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Consumer Acceptability of Gulf of Maine Sugar Kelp Seaweed in Baked Bread

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CONSUMER ACCEPTABILITY OF GULF OF MAINE SUGAR KELP SEAWEED IN BAKED BREAD

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Thesis Advisor: Dr. Mary Ellen Camire

An Abstract of the Thesis Presented
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Although steady interest in edible seaweed cultivation continues to grow in Maine, research is lacking regarding consumer preferences and purchasing behavior of seaweed-containing products. The purpose of this study was to determine consumer acceptability of seaweed baked bread and provide insights into purchasing behavior to reveal potential consumer groups that are most likely to buy and eat baked products containing seaweed. Consumer preferences were determined by a sensory evaluation test and an online survey.

Sixty-five participants completed the central location test of freshly-baked bread containing seaweed. Participants were required to be at least 18 years of age, willing to eat bread containing seaweed, and have no known allergies or sensitives to bread ingredients. The three experimental formulations, baked by Big Sky Bread Company, contained sugar kelp meal, sugar kelp flakes, or sugar kelp powder. All kelp products were added as 5% of the weight of flour in a basic white bread recipe. The bread was baked into traditional-sized loaves and sliced by the baker to yield 31 slices. The 9-point hedonic scale was utilized to rate the acceptability of appearance, color, aroma, taste, texture, and overall acceptability. Statistically significant differences ($p < 0.05$) were found between the seaweed meal and powder bread formulations for all six hedonic attributes. The seaweed flake bread formulation was also liked significantly more

than the seaweed powder formulation was for aroma, taste, and overall acceptability. However, it was not found to be statistically different from the seaweed meal formulation. Mean scores for the flake and meal slices of bread ranged from 6.6 - 7.5 (slightly to moderately acceptable). Penalty analysis for Just About Right (JAR) scores related to particle size confirmed consumer's inferred preferences and adjusted overall liking for the seaweed meal bread formulation overall. While only 52% of the consumers would consider buying the seaweed powder bread, over 85% said they would purchase the seaweed flake and meal bread formulations.

An online consumer survey was launched in August 2019. A total of 3,626 people met the inclusion criteria by being 18 years of age or older, living within the U.S., and willing to participate and complete the online survey. Dynata recruited and continually screened participants during the data collection period to meet goals for gender, age, and regional geographic distribution. Data points were analyzed for relationships among consumer interest and seaweed consumption with demographic traits. Seaweed consumption, willingness and frequency of buying seaweed bread, and higher price points had positive associations with younger age, higher income, higher education levels, and those who lived in the Mid-Atlantic, Pacific, and South-Atlantic U.S. regions. Consumers liked the appearance of bread containing the seaweed powder over the other two samples ($p < 0.0001$); these findings, however, did not agree with the results for the sensory evaluation test. The development of low-moisture seaweed products, such as baked bread, shows promise in overall consumer acceptability, which may prove helpful in future product innovations and marketing strategies.

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CHAPTER ONE

INTRODUCTION

Aquaculture is the fastest-growing food production sector in the world, increasing 5.8% annually between 2001 and 2016 (Food and Agriculture Organization of the United Nations [FAO], 2018b). Seaweed accounted for 27% of the global aquaculture production in 2016, making macroalgae among the most significant cultivated marine organisms worldwide (FAO, 2018b; Barsanti & Gualtieri, 2014). Global production of seaweed continues to grow in volume with the largest producers of cultured species including China, Indonesia, and the Philippines (Food and Agriculture Organization of the United Nations [FAO], 2018a). Whereas, the largest producers of wild-harvested species include Chile, China, and Norway (FAO, 2018a). Domestically, the production of edible farmed and wild-harvested seaweed also continues to grow. In Maine, 2019 harvests were more than four times greater than that of 2015 harvests (Piconi et al., 2020).

Several species of seaweed are harvested from the Maine coastline, including the first commercial seaweed crop to be cultivated in 2010, sugar kelp (*Saccharina latissima*) (Maine Sea Grant, 2018; Augyte et al., 2017). Maine represents a valued and established local-regional brand known for its high-quality cold, clean waters. Researchers in Spain found that consumers are increasingly looking to spend more on fresh, local, and sustainably sourced foods where strong local identity and commitment to the region exists (Fernandez-Ferrin et al., 2018). Additionally, there is an increased need for environmentally-sustainable, nutrient-rich foods that will nourish the projected growing world population of 9.5 billion people by the year 2050 (United Nations [U.N.], 2019). Piconi and colleagues (2020) predict that Maine edible seaweed farms will grow from their current cultivation of 325,000 pounds per year (wet weight) to approximately 1.24

million pounds per year (wet weight) in the next five years (Piconi et al., 2020). This expansion would increase the harvest value of farmed seaweed from $195,000 to $1.26 million per year (Piconi et al., 2020).

In addition to its potential positive impact on the state's economy and its status as a local Maine food product, seaweed is also valued for its nutritional content. It is important to note that the amount of nutrients varies by species, geographic location, processing, and environmental factors, such as salinity, light exposure, temperature, and the season (Rioux et al., 2017; Roleda & Hurd, 2019; Wells et al., 2017). Most edible algae, such as sugar kelp (*Saccharina latissima*), are excellent sources of dietary fiber and contain all essential amino acids, polyunsaturated fatty acids, vitamins, and minerals needed to support life (Cherry et al., 2019; Rioux et al., 2017; Shannon & Abu-Ghannam, 2019; Wells et al., 2017). Common vitamins found in edible algae include A, E, K, and water-soluble vitamins C, thiamin (B_1), riboflavin (B_2), niacin (B_3), pyridoxine (B_6), folate (B_9), and cobalamin (B_{12}). Minerals in seaweed include potassium, iron, calcium, magnesium, zinc, and iodine (Cherry et al., 2019; Rioux et al., 2017; Shannon & Abu-Ghannam, 2019; Wells et al., 2017). Daily iodine requirements of 150 µg per day can easily be met by the consumption of small quantities of seaweed. According to the World Health Organization (WHO) (2013), iodine deficiency is the most preventable cause of brain damage and impaired cognitive development in children worldwide. In addition to a rich macro- and micronutrient profile, seaweed also contains bioactive compounds, such as antioxidants and phytochemicals that are not found readily in terrestrial plants and may reduce risk of chronic diseases when consumed (Brown et al., 2014; Cherry et al., 2019; Holdt & Kraan, 2010; Rioux et al., 2017; Shannon & Abu-Ghannam, 2019; Salehi et al., 2019; Wells et al., 2017; Zuckerbrot, 2014).

Seaweed has been consumed and used as medicine as far back as 14,000 years before the present (Dillehay et al., 2008). Seaweed can provide rich texture and flavor to food, mainly attributed to the amino acid glutamate that enhances the umami taste in food products (Rico et al., 2018). Seaweed, in the form of extracted complex polysaccharides, is currently found in more food products then commonly recognized. The most well-known and widely consumed being carrageenan from red seaweed, such as *Chondrus crispus*. Carrageenan is used as a thickening agent in bakery products, salad dressings, ice creams, toothpaste, dairy products (i.e., chocolate milk and heavy cream), chewing gum, processed desserts, and more (FAO, 2018a). Carrageenan is also commonly used within the pharmaceutical industry as binders, stabilizers, and emulsifiers (FAO, 2018a).

Funding was awarded to VitaminSea Seaweed, LLC, by the USDA through the National Institute of Food and Agriculture's SBIR grant program. Atlantic Corporation and the University of Maine are subcontractors on the grant. Funding included the online consumer survey and sensory evaluation test for this research project. The objective of VitaminSea Seaweed, LLC's United States Department of Agriculture (USDA) Small Business Innovation Research (SBIR) project (Phase I and II), is to develop a sugar kelp-based ingredient that is acceptable to consumers in low-moisture foods, such as bread. The direct benefit of increased utilization of Maine seaweed in baked products to Maine small business owners and harvesters within the aquaculture industry would include increased demand and potential markets. The direct benefit to consumers is a product with increased shelf-life and nutritional content. Furthermore, the direct benefit to VitaminSea Seaweed, LLC, would be increased demand for their dehydrated seaweed products.

Building upon the results from the Phase I preliminary evaluations and consumer sensory acceptance of seaweed incorporated into freshly-baked French bread, VitaminSea Seaweed, LLC, in conjunction with Atlantic Corporation and the University of Maine, launched into Phase II of the SBIR grant cycle. Consumer acceptance assessments were determined by a sensory evaluation test and an online survey. The 9-point hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely) was utilized to rate the appearance, color, aroma, taste, texture, and overall acceptability of bread containing different seaweed particle sizes (Peryam & Pilgrim, 1957).

CHAPTER TWO

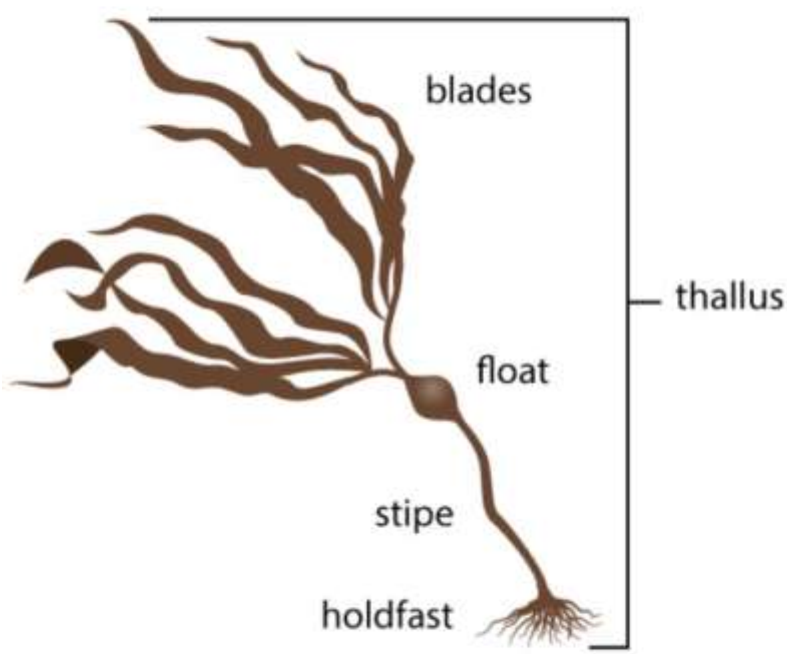
LITERATURE REVIEW

2.1 Marine algae “seaweed”

Seaweed, otherwise known as macroalgae, grow in coastal climatic zones worldwide. The word ‘algae’ is used to classify a large group of heterogenous organisms that do not have a specific taxonomic status (Singh & Singh, 2015). Over 35,000 species of algae, both terrestrial and aquatic, have been discovered and classified in a wealth of colors, shapes, and sizes (Mouritsen, 2013). Aquatic algae are found in both fresh and saltwater, and similar to terrestrial plants, produce carbohydrates and energy through photosynthesis. Of the 35,000 species of algae, 10,000 species of seaweed have been discovered from the equatorial tropics to the polar regions around the world (Mac Monagail et al., 2017; Mouritsen, 2013). For this research, marine macroalgae will be explicitly discussed, henceforth referred to as seaweed.

Although seaweed, like plants, take on many distinct shapes and structures, the four basic parts consist of a holdfast, stipe, blade, and pneumatocyst (Figure 2.1). The structure as a whole is called the thallus (Hu & Fraser, 2016). Seaweeds have no use for a root system as they do not need to take in water or nutrients like land plants do from the soil. Chemical exchanges occur directly across the surface of the seaweed by passive diffusion and active transport (Roleda & Hurd, 2019). Some seaweeds do, however, have a holdfast, which acts as an anchor to firm substrates such as rocks, other marine organisms, or the seabed itself. The majority of seaweed is found in the intertidal zones in transitional coastal regions where cycling tides, waves, and wind along rocky shores and sandy beaches are the most powerful influencing factors (Hu & Fraser, 2016). Some species, such as sea lettuce (*Ulva lactuca*), are entirely free-floating organisms similar to plankton. The stipe, relative to a plant's stem, supports and adds structure to the seaweed. Unlike a plant, however, most seaweed stipes do not have a vascular purpose or nutrient transport function (Hu & Fraser, 2016). Photosynthesis takes place primarily in the blade of the seaweed. Seaweeds may have a single blade, such as sugar kelp (*Saccharina latissima*), or many blades, such as dulse (*Palmaria palmata)*. The stipe must be long enough to position the blade close to the water's surface to reach the light for photosynthesis to occur (Hu & Fraser, 2016). Another way to accomplish this is by having pneumatocysts or bladder floats. Some species of seaweed have air-filled bladders, such as bladderwrack (*Fucus vesiculosus*), that position the blades upright in the water column to reach the light from above (Hu & Fraser, 2016). Photosynthesis allows the formation of glucose from the conversion of light energy from the sun.

Figure 2.1 Diagram showing general seaweed morphology (Inouye, 2019)



There are three different groups of seaweed: brown macroalgae (*Phaeophyta*), red macroalgae (*Rhodophyta*), and green macroalgae (*Chlorophyta*). Distinctions between the three groups revolve around pigments, carbohydrate storage chemicals, and cell wall structure (Singh & Singh, 2015). All species of seaweed contain chlorophyll, but this color is often masked by other pigments, resulting in brown, red, and yellowish tones (Singh & Singh, 2015). Many species of seaweed are surprisingly durable and can withstand being dried out, tolerate exposure to frost, or subject to considerable fluctuations in temperature and salt concentrations.

2.1.1 Sugar Kelp (*Saccharina latissima*)

Belonging to the biological order Laminariales, mature sugar kelp (*Saccharina latissima*) can vary in size from five to twenty-five feet long and ten to twenty inches wide (Bolton, 2010; Breton et al., 2018). The brown seaweed is anchored by a sizeable branched holdfast and stabilized by a hollow stipe, which helps the blade float in the water current. The blade consists of a single, undivided, flat olive to golden brown structure with ruffled edges (Sappati et al., 2019). Sugar kelp derives its name from the natural sugar mannitol it exudes when dried, which is sweet (Hurd et al., 2014; Kim & Bhatnagar, 2011; MacArtain et al., 2007).

This species of kelp is considered a perennial and can grow for several years. Although it usually completes its growth in less than a year, from October to May, when it is typically harvested (Borum et al., 2002; Breton et al., 2018; Sappati et al., 2019). Sugar kelp prefers cooler climates with clean, cold waters. In the Northern hemisphere, kelp reaches its peak growth rate in February when competition for nutrients is low, making it a ‘Winter’ crop (Hurd et al., 2014). Its preferred habitat is near the shore in the subtidal zone of protected bays, coves, and estuaries forming dense beds or ‘kelp forests’ (Bolton, 2010; Breton et al., 2018). Giant kelp forests help create safe, calm ecosystems and nurseries for small fish and shellfish. Sugar kelp can tolerate brackish water, tidepools, strong currents, and even depths of sixty feet or more (Bolton, 2010).

Sugar kelp is harvested when the blade is a translucent golden brown with little to no dark spores (Flavin et al., 2013; Mac Monagail et al., 2017). The blade is cut approximately six inches above the point where the blade joins the stipe to allow for regeneration (Flavin et al., 2013). The harvest season typically runs from March through June, but can ultimately depend on water temperature, depth of the bed, currents, and appearance (Flavin et al., 2013).

After the kelp is harvested, it is traditionally rinsed and dried, typically in the sun, then pressed and packaged whole, processed into pieces, or ground into coarse granules (Flavin et al., 2013). Some Maine companies are now processing fresh kelp directly without drying. Due to its tough texture and high iodine content, kelp is often blanched before consumption. Sugar kelp is often incorporated into soups, salads, baked goods, and snacks to enhance flavor and nutrition (Griffin & Warner, 2017). Sugar kelp has also been found to be a good substitute for other seaweeds in recipes (Griffin & Warner, 2017). Kelp contains large quantities of monosodium glutamate, which gives it the classic umami taste one expects from seaweed (Rioux et al., 2017).

Umami is the fifth taste of ‘savory,’ alongside sweet, salty, sour, and bitter. Although Japanese chemist Kikunae Ikeda revealed the discovery of umami as the fifth basic taste in 1909, it was not officially recognized by the scientific community until 1985 (Ikeda, 1909; Kurihara, 2015). The umami taste is mainly attributed to the amino acid glutamate, an ester of glutamic acid that enhances the umami taste in food products (Rico et al., 2018). However, there are many other compounds associated with the umami taste, such as the amino acid aspartic acid, umami peptides, the organic acid succinic acid, and disodium 5’-nucleotides, mainly 5’-inosinate (IMP), 5’-guanylate (GMP), and 5’-adenylate (AMP) (Zhao et al., 2019).

Kelp has high amounts of glutamic acid (1,608 mg/100g), compared to beef (10 mg/100g), chicken (22 mg/100g), and scallops (140 mg/100g) (Yamaguchi & Ninomiya, 2000). Other foods that have high levels of glutamic acid include soy sauce (~846 mg/100g), fish sauce (~977 mg/100g), and parmesan cheese (1,680 mg/100g) (Yamaguchi & Ninomiya, 2000). Between 30.2% - 52.1% of sugar kelp's amino acid profile consists of glutamic and aspartic acid (Bak et al., 2019). However, the glutamic acid content of sugar kelp fluctuates with the season with a higher concentration in the Winter months and a lower concentration in the Summer months (Bak et al., 2019).

Kombu, an edible kelp from the Laminariaceae family, was first used to extract glutamate and its monosodium salt, termed monosodium glutamate (MSG) (Zhao et al., 2019). Although food lovers covet the umami taste, there is controversy over MSG as an added ingredient to elicit umami taste in foods. The United States Food and Drug Administration (FDA) has classified MSG as "generally recognized as safe" or GRAS (United States Food and Drug Administration [U.S. FDA], 2012; Zanfirescu et al., 2019). However, many still question the safety of MSG and the adverse reactions it is reported to cause. Symptoms of MSG symptom complex include burning sensation, facial pressure and tightness, chest pain, headache, nausea, palpitations, bronchospasms, and generalized weakness (Zanfirescu et al., 2019). While evidence shows large doses of MSG (>3 g/d) consumed on an empty stomach causes symptoms in sensitive individuals, one should not conclude that MSG consumed as part of a typical Western diet would likely induce symptoms (Williams & Woessner, 2009; Zanfirescu et al., 2019).

2.1.2 Seaweed: A history

Seaweed has been utilized for food, medicine, and fertilizer for thousands of years. Consumption as food and medicine dates as far back as 14,000 years before present in Chile (Dillehay et al., 2008). Seaweed remnants were discovered in hearths and other features in Monte Verde. This discovery proves early settlement of South America originated along the Pacific coast and included seaweeds as a part of their diet and health (Dillehay et al., 2008).

Seaweeds, mixed with fish bones and shell fragments, were also discovered in Chinese settlements from the Jōmon (10,500 – 300 BCE) and Yayoi (200 BCE – 200 CE) periods (Mouritsen et al., 2018; Nisizawa et al., 1987). This mixture was cooked in clay pots, similar to nabemono, a traditional hot-pot Japanese dish still eaten to this day (Mouritsen et al., 2018). The first written description of seaweed dates back to 600 BCE in China (FAO, 2018a; Pereira, 2018). The Chinese philosopher, Sze Teu, wrote that seaweed was for "most honorable guest, even the king himself" (FAO, 2018a; Pereira, 2018).

Seaweed also has close ties to Northern Europe and Nordic countries. Remnants of seaweeds, along with fish and shellfish, have been discovered in Northern coastal areas across Europe from the Mesolithic Era (9,000 – 4,000 BCE) (Mouritsen et al., 2018). The Brehon Laws of Ireland, first written down in the 5th century CE, reference the use of seaweed with bread and butter (Mouritsen et al., 2018), while written Nordic sagas reference the use of seaweeds as food as far back as the 10th century CE (Pereira, 2016). Seaweeds have also been used as fertilizer on fields and to feed livestock for thousands of years (Fleurence & Levine, 2016). In Europe, seaweed was utilized to increase nutrients in the soil as far back as the 12th century CE in Ireland (Pereira, 2016). Historic uses for seaweed as medicine, food, and fodder repeatedly are seen throughout this region for thousands of years. (FAO, 2018a; Fleurence & Levine, 2016; Mouritsen et al., 2018; Pereira, 2016).

For millennia, seaweed was widely eaten by indigenous communities across the North American continent (Pérez-Lioréns, 2019). Northwest coastal communities, such as the Kwakwake'wakw, Haida, Heiltsuk, and Tsimshian, relied on red laver and bull kelp in times of famine to provide essential vitamins and minerals (Pérez-Lioréns, 2019). Northeast indigenous people of the Iroquois, Wampanoag, and Arcadian communities consumed and preserved food with sea lettuce and red laver; from which they obtained necessary salts and trace minerals for survival (Pérez-Lioréns, 2019). The Diegueno (or Kumeyaay), Hupa, and Pomo Native Americans from present-day California consumed sun-dried seaweed, which was considered a delicacy (Pérez-Lioréns, 2019). While the Chumash's most well-known dance is a prayer to the bountiful offshore kelp forests (Onofrio, 1993).

2.2 Seaweed cultivation, harvest, and processing

There are over 250 species of seaweed in the Gulf of Maine, although only eleven are commercially harvested (Maine Sea Grant, 2018). These species include reddish-purple dulse (*Palmaria palmata*), sugar kelp (*Saccharina latissima*), horsetail kelp (*Laminaria digitate*), winged kelp (*Alaria esculenta*), sea lettuce (*Ulva lactuca*), nori (*Porphyra umbillicalis*), and rockweed (*Ascophyllum nodosum*) (Maine Sea Grant, 2018). Seaweed is cultivated and collected by wild harvest and aquaculture farms. Globally, 97% or 77 billion pounds of seaweed is currently being harvested through aquaculture (FAO, 2018a; Piconi et al., 2020). Maine is encouraging the cultivation of edible seaweed on sea farms as a way for fishermen to diversify their operations during the winter months (Redmond et al., 2016). Environmental factors, such as wind, currents, salinity, proximity to river mouths, depth, and temperature all play a vital role in seaweed farming location (De San, 2012). It is best to look for locations where the native species already grows and thrives. Kelp, for example, grows best in cold, clean waters between 5°C and 15°C (41°F – 59°F) and within a pH range of 7.0 to 9.0 (Flavin et al., 2013). Generally, seaweed farms consist of long seeded ropes with seaweed spores of a specific species. This line is then strung between two moorings that are adjusted to the correct depth and temperature for optimal growth (Satria et al., 2017). Seaweeds tend to have a faster-growing rate than that of terrestrial plants, allowing them to be produced more rapidly and more abundantly (De San, 2012).

Different types of seaweed require different harvesting practices. Traditionally, people gathered wild seaweed during low tide by hand along the seashore. Other mechanisms include raking, diving, using a boat, or mechanically harvesting (Mac Monagail et al., 2017). Kelp, for example, is best harvested on cloudy days at an air temperature between 0°C and 10°C (32°F – 50°F) to maintain quality (Flavin et al., 2013).

While some species of seaweed are eaten raw, most need to be processed in some way, usually by drying, cooking, blanching, freezing, or toasting to improve flavor (Badmus et al., 2019). Conventional methods of drying seaweed include freeze-drying, sun drying, oven drying, and humidity and temperature-controlled drying (Badmus et al., 2019; Duran-Frontera, 2017; Sappati et al., 2019). Drying helps prevent microbiological activity and oxidation, thus prolonging the seaweed's shelf-life (Badmus et al., 2019). However, drying methods can have adverse effects on the nutritional and phytochemical content of seaweed (Badmus et al., 2019). Research shows that the best method in terms of processing costs and preservation of nutritional content is drying methods that utilize lower temperatures (< 50°C) and lower humidity (Badmus et al., 2019; Duran-Frontera, 2017; Sappati et al., 2019).

Maine's edible seaweed processing infrastructure consists of two-stage processing (Piconi et al., 2020). The first stage consists of wet seaweed being dried, blanched, or frozen in preparation for further processing, and the second stage consists of the conversion of processed seaweed into consumer-ready products or dried bulk ingredients for consumer products (Piconi et al., 2020). Currently, five edible seaweed processors in Maine produce consumer-ready products from their growing operations or independent growing contractors; they include VitaminSea Seaweed, Atlantic Sea Farms, Maine Coast Sea Vegetables, Ocean's Balance, and Springtide Seaweed (Piconi et al., 2020). Gross sales of Maine wild edible seaweed products are estimated at $3.5 million in 2019 while gross sales of Maine farmed edible seaweed products are estimated at $4.6 million (Piconi et al., 2020).

2.3 Current regulations and policy in Maine

Maine law requires any individual, partnership, or corporation who wishes to engage in aquaculture requiring gear in Maine to obtain either a standard lease, an experimental lease, or a limited-purpose aquaculture license (LPA) from the Maine Department of Marine Resources (DMR) (Maine Department of Marine Resources, 2019). These leases allow individuals the ability to engage in the suspended culture of any marine organism provided they meet all DMR requirements for state and federal water quality, Endangered Species Act compliances, and navigation marking requirements by the U.S. Army Corps of Engineers and U.S. Coast Guard (Maine Department of Marine Resources, 2019). The application fee for the standard lease is $1,500 for up to ten years and is renewable (Maine Department of Marine Resources, 2019). The lease allows for up to one-hundred acres of either bottom, suspended, or both aquaculture practices and gear, and requires a rental fee of $100 per acre per year (Maine Department of

Marine Resources, 2019). There are currently 12 active standard leases cultivating a combined total of 65.4 acres (Piconi et al., 2020). Beginning aquaculturists may want to obtain a temporary lease or a limited-purpose aquaculture license (LPA). The application fee for the experimental lease is $100 for up to three years and is non-renewable (Maine Department of Marine Resources, 2019). The lease allows for up to four acres of either bottom, suspended, or both aquaculture practices and gear, and requires a rental fee of $100 per acre per year (Maine Department of Marine Resources, 2019). There are currently ten active experimental leases cultivating a combined total of 23.6 acres (Piconi et al., 2020). The application fee for the LPA is $50 for up to one calendar year and is renewable annually (Maine Department of Marine Resources, 2019). The lease allows for up to four-hundred square feet of designated types of gear in a single location (Maine Department of Marine Resources, 2019). An individual is allowed to apply for up to four LPA's per year (Piconi et al., 2020). There are currently 187 active LPA's issued to 49 different holders cultivating a combined total of 1.7 acres (Piconi et al., 2020).

For wild harvesters, Maine law currently allows anyone to harvest up to fifty pounds of wild seaweed daily for personal use (Maine Seaweed Council, 2019). Personal harvesters and businesses working under a commercial license must obtain a marine license for seaweed from the Maine Department of Marine Resources for any amount over this limit (Maine Seaweed Council, 2019). There are approximately 154 current licensed seaweed harvesters in the state of Maine (McGuire, 2019).

Seaweed has traditionally been harvested by hand along Maine's rocky coast. Despite Maine's abundant coastline of 5,400 miles, public access to the coastline is dwindling. Maine has held longstanding common law embodied in the Massachusetts Bay Colony's Colonial Ordinance of 1641-47 that allows the public to "fish, fowl, or navigate on the privately owned land for pleasure as well as for business or sustenance" (Ross v. Acadian Seaplants, LTD., 2019). This law refers to the public's dominant rights to the intertidal zone now owned by upland proprietors (Ross v. Acadian Seaplants, LTD., 2019). Seaweed was once presumed to be within the scope of this public trust doctrine (Ross v. Acadian Seaplants, LTD., 2019). However, in March of 2019, Maine's Supreme Judicial Court ruled that seaweed along the coastline is, in fact, not public property. This decision upheld the 2017 Washington County Superior Court decision that denies public access to harvest seaweed in the intertidal zone (between high and low tide marks) without permission from the landowner (McGuire, 2019). The decision was made to protect tidal ecosystems from overharvesting. This landmark case will define the local wild seaweed industry in Maine over the next few years.

2.4 Environmental impact and sustainability

Seaweed cultivation provides four essential ecosystem services: oxygenation, carbon sequestration, uptake of nutrients, and habitat protection for humans and marine organisms. Seaweed, like terrestrial plants, produce oxygen through photosynthesis. This photosynthetic process removes carbon dioxide from the water and atmosphere and produces oxygen as a byproduct. Marine algae may be responsible for producing 80% of the world's oxygen (Witman, 2017; Durate et al., 2017), and up to 80% of the organic matter on Earth (Mouritsen, 2013). Scientists are also studying the climate change mitigation properties of seaweed used in animal feed. New research shows a 67% decrease in methane emissions from belching cows when fed a diet with 1% seaweed (Roque et al., 2019).

Kelp and other seaweeds are rapid and effective absorbers of nutrients in the water surrounding them (Roleda & Hurd, 2019). Seaweed can purify water by absorbing environmental toxins, such as nitrogen, phosphorus, and heavy metals, by placing seaweed farms in high contaminant zones. Research shows that by cultivating large seaweed sites at the mouth of rivers and lakes can help purify the water from potentially harmful nutrient runoff (Arumugam et al., 2018; Omori et al., 2012). This same concept is utilized in integrated multi-trophic aquaculture (IMTA) systems. IMTA can mitigate some of the adverse effects of fish farming by recycling waste and absorbing excess nutrients created by the farmed fish species (Ellis & Tiller, 2019).

