Though some studies suggest a link between seaweed consumption and type 2 diabetes control, there is no hard evidence of this and overall has minimal effect on regulating insulin levels (Brown et al., 2014).

Seaweeds have also been known to have antiviral properties related to high levels of consumption. Research has found that both carrageenans and fucoidans have significant antiviral activity against herpes and human immunodeficiency virus (HIV) (Brown et al., 2014). Some seaweed extracts are being used in certain types of cancer treatment (Wells et al., 2017). Some of the types of cancer that may be positively impacted by increased seaweed consumption include colon, lung skin, and urinary tract (Wells et al., 2017).

Seaweeds have potential as functional food ingredients because some species are high in potassium salts and have 70% less sodium than table salt (Gupta & Abu-Ghannam, 2011). Potassium salts are a good option for those who suffer from health risks such as cardiovascular disease and high blood pressure. Other beneficial nutritional properties that seaweeds have include high dietary fiber, protein, and a good amino acid profile, as well as a low lipid profile (Gupta & Abu-Ghannam, 2011). Seaweeds are being used as both a source of antioxidant and antimicrobial compounds (Gupta & Abu-Ghannam, 2011). Seaweed extracts have also become a more often utilized additive due to their nutritional properties.

2.7 Product Labeling & Health Claims

Consumers are becoming more aware of what they are purchasing at the grocery store. Consumers can be seen looking at labels on food packages for a variety of things such as; nutritional information, health claims, environmental claims, and even where it was produced. However, a study done by Hieke, Grunert, and Pravst (2016) showed that the majority of people who are looking for nutritional and health claims, specifically, on food packages are those who either follow a strict diet, have food restrictions, or food allergies. They went on to talk about how labels & claims are not geared towards to the average consumer (Hieke, Grunert, & Pravst, 2016). Some symbols may not be readily understood by consumers with minimal knowledge of food labels (Hieke et al., 2016). The same can be said for health claims on food labels (Hieke et al., 2016). Though consumers may not understand what exactly the label is stating, using buzz words like "reduces cholesterol" and "organic" increases the consumer's willingness to pay for these products (Cagalj, Haas, & Morawetz, 2016). When specific environmental claims are listed, the willingness to pay increases by 16 to 20 percent and when it is health claims the willingness to pay increases by 12 percent (Cagalj et al., 2016).

A study completed by Everett, Jensen, Boyer, and Hughes (2017) looked at southern American consumers' willingness to purchase locally produced wines based on a variety of factors. Over 40 percent of their participants stated they drink wine at least once a week (Everett, Jensen, Boyer, and Hughes, 2017). Nearly 40 percent of those surveyed stated they had purchased wine from a local winery in the past year (Everett et al., 2017). Increased age and being male had a positive effect on purchasing local

wines. However, living in a metro area had a negative impact on consumers' willingness to purchase local wines (Everett et al., 2017). Over 30 percent of those surveyed stated they had never tried local wines before (Everett et al., 2017). This result shows that there is a want for local products there just needs to be more opportunities for them to be in the marketplace as well as an emphasis on marketing towards younger consumers who live in metro areas.

Another study found that there are many reasons the average person purchases local foods overall including; to help minimize the miles food travels resulting in using less energy, they are perceived as safer and more of a quality product, and to help support agriculture and local economy (Thilmany, Bond & Bond, 2008). Consumers want to feel like they are getting good value, and some believe that is most likely when shopping locally, and they feel better that their money is helping local businesses and not larger corporations (Thilmany et al., 2008).

2.8 Food Neophobia

Food neophobia is defined as one's hesitation to eat, or avoidance of, new or novel foods. People who are considered neophobic often show more of a negative attitude towards such foods than people who are considered food neophilic (Nordin et al., 2004). Pliner and Hobden developed a food neophobia scale in 1992 to standardize the measurement of food neophobia from person to person or population to population. The scale consists of ten questions that are scored on a 7-point Likert scale individually. Scores for the scale can range from 10 to 70, with the low end being more

food neophilic and the high end being more food neophobic. However, there is no clear cutoff score.

Current neophobia data in the US and Sweden suggest a trend of decreasing food neophobia with increasing education and income. Neophobia is affected by exposure to foods in one's personal life, and also increasing wealth and understanding make for greater approachability and exposure in the world of food (Dovey, Staples, Gibson, & Halford, 2008). Other factors that may play a part in a person being food neophobic include; food allergies, an acute sense of taste or smell, and consistently gaging or vomiting on foods with certain textures (Levene & Williams, 2018). A person may also have had past food-related trauma including; episodes of choking, reflux, and digestive disorders (Levene & Williams, 2018). Food neophobia is very different from being a picky eater. A person with food neophobia may not be able to get the nutrients they need due to lack of variety. They may also even eat nothing for an extended period (Levene & Williams, 2018). Food neophobia can also lead to mental diseases such as; social anxiety and depression (Levene & Williams, 2018). Levene and Williams (2018) also stated that food neophobia might impact growth in children and management of other diseases. However, it is important to note that food neophobia is a spectrum and not all children or adults with it will encounter all these adverse effects.

2.9 Adding Seaweed to the Western Diet

Seaweed consumption has been slowly expanding across the globe as more people learn about the beneficial properties of the Japanese staple. Over the past

decade, the number of food products containing seaweeds has greatly increased (Rebours et al. 2014). Seaweeds have been given other names to make them more marketable to consumers such as sea vegetables and sea greens. This scheme is an attempt to debunk the ordinary concept consumers have of seaweed that they may see floating in the ocean. The most common form that seaweed is currently consumed in western diets is in different varieties of sushi (Chapman, Stévant, & Larssen, 2015). Some of the other commonly consumed species in the western diet include wakame (Undaria pinnatifida), kombu (Saccharina japonica), dulse (Palmaria palmata), sugar kelp (Saccharina latissima), red seaweed (Gracilaria spp.) and winged kelp (Alaria esculenta) (Gardner & Marriott, 2015). Though these are the currently popular species, seaweeds have been used in food products for many years. They have mostly been used as additives in the form of agar, alginates, and carrageenans, all types of hydrocolloids (Chapman et al., 2015). These products are used mainly as thickening agents in a variety of food and beverage products. However, these additives do not add any distinct seaweed flavor identifiable by the ordinary consumer. Many people in the food industry attribute the increased desire for seaweed in the western diet to its recent "superfood" title. Superfoods are deemed nutrient-dense foods that are beneficial to health and overall well-being (Lunn, 2006).

Historically, seaweeds were initially used for their medicinal purposes and as fertilizer (Gardner & Marriott, 2015). White & Keleshian (1994) also stated that records of the Chinese using seaweed as medicine date back to 3000 B.C. In other countries, seaweed was only consumed by ruminants as their energy source. In the past, New England states used certain seaweeds as a packing medium in the transport of live lobsters and clams (White & Keleshian, 1994). Another large user of seaweed has been the pharmaceutical industry. Seaweeds have been used for many different drugs such as anticoagulants, antibiotics, antihypertensive agents, and statins (Smit, 2004).

Currently, seaweed production is the highest in the coastal regions in the west such as Norway, Ireland, and the Gulf of Maine (Chapman et al., 2015). Since seaweeds do not need fresh water or land to grow, they can be very beneficial products for those who are near a coast. The appeal of seaweed has also advanced from the continual interest in local foods. Some of the good qualities of seaweeds are that they are high in certain minerals, vitamins, and trace elements (Chapman et al., 2015). There are four major forms of seaweed used in the food industry including fresh whole, fresh puree, dry whole, and dried powder (Gardner & Marriott, 2015 Griffin & Warner, 2017). Seaweed has been added to a variety of foods such as; bread, fresh cheeses, soups, salads, and ice cream to expand its consumers' demographics. Any new crop or food product that is mainstreamed in public is slow to start, and there is initial hesitation. Most of the hesitation comes from unfamiliarity with the product, how it will interact with different products in a recipe and how it will react to different cooking methods (Chapman et al., 2015). Seaweeds have been making an appearance in many different food products. Basic products containing seaweed such as a side salad or flake/powder have been on the market for a while. However, new innovative seaweed products are being brought to the marketplace all the time including: seasonings (sea salt and sugar), sauces (tartars, mayonnaise, and pesto), soups, pasta sauces, baked goods (breads and

crackers), pasta, beverages (teas, wine, and beer), pizza, sausages, and chocolate (Abreu et al., 2015).

With so much variety of seaweed products, they have been making their way into more and more households. As more individuals become aware of seaweeds nutritional benefits, they will be more inclined to try and purchase new products containing seaweeds. One overall concern consumers have with seaweeds is their high prices, and until they become a more mainstream item, the price will continue to be inflated (Abreu et al., 2015). Seaweeds satisfy all different types of people. Meat lovers can get the umami flavor they experience from meat in a vegetable while vegetarians and vegans get a functional food with many nutritional advantages (Abreu et al., 2015). Seaweeds also are an excellent product for consumers looking for organic products. Abreu et al. (2015) stated that though so many people are aware of all these positive attributes most still see seaweeds as exotic food. However, education can play a significant role by giving consumers knowledge about different types of seaweeds and how they differ. People's food habits are not going to change overnight, but with the right communications and marketing tactics, we can begin to integrate seaweeds into the American diet slowly. One good example of this is packages that include the correct seaweed name so consumers can know exactly what they are eating and are not just told it is seaweed or algae (Abreu et al., 2015). Many steps still need to be taken to make seaweed a mainstream food item, but the west is on track to see more seaweed products in the very near future.

2.10 The Future of Seaweed

Many are aware of the global environmental change occurring; this is affecting many things including seaweeds. Activities by humans have increased CO₂ emissions which have caused a decrease in the pH of the ocean and increased surface temperatures (Chung, Sondak, & Beardall, 2017). These changes have led to altered nutrient supply in the ocean at different depths (Chung et al., 2017). The extra CO₂ may impact certain seaweeds growing rate or health of the plant (Chung et al., 2017). Decreased ocean pH or ocean acidification has been impacting lots of marine industries, and now more research is being done on how it will impact the seaweed industry. Research has found that some species will begin to break down or become softer due to the acidification (Chung et al., 2017). As for the rising temperature, there are both some good aspects and some bad aspects. When the ocean temperature starts to rise it may help some seaweeds grow to their full potential at a quicker rate, but once the temperature gets too high, seaweed growth could be affected.

There are many ways researchers are looking into combating climate change; one of the most recent ones is the use of seaweeds to decrease atmospheric CO₂ levels. Seaweeds have been known to be able to uptake CO₂ which could alleviate some from the air and oceans (Chung et al., 2017). However, under current legislation seaweeds would not be able to be recognized as a way of combating atmospheric CO₂ levels as there is not enough information about how much CO₂ they can uptake and how long it takes for them to complete this process (Chung et al., 2017). Merging culinary arts and food science may increase the usage of seaweed at home and in industrially produced food products. Seaweed already has many known uses such as texturizing, flavor enhancing and improving specific protein bioavailability (Rioux, Beaulieu, & Turgeon, 2017). Seaweed has endless possibilities going forward and has a very indefinite future.

2.11 Project Objectives

The objective for the first part of the study was to identify suitable processing for a sugar kelp-based broth. The objective of the second part of the study was to understand how consumers' characteristics and food neophobia, as well as products characteristics, impact broth acceptability.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Preliminary Sugar Kelp Broth Processing

The first factor to be evaluated was the ratio of sugar kelp to water. Ratios of 10, 20, and 30% weight by weight (w/w) were tested to find a practical option. These broths were heated for 20 minutes at 93.3°C. Each broth was evaluated visually for clarity and color to determine the most suitable ratio. The ratios of 20% and 30% sugar kelp to water had similar appearances, so 20% was selected to help reduce production expenses.

The next factors studied were cooking method and time. The first method that was used to create the sugar kelp broth used a C. van't Riet zuiveltechnologie B.V. cheese vat (C. van't Riet zuiveltechnologie B.V., Nieuwkoop, Netherlands) at the University of Maine Dr. Matthews Highlands Food Pilot Plant. The cheese vat was selected as an option for its constant stirring motion. The sugar kelp was heated for 20 minutes at 43.3°C; this temperature was used because that was the maximum temperature for the cheese vat. Then the broth was strained through a mesh sieve, which was the process used for straining for all of the trials. This cheese vat trial produced a broth with minimal flavor using benchtop testing. All of the following broth processing trials can be found in Table 3.1. It was then determined that a longer time was needed to develop more flavor and that the cheese vat would not be a suitable cooking vessel because it required too much product to reach the spinning blade for

trials runs. Cheese vats are also not a commonly-available piece of equipment for kitchens or manufacturers. Sous vide was also determined to not be a viable option for a cooking vessel due to its small bag size (1 quart) which would not be practical when it came to time to scale up.

A 32-quart stockpot was then used as the next cooking vessel, as this can be easily found in a kitchen or at a manufacturer. The first trial in the stockpot heated the broth for one hour at 93.3°C. This broth still resulted in minimal flavor. It was next decided to reduce the broth by 50% to concentrate the flavor. This process resulted in a strong bitter tasting broth. The initial broth was then reduced in volume by 25%. The concentrated broth had less bitter flavor and but still could benefit from a stronger flavor.

Next, frozen sugar kelp was compared with fresh sugar kelp because the harvesting season is short. A variety of frozen sugar kelp trials were completed. All the following trials were done by heating the sugar kelp for one hour at 93.3°C then reducing by 25% for consistency. Reduction time varied from trial to trial based on the amount of heat used and amount of broth used. When frozen sugar kelp was directly added to the 93.3°C water a weak flavor resulted, even after volume reduction. Frozen and thawed sugar kelp was used in the next trial, and both products resulted in broths with similar looking and tasting product as the fresh sugar kelp.

Thawing method was then tested to see if that resulted in any differences. Two quick thawing methods were attempted- one where the frozen sugar kelp, still in

labeled one-gallon (3.785 L) Ziploc[®] polyethylene freezer bags (S.C. Johnson and Sons Inc., Racine, WI), was thawed under a constant stream of cold water (the cold method), and the other where the frozen sugar kelp was put on a china plate and quick-thawed in the microwave for one-minute intervals to allow the sugar kelp to be broken up and heated consistently throughout (the hot method). Both the hot and cold methods resulted in small flavor differences in the initial and concentrated trials.

Next, the focus was shifted onto possible flavor enhancements, as it is common for a variety of flavor enhances to be used in dashi. One of the more common flavor enhancers is bonito flakes. A trial was completed using the already made 25% concentrated fresh sugar kelp broth. Both the package instructions and traditional recipes stated to use a ratio of 25% bonito flakes to liquid. The bonito flakes (JFC International, Inc., Los Angeles, CA) were steeped in the broth on low heat (37.8°C) for 10 minutes then strained out. The resulting broth tasted strongly of smoked fish and had an oily mouthfeel. It was determined that the bonito flakes produced too strong a flavor and overpowered any sugar kelp flavor that was initially present.

The next trials included blanching the fresh and frozen sugar kelp before using it to make the broth. The technique was used because blanching locks in color of vegetables and may also bring out different flavors in vegetables. It was speculated that blanching would give the broth a greener color than the previous light brown colors, similar to a light black tea, then the untreated sugar kelp provided. Sugar kelp was blanched by placing it in boiling water for 3 minutes and made into broth using the same time and temperatures from previous trials followed by 25% volume reduction.

The resulting broth tasted like over-steeped black tea and it was decided to use a shorter blanching time. Sugar kelp was blanched for 30 seconds then used to make broth using the same method as before. This broth again resulted in an over-steeped black tea taste. Both broths also had a minimal color difference from the broth made with the untreated sugar kelp.

The next cooking method tested was higher heat for a shorter amount of time. This method was chosen after the leftover blanching water resembled a similar color and aroma of the previous successful trials. The first trial with this method included heating the water to 100°C and cooking the sugar kelp for three minutes. While this resulted in a similar color and aroma to the 25% concentrated fresh/frozen sugar kelp broth, the flavor was weak even after concentrating. The next trial was conducted using the same temperature, but this time the sugar kelp was cooked for 15 minutes. This broth, both concentrated and unconcentrated, tasted similar to the 25% concentrated fresh/frozen sugar kelp broth with a more sea-like flavor. Then the next trial used the same temperature but cooked the sugar kelp for 30 minutes. The broth that resulted from this was dark and murky and had subtle bitter flavors.

Then it was realized that the previous broths were losing a lot of the initial water (10-20%) due to the boiling temperature and times. The next step was to find a method of cooking that resulted in a similar flavor without losing as much water. The method that was selected was using a Cleveland Steamer Cub (Cleveland, Cleveland, OH). The first trial with this method used a full-sized non-perforated hotel pan (The Vollrath Company, Sheboygan, WI) to cook the broth. The water and fresh or thawed sugar kelp

were placed in the preheated steamer ranging from 85 to 95°C for 15 minutes. The resulting broth had a similar flavor to the broth boiled for 15 minutes. However, this broth had a transparent light brown/orange color to it, unlike the previous broths that were more translucent. The same method was utilized again at 30 minutes this time. This broth resulted in stronger flavored broth with no bitter notes. The color of this broth was an exact match of the 15-minute steamed broth. The total water loss of these broths was much lower (2%). Another thing that was different about these two broths was that they had very little noticeable sediment. All of the other previous broths had sediment at the bottom when left overnight in the refrigerator.

For another method where minimal water would be lost, cold steeping was tried. The sugar kelp was placed in room temperature water (21.1°C) in an 8-quart plastic Cambro container (Cambro, Huntington Beach, CA) and let sit for two different amounts of time, 10 hours and 12 hours. The resulting broth at 10 hours had a taste that differed from other trials but had a similar appearance to the boiled broth. The broth steeped for 12 hours had a slightly stronger flavor but had a different mouthfeel than others. Though this method was used to minimize water loss, it still ended up losing about 20% which was absorbed into the sugar kelp.

It was determined that the broth made by heating the broth to 100°C or boiling and cooking for 15 minutes would make a good option for a sensory test as it had no bitter flavors. Also, a steamed broth would make a good selection since it had the least amount of water loss. Though the steamed broth at 15 minutes had a similar taste to the boiled 15-minute broth, the 30-minute steamed broth had a stronger flavor, making this broth a more viable option for sensory evaluation. The boiled 15-minute broth used previously frozen sugar kelp for the sensory evaluation, and it was determined that the broth steamed for 30 minutes would use both fresh and previously frozen sugar kelp in separate broths to determine if sensory panelists could tell any differences. The steamed method was selected over the boiled method to use both the fresh and previously frozen sugar kelp because it had much less water loss.

| Cooking Vessel | Treatment of | Cooking | Cooking | Concentration |
|--|--|-----------|-------------|-------------------------|
| | Sugar Kelp | time | Temperature | amount (%) ^b |
| | | (minutes) | (°C) | |
| Cheese vat | Fresh | 20 | 43.3 | Х |
| 32 Qt stockpot | Fresh | 60 | 93.3 | 50/25 |
| 32 Qt stockpot | Frozen | 60 | 93.3 | 25 |
| 32 Qt stockpot | Frozen/Thawed | 60 | 93.3 | 25 |
| 32 Qt stockpot Quick thawe (Cold Metho | | 60 | 93.3 | 25 |
| 32 Qt stockpot | Quick thawed (Hot Method) | 60 | 93.3 | 25 |
| 32 Qt stockpot | Qt stockpot Fresh w/ 25% bonito flakes | | 37.8 | 25 |
| 32 Qt stockpot | Fresh Blanched for 3 mins | 60 | 93.3 | 25 |
| 32 Qt stockpot | Fresh Blanched for 30 seconds | 60 | 93.3 | 25 |
| 32 Qt stockpot | Fresh | 3 | 100 | 25 |
| 32 Qt stockpot | Fresh & Frozen/Thawed | 15 | 100 | 25 |
| 32 Qt stockpot | 2 Qt stockpot Fresh & Frozen/Thawed ^a | | 100 | 25 |
| Steamer | Fresh & Frozen/Thawed | 15 | 85-95 | x |
| Steamer Fresh ^a & Frozen/Thawed ^a | | 30 | 85-95 | x |
| 8 Qt Cambro | Frozen/Thawed | 600 | 21.1 | х |
| 8 Qt Cambro | Frozen/Thawed | 720 | 21.1 | X |

^a Broths used for sensory evaluation

^b Concentration amount refers to the percentage that the broth was reduced by to help concentrate flavors

3.2 Experimental Design

Sugar kelp (Saccharina latissima) was utilized to create three different broths to

be evaluated for their sensory acceptability. Sugar kelp broth was either boiled or

steamed for sensory analysis. Both fresh and previously frozen sugar kelp were steamed in a water bath, and previously frozen sugar kelp was boiled to create the three different broths. A vegetable broth control was also used. Sugar kelp from three different dates, April 20th, 2018, May 29th, 2018, and June 7th, 2018, were used to create replicate broth for the different methods. Analyses conducted on all four broths included sensory analysis, viscosity, color, pH, glutamic acid, total solids, and sodium content.

3.3 Sugar Kelp Harvest and Storage

Sugar kelp was grown at Clark Cove in the Damariscotta River in South Bristol, Maine by Maine Sea Farms. Sugar kelp seeds were placed on a horizontal longline on October 15, 2017, and harvested on March 29, 2018, through June 7, 2018. The area where the sugar kelp was grown is six acres large. The horizontal longlines were placed on average about five feet (1.5 m) below the water's surface. No agricultural treatments such as fertilizers or pesticides were used during the growth of the sugar kelp. Harvesting was done by hand using sharp knives.

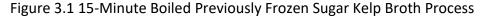
Once the sugar kelp was harvested, it was then transferred to Orono, Maine in coolers with several ice packs. Once the sugar kelp reached Orono, Maine it was stored at the University of Maine at the Dr. Matthews Highlands Food Pilot Plant in a walk-in cooler at 4° C or the walk-in freezer at -11° C.

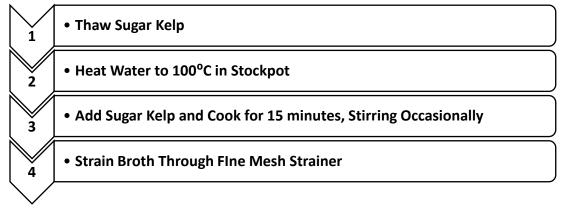
3.4 Sugar Kelp Preparation

When the sugar kelp was received, it was rinsed using cold water and trimmed by hand to remove any barnacles or other unwanted foreign objects. After cleaning half of the sugar kelp was placed in the walk-in cooler while the other half was blast frozen. The sugar kelp that was going to be blast frozen was laid out on perforated metal racks and placed on a rolling rack. The rolling rack was then placed in the blast freezer (Southeast Cooler, Lithia Springs, GA) at -20° C, which was turned on one hour before use, for 10-15 minutes. The frozen sugar kelp was then placed into labeled one-gallon (3.785 L) Ziploc® polyethylene freezer bags (S.C. Johnson and Sons Inc., Racine, WI) and stored in the walk-in freezer (-11°C). Two days prior to the sensory testing, frozen sugar kelp was removed from the walk-in freezer in the Dr. Matthew Highlands Food Pilot Plant and allowed to thaw under refrigeration (5° C). On the day before the sensory testing began, sugar kelp was removed from the walk-in cooler in the Dr. Matthew Highlands Food Pilot Plant. Both water and sugar kelp were measured separately. A ratio of 20% w/w of sugar kelp to water was used for the sensory testing.

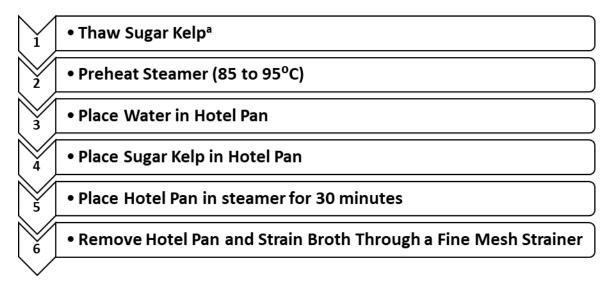
For the boiled broth (Figure 3.1), water was placed into a 32-quart stockpot (Winco, China) and allowed to come to a boil (100°C). Then the sugar kelp was added to the boiling water and cooked for 15 minutes while stirring occasionally. The stockpot was then removed from the heat, and the sugar kelp was strained out of the broth using a fine mesh strainer (Bradshaw international, Rancho Cucamonga, CA). The broth was then placed in an air-tight 18-quart Cambro plastic container (Cambro, Huntington Beach, CA) and placed in the walk-in cooler (4°C) in the Dr. Matthew Highlands Food

Pilot Plant. This process was only completed using the previously frozen sugar kelp. The boiled broth made for sensory analysis used previously frozen sugar kelp from April 20th, 2018.