Seaweed also provides vital habitat protection to both humans and marine organisms alike. Seaweed ecosystems offshore can lessen wave energy and protect shorelines during storms and surges (Durate et al., 2017). Seaweed also provides shelter and creates vibrant nurseries for young marine organisms. Kelp forests support high biodiversity and foster critical marine species, such as lobsters, crabs, mollusks, echinoderms, and crustaceans, that play a vital role in mitigating ocean acidification (Durate et al., 2017).

Seaweeds are considered a cost-effective and sustainable product. Seaweeds not only lessen the socio-economic and environmental impact of the agriculture industry, but they also have zero reliance on freshwater or nutrient supplies that current farming practices require (FAO, 2018a). Wild dense beds can tolerate more biomass removal than thinner beds (Mac Monagail et al., 2017). Cutting mature fronds above the holdfast, leaving an understory of younger plants, is the only way to assure a bed's continued productivity (Migne et al., 2015). Aquaculture seems to be the way of the future to prevent this sustainability problem, but its growth is not without risk (FAO, 2018a). Commercially-grown species, throughout the history of agriculture, have tended to crowd out wild native varieties, which in turn reduces biodiversity (Mac Monagail et al., 2017). Seaweeds have a strong influence on intertidal community structures (Thompson et al., 2010). If not adequately managed, overharvesting of wild and farmed species can lead to adverse conditions for the marine organisms that live in balance with the seaweed (Migne et al., 2015). Although seaweed cultivation does not contribute to any adverse environmental concerns, sustainable marine aquaculture still requires ethical regulations, local laws, and sustainable practices (Hafting et al., 2012). There has been general recognition and consensus among multiple entities to establish a best practice code of conduct for the successful sustainable exploitation of seaweeds (Rebours et al., 2014). Overexploitation of any natural resource may lead to potentially significant, negative ecological responses (Mac Monagail et al., 2017).

2.5 Nutrient profile

The majority of seaweed species around the world are edible, but not all are safe or suitable for human consumption. The chemical composition and abundance of nutrients vary among seaweed species, time of the year, harvesting and processing practices, age, light intensity, salinity, and geographic location (Rioux et al., 2017; Roleda & Hurd, 2019; Wells et al., 2017). New research reveals that seaweed has varying chemical compositions at different times throughout the harvest season (Buschmann et al., 2017; Sappati et al., 2019; Vilg et al., 2015). Most seaweeds, however, are packed with beneficial nutrients and can contain all essential minerals, vitamins, fatty acids, and amino acids needed to support life (Cherry et al., 2019; Rioux et al., 2017; Shannon & Abu-Ghannam, 2019; Wells et al., 2017).

Depending on the species, water makes up approximately 85% of the weight of fresh seaweed (Badmus et al., 2019; Salehi et al., 2019; Schiener et al., 2015). Seaweed is considered a low-calorie food with approximate nutrient composition proportions consisting of 12% - 71% complex carbohydrates, 4% - 47% protein, 0.2% - 5% fat, and a large number of vitamins and minerals, up to 36% dry weight (Cherry et al., 2019; Holdt & Kraan, 2010; Mouritsen, 2013;

Salehi et al., 2019). Seaweed also contains unique polysaccharides, soluble and insoluble dietary fiber, polyphenols, and antioxidants not found in terrestrial plants (Brown et al., 2014; Cherry et al., 2019; Holdt & Kraan, 2010; Salehi et al., 2019; Wells et al., 2017).

Table 2.1 Sugar kelp nutrition information (100g fresh weight) (USDA, 2019)

Nutrient	**Amount**
Water	81.6 g
Energy	43 kcals
Protein	1.68 g
Fat, total	0.56 g
Saturated Fatty Acids, total	0 g
Carbohydrate	9.57 g
Sugars, total	0.6 g
Fiber, total dietary	1.3 g
Sodium	233 mg

The total dietary fiber content of seaweed ranges between 25% - 75% of dry weight, of which 51% - 85% is soluble fiber, which is situated between cells and binds them together (Jimenez-Escrig & Sanchez-Muniz, 2000). This fiber consists of complex polysaccharides such as agar, carrageenan, alginate, fucoidan, and laminarin (Cherry et al., 2019). Soluble fibers can absorb water in the digestive tract to form a gelatinous substance that slows the rate at which nutrients are absorbed. Soluble fiber has been proven to help lower blood sugar and blood cholesterol levels and reduce appetite (Cherry et al., 2019). Hall and colleagues (2012) found rockweed (*Ascophyllum nodosum*) enriched (4%) bread reduced energy intake in overweight men by 109 kcals and 506 kcals at four and twenty-four hours post-consumption. Insoluble fiber, derived from the rigid cell walls of the plant, constitute between 15% - 49% of the total dietary fiber (Jimenez-Escrig & Sanchez-Muniz, 2000). Insoluble fiber can add to fecal bulk, provide nutrients to the colonies of bacteria and other microbes in the gut, and reduce transit time in the gastrointestinal tract. Many populations, especially those consuming a typical Western diet, are failing to meet the daily dietary fiber requirement of 14 grams per 1,000 calories a day (United States Department of Health and Human Services & United States Department of Agriculture, 2015). Consuming a five-gram serving of brown, red, or green seaweed would contribute up to 14.3%, 10.6%, or 12.1% of daily dietary fiber intake, respectively (Cherry et al., 2019).

Seaweed is gaining considerable attention for its protein content, given the rise of health foods and the emerging challenges to improve food security from sustainable protein sources (Cherry et al., 2019; Harnedy & FitzGerald, 2011; Rioux et al., 2017). Seaweed contains all essential and non-essential amino acids, making it a complete protein with high biological value (Cherry et al., 2019; Harnedy & FitzGerald, 2011; Rajapakse & Kim, 2011). It should be noted that a nitrogen conversion factor of 6.25 (Kjeldahl method) is used to determine the total protein content of seaweed, which may be an overestimate given seaweeds amount of nonprotein nitrogen present (Cherry et al., 2019; Lourenco et al., 2002). Thus, species-specific nitrogen conversion factors, ranging from 3.57 to 5.72, maybe needed (Cherry et al., 2019; Lourenco et al., 2002).

Seaweed contains a small amount of fat, but the lipid profile, mainly the essential fatty acids omega-3 and omega-6, of most seaweeds is substantial. Polyunsaturated fats, such as omega-3 and omega-6, make up approximately 31% - 54% of the total fat content depending on the species and the season (Marinho et al., 2015). The fat content of seaweed typically tends to be highest in the winter and lowest in the summer, although some species, such as sugar kelp, show variation with higher concentrations in March and November and lower concentrations in January (Cherry et al., 2019; Marinho et al., 2015). Essential fatty acids are not created by the human body, and therefore need to be consumed from the diet. Consumers receive most of their essential fatty acids from the consumption of fish and seafood, which is not produced by these organisms but obtained via the food chain from algae. Polyunsaturated fatty acids are essential components of cell membranes and may reduce the risk of cardiovascular disease, cancer, osteoporosis, and diabetes (Simopoulos, 2016). The proportion of omega-6 to omega-3 fatty acids falls approximately between 0.6 to 1.2 for most seaweeds, depending on the species, location, and time of year (Marinho et al., 2015). The typical Western diet has a considerably higher proportion of omega-6 to omega-3 fatty acids (20:1 or higher) (Simopoulos, 2016). Researchers have proposed that the increase in the consumption of omega-6 fatty acids may be related to rises in chronic systemic inflammation and obesity (Simopoulos, 2016). There is currently no optimal ratio for fatty acid intake, but studies have shown a potential decrease in total mortality with an omega-6/omega-3 ratio of less than 4:1 (Zarate et al., 2017). Seaweeds provide an appropriate ratio of fatty acids that is within this optimal ratio.

An abundance of vitamins are present in seaweeds; however, it is important to note again that amounts vary by species, geographic location, processing, and environmental factors, such as salinity, light exposure, temperature, and the season (Rioux et al., 2017; Roleda & Hurd, 2019; Wells et al., 2017). These vitamins include A, E, K, and water-soluble vitamins C, thiamin (B_1), riboflavin (B_2), niacin (B_3), pyridoxine (B_6), folate (B_9), and cobalamin (B_{12}) (Brown et al., 2014; Cherry et al., 2019; Rioux et al., 2017; Shannon & Abu-Ghannam, 2019; Wells et al., 2017; Zuckerbrot, 2014). Of particular interest to vegans and vegetarians, many seaweeds contain a non-animal source of vitamin B_{12}. Vitamin B_{12} is essential to human health and plays a crucial role in DNA synthesis and cell growth and development (Kumudha & Sarada, 2016). Vitamin B_{12} is not found readily in terrestrial plants, and in the Western diet, typically consumed solely from animal-derived sources, such as eggs, meat, and dairy products. Seaweeds and microalgae are rapid and effective absorbers of nutrients and other chemicals and can obtain exogenous vitamin B_{12} from absorbing bacteria in the water surrounding them (Circuncisão et al., 2018; Mouritsen, 2013). There is, however, continued debate and uncertainty surrounding the content and bioavailability of this vitamin source. Many researchers have suggested the vitamin B_{12} found in algae is not comparable to animal sources and is only present in an inactive analog form (Dagnelie et al., 1991; Herbert & Drivas, 1982; Maine Seaweed Council, 2019; Medeiros & Wildman, 2019; Van den Berg et al., 1988). However, current research by Castillejo et al., 2017; Kumudha & Sarada, 2016; Kumudha et al., 2015; Martinez-Hernandez et al., 2017 demonstrates that both seaweed and microalgae species do provide a plant source of bioavailable vitamin B_{12}. Red seaweed and microalgae species, such as nori, *Spirulina, Chlorella,* and *Dunaliella,* showed the highest content and bioavailability of vitamin B_{12}. However, significant variations were found between the studies, even within similar species of algae (Castillejo et al., 2017; Kumudha & Sarada, 2016; Kumudha et al., 2015; Martinez-Hernandez et al., 2017).

Seaweed also contains a wide range of essential minerals, not found in edible land plants (Rupérez, 2002; Schiener et al., 2015). These minerals also tend to be in chelated or colloidal forms that enhance bioavailability within the body (Circuncisão et al., 2018). The primary mineral components of seaweeds are iodine, calcium, potassium, phosphorus, magnesium, iron, sodium, and chlorine (Circuncisão et al., 2018; Mouritsen, 2013; Rupérez, 2002; Schiener et al., 2015). Trace minerals of seaweeds also include zinc, copper, manganese, selenium, molybdenum, and chromium (Circuncisão et al., 2018; Mouritsen, 2013; Rupérez, 2002;

Schiener et al., 2015). The mineral composition, especially, varies significantly between species (Circuncisão et al., 2018).

The iodine content of seaweed is highly dependent on the location, harvesting process, and species. Kelps, for example, can concentrate iodine up to 100,000 times that of the surrounding seawater, and exceed the minimum dietary requirement of 150 µg when consumed (Mouritsen, 2013). Iodine is essential to human health and promotes proper thyroid functioning. The salty taste of seaweed is derived mostly from its potassium composition, not from sodium (Circuncisão et al., 2018; Ganesan et al., 2019). Potassium is essential to our bodies and offers a healthier alternative to sodium in the diet. Seaweeds added to processed foods could reduce the use of added sodium while enhancing the mineral content, such as iodine, potassium, and calcium, which are generally lacking in typical Western diets (Circuncisão et al., 2018). Studies show that decreasing sodium consumption and increasing potassium may reduce blood pressure and the incidence of hypertension (Miranda, 2019). The calcium content of some seaweed species may be as high as 7% of the dry weight (Rajapakse & Kim, 2011). An 8 g (dry weight) portion of seaweed provides approximately 560 mg of calcium, which is considerable in reference to the recommended daily allowance of 800 - 1000 mg (Rajapakse & Kim, 2011). In seaweeds, calcium is in the bioavailable form of calcium carbonate (Ganesan et al., 2019; Rajapakse & Kim, 2011).

2.5.1 Health benefits

Beyond macro- and micronutrients, seaweeds also contain bioactive compounds such as antioxidants, polyphenols, sterols, and other phytochemicals. Seaweed has been considered food and medicine for thousands of years by coastal inhabitants throughout the world (Dillehay et al., 2008; FAO, 2018a). In the last few decades, the movement to embrace seaweeds for their beneficial properties has made a resurgence. The consumption of seaweed has been linked to a reduced risk of chronic diseases, such as cancer, hyperlipidemia, hypertension, hyperglycemia, and coronary heart disease (CHD) (Brown et al., 2014). These findings mostly come from epidemiological studies comparing Japanese and Western diets; there is a great need for continued research in this specialty (Brown et al., 2014). One small clinical study found the daily consumption of bread containing five grams of *Palmaria palmata*, 2% seaweed by weight, increased C-reactive protein, serum triglyceride, and thyroid-stimulating hormone (TSH) levels compared to the placebo group, but the levels of all research participants were well within normal limits (Allsopp et al., 2016).

Fucoidan, a complex polysaccharide found in brown seaweeds, has been shown to have anticancer, antiviral, anticoagulant, and antioxidant properties, among others (Brown et al., 2014; Salehi et al., 2019; Wells et al., 2017). Clinical studies showed that consumption of fucoidans was found to reduce postprandial glycemic levels in persons with diabetes mellitus (Cho et al., 2011). Fucoidan consumption has also been shown to reduce the intensity of inflammation and promotes rapid tissue repair (Fitton et al., 2015; Pereira, 2018). Ingestion of fucoidan is recommended after sports injuries, bruising, muscle and joint damage, deep tissue cuts, trauma, and surgery (Pereira, 2018). Fucoidan has been shown to exhibit antiviral activity against viruses such as herpes, human papillomavirus (HPV), and human immunodeficiency virus (HIV) (Ahmadi et al., 2015; Brown et al., 2014; Salehi et al., 2019). Fucoidan and other polysaccharides protect the surface of cells, preventing the virus from entering. However, most of the research was conducted using isolated and purified fucoidan, and it is not yet known how ingestion of intact seaweed might limit the bioavailability of this compound.

Pigments, such as fucoxanthin in brown seaweeds, are carotenoids with antioxidant effects (Shannon & Abu-Ghannam, 2016; Salehi et al., 2019). Fucoxanthin may inhibit tumor activity, cardiovascular disease, bacteria growth, oxidative stress, and metabolic syndrome (Cardoso et al., 2015; D'Orazio et al., 2012; Mei et al., 2017; Nishikawa et al., 2012; Shannon & Abu-Ghannam, 2016). Fucoxanthin has also been shown to reduce body weight and abdominal adipose tissue in animal studies (Maeda et al., 2009; Salehi et al., 2019). Like fucoidan, most of the research on fucoxanthin has relied upon purified extracts rather than seaweed as commonly eaten; thus, consumers eating whole seaweed may or may not experience similar effects.

There is a great need to characterize the composition of seaweeds in relation to geographic location, seasonality, and the nutrients they provide (Cherry et al., 2019). It is challenging to quantify the nutritional content of seaweeds with precision, and thus, companies may have difficulty in making specific health claims and recommendations identifying the optimal daily intake (Wells et al., 2017). The significant variations in bioactive compounds present challenges to the food industry to create proper labeling information. Nevertheless, the bioactive compounds found in seaweed show tremendous potential for human health and should be researched further. The health benefits of seaweeds are not attributable to just one bioactive compound, but rather the organism as a whole. To obtain the maximum health benefits from the vast nutritional composition of seaweed, consumers should incorporate a variety of brown, green, and red seaweed species into one's diet in moderation.

2.5.2 Health risks

Significant risk factors and potential hazards of seaweed consumption include overconsumption of iodine, vitamin K, pathogenic bacteria, and heavy metals, such as arsenic and mercury from the surrounding seawater. Brown seaweeds, such as sugar kelp, can contain substantial amounts of iodine. Excessive iodine intake can lead to medical problems related to the thyroid gland (Paz et al., 2019). The thyroid gland produces hormones used throughout the body that control metabolism. Iodine consumption of 400 µg or more may induce hypothyroidism (Sang et al., 2012). To limit iodine consumption from sugar kelp, Luning & Mortensen (2015) estimated that only ten grams of fresh weight, or one gram dry weight, should be eaten per day.

Seaweed, similar to leafy green vascular terrestrial plants, contain high amounts of phylloquinone, a vitamin K vitamer (Basset et al., 2016; Kamao et al., 2007; Kim et al., 2013; USDA, 2019). Although vitamin K toxicity is rare, excessive vitamin K intake can interfere with medications, such as the blood thinner, warfarin (Coumadin) (Leblanc et al., 2016). Vitamin K is a co-enzyme required for the formation of blood clotting factors within the body and plays an essential role in bone health. Anticoagulant medications, such as warfarin, are prescribed to patients with increased risk of thromboembolic conditions. These blood clots can cause serious health problems by blocking the flow of blood to the heart, brain, or other vital organs. Warfarin can prevent harmful blood clots from forming by blocking the activity of vitamin K in the body and lengthening the time it takes for a clot to form (Chang et al., 2014). The daily variation in dietary vitamin K intake is the main factor contributing to warfarin therapy instability (Leblanc et al., 2016). Fluctuations in vitamin K intake (both increased and decreased amounts) can counteract the anticoagulant effect of warfarin (Coumadin) (Chang et al., 2014). Maintaining a moderate and consistent level of vitamin K rich foods, such as seaweed, while taking warfarin, is the best-prescribed diet therapy (Chang et al., 2014; Leblanc et al., 2016; Violi et al., 2016).

Seaweeds are rapid and effective absorbers of elements in the water surrounding them, including mercury, lead, copper, nickel, arsenic, and cadmium (Roleda & Hurd, 2019; Wells et al., 2017). Contamination with heavy metals is an unfortunate potential hazard of consuming marine products. Bioaccumulation, like nutrient content, depends on environmental conditions, time of harvest, species, and modes of harvesting and processing. Organic certification at the processing level requires rigorous testing for heavy metals, herbicides, and other microbiological contaminants throughout processing (Piconi et al., 2020). Although general levels of heavy metals in commercially available seaweeds are below the safety limits imposed by regulatory authorities (Cherry et al., 2019; Paz et al., 2019), the lack of proper labeling information and significant variations within different species, make consumption of large quantities of seaweed potentially hazardous. As pollution increases from human activities, research improving the resistance of seaweeds against heavy metal pollution will be vital to the future of this industry (Fantonalgo & Falguisana, 2017). New research shows that fermentation reduced mercury and cadmium content by 37% and 35%, respectively when compared to fresh sugar kelp (Bruhn et al., 2019).

2.6 Consumer food preferences and purchasing behaviors

In comparison to other countries, such as Japan, seaweed is not as highly consumed or incorporated into the typical American diet, and markets rely heavily on imported products to meet most demand (Nova et al., 2020; Palmieri & Forleo, 2020; Piconi et al., 2020). The largest primary channels for edible seaweed in the U.S. are Asian restaurants and markets which typically utilize imported seaweed products (Piconi et al., 2020). Secondary channels include health and natural food stores, fine dining restaurants, universities/colleges, and select grocery store chains where domestically-produced edible seaweed products are more likely to be found (Piconi et al., 2020). It is to be expected that seaweed exporters to the U.S. will increasingly attempt to evolve and develop products to meet consumer preferences. Current food trends include natural clean ingredient labels, sustainability, locally/regionally sourced, snacking/on-the-go options, organic, plant-based, limited or reduced packaging, healthy without sacrificing taste, and ethnic menu experimentation (Nova et al., 2020; Piconi et al., 2020). Market research anticipates that seaweed products will enter more mainstream channels, such as supermarkets and convenience stores, as these markets embrace products, such as edible seaweed, for their perceived health positioning (clean labels, locally sourced, organic, etc.) and the growing consumer interest in plant-based meals and convenience snacks (Nova et al., 2020; Palmieri & Forleo, 2020; Piconi et al., 2020).

While the majority of competition of edible seaweed volume is imported, Maine seaweed producers more often compete directly with other health-oriented products for retail shelf space, food service menu presence, and overall consumer purchase (Piconi et al., 2020). The use of product label information may increase consumers' willingness to purchase seaweed products and remove inhibitions regarding consumption. Consumer motivations and behaviors are influenced by socio-demographic characteristics, such as gender, age, and educational level; while consumer preferences are influenced by external factors, such as health benefits, environmental benefits, price, and country of origin (Kraus et al., 2017; Tudoran et al., 2009). In a study by Kraus and colleagues (2017), researchers found that the nutritional value, product quality, naturalness, and food safety were valued highest among women aged 35-60 years old with a college-level education than by men of similar age and education. Consumers of the study, regardless of gender and age, were also found more likely to purchase functional food products that connected health claims with the consequence of their consumption (e.g., fiber consumption lowers cholesterol) (Kraus et al., 2017). Researchers found younger participants were more willing to purchase products that contributed to improved appearance as a health attribute when compared to the motivations of older consumers (Kraus et al., 2017). In Croatia, a study by Čagalj and colleagues (2016) found that the use of environmental claims on product labels, such as “organic” increased consumers' willingness to pay by 16-20% more, and the use of health claims, such as “reduces cholesterol” increased consumers' willingness to pay by 12% more. Banus (2017) concluded similar results after surveying participants in the Northeast, U.S and found that claims such as “low calorie,” “source of antioxidants,” and “organic” were rated highest for motivating purchasing behavior towards seaweed products (Banus, 2017). Thus, the incorporation of specific health-related benefits and environmental claims on a company’s product for marketing seaweed products may be advantageous (Banus, 2017; Čagalj et al., 2016; Kraus et al., 2017).

2.6.1 The Maine brand

The country of origin and locality of food products that combines local, regional, and traditional features increases the valuation and represents a new element in overall food quality (Fernández-Ferrín et al., 2018; Lang et al., 2014). The local food trend has evolved from more than just food miles and is redefining food quality, supply chain transparency, and sustainability (Dernini et al., 2016; Lang et al., 2014; Nova et al., 2020). Maine is the leader in the U.S. for domestic edible seaweed harvest, accounting for 555,000 lbs. (wet weight) or approximately

55% of the total U.S. harvest volume (farmed and wild) (Piconi et al., 2020). Per the domestic market growth findings by Piconi et al. (2020), consumer demand for Maine sourced edible seaweed will continue to grow. Consumers have a new desire to have a personal connection to where their food comes from and who produced it (Dernini et al., 2016; Lang et al., 2014; Nova et al., 2020). This understanding of the expanding food market trends to develop and present local food offerings to consumers will be a vital advantage. Maine harvesters, producers, and whole sellers are well-positioned to leverage the established expertise, current fishery/shellfish infrastructure, location, water quality, and brand equity advantages to secure a major role in the U.S. marketplace.

The seaweed industry in Maine benefits from the strong Maine brand halo. Maine's reputation has been built upon the successful lobster industry, high-quality seafood, pristine coastline location, and fresh, sustainably produced products (Piconi et al., 2020). Research shows that consumers are willing to pay more for seaweed that originates from areas that place a high premium on food safety, sustainability, and strictly enforced integrated coastal management policy (FAO, 2018a). Chamberlain et al. (2013) found that Danish consumers were willing to pay an additional price premium for local products, with enhanced willingness to pay if the consumers had a stronger positive perception of the local product. Maine's brand equity is an advantage for products produced in Maine over imported products with long supply chains and largely unknown quality control mechanisms (Piconi et al., 2020).

Sustainability and local foods are often incorporated into the same conversation. Consumers increasingly want to know where their food comes from, how it has been processed, and the environmental impact it has (Dernini et al., 2016; Lang et al., 2014). Maine has direct access to the cold, clean waters that are optimal for edible seaweed farming. As the sea temperatures around the world begin to warm, southern locations will experience greater challenges and fluctuations with sustainable edible kelp yields and product quality (Piconi et al., 2020; Rogers et al., 2019). Maine's seaweed industry is expected to be less impacted by rising ocean temperatures, as the state's waters are projected to remain cold enough to sustain quality seaweed farming (Piconi et al., 2020; Rogers et al., 2019). As a market leader, Maine's seaweed industry is well-positioned to capitalize on the growth, sustainability, and brand equity it has acquired.

2.7 Incorporating seaweed into the American diet

The global seaweed market is experiencing continued steady growth. A renewed interest in seaweed consumption has occurred in Norway, Iceland, and Ireland, where it once was a traditional part of the diet (Pereira, 2016). North America is experiencing a similar increase in seaweed consumption due to its reputation as a health or "superfood," the high demand for snack foods, and the increasing popularity of Asian cuisine (FAO, 2018a). In Japan, seaweed makes up 10-15% of the population's total nutritional intake (Abreu et al., 2015; Mouritsen, 2013). The contribution of seaweed in American diets has yet to be studied.

Developing innovative products with high volume potential and effective broad consumer appeal is critical to building market share (Piconi et al., 2020). Seaweed, incorporated into food, can add flavor, texture, and added nutrients to loaves of bread, soups, salads, and even ice cream. Current examples of existing value-added products for edible seaweed include salsas, sauces, salads, pasta, snack bars/chips, seasonings, and flavored products (Piconi et al., 2020). Incorporating seaweed flakes or meal into dough may be the most practical and easiest way to increase consumption in the Western diet (Mouritsen, 2013).

In the baking industry, hydrocolloids found in seaweed, are increasingly being sought for their ability to improve dough handling properties, increase the quality of fresh bread, and extend shelf life of stored bread (Mamat et al., 2014). A study by Arufe and colleagues (2018) found that brown seaweed powder concentrations added to bread < 4% did not impair the density and crumb texture of baked bread. Researchers did conclude, however, that the seaweed powder did significantly increase the green color of the bread crust, which could be a non-positive effect on consumer's acceptance (Arufe et al., 2018). Seaweed is now appearing globally in different types of food products, but optimization is needed to improve sensory quality to ensure repeat purchases by consumers (Nova et al., 2020). Merging culinary arts, food science, and aquaculture may increase consumers' acceptability and decrease hesitation to try this novel food product.

2.8 VitaminSea Seaweed, LLC

VitaminSea Seaweed, LLC, is a small, family-owned seaweed company that has been operating in Maine for the past twenty-five years. They harvest, process, and package all of their seaweed products. The company holds Maine commercial seaweed licenses and harvest their seaweed sustainably by hand year-round in the Gulf of Maine (VitaminSea Seaweed, 2019). The seaweeds are then naturally sun-dried to preserve nutrients. Seaweed species they offer include alaria, bladderwrack, dulse, Irish moss, laver, sea lettuce, kombu, and sugar kelp (VitaminSea Seaweed, 2019). Products include whole leaf, flakes, and granular seaweed, SeaCrunch kelp chips, Sea'sonings, animal supplements, and lawn and garden fertilizers (VitaminSea Seaweed, 2019). The company possesses kosher and vegan certification for all products, and organic certification following NOP Standards for their VitaminSea Kelp Chips and VitaminSea Kelp Meal (VitaminSea Seaweed, 2019).

VitaminSea Seaweed, LLC, received the Small Business Innovation Research (SBIR) grant in 2017 from the USDA (VitaminSea Seaweed, 2018). The objective of phase I was to study how kelp-based additives in baked bread may affect the baking process and consumer acceptability. A supply chain and cost/benefit analysis were also conducted. Through laboratory testing, bread samples with 5% kelp based additive showed increased nutritional content and longer shelf life than traditionally baked bread (VitaminSea Seaweed, 2018). Consumer acceptance trials revealed a preference for bread with 1.5% to 3% kelp additive (VitaminSea Seaweed, 2018). Phase I concluded that adding 5% kelp provides significant nutritional benefits while maintaining consumer acceptability and increasing the shelf life of the product (VitaminSea Seaweed, 2018). Supply chain analysis revealed that sufficient kelp is available to support the projected sales of this project sustainably here in Maine.

Building upon the research of Phase I's preliminary evaluations and consumer sensory testing, VitaminSea Seaweed, in conjunction with Atlantic Corporation and the University of Maine, launched into Phase II of the SBIR grant cycle. This phase includes further consumer preference assessments, advanced sensory evaluation testing, retail market testing, bakery surveys, advanced nutritional and shelf-life analysis, manufacturing regulation review, and plant and equipment design testing (VitaminSea Seaweed, 2018).

2.9 Research objectives

The first objective of the study was to determine consumers' acceptability for different particle sizes of seaweed added to baked bread. The second objective of the study was to provide insights about motivational factors and purchasing behavior of seaweed products and reveal potential consumer groups that are most likely to purchase and consume low-moisture seaweed products. These insights may provide helpful input for product innovations, creative positioning, and marketing strategies.

CHAPTER THREE

SENSORY EVALUATION TEST – MATERIALS AND METHODS

The University of Maine Institutional Review Board approved this research on July 8th, 2019.

3.1 Participant recruitment

Inclusion criteria for the test included: survey participants be at least 18 years old, within the Portland, Maine area on the test day, willing to eat bread containing seaweed, and have no known allergies or sensitives to bread ingredients. No other specific demographic criteria were constrained.

Participants were recruited through advertisements (Appendix A) placed in the Portland Press Herald and Forecaster newspaper, Visit Portland Maine tourism website, and on the University of Maine Sensory Evaluation Center Instagram and Facebook accounts. An email was also sent to the University of Maine Sensory Evaluation Center's email notification contact list (Appendix B); because some members of the contact list live within the Portland, Maine area during the summer months. The University of Maine issued a press release on July 9, 2019, that was reported by Portland's News Center Maine (WCSH) website (Ruhlin, 2019).

A target goal of one-hundred total sensory evaluation test participants was predetermined using a sample size and power calculator for sensory evaluation panels (Talsma, 2018). Based on an effect size to be detected of 0.4 on the 9-point hedonic liking scale, three products, and alpha and beta probabilities of 0.05, a sample size of ninety-two persons was calculated. This figure was rounded up to one-hundred persons to account for missing data from people who did not complete the test.

3.2 Seaweed bread preparation

Big Sky Bread Company of Portland, Maine, baked the three formulations tested. The three experimental formulations contained either sugar kelp flakes, meal, or powder. All kelp products were added as 5% of the weight of flour in a basic white bread recipe. The bread ingredients included: non-bromated unbleached white flour, honey, yeast, sea salt, water, and either dried sugar kelp flakes, meal or powder to the 5% specified weights. The bread was baked into traditional-sized loaves and sliced by the baker to yield 31 slices.

The bread was baked, sliced, and transported the morning of the sensory evaluation test (July 14, 2019). The ends and two adjacent slices were not served to test participants to reduce variations in slice texture and size. The slices of the three freshly baked formulations were cut in half vertically as needed to minimize staling in between assessment appointments (Figure 3.1).

Figure 3.1 Serving size of the sliced bread cut in half vertically

The picture was taken by Laurel Simone

3.3 Sensory evaluation

Two students within the University of Maine's Food Science and Human Nutrition program, Douglas Everett (Undergraduate) and Wenshu He (MS Graduate candidate), assisted with the sensory evaluation test. These students had completed the Collaborative Institutional Training Initiative (CITI) human subjects training, taken two courses in sensory evaluation, and had both assisted with several previous sensory evaluation studies at the University of Maine.

Sixty-five participants participated in the sensory evaluation test of freshly baked bread containing seaweed on July 14th, 2019, between 11:00 a.m. and 4:30 p.m. at the Westin Hotel in Portland, Maine. Copies of the informed consent were provided at the check-in desk, and participants were asked to read the consent form in its entirety before starting. Copies of the informed consent were available to any individual who wished to have a copy for further reference (Appendix C). Completing the test indicated consent. The Flesch-Kincaid reading level for the sensory evaluation consent form was 8.8. This evaluation indicates that persons with at least a ninth-grade education should be able to read and understand the form. Participants were escorted to a seat and provided with verbal instructions on how to begin the test.

The three samples were served on six-inch white coated paper plates (Hannaford, Scarborough, Maine, USA), which were labeled with 3-digit identifying codes and arranged according to the randomized serving order for each participant (Figure 3.2). Each tray consisted of the three bread formulation samples, a napkin, and a five-ounce cup (Dart Container Corporation, Mason, Michigan, USA) of spring water (Poland Spring®, Poland Spring, Maine, USA) used to cleanse participants' palates between samples (Figure 3.2). Each tray was numbered in the upper right-hand corner with a specific participation number (Figure 3.2). Participants were instructed to evaluate the sample on the left (facing them) first, followed by the sample of the right, and finally, the sample at the back of the tray (Figure 3.2). Twelve-inch high corrugated cardboard privacy screens (Flipside Products, Cincinnati, Ohio, USA) were placed at each seat to prevent participant's responses from being observed by others. Consumers recorded their responses to questions anonymously on touchscreen tablet computers. Data was collected and saved using SIMS Cloud Sensory Software (version 6, Berkeley Heights, New Jersey).

Figure 3.2 Sensory evaluation test participant tray set up

The picture was taken by Laurel Simone

The sensory evaluation questionnaire took approximately 20-30 minutes to complete. Participants were not required to eat the entirety of each bread sample. Each participant was asked to eat at least two bites of each sample and answer acceptability questions fully to receive compensation. Participants were compensated with $10.00 for their completion of the survey. All sixty-five participants completed the sensory evaluation test in its entirety.

3.4 Sensory evaluation test questionnaire

SIMS 2000 Sensory Software (version 6, Berkeley Heights, New Jersey) was utilized to create and design the questionnaire, execute the test, and analyze the results. Random 3-digit codes were assigned to the three bread samples. The sample presentation order was randomized so that every sample was evaluated in each positional order (first, middle, or last) by an equal number of persons.

All test participants were asked the same questions. The questionnaire began by asking participants about their demographic traits (gender, age, race, Hispanic ethnicity, home residence, and annual income) (Appendix D). Seven questions asked participants about shopping habits and preferences for bread types and seaweed products. Consumer acceptability was measured using the 9-point hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely) for each of the three bread formulations to assess the appearance, color, aroma, taste, texture, and overall acceptability (Peryam & Pilgrim, 1957). The Just About Right Scale (1 = much too small, 2 = slightly too small, 3 = just about right, 4 = slightly too large, and 5 = much too large) was utilized to measure consumer liking for the three sizes of seaweed pieces added (flake, meal, and powder) (Peryam & Pilgrim, 1957).

3.5 Statistical analyses

Statistical analyses of sensory evaluation data were produced through the SIMS 2000 Sensory Software (version 6, Berkeley Heights, New Jersey) using PC-SAS version 9.4 (SAS Institute Inc., Cary, North Carolina), R version 3.4.2 (The R Foundation, Vienna, Austria), and

XLSTAT 2019 by Addinsoft, INC. (Boston, Massachusetts). A probability level of less than 0.05 ($p < 0.05$) was considered to be significant for this study. Data obtained from the 9-point hedonic liking scale was analyzed parametrically by analysis of variance. Tukey's Honest Significant Difference (HSD) test was utilized for *post hoc* analyses to find possible significant differences among the three seaweed bread formulations. The top two and bottom two boxes were calculated by adding the top two scores (scores ≥ 8) together and the bottom two scores (scores ≤ 2) together and evaluating the summed scores for a significance value of $p < 0.05$. A Principal Component Analysis (PCA) was conducted to evaluate multiple data sets in a two-dimensional plane. Pearson correlation was calculated to evaluate how closely the dependent hedonic attribute variables were related to one another. A penalty analysis was used to evaluate the responses to the 5-point Just About Right (JAR) scale to determine seaweed piece size acceptability and adjusted for overall liking on the 9-point hedonic scale. Lastly, a two-way analysis of variance (ANOVA) was utilized to assess relationships among demographic traits and consumer interest in foods containing seaweed.

CHAPTER FOUR

SENSORY EVALUATION TEST – RESULTS AND DISCUSSION

4.1 Participant demographic information

A total of sixty-five people participated in the sensory evaluation test. The gender, age, race, and ethnicity of the test participants are presented in Table 4.1. Participants were required to be at least 18 years of age. Significantly more females (61.5%) then males (38.5%) took part in the test ($p < 0.001$) (Table 4.1). The age of the participants was not evenly distributed ($p < 0.0001$). There was a high percentage (30.8%) who were between the ages of 65-74 years old. Fourteen participants (21.5%) reported being between the ages of 55-64 years old, and fourteen (21.5%) were between the ages of 25-34 years old (Table 4.1). The 2019 U.S. Census reported Maine's population consists of 51% females and 49% males, with a median age is 45 years old (United States [U.S.] Census Bureau, 2019b).

The majority of the participants (87.7%, $p < 0.0001$) indicated their race as White/Caucasian, and a significant proportion (95.4%, $p < 0.0001$) said they were of non-Hispanic descent (Table 4.1). The 2019 U.S. Census reported that Maine's population consists of 93% white (non-Hispanic) residents (U.S. Census Bureau, 2019b). Participants' state of residency and income are shown in Table 4.2. The most frequently reported state of residency was Maine (90.8%, $p < 0.0001$), but there were participants from Florida (3.1%), Massachusetts (1.5%), Connecticut (1.5%), New York (1.5%), and California (1.5%) (Table 4.2). Self-reported income was also not evenly distributed among participants ($p < 0.0001$). Sixteen participants (24.6%) reported having an annual household income of $26,000 - $50,000, fifteen participants (23.1%) reported having an annual household income of $51,000 - $75,000, and thirteen participants (20.1%) reported an income of over $100,000 (Table 4.2). The 2019 U.S. Census reported a mean annual household income of $73,210 for Maine residents, which is consistent with the results from this study (mean income bracket of test participants who preferred to answer was $51,000 - $75,000) (U.S. Census Bureau, 2019b).

Table 4.1 Demographic characteristics of sensory evaluation test participants

Category	Number (percent of total responses) [a]	Probability [b]
Gender		
Female	40 (61.5%)	0.001
Male	25 (38.5%)	
Other	0 (0%)	
Prefer not to answer	0 (0%)	
Age		
18 - 24 years	3 (4.6%)	< 0.0001
25 - 34 years	14 (21.5%)	
35 - 44 years	6 (9.2%)	
45 - 54 years	5 (7.7%)	
55 - 64 years	14 (21.5%)	
65 - 74 years	20 (30.8%)	
75 years or older	3 (4.6%)	
Prefer not to answer	0 (0%)	
Race		
American Indian/Alaska Native	1 (1.5%)	< 0.0001
Asian/Pacific Islander	2 (3.1%)	
Black/African American	1 (1.5%)	
White/Caucasian	57 (87.7%)	
Other	1 (1.5%)	
More than one race	1 (1.5%)	
Prefer not to answer	2 (3.1%)	
Hispanic		
Yes	2 (3.1%)	< 0.0001
No	62 (95.4%)	
Prefer not to answer	1 (1.5%)	

[a] Counts are followed by the percentage of total responses (n=65).
[b] Probabilities less than 0.05 are considered significant.

Table 4.2 Residency and income of sensory evaluation test participants

Category	Number (percent of total responses) [a]	Probability [b]
State of residency		
I live outside of the U.S.	0 (0%)	< 0.0001
California	1 (1.5%)	
Connecticut	1 (1.5%)	
Florida	2 (3.1%)	
Maine	59 (90.8%)	
Massachusetts	1 (1.5%)	
New York	1 (1.5%)	
Prefer not to answer	0 (0%)	
Income		
Less than $25,000	6 (9.2%)	< 0.0001
$26,000 - $50,000	16 (24.6%)	
$51,000 - $75,000	15 (23.1%)	
$76,000 - $100,000	11 (16.9%)	
$101,000 - $125,000	4 (6.2%)	
$126,000 - $150,000	2 (3.1%)	
More than $150,000	7 (10.8%)	
Prefer not to answer/not sure	4 (6.2%)	

[a] Counts are followed by the percentage of total responses (n=65).
[b] Probabilities less than 0.05 are considered significant.

4.2 Participant food shopping and purchasing habits

Primary household food purchasers have the strongest influence on the brands and products consumed by the household (Crane et al., 2019). Food purchasing patterns differ according to consumers' income, education, race, age, and gender. In this study, participants were asked to indicate the amount of grocery shopping they did for their household; 41.5% of the participants surveyed claimed responsibility for all of their household's food shopping (Table 4.3). When asked to select all the types of bread that the participant usually purchases, 69.2% answered whole-grain, 58.5% answered artisanal, and 46.2% answered sliced (Table 4.3). Other answers included: mass-produced (33.8%), home-made (30.8%), and refined flour (9.2%) (Table

4.3). The majority of the participants (61.5%) indicated that they usually buy their bread at the grocery store (Table 4.3). Although, several people commented, within the comment section of the test, that they typically bought bread from several types of vendors. When asked how much you agree with the following statement, 'I prefer to buy local foods instead of mass-produced foods,' nearly half (49.2%, n=32) of participants strongly agreed (Table 4.3).

Table 4.3 Food shopping and bread purchasing profile of participants

Category	Number (percent of total responses) [a]	Probability [b]
Food shopping percentage		
None at all	1 (1.5%)	< 0.0001
25%	8 (12.3%)	
50%	14 (21.5%)	
75%	15 (23.1%)	
100%	27 (41.5%)	
Prefer not to answer	0 (0%)	
Type of bread you buy [c]		
Artisanal	38 (58.5%)	< 0.0001
Home-made	20 (30.8%)	
Mass-produced	22 (33.8%)	
Refined flour	6 (9.2%)	
Whole grain	45 (69.2%)	
Sliced	30 (46.2%)	
Prefer not to answer, or I do not know	0 (0%)	
Where do you buy your bread?		
Grocery store	40 (61.5%)	< 0.0001
Local independent bakery	19 (29.2%)	
Bakery store chain	0 (0%)	
Big box store	1 (1.5%)	
Club store	1 (1.5%)	
Bakery outlet	1 (1.5%)	
Online store	0 (0%)	
Do not buy – bake at home	2 (3.1%)	
None of the above/do not buy bread	1 (1.5%)	
Local buying habits		
Strongly disagree	5 (7.7%)	< 0.0001
Slightly disagree	3 (4.6%)	
Neither agree nor disagree	6 (9.2%)	
Slightly agree	19 (29.2%)	
Strongly agree	32 (49.2%)	

[a] Counts are followed by the percentage of total responses (n=65).

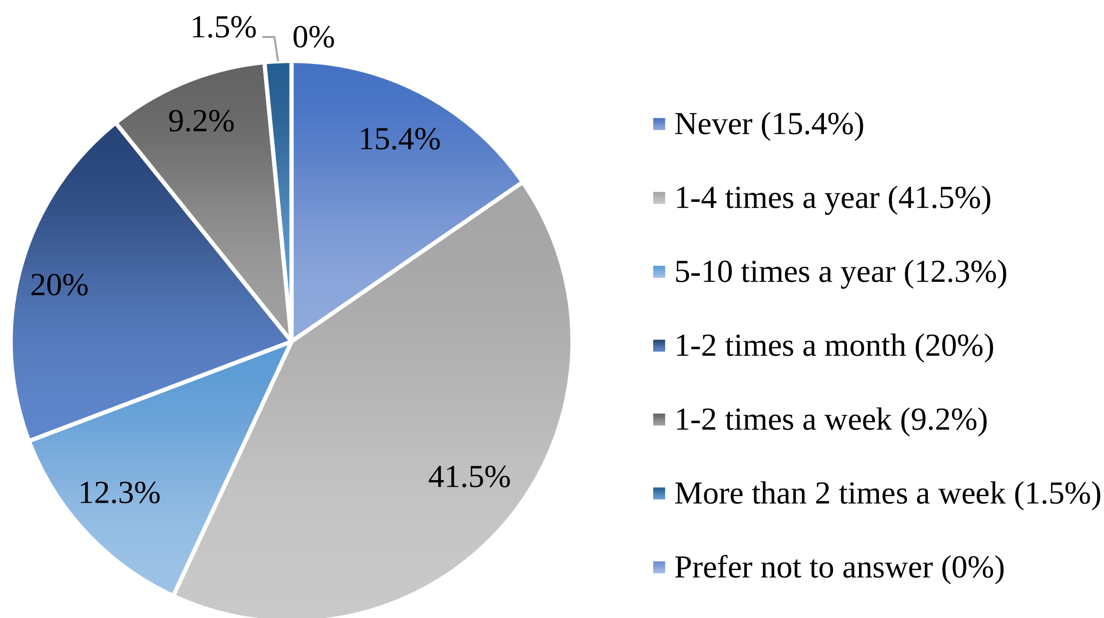
[b] Probabilities less than 0.05 are considered significant.

[c] Study participants could select more than one answer; counts exceed the number of participants (n=65). Percentages reflect the total number of responses.

4.3 Participant seaweed consumption habits

Participants' prior seaweed consumption can be seen in Figure 4.1 and Table 4.4. The majority of participants (84.6%) reported having consumed seaweed in the last twelve months (Figure 4.1). However, the consumption of seaweed is relatively low, with only 30.7% of respondents having eaten seaweed one or more times a month in the past twelve months (Figure 4.1). Consumers who have eaten or tasted seaweed in the past are more likely to eat seaweed in the coming twelve months (Birch et al., 2019).

Figure 4.1 Participant seaweed consumption in the past twelve months (n=65)



When asked whether they would consider buying bread that contained seaweed, an overwhelming majority (98.5%, n=64) said yes ($p < 0.0001$) (Table 4.4). In a study by Birch et al. (2019), food neophobia was the most significant predictor of future seaweed consumption. A one-unit increase on the food neophobia scale was associated with a 77.2% decrease in predicted odds of future seaweed consumption (Birch et al., 2019). Participants were also asked to select all reasons that would make them consume bread containing seaweed more often, 75.4% answered ‘greater availability where I shop,’ 69.2% answered ‘higher nutritional content,’ 46.2% answered ‘sold fresh,’ 43.1% answered ‘sustainably grown,’ 43.1% answered ‘minimally processed,’ and 21.5% answered ‘longer shelf-life’ (Table 4.4).

Table 4.4 Seaweed consumption profile of participants

Category	**Number (percent of total responses) [a]**	**Probability [b]**
Seaweed Consumption		
Never	10 (15.4%)	< 0.0001
1-4 times a year	27 (41.5%)	
5-10 times a year	8 (12.3%)	
1-2 times a month	13 (20%)	
1-2 times a week	6 (9.2%)	
More than 2 times a week	1 (1.5%)	
Prefer not to answer	0 (0%)	
Buying bread with seaweed		
Yes	64 (98.5%)	< 0.0001
No	1 (1.5%)	
Eating seaweed more often [c]		
Greater availability where I shop	49 (75.4%)	< 0.0001
Longer shelf-life	14 (21.5%)	
Sustainably grown	28 (43.1%)	
Minimally processed	28 (43.1%)	
Higher nutritional content	45 (69.2%)	
Sold fresh	30 (46.2%)	

[a] Counts are followed by the percentage of total responses (n=65).
[b] Probabilities less than 0.05 are considered significant.
[c] Study participants could select more than one answer; counts exceed the number of participants (n=65). Percentages reflect the total number of responses.

4.4 Sensory evaluation test results

Mean values of bread hedonic attribute scores were compared by one-way analysis of variance (Table 4.5). Despite the lower than expected turn-out rate, the study had adequate power to detect differences in liking for all six attributes based on the 9-point hedonic scale (Peryam & Pilgrim, 1957). It is important to note that most adults do not consume a slice of bread without some form of cooking preparation or added spread, such as butter. Hall, Fairclough, Mahadevan, & Paxman (2010) served bread enriched with 5 – 20 grams of the brown seaweed *Ascophyllum nodosum* to consumers after toasting the slices and topping them with scrambled eggs. Although the seaweed bread samples were liked less than the control containing no seaweed, there was no significant difference in mean overall acceptability scores (5.79 – 5.95) utilizing the nine-point hedonic scale (Hall et al., 2010).

All hedonic attribute mean scores fell between 'neither like nor dislike' and 'like moderately,' a five to seven on the hedonic scale (Table 4.5). A mean acceptability score of seven or higher on the 9-point hedonic scale is considered to be of significant quality (Stone et al., 2012). A significance of $p = 0.0001$ was found among the three bread formulations for appearance, aroma, taste, and overall acceptability, and a $p = 0.05$ for color and texture (Table 4.5). Tukey's HSD test revealed significant differences between the seaweed meal and seaweed powder formulations for each of the six attributes surveyed and between the seaweed flake and seaweed powder for aroma, taste, and overall liking (Table 4.5). There was no significant difference between the seaweed meal and seaweed flake bread formulations. Although each bread formulation had the same amount of seaweed added (5%), the fine particle size of the seaweed powder bread affected the appearance and darkened the color of the sample. This, however, did not have a significant effect on the appearance, color, and texture scores of the seaweed powder bread when compared to the seaweed flake bread formulation ($p < 0.05$) (Table 4.5). Figure 4.2 shows the consumer's overall preference for the seaweed meal over the seaweed powder.

Table 4.5 Consumer acceptance of bread containing seaweed [a]

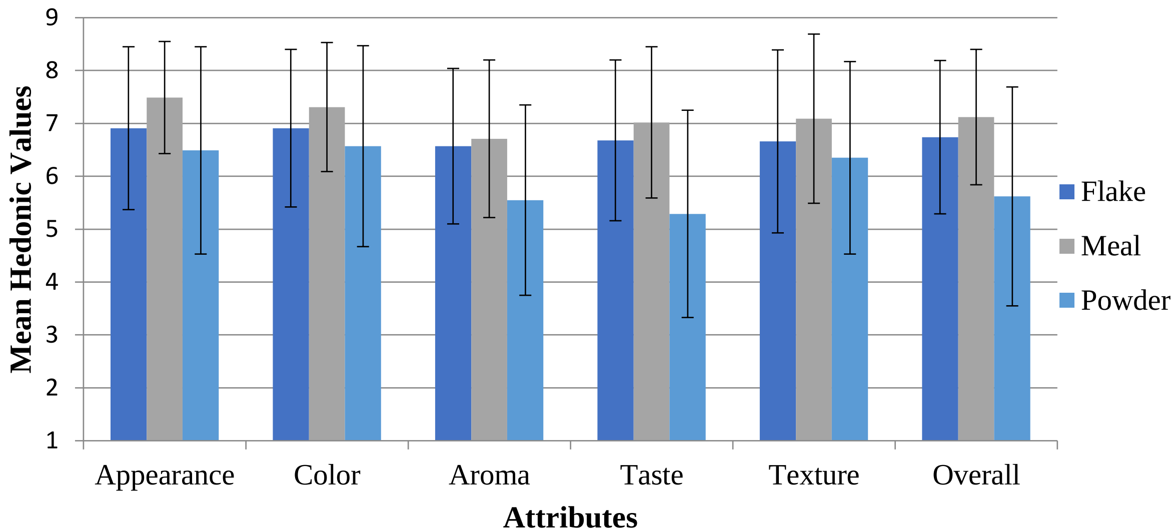
Mean 9-Point Hedonic Attribute Ratings [b]					
Attribute	**Flake**	**Meal**	**Powder**	**Probability**	**Significance [c]**
Appearance	6.9 ± 1.5 ab	7.5 ± 1.1 a	6.5 ± 2.0 b	0.0001	***
Color	6.9 ± 1.5 ab	7.3 ± 1.2 a	6.6 ± 1.9 b	0.0157	*
Aroma	6.6 ± 1.5 a	6.7 ± 1.5 a	5.6 ± 1.8 b	0.0001	***
Taste	6.7 ± 1.5 a	7.0 ± 1.4 a	5.3 ± 2.0 b	0.0001	***
Texture	6.7 ± 1.7 ab	7.1 ± 1.6 a	6.4 ± 1.8 b	0.0124	*
Overall	6.7 ± 1.5 a	7.1 ± 1.3 a	5.6 ± 2.1 b	0.0001	***

[a] Means ± standard deviation (n=65) followed by a different letter within the same row are significantly different from each other (Tukey’s HSD, $p \leq 0.05$).

[b] 9-point hedonic scale: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely (Peryam & Pilgrim, 1957).

[c] One-Way Analysis of Variance between sample groups: * < 0.05, ** < 0.01, *** < 0.001, NS = No significance.

Figure 4.2 Consumer acceptance of bread containing seaweed (n=65) [a,b]



[a] The bars represent the standard deviations in scores for each attribute and bread sample.
[b] 9-point hedonic scale: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely (Peryam & Pilgrim, 1957).

The frequency distribution of appearance, color, and aroma hedonic attribute ratings can be found in Table 4.6. The largest percentage of participants answered that they liked the appearance and color 'very much' for all three seaweed bread samples (Table 4.6). Large variations were found in the frequency distribution of participants' perception of aroma (Table 4.6). Multiple participants commented that the strong fishy/ocean smell of the seaweed powder bread formulation was disliked significantly more than the aromas of the other two samples. Seaweed aroma plays a significant role in the taste sensations they induce. It is not surprising that the aroma and taste attribute scores were similar for this test. The aroma and taste scores for the seaweed powder bread fell between 'neither like nor dislike' and 'like slightly' on the hedonic scale, a five and six, respectively (Table 4.5).

Table 4.6 Frequency of the appearance, color, and aroma hedonic attribute ratings for the three seaweed bread formulations [a]

Attribute	Flake	Meal	Powder
Appearance			
Dislike Extremely	0 (0%)	0 (0%)	1 (1.5%)
Dislike Very Much	0 (0%)	0 (0%)	1 (1.5%)
Dislike Moderately	2 (3.1%)	0 (0%)	4 (6.2%)
Dislike Slightly	5 (7.7%)	2 (3.1%)	7 (10.8%)
Neither Like nor Dislike	5 (7.7%)	1 (1.5%)	8 (12.3%)
Like Slightly	9 (13.8%)	6 (9.2%)	4 (6.2%)
Like Moderately	13 (20%)	17 (26.2%)	7 (10.8%)
Like Very Much	26 (40%)	32 (49.2%)	31 (47.7%)
Like Extremely	5 (7.7%)	7 (10.8%)	2 (3.1%)
Color			
Dislike Extremely	0 (0%)	0 (0%)	1 (1.5%)
Dislike Very Much	0 (0%)	0 (0%)	0 (0%)
Dislike Moderately	1 (1.5%)	0 (0%)	3 (4.6%)
Dislike Slightly	3 (4.6%)	2 (3.1%)	10 (15.4%)
Neither Like nor Dislike	11 (16.9%)	6 (9.2%)	7 (10.8%)
Like Slightly	8 (12.3%)	5 (7.7%)	1 (1.5%)
Like Moderately	10 (15.4%)	15 (23.1%)	11 (16.9%)
Like Very Much	27 (41.5%)	31 (47.7%)	29 (44.6%)
Like Extremely	5 (7.7%)	6 (9.2%)	3 (4.6%)
Aroma			
Dislike Extremely	0 (0%)	0 (0%)	1 (1.5%)
Dislike Very Much	0 (0%)	0 (0%)	2 (3.1%)
Dislike Moderately	1 (1.5%)	1 (1.5%)	3 (4.6%)
Dislike Slightly	1 (1.5%)	2 (3.1%)	16 (24.6%)
Neither Like nor Dislike	19 (29.2%)	15 (23.1%)	11 (16.9%)
Like Slightly	11 (16.9%)	10 (15.4%)	9 (13.8%)
Like Moderately	10 (15.4%)	12 (18.5%)	10 (15.4%)
Like Very Much	18 (27.7%)	19 (29.2%)	13 (20%)
Like Extremely	5 (7.7%)	6 (9.2%)	0 (0%)

[a] Counts are followed by the percentage of total responses (n=65).

Table 4.7 contains the frequency distribution of taste, texture, and overall liking hedonic attribute ratings. Although the taste of the seaweed powder bread was liked significantly less than the other two samples, 22 people liked the taste ‘moderately’ or ‘very much’ (Table 4.7). Bread texture was liked ‘very much’ by the most amount of people for all three seaweed bread treatment samples (Table 4.7). The seaweed meal bread received the highest overall liking scores and the lowest overall disliking scores, followed by the seaweed flake bread, and lastly, the seaweed powder bread formulation (Table 4.5 and Table 4.7). The number of overall dislike scores adversely affected the liking for the powder bread formulation.

Table 4.7 Frequency of taste, texture, and overall acceptability hedonic attribute ratings for the three seaweed bread formulations [a]

Attribute	Flake	Meal	Powder
Taste			
Dislike Extremely	0 (0%)	0 (0%)	2 (3.1%)
Dislike Very Much	1 (1.5%)	0 (0%)	4 (6.2%)
Dislike Moderately	2 (3.1%)	1 (1.5%)	7 (10.8%)
Dislike Slightly	5 (7.7%)	5 (7.7%)	11 (16.9%)
Neither Like nor Dislike	2 (3.1%)	5 (7.7%)	8 (12.3%)
Like Slightly	13 (20%)	6 (9.2%)	11 (16.9%)
Like Moderately	22 (33.8%)	16 (24.6%)	13 (20%)
Like Very Much	16 (24.6%)	28 (43.1%)	9 (13.8%)
Like Extremely	4 (6.2%)	4 (6.2%)	0 (0%)
Texture			
Dislike Extremely	0 (0%)	0 (0%)	1 (1.5%)
Dislike Very Much	1 (1.5%)	1 (1.5%)	2 (3.1%)
Dislike Moderately	2 (3.1%)	3 (4.6%)	2 (3.1%)
Dislike Slightly	9 (13.8%)	3 (4.6%)	5 (7.7%)
Neither Like nor Dislike	4 (6.2%)	3 (4.6%)	9 (13.8%)
Like Slightly	5 (7.7%)	3 (4.6%)	10 (15.4%)
Like Moderately	17 (26.2%)	15 (23.1%)	14 (21.5%)
Like Very Much	23 (35.4%)	33 (50.8%)	19 (29.2%)
Like Extremely	4 (6.2%)	4 (6.2%)	3 (4.6%)
Overall			
Dislike Extremely	0 (0%)	0 (0%)	2 (3.1%)
Dislike Very Much	0 (0%)	0 (0%)	3 (4.6%)
Dislike Moderately	3 (4.6%)	0 (0%)	7 (10.8%)
Dislike Slightly	3 (4.6%)	4 (6.2%)	11 (16.9%)
Neither Like nor Dislike	5 (7.7%)	5 (7.7%)	5 (7.7%)
Like Slightly	12 (18.5%)	6 (9.2%)	7 (10.8%)
Like Moderately	19 (29.2%)	18 (27.7%)	15 (23.1%)
Like Very Much	20 (30.8%)	28 (43.1%)	15 (23.1%)
Like Extremely	3 (4.6%)	4 (6.2%)	0 (0%)

[a] Counts are followed by the percentage of total responses (n=65).