For the steamed broth (Figure 3.2), water and sugar kelp were combined in a full-size non-perforated hotel pan (The Vollrath Company, Sheboygan, WI). The hotel pan was inserted into a Cleveland Steamer Cub (Cleveland, Cleveland, OH), and steamed between 85° C and 100° C for 30 minutes. The hotel pan was then removed from the steamer, and the sugar kelp was strained out of the broth using a fine mesh strainer (Bradshaw International, Rancho Cucamonga, CA). The broth was then placed in an airtight Cambro plastic container (Cambro, Huntington Beach, CA) and placed in the walkin cooler in the Dr. Matthew Highlands Food Pilot Plant. This process was completed using both fresh and previously frozen sugar kelp. The steamed broth made for sensory analysis used previously frozen sugar kelp from April 20th, 2018 and fresh sugar kelp from May 29th, 2018. Figure 3.2 30-Minute Steamed Fresh and Previously Frozen Sugar Kelp Broth Process



On the day of the sensory testing, the Cambro plastic containers (Cambro, Huntington Beach, CA) were removed from the walk-in cooler in the Dr. Matthew Highlands Food Pilot Plant. The broths were then transferred into half hotel pans (The Vollrath Company, Sheboygan, WI) in a Duke Warming Unit (Duke Manufacturing, St. Louis, MO) until served. Samples were held at a temperature of 75° C until served.

3.5 Sensory Analysis

Sensory analysis was completed on three sugar kelp broths, one was made using previously frozen sugar kelp and boiled for 15 minutes, another was made using previously frozen sugar kelp and steamed for 30 minutes, and the last was made using fresh sugar kelp and steamed for 30 minutes. Sensory analysis of the sugar kelp broths also included a store-bought vegetable broth to gauge consumer acceptability of vegetable broth. College Inn Reduced Sodium Garden Vegetable Broth (Del Monte Foods, Walnut Creek, CA) was used as the control vegetablele broth. SIMS 2000 Sensory Software (Version 6, Berkley Heights, New Jersey) was used to build the questionnaire, test design, and test execution. SIMS 2000 also provided a randomized and balanced design for the sensory test so that panelists received the different broth varieties in different sample orders to prevent positional bias.

Approval for testing was received by the Institutional Review Board (IRB) at the University of Maine (2018-03-15). The panel consisted of 56 participants over the age of 18 with no sensitivities or aversions to sugar kelp or seaweed. Untrained panelists were recruited via the Sensory Evaluation Center panelist database, and through paper flyers throughout the University of Maine campus in Orono. Panelists could either reserve a spot for the test by signing up in advance or come anytime they preferred during the testing time. Testing was completed on May 30th and May 31st to accommodate more panelists.

Every panelist was provided a private testing booth with uniform lighting. Each panelist evaluated the samples individually under a combination of incandescent and fluorescent lighting: a T-8 cool light fluorescent bulb with a 3600 °K average 29 color temperature, and a compact full spectrum bulb with a 5900 °K average color temperature. Testing was completed at ambient temperature with a positive pressure flow, which was used to eliminate any aromas from the kitchen area. Before analyzing the samples, panelists were required to read an informed consent form (Appendix A). After reading the informed consent document, participants were assigned to either a tablet computer (Hewlett Packard ElitePad 1000G2, Palo Alto, CA) or a desktop computer (Gateway FPD1530 E series, Irvine, CA) in the Sensory Evaluation Center on

the University of Maine Orono campus. Panelists were asked to initially answer demographic questions that included age, gender, seaweed eating habits, and what type of claims they look for when purchasing a product (Appendix B). After completion of the demographic questions, panelists were provided with 1.25 ounces (37 mL) of all four broth samples in a randomized order determined by SIMS 2000. Each sample was labeled with a 3-digit randomized code and placed in a 2-ounce white china ramekin (Ultima, China) on a beige plastic tray with a cup of spring water (Poland Spring, Dallas Plantation, ME), a napkin, and a metal spoon. Panelists were encouraged to cleanse their palate by taking a drink of water between each sample. Samples were rated for appearance, aroma, flavor, thickness, and overall acceptability on a 9-point hedonic scale (Peryam & Girardot, 1952). The 9-point hedonic scale used for this evaluation was affixed by (1) "dislike extremely" and (9) "like extremely," and (5) "neither like nor dislike" in the middle. Samples were also rated for thickness on a 5-point JAR scale (Lawless & Heymann, 2010). The 5-point JAR scale was anchored by (1) "much too thin" and (5) "much too thick" and (3) "just right" in the middle. Panelists were also given the opportunity to write optional comments about each sample. After rating all four samples, panelists were also asked to complete a food neophobia questionnaire (Pliner & Hobden, 1992). Once the test was finished, panelists were compensated with \$5.00 cash for completing the sensory test.

3.6 Color

Broth color was measured using a Hunter L*a*b* LabScan XE benchtop colorimeter (HunterLab, Reston, VA). The L* value represents how dark (0) or light (100)

a sample is, a* value is a green (-) to red (+) scale, and the b* value represents blue (-) to yellow (+) scale. The colorimeter was turned on 30 minutes prior to color analysis and standardized using black and white standard plates. Sugar kelp broths were prepared the same way as they were prepared for the sensory analysis. Sugar kelp broths were made using sugar kelp harvested on April 20th, 2018, May 29th, 2018, and June 7th, 2018. All three experimental broths that were used for sensory analysis were made using the sugar kelp from May 29th and June 7th. While only the 30-minute steamed broth and the 15-minute boiled broth were made using previously frozen sugar kelp from April 20th. EasyMatchQC version 4.81 was the software used for this measurement (HunterLab, Reston, Virginia). A 2.5-inch (64 mm) sample cup was used for measurement, and broth was added to the 25 mm line in the sample cup to cover the base of the sample cup. Triplicate measurements were made on all replicate samples, and in between each reading, the sample cup was rotated 90°. After three readings, the results were averaged.

3.7 pH

Broth pH was measured using a Thermo Scientific Orion Star A211 Benchtop pH meter (Thermo Fisher Scientific, Waltham, MA). pH measures how acidic or alkaline a substance on a scale from 0 to 14 with a pH of 7 being neutral. The pH meter was calibrated using three pH buffers (4.0, 7.0, & 10.0) prior to use. Sugar kelp broths were prepared the same way as they were prepared for the sensory analysis utilizing sugar kelp from the three dates available, April 20th, May 29th, and June 7th. Three ounces (88.7 mL) of each broth was placed into seven-ounce (207 mL) plastic cups for

measuring. The pH probe was rinsed in between each sample with distilled water and patted dry with a Kimwipe (Kimberly-Clark, Irving, TX). Triplicate measurements were made on all replicate samples.

3.8 Viscosity

Broth viscosity was measured using a Brookfield DV-II+ Pro viscometer (Brookfield Engineering Laboratories, Middleboro, MA). Viscosity measures the force per unit area resisting a flow. An RV 01 spindle was attached to the viscometer, and the viscometer was set up appropriately to match the spindle. The viscometer was then set to 100 RPM and kept consistent through all trials. Centipoise and percent torque were measured. Sugar kelp broths were prepared the same way as they were prepared for the sensory analysis utilizing sugar kelp from the three dates available, April 20th, May 29th, and June 7th. A sample of 500 mL of each broth was placed into a 600 mL beaker. The beaker was then centered on the spindle. The spindle was rinsed and dried between each sample. Triplicate measurements were made on all replicate samples.

3.9 Sodium

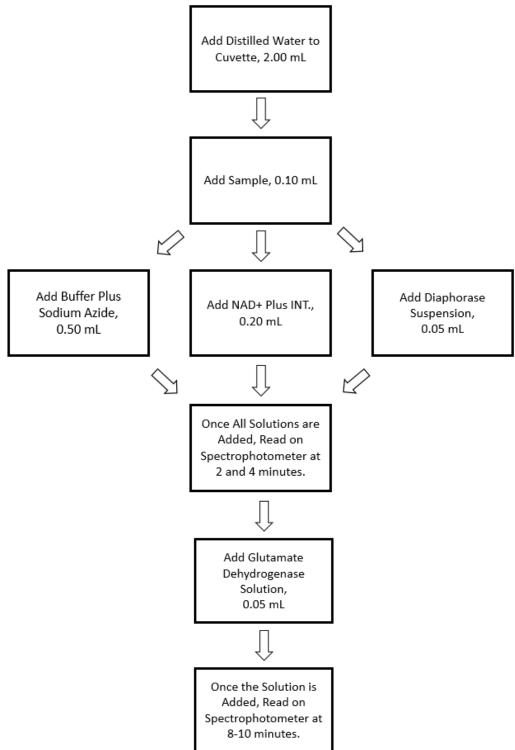
Samples were sent to the Soil Laboratory in Deering Hall at the University of Maine for sodium analysis. Free sodium ions in the broths were measured using a Thermo Electron iCap 6000 ICP-OES emission spectrometer (Thermo Fisher Scientific, Waltham, MA). Free sodium ions were measured in mg/g. Sodium content labeling allows consumers to understand how much sodium is in a food item, which is important for those who may have heart-related issues. Sugar kelp broths were prepared the same

way as they were prepared for the sensory analysis utilizing sugar kelp from the three dates available, April 20th, May 29th, and June 7th. All broths were diluted 10x to fit within the appropriate standard. Triplicate measurements were made on all replicate samples

3.10 Glutamic Acid

The glutamic acid in the broths was measured using a Megazyme L-Glutamic Acid Assay Kit (Megazyme, Bray, Ireland) and a Spectronic 200+ Spectrophotometer (Thermo Fisher Scientific, Waltham, MA). Glutamic acid is one of the 22 amino acids and is related to umami flavors found in some foods. The spectrophotometer was set to a wavelength of 492 and then set to absorbance and zeroed using distilled water. Sugar kelp broths were prepared the same way as they were prepared for the sensory analysis utilizing sugar kelp from the three dates available, April 20th, May 29th, and June 7th. All broths were then filtered through Whatman No. 1 filter paper (Whatman Plc, Maidstone, United Kingdom). The Manual Assay Procedure was followed as written in the Megazyme L-Glutamic Acid Assay Procedure data booklet. Solutions used in the assay included buffer plus sodium azide, NAD+ plus INT, diaphorase suspension, and glutamate dehydrogenase solution. Broths were not diluted. All samples were measured using an Eppendorf Repeater[®] Plus Pipette (Eppendorf, Hamburg, Germany). The broth and solutions were placed into a three mL cuvette. Distilled water, broth, buffer plus sodium azide, NAD+ plus INT, diaphorase suspension were added to the cuvette and read on the spectrometer at two and four minutes. Then glutamate dehydrogenase solution was added to the same cuvette and read on the spectrometer at ten minutes.

Glutamic acid was calculated in g/100g using the Mega-Calc[™] software tool found (Megazyme, 2018). Triplicate measurements were made on all replicate samples





3.11 Total Solids

Total solids of the broths were measured gravimetrically using a VWR drying oven (VWR International, Radnor, PA). Total solids is a measure of the suspended and dissolved solids in an aqueous solution. AOAC official method 925.19 was used (AOAC, 2005). Aluminum weighing dishes (Thermo Fisher Scientific, Waltham, MA) of various sizes were used to hold samples while drying and large bowls were used to cover the smaller bowls. A Sartorius A200S Analytical Balance (Sartorius AG, Göttingen, Germany) was used to gather all measurements. The balance has a readability of 0.0001 g. The aluminum bowls and lids along with Drierite were dried overnight using the VWR drying oven set at 105° C. The aluminum bowls and lids along with the Drierite were placed in a desiccator to allow the bowls and lids to cool. Sugar kelp broths were prepared the same way as they were prepared for the sensory analysis utilizing sugar kelp from the three dates available, April 20th, May 29th, and June 7th. Bowls were then measured, and then 2 g of each broth were placed into individual bowls. Then the bowls containing the broths were covered with the lid and weighed again. Bowls and lids with the broths were moved to a metal sheet pan with tongs. The broths were left in the drying oven overnight at 105°C. The broths were then removed and placed into desiccators containing Drierite to cool down. Once cool, the broths along with the aluminum bowls and lids were placed on the balance and measured. Equation 3.1 was used to calculate the total solids percentage. All samples were measured three times. A total of nine samples were measured.

Equation 3.1 Calculations of Total Solids

 $\frac{intial\,wt,\ g-wt\,loss\,on\,drying,\ g}{wt\,test\,portion,\ g} = Total\,Solids\,\%\,(w/w)$

3.12 Statistical Analyses

Statistical analysis of sensory data was conducted using PC-SAS version 9.4 (SAS Institute Inc., Cary, NC). A complete factorial design with harvest date, fresh versus frozen processing, and type of cooking was not possible because there was not enough fresh kelp available from the first date. Since there was only one factor (type of broth) one-way analysis of variance (ANOVA) was used to find possible significant differences among the different types of broth. Tukey's Honest Significant Difference (HSD) test was utilized for post hoc analyses of data with the significance value (p) set at $p \le 0.05$. The nine-point hedonic scale used for the sensory evaluation provides data that would otherwise be considered ordinal, but it is commonplace in sensory science to analyze the nine-point hedonic scale data as interval data. Top two (scores \ge 8) and bottom two (scores \le 2) boxes were calculated using PC-SAS in which all scores \ge eight for the hedonic rating of an attribute summed for the top two boxes.

Principal Component Analysis (PCA) was produced through the SIMS 2000 Sensory Software (Version 6, Berkley Heights, NJ) using R version 3.4.2 (The R Foundation, Vienna, Austria). PCA aids the conceptualization of multiple data sets in a two-dimensional plane. A significance value of $p \le 0.05$ was determined for all statistical analyses conducted.

Statistical analysis of color, pH, viscosity, sodium, glutamic acid, and total solids data was conducted using PC-SPSS version 24 (The International Business Machines Corporation, Armonk, NY). Prior to statistical analyses, triplicate readings of each treatment were averaged. Since there was only one factor (type of broth) one-way analysis of variance (ANOVA) was used to find possible significant differences among the different types of broth. Tukey's Honest Significant Difference (HSD) test was utilized for post hoc analyses of data with the significance value (p) set at $p \le 0.05$. Pearson correlation was also run on PC-SPSS version 24 to determine the correlation between chemical, physical properties, and hedonic scoring.

CHAPTER FOUR

SUGAR KELP BROTH – RESULTS AND DISCUSSION

4.1 Consumer Panel Demographic Information

The sensory panel for this study was completed at the University of Maine Orono campus. This location is important to note as it could be a source of potential bias. Fifty-six consumers, composed of 41% male, and 59% female, participated in the sensory panel for sugar kelp broth (Table 4.1). The largest age group for the of the panelists in this study was those aged between 26-40 (43%) (Table 4.1). Nearly all the panelists (98%) stated they had eaten seaweed before (Table 4.1).

According to Chapman et al. (2015), the most common seaweed product consumed in the Western diet is sushi which is consistent with the results from this study, as the majority of the panelists (82%) had stated they had eaten sushi before (Table 4.1). Also, over half of the panelists (33) stated they had eaten seaweed soup prior to this study (Table 4.1). However, it is not known how many of those individuals had taken part in another project on kelp-based soup that took place a few weeks before this study. The acceptance or rejection of a given food occurs when the human brain compares with information stored in the memory of past experiences (Costell, Tárrega, & Bayarri, 2009).

| Demographic Characteristic | Response | Sugar | Percent |
|--------------------------------------|----------------------------|--------|----------|
| | | Kelp | of Total |
| | | Broth | Panel |
| | | Panel | |
| | | (n=56) | |
| Gender | Male | 23 | 41.1 |
| | Female | 33 | 58.9 |
| Age | 18-25 | 18 | 32.1 |
| | 26-40 | 24 | 42.9 |
| | 41-70 | 14 | 25 |
| Have you eaten seaweed before? | Yes | 55 | 98.2 |
| | No | 1 | 1.8 |
| How have you eaten seaweed before? | Sushi | 46 | 82.1 |
| (multiple answers were allowed) | Soup | 33 | 58.9 |
| | Salad | 24 | 42.9 |
| | Fresh | 16 | 28.6 |
| | Snacks | 33 | 58.9 |
| What do you look for on a label when | Health Claims (Low | 26 | 51.8 |
| purchasing an item? (multiple | Sodium, 25% daily | | |
| answers were allowed) | Protein, etc.) | | |
| | Where it came from | 39 | 69.9 |
| | (Locally Sourced, Made | | |
| | in the USA, etc.) | | |
| | Dietary Choices (Vegan, | 8 | 14.3 |
| | Vegetarian) | | |
| | Ingredients (Amount of, | 46 | 82.1 |
| | Easy to Read Words, | | |
| | etc.) | | |
| | Nutrition Facts (Calories, | 42 | 75.0 |
| | Serving Size, etc.) | | |

| Table 4.1 Sugar Kel | p Broth Sensor | v Panel Demogra | phic Information |
|---------------------|----------------|-----------------|------------------|
| | | | |

Panelists were also asked what they look for on labels of food products when purchasing them. A majority (70%) of the panelists stated that they look for where the product comes from when purchasing products (Table 4.1). According to Everett et al. (2017) and Thilmany et al. (2008), the most common populations to purchase local products were men and those of increased age. However, as shown in Table 4.2 both males and females had very similar percentages when it came to purchasing products based on the source location. Similarly, age also did not have a large difference on purchasing products based the source location, and a higher percent of panelists under 50 years old chose where a product comes from as something they look for on labels (Table 4.2). Specifically, those under 30 years old had the highest percent of the 3 groups (Table 4.2). This finding contrasts those of Everett et al. (2017) who stated younger consumers and those who live in metro areas were the least likely to purchase locally-sourced products.

Table 4.2 Sugar Kelp Broth Sensory Panel Demographics Based on Whether *Where it came from (Locally Sourced, Made in the USA, etc.)* Was Selected.

| Demographic | Response | Panelists Who Percent of | |
|----------------|----------------|--------------------------|---------------------|
| Characteristic | | Chose - Where it | Selected Response |
| | | came from | Based on |
| | | (Locally Sourced, | Individual n Values |
| | | Made in the USA, | |
| | | etc.) | |
| Gender | Male (n=23) | 16 | 69.6 |
| | Female (n=33) | 23 | 69.7 |
| Age | Under 30(n=25) | 18 | 72.0 |
| | 30-50 (n=21) | 15 | 71.4 |
| | Over 50 (n=10) | 6 | 60.0 |

4.2 Sensory Evaluation Results

Significant differences in liking among the four broths were found for aroma, flavor, and overall acceptability (Table 4.3). However, there were no significant differences in liking among the four broths for appearance. Thickness was considered close to "just

right" for all four broths. All experimental versions of the sugar kelp broth, 15-minute boil frozen, 30-minute steam fresh, and 30-minute steam frozen, had no significant difference among themselves and also compared to the control broth, College Inn vegetable broth, for appearance (Table 4.3). This finding is important because consumers often look for familiar colors in new products they are willing to try, and appearance is one of the significant factors that go into the acceptance of a new food product (Elzerman, Hoek, Boekel, Luning, 2015). Though there were significant differences found between the broths for aroma, flavor and overall acceptability, there was no significant difference found between any of the three experimental versions of the sugar kelp broth (Table 4.3). The only significant difference that was found was between the control vegetable broth and the experimental versions. It is important to note this because there were no significant differences found between the broth made with fresh sugar kelp and the broths made with previously frozen sugar kelp. The season for harvesting sugar kelp is only from late February to early June (Lüning & Mortensen, 2015). Since all three broths scored similarly across all attributes, it is a good sign that a sugar kelp product could be made year-round. A recent study was completed using Australian seaweed to make soup dishes that resulted in the four experimental soup dishes receiving hedonic scores for overall satisfaction that were not significant from each other (Skrzypczyk et al., 2018). While the hedonic scores for overall satisfaction in the Australian study were higher than the ones for this study, Skrzypczyk et al. (2018) concluded that because all their soup dishes scored similarly. Further investigations towards improving our understanding of the potential and limits of local seaweed

farming plus understanding the long-term environmental sustainability of an Australian seaweed industry are needed (Skrzypczyk et al., 2018).

However, no experimental version of the sugar kelp broth received a score above seven (like moderately). However, since no sample received a score of seven or higher, further testing and formulating needs to be completed for the sugar kelp broths.

Along with hedonic scores, panelists were also able to leave comments about the broths during the sensory evaluation. Some common comments that panelists left for the sugar kelp broths included that they had little flavor, but a seaweed or sea flavor, unseasoned, and watered down. For the vegetable broth control, common comments left by the panelists included that it had a much stronger taste than the sugar kelp broths and they enjoyed the balance of flavor in the broth.

| Attribute | 15-minute boiled frozen | 30-minute steamed fresh | 30-minute steamed frozen | Vegetable Broth | Probability Value ^c |
|-------------------------|-------------------------------|-------------------------------|--------------------------------|--------------------|-----------------------------------|
| Appearance ^b | 6.4 ± 1.4 a | 6.3 ± 2.0 a | 6.4±1.2a | 6.0 ± 1.6 a | > 0.05 |
| Aroma ^b | 5.0 ± 1.5 b | 5.3 ± 1.5 b | 4.9 ± 1.6 b | 6.8 ± 1.7 a | <0.001 |
| Flavor ^b | 4.8 ± 2.0 b | 4.5 ± 1.8 b | 4.4 ± 1.8 b | 7.2 ± 1.8 a | <0.001 |
| Thickness ^d | 3.4 ± 0.6 a | 3.4 ± 0.8 a | 3.5 ± 0.6 a | 3.3 ± 0.7 a | > 0.05 |
| Overall ^b | 4.8 ± 1.9 b | 4.6 ± 1.7 b | 4.4 ± 1.7 b | 7.0 ± 1.7 a | <0.001 |

Table 4.3 Consumer Acceptance of Sugar Kelp and Vegetable Broth ^a

^a n = 56, Counts sharing a letter within the same row are not statistically different from each other (Tukey's HSD, $p \le 0.05$).

^b Nine-point hedonic scale: 1 = dislike extremely; 5 = neither like nor dislike; 9 = like extremely).

^c Not significant if the p value was > 0.05.

^d Five-point Just About Right Scale: 1= much too thin; 2 = little too thin; 3 = just right; 4 = little too thick; 5 = much too thick.

Top two and bottom two scores were calculated for the four broths. The top two value is the number of scores of eight or nine (like very much or like extremely) on the hedonic scale, and bottom two is the total of 1 and 2 (dislike extremely and dislike very much) scores. The top two and bottom two scores can reveal differences in liking that may not be found in the mean score as most panelists tend to make the error of central tendency, that is, utilize the middle of the hedonic scale more than the ends of the scale. The top two and bottom two scores also have a substantial impact on the overall mean scores more so than the middle of the hedonic scale. Significant differences were found between top scores for aroma, flavor, and overall acceptability with the vegetable broth control receiving significantly more top two scores than the three experimental sugar kelp broths. These results are similar to the mean score results as the control vegetable broth received significantly higher top two scores across the three attributes (Table 4.4). There were also no significant differences between the experimental sugar kelp broths (Table 4.4). Significant differences were also found between the bottom two scores for flavor. All the experimental broths received higher bottom two scores, which is similar to the mean score results (Table 4.3). No significant differences in top two and bottom two scores were found among the broths for appearance or thickness (Table 4.4). All broths received at least one top two and one bottom two score for each attribute (Table 4.4).

| Attribute | 15-minute | 30-minute | 30-minute | Vegetable | P- | Sig. |
|-------------------------------|-------------|-------------|------------|------------|--------------------|------|
| | boil frozen | steam fresh | steam | broth | Value ^b | С |
| | | | frozen | | | |
| | | | | | | |
| Appearance T2 ^d | 11 (20%) a | 17 (30%) a | 7 (12%) a | 9 (16%) a | >0.05 | NS |
| Appearance B2 ^e | 1 (2%) a | 3 (5%) a | 1 (2%) a | 1 (2%) a | >0.05 | NS |
| Aroma T2 | 3 (5%) b | 4 (7%) b | 1 (2%) b | 24 (43%) a | <0.001 | *** |
| Aroma B2 | 4 (7%) a | 3 (5%) a | 5(9%) a | 1 (2%) a | >0.05 | NS |
| Flavor T2 | 3 (5%) b | 1 (2%) b | 1(2%) b | 29 (52%) a | <0.001 | *** |
| Flavor B2 | 9 (16%) a | 10 (18%) a | 11 (20%) a | 1 (2%) b | <0.05 | * |
| Thickness | 24 (43%) a | 21 (38%) a | 28 (50%) a | 17 (30%) a | >0.05 | NS |
| Т2 | | | | | | |
| Thickness | 2 (4%) a | 5 (9%) a | 1 (2%) a | 3 (5%) a | 0.3451 | NS |
| B2 | | | | | | |
| Overall T2 | 2 (4%) b | 2 (4%) b | 1 (2%) b | 26 (46%) a | 0.0001 | *** |
| Overall B2 | 8 (14%) a | 9 (16%) a | 9 (16%) a | 2 (4%) a | 0.1367 | NS |

Table 4.4 Frequency of Top Two and Bottom Two Hedonic Attribute Ratings for Sugar Kelp and Vegetable Broths (n= 56) ^a

^a Counts sharing a letter within the same row are not statistically different from each other (Tukey's HSD, $p \le 0.05$).

^b Probability value of obtaining a greater F value.

^c Significance (N.S= not significant because the p-value exceeds 0.05).

^d T2 indicates a hedonic score at the top of the scale (8, like very much, and 9, like extremely).

^e B2 indicates a hedonic score at the bottom of the scale (1, dislike extremely, and 2, dislike very much).

Principal Component Analysis (PCA) converts a set of observations of possibly

correlated variables into a two-dimensional representation (Adbi & Williams, 2010).