The top two and bottom two scores were calculated for the three bread formulations (Table 4.8). The top two value is the total number of responses of a score of eight (like very much) and a score of nine (like extremely) on the 9-point hedonic scale. The bottom two value is the total number of responses of a score of two (dislike very much) and a score of one (dislike extremely) on the 9-point hedonic scale. Survey respondents tend to make the error of central tendency, which is the natural propensity to choose scores within the middle of the 9-point hedonic scale more often than the outlying or outer ends of the 9-point hedonic scale (Meilgaard et al., 2007). Table 4.8 shows the importance of the top two and bottom two scores on the impact of the overall mean scores shown in Table 4.5.

Significant differences ($p \leq 0.001$) were found between all three bread formulations and the top two scores for taste, and between the top two scores for the seaweed powder formulation when compared to the meal formulation for texture ($p \leq 0.05$) and overall liking ($p \leq 0.01$) (Table 4.8). Significant differences were also found between the bottom two scores for the seaweed powder formulation when compared to the other two formulations for aroma ($p \leq 0.05$), taste ($p \leq 0.01$), and overall liking ($p \leq 0.01$) (Table 4.8). No significant differences were found among the three seaweed bread formulations for appearance and color (Table 4.8).

Table 4.8 Frequency of the top two and the bottom two hedonic attribute ratings for the three bread formulations

Top Two and Bottom Two of 9-Point Hedonic Attribute Ratings [a]					
Attribute	**Flake**	**Meal**	**Powder**	**P-Value [b]**	**Significance [c]**
Appearance T2 [d]	36 (56%) a	46 (71%) a	35 (54%) a	> 0.05	NS
Appearance B2 [e]	0 (0%) a	0 (0%) a	3 (5%) a	> 0.05	NS
Color T2	37 (57%) a	43 (66%) a	35 (54%) a	> 0.05	NS
Color B2	0 (0%) a	0 (0%) a	2 (4%) a	> 0.05	NS
Aroma T2	28 (43%) a	31 (38%) a	13 (20%) a	> 0.05	NS
Aroma B2	0 (0%) b	0 (0%) b	4 (7%) a	≤ 0.05	*
Taste T2	24 (37%) b	36 (55%) a	9 (14%) c	≤ 0.001	***
Taste B2	1 (2%) b	0 (0%) b	8 (11%) a	≤ 0.01	**
Texture T2	31 (48%) ab	41 (63%) a	25 (39%) b	≤ 0.05	*
Texture B2	1 (2%) a	1 (2%) a	4 (7%) a	> 0.05	NS
Overall T2	26 (38%) ab	36 (55%) a	15 (23%) b	≤ 0.01	**
Overall B2	0 (0%) b	0 (0%) b	7 (11%) a	≤ 0.01	**

[a] Counts are followed by the percentage of total responses (n=65). Each value is also followed by a different letter within the same row are significantly different from each other (Tukey's HSD, $p \leq 0.05$).
[b] Probability value of obtaining a greater F value.
[c] One-Way Analysis of Variance between sample groups: * < 0.05, ** < 0.01, *** < 0.001, NS = No significance.
[d] T2 indicates a hedonic score at the top of the 9-point hedonic scale (8 = like very much and 9 = like extremely).
[e] B2 indicates a hedonic score at the bottom of the 9-point hedonic scale (2 = dislike very much and 1 = dislike extremely).

The Principal Component Analysis (PCA) preserves the variance within the data and produces a two-dimensional visualization. The PCA revealed that principal Component 1 and principal Component 2 explain 100% of the total variance (Figure 4.3). The amount of variance retained by each principal component is expressed in eigenvalues displayed in Table 4.9. Attributes that cluster together are highly correlated with one another. Aroma, taste, and overall liking fluctuate together and are therefore highly correlated (Figure 4.3). This principle is the same for color, appearance, and texture attributes as well. The seaweed powder bread formulation falls on the opposite side, which can be attributed to lower hedonic scores for all attributes surveyed, specifically an inverse relation to the aroma, taste, and overall acceptability (Figure 4.3).

Figure 4.3 Principle Component Analysis of the three seaweed bread formulations

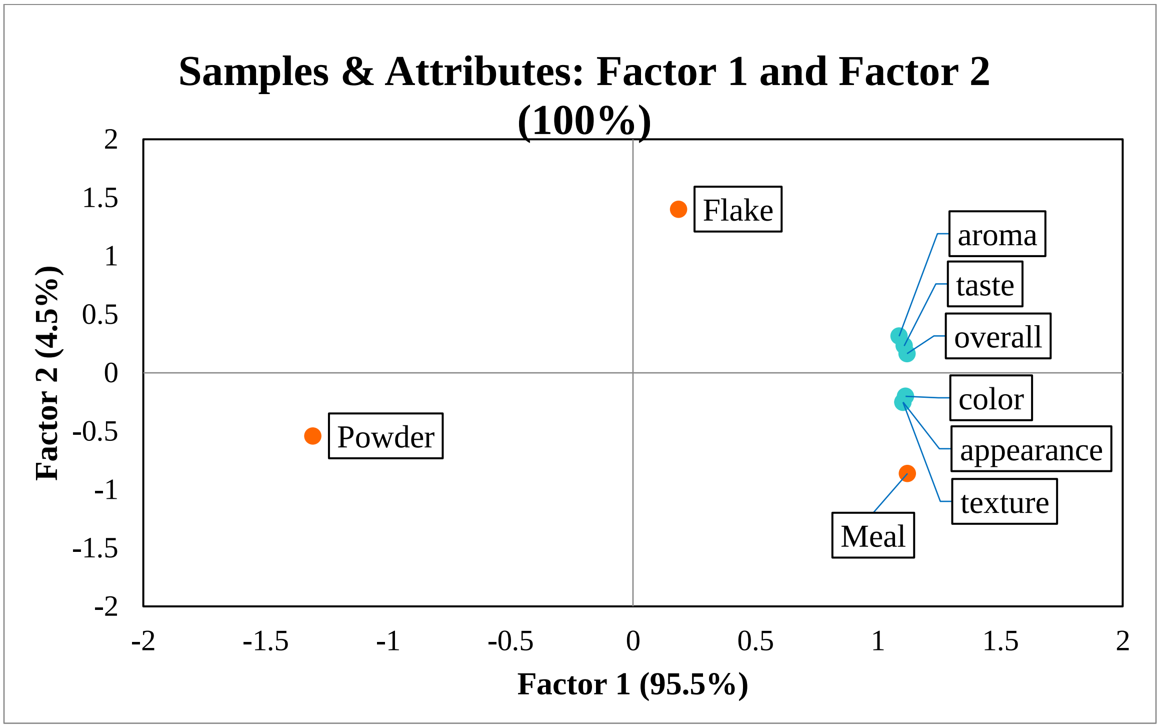


Table 4.9 Eigenvalues of Principal Component Analysis of the three seaweed bread formulations

	Component 1	**Component 2**
Eigenvalue	5.73	0.27
Percentage of Variance	95.5	4.50
Cumulative Sum	95.5	100

Pearson correlation is a statistical method that shows how closely dependent attribute variables are related to one another. Correlations among hedonic factors can be calculated as part of the PCA, or independently, which includes greater variation because the calculations are not based on means. Correlation coefficients range from -1 to 1; values of ± 0.75 or higher are considered to be strong direct positive/negative correlations. In this study, all of the six attributes had a strong positive correlation with each other (Table 4.10). Taste had the highest correlation with overall liking with a correlation coefficient of 0.998 (Table 4.10). The strongest correlation of two attributes was between appearance and texture, with a correlation coefficient of one (Table 4.10).

Table 4.10 Principal Component Analysis Pearson correlation coefficients among hedonic attributes (n=65)

	Appearance	**Color**	**Aroma**	**Taste**	**Texture**	**Overall**
Appearance	1					
Color	0.999	1				
Aroma	0.875	0.896	1			
Taste	0.909	0.927	0.997	1		
Texture	1	0.999	0.875	0.909	1	
Overall	0.932	0.948	0.991	0.998	0.932	1

The frequency distribution of seaweed pieces 5-point JAR attribute ratings can be found in Table 4.11. In this study, the majority of participants answered that the amount of seaweed pieces was ‘just about right’ for all three seaweed bread formulations. The adjusted overall liking, utilizing penalty analysis and the JAR scale of the seaweed pieces attribute, can be found in Table 4.12. Despite having fewer test participants than expected, the study had adequate power to detect differences in seaweed particle size acceptability. Penalty analysis evaluated the number of responses that were not JAR. The adjusted overall liking establishes the consumers' inferred preference for the seaweed meal bread particle size over the other two bread formulations.

Table 4.11 Frequency of 'Just About Right' (JAR) ratings for seaweed pieces for the three seaweed bread varieties [a]

Attribute	Flake	Meal	Powder
Seaweed pieces			
Much too small	0 (0%)	1 (1.5%)	15 (23.1%)
Slightly too small	1 (1.5%)	9 (13.8%)	11 (16.9%)
Just about right	38 (58.5%)	53 (81.5%)	39 (60%)
Slightly too large	24 (36.9%)	2 (3.1%)	0 (0%)
Much too large	2 (3.1%)	0 (0%)	0 (0%)

[a] Counts are followed by the percentage of total responses (n=65).

Table 4.12 Penalty analysis of Just About Right (JAR) scale for seaweed particle size [a]

Bread Type	% JAR	Penalty/mean drop	Adjusted overall liking [b]
Flake	58	0.5 / 1.2	5.5
Meal	82	0 / 0	7.1
Powder	60	0.4 / 0.9	4.7

[a] 5-point 'Just About Right Scale': 1 = much to small; 2 = slightly to small; 3 = just about right; 4 = slightly too large; and 5 = much too large.
[b] Adjusted overall liking correlates to the 9-point hedonic scale: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like or dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely (Peryam & Pilgrim, 1957).

Two-way analysis of variance (ANOVA) was utilized to evaluate how demographic characteristics may have influenced the overall acceptability of the different seaweed bread formulations. Table 4.13 reveals the mean overall liking hedonic scores related to gender, age, and income. Tukey's Honest Significant Difference (HSD) test was utilized for *post hoc* analyses of data to find possible significant differences among the three seaweed bread samples. Significant differences were found between overall liking of the seaweed meal and flake bread formulations when compared to the seaweed powder bread formulation for females ($p < 0.0001$). No significant differences were found in overall liking for each of the seaweed bread formulations when compared to age ($p = 0.001$) or annual income ($p = 0.008$).

Table 4.13 Two-way analysis of variance (ANOVA) of demographic influences on bread acceptability [a]

Category	Seaweed Bread Formulations [b,c]			Mean values
	Flake	Meal	Powder	
Gender (n=65)				
Male (n=25)	6.8 ± 0.3 a	7.2 ± 0.3 a	6.0 ± 0.3 ab	6.6 ± 0.2
Female (n=40)	6.7 ± 0.3 a	7.1 ± 0.3 a	5.4 ± 0.3 b	6.4 ± 0.2
Age (n=65)				
18 - 24 years (n=3)	6.0 ± 0.9 a	6.3 ± 0.9 a	5.3 ± 0.9 a	5.9 ± 0.5
25 - 34 years (n=14)	6.9 ± 0.4 a	7.1 ± 0.4 a	4.7 ± 0.4 a	6.2 ± 0.3
35 - 44 years (n=6)	7.0 ± 0.7 a	7.8 ± 0.7 a	6.5 ± 0.7 a	7.1 ± 0.4
45 - 54 years (n=5)	7.4 ± 0.7 a	6.6 ± 0.7 a	5.8 ± 0.7 a	6.6 ± 0.4
55 - 64 years (n=14)	6.5 ± 0.4 a	6.9 ± 0.4 a	4.9 ± 0.4 a	6.1 ± 0.3
65 - 74 years (n=20)	6.7 ± 0.4 a	7.3 ± 0.4 a	6.3 ± 0.4 a	6.7 ± 0.2
75 years or older (n=3)	7.0 ± 0.9 a	7.7 ± 0.9 a	7.0 ± 0.9 a	7.2 ± 0.5
Income (n=61)				
Less than $25,000 (n=6)	6.8 ± 0.7 a	7.3 ± 0.7 a	6.0 ± 0.7 a	6.7 ± 0.4
$26,000 - $50,000 (n=16)	6.6 ± 0.4 a	6.9 ± 0.4 a	5.3 ± 0.4 a	6.3 ± 0.2
$51,000 - $75,000 (n=15)	6.9 ± 0.4 a	7.0 ± 0.4 a	5.2 ± 0.4 a	6.4 ± 0.3
$76,000 - $100,000 (n=11)	7.0 ± 0.5 a	7.3 ± 0.5 a	5.6 ± 0.5 a	6.6 ± 0.3
$101,000 - $125,000 (n=4)	7.0 ± 0.8 a	7.0 ± 0.8 a	7.0 ± 0.8 a	7.0 ± 0.5
$126,000 - $150,000 (n=2)	4.0 ± 1.2 a	7.5 ± 1.2 a	5.5 ± 1.2 a	5.7 ± 0.7
More than $150,000 (n=7)	6.4 ± 0.6 a	7.6 ± 0.6 a	6.4 ± 0.6 a	6.7 ± 0.4

[a] The independent variables consist of each demographic trait, dried seaweed particle size, and their interaction.
[b] 9-point hedonic scale: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely (Peryam & Pilgrim, 1957).
[c] Means ± standard deviation followed by a different letter within the same row are significantly different from each other (Tukey's HSD, $p \leq 0.05$).

Sensory evaluation test participants were asked three supporting questions after they were finished evaluating each of the three seaweed bread formulations. Context variables have been the most investigated extrinsic variables in food studies (Iop et al., 2006). When asked whether the participant would consider buying each bread sample, 86.2% (n=56) answered 'yes' for the seaweed meal treatment; 84.6% (n=55) answered 'yes' for the seaweed flake treatment, and 52.3% (n=34) answered 'yes' for the seaweed powder treatment (Table 4.14). The findings suggest producing a loaf of bread with the seaweed powder would have limited success.

Table 4.14 Frequency of consumer ratings for the three seaweed bread varieties [a]

Category	Flake	Meal	Powder
Would you buy this bread			
Yes	55 (84.6%)	56 (86.2%)	34 (52.3%)
No	10 (15.4%)	9 (13.8%)	31 (47.7%)

[a] Counts are followed by the percentage of total responses (n=65) ($p < 0.0001$).

When asked to select the price the participant would be willing to pay for a loaf of each of the bread samples, the largest percentage of participants answered '$4.00' for the seaweed meal treatment 44.6% (n=29), and the seaweed flake treatment 26.2% (n=17) (Table 4.15). The largest percentage of participants for the seaweed powder treatment stated they would not buy this bread 40% (n=26) (Table 4.15). The mean price consumers are willing to pay, excluding consumers who answered they would not buy this bread, is $4.24, $4.27, and $4.33 for the flake, meal, and powder seaweed bread formulations, respectively. The prices presented in the test were based on prices for loaves of bread in grocery stores and artisanal bakeries. A suggested retail price of $5.00 or less would likely be more successful than higher-priced loaves of bread unless the seaweed bread was sought for special occasions.

Table 4.15 Frequency of price ratings for the three seaweed bread varieties [a]

Category	Flake	Meal	Powder
Price you would pay for seaweed bread			
$3.00	16 (24.6%)	11 (16.9%)	7 (10.8%)
$4.00	17 (26.2%)	29 (44.6%)	19 (29.2%)
$5.00	14 (21.5%)	12 (18.5%)	7 (10.8%)
$6.00	6 (9.2%)	6 (9.2%)	5 (7.7%)
$7.00	1 (1.5%)	1 (1.5%)	1 (1.5%)
$8.00	0 (0%)	0 (0%)	0 (0%)
I would not buy this bread	11 (16.9%)	6 (9.2%)	26 (40%)

[a] Counts are followed by the percentage of total responses (n=65) (p = 0.005).

Lastly, consumers were asked to select all occasions on which they would buy each of the three seaweed bread samples (Table 4.16). The largest percentage of participants indicated they would consider buying all three seaweed bread samples for ‘sandwiches,’ followed by ‘with soup.’ The top three choices for the seaweed meal bread treatment included: ‘sandwiches’ (83.1%), ‘with soup’ (64.6%), and ‘every day’ (55.4%) (Table 4.16). The top three choices for the seaweed flake bread treatment included: ‘sandwiches’ (69.2%), ‘with soup’ (61.5%), and ‘with cheese or spread like hummus’ (52.3%) (Table 4.16). The top three choices for the seaweed powder bread treatment included: ‘sandwiches’ (47.7%), ‘with soup’ (41.5%), and ‘I would not buy this bread’ (41.5%) (Table 4.16).

Table 4.16 Frequency of ratings of occasions to buy bread for the three seaweed bread varieties [a]

Category	Flake	Meal	Powder
Occasions to buy bread [b]			
Sandwiches	45 (69.2%)	54 (83.1%)	31 (47.7%)
With cheese or spreads like hummus	34 (52.3%)	31 (47.7%)	24 (36.9%)
As a bread bowl	10 (15.4%)	13 (20%)	8 (12.3%)
With soup	40 (61.5%)	42 (64.6%)	27 (41.5%)
Parties	13 (20%)	12 (18.5%)	5 (7.7%)
Every day	24 (36.9%)	36 (55.4%)	17 (26.2%)
Picnics	12 (18.5%)	17 (26.2%)	9 (13.8%)
As a gift	12 (18.5%)	13 (20%)	4 (6.2%)
I would not buy this bread	10 (15.4%)	5 (7.7%)	27 (41.5%)

[a] Counts are followed by the percentage of total responses (n=65).
[b] Study participants could select more than one answer; counts exceed the number of participants (n=65). Percentages reflect the total number of responses.

Participants were able to provide comments about the three seaweed bread formulations during the sensory evaluation test. Some general comments that participants left for the seaweed meal bread formulation included that it had a gritty texture and a subtle seaweed taste. It would be helpful to know whether the bakers allowed the seaweed products to hydrate before mixing with the other ingredients. Dried materials high in dietary fiber can be slow to absorb water, resulting in grittiness in baked goods. The sensory detection threshold for rye bran particles was found to be quite low in a starch gel system (Petersson et al., 2013), so some adjustments for particle size, hydration capacity, and hardness may be needed to optimize seaweed use in baked products. For the seaweed flake bread formulation, general comments included that it was the most visually appealing and had the least ‘fishy’ taste. For the seaweed powder bread formulation, general comments from participants included that it tasted very ‘fishy’ and had the most potent aroma of the three samples.

CHAPTER FIVE

ONLINE CONSUMER SURVEY – MATERIALS AND METHODS

The University of Maine Institutional Review Board approved this research on July 8, 2019, and approved a modified questionnaire on August 14, 2019.

5.1 Participant recruitment

The inclusion criteria specified that survey participants be at least eighteen years old living within the U.S. and willing to participate and complete the entirety of the online survey. No other specific demographic criteria were constrained. Dynata (formerly Survey Sampling International (SSI)) of Shelton, Connecticut, recruited participants. Dynata randomly emailed a generic invitation to persons within their database that met the inclusion criteria without mention of the survey topic or compensation (Appendix E). The email invitation contained a link to the informed consent form (Appendix F) and the survey questionnaire (Appendix G). Participants that continued to the survey were assumed to have provided their consent.

Persons who had signed up to be survey respondents were continually screened by Dynata during the data collection period to meet goals for gender, age, and regional geographic distribution. A target of 3,600 total survey participants was selected with an even split of men and women (approximately 1,800 participants each), approximately 515 participants from each of the seven age categories (18-24 years old, 25-34 years old, 35-44 years old, 45-54 years old, 55-64 years old, 65-74 years old, 75 years or older), and approximately 400 participants from each of the nine U.S. geographical regions (New England, Mid-Atlantic, East-North Central, West-North Central, South Atlantic, East-South Central, West-South Central, Mountain, and Pacific).

5.2 Online consumer survey

The electronic survey instrument was created using the University of Maine's Qualtrics® software (Provo, Utah) online account, and optimized for smartphone and tablet viewing. The informed consent, which is required by federal regulations, was the first text that survey participants saw. The Flesch-Kincaid reading level for the invitation and informed consent form was 7.3. In general, writing a document to an eighth-grade or lower reading level helps to ensure that everyone can read and understand the text (Hadden et al., 2017). People could then choose to take part in the survey or not. Those who chose not to take part were thanked in a separate message. Survey questions were drafted to determine prior consumer preferences, experiences, and buying habits around seaweed. It was also essential to understand future attitudes and drivers for purchasing seaweed bread and other products, ideal packaging configurations, price points, and value.

The survey instrument was pre-tested by the University of Maine and Dynata staff on August 22, 2019. The responses from the pre-test were not analyzed in this research. Upon the start of distribution, Dynata sent the online survey to 100 participants on August 23, 2019, to ensure the survey was functioning correctly, and questions were yielding expected responses. Those 100 responses are included in this research analysis. The survey was reopened to participants until August 29, 2019, to reach a total of 3,973 responses.

One branch pathway was created within the survey that depended upon the participants' answers to question 14 (Appendix G). If the participant indicated that they had an interest in purchasing bread that contained seaweed, they were then directed to subsequent questions regarding the amount they would be willing to pay, which types of packaging they would prefer, and how often and on what occasions they would consider buying bread that contained seaweed.

Participants that answered ‘no’ or ‘not sure’ were coded to deny access to these supplemental questions and were directed to the next questions that were shown to all participants.

All survey respondents were asked eight demographic, four food purchasing habits, four seaweed consumption, and three 9-point hedonic scale appearance questions (Appendix G). The last three questions of the survey assessed attitudes and beliefs related to the health benefits and potential risks of seaweed consumption and attributes that would affect seaweed bread purchasing (Appendix G). Input on survey questions was provided by Mr. Shep Erhart of Maine Coast Sea Vegetables. Questions consisted of thirteen multiple-choice, five select all-that-apply, and one drop-down menu question (Appendix G). Three survey questions included pictures of seaweed bread from the consumer sensory test in July 2019 (Figure 5.1, 5.2, and 5.3). They asked participants to rate the appearance of the bread utilizing the 9-point hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely) (Peryam & Pilgrim, 1957).

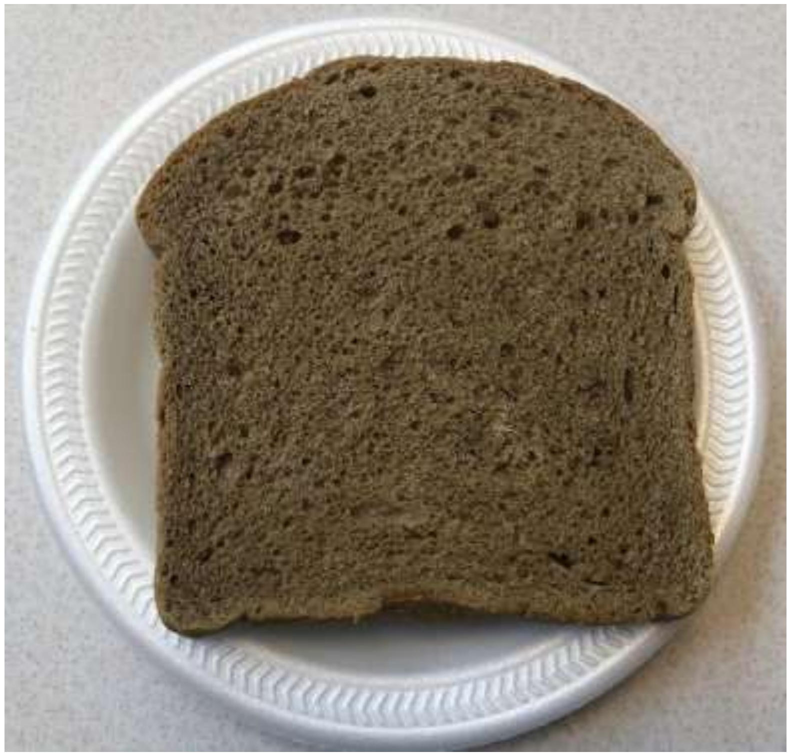
Figure 5.1 A slice of the 5% sugar kelp flake bread formulation

The picture was taken by Dr. Mary Camire

Figure 5.2 A slice of the 5% sugar kelp meal bread formulation

The picture was taken by Dr. Mary Camire

Figure 5.3 A slice of the 5% sugar kelp powder bread formulation



The picture was taken by Dr. Mary Camire

Data was collected confidentially. Although Dynata has access to participants' names and email addresses, no identifiable information was shared with researchers. The survey did not collect Internet Protocol (IP) addresses, geographic coordinates, or any other personal information. The survey termination options were set to "anonymous" so that IP addresses and other identifying information were not collected. Dynata staff will not have access to survey responses. Only the summaries of the data will be shared with VitaminSea, LLC and Atlantic Corporation staff.

5.3 Compensation

Thousands of consumers have provided Dynata with their contact information to take surveys in return for compensation, such as discount coupons, in their Dynata Rewards accounts. Dynata compensates online survey respondents with a standard amount based on the length of the survey. Dynata uses a reasonable level of reward based on the amount of effort required, the population, and appropriate regional customs. Regardless of the type of incentive, the value is the same for every respondent in a given study. For example, the value for a 15-minute survey would be approximately $1.00.

All participants are assigned a unique ID number by Dynata to participate in numerous surveys during their membership time. The programming platform monitors the respondents' progress. When a participant answers all required questions within a survey, they are recorded as complete. If they do not answer all required questions, they are not counted as a complete survey and therefore not compensated.

Dynata offers diversified incentives as some people are motivated by cash, points, or by being able to donate to charity. Others are motivated by the opportunity to make a difference, make their voice heard, have fun taking a survey, or by having a say in the products and services of the future. Learning opportunities provided by the survey, or by the promise of receiving information after taking it, may prompt other consumers to take part. Dynata aims to respond to all of these individual motivations to provide a research sample that is diverse and as representative as possible of the target population.

5.4 Statistical analyses

Statistical analyses of sensory evaluation data were analyzed with XLSTAT 2019 by Addinsoft, INC. (Boston, Massachusetts). A probability level of less than 0.05 ($p < 0.05$) was considered to be significant for this study. Chi-squared analyses were used to determine whether responses to demographic and shopping questions had distributions that were not equal. Questions that allowed participants to select more than one answer were not analyzed for significance because a suitable test is not available for this purpose. Data obtained from the 9-point hedonic liking scale was analyzed parametrically by analysis of variance (ANOVA). Tukey's Honest Significant Difference (HSD) test was utilized for *post hoc* analyses of data to find possible significant differences among the appearances of the three seaweed bread samples. The top two and bottom two boxes were calculated by adding the top two scores (scores ≥ 8) together and the bottom two scores (scores ≤ 2) together and evaluating the summed scores for a significance value of $p < 0.05$. Lastly, cross-tabulations were utilized to assess relationships among demographic traits and consumer interest in foods containing seaweed and seaweed consumption.

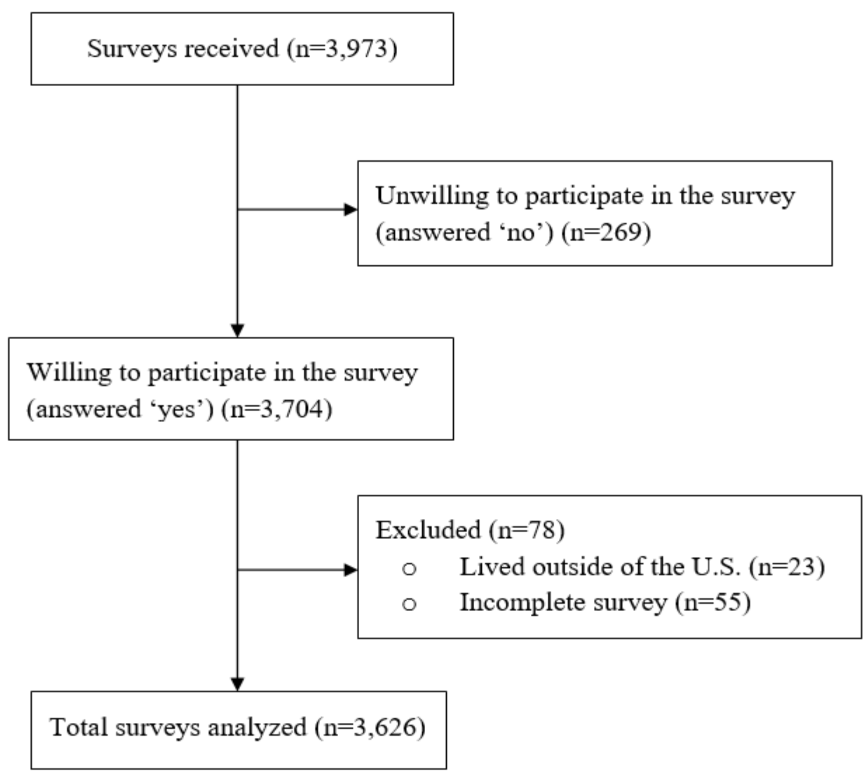
CHAPTER SIX

ONLINE CONSUMER SURVEY – RESULTS AND DISCUSSION

6.1 Consumer demographic information

A total of 3,973 people participated in the online consumer survey. Participants were required to be at least 18 years of age, live within the U.S., and willing to participate and complete the online survey. Of the 3,973 total responses assessed for eligibility, 269 were unwilling to participate in the survey (answered ‘no’). Twenty-three participants were excluded for stating they lived outside of the U.S., and 55 participants were excluded for not completing the survey. Of the 3,704 participants willing to participate in the online consumer survey, 3,626 met the inclusion criteria and were included in the analysis (Figure 6.1).