Data points in the upper right quadrant are strongly related to component one, which is

on the x-axis and increases up to five. This correlation denotes that aroma, flavor, and overall acceptability fluctuate together and are highly correlated (Figure 4.1). The Principal Component Analysis (PCA) disclosed that two components accounted for 99.40% of the variance (Figure 4.1). The PCA also uses eigenvalues which are a set of values of a parameter for which a different equation has a nonzero solution under given conditions. Aroma, flavor, and overall acceptability were represented within Component 1 (Eigenvalue = 4.61) which were all correlated to the control vegetable broth (Table 4.5). Only thickness was represented within Component 2 (Eigenvalue = 0.36) which was correlated to the 30-minute steamed broth with previously frozen sugar kelp (Table 4.5). Components 1 and components 2 account for 92.14% and 7.25% of the PCA, respectively (Figure 4.1). Appearance was negatively correlated with both the 15-minute boiled broth with previously frozen sugar kelp and the 30-minute steamed broth with fresh sugar kelp (Figure 4.1). Table 4.5 below shows the eigenvalues for all three components.

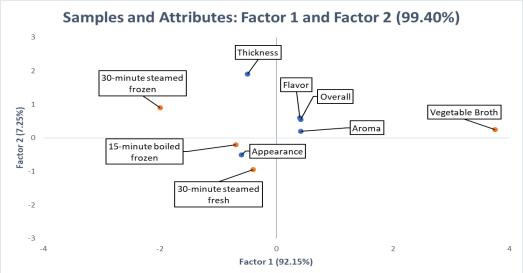


Figure 4.1 Principal Component Analysis of Sugar Kelp and Vegetable Broths

Table 4.5 Eigenvalues of Principal Component Analysis for Sugar Kelp Broth Sensory Evaluation

| | Component 1 | Component 2 | Component 3 |
|------------------------|-------------|-------------|-------------|
| Eigenvalue | 4.61 | 0.36 | 0.03 |
| Percentage of Variance | 92.15 | 7.25 | 0.60 |
| Cumulative Sum | 92.15 | 99.40 | 100.00 |

As envisioned both aroma and flavor were the most correlated with overall acceptability with a Pearson correlation coefficient of 0.99 and 1.00, respectively (Table 4.6). Both aroma and flavor are essential factors for consumer acceptance (lop, Teixeria, & Deliza, 2006). The other two attributes, appearance and thickness, were both negatively correlated with the overall acceptability (Table 4.6).

| | Appearance | Aroma | Flavor | Thickness | Overall |
|------------|------------|-------|--------|-----------|---------|
| Appearance | 1.00 | -1.00 | -0.98 | 0.76 | -0.98 |
| Aroma | -1.00 | 1.00 | 0.98 | -0.81 | 0.99 |
| Flavor | -0.98 | 0.98 | 1.00 | -0.74 | 1.00 |
| Thickness | 0.76 | -0.81 | -0.74 | 1.00 | -0.75 |
| Overall | -0.98 | 0.99 | 1.00 | -0.75 | 1.00 |

Table 4.6 Pearson Correlation Coefficients for Sugar Kelp Broth Sensory Evaluation

4.3 Food Neophobia

Food neophobia can have a large role in whether consumers reject or accept new food products. Some studies have categorized people food neophobic or food

neophilic. There have been several approaches to categorizing consumers based on their food neophobia score (Henriques, King, & Meiselman, 2009). However, other researchers have broken down the food neophobia score into tertiles to describe different levels of food neophobia: high, medium, and low (Jaeger, Rasmussen, Prescott, 2017). The mean food neophobia score for this study was 24.7 (standard deviation of 9.1) and a range of 10-52, with 10 being the lowest possible score of the scale and 70 as the highest. The tertiles ranges for this study were categorized as low (10-19, n=19), medium (20-27, n=18), and high (29-52, n=19) food neophobia. The frequency distribution of the Food Neophobia Scores can be found in Figure 4.2.

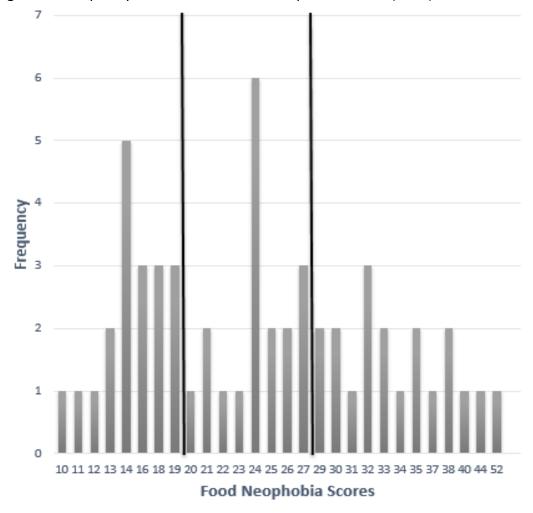


Figure 4.2 Frequency Distribution of Food Neophobia Scores (n=56) ^a

^a Vertical lines indicate tertile cut-offs for Food Neophobia Scores: 10-19, Low; 20-27, Medium; 29-52, High

Cronbach's alpha for the food neophobia score was 0.84, indicating high internal validity and concurs with other reported food neophobia score validity scores (Jaeger et al., 2017). The food neophobia questionnaire was designed so that half the questions measure food neophilia (1, 4, 6, 9, 10) and thus are reverse-coded, and half the questions measure food neophobia (2, 3, 5, 7, 8). In this study all food neophobia

questions were asked so that "Agree Extremely" was always on the leftmost side of the scale (Appendix B). For food neophilic based questions "Agree Extremely" received a score of 1 while for food neophobic based questions "Agree Extremely" received a score of 7. For this study, a mean score of less than 4(Neither Agree or Disagree) was received for each question (Table 4.7). However, the range for each question was either five or six; meaning for each question panelists either selected every possible answer or all but one of the possible answers (Table 4.7). This result shows that even though the range spanned the majority of the scale, more panelists chose answers from the middle or lower ends of the respective scales.

| Food Neophobia Question | Mean Score (n=56) | Range |
|--|-------------------|-------|
| I am constantly sampling | 2.4 ± 1.2 | 1-6 |
| new and different foods. ^a | | |
| | | |
| I don't trust new foods. ^b | 2.2 ± 1.3 | 1-6 |
| If I don't know what is in a | 3.2 ± 1.8 | 1-6 |
| food, I won't try it. ^b | | |
| | | |
| I like foods from different | 1.8 ± 1.0 | 1-6 |
| countries. ^a | | |
| | | |
| I find ethnic food too | 2.0 ± 1.3 | 1-7 |
| weird to eat. ^b | | |
| At dinner parties, I will try | 1.8 ± 1.0 | 1-7 |
| new food. ^a | | |
| | | |
| I am afraid to eat things I | 2.2 ± 1.5 | 1-7 |
| have never tried before. ^b | | |
| I am very particular about | 3.7 ± 1.8 | 1-7 |
| the foods I eat. ^b | | |
| I will eat almost anything. ^a | 3.3 ± 1.7 | 1-7 |
| I like to try new ethnic | 2.1 ± 1.4 | 1-6 |
| restaurants. ^a | | |

Table 4.7 Mean Score and Range for Food Neophobia Questionnaire (n=56)

^a Food neophilic question (1(Agree Extremely), 2(Agree Moderately), 3(Agree Slightly), 4(Neither Agree or Disagree), 5(Disagree Slightly), 6(Disagree Moderately), 7(Disagree Extremely).

^b Food neophobic question (7(Agree Extremely), 6(Agree Moderately), 5(Agree Slightly), 4(Neither Agree or Disagree), 3(Disagree Slightly), 2(Disagree Moderately), 1(Disagree Extremely).

Food neophobia can also influence the hedonic rating of new food product

acceptability (Henriques et al., 2009). However, for this study, there were no significant

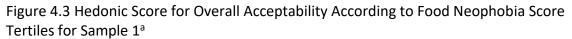
differences found between Food Neophobia groups and hedonic scores. The breakdown

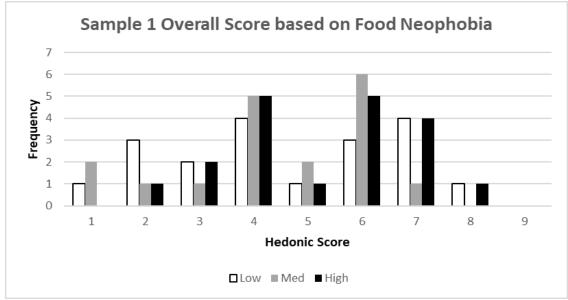
of each for each sample's overall hedonic score between Food Neophobia groups shows minimal differences between groups (Figures 4.3, 4.4, 4.5, 4.6). Food Neophobia can also negatively impact consumers' willingness to try new functional foods (Stratton, Vella, Sheeshka, & Duncan, 2015). Food Neophobia Scores for this study all had similar median ages for each tertile, low (36), medium (34.5) and high (33.3). As for gender, there was no significant difference between males (61%) and females (70%) who scored medium and high for food neophobia (Table 4.8). Those scoring high for food neophobia, overall, selected significantly fewer ways they have eaten seaweed in the past compared to those who are considered medium for food neophobia (p = 0.04).

| Age | Overall(n=56) | Low Food Neophobia (n=19) | Medium Food Neophobia (n=18) | High Food Neophobia (n=19) |
|--|---------------|---------------------------------|---------------------------------------|----------------------------------|
| 20-29 | 25(44.6) | 9(47.4) | 7(38.9) | 9(47.4) |
| 30-39 | 17(30.4) | 4(21.0) | 7(38.9) | 6(31.6) |
| 40-49 | 4(7.1) | 0 | 2(11.1) | 2(10.5) |
| 50-59 | 7(12.5) | 5(26.3) | 2(11.1) | 0 |
| 60+ | 3(5.4) | 1(5.3) | 0 | 2(10.5) |
| Median Age | 34.4 | 36 | 34.5 | 33.3 |
| Gender | | | | |
| Male | 23(41.1) | 9(47.4) | 4(22.2) | 10(52.6) |
| Female | 33(58.9) | 10(52.6) | 14(77.8) | 9(47.4) |
| How have panelists eaten seaweed before? (Multiple answers were allowed) | | | | |
| Sushi | 46(82.1) | 17(89.5) | 16(88.9) | 13(68.4) |
| Soup | 33(58.9) | 9(47.4) | 15(83.3) | 9(47.4) |
| Salad | 24(42.9) | 10(52.6) | 8(44.4) | 6(31.6) |
| Fresh | 16(28.6) | 6(31.6) | 6(33.3) | 4(21.0) |
| Snacks | 33(58.9) | 13(68.4) | 13(72.2) | 7(36.8) |

Table 4.8 Sugar Kelp Broth Sensory Panel Demographic Information According to Food Neophobia Score Tertiles ^a

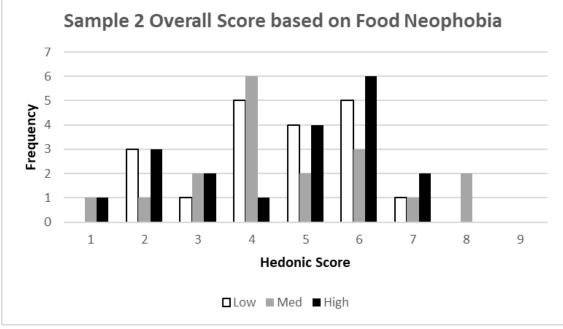
^a Number in parentheses are a percentage of the total.





^a Sample 1 is sugar kelp broth boiled for 15 minutes using previously frozen sugar kelp form 4/20/2018

Figure 4.4 Hedonic Score for Overall Acceptability According to Food Neophobia Score Tertiles for Sample 2^a



^a Sample 2 is sugar kelp broth steamed for 30 minutes using fresh sugar kelp form 5/29/2018

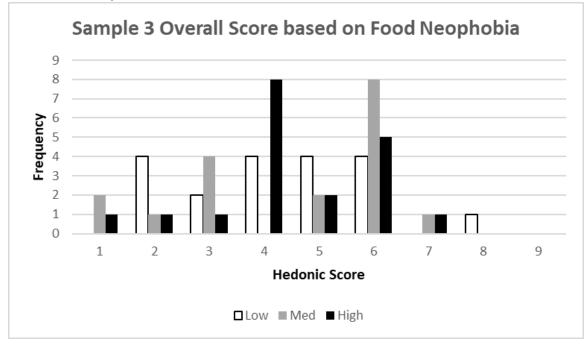
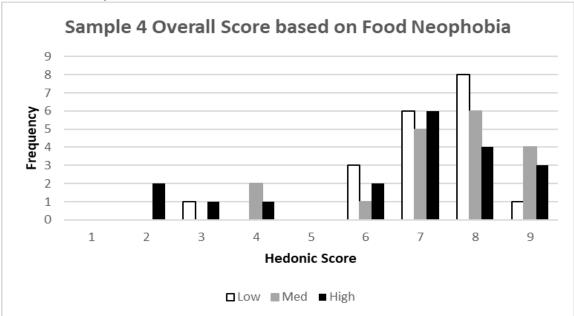


Figure 4.5 Hedonic Score for Overall Acceptability According to Food Neophobia Score Tertiles for Sample 3^a

^a Sample 3 is sugar kelp broth steamed for 30 minutes using previously frozen sugar kelp form 4/20/2018

Figure 4.6 Hedonic Score for Overall Acceptability According to Food Neophobia Score Tertiles for Sample 4^a



^a Sample 4 is the vegetable broth control (College Inn Reduced Sodium Garden Vegetable Broth)

4.4 Color

Colorimetric L* values measure lightness and range from 0 to 100, where 0 is black, and 100 is white. The a* values measure the green (-) to red (+) scale and b* values measure the blue (-) to yellow (+) scale. The sugar kelp broths made using fresh sugar kelp and steamed for 30 minutes produced a significantly darker color compared to the other broths made from the same harvest date (Table 4.9). Besides the control vegetable broth, the next lightest broths were typically those made with previously frozen sugar kelp and steamed for 30 minutes (Table 4.9). However, there was some crossover with the broths made with previously frozen sugar kelp and boiled for 15 minutes (Table 4.9). Overall, there was no significant difference in color throughout the different harvest dates (Table 4.9) Even though there was a vast range of colors produced by the broths used for sensory evaluation there were no significant differences in hedonic scores for appearance meaning that panelists are willing to accept a variety of colors when it comes to broths (Table 4.3, 4.9).

| 18012 4.9 CC | Hunter CIE L*a*b* Scores | | | | | | |
|---------------------|--------------------------|---------|-----------|---------------------|---------------------|---------------------|--|
| Type of | Date | Cooking | Cooking | L* | a* | b* | |
| Sugar Kelp | Harvested | Method | Time | values ^c | values ^c | values ^c | |
| | | | (Minutes) | | | | |
| Previously | 4/20/18 | Boil | 15 | 4.65 ± | 2.49 ± | 4.96 ± | |
| Frozen ^b | | | | 0.06 de | 0.18 c | 0.12 c | |
| Previously | 4/20/18 | Steam | 30 | 6.65 ± | 1.97 ± | 5.05 ± | |
| Frozen ^b | | | | 0.24 b | 0.13 d | 0.10 c | |
| Previously | 5/29/18 | Boil | 15 | 5.74 ± | 3.34 ± | 5.55 ± | |
| Frozen | | | | 0.29 c | 0.21 b | 0.07 b | |
| Fresh ^b | 5/29/18 | Steam | 30 | 1.75 ± | 1.82 ± | 1.07 ± | |
| | | | | 0.08 f | 0.06 d | 0.09 e | |
| Previously | 5/29/18 | Steam | 30 | 5.48 ± | 2.80 ± | 4.87 ± | |
| Frozen | | | | 0.16 c | 0.21 c | 0.05 c | |
| Previously | 6/07/18 | Boil | 15 | 4.84 ± | 3.26 ± | 3.54 ± | |
| Frozen | | | | 0.24 d | 0.13 b | 0.17 d | |
| Fresh | 6/07/18 | Steam | 30 | 4.37 ± | 4.18 ± | 3.50 ± | |
| | | | | 0.46 e | 0.66 a | 0.44 d | |
| Previously | 6/07/18 | Steam | 30 | 5.55 ± | 3.81 ± | 5.12 ± | |
| Frozen | | | | 0.47 c | 0.10 a | 0.21 c | |
| Control | NA | NA | NA | 15.00 ± | 0.12 ± | 9.77 ± | |
| (Vegetable | | | | 0.19 a | 0.09 e | 0.27 a | |
| Broth) ^b | | | | | | | |

Table 4.9 Color Analysis of Sugar Kelp and Vegetable Broths^a

^a Means \pm standard deviation (n =3), values not sharing a letter are significantly different within columns (Tukey's HSD, p≤0.05).

^b Broths used for sensory evaluation.

^c L* values measure lightness and range from 0 to 100, where 0 is black, and 100 is white, a* values measures green (-) to red (+) scale and b* values measure blue (-) to yellow (+) scale.

pH measures how acidic or alkaline a substance is on a scale from 0 to 14. The sugar kelp broths with the highest pH were made using previously frozen sugar kelp and steamed for 30 minutes (Table 4.10). Both the sugar kelp broth made using previously frozen sugar kelp and boiled for 15 minutes and the sugar kelp broth made from fresh sugar kelp and steamed for 30 minutes showed an increase in pH as the harvest dates got later in the season (Table 4.10). The broths used for sensory evaluation had a range of pH from 4.35 to 6.83 (Table 4.10). As seen in table 4.3, there was a significant difference between the flavors of the broths with the control vegetable broth scoring the highest, meaning panelists preferred the broth that was most acidic. Commercially vegetable soups typically range from a pH of 4.99 to 5.16, which is lower than all the experimental sugar kelp broths, but above the control vegetable broth. Panelists may have scored the control vegetable higher than the experimental broths because it had a similar acidity to a commercially produced vegetable broth (Anon, 1962).

Table 4.10 pH Analysis of Sugar Kelp and Vegetable Broths

| Type of Sugar | Date | Cooking | Cooking Time | pH ^a |
|---------------------|-----------|---------|--------------|-----------------|
| Kelp | Harvested | Method | (Minutes) | |
| Previously | 4/20/18 | Boil | 15 | 5.56 ± 0.67 b |
| Frozen ^b | | | | |
| Previously | 4/20/18 | Steam | 30 | 6.83 ± 0.03 a |
| Frozen ^b | | | | |
| Previously | 5/29/18 | Boil | 15 | 6.18 ± 0.61 ab |
| Frozen | | | | |
| Fresh ^b | 5/29/18 | Steam | 30 | 6.37 ± 0.37 ab |
| Previously | 5/29/18 | Steam | 30 | 6.75 ± 0.01 a |
| Frozen | | | | |
| Previously | 6/07/18 | Boil | 15 | 6.20 ± 0.26 ab |
| Frozen | | | | |
| Fresh | 6/07/18 | Steam | 30 | 6.57 ± 0.01 a |
| Previously | 6/07/18 | Steam | 30 | 6.69 ± 0.01 a |
| Frozen | | | | |
| Control | NA | NA | NA | 4.35 ± 0.03 c |
| (Vegetable | | | | |
| Broth) ^b | | | | |

^a Means \pm standard deviation (n = 3), values not sharing a letter are significantly different (Tukey's HSD, p≤0.05).

^b Broths used for sensory evaluation.

4.6 Viscosity

Viscosity measures how thick the consistency of a product is due to its internal

friction. Besides the control vegetable broth, the next thickest broths were all produced

by sugar kelp that was harvested on June 7th, 2018 (Table 4.11). The thinnest broths

were produced by sugar kelp that was harvested on May 29th, 2018 (Table 4.11). However, the broths produced by sugar kelp that was harvest on April 20th, 2018 that was not significantly different from the majority of the broths made using sugar kelp from the other two harvest dates (Table 4.11). One factor that has been found to increase viscosity in broths is increased cooking temperature. However since all the broth were cooked at a similar temperature (85°C, 100°C) there were no substantial differences between them (Krasnow, Bunch, Shoemaker, & Loss , 2012). The broths used for sensory evaluation had a significant difference in the range of viscosity (Table 4.11) There were also no significant differences in just-about-right scores for thickness (Table 4.3, 4.11).

Table 4.11 Viscosity Analysis of Sugar Kelp and Vegetable Broths

| Type of | Date | Cooking | Cooking | Centipoise | Torque (%) ^a |
|---------------------|-----------|---------|-----------|----------------|-------------------------|
| Sugar Kelp | Harvested | Method | Time | (cP)ª | |
| | | | (Minutes) | | |
| Previously | 4/20/18 | Boil | 15 | 8.40 ± 0.30 bc | 8.40 ± 0.30 bc |
| Frozen ^b | | | | | |
| Previously | 4/20/18 | Steam | 30 | 8.47 ± 0.15 bc | 8.47 ± 015 bc |
| Frozen ^b | | | | | |
| Previously | 5/29/18 | Boil | 15 | 8.03 ± 0.15 cd | 8.03 ± 0.15 cd |
| Frozen | | | | | |
| Fresh ^b | 5/29/18 | Steam | 30 | 7.73 ± 0.11 d | 7.73 ± 0.11 d |
| Previously | 5/29/18 | Steam | 30 | 7.93 ± .011 cd | 7.93 ± 0.11 cd |
| Frozen | | | | | |
| Previously | 6/07/18 | Boil | 15 | 8.63 ± 0.21 b | 8.63 ± 0.21 b |
| Frozen | | | | | |
| Fresh | 6/07/18 | Steam | 30 | 8.70 ± 0.10 b | 8.70 ± 0.10 b |
| Previously | 6/07/18 | Steam | 30 | 8.80 ± 0.30 b | 8.80 ± 0.30 b |
| Frozen | | | | | |
| Control | NA | NA | NA | 9.30 ± 0.20 a | 9.30 ± 0.20 a |
| (Vegetable | | | | | |
| Broth) ^b | | | | | |

^a Means \pm standard deviation (n = 3), values not sharing a letter are significantly different within columns (Tukey's HSD, $p \le 0.05$).

^b Broths used for sensory evaluation.

4.7 Sodium

Sodium occurs naturally in many foods and is also added in the form of salt (NaCl) or

other sodium-containing substances. The sodium analyses completed for this study

looked at free Na levels in the sugar kelp and vegetable broths. The broth with the highest amount of sodium was the vegetable broth control which had 40% less sodium than the original version of the vegetable broth (Table 4.12). The next highest amount of sodium was found in the broth that used sugar kelp from May 29th, 2018 and was boiled for 15 minutes (Table 4.12). However, this broth had 80% less sodium than the vegetable broth control (Table 4.12) Within the experimental broths, those boiled for 15 minutes using previously frozen sugar kelp, overall, contained the highest levels of sodium followed by those steamed for 30 minutes using previously frozen sugar kelp and those steamed for 30 minutes using fresh sugar kelp (Table 4.12). The broths used in the sensory evaluation had a wide range of sodium levels. The low levels of sodium in the kelp broths may have impacted the hedonic scores considering most Americans consume 1500 to 2000 mg of sodium per day above the recommended maximum limit (U.S., 2015). Since consumers may be used to diets high in sodium, tasting a product that is significantly lower in sodium might result in the product being bland or unpleasing to them.

Table 4.12 Sodium Analysis of Sugar Kelp and Vegetable Broths

| Type of Sugar | Date | Cooking | Cooking Time | Sodium (mg/g) ^a |
|---------------------|-----------|---------|--------------|----------------------------|
| Kelp | Harvested | Method | (Minutes) | |
| Previously | 4/20/18 | Boil | 15 | 0.288 ±3.82 de |
| Frozen ^b | | | | |
| Previously | 4/20/18 | Steam | 30 | 0.347 ± 7.66 b |
| Frozen ^b | | | | |
| Previously | 5/29/18 | Boil | 15 | 0.356 ± 13.40 b |
| Frozen | | | | |
| Fresh ^b | 5/29/18 | Steam | 30 | 0.269 ± 5.14 e |
| Previously | 5/29/18 | Steam | 30 | 0.268 ± 5.46 e |
| Frozen | | | | |
| Previously | 6/07/18 | Boil | 15 | 0.355 ± 8.55 b |
| Frozen | | | | |
| Fresh | 6/07/18 | Steam | 30 | 0.304 ± 7.78 cd |
| Previously | 6/07/18 | Steam | 30 | 0.318 ± 3.89 c |
| Frozen | | | | |
| Control | NA | NA | NA | 1.859 ± 9.53 a |
| (Vegetable | | | | |
| Broth) ^b | | | | |

^a Means ± standard deviation (n = 3), values not sharing a letter are significantly different (Tukey's HSD, $p \le 0.05$)