Figure 6.1 Inclusion criteria for the study sample and the number of participants



The gender, age, race, and ethnicity of the survey participants are presented in Table 6.1. Participants consisted of 1,831 females (50.5%), 1,777 males (49%), 12 who indicated other (0.3%), and 6 who preferred not to identify gender (0.2%) ($p < 0.0001$) (Table 6.1). The ages of the participants are represented in Table 6.1; the lowest percentages are seen in the 18-24 years old and > 75 years old age ranges ($p < 0.\ 0001$). The current 2019 U.S. population consists of 51% females and 49% males, with a median age is 38 years old (United States [U.S.] Census Bureau, 2019c). While females and younger consumers reported higher levels of seaweed consumption in other seaweed consumer research studies, gender and age demographics have been found to have no significant effect on future seaweed consumption (Altintzoglou et al., 2016; Birch et al., 2019). The majority of the participants (77.2%, $p < 0.\ 0001$) indicated their race as White or Caucasian, and a significant proportion (90%, $p < 0.\ 0001$) said they were of non-Hispanic descent (Table 6.1). The current 2019 U.S. population consists of 75.5% White/Caucasian residents, and 61.1% non-Hispanic-descent residents (U.S. Census Bureau, 2019c).

Table 6.1 Demographic characteristics of survey participants

Category	Number (percent of total responses) [a]	Probability [b]
Gender		
Female	1,831 (50.5%)	< 0.0001
Male	1,777 (49%)	
Other	12 (0.3%)	
Prefer not to answer	6 (0.2%)	
Age		
18 - 24 years	385 (10.6%)	< 0.0001
25 - 34 years	624 (17.2%)	
35 - 44 years	613 (16.9%)	
45 - 54 years	570 (15.7%)	
55 - 64 years	577 (15.9%)	
65 - 74 years	506 (14%)	
75 years or older	327 (9%)	
Prefer not to answer	24 (0.7%)	
Race		
American Indian/Alaska Native	41 (1.1%)	< 0.0001
Asian	217 (6%)	
Black/African American	365 (10.1%)	
White/Caucasian	2,798 (77.2%)	
Native Hawaiian/Pacific Islander	25 (0.7%)	
More than one race	114 (3.1%)	
Prefer not to answer	66 (1.8%)	
Hispanic		
Yes	328 (9%)	< 0.0001
No	3,262 (90%)	
Prefer not to answer	36 (1%)	

[a] Counts are followed by the percentage of total responses (n=3,626).
[b] Probabilities less than 0.05 are considered significant.

Participants’ state of residency and geographic location by region are presented in Table 6.2. The most frequently reported state of residency was California (8.2%), followed by Texas (7.3%) and New York (4.8%) (Table 6.2). There were participants from all fifty states, Puerto Rico, and the District of Columbia. Although we were striving for 400 persons per region (New England, Mid-Atlantic, East-North Central, West-North Central, South Atlantic, East-South

Central, West-South Central, Mountain, and Pacific), there were slightly more survey respondents from New England, South Atlantic, and Pacific regions ($p < 0.0001$) (Table 6.2).

Table 6.2 Geographic location and state of residency of survey participants

Category	**Number (percent of total responses)** [a]	**U.S. Population** [b]
Geographic U.S. region		
New England	424 (11.7%)	14,853,290 (4.5%)
Connecticut	112 (3.1%)	
Maine	30 (0.8%)	
Massachusetts	169 (4.7%)	
New Hampshire	50 (1.4%)	
Rhode Island	17 (0.5%)	
Vermont	12 (0.3%)	
Mid-Atlantic	392 (10.8%)	41,257,789 (12.6%)
New Jersey	93 (2.6%)	
New York	174 (4.8%)	
Pennsylvania	137 (3.8%)	
East-North Central	403 (11.1%)	46,931,863 (14.4%)
Illinois	122 (3.4%)	
Indiana	55 (1.5%)	
Michigan	82 (2.3%)	
Ohio	92 (2.5%)	
Wisconsin	48 (1.3%)	
West-North Central	404 (11.1%)	21,376,861 (6.5%)
Iowa	46 (1.3%)	
Kansas	61 (1.7%)	
Minnesota	109 (3%)	
Missouri	125 (3.5%)	
Nebraska	37 (1%)	
North Dakota	11 (0.3%)	
South Dakota	13 (0.4%)	

[a] Counts are followed by the percentage of total responses (n=3,626).

[b] Counts are U.S. population estimates (by geographic census region division) as of July 1, 2019, followed by the percentage of the total U.S. population (United States [U.S.] Census Bureau, 2019a).

Table 6.2 Continued

Category	Number (percent of total responses) [a]	U.S. Population [b]
Geographic U.S. region		
South Atlantic	416 (11.5%)	65,322,408 (20%)
Delaware	2 (0.1%)	
District of Columbia	5 (0.1%)	
Florida	162 (4.5%)	
Georgia	63 (1.7%)	
Maryland	30 (0.8%)	
North Carolina	73 (2%)	
South Carolina	31 (0.9%)	
Virginia	38 (1%)	
West Virginia	9 (0.3%)	
East-South Central	389 (10.7%)	19,112,813 (5.8%)
Alabama	87 (2.4%)	
Kentucky	125 (3.5%)	
Mississippi	56 (1.5%)	
Tennessee	128 (3.5%)	
West-South Central	397 (11%)	40,318,727 (12.3%)
Arkansas	44 (1.2%)	
Louisiana	61 (1.7%)	
Oklahoma	36 (1%)	
Texas	265 (7.3%)	
Mountain	386 (10.7%)	24,552,385 (7.5%)
Arizona	147 (4.1%)	
Colorado	89 (2.5%)	
Idaho	26 (0.7%)	
Montana	7 (0.2%)	
Nevada	65 (1.8%)	
New Mexico	28 (0.8%)	
Utah	32 (0.9%)	
Wyoming	4 (0.1%)	
Pacific	415 (11.4%)	53,441,278 (16.3%)
Alaska	6 (0.2%)	
California	298 (8.2%)	
Hawaii	17 (0.5%)	
Oregon	38 (1%)	
Washington	58 (1.6%)	
Puerto Rico	1 (0.03%)	3,195,153 (1%) [c]

[a] Counts are followed by the percentage of total responses (n=3,626).
[b] Counts are U.S. population estimates (by geographic census region division) as of July 1, 2019, followed by the percentage of the total U.S. population (U.S. Census Bureau, 2019a).
[c] Puerto Rico is not part of the U.S. Census region division. Total counts are current population totals, followed by the percentage of the total U.S. population (U.S. Census Bureau, 2019a).

Participants' annual income and education levels are presented in Table 6.3 (*p* < 0. 0001). The largest number of responses, 475 (13.1%), reported having an annual income of less than $20,000, followed by 428 (11.8%) participants who reported having an annual income of $100,000 - $149,000 (Table 6.3). A small portion of the participants, 221 (6.1%), preferred not to answer the question (Table 6.3). The 2019 U.S. Census reported a mean annual income of $84,938, which is higher than the results from this survey (mean income bracket of survey participants who preferred to answer was $60,000 - $69,999) (U.S. Census Bureau, 2019c).

The educational level varied among the participants who chose to answer (Table 6.3). The largest group of participants (33.5%) reported earning a high school or GED degree. Other answers included a four-year degree (26.3%), a two-year degree (17.8%), a graduate degree (17.1%), and a doctoral degree (3.5%) (Table 6.3). A small portion of the participants, 66 (1.8%), preferred not to answer the question (Table 6.3). In other seaweed consumer research studies, participants with a university degree were four times more likely to eat seaweed products in the coming twelve months as compared to less educated participants (Birch et al., 2019). These findings are also consistent with previous analyses of food neophobia and education. Banus (2017), Meiselman et al. (2010), and Tuorila et al. (2001) found that food neophobia decreased with higher levels of education.

Table 6.3 Income and education level of survey participants

Category	Number (percent of total responses) [a]	Probability [b]
Income		
Less than $20,000	475 (13.1%)	< 0.0001
$20,000 - $29,999	361 (10%)	
$30,000 - $39,999	390 (10.8%)	
$40,000 - $49,999	306 (8.4%)	
$50,000 - $59,999	322 (8.9%)	
$60,000 - $69,999	223 (6.2%)	
$70,000 - $79,999	264 (7.3%)	
$80,000 - $89,999	159 (4.4%)	
$90,000 - $99,999	191 (5.3%)	
$100,000 - $149,999	428 (11.8%)	
More than $150,000	286 (7.9%)	
Prefer not to answer/not sure	221 (6.1%)	
Education Level		
High school or GED	1,213 (33.5%)	< 0.0001
2-year degree	646 (17.8%)	
4-year degree	955 (26.3%)	
Graduate degree	621 (17.1%)	
Doctorate	125 (3.5%)	
Prefer not to answer	66 (1.8%)	

[a] Counts are followed by the percentage of total responses (n=3,626).
[b] Probabilities less than 0.05 are considered significant.

6.2 Consumer food purchasing habits

Participants were asked to indicate the amount of grocery shopping they were responsible for in their household (Table 6.4). Food purchasing patterns differ according to consumers' income, education, race, age, and gender (Crane et al., 2019). Primary household food purchasers have the most substantial influence on the brands and products consumed by the household (Crane et al., 2019). The majority of participants surveyed (62.2%) claimed responsibility for 76% to 100% of the household's food shopping ($p < 0.05$) (Table 6.4).

When asked to select all types of grain products typically bought, the largest group of consumers chose sliced bread (82.6%), followed by pasta (68.5%) and crackers (65.2%) (Table 6.4). Other answers included: bagels (46.3%), rolls (40.7%), English muffins (38.8%), muffins (33.5%), croissants (25.7%), unsliced bread (18.6%), pizza crusts (18.4%), and flatbreads (16.2%) (Table 6.4). When asked to select all types of bread typically purchased, 62.1% answered whole grain, 34% answered mass-produced, and 20.7% answered artisanal (Table 6.4). Other answers included: organic (17.3%), refined flour (12.3%), and non-GMO (11.1%) (Table 6.4).

Consumer's preference for white bread has fallen by 20% since 2005, while whole-grain bread has risen 70% (Ferdman, 2014). The movement from white bread to whole-grain is not the only change in the bread aisle, Americans are also spending more money on alternative grain products, such as flatbreads, pita, naan, buns, and tortillas (Ferdman, 2014). Tortilla consumption in the U.S. has increased more than 60% over the past decade, a new $2.5 billion industry (Ferdman, 2014). Alternative grain products are popular for their health perception and easy eating for the on-the-go lifestyles. These various grain products also complement ethnic dishes Americans are seeking (Wiber & Atchley, 2018). Mintel's "Packaged Bread – U.S. – July 2016" report found that 57% of participants surveyed liked sampling bread from other cultures (Wiber & Atchley, 2018). The report also indicated that 66% of participants surveyed enjoyed trying new varieties of bread and other grain products (Wiber & Atchley, 2018). The majority of participants from this study (84.8%) indicated that they typically buy their bread at a grocery store (Table 6.4). Other answers included big-box stores, such as Target and Walmart (32.2%) and club stores, such as BJ's, Sam's Club, and Costco (16.7%) (Table 6.4).

Table 6.4 Food shopping and bread purchasing profile of participants

Category	**Number (percent of total responses) [a]**	**Probability [b]**
Food shopping percentage		
0% - 25%	259 (7.1%)	< 0.05
26% - 50%	534 (14.7%)	
51% - 75%	543 (15%)	
76% - 100%	2,256 (62.2%)	
Prefer not to answer	34 (1%)	
Type of grain products you buy [c]		
Sliced bread	2,995 (82.6%)	Not applicable
Unsliced bread	673 (18.6%)	
Rolls	1,475 (40.7%)	
Muffins	1,215 (33.5%)	
Bagels	1,680 (46.3%)	
Pizza crusts	666 (18.4%)	
Flatbreads	587 (16.2%)	
English muffins	1,407 (38.8%)	
Croissants	931 (25.7%)	
Crackers	2,365 (65.2%)	
Pasta	2,482 (68.5%)	
None of the above products	159 (4.4%)	
Type of bread you buy [c]		
Artisanal	751 (20.7%)	Not applicable
Mass-produced	1,232 (34%)	
Refined flour	446 (12.3%)	
Whole grain	2,251 (62.1%)	
Organic	626 (17.3%)	
Non-GMO	403 (11.1%)	
I do not know	350 (9.7%)	
Where do you buy your bread [c]		
Grocery store	3,075 (84.8%)	Not applicable
Local independent bakery	362 (10%)	
Bakery store chain	262 (7.2%)	
Big box store	1,166 (32.2%)	
Club store	607 (16.7%)	
Bakery outlet	263 (7.3%)	
Online store	118 (3.3%)	
Do not buy – bake at home	45 (1.2%)	
None of the above/do not buy bread	103 (2.8%)	

[a] Counts are followed by the percentage of total responses (n=3,626).
[b] Probabilities less than 0.05 are considered significant.
[c] Study participants could select more than one answer; counts exceed the number of participants (n=3,626). Percentages reflect the total number of responses.

6.3 Consumer seaweed consumption habits

The majority (60.3%) of participants reported having never consumed seaweed (p < 0. 0001) (Table 6.5). Overall, regular consumption of seaweed was relatively low, with only 14% of respondents having eaten seaweed one or more times a month in the past twelve months. Banus (2017) found that 46.5% of 1,065 consumers living in the Northeast U.S. reported eating seaweed in the past year. Australian consumers who have eaten or tasted seaweed in the past were found more likely to eat seaweed in the coming twelve months (Birch et al., 2019). Consumers who are familiar with seaweed products (i.e., are aware that sushi is wrapped in seaweed) are 7.6 times more likely to consume products with seaweed in them (Birch et al., 2019).

When asked whether the survey participant would consider buying bread that contained seaweed, only 38.7% answered yes, followed by 32.2% who were not sure, and 29.1% who answered no ($p < 0.0001$) (Table 6.5). In a study by Birch et al. (2019), food neophobia was the most significant predictor of future seaweed consumption in Australia. A one-unit increase on the food neophobia scale was associated with a 77.2% decrease in predicted odds of future seaweed consumption (Birch et al., 2019). Food neophobia is the avoidance of new or unfamiliar foods. Food neophobia was not measured in this study, but Banus (2017) assessed this trait in American consumers in the Northeast U.S. and found that one-third of consumers surveyed with high food neophobia had previously eaten seaweed compared with 63.6% of participants with low food neophobia.

Participants were also asked to select all reasons that would make them consume seaweed bread more often (Table 6.5). The most commonly-selected responses were: ‘more availability’ (23.6%), ‘lower calories’ (23.4%), and ‘none of the above motivate me’ (22.9%) (Table 6.5).

The options chosen by less than 400 participants were: more seaweed flavor, vegan source of vitamin B_{12}, local, and grown in Maine (Table 6.5).

Consumers were also asked to choose which grain products they would consider trying that contained seaweed (Table 6.6). The largest number of participants chose bread (45.4%), followed by crackers (39.1%), bagels (33.6%), and pasta (32.5%) (Table 6.6). Thirty percent of the survey respondents (n=1,103) did not want to try any of the listed products. Consumers were also asked to select the characteristic(s) that would prevent them from buying bread containing seaweed (Table 6.6). The question was misworded since survey participants could only select one answer. The largest percentage chose flavor (37.2%), followed by price (20.5%), appearance (16.6%), none of the above (12.4%), aroma (7.1%), and texture (6.2%) ($p < 0.0001$) (Table 6.6).

Table 6.5 Seaweed consumption and willingness to purchase seaweed bread

Category	Number (percent of total responses) [a]	Probability [b]
Seaweed Consumption		
Never	2,184 (60.3%)	< 0.0001
1-4 times a year	567 (15.7%)	
5-10 times a year	309 (8.5%)	
1-2 times a month	269 (7.4%)	
1-2 times a week	131 (3.6%)	
2 or more times a week	80 (2.2%)	
Daily	30 (0.8%)	
Prefer not to answer	56 (1.5%)	
Buying bread with seaweed		
Yes	1,402 (38.7%)	< 0.0001
No	1,057 (29.1%)	
Not Sure	1,167 (32.2%)	
What would make you consume seaweed bread more often [c]		
More availability	854 (23.6%)	Not applicable
Natural preservatives	589 (16.2%)	
More seaweed flavor	237 (6.5%)	
Sustainably-grown	429 (11.8%)	
Minimally processed	600 (16.5%)	
Lower calories	850 (23.4%)	
Good source of iodine	496 (13.7%)	
Less seaweed flavor	582 (16.1%)	
Vegan source of vitamin B_{12}	392 (10.8%)	
Organic	561 (15.5%)	
Local	351 (9.7%)	
Grown in Maine	232 (6.4%)	
Source of antioxidants	760 (21%)	
Good source of calcium	665 (18.3%)	
I have no interest in purchasing	619 (17.1%)	
None of the above motivates me	832 (22.9%)	

[a] Counts are followed by the percentage of total responses (n=3,626).

[b] Probabilities less than 0.05 are considered significant.

[c] Study participants could select more than one answer; counts exceed the number of participants (n=3,626). Percentages reflect the total number of responses.

Table 6.6 Interest in other seaweed products and barriers to purchasing

Category	Number (percent of total responses) [a]	Probability [b]
Which products would you try if they contained seaweed? [c]		
Bagels	1,220 (33.6%)	Not applicable
Breads	1,645 (45.4%)	
Crackers	1,418 (39.1%)	
Flatbreads	868 (23.9%)	
Rolls	856 (23.6%)	
Croissants	612 (16.9%)	
Muffins	672 (18.5%)	
English muffins	679 (18.7%)	
Pasta	1,177 (32.5%)	
None of the above	1,103 (30.4%)	
What would prevent you from buying seaweed bread?		
Appearance	603 (16.6%)	< 0.0001
Flavor	1,350 (37.2%)	
Price	742 (20.5%)	
Aroma	257 (7.1%)	
Texture	224 (6.2%)	
None of the above	450 (12.4%)	

[a] Counts are followed by the percentage of total responses (n=3,626).

[b] Probabilities less than 0.05 are considered significant.

[c] Study participants could select more than one answer; counts exceed the number of participants (n=3,626). Percentages reflect the total number of responses.

Table 6.7 shows participants' interest in purchasing bread that contains seaweed. Participants that answered 'no' or 'not sure' to buying seaweed bread were not able to answer these supplemental questions. When asked to select the price they would pay for a one-pound loaf of seaweed bread, the largest percentage of participants (43.6%) answered that they would pay 'less than $4.00', 20.9% selected '$4.00', and 19.4% selected '$5.00' ($p < 0.0001$) (Table 6.7). The prices presented in the test were based on current prices for loaves of bread in local grocery stores and artisanal bakeries. According to the U.S. Bureau of Labor Statistics (2020), the current average price of whole wheat bread (as of June 2020) is $2.12 per pound, and the current price of white bread is $1.47 per pound. The next question asked consumers how much they would be willing to pay for a one-pound loaf of seaweed bread containing Maine seaweed. The largest percentage of participants (39.1%) answered that they would pay 'less than $4.00', 21.4% selected '$4.00', and 19.8% selected '$5.00' ($p < 0.0001$) (Table 6.7).

Answers varied slightly between the two pricing questions but followed a similar trend; 338 participants changed their answer (either decreased or increased) from the first pricing question. Of the 338 participants, 260 increased the price they would pay for seaweed bread from Maine compared to regular seaweed bread (Table 6.8). Of these consumers, the majority (n=193, 74%) reported they would pay $1.00 more for the seaweed bread from Maine. Twenty-one percent reported they would pay $2.00 more, 3.5% reported they would pay $3.00 more, 0.9% reported they would pay $4.00 more, and 0.5% reported they would pay $6.00 more for the seaweed bread from Maine. Table 6.8 shows the demographic influences of participants willing to pay more for seaweed bread from Maine. No significant differences were found between the demographic attributes of participants. Of the 338 participants, 78 decreased the price they would pay for seaweed bread from Maine. Of these consumers, the majority (n=57, 73.1%)

reported they would pay $1.00 less for the seaweed bread from Maine compared to regular seaweed bread (Table 6.8).

Participants were also asked to indicate their preferred packaging for seaweed bread (Table 6.7). Six hundred sixty-nine participants selected ‘resealable plastic’ (47.7%), 663 participants selected ‘paper with clear viewing window’ (47.3%), 354 selected ‘clear plastic’ (25.2%), 285 selected ‘paper’ (20.3%), and 28 participants selected ‘no packaging at all’ (2%) (Table 6.7).

Selected consumers were also asked to indicate how often, and on which occasions they would purchase bread containing seaweed (Table 6.7). A third of participants indicated that they would purchase bread containing seaweed 1-3 times per month (33.8%); followed by once a week (31.5%), several times a year (24.7%), and more than once a week (10%) ($p < 0.0001$) (Table 6.7). While bread remains a staple within the American diet, U.S. shoppers are consuming bread less frequently than in previous years and compared with shopping in other countries. Packaged bread sales have remained relatively steady, with an increase in sales of 6% between 2011 and 2016, a 1% decrease when adjusted for inflation (Wiber & Atchley, 2018).

Popular occasions consumers indicated they would buy seaweed bread included for sandwiches (81.3%), with cheese (49.1%), and snacks (47.8%) (Table 6.7). Other answers included parties (32.4%), picnics (29.2%), and a write-in ‘other’ option (4.2%) (Table 6.7). Popular answers consumers wrote in for ‘other’ included toast (n=11), everyday bread use (n=8), with breakfast (n=5), and with soup (n=4). A suggested retail price of $5.00 would likely be more successful than higher-prices unless the seaweed bread was sought for special occasions.

Table 6.7 Seaweed consumption profile of participants willing to buy bread containing seaweed

Category	Number (percent of total responses) [a]	Probability [b]
Price you would pay for seaweed bread		
Less than $4.00	611 (43.6%)	< 0.0001
$4.00	293 (20.9%)	
$5.00	272 (19.4%)	
$6.00	143 (10.2%)	
$7.00	46 (3.3%)	
$8.00	16 (1.1%)	
More than $8.00	21 (1.5%)	
Price you would pay for Maine seaweed bread		
Less than $4.00	548 (39.1%)	< 0.0001
$4.00	300 (21.4%)	
$5.00	278 (19.8%)	
$6.00	147 (10.5%)	
$7.00	72 (5.2%)	
$8.00	34 (2.4%)	
More than $8.00	23 (1.6%)	
Packaging preferences of seaweed bread [c]		
Paper	285 (20.3%)	Not applicable
Paper with clear viewing window	663 (47.3%)	
Resealable plastic	669 (47.7%)	
Clear plastic	354 (25.2%)	
No packaging at all	28 (2%)	
How often would you buy seaweed bread?		
More than once a week	140 (10%)	< 0.0001
Once a week	442 (31.5%)	
1-3 times per month	474 (33.8%)	
Several times a year	346 (24.7%)	
Occasions to buy seaweed bread [c]		
Sandwiches	1,140 (81.3%)	Not applicable
With Cheese	688 (49.1%)	
Parties	454 (32.4%)	
Snacks	670 (47.8%)	
Picnics	410 (29.2%)	
Other	59 (4.2%)	

[a] Counts are followed by the percentage of total responses (n=1,402).
[b] Probabilities less than 0.05 are considered significant.
[c] Study participants could select more than one answer; counts exceed the number of participants (n=1,402). Percentages reflect the total number of responses.

Table 6.8 Demographic influences of participants willing to pay more for seaweed bread from Maine then regular seaweed bread

Category	Number (percent of total responses) [a]
Gender	
Female	141 (54.2%)
Male	116 (44.6%)
Other	2 (0.8%)
I prefer not to answer	1 (0.4%)
Age	
18 – 24 years old	54 (20.8%)
25 – 34 years old	67 (25.8%)
35 – 44 years old	57 (21.9%)
45 – 54 years old	46 (17.7%)
55 – 64 years old	20 (7.7%)
65 – 74 years old	10 (3.8%)
75 years or older	5 (1.9%)
I prefer not to answer	1 (0.4%)
Geographic Location	
East-North Central	24 (9.2%)
East-South Central	22 (8.5%)
Mid-Atlantic	39 (15%)
Mountain	18 (6.9%)
New England	31 (11.9%)
Pacific	42 (16.2%)
South Atlantic	27 (10.4%)
West-North Central	21 (8.1%)
West-South Central	36 (13.8%)

[a] Counts are followed by the percentage of total responses (n=260).

Table 6.8 Continued

Category	Number (percent of total responses) [a]
Annual Income	
Less than $20,000	27 (10.4%)
$20,000 - $29,999	28 (10.8%)
$30,000 - $39,999	27 (10.4%)
$40,000 - $49,999	26 (10%)
$50,000 - $59,999	24 (9.2%)
$60,000 - $69,999	20 (7.7%)
$70,000 - $79,999	29 (11.2%)
$80,000 - $89,999	10 (3.8%)
$90,000 - $99,999	16 (6.2%)
$100,000 - $149,999	28 (10.8%)
More than $150,000	22 (8.5%)
I prefer not to answer	3 (1.2%)
Education	
High school or GED	78 (30%)
2-year degree	53 (20.4%)
4-year degree	66 (25.4%)
Graduate Degree	51 (19.6%)
Doctorate	9 (3.5%)
I prefer not to answer	3 (1.2%)

[a] Counts are followed by the percentage of total responses (n=260).

The last two questions of the survey revolved around the benefits and risks of seaweed consumption (Table 6.9). Consumers were asked if they considered seaweed or seaweed products to be healthful. Almost half of the participants (49.3%) said yes, 36% said maybe, and 14.7% said no (p < 0.0001) (Table 6.9). When asked if consumers are concerned that seaweed, like other seafood products, may contain heavy metals, 30.1% of participants said no, 26.2% answered maybe, 22% answered not sure, and 21.7% answered yes (p < 0.0001) (Table 6.9). Seaweeds are rapid and effective absorbers of nutrients and other chemicals in the water surrounding them, including the toxic compounds cadmium, lead, copper, nickel, arsenic, and mercury (Roleda & Hurd, 2019; Wells et al., 2017). Although concentrations of heavy metals in commercially available seaweeds may be below the safety limits imposed by regulatory authorities (Cherry et al., 2019; Paz et al., 2019), the lack of proper labeling information and significant variations within different species and geographic location makes consumption of large quantities of seaweed potentially hazardous. Paz et al. (2019) suggest the consumption of no more than 5 grams per day of dried seaweed; this amount should not pose a health risk to healthy adults. This is equivalent to roughly three slices of 5% seaweed baked bread consumed per day at an approximate whole weight of 30 grams per slice.

Table 6.9 Survey participants attitudes and beliefs towards potential health benefits and risks of seaweed consumption

Category	Number (percent of total responses) [a]	Probability [b]
Do you consider seaweed or seaweed products healthful?		
Yes	1,786 (49.3%)	< 0.0001
No	535 (14.7%)	
Maybe	1,305 (36%)	
Are you concerned that seaweed, like other seafood products, may contain heavy metals?		
Yes	788 (21.7%)	< 0.0001
No	1,091 (30.1%)	
Maybe	951 (26.2%)	
Not sure	796 (22%)	

[a] Counts are followed by the percentage of total responses (n=3,626).
[b] Probabilities less than 0.05 are considered significant.

6.4 Evaluation of seaweed bread appearance

Consumers were asked to rate the appearance of pictures of the three seaweed bread formulations (flake, meal, and powder) (Figure 5.1, 5.2, and 5.3). The photos were taken at the sensory evaluation test in Portland, Maine, on July 14, 2019. The standard 9-point hedonic scale was used (Peryam & Pilgrim, 1957). Mean scores were analyzed parametrically by one-way analysis of variance (ANOVA) (Table 6.10). Tukey's Honest Significant Difference (HSD) test was utilized for *post hoc* analyses of data to find possible significant differences among the appearances of the three seaweed bread samples. All hedonic appearance mean scores fell between 'dislike slightly' and 'neither like nor dislike,' a four to five on the hedonic scale (Table 6.10), which is well below the desirable hedonic score of seven or higher. A mean acceptability score of seven or higher on the 9-point hedonic scale is considered to be of significant quality (Stone et al., 2012). However, Jimenez et al. (2014) advise caution in drawing conclusions from hedonic evaluations of foods where subjects look at pictures of a food item rather than consume it.

Significant differences were found between all three bread formulations for appearance ($p < 0.0001$) (Table 6.10). Although each bread formulation had the same amount of seaweed added (5%), the fine particle size of the seaweed powder bread affected the appearance by darkening the color of the sample. This darkness may have had a significant effect on the appearance scores of the seaweed powder bread when compared to the seaweed flake and seaweed meal bread formulations ($p < 0.0001$) (Table 6.10). Consumers showed a preference for the appearance of the seaweed powder over the seaweed meal and a higher preference for the seaweed meal over the seaweed flake sample. The dark color of the seaweed powder bread closely resembled whole wheat or dark rye bread, which may have seemed more familiar to survey participants than the flecked bread containing seaweed flakes or meal. These findings do not agree with the results for the sensory evaluation conducted in July, which found participants liked the appearance and color of the seaweed meal bread significantly more than the appearance of the seaweed powder bread. The strong taste and aroma of the powder-containing bread were correlated with the low acceptability of the seaweed powder bread formulation.

The frequency distribution of the appearance attribute rating for each of the three seaweed bread formulations can be found in Table 6.11. The largest percentage of participants answered that they 'neither liked nor disliked' the appearance for all three seaweed bread samples (Table 6.11).

Table 6.10 Consumer acceptance of the appearance of the three seaweed bread formulations

Mean 9-Point Hedonic Appearance Attribute Ratings [b]					
Attribute	**Flake**	**Meal**	**Powder**	**Probability**	**Significance [c]**
Appearance [a]	4.4 ± 2.4 c	4.9 ± 2.4 b	5.1 ± 2.3 a	< 0.0001	***

[a] Means ± standard deviation (n=3,626) followed by a different letter within the same row are significantly different from each other (Tukey's HSD, $p \leq 0.05$).
[b] 9-point hedonic scale: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely (Peryam & Pilgrim, 1957).
[c] One-way analysis of variance between sample groups: * < 0.05, ** < 0.01, *** < 0.001, NS = No significance.

Table 6.11 Frequency of the appearance attribute ratings for the three seaweed bread formulations [a]

Attribute	Flake	Meal	Powder
Appearance			
Dislike Extremely	646 (17.8%)	525 (14.5%)	419 (11.6%)
Dislike Very Much	287 (7.9%)	238 (6.5%)	203 (5.6%)
Dislike Moderately	322 (8.9%)	246 (6.8%)	245 (6.8%)
Dislike Slightly	390 (10.8%)	378 (10.4%)	338 (9.3%)
Neither Like nor Dislike	891 (24.6%)	782 (21.6%)	857 (23.6%)
Like Slightly	306 (8.4%)	430 (11.9%)	433 (11.9%)
Like Moderately	379 (10.4%)	503 (13.9%)	475 (13.1%)
Like Very Much	250 (6.9%)	338 (9.3%)	415 (11.5%)
Like Extremely	155 (4.3%)	186 (5.1%)	241 (6.6%)

[a] Counts are followed by the percentage of total responses (n=3,626).

The top two and bottom two scores were calculated for the appearance of the three bread formulations (Table 6.12). The top two value is the total number of responses of a score of eight (like very much) and a score of nine (like extremely) on the 9-point hedonic scale. The bottom two value is the total number of responses of a score of two (dislike very much) and a score of one (dislike extremely) on the 9-point hedonic scale. Survey respondents tend to make the error of central tendency, which is the natural propensity to choose scores within the middle of the 9-point hedonic scale more often than the outlying or outer ends of the 9-point hedonic scale (Meilgaard et al., 2007). Significant differences ($p \leq 0.001$) were found between all three bread formulations for the top two and bottom two scores (Table 6.12). The seaweed powder bread formulation received significantly more top two scores (like very much and like extremely) than the other two bread formulations ($p < 0.0001$) (Table 6.12). These results are similar to the three mean attribute hedonic ratings in Table 6.10. The seaweed flake bread formulation received significantly more bottom two scores (dislike very much and dislike extremely) than the other two bread formulations (Table 6.12).

Table 6.12 Frequency of the top two and the bottom two appearance hedonic attribute ratings for the three bread formulations

Top Two and Bottom Two of 9-Point Hedonic Appearance Attribute Ratings [a]					
Attribute	**Flake**	**Meal**	**Powder**	**P-Value [b]**	**Significance [c]**
Appearance T2 [d]	405 (11.2%) c	524 (14.5%) b	656 (18.1%) a	< 0.0001	***
Appearance B2 [e]	933 (25.7%) c	763 (21.1%) b	622 (17.2%) a	< 0.0001	***

[a] Counts are followed by the percentage of total responses (n=3,626). Different letters within the same row indicate a significant difference from each other (Tukey's HSD, $p \leq 0.05$).

[b] Probability value of obtaining a greater F value.

[c] One-way analysis of variance between sample groups: * < 0.05, ** < 0.01, *** < 0.001, NS = No significance.

[d] T2 indicates a hedonic score at the top of the 9-point hedonic scale (8 = like very much and 9 = like extremely).

[e] B2 indicates a hedonic score at the bottom of the 9-point hedonic scale (2 = dislike very much and 1 = dislike extremely).

Two-way analysis of variance (ANOVA) was utilized to evaluate how demographic characteristics of the survey participants interacted with the three seaweed bread formulations for appearance acceptability. Table 6.13 and 6.14 display the mean hedonic appearance scores related to gender, age, geographic region, income, and education level. The only difference detected according to gender was that those who answered 'other' liked the appearance of the seaweed powder bread significantly more than did participants that answered 'I prefer not to answer' ($p = 0.039$) (Table 6.13). No significant differences were found based on gender for the seaweed flake and meal formulations or between males and females for each of the three samples (Table 6.13). Significant differences ($p < 0.0001$) were found between those that answered 'I prefer not to answer' for age for the seaweed powder and meal formulations (Table 6.13). No significant differences were found based on age for the seaweed flake formulation or those between the ages of 18-24 and > 55 for the seaweed meal formulation (Table 6.13).

Table 6.13 Two-way analysis of variance (ANOVA) of bread type and demographic influences (age and gender) on seaweed bread appearance acceptability

Category	**Seaweed Bread Formulations [a,b]**			**Mean values**
	Flake	**Meal**	**Powder**	
Gender				
Male	4.5 ± 0.1 a	4.9 ± 0.1 a	5.2 ± 0.1 ab	4.8 ± 0.1
Female	4.4 ± 0.1 a	4.9 ± 0.1 a	5.1 ± 0.1 ab	4.8 ± 0.1
Other	5.9 ± 0.7 a	6.0 ± 0.7 a	6.0 ± 0.7 a	6.0 ± 0.7
Prefer not to answer	6.2 ± 1.0 a	4.5 ± 1.0 a	2.8 ± 1.0 b	4.5 ± 1.0
Age				
18 – 24 years old	4.1 ± 0.1 a	4.6 ± 0.1 ab	5.0 ± 0.1 a	4.6 ± 0.1
25 – 34 years old	4.7 ± 0.1 a	5.2 ± 0.1 a	5.5 ± 0.1 a	5.1 ± 0.1
35 – 44 years old	4.6 ± 0.1 a	5.1 ± 0.1 a	5.3 ± 0.1 a	5.0 ± 0.1
45 – 54 years old	4.7 ± 0.1 a	5.1 ± 0.1 a	5.2 ± 0.1 a	5.0 ± 0.1
55 – 64 years old	4.3 ± 0.1 a	4.6 ± 0.1 ab	4.8 ± 0.1 a	4.6 ± 0.1
65 – 74 years old	4.1 ± 0.1 a	4.5 ± 0.1 ab	5.0 ± 0.1 a	4.5 ± 0.1
75 years or older	4.5 ± 0.1 a	4.8 ± 0.1 ab	5.3 ± 0.1 a	4.8 ± 0.1
Prefer not to answer	3.9 ± 0.5 a	4.1 ± 0.5 b	3.8 ± 0.5 b	3.9 ± 0.5

[a] 9-point hedonic scale: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely (Peryam & Pilgrim, 1957).

[b] Mean values are followed by the standard deviation (n=3,626). Each value is also followed by a different letter within the same column for each demographic category and indicates a significant difference from each other (Tukey's HSD, $p \leq 0.05$).

The only difference detected according to geographic region was that participants from the East-North Central region liked the appearance of the seaweed powder bread significantly more than did participants from the South Atlantic region ($p = 0.09$) (Table 6.14). No significant differences were found between the geographic location for the seaweed flake and meal formulations (Table 6.14). Significant differences were found between all three seaweed bread formulations when compared to participants' annual household income ($p < 0.0001$), with a positive association between mean appearance scores and higher annual household income (Table 6.14). Significant differences were also found between all three seaweed bread formulations when compared to participants' education level ($p < 0.0001$), with a positive association between mean appearance scores and higher education levels (Table 6.14).

Table 6.14 Two-way analysis of variance (ANOVA) of bread type and demographic influences (geographic location, income, and education level) on seaweed bread appearance acceptability

Category	Seaweed Bread Formulations [a,b]			Mean values
	Flake	Meal	Powder	
Geographic location				
New England	4.6 ± 0.1 a	5.0 ± 0.1 a	5.2 ± 0.1 ab	4.9 ± 0.1
Mid-Atlantic	4.4 ± 0.1 a	4.9 ± 0.1 a	5.2 ± 0.1 ab	4.8 ± 0.1
South Atlantic	4.3 ± 0.1 a	4.7 ± 0.1 a	4.8 ± 0.5 b	4.6 ± 0.1
East-North Central	4.4 ± 0.1 a	4.8 ± 0.1 a	5.3 ± 0.1 a	4.8 ± 0.1
East-South Central	4.5 ± 0.1 a	4.9 ± 0.1 a	5.1 ± 0.1 ab	4.8 ± 0.1
West-North Central	4.3 ± 0.1 a	4.8 ± 0.1 a	5.1 ± 0.1 ab	4.7 ± 0.1
Mountain	4.6 ± 0.1 a	5.0 ± 0.1 a	5.3 ± 0.1 ab	4.9 ± 0.1
West-South Central	4.3 ± 0.1 a	4.8 ± 0.1 a	5.1 ± 0.1 ab	4.7 ± 0.1
Pacific	4.5 ± 0.1 a	5.1 ± 0.1 a	5.2 ± 0.1 ab	4.9 ± 0.1
Income				
Less than $20,000	4.2 ± 0.1 ab	4.6 ± 0.1 ab	4.7 ± 0.1 cd	4.5 ± 0.1
$20,000 - $29,999	4.3 ± 0.1 ab	4.7 ± 0.1 ab	4.9 ± 0.1 bcd	4.6 ± 0.1
$30,000 - $39,999	4.3 ± 0.1 ab	4.8 ± 0.1 ab	5.1 ± 0.1 abcd	4.7 ± 0.1
$40,000 - $49,999	4.6 ± 0.1 a	5.0 ± 0.1 a	5.2 ± 0.1 abc	4.9 ± 0.1
$50,000 - $59,999	4.6 ± 0.1 a	5.1 ± 0.1 a	5.4 ± 0.1 abc	5.0 ± 0.1
$60,000 - $69,999	4.6 ± 0.2 a	5.1 ± 0.2 a	5.4 ± 0.2 ab	5.0 ± 0.2
$70,000 - $79,999	4.6 ± 0.1 a	4.9 ± 0.2 ab	5.2 ± 0.1 abcd	4.9 ± 0.1
$80,000 - $89,999	4.6 ± 0.2 ab	5.0 ± 0.2 a	5.6 ± 0.2 a	5.0 ± 0.2
$90,000 - $99,999	4.7 ± 0.2 a	5.1 ± 0.2 a	5.4 ± 0.2 abc	5.0 ± 0.2
$100,000 - $149,999	4.6 ± 0.1 a	5.1 ± 0.1 a	5.3 ± 0.1 abc	5.0 ± 0.1
More than $150,000	4.6 ± 0.1 a	5.0 ± 0.1 a	5.3 ± 0.1 abc	5.0 ± 0.1
Prefer not to answer	3.8 ± 0.2 b	4.3 ± 0.2 b	4.6 ± 0.2 d	4.2 ± 0.2
Education level				
High school or GED	4.1 ± 0.1 bc	4.5 ± 0.1 b	4.8 ± 0.1 ab	4.5 ± 0.1
2-year degree	4.6 ± 0.1 ab	5.0 ± 0.1 a	5.1 ± 0.1 ab	4.9 ± 0.1
4-year degree	4.6 ± 0.1 ab	5.1 ± 0.1 a	5.4 ± 0.1 a	5.0 ± 0.1
Graduate degree	4.8 ± 0.1 a	5.1 ± 0.1 a	5.4 ± 0.1 a	5.1 ± 0.1
Doctorate degree	4.6 ± 0.2 ab	5.2 ± 0.2 a	5.4 ± 0.2 a	5.1 ± 0.2
Prefer not to answer	3.8 ± 0.3 c	4.2 ± 0.3 b	4.7 ± 0.3 b	4.2 ± 0.3

[a] 9-point hedonic scale: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely (Peryam & Pilgrim, 1957).

[b] Mean values are followed by the standard deviation (n=3,626). Each value is also followed by a different letter within the same column for each demographic category and indicates a significant difference from each other (Tukey's HSD, $p \leq 0.05$).

6.5 Demographic influences on potential seaweed product purchasing

Relationships among demographic traits were cross-tabulated with consumer interest in foods containing seaweed and seaweed consumption (Table 6.15, 6.16, 6.17, 6.18, & 6.19). Chi-squared analyses were used to determine whether responses to demographic and shopping questions had distributions that were not equal. No significant differences were found between gender and willingness to buy seaweed bread ($p = 0.26$), frequency of buying seaweed bread ($p = 0.77$), or price consumers are willing to pay for seaweed bread ($p = 0.29$) (Table 6.15). Significant differences were detected for gender when compared to the frequency of seaweed consumption; 61% of males and 60% of females stated they never consume seaweed, while 50% that answered 'other' stated they consume seaweed at least 5-10 times a year ($p < 0.0001$) (Table 6.15). Significant differences were also detected for gender when compared to the price participants are willing to pay for seaweed bread from Maine; 80.6% of males, 80.3% of females, and 60% who answered 'other' are willing to pay $5.00 or less for a loaf of seaweed bread from Maine ($p = 0.01$) (Table 6.15).

Table 6.15 Cross-tabulation of gender influences on seaweed consumption and seaweed bread acceptability [a]

	Female	**Male**	**Other**	**I prefer not to answer**
Totals	**1,831**	**1,777**	**12**	**6**
How often do you eat seaweed? (n=3,626)				
Daily	16 (0.4%)	13 (0.4%)	0 (0%)	1 (0%)
2 or more times a week	42 (1.2%)	37 (1%)	1 (0%)	0 (0%)
1-2 times a week	68 (1.9%)	62 (1.7%)	1 (0%)	0 (0%)
1-2 times a month	145 (4%)	121 (3.3%)	3 (0.1%)	0 (0%)
1-4 times a year	283 (7.8%)	279 (7.7%)	5 (0.1%)	0 (0%)
5-10 times a year	152 (4.2%)	156 (4.3%)	1 (0%)	0 (0%)
Never	1,098 (30.3%)	1,083 (29.9%)	1 (0%)	2 (0.1%)
I prefer not to answer	27 (0.7%)	26 (0.7%)	0 (0%)	3 (0.1%)
Would you buy seaweed bread? (n=3,626)				
Yes	685 (18.9%)	711 (19.6%)	5 (0.1%)	1 (0.1%)
No	526 (14.5%)	527 (14.5%)	2 (0.1%)	2 (0.1%)
Not sure	620 (17.1%)	539 (14.9%)	5 (0.1%)	3 (0.1%)

[a] Counts are followed by the percentage of total responses (n=3,626).

Table 6.15 Continued [a]

	Female	Male	Other	I prefer not to answer
Totals	**685**	**711**	**5**	**1**
How often would you buy seaweed bread? (n=1,402) [b]				
More than once a week	73 (5.2%)	66 (4.7%)	1 (0.1%)	0 (0%)
Once a week	220 (15.7%)	220 (15.7%)	2 (0.1%)	0 (0%)
1-3 times per month	222 (15.8%)	251 (17.9%)	1 (0.1%)	0 (0%)
Several times a year	170 (12.1%)	174 (12.4%)	1 (0.1%)	1 (0.1%)
Price you would pay for seaweed bread (n=1,402) [b]				
Less than $4.00	328 (23.4%)	282 (20.1%)	0 (0%)	1 (0.1%)
$4.00	137 (9.8%)	154 (11%)	2 (0.1%)	0 (0%)
$5.00	119 (8.5%)	152 (10.8%)	1 (0.1%)	0 (0%)
$6.00	62 (4.4%)	79 (5.6%)	2 (0.1%)	0 (0%)
$7.00	21 (1.5%)	25 (1.8%)	0 (0%)	0 (0%)
$8.00	6 (0.4%)	10 (0.7%)	0 (0%)	0 (0%)
More than $8.00	12 (0.9%)	9 (0.6%)	0 (0%)	0 (0%)
Price you would pay for Maine seaweed bread (n=1,402) [b]				
Less than $4.00	287 (20.5%)	260 (18.5%)	1 (0.1%)	0 (0%)
$4.00	140 (10%)	159 (11.3%)	1 (0.1%)	0 (0%)
$5.00	123 (8.8%)	154 (11%)	1 (0.1%)	0 (0%)
$6.00	80 (5.7%)	66 (4.7%)	1 (0.1%)	0 (0%)
$7.00	33 (2.4%)	37 (2.6%)	1 (0.1%)	1 (0.1%)
$8.00	10 (0.7%)	24 (1.7%)	0 (0%)	0 (0%)
More than $8.00	12 (0.9%)	11 (0.8%)	0 (0%)	0 (0%)

[a] Counts are followed by the percentage of total responses (n=1,402).

[b] Seaweed consumption profile of participants willing to buy bread containing seaweed (answered ‘yes’).

Significant differences in consumer interest and consumption, when compared to age, are shown in Figure 6.2 and Table 6.16. Seaweed consumption within the last 12 months ($p <$ 0.0001), willingness to buy seaweed bread ($p < 0.0001$), frequency of buying seaweed bread ($p <$ 0.0001), and the price consumers are willing to pay for seaweed bread ($p < 0.0001$) and seaweed bread from Maine ($p < 0.0001$) all decreased with older age (Figure 6.2 and Table 6.16). Meiselman et al. (2010) noted that food neophobia tends to increase with age. The highest percentage of consumers for consumption within the last 12 months and willingness to buy seaweed bread were between the ages of 25-34 years old followed by 18-24 years old and 35-44 years old ($p < 0.0001$) (Table 6.16). The highest percentage of consumers for weekly buying frequency and willingness to pay greater than $5.00 for seaweed bread and seaweed bread from Maine were between the ages of 18-24 years old followed by 25-34 years old ($p < 0.0001$) (Table 6.16).

Figure 6.2 Consumer interest in buying seaweed bread varies by age (n=3,626)

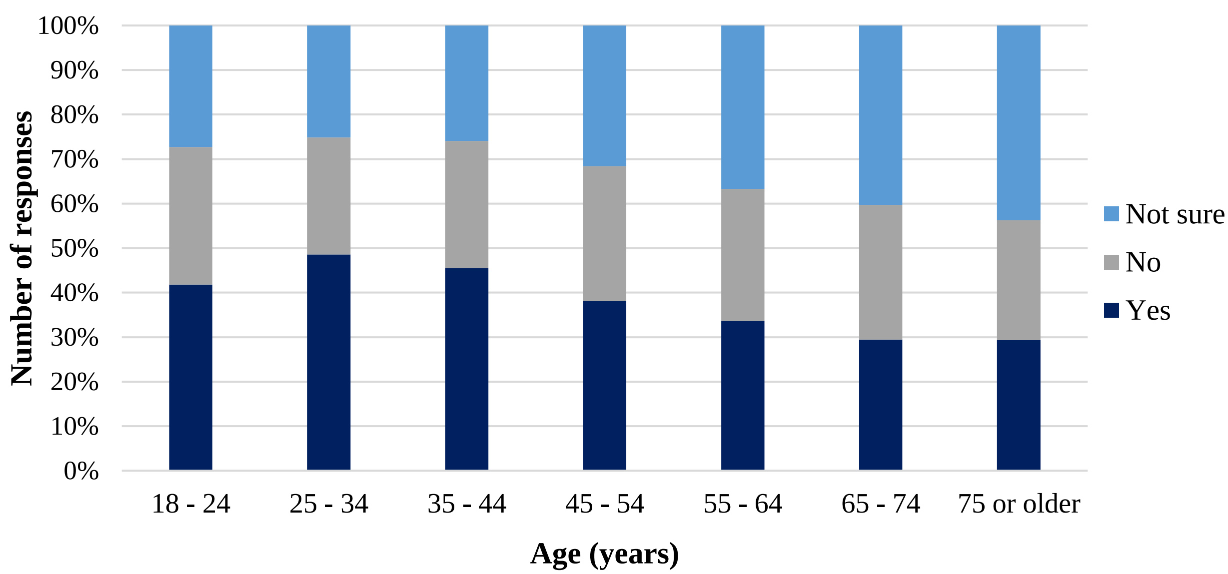


Table 6.16 Cross-tabulation of age on seaweed consumption and seaweed bread acceptability [a]

	18 - 24 years old	25 - 34 years old	35 - 44 years old	45 - 54 years old	55 - 64 years old	65 - 74 years old	75 years or older	prefer not to answer
Totals	**385**	**624**	**613**	**570**	**577**	**506**	**327**	**24**
How often do you eat seaweed? (n=3,626)								
Daily	8 (0.2%)	9 (0.2%)	4 (0.1%)	5 (0.1%)	2 (0.1%)	0 (0%)	2 (0.1%)	0 (0%)
2 or more times a week	12 (0.3%)	18 (0.5%)	28 (0.8%)	11 (0.3%)	3 (0.1%)	6 (0.2%)	2 (0.1%)	0 (0%)
1-2 times a week	22 (0.6%)	44 (1.2%)	36 (1%)	12 (0.3%)	11 (0.3%)	5 (0.1%)	0 (0%)	1 (0%)
1-2 times a month	45 (1.2%)	70 (1.9%)	63 (1.7%)	49 (1.4%)	21 (0.6%)	16 (0.4%)	5 (0.1%)	0 (0%)
1-4 times a year	57 (1.6%)	119 (3.3%)	106 (2.9%)	95 (2.6%)	83 (2.3%)	63 (1.7%)	37 (1%)	7 (0.2%)
5-10 times a year	54 (1.5%)	82 (2.3%)	58 (1.6%)	50 (1.4%)	25 (0.7%)	33 (0.9%)	5 (0.1%)	2 (0.1%)
Never	175 (4.8%)	272 (7.5%)	307 (8.5%)	341 (9.4%)	428 (11.8%)	378 (10.4%)	272 (7.5%)	11 (0.3%)
Prefer not to answer	12 (0.3%)	10 (0.3%)	11 (0.3%)	7 (0.2%)	4 (0.1%)	5 (0.1%)	4 (0.1%)	3 (0.1%)
Would you buy seaweed bread? (n=3,626)								
Yes	161 (4.4%)	303 (8.4%)	279 (7.7%)	217 (6%)	194 (5.4%)	149 (4.1%)	96 (2.6%)	3 (0.1%)
No	119 (3.3%)	164 (4.5%)	175 (4.8%)	173 (4.8%)	171 (4.7%)	153 (4.2%)	88 (2.4%)	14 (0.4%)
Not sure	105 (2.9%)	157 (4.3%)	159 (4.4%)	180 (5%)	212 (5.8%)	204 (5.6%)	143 (3.9%)	7 (0.2%)

[a] Counts are followed by the percentage of total responses (n=3,626).

Table 6.16 Continued [a]

	18 - 24 years old	25 - 34 years old	35 - 44 years old	45 - 54 years old	55 - 64 years old	65 - 74 years old	75 years or older	Prefer not to answer
Totals	**161**	**303**	**279**	**217**	**194**	**149**	**96**	**3**
How often would you buy seaweed bread? (n=1,402) [b]								
More than once a week	25 (1.8%)	43 (3.1%)	37 (2.6%)	19 (1.4%)	6 (0.4%)	6 (0.4%)	3 (0.2%)	1 (0.1%)
Once a week	56 (4%)	107 (7.6%)	91 (6.5%)	82 (5.8%)	50 (3.6%)	33 (2.4%)	22 (1.6%)	1 (0.1%)
1-3 times per month	57 (4.1%)	92 (6.6%)	96 (6.8%)	68 (4.9%)	74 (5.3%)	46 (3.3%)	41 (2.9%)	0 (0%)
Several times a year	23 (1.6%)	61 (4.4%)	55 (3.9%)	48 (3.4%)	64 (4.6%)	64 (4.6%)	30 (2.1%)	1 (0.1%)
Price you would pay for seaweed bread (n=1,402) [b]								
Less than $4.00	43 (3.1%)	95 (6.8%)	114 (8.1%)	93 (6.6%)	119 (8.5%)	77 (5.5%)	69 (4.9%)	1 (0.1%)
$4.00	28 (2%)	68 (4.9%)	60 (4.3%)	45 (3.2%)	36 (2.6%)	42 (3%)	14 (1%)	0 (0%)
$5.00	40 (2.9%)	65 (4.6%)	58 (4.1%)	51 (3.6%)	27 (1.9%)	19 (1.4%)	10 (0.7%)	2 (0.1%)
$6.00	31 (2.2%)	44 (3.1%)	27 (1.9%)	21 (1.5%)	10 (0.7%)	9 (0.6%)	1 (0.1%)	0 (0%)
$7.00	11 (0.8%)	16 (1.1%)	12 (0.9%)	3 (0.2%)	1 (0.1%)	1 (0.1%)	2 (0.1%)	0 (0%)
$8.00	4 (0.3%)	4 (0.3%)	5 (0.4%)	2 (0.1%)	1 (0.1%)	0 (0%)	0 (0%)	0 (0%)
More than $8.00	4 (0.3%)	11 (0.8%)	3 (0.2%)	2 (0.1%)	0 (0%)	1 (0.1%)	0 (0%)	0 (0%)
Price you would pay for Maine seaweed bread (n=1,402) [b]								
Less than $4.00	31 (2.2%)	86 (6.1%)	101 (7.2%)	79 (5.6%)	111 (7.9%)	73 (5.2%)	65 (4.6%)	2 (0.1%)
$4.00	35 (2.5%)	64 (4.6%)	58 (4.1%)	46 (3.3%)	38 (2.7%)	42 (3%)	17 (1.2%)	0 (0%)
$5.00	38 (2.7%)	68 (4.9%)	59 (4.2%)	51 (3.6%)	29 (2.1%)	23 (1.6%)	10 (0.7%)	0 (0%)
$6.00	30 (2.1%)	38 (2.7%)	31 (2.2%)	26 (1.9%)	11 (0.8%)	9 (0.6%)	1 (0.1%)	1 (0.1%)
$7.00	16 (1.1%)	25 (1.8%)	19 (1.4%)	7 (0.5%)	2 (0.1%)	0 (0%)	3 (0.2%)	0 (0%)
$8.00	7 (0.5%)	13 (0.9%)	7 (0.5%)	5 (0.4%)	2 (0.1%)	0 (0%)	0 (0%)	0 (0%)
More than $8.00	4 (0.3%)	9 (0.6%)	4 (0.3%)	3 (0.2%)	1 (0.1%)	2 (0.1%)	0 (0%)	0 (0%)

[a] Counts are followed by the percentage of total responses (n=1,402).

[b] Seaweed consumption profile of participants willing to buy bread containing seaweed (answered ‘yes’).

Seaweed consumption within the last 12 months differed by geographic location, the highest percentage of consumers being from the Pacific (55%) followed by the Mid-Atlantic (44%) and Mountain (40%) regions ($p < 0.0001$) (Table 6.17). The highest percentage of consumers with weekly seaweed consumption being from the Pacific (10%) followed by the Mid-Atlantic (10%) and South Atlantic (9%) regions ($p < 0.0001$) (Table 6.17). Willingness to buy seaweed bread did not differ by geographic location ($p = 0.183$) (Table 6.17). More people from the Mid-Atlantic (52%) followed by the East-North Central (44%) and South Atlantic (44%) regions stated that they would buy seaweed bread more frequently on a weekly basis than did people in other regions ($p = 0.043$) (Table 6.17). Consumers willing to pay $5.00 or more for seaweed bread, and seaweed bread from Maine differed with geographic location; the highest percentage of participants being from the Mid-Atlantic followed by the Pacific and South-Atlantic regions for each category ($p = 0.0001$) (Table 6.17).