^b Broths used for sensory evaluation

4.8 Glutamic Acid

Glutamic acid is one of the naturally occurring amino acids in foods and also provides the umami flavor that some define as meaty or savory. The glutamic acid analyses completed for this study looked at the extracted glutamic acid from the sugar kelp and other vegetables in the broths. The broth with the highest amount of glutamic acid was the vegetable broth control because the vegetable broth was made with multiple vegetables with containing different amounts of glutamic acid while the experimental sugar kelp broths only utilized sugar kelp as a source of glutamic acid (Table 4.13). The next highest amount of glutamic acid was found in both broths that used sugar kelp from April 20, 2018 (Table 4.13). The rest of the experimental broths had glutamic acid levels of less than 0.1 g/100g and generally decreased with later dates (Table 4.13) These results follow true to what was in another study, that glutamic acid levels in sugar kelp decrease later into the harvesting season (Marinho et al., 2015). Two of the experimental broths had no glutamic acid present according to the method used in this study. However, since the levels of glutamic acids were so minuscule any slight mistake in using the pipette may have caused the zero results. The broths used in the sensory evaluation had a range of 0 to 1.54 g/100g of glutamic acid. This low level may have impacted the hedonic score considering that the glutamic acid provides umami flavor which is desirable in foods and those that lack it may taste underwhelming. Sugar kelp itself has a range of glutamic acid from 1.3 to 10.8 g/100g throughout the harvesting season meaning that not all the glutamic acid found in the sugar kelp was extracted into

the broth (Marinho et al., 2015). Also, it could mean that not all the glutamic acid found in sugar kelp is in a free form and some may be peptide-bound.

| Type of Sugar | Date Harvested | Cooking | Cooking | Glutamic Acid |
|---------------------|----------------|---------|-----------|-----------------------|
| Kelp | | Method | Time | (g/100g) ^a |
| | | | (Minutes) | |
| Previously | 4/20/18 | Boil | 15 | 0.22 ± 0.03 b |
| Frozen ^b | | | | |
| Previously | 4/20/18 | Steam | 30 | 0.23 ± 0.00 b |
| Frozen ^b | | | | |
| Previously | 5/29/18 | Boil | 15 | 0.06 ± 0.03 b |
| Frozen | | | | |
| Fresh ^b | 5/29/18 | Steam | 30 | Not Detected |
| Previously | 5/29/18 | Steam | 30 | Not Detected |
| Frozen | | | | |
| Previously | 6/07/18 | Boil | 15 | 0.05 ± 0.04 b |
| Frozen | | | | |
| Fresh | 6/07/18 | Steam | 30 | 0.05 ± 0.03 b |
| Previously | 6/07/18 | Steam | 30 | 0.02 ± 0.01 b |
| Frozen | | | | |
| Control | NA | NA | NA | 1.54 ± 1.26 a |
| (Vegetable | | | | |
| Broth) ^b | | | | |

Table 4.13 Glutamic Acid Analysis of Sugar Kelp and Vegetable Broths

^a Means \pm standard deviation (n=2), values not sharing a letter are significantly different (Tukey's HSD, p≤0.05).

^b Broths used for sensory evaluation.

4.9 Total Solids

Total solids calculations are used to measure the amount of suspended and dissolved solids in water. The total solids percentage is gathered by completing a moisture assay to understand how much of the broth is water or liquid-based versus solid particles. The vegetable broth control had the highest percentage of total solids (Table 4.14). This is because the vegetable broth contains more dissolved and suspended solids including; salt, onion and garlic powder and xanthan gum while the experimental sugar kelp broths only contained sugar kelp and water resulting in less total solids. The broths that had the next highest total solids, overall, were made from sugar kelp harvested on May 29th, 2018 (Table 4.14). However, there were no significant differences between the broths made with sugar kelp harvested on April 20th, 2018 and June 7th, 2018 (Table 4.14). Though all the broths had only a small number of total solids, they all still had some sediment that was noticeable during the sensory analysis. The sediment could have factored into the scoring of the appearance of the broths on the hedonic scale (Table 4.3). Completing a total solids analysis for any product can be difficult to achieve accurate and precise calculations. Since the amounts were so small many things could have thrown them off including the humidity in the room or if the seal on the desiccator was not tight. Though all of the standard deviations were low, there is still a possibility for inaccurate data when completing this analysis.

Table 4.14 Total Solids Analysis of Sugar Kelp and Vegetable Broths

| Type of Sugar | Date | Cooking | Cooking Time | % Total solids |
|---------------------|-----------|---------|--------------|----------------|
| Kelp | Harvested | Method | (Minutes) | (w/w) ª |
| Previously | 4/20/18 | Boil | 15 | 0.83 ± 0.02 de |
| Frozen ^b | | | | |
| Previously | 4/20/18 | Steam | 30 | 0.84 ± 0.02 de |
| Frozen ^b | | | | |
| Previously | 5/29/18 | Boil | 15 | 1.25 ± 0.02 b |
| Frozen | | | | |
| Fresh ^b | 5/29/18 | Steam | 30 | 0.90 ± 0.05 cd |
| Previously | 5/29/18 | Steam | 30 | 0.95 ± 0.004 c |
| Frozen | | | | |
| Previously | 6/07/18 | Boil | 15 | 0.84 ± 0.02 de |
| Frozen | | | | |
| Fresh | 6/07/18 | Steam | 30 | 0.76 ± 0.03 e |
| Previously | 6/07/18 | Steam | 30 | 0.88 ± 0.01 cd |
| Frozen | | | | |
| Control | NA | NA | NA | 2.64 ± 0.07 a |
| (Vegetable | | | | |
| Broth) ^b | | | | |

^a Means \pm standard deviation (n = 3), values not sharing a letter are significantly different (Tukey's HSD, p≤0.05).

^b Broths used for sensory evaluation.

4.10 Sensory Attributes, Chemical, and Physical Properties

Many factors can go into why panelists select certain hedonic scores for certain

attributes. A Pearson correlation was done between the hedonic attributes' mean

scores, and the chemical and physical properties mean values for the four broths used in

the sensory evaluation. Appearance was negatively correlated with sodium content,

glutamic acid levels, and total solids (Table 4.15). Total solids or any free-floating particles could have had a negative impact on overall appearance hedonic score. Aroma was positively correlated with sodium content and total solids (Table 4.15). Flavor was positively correlated with sodium content, glutamic acid levels, and total solids (Table 4.15). Glutamic acid contributes to flavor perception and could have had a positive impact on overall flavor. Overall acceptability was positively correlated with sodium content, glutamic acid levels, and total solids (Table 4.15). Since overall acceptability was highly correlated to flavor, this could have impacted the correlation between glutamic acid content and overall acceptability (Table 4.6). No sensory attributes were correlated with lightness (L* values), pH, or viscosity (Table 4.15). Lightness (L* values) was positively correlated with viscosity and glutamic acid content (Table 4.15). Glutamic acid was positively correlated with sodium content and total solids (Table 4.15), possibly because glutamic acid was measured as part of total solids. Total solids were positively correlated with sodium content (Table 4.15).

Table 4.15 Pearson Correlation Coefficients for Sensory Attributes, Chemical, and Physical Properties ^a

| | Color | рН | Viscosity | Sodium | Glutamic | Total |
|--------------|-------------------|-------|-------------------|--------------------|--------------------|--------------------|
| | (L* Values) | | | | Acid | Solids |
| Appearance | -0.89 | 0.85 | -0.77 | -0.99 ^b | -0.96 ^b | -0.99 ^b |
| Aroma | 0.85 | -0.89 | 0.74 | 0.97 ^b | 0.95 | 0.99 ^b |
| Flavor | 0.92 | -0.93 | 0.85 | 0.99 ^b | 0.98 ^b | 0.99 ^b |
| Thickness | -0.41 | 0.80 | -0.29 | -0.67 | -0.61 | -0.71 |
| Overall | 0.91 | -0.92 | 0.84 | 0.99 ^b | 0.98 ^b | 0.99 ^b |
| Color | 1 | -0.77 | 0.97 ^b | 0.95 | 0.97 ^b | 0.92 |
| (L* Values) | | | | | | |
| рН | -0.77 | 1 | -0.76 | -0.86 | -0.87 | -0.87 |
| Viscosity | 0.97 ^b | -0.76 | 1 | 0.86 | 0.92 | 0.83 |
| Sodium | 0.95 | -0.86 | 0.86 | 1 | 0.99 ^b | 0.99 ^b |
| Glutamic | 0.97 ^b | -0.87 | 0.92 | 0.99 ^b | 1 | 0.98 ^b |
| Acid | | | | | | |
| Total Solids | 0.92 | -0.87 | 0.83 | 0.99 ^b | 0.98 ^b | 1 |

^a Correlations were based on the mean scores of the four broths used for sensory evaluation.

^b Indicates values had a p-value ≤ 0.05 .

CHAPTER FIVE

CONCLUSIONS

Seaweed has been around for many thousands of years and has had many uses including medicine, fertilizer, and even fashion as it was used in leis. Seaweed did not become known as food until around 2000 years ago in Japan, Korea, and China. Now seaweed can be found all over the globe with many diverse uses from biofuels to cosmetics. Even though seaweed now is utilized by many different industries, some consumers still find that trying new seaweed food products is a challenge. While there are new seaweed-based food products coming onto shelves regularly, some consumers may still find them too exotic or novel. However, there are a few key terms that tend to sway some opinions towards wanting to purchase seaweed-based products such as "health benefits" and "local." This study examined the feasibility of creating a locallysourced seaweed broth to help benefit the economy of Maine farms.

Broth is a very common food ingredient in most restaurants around the world and has a variety of uses. Broth is usually made from food items that are byproducts of other recipes such as vegetable peels, animal bones and meat, or other scraps that are seen as unusable for other recipes. In this study, however, fresh and previously frozen fresh sugar kelp was used instead of byproducts. This production practice leaves the opportunity for more research to be conducted on the sugar kelp that is strained out of the broth in either a second extraction of the sugar kelp or using just the sugar kelp to make a condiment with other spices and flavorings.

Food products that contain high amounts of sodium are a major concern for Americans as most Americans tend to eat much more sodium than is recommended. Excess sodium intake has been known to cause many diseases. Panelists did not rate any of the experimental sugar kelp broths a high hedonic score which may have been related to the fact that they had 80% less sodium than the low sodium vegetable broth that was used as a control. When it comes to reducing sodium in Americans' diet, there is a threshold of how much they are willing to give up before products start tasting bland. One way to increase the flavor of the experimental sugar kelp broths could have been to add more aromatics or spices to help create more depth of flavor. More research should be completed on how to reduce sodium intake by utilizing other ingredients to enhance flavors.

Before any new product gets introduced into the marketplace, consumer acceptability is assessed. Consumer acceptance is especially needed with new and novel food products like a seaweed-based broth. Significant differences were found in aroma, flavor, and overall acceptability between the sugar kelp broths and the vegetable broth control. No significant differences were found between any of the broths for appearance and thickness. There are other possible ways that the broth can be produced such as different cooking methods, amount of time, and temperatures. Also, there could be further processing done to existing broths to create more pleasing flavor profiles. However, the broths that were steamed for 30 minutes produced a transparent product with minimal (2%) product lost during the cooking process compared to the broth that was boiled (17%), making it a good candidate for further research.

Limited inferences can be made from only having 56 consumers participate in a sensory panel. Additional research needs to be conducted with a panel that is of greater size and diversity among panelists. It is also essential to understand the segment of consumers that currently use vegetable broth and how they use it. Understanding this use will allow for further testing to be done with the sugar kelp broth as part of a more complex dish such as a noodle-based soup or grain dish. There are many vegetable broths currently on the market, and they range in color from pale yellow, deep red, to even dark brown. This diversity indicates that consumers are willing to accept a wide variety of broths, but the impact of color on using broth in complex dishes should be studied.

Although viscosity was determined for this study, it should be further explored using appropriate equipment. When measuring viscosity, the percentage of torque should be over ten percent. However, there was no equipment available at the School of Food and Agriculture at the University of Maine that could reach this percentage for the broth at the time of this study. Further calculations should be conducted using the LV- 1 (61) spindle for the Brookfield DV-II+ Pro viscometer as it has more surface area than the RV-1 spindle that was used for this study. Viscosity and textures of foods have been found to be one of the many factors affecting food neophobia in consumers. Food neophobia is a complex psychological condition that impacts many consumers at varying levels. This study shows that even though the panelists had varying degrees of food neophobia, there were minimal differences between the overall acceptability of the different broths between groups. Further research should be conducted on how prior exposure to foods

impacts food neophobia, as many of the panelists have completed other sensory analyses of other seaweed-based products.

Free glutamic acid levels were also measured for this study as sugar kelp can have anywhere from 1.3 to 10.8% glutamic acid which fluctuates through the harvesting season. However, even though glutamic acid has no negative connotations, it is still closely related to MSG which is still a taboo food ingredient to some consumers. Glutamic acid also is a part of the umami flavor that some foods have. The traditional Japanese dashi flavors come from kombu, which is a kelp similar to sugar kelp, and other additional ingredients. Japan has been utilizing seaweed in food for many years while the United States has only been using it for a few years now. So even though the broth for this study was modeled after dashi, it is still an unfamiliar flavor for most Americans. The experimental broths contained a range of glutamic acid of 0 - 0.23 g/100g which is about 93% less than chicken, 69% less than commercial chicken broth, 36% less than commercial vegetable broth, and 15% less than kombu kelp (USDA, 2018). Making a broth allows for free amino acids to be extracted from whole foods without having to consume the whole food itself. Further research should be completed using other seaweeds that contain glutamic acid to understand how much glutamate/flavor can be extracted from them.