Significant differences in consumers' seaweed interest and consumption, when compared to annual household income, are shown in Table 6.18. Seaweed consumption ($p < 0.0001$), willingness to buy seaweed bread ($p < 0.0001$), and price consumers are willing to pay for seaweed bread ($p = 0.0005$) and seaweed bread from Maine ($p = 0.008$) were associated with higher income levels (Table 6.18). The highest percentage of consumers who have consumed seaweed within the last 12 months by those who make more than $150,000 a year (47%) followed by those who make between $80,000-$89,999 (45%) a year and $100,000-$149,999 a year (44%) ($p < 0.0001$) (Table 6.18). The highest percentage of consumers willing to buy seaweed bread were those that made more than $150,000 a year (46%) followed by those that make between $70,000-$79,999 a year (45%) and $90,000-$99,999 a year (45%) ($p < 0.0001$) (Table 6.18). The frequency of buying seaweed bread had no significant differences when compared to annual income (p = 0.46) (Table 6.18). The highest percentage of participants willing to pay $5.00 or more for seaweed bread were those making between $90,000-$99,999 a year (48%) followed by $70,000-$79,999 a year (48%) and those who make more than $150,000 a year (42%) ($p$ = 0.0005) (Table 6.18). The highest percentage of participants willing to pay $5.00 or more for seaweed bread from Maine were those making between $70,000-$79,999 a year (56%) followed by $90,000-$99,999 a year (46%) and those who make more than $150,000 a year (45%) ($p$ = 0.008) (Table 6.18).

Table 6.17 Cross-tabulation of geographic location on seaweed consumption and seaweed bread acceptability [a]

	East-North Central	East-South Central	Mid-Atlantic	Mountain	New England	Pacific	South Atlantic	West-North Central	West-South Central
Totals	**403**	**389**	**392**	**386**	**424**	**415**	**416**	**404**	**397**
How often do you eat seaweed? (n=3,626)									
Daily	5 (0.1%)	4 (0.1%)	3 (0.1%)	2 (0.1%)	2 (0.1%)	5 (0.1%)	3 (0.1%)	1 (0%)	5 (0.1%)
2 or more times a week	3 (0.1%)	4 (0.1%)	13 (0.4%)	7 (0.2%)	9 (0.2%)	18 (0.5%)	13 (0.4%)	6 (0.2%)	7 (0.2%)
1-2 times a week	8 (0.2%)	8 (0.2%)	23 (0.6%)	19 (0.5%)	9 (0.2%)	20 (0.6%)	21 (0.6%)	10 (0.3%)	13 (0.4%)
1-2 times a month	24 (0.7%)	14 (0.4%)	28 (0.8%)	22 (0.6%)	33 (0.9%)	54 (1.5%)	31 (0.9%)	29 (0.8%)	34 (0.9%)
1-4 times a year	52 (1.4%)	53 (1.5%)	73 (2%)	76 (2.1%)	72 (2%)	81 (2.2%)	49 (1.4%)	54 (1.5%)	57 (1.6%)
5-10 times a year	23 (0.6%)	28 (0.8%)	31 (0.9%)	30 (0.8%)	45 (1.2%)	49 (1.4%)	39 (1.1%)	31 (0.9%)	33 (0.9%)
Never	278 (7.7%)	273 (7.5%)	220 (6.1%)	226 (6.2%)	248 (6.8%)	182 (5%)	250 (6.9%)	264 (7.3%)	243 (6.7%)
Prefer not to answer	10 (0.3%)	5 (0.1%)	1 (0%)	4 (0.1%)	6 (0.2%)	6 (0.2%)	10 (0.3%)	9 (0.2%)	5 (0.1%)
Would you buy seaweed bread? (n=3,626)									
Yes	132 (3.6%)	154 (4.2%)	164 (4.5%)	151 (4.2%)	172 (4.7%)	168 (4.6%)	151 (4.2%)	143 (3.9%)	167 (4.6%)
No	117 (3.2%)	111 (3.1%)	120 (3.3%)	109 (3%)	118 (3.3%)	117 (3.2%)	120 (3.3%)	125 (3.4%)	120 (3.3%)
Not sure	154 (4.2%)	124 (3.4%)	108 (3%)	126 (3.5%)	134 (3.7%)	130 (3.6%)	145 (4%)	136 (3.8%)	110 (3%)

[a] Counts are followed by the percentage of total responses (n=3,626).

Table 6.17 Continued [a]

	East-North Central	East-South Central	Mid-Atlantic	Mountain	New England	Pacific	South Atlantic	West-North Central	West-South Central
Totals	**132**	**154**	**164**	**151**	**172**	**168**	**151**	**143**	**167**
How often would you buy seaweed bread? (n=1,402) [b]									
More than once a week	18 (1.3%)	11 (0.8%)	28 (2%)	8 (0.6%)	21 (1.5%)	14 (1%)	19 (1.4%)	8 (0.6%)	13 (0.9%)
Once a week	40 (2.9%)	45 (3.2%)	58 (4.1%)	49 (3.5%)	50 (3.6%)	57 (4.1%)	47 (3.4%)	38 (2.7%)	58 (4.1%)
1-3 times per month	40 (2.9%)	61 (4.4%)	50 (3.6%)	48 (3.4%)	63 (4.5%)	54 (3.9%)	45 (3.2%)	55 (3.9%)	58 (4.1%)
Several times a year	34 (2.4%)	37 (2.6%)	28 (2%)	46 (3.3%)	38 (2.7%)	43 (3.1%)	40 (2.9%)	42 (3.0%)	38 (2.7%)
Price you would pay for seaweed bread (n=1,402) [b]									
Less than $4.00	66 (4.7%)	88 (6.3%)	52 (3.7%)	71 (5.1%)	70 (5%)	59 (4.2%)	61 (4.4%)	70 (5%)	74 (5.3%)
$4.00	27 (1.9%)	31 (2.2%)	31 (2.2%)	37 (2.6%)	38 (2.7%)	42 (3%)	30 (2.1%)	26 (1.9%)	31 (2.2%)
$5.00	20 (1.4%)	22 (1.6%)	45 (3.2%)	25 (1.8%)	38 (2.7%)	39 (2.8%)	23 (1.6%)	28 (2%)	32 (2.3%)
$6.00	8 (0.6%)	10 (0.7%)	24 (1.7%)	10 (0.7%)	17 (1.2%)	24 (1.7%)	18 (1.3%)	13 (0.9%)	19 (1.4%)
$7.00	5 (0.4%)	2 (0.1%)	7 (0.5%)	5 (0.4%)	2 (0.1%)	1 (0.1%)	14 (1%)	4 (0.3%)	6 (0.4%)
$8.00	2 (0.1%)	0 (0%)	3 (0.2%)	2 (0.1%)	5 (0.4%)	1 (0.1%)	0 (0%)	0 (0%)	3 (0.2%)
More than $8.00	4 (0.3%)	1 (0.1%)	2 (0.1%)	1 (0.1%)	2 (0.1%)	2 (0.1%)	5 (0.4%)	2 (0.1%)	2 (0.1%)

[a] Counts are followed by the percentage of total responses (n=1,402).

[b] Seaweed consumption profile of participants willing to buy bread containing seaweed (answered ‘yes’).

Table 6.17 Continued [a]

	East-North Central	East-South Central	Mid-Atlantic	Mountain	New England	Pacific	South Atlantic	West-North Central	West-South Central
Totals	**132**	**154**	**164**	**151**	**172**	**168**	**151**	**143**	**167**
Price you would pay for Maine seaweed bread (n=1,402) [b]									
Less than $4.00	60 (4.3%)	84 (6%)	49 (3.5%)	61 (4.4%)	58 (4.1%)	49 (3.5%)	56 (4%)	66 (4.7%)	65 (4.6%)
$4.00	24 (1.7%)	29 (2.1%)	24 (1.7%)	43 (3.1%)	43 (3.1%)	38 (2.7%)	32 (2.3%)	33 (2.4%)	34 (2.4%)
$5.00	26 (1.9%)	23 (1.6%)	43 (3.1%)	29 (2.1%)	42 (3%)	41 (2.9%)	24 (1.7%)	22 (1.6%)	28 (2%)
$6.00	9 (0.6%)	6 (0.4%)	22 (1.6%)	14 (1%)	14 (1%)	26 (1.9%)	19 (1.4%)	13 (0.9%)	24 (1.7%)
$7.00	4 (0.3%)	7 (0.5%)	20 (1.4%)	2 (0.1%)	7 (0.5%)	9 (0.6%)	9 (0.6%)	5 (0.4%)	9 (0.6%)
$8.00	3 (0.2%)	4 (0.3%)	3 (0.2%)	2 (0.1%)	5 (0.4%)	3 (0.2%)	6 (0.4%)	3 (0.2%)	5 (0.4%)
More than $8.00	6 (0.4%)	1 (0.1%)	3 (0.2%)	0 (0%)	3 (0.2%)	2 (0.1%)	5 (0.4%)	1 (0.1%)	2 (0.1%)

[a] Counts are followed by the percentage of total responses (n=1,402).

[b] Seaweed consumption profile of participants willing to buy bread containing seaweed (answered 'yes').

Table 6.18 Cross-tabulation of annual income on seaweed consumption and seaweed bread acceptability [a]

	Less than $20,000	**$20,000 - $29,999**	**$30,000 - $39,999**	**$40,000 - $49,999**	**$50,000 - $59,999**	**$60,000 - $69,999**	**$70,000 - $79,999**	**$80,000 - $89,999**	**$90,000 - $99,999**	**$100,000 - $149,999**	**More than $150,000**	**Prefer not to answer**
Totals	**475**	**361**	**390**	**306**	**322**	**223**	**264**	**159**	**191**	**428**	**286**	**221**
How often do you eat seaweed? (n=3,626)												
Daily	3 ‘(0.1%)	4 (0.1%)	1 (0%)	3 (0.1%)	2 (0.1%)	2 (0.1%)	1 (0%)	0 (0%)	3 (0.1%)	4 (0.1%)	5 (0.1%)	2 (0.1%)
2 or more times a week	3 (0.1%)	5 (0.1%)	7 (0.2%)	10 (0.3%)	7 (0.2%)	4 (0.1%)	11 (0.3%)	5 (0.1%)	9 (0.2%)	10 (0.3%)	9 (0.2%)	0 (0%)
1-2 times a week	13 (0.4%)	10 (0.3%)	14 (0.4%)	10 (0.3%)	12 (0.3%)	10 (0.3%)	13 (0.4%)	8 (0.2%)	8 (0.2%)	20 (0.6%)	11 (0.3%)	2 (0.1%)
1-2 times a month	25 (0.7%)	31 (0.9%)	22 (0.6%)	23 (0.6%)	23 (0.6%)	17 (0.5%)	19 (0.5%)	11 (0.3%)	14 (0.4%)	43 (1.2%)	29 (0.8%)	12 (0.3%)
1-4 times a year	62 (1.7%)	47 (1.3%)	62 (1.7%)	43 (1.2%)	47 (1.3%)	31 (0.9%)	50 (1.4%)	32 (0.9%)	24 (0.7%)	71 (2%)	59 (1.6%)	39 (1.1%)
5-10 times a year	35 (1%)	36 (1%)	34 (0.9%)	20 (0.6%)	30 (0.8%)	24 (0.7%)	22 (0.6%)	16 (0.4%)	22 (0.6%)	42 (1.2%)	20 (0.6%)	8 (0.2%)
Never	321 (8.9%)	221 (6.1%)	246 (6.8%)	193 (5.3%)	198 (5.5%)	134 (3.7%)	145 (4%)	87 (2.4%)	110 (3%)	234 (6.5%)	152 (4.2%)	143 (3.9%)
Prefer not to answer	13 (0.4%)	7 (0.2%)	4 (0.1%)	4 (0.1%)	3 (0.1%)	1 (0%)	3 (0.1%)	0 (0%)	1 (0%)	4 (0.1%)	1 (0%)	15 (0.4%)
Would you buy seaweed bread? (n=3,626)												
Yes	156 (4.3%)	147 (4.1%)	138 (3.8%)	122 (3.4%)	130 (3.6%)	92 (2.5%)	119 (3.3%)	70 (1.9%)	85 (2.3%)	175 (4.8%)	130 (3.6%)	38 (1%)
No	176 (4.9%)	99 (2.7%)	129 (3.6%)	89 (2.5%)	89 (2.5%)	60 (1.7%)	75 (2.1%)	31 (0.9%)	53 (1.5%)	104 (2.9%)	70 (1.9%)	82 (2.3%)
Not sure	143 (3.9%)	115 (3.2%)	123 (3.4%)	95 (2.6%)	103 (2.8%)	71 (2%)	70 (1.9%)	58 (1.6%)	53 (1.5%)	149 (4.1%)	86 (2.4%)	101 (2.8%)

[a] Counts are followed by the percentage of total responses (n=3,626).

Table 6.18 Continued [a]

	Less than $20,000	$20,000 - $29,999	$30,000 - $39,999	$40,000 - $49,999	$50,000 - $59,999	$60,000 - $69,999	$70,000 - $79,999	$80,000 - $89,999	$90,000 - $99,999	$100,000 - $149,999	More than $150,000	Prefer not to answe r
Totals	**156**	**147**	**138**	**122**	**130**	**92**	**119**	**70**	**85**	**175**	**130**	**38**
How often would you buy seaweed bread? (n=1,402) [b]												
More than once a week	25 (1.8%)	18 (1.3%)	13 (0.9%)	14 (1%)	11 (0.8%)	9 (0.6%)	11 (0.8%)	6 (0.4%)	5 (0.4%)	14 (1%)	12 (0.9%)	2 (0.1%)
Once a week	42 (3%)	48 (3.4%)	44 (3.1%)	46 (3.3%)	39 (2.8%)	30 (2.1%)	40 (2.9%)	25 (1.8%)	30 (2.1%)	55 (3.9%)	39 (2.8%)	4 (0.3%)
1-3 times per month	54 (3.9%)	48 (3.4%)	44 (3.1%)	34 (2.4%)	51 (3.6%)	28 (2%)	44 (3.1%)	26 (1.9%)	27 (1.9%)	58 (4.1%)	44 (3.1%)	16 (1.1%)
Several times a year	35 (2.5%)	33 (2.4%)	37 (2.6%)	28 (2%)	29 (2.1%)	25 (1.8%)	24 (1.7%)	13 (0.9%)	23 (1.6%)	48 (3.4%)	35 (2.5%)	16 (1.1%)
Price you would pay for seaweed bread (n=1,402) [b]												
Less than $4.00	86 (6.1%)	69 (4.9%)	75 (5.3%)	54 (3.9%)	57 (4.1%)	46 (3.3%)	41 (2.9%)	29 (2.1%)	28 (2%)	58 (4.1%)	43 (3.1%)	25 (1.8%)
$4.00	28 (2%)	39 (2.8%)	18 (1.3%)	27 (1.9%)	29 (2.1%)	20 (1.4%)	21 (1.5%)	13 (0.9%)	16 (1.1%)	48 (3.4%)	32 (2.3%)	2 (0.1%)
$5.00	29 (2.1%)	20 (1.4%)	32 (2.3%)	20 (1.4%)	23 (1.6%)	13 (0.9%)	30 (2.1%)	13 (0.9%)	23 (1.6%)	36 (2.6%)	26 (1.9%)	7 (0.5%)
$6.00	8 (0.6%)	11 (0.8%)	7 (0.5%)	15 (1.1%)	11 (0.8%)	10 (0.7%)	19 (1.4%)	13 (0.9%)	13 (0.9%)	20 (1.4%)	12 (0.9%)	4 (0.3%)
$7.00	1 (0.1%)	3 (0.2%)	4 (0.3%)	3 (0.2%)	7 (0.5%)	2 (0.1%)	6 (0.4%)	1 (0.1%)	4 (0.3%)	7 (0.5%)	8 (0.6%)	0 (0%)
$8.00	1 (0.1%)	2 (0.1%)	1 (0.1%)	1 (0.1%)	0 (0%)	1 (0.1%)	0 (0%)	1 (0.1%)	0 (0%)	4 (0.3%)	5 (0.4%)	0 (0%)
More than $8.00	3 (0.2%)	3 (0.2%)	1 (0.1%)	2 (0.1%)	3 (0.2%)	0 (0%)	2 (0.1%)	0 (0%)	1 (0.1%)	2 (0.1%)	4 (0.3%)	0 (0%)

[a] Counts are followed by the percentage of total responses (n=1,402).

[b] Seaweed consumption profile of participants willing to buy bread containing seaweed (answered ‘yes’).

Table 6.18 Continued [a]

	Less than $20,000	$20,000 - $29,999	$30,000 - $39,999	$40,000 - $49,999	$50,000 - $59,999	$60,000 - $69,999	$70,000 - $79,999	$80,000 - $89,999	$90,000 - $99,999	$100,000 - $149,999	More than $150,000	Prefer not to answer
Totals	**156**	**147**	**138**	**122**	**130**	**92**	**119**	**70**	**85**	**175**	**130**	**38**
Price you would pay for Maine seaweed bread (n=1,402) [b]												
Less than $4.00	78 (5.6%)	61 (4.4%)	65 (4.6%)	45 (3.2%)	46 (3.3%)	38 (2.7%)	37 (2.6%)	29 (2.1%)	29 (2.1%)	56 (4%)	41 (2.9%)	23 (1.6%)
$4.00	30 (2.1%)	40 (2.9%)	23 (1.6%)	24 (1.7%)	35 (2.5%)	24 (1.7%)	16 (1.1%)	11 (0.8%)	17 (1.2%)	44 (3.1%)	31 (2.2%)	5 (0.4%)
$5.00	30 (2.1%)	23 (1.6%)	30 (2.1%)	29 (2.1%)	26 (1.9%)	14 (1%)	31 (2.2%)	13 (0.9%)	22 (1.6%)	30 (2.1%)	25 (1.8%)	5 (0.4%)
$6.00	12 (0.9%)	10 (0.7%)	11 (0.8%)	14 (1%)	11 (0.8%)	9 (0.6%)	21 (1.5%)	10 (0.7%)	8 (0.6%)	24 (1.7%)	12 (0.9%)	5 (0.4%)
$7.00	3 (0.2%)	7 (0.5%)	7 (0.5%)	6 (0.4%)	6 (0.4%)	5 (0.4%)	9 (0.6%)	5 (0.4%)	6 (0.4%)	12 (0.9%)	6 (0.4%)	0 (0%)
$8.00	2 (0.1%)	2 (0.1%)	1 (0.1%)	2 (0.1%)	3 (0.2%)	2 (0.1%)	3 (0.2%)	2 (0.1%)	2 (0.1%)	7 (0.5%)	8 (0.6%)	0 (0%)
More than $8.00	1 (0.1%)	4 (0.3%)	1 (0.1%)	2 (0.1%)	3 (0.2%)	0 (0%)	2 (0.1%)	0 (0%)	1 (0.1%)	2 (0.1%)	7 (0.5%)	0 (0%)

[a] Counts are followed by the percentage of total responses (n=1,402).

[b] Seaweed consumption profile of participants willing to buy bread containing seaweed (answered 'yes').

Significant differences in consumer interest and consumption, when compared to education level, are shown in Figure 6.3 and Table 6.19. Educational levels were not evenly distributed among the survey respondents; one-third (n = 1,213) of participants reported having a high school or GED education, and only 125 participants said that they held a doctoral degree. Seaweed consumption within the last 12 months ($p < 0.0001$), willingness to buy seaweed bread ($p < 0.0001$), and the price consumers are willing to pay for seaweed bread ($p = 0.001$) and seaweed bread from Maine ($p < 0.008$) all increased with higher education levels (Figure 6.3 and Table 6.19). The frequency of buying seaweed bread had no significant differences when compared to education level ($p = 0.328$) (Table 6.19). Consumers with higher education, specifically those with a doctorate followed by a graduate degree and 4-year degree, consumed seaweed more often ($p < 0.0001$), were more willing to buy seaweed bread ($p < 0.0001$), and were willing to pay more for seaweed bread ($p = 0.001$) and seaweed bread from Maine ($p = 0.008$) (Figure 6.3 and Table 6.19).

Figure 6.3 Consumer interest in buying seaweed bread varies by education level (n=3,626)

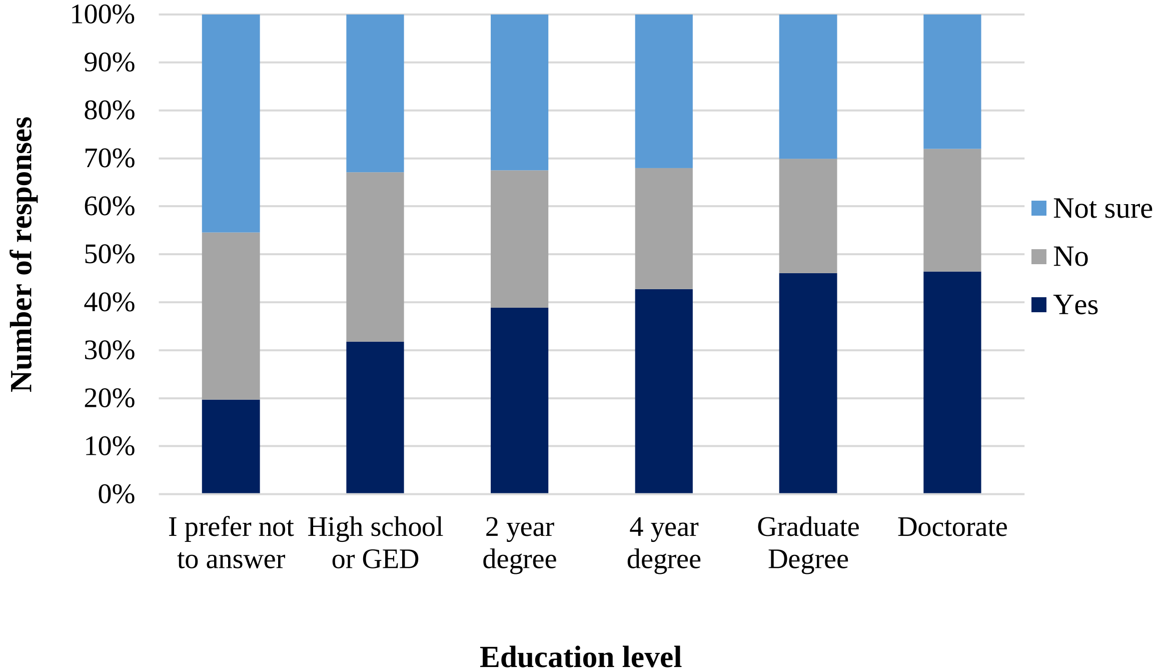


Table 6.19 Cross-tabulation of education level on seaweed consumption and seaweed bread acceptability [a]

	High school or GED	2 year degree	4 year degree	Graduate degree	Doctorate	Prefer not to answer
Totals	**1,213**	**646**	**955**	**621**	**125**	**66**
How often do you eat seaweed? (n=3,626)						
Daily	8 (0.2%)	5 (0.1%)	5 (0.1%)	9 (0.2%)	3 (0.1%)	0 (0%)
2 or more times a week	19 (0.5%)	9 (0.2%)	27 (0.7%)	20 (0.6%)	5 (0.1%)	0 (0%)
1-2 times a week	31 (0.9%)	16 (0.4%)	42 (1.2%)	37 (1%)	4 (0.1%)	1 (0%)
1-2 times a month	61 (1.7%)	36 (1%)	97 (2.7%)	57 (1.6%)	16 (0.4%)	2 (0.1%)
1-4 times a year	143 (3.9%)	104 (2.9%)	169 (4.7%)	110 (3%)	31 (0.9%)	10 (0.3%)
5-10 times a year	78 (2.2%)	62 (1.7%)	93 (2.6%)	61 (1.7%)	10 (0.3%)	5 (0.1%)
Never	852 (23.5%)	409 (11.3%)	513 (14.1%)	314 (8.7%)	55 (1.5%)	41 (1.1%)
Prefer not to answer	21 (0.6%)	5 (0.1%)	9 (0.2%)	13 (0.4%)	1 (0%)	7 (0.2%)
Would you buy seaweed bread? (n=3,626)						
Yes	386 (10.6%)	251 (6.9%)	408 (11.3%)	286 (7.9%)	58 (1.6%)	13 (0.4%)
No	428 (11.8%)	185 (5.1%)	241 (6.6%)	148 (4.1%)	32 (0.9%)	23 (0.6%)
Not sure	399 (11%)	210 (5.8%)	306 (8.4%)	187 (5.2%)	35 (1%)	30 (0.8%)

[a] Counts are followed by the percentage of total responses (n=3,626).

Table 6.19 Continued [a]

	High school or GED	2 year degree	4 year degree	Graduate degree	Doctorate	Prefer not to answer
Totals	**386**	**251**	**408**	**286**	**58**	**13**
How often would you buy seaweed bread? (n=1,402) [b]						
More than once a week	44 (3.1%)	31 (2.2%)	30 (2.1%)	27 (1.9%)	7 (0.5%)	1 (0.1%)
Once a week	123 (8.8%)	83 (5.9%)	126 (9%)	94 (6.7%)	16 (1.1%)	0 (0%)
1-3 times per month	130 (9.3%)	80 (5.7%)	147 (10.5%)	92 (6.6%)	17 (1.2%)	8 (0.6%)
Several times a year	89 (6.3%)	57 (4.1%)	105 (7.5%)	73 (5.2%)	18 (1.3%)	4 (0.3%)
Price you would pay for seaweed bread (n=1,402) [b]						
Less than $4.00	206 (14.7%)	113 (8.1%)	157 (11.2%)	107 (7.6%)	21 (1.5%)	7 (0.5%)
$4.00	73 (5.2%)	59 (4.2%)	87 (6.2%)	62 (4.4%)	9 (0.6%)	3 (0.2%)
$5.00	62 (4.4%)	45 (3.2%)	98 (7%)	53 (3.8%)	12 (0.9%)	2 (0.1%)
$6.00	27 (1.9%)	27 (1.9%)	41 (2.9%)	38 (2.7%)	10 (0.7%)	0 (0%)
$7.00	12 (0.9%)	4 (0.3%)	14 (1%)	14 (1%)	1 (0.1%)	1 (0.1%)
$8.00	2 (0.1%)	0 (0%)	7 (0.5%)	5 (0.4%)	2 (0.1%)	0 (0%)
More than $8.00	4 (0.3%)	3 (0.2%)	4 (0.3%)	7 (0.5%)	3 (0.2%)	0 (0%)
Price you would pay for Maine seaweed bread (n=1,402) [b]						
Less than $4.00	178 (12.7%)	95 (6.8%)	149 (10.6%)	99 (7.1%)	20 (1.4%)	7 (0.5%)
$4.00	82 (5.8%)	62 (4.4%)	83 (5.9%)	60 (4.3%)	11 (0.8%)	2 (0.1%)
$5.00	67 (4.8%)	54 (3.9%)	88 (6.3%)	57 (4.1%)	10 (0.7%)	2 (0.1%)
$6.00	33 (2.4%)	25 (1.8%)	47 (3.4%)	34 (2.4%)	7 (0.5%)	1 (0.1%)
$7.00	16 (1.1%)	11 (0.8%)	23 (1.6%)	18 (1.3%)	4 (0.3%)	0 (0%)
$8.00	5 (0.4%)	2 (0.1%)	14 (1%)	12 (0.9%)	1 (0.1%)	0 (0%)
More than $8.00	5 (0.4%)	2 (0.1%)	4 (0.3%)	6 (0.4%)	5 (0.4%)	1 (0.1%)

[a] Counts are followed by the percentage of total responses (n=1,402).
[b] Seaweed consumption profile of participants willing to buy bread containing seaweed (answered ‘yes’).

CHAPTER SEVEN

SUMMARY AND CONCLUSIONS

The study aimed to provide insights into the consumption of value-added seaweed products and reveal potential consumer groups that are most likely to buy and eat low-moisture seaweed products, such as baked bread. These insights may provide helpful input for product innovations, creative positioning, and marketing strategies to capitalize on the growing acceptance of seaweed products in western societies and help pave the way for increased consumption (Birch et al., 2019; Palmieri et al., 2020). While Maine leads the country in edible seaweed harvest volume, the domestic industry is still in its relative infancy (Piconi et al., 2020). As noted in the research, imported seaweed products account for approximately 99% of total U.S. seaweed consumption (Piconi et al., 2020). Given the challenges of competing with low-cost imported products, Maine edible seaweed producers' greatest potential for profitable growth requires brand building, customer awareness, and the development of differentiated, value-added products with broad consumer appeal.

The brand building and customer awareness process should address both company-specific brands, such as VitaminSea Seaweed, as well as interest in domestic edible seaweed as an industry. Marketing strategies should include sustainability, health and environmental benefits, and differentiating characteristics of domestically sourced products. For example, edible seaweeds are a sustainable source of both macro- and micronutrients, but in areas of the world where water quality does not meet higher U.S. standards, seaweeds may contain increased amounts of heavy metals (Cherry et al., 2019; Piconi et al., 2020). Maine's water quality offers a potential competitive advantage that can be leveraged against competitors for greater market positioning (Piconi et al., 2020).