In this study, both fresh and previously frozen sugar kelp were utilized to produce the experimental broths. It was essential to look at both types of seaweed as the Maine seaweed harvesting season only lasts for about half the year. There were no significant differences found between the fresh or previously frozen sugar kelp for any attribute in

the sensory evaluation. This result is very important to the Maine economy as Maine is one of the biggest seaweed producers for the Northeastern United States and will allow seaweed to be sold and utilized throughout the state year-round. Since purchasing products that were locally sourced was important to some panelists, it would be beneficial to have locally sourced seaweed during every season. Further testing should be done to understand the frozen shelf life of seaweed to help make seaweed farming more sustainable for years to come. Additional research should also be done on how the time of harvest impacts overall acceptability as well as shelf life.

Though limited conclusions can be drawn from a sensory panel of only 56 consumers, there was still some important information gathered. One was that sugar kelp produces a comparable appearance and thickness to those vegetable broths on the market today. Another was that there were no significant differences between broth made with fresh or previously frozen sugar kelp allowing for the possibility of seaweed becoming a more sustainable crop. This research provides a premise for further research which can be administered on different cooking methods or even different types of seaweed. Next steps would include broader sensory panels not only in size but also in diversity among panelists completed across different regions of the United States. Also understanding how consumer acceptance will be impacted by the knowledge of health benefits and product sourcing of seaweed-based food products needs to be additionally established.

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APPENDIX A: SUGAR KELP BROTH INFORMED CONSENT FORM

Hello-

You are invited to take part in a M.S. thesis research by Zachary Bonelli in the University of Maine School of Food and Agriculture under the direction of Professor Mary Ellen Camire. The purpose of this test is to learn how consumers like soup broth made from Maine seaweed. If you are allergic to sugar kelp or do not like seaweed, please do not take part. You must be at least 18 years old to participate.

What Will You Be Asked to Do?

You will be served three samples of soup broth and asked to tell us about yourself and how you like the soup broth. This test will take less than 30 minutes of your time.

Risks

The risk is no greater than the normal daily eating. Other risks include inconvenience and loss of your time.

Benefits

There are no direct benefits to you, but this research may help seaweed companies find new markets.

Compensation

Persons who complete the test in full will be compensated with \$5.00.

Confidentiality

Your name will not be connected to the information that you give us. All data will be collected anonymously, stored indefinitely on a password-protected computer.

Voluntary

Participation in this study is voluntary. If you choose to take part in this study, you may stop at any time, but you will only receive the \$5.00 if you complete the test in full.

Contact Information

If you have any questions or concerns, please contact:

• Zachary Bonelli, phone: 207-581-1733, email: zachary.bonelli@maine.edu

If you have any questions about your rights as a research participant, please contact Gayle Jones, Assistant to the University of Maine's Protection of Human Subjects Review Board, phone: 207-581-1498, email: UMRIC@maine.edu

Your participation in these tests is assumed to indicate your consent.

APPENDIX B: SUGAR KELP BROTH QUESTIONNAIRE

Attribute #1 (Instruction Box)

Thank you for taking the time to participate in our research. Please evaluate the samples in the order that they are displayed to you on the computer screen (also from left to right on the tray), and take a sip of water before tasting and evaluating each sample. Please make sure that the 3-digit code matches the code on the computer screen.

Attribute #2 (All That Apply)

Please select your gender below.

 \square Male

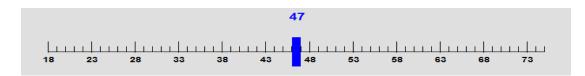
Female

□ Other

□ Prefer not to say

Attribute #3 (Line Scale)

Please select your age as if your most recent birthday.



Attribute #4 (Yes or No)

Have you eaten seaweed before?

🗆 Yes

 $\square \ No$

Attribute #5 (All That Apply)

How have you eaten seaweed before?

🗆 Sushi

□ Soup

 \Box Salad

Fresh

Snacks

□ Other (Please provide an example below)

□ I have not eaten seaweed before

Attribute #6 (Open Ended Comment)

If you selected other from above, please provide examples below.

Attribute #7 (All That Apply)

What claims are important to you on a food product/label?

- □ Health Claims (Low Sodium, 25% Daily Protein, etc.)
- □ Where it came from (Locally Sourced, Made in the USA, etc.)
- □ Dietary Choices (Vegan, Vegetarian, etc.)
- □ Ingredients (Amount of, Easy to Read Words, etc.)
- □ Nutrition Facts Label (Calories, Serving Size, etc.)

Attribute #8 (Page Break)

Attributes 9-14 were shown four times once for each sample used in this sensory evaluation

Attribute #9 (Hedonic scale)

Please rate the appearance of the sample below.

| Dislike | Dislike | Dislike | Dislike | Neither | Like | Like | Like | Like |
|-----------|---------|------------|----------|---------|----------|------------|------|-----------|
| Extremely | Very | Moderately | Slightly | Like or | Slightly | Moderately | Very | Extremely |
| | Much | | | Dislike | | | Much | |
| | | | | | | | | |

Attribute #10 (Hedonic Scale)

Please rate the aroma of the sample below.

| Dislike | Dislike | Dislike | Dislike | Neither | Like | Like | Like | Like |
|-----------|---------|------------|----------|---------|----------|------------|------|-----------|
| Extremely | Very | Moderately | Slightly | Like or | Slightly | Moderately | Very | Extremely |
| | Much | | | Dislike | | | Much | |
| | [| | | | | | | |

Attribute #11 (Hedonic Scale)

Please rate the flavor of the sample below.

| Dislike | Dislike | Dislike | Dislike | Neither | Like | Like | Like | Like |
|-----------|---------|------------|----------|---------|----------|------------|------|-----------|
| Extremely | Very | Moderately | Slightly | Like or | Slightly | Moderately | Very | Extremely |
| | Much | | | Dislike | | | Much | |
| | | | | | | | | |

Attribute #12 (JAR Scale)

How would you describe the thickness of the sample below?

| Much Too Thin | Little Too Thin | Just Right | Little Too Thick | Much Too Thick |
|---------------|-----------------|------------|------------------|----------------|
| | | | | |

Attribute #13 (Hedonic Scale)

Please rate the overall acceptability of the sample below.

| Dislike Extremely | Dislike Very | Dislike Moderately | Dislike Slightly | Neither Like or | Like Slightly | Like Moderately | Like Very | Like Extremely |
|----------------------|-----------------|-----------------------|---------------------|--------------------|------------------|--------------------|--------------|-------------------|
| | Much | | υ, | Dislike | 0, | , | Much | |
| | | | | | | | | |

Attribute #14 (Open Ended Comment)

Please leave any additional comments below.

Attribute #15 (Page Break)

Attribute #16 (Food Neophobia Scale) R

I am constantly sampling new and different foods.

| Agree Extremely | Agree Moderately | Agree Slightly | Neither Agree or Disagree | Disagree Slightly | Disagree Moderately | Disagree Extremely |
|--------------------|---------------------|-------------------|---------------------------------|----------------------|------------------------|-----------------------|
| | | | | | | |

R denotes that the question is reverse scored.

Attribute #17 (Food Neophobia Scale)

I don't trust new foods.

| Agree Extremely | Agree Moderately | Agree Slightly | Neither Agree or Disagree | Disagree Slightly | Disagree Moderately | Disagree Extremely |
|--------------------|---------------------|-------------------|---------------------------------|----------------------|------------------------|-----------------------|
| | | | | | | |

Attribute #18 (Food Neophobia Scale)

If I don't know what is in a food, I won't try it.

| Agree Extremely | Agree Moderately | Agree Slightly | Neither Agree or Disagree | Disagree Slightly | Disagree Moderately | Disagree Extremely |
|--------------------|---------------------|-------------------|---------------------------------|----------------------|------------------------|-----------------------|
| | | | | | | |

Attribute #19 (Food Neophobia Scale) R

I like foods from different countries.

| Agree Extremely | Agree Moderately | Agree Slightly | Neither Agree or Disagree | Disagree Slightly | Disagree Moderately | Disagree Extremely |
|--------------------|---------------------|-------------------|---------------------------------|----------------------|------------------------|-----------------------|
| | | | | | | |

R denotes that the question is reverse scored.

Attribute #20 (Food Neophobia Scale)

I find ethnic food too weird to eat.

| Agree Extremely | Agree Moderately | Agree Slightly | Neither Agree or Disagree | Disagree Slightly | Disagree Moderately | Disagree Extremely |
|--------------------|---------------------|-------------------|---------------------------------|----------------------|------------------------|-----------------------|
| | | | | | | |

Attribute #21 (Food Neophobia Scale) R

At dinner parties, I will try new food.

| Agree Extremely | Agree Moderately | Agree Slightly | Neither Agree or Disagree | Disagree Slightly | Disagree Moderately | Disagree Extremely |
|--------------------|---------------------|-------------------|---------------------------------|----------------------|------------------------|-----------------------|
| | | | | | | |

R denotes that the question is reverse scored.

Attribute #22 (Food Neophobia Scale)

I am afraid to eat things I have never tried before.

| Agree Extremely | Agree Moderately | Agree Slightly | Neither Agree or Disagree | Disagree Slightly | Disagree Moderately | Disagree Extremely |
|--------------------|---------------------|-------------------|---------------------------------|----------------------|------------------------|-----------------------|
| | | | | | | |

Attribute #23 (Food Neophobia Scale)

I am very particular about the foods I eat.

| Agree Extremely | Agree Moderately | Agree Slightly | Neither Agree or Disagree | Disagree Slightly | Disagree Moderately | Disagree Extremely |
|--------------------|---------------------|-------------------|---------------------------------|----------------------|------------------------|-----------------------|
| | | | | | | |

Attribute #24 (Food Neophobia Scale) R

I will eat almost anything.

| Agree Extremely | Agree Moderately | Agree Slightly | Neither Agree or Disagree | Disagree Slightly | Disagree Moderately | Disagree Extremely |
|--------------------|---------------------|-------------------|---------------------------------|----------------------|------------------------|-----------------------|
| | | | | | | |

R denotes that the question is reverse scored.

Attribute #25 (Food Neophobia Scale) R

I like to try new ethnic restaurants.

| Agree Extremely | Agree Moderately | Agree Slightly | Neither Agree or Disagree | Disagree Slightly | Disagree Moderately | Disagree Extremely |
|--------------------|---------------------|-------------------|---------------------------------|----------------------|------------------------|-----------------------|
| | | | | | | |

R denotes that the question is reverse scored.

Attribute #26 (Page Break)

Attribute #27 (Instruction Box)

Thank you for participating in this study. Please raise your window slightly and return your tablet computer and mouse to receive your \$5.00.

APPENDIX C: SUGAR KELP BROTH TESTING RECRUITMENT NOTICE

If you are at least 18 years old and like sugar kelp, please help University of Maine researchers evaluate sugar kelp soup broths as part of a M.S. thesis research project for Zachary Bonelli to help seaweed farmers create more market opportunities and develop more foods using local Maine ingredients. If you do not like seaweed or have an allergy to sugar kelp, please do not participate.

Testing will take no more than 30 minutes to complete. Participants will be

compensated with

\$5.00 for completing the test.

If you do not like seaweed or have an allergy to sugar kelp, please do not participate.

Please refrain from eating or drinking anything other than water for at least one hour before testing.

If you are willing and able to participate, please reserve a testing time on our poll:

[Scheduling URL] https://doodle.com/poll/vp3utypvmwrbyz6c

When? Testing will be held on Wednesday, May 30th 3:00 pm until 5:30 pm, and Thursday, May 31st 11:00 am until 3:00 pm

Where? The Sensory Evaluation Center located in Hitchner Hall (Room 158A and 158B) at The University of Maine.

If you have any questions, please contact Zachary Bonelli at zachary.bonelli@maine.edu or 207-581-1733 for more information.

BIOGRAPHY OF THE AUTHOR

Zachary Bonelli was born in Philadelphia, Pennsylvania. He was raised in Clementon, New Jersey and graduated from Highland High School in Blackwood, New Jersey in 2012. He completed his Associate degree in Culinary Arts from Johnson & Wales University in Providence, Rhode Island. He was then accepted into the Johnson & Wales University Culinary Nutrition program. He graduated magna cum laude with his Bachelor of Science in Culinary Nutrition with a concentration in Food Science in May 2016 as a member of Omicron Delta Kappa Honors Society. That same year he was accepted into the University of Maine Graduate School. Zachary is a member of Kappa Omicron Nu Honors Society on campus. He is a candidate for the Master of Science degree in Food Science and Human Nutrition from the University of Maine in August 2018.