Seaweed consumption, frequency of buying seaweed bread, and price consumers are willing to pay had a positive correlation with younger age, higher income, and higher education levels. The research shows a high level of willingness to eat seaweed among consumers tested. This willingness may indicate consumers becoming more receptive to novel foods (Palmieri et al., 2020). Developing sophisticated seaweed products that appeal to higher educated consumers may increase consumption and product sales. Other potential marketing strategies include accentuating the significant health and nutritional benefits of seaweed consumption (Birch et al., 2019; Palmieri et al., 2020). In an opinion paper by Prager (2017), more health-conscious and educated consumers are a primary market for seaweed products.

Seaweed particle size was also found to affect consumer acceptance of the bread. The finer particle size of the seaweed powder imparted a much darker color than did the seaweed flakes or meal. This darkness may have had a significant effect on the appearance scores of the seaweed powder-containing bread. The dark color closely resembled whole wheat or dark rye bread, which may have seemed more familiar to online survey participants than the flecked breads containing seaweed flakes or meal. Consumers surveyed online liked the appearance of the seaweed powder over the other two samples. While it is advised to be cautious in drawing conclusions from hedonic evaluations of food images, these judgments could be viewed as similar to real-world situations, such as choosing a picture of a meal on a restaurant advertisement, a printed menu, or a food item on the grocery store shelf (Jimenez et al., 2014). These findings, however, did not agree with the results from the sensory evaluation test. The appearance and color of the seaweed meal bread were liked significantly more than the appearance of the seaweed powder bread. The intensified taste and aroma of the powder-containing bread was correlated with low acceptability. Seaweed aroma plays a significant role in the taste sensations they induce. It is not surprising that the aroma and taste attribute scores were highly correlated with the sensory evaluation test. The noted strong fishy/ocean smell of the seaweed powder bread formulation was disliked significantly more than the aromas of the other two samples. Managing sensory characteristics of appearance, aroma, and taste will be vital to broader market acceptance, given that food neophobia is the greatest obstacle to consuming novel products, such as seaweed (Birch et al., 2019). Although most people in the sensory evaluation study stated they would buy the bread containing the larger sized seaweed pieces, a larger marketing study is needed. Some refinements may be necessary to improve the acceptability of baked products containing seaweed. Dried seaweed added to whole wheat bread should also be evaluated in future studies.

The development of new varieties of seaweed added to low-moisture products, such as baked bread, shows promise in overall consumer acceptability. Opportunities exist for producers to incorporate dried seaweed for added umami flavor, nutrients, and novelty. Consumers' overall preference favored the seaweed meal and seaweed flakes over the seaweed powder, but few significant differences existed between the seaweed meal and seaweed flakes. Future markets for seaweed bread may exist most within younger, higher-educated, and higher-income markets within the Mid-Atlantic, Pacific, and South-Atlantic regions. A considerable number of people were not sure whether they would buy seaweed bread, which is a reasonable answer because the product is novel. Opportunities to familiarize consumers with seaweed bread, such as sample tastings in stores or at food fairs, should be evaluated. Future considerations might include further exploration of consumer preferences for other innovative and nutritious low-moisture seaweed products and how to best market these products to consumers as an alternative healthy food choice.

REFERENCES

Abreu, M. H., Pereira, R., & Sassi, J. (2015). Marine algae and the global food industry. In Pereira L., Magalhaes, J. (Eds.), *Marine algae: Biodiversity, taxonomy, environmental assessment, and biotechnology,* (pp. 300-319). CRC Press, Boca Raton, FL.

Ahmadi, A., Moghadamtousi, S. Z., Abubaker, S., & Zandi, K. (2015). Antiviral potential of algae polysaccharides isolated from marine sources: A review. *Biomed Research International*, 2015, e1-e10.

Allsopp, P., Crowe, W., Bahar, B., Harnedy, P. A., Brown, E. S., Taylor, S. S., … McSorley, E. M. (2016). The effect of consuming Palmaria palmata-enriched bread on inflammatory markers, antioxidant status, lipid profile and thyroid function in a randomised placebo-controlled intervention trial in healthy adults. *European journal of nutrition*, 55(5), 1951–1962.

Altintzoglou, T., Heide, M., Wien, A. & Honkanen, P. (2016). Traditional sushi for modern consumers: A comparison between sushi consumption behavior in Japan and Norway. *Journal of Food Products Marketing,* 27(6), 717-732.

Arufe, S., Della Valle, G., Chiron, H., Chenlo, F., Sineiro, J., & Moreira, R. (2018). Effect of brown seaweed powder on physical and textural properties of wheat bread. *European Food Research and Technology,* 244, 1-10.

Arumugam, N., Chelliapan, S., Kamyab, H., Thirugnana, S., Othman, N., & Nasri, N. S. (2018). Treatment of wastewater using seaweed: A review. *International Journal of Environmental Research and Public Health,* 15(12), 2851-2868.

Augyte, S., Yarish, C., Redmond, S., & Kim, J. K. (2017). Cultivation of a morphologically distinct strain of the sugar kelp, *Saccharina latissima* forma *angustissima*, from coastal Maine, USA, with implications for ecosystem services. *Journal of Applied Phycology,* 29(4), 1967-1976.

Badmus, U. O., Taggart, M. A., & Boyd, K. G. (2019). The effect of different drying methods on certain nutritionally important chemical constituents in edible brown seaweeds. *Journal of Applied Phycology,* 31, 3883-3897.

Bak, U. G., Nielsen, C. W., Marinho, G. S., Gregersen, O., Jónsdóttir, R., & Holdt, S. L. (2019). The seasonal variation in nitrogen, amino acid, protein and nitrogen-to-protein conversion factors of commercially cultivated Faroese *Saccharina latissima. Algal Research,* 42, e1-e10.

Banus, C. (2017). Consumer attitudes toward seaweed in the eastern United States. University of Maine. *Electronic Theses and Dissertations,* 2785.

Barsanti, L., & Gualtieri, P. (2014). *Algae: Anatomy, Biochemistry, and Biotechnology*. (2nd Ed.). Boca Raton, Florida: CRC Press.

Basset, G., Latimer, S., Fatihi, A., Soubeyrand, E., & Block, A. (2016). Phylloquinone (vitamin K_1): Occurrence, biosynthesis and functions. *Mini-Reviews in Medicinal Chemistry,* 17(12), 1028-1038.

Birch, D., Skallerud, K., & Paul, N. A. (2019). Who are the future seaweed consumers in a Western society? Insights from Australia. *British Food Journal*, 121(2), 603-615.

Bolton, J. J. (2010). The biogeography of kelps (Laminariales, Phaeophyceae): a global analysis with new insights from recent advances in molecular phylogenetics. *Helgoland Marine Research,* 64(4), 263-279.

Borum, J., Pedersen, M., Krause-Jensen, D., Christensen, P., & Nielsen, K. (2002). Biomass, photosynthesis and growth of *Laminaria saccharina* in a high-artic fjord, NE Greenland. *Marine Biology,* 141, 11-19.

Breton, T. S., Nettleton, J. C., O'Connell, B., & Bertocci, M. (2018). Fine-scale population genetic structure of sugar kelp, *Saccharina latissima* (Laminariales, Phaeophyceae), in eastern Maine, USA. *Phycologia,* 57, 32-40.

Brown, E. M., Allsopp, P. J., Magee, P. J., Gill, C. I. R., Nitecki, S., Strain, C. R., & McSorley, E. M. (2014). Seaweed and human health. *Nutrition Reviews*, 72, 205-216.

Bruhn, A., Brynning, G., Johansen, A., Lindegaard, M. S., Sveigaard, H. H., Aarup, B., … Børsting, M. E. (2019). Fermentation of sugar kelp (*Saccharina latissima*) – effects on sensory properties, and content of minerals and metals. *Journal of Applied Phycology,* 31(5), 3175-3187.

Buschmann, A. H., Camus, C., Infante, J., Neori, A., Israel, A., Hernandez-Gonzalez, M. C., . . . Critchley, A. T. (2017). Seaweed production: Overview of the global state of exploitation, farming, and emerging research activity. *European Journal of Phycology,* 52(4), 391-406.

Čagalj, M., Haas, R., & Morawetz, U.B. (2016). Effects of quality claims on willingness to pay for organic food: Evidence from experimental auctions in Croatia. *British Food Journal.* 118, 2218-2233.

Castillejo, N., Martinez-Hernandez, G. B., Goffi, V., Gomez, P. A., Aguayo, E., Artes, F., & Artes-Hernandez, F. (2018). Natural vitamin B_{12} and fucose supplementation of green smoothies with edible algae and related quality changes during their shelf life. *Journal of the Science of Food and Agriculture,* 98, 2411-2421.

Cardoso, S. M., Pereira, O. R., Seca, A. M., Pinto, D. C., & Silva, A. M. (2015). Seaweeds as preventive agents for cardiovascular diseases: From nutrients to functional foods. *Marine Drugs*, 13(11), 6838-6865.

Chang, C. H., Wang, Y. W., Yeh Liu, P. Y., & Kao Yang, Y. H. (2014). A Practical approach to minimize the interaction of dietary vitamin K with warfarin. *Journal of Clinical Pharmacy and Therapeutics*, 39, 56-60.

Cherry, P., O'Hara, C., Magee, P. J., McSorley, E. M., & Allsopp P. J. (2019). Risks and benefits of consuming edible seaweeds. *Nutrition Reviews*, 0(0), 1-23.

Cho, M. L., Han, J. H., & You, S. G. (2011). Inhibitory effects of fucan sulfates on enzymatic hydrolysis of starch. *LWT Food Science and Technology*, 44, 1164-1171.

Circuncisão, A. R., Catarino, M. D., Cardoso, S. M., & Silva, A. M. S. (2018). Minerals from macroalgae origin: Health benefits and risks for consumers. *Marine Drugs*, 16(11), e1-e30.

Crane, M. M., Tangney, C. C., French, S. A., Wang, Y., Appelhans, B. M. (2019). Gender comparison of the diet quality and sources of food purchases made by urban primary household food purchases. *Journal of Nutrition Education and Behavior*, 51, 199-204.

Dagnelie, P. C., Van Staveren, W. A., & Van den Berg, H. (1991). Vitamin B_{12} from algae appears not to be bioavailable. *American Journal of Clinical Nutrition*, 53, 695-697.

Dernini, S., Berry, E. M., Serra-Majem, L., La Vecchia, C., Capone, R., Medina, F. X., … Trichopoulou, A. (2017). Med Diet 4.0: the Mediterranean diet with four sustainable benefits. *Public health nutrition*, 20(7), 1322–1330.

De San, M. (2012). The farming of seaweed. European Union. Retrieved from http://www. fao.org/3/a-bl759e.pdf.

Dillehay T.D., Ramirez, C., Pino, M., Collins, M.B., Rossen, J., Pinot-Navarro, J. D. (2008). Monte Verde: Seaweed, food, medicine and the peopling of South America. *Science*, 320, 784-789.

D'Orazio, N., Gammone, M. A., Gemello, E., De Girolamo, M., Cusenza, S., & Riccioni, G. (2012). Marine bioactives: pharmacological properties and potential applications against inflammatory diseases. *Marine Drugs*, 10, 812-833.

Duran-Frontera, E. (2017). Development of a process approach for retaining seaweed sugar kelp (Saccharina latissima) nutrients. The University of Maine. *Honors College*, 297.

Durate, C. M., Wu, J., Xiao, X., Bruhn, A., & Krause-Jensen, D. (2017). Can seaweed farming Play a role in climate change mitigation and adaptation? *Frontier in Marine Science*, 4, e1-e8.

Ellis, J., & Tiller, R. (2019). Conceptualizing future scenarios of integrated multi-trophic Aquaculture (IMTA) in the Norwegian salmon industry. *Marine Policy,* 104, 198-209.

Fantonalgo, R., & Falguisana, M. N. (2017). Detrimental effects of the selected heavy metals to seaweeds: A review. *Journal of Environmental and Earth Science,* 7(7), 30-39.

Ferdman, R. A. (2014, June 19). What America's changing bread preferences say about its politics. *The Washington Post.* Retrieved from https://www.washingtonpost.com/news/wonk/wp/2014/06/19/what-americas-changing-bread-preferences-say-about-its-politics/.

Fernandez-Ferrin, P., Calvo-Turrientes, A., Bande, B., Artaraz-Minon, M., & Galan-Ladero, M. M. (2018). The valuation and purchase of food products that combine local, regional and traditional feature: The influence of consumer ethnocentrism. *Food Quality and Preference,* 64, 138-147.

Fitton, J. H., Stringer, D. N., Karpiniec, S. S. (2015). *Marine Drugs,* 13(9), 5920-5946.

Flavin, K., Flavin, N., & Flahive, B. (2013). *Kelp farming manual: A guide to the processes, techniques, and equipment for farming kelp in New England water.* Saco, Maine: Ocean Approved. Retrieved from https://static1.squarespace.com/static/52f23e95e4b0a96c7b53ad7c/t/52f78b0de4b0374e6a0a4da8/1391954701750/OceanApproved_KelpManualLowRez.pdf.

Fleurence, J., & Levine, I. (2016). *Seaweed in health and disease prevention*. San Diego, California: Academic Press.

Food and Agriculture Organization of the United Nations (FAO). (2018a). The global state of seaweed production, trade and utilization. Rome, 1-24. Retrieved from http://www.fao.org/3/CA1121EN/ca1121en.pdf.

Food and Agriculture Organization of the United Nations (FAO). (2018b). The state of world fisheries and aquaculture 2018. Rome, 1-227. Retrieved from http://www.fao.org/3/i9540en/i9540en.pdf.

Ganesan, A. R., Subramani, K., Shanmugam, M., Seedevi, P., Park, S., Alfarham, A. H., … Balasubramanian, B. (2019). A comparison of nutritional value of underexploited edible seaweeds with recommended dietary allowances. *Journal of King Saud University – Science,* https://doi.org/10.1016/j.jksus.2019.11.009.

Griffin, J., & Warner, B. (2017). *In pursuit of sea vegetable expansion: Consumer preferences and product innovation.* Rockland, Maine: Island Institute.

Hadden, K.B., Prince, L.Y., Moore, T.D., James, L.P., Holland, J.R., & Trudeau, C.R. (2017). Improving readability of informed consents for research at an academic medical institution. *Journal of Clinical and Translational Science,* 1(6), 361-365.

Hafting, J. T., Critchley, A. T., Cornish, M. L., Hubley, S. A., & Archibald, A. F. (2012). On-land cultivation of functional seaweed products for human usage. *Journal of Applied Phycology,* 24, 385-392.

Hall, A. C., Fairclough, A. C., Mahadevan, K., & Paxman, J. R. (2012). Ascophyllum nodosum enriched bread reduces subsequent energy intake with no effect on post-prandial glucose and cholesterol in healthy, overweight males: A pilot study. *Appetite,* 58(1), 379-386.

Harnedy, P. A., & FitzGerald, R. J. (2011). Bioactive proteins, peptides, and amino acids from macroalgae. *Journal of Phycology,* 47(2), 218-232.

Herbert, V., & Drivas, G. (1982). Spirulina and vitamin B_{12}. *Journal of the American Medical Association,* 248(23), 3096-7.

Holdt, S. L., & Kraan, S. (2010). Bioactive compounds in seaweed: Functional food applications and legislation. *Journal of Applied Phycology,* 23, 543-597.

Hu, Z-M., & Fraser, C. (2016). Seaweed phylogeography: Adaptation and evolution of seaweeds under environmental change. Dordrecht, Netherlands: Springer.

Hurd, C. L., Harrison, P. J., Bischof, K., & Lobban, C. S. (2014). *Seaweed ecology and physiology* (2^{nd} Ed.). Cambridge, New York: Cambridge University Press.

Ikeda, K. (1909). New Seasonings. *Journal of Tokyo Chemical Society,* 30, 820-836. (in Japanese).

Inouye, B. (Artist). (2019). [Figure]. Fig. 2.20. (A) Diagram showing general alga morphology. Retrieved from https://manoa.hawaii.edu/exploringourfluidearth/media_colorbox/3037/media_original/en.

Iop, S. C. F., Teixeira, E., & Deliza, R. (2006). Consumer research: Extrinsic variables in food studies. *British Food Journal,* 108(10-11), 894-903.

Jimenez, M., Rodriquez, D., Greene, N., Zellner, D. A., Cardello, A. V., & Nestrud, M. (2014). Seeing a meal is not eating it: Hedonic context effects differ for visually presented and actually eaten foods. *Food Quality and Preference*, 41, 96-102.

Jimenez-Escrig, A., & Sanchez-Muniz, F. J. (2000). Dietary fibre from edible seaweeds: Chemical structure, physicochemical properties and effects on cholesterol metabolism. *Nutrition Research,* 20(4), 585-598.

Kamao, M., Suhara, Y., Tsugawa, N., Uwano, M., Yamaguchi, N., Uenishi, K., … Okano, T. (2007). Vitamin K content of foods and dietary vitamin K intake in Japanese young women. *Journal of Nutritional Science and Vitaminology,* 53, 464-470.

Kim, S-K., & Bhatnagar, I. (2011). Physical, chemical, and biological properties of wonder kelp – Laminaria. *Advances in Food and Nutrition Research,* 64, 85-96.

Kim, E-S., Kim, M-S., Na, W-R., & Sohn, C-M. (2013). Estimation of vitamin K intake in Koreans and determination of the primary vitamin K-containing food sources based on the fifth Korean National Health and Nutrition Examination Survey (2010-2011). *Nutrition Research and Practice*, 7(6), 503-509.

Kraus, A., Annunziata, A., & Vecchio, R. (2017). Sociodemographic factors differentiating the consumer and the motivations for functional food consumption. *Journal of the American College of Nutrition*, 36, 116-126.

Kumudha, A., & Sarada, R. (2016). Characterization of vitamin B_{12} in *Dunaliella salina*. *Journal of Food Science and Technology*, 53(1), 888-894.

Kumudha, A., Selvakumar, S., Dilshad, P., Vaidyanathan, G., Thakur, M. S., & Sarada, R. (2015). Methylcobalamin – A form of vitamin B_{12} identified and characterized in *Chlorella vulgaris*. *Food Chemistry*, 170, 316-320.

Kurihara, K. (2015). Umami the fifth basic taste: History of studies on receptor mechanisms and role as a food flavor. *BioMed Research International,* 2015, e1-e10.

Lang, M., Stanton, J., & Qu, Y. (2014). Consumers' evolving definition and expectations for local foods. *British Food Journal*, 116, 1808-1820.

Leblanc, C., Dube, M. P., Presse, N., Dumas, S., Nguyen, M., Rouleau-Mailloux, E., … Ferland, G. (2016). Avoidance of vitamin K rich foods is common among warfarin users and translates into lower usual vitamin K intakes. *Journal of the Academy of Nutrition and Dietetics,* 116, 1000-1007.

Lourenco, S. O., Barbarino, E., De-Paula, J. C., Pereira, L. O. d. S., & Marquez, U. M L. (2002). Amino acid composition, protein content and calculation of nitrogen-to-protein conversion factors for 19 tropical seaweeds. *Phycological Research,* 50, 233-241.

Luning, K., & Mortensen, L. (2015). European aquaculture of sugar kelp (*Saccharina latissima*) for food industries: iodine content and epiphytic animals as major problems. *Botanica Marina,* 58, 449-455.

MacArtain, P., Gill, C. I. R., Brooks, M., Campbell, R., & Rowland, I. R. (2007). Nutritional value of edible seaweeds. *Nutrition Reviews,* 65(12), 535-543.

Mac Monagail, M., Cornish, L., Morrison, L., Araujo, R., & Critchley, A. T. (2017). Sustainable harvesting of wild seaweed resources. *European Journal of Phycology,* 52(4), 371-390.

Maeda, H., Tsukui, T., Sashima, T., Hosokawa, M., & Miyashita, K. (2009). Seaweed carotenoid, fucoxanthin, as a multi-functional nutrient. *Asia Pacific Journal of Clinical Nutrition*, 17, 196-199.

Maine Department of Marine Resources. (2019). Aquaculture lease applications and forms. Retrieved from https://www.maine.gov/dmr/aquaculture/forms/index.html.

Maine Sea Grant. (2018). Maine Seafood Guide - Seaweed. Retrieved from https://www.seagrant .umaine.edu/maine-seafood-guide/seaweed.

Maine Seaweed Council. (2019). MSC harvester information. Harvester's field guide to Maine seaweeds. Retrieved from https://www.seaweedcouncil.org/msc-harvester-information/.

Mamat, H., Matanjun, P., Ibrahim, S., Amin, S. F., Hamid, M. A., & Rameli, A. S. (2014). The effect of seaweed composite flour on the textural properties of dough and bread. *Journal of Applied Phycology*, 26, 1057-1062.

Marinho, G. S., Holdt, S. L., Jacobsen, C., & Angelidaki, I. (2015). Lipids and composition of fatty acids of *Saccharina latissima* cultivated year-round in integrated multi-trophic aquaculture. *Marine Drugs,* 13(7), 4357-4374.

Martinez-Hernandez, G. B., Castillejo, N., Carrion-Monteagudo, M. D. M., Artes, F., & Artes-Hernandez, F. (2017). *Food Science and Technology International*, 24(2), 172-182.

McGuire, P. (2019, October 28). Rockweed industry adrift after ruling allows landowners to restrict access. *Portland Press Herald.* Retrieved from https://www.pressherald.com/ 2019/10/28/rockweed-industry-clobbered-by-courts-tidal-ruling/.

Medeiros, D. M., & Wildman, R. E. C. (2019). Advanced human nutrition. Burlington, Vermont: Jones & Bartlett.

Mei, C., Zhou, S., Zhu, L., Ming, J., Zeng, F. & Xu, R. (2017). Antitumor effects of Laminaria extract fucoxanthin on lung cancer. *Marine Drugs,* 15(2), 39-51.

Meilgaard, D., Civille, G.V., & Carr, B. (2007). *Sensory evaluation techniques.* (4^{th} ed.). Boca Raton, FL: CRC Press.

Meiselman, H. L., King, S. C., & Gillette, M. (2010). The demographics of neophobia in a large commercial U.S. sample. *Food Quality and Preference,* 21, 893-897.

Migne, A., Gollety, C., & Davoult, D. (2015). Effect of canopy removal on a rocky shore community metabolism and structure. *Marine Biology*, 162, 449-457.

Miranda J. J. (2019, September 2). Salt substitution and community-wide reductions in blood pressure and hypertension incidence. Presented at the 2019 European Society of Cardiology (ESC) meeting. Paris, France.

Mouritsen, O. G. (2013). The science of seaweeds. *American Scientist,* 101(6), 458-465.

Mouritsen, O. G., Rhatigan, P., & Pérez-Lloréns, J. L. (2018). World cuisine of seaweeds: Science meets gastronomy. *International Journal of Gastronomy and Food Science,* 14, 55-65.

Nova, P., Martins, A. P., Teixeira, C., Abreu, H., Silva, J. G., Machado, A., … Gomes, A. M. (2020). Foods with microalgae and seaweeds fostering consumers health: a review on scientific and market innovations. *Journal of Applied Phycology*, 32, 1789-1802.

Nishikawa, S., Hosokawa, M. & Miyashita, K. (2012). Fucoxanthin promotes translocation and induction of glucose transporter 4 in skeletal muscles of diabetic/obese KK-A(y) mice. *Phytomedicine*, 19, 389-394.

Nisizawa, K., Noda, H., Kikuchi, R., & Watanabe, T. (1987). The main seaweed foods in Japan. Presented at the 1986 Twelfth International Seaweed Symposium. Sao Paulo, Brazil.

Omori, T., Otsuka, K., Ishii, T., & Nakatani, N. (2012). The basic engineering design of large scale factory for culture of seaweeds aimed at water purifications in coastal sea area. 2012 *Oceans – Yeosu,* e1-e5.

Onofrio, J. (1993). *Dictionary of Indian Tribes of the Americas.* American Indian Publishers.

Palmaieri, N., & Forleo, M. B. (2020). The potential of edible seaweed within the western diet. A segmentation of Italian consumers. *International Journal of Gastronomy and Food Science*, 20, 100202.

Paz, S., Rubio, C., Frias, I., Gutierrez, A. J., Gonzalez-Weller, D., Martin, V., … Hardisson, A. (2019). Toxic metals (Al, Cd, Pb, and Hg) in the most consumed edible seaweeds in Europe. *Chemosphere*, 218, 879-884.

Pereira, L. (2016). *Edible Seaweeds of the World.* Boca Raton, Florida: CRC Press.

Pereira, L. (2018). Seaweeds as source of bioactive substances and skincare therapy – cosmeceuticals, algotheraphy, and thalassotherapy. *Cosmetics*, 5(4), e1-e41.

Pérez-Lioréns, J.L. (2019). Seaweed consumption in the Americas. *Gastronomica,* 19(4), 49-59.

Peryam, D. R., & Pilgrim, F. J. (1957). Hedonic scale method of measuring food preference. *Food Technology*, 11, 9-14.

Petersson, K., Eliasson, A-C., Tornberg, E., & Bergenståhl, B. (2013). Sensory perception of rye bran particles of varying size and concentration in a viscous phase. *Journal of Texture Studies*, 4, 459-467.

Piconi, P., Veidenheimer, R., & Chase, B. (2020). *Edible seaweed market analysis.* The Island Institute. Retrieved from http://www.islandinstitute.org/edible-seaweed-market-analysis-2020.

Prager, H. (2017). Investigating the acceptance of seaweed as a viable source of a complete protein. Retrieved from www.ntnu.edu/documents/139799/1273574286/TPD4505. Henry.Prager.pdf/bcb465ea-79e3-45c0-b1d2-1775b3d1852f.

Rajapakse, N., & Kim, S-K. (2011). Nutritional and digestive health benefits of seaweed. *Advances in Food and Nutrition Research.* 64, 17-28.

Rebours, C., Marinho-Soriano, E., Zertuche-Gonzalez, J. A., Hayashi, L., Vasquez, J. A., Kradolfer, P., … Robledo, D. (2014). Seaweeds: An opportunity for wealth and sustainable livelihood for coastal communities. *Journal of Applied Phycology*, 26, 1939-1951.

Redmond, S., Belknap, S., & Clark Uchenna, R. (2016). Aquaculture in shared waters fact sheet: Kelp aquaculture. Maine Sea Grant Publications. Retrieved from https://digitalcommons. library.umaine.edu/seagrant_pub/127/.

Rico, D., De Linaje, A. A., Herrero, A., Asensio-Vegas, C., Miranda, J., Martinez-Villaluenga, C., … Martin-Diana, A. B. (2018). Carob by-products and seaweeds for the development of functional bread. *Journal of Food Processing and Preservation,* 42, 1-9.

Rioux, L-E., Beaulieu, L., & Turgeon, S. L. (2017). Seaweeds: A traditional ingredients for new gastronomic sensation. *Food Hydrocolloids,* 68, 255-265.

Rogers L.A., Griffin R., Young T., Fuller E., St. Martin K., & Pinksy M.L. (2019). Shifting habitats expose fishing communities to risk under climate change. *Nature Climate Change*, 9, 512–516.

Roleda, M. Y., & Hurd, C. L. (2019). Seaweed nutrient physiology: application of concepts to aquaculture and bioremediation. *Phycologia*, 58(5), 552-562.

Roque, B. M., Salwen, J. K., Kinley, R., & Kebreab, E. (2019). Inclusion of *Asparagopsis armata* in lactating dairy cows' diet reduces enteric methane emission by over 50 percent. *Journal of Cleaner Production,* 234, 132-138.

Ross v. Acadian Seaplants, LTD. (2019). ME 45, 206 A.3d 283.

Ruhlin, H. (2019, July 9). These Portland researchers will pay you to try seaweed bread. *News Center Maine.* Retrieved from https://www.newscentermaine.com/article/news/these-portland-researchers-will-pay-you-to-try-seaweed-bread/97-a0d4cdfd-94ff-4339-9c6c-1eac9371c653.

Rupérez, P. (2002). Mineral content of edible marine seaweeds. *Food Chemistry,* 79(1), 23-26.

Salehi, B., Sharifi-Rad, J., Seca, A. M. L., Pinto, D. C. G. A., Michalak, I., Trincone, A., … Martins, N. (2019). Current trends on seaweeds: Looking at chemical composition, phytopharmacology, and cosmetic applications. *Molecules,* 24, doi:10.3390/molecules24224182.

Sang, Z., Wang, P. P., Yao, Z., Shen, J., Halfyard, B., Tan, L., & Zhang, W. (2012). Exploration of the safe upper level of iodine intake in euthyroid Chinese adults: a randomized double-blind trial. *The American Journal of Clinical Nutrition*, 95, 367-373.

Sappati, P. K., Nayak, B., VanWalsum, G. P., & Mulrey, O. T. (2019). Combined effects of seasonal variation and drying methods on the physicochemical properties and antioxidant activity of sugar kelp (Saccharina latissima). *Journal of Applied Phycology,* 31, 1311-1332.

Satria, A., Muthohharoh, N. H., Suncoko, R. A., & Muflikhati, I. (2017). Seaweed farming, property rights, and inclusive development in coastal areas. *Ocean & Coastal Management,* 150, 12-23.

Schiener, P., Black, K. D., Stanley, M. S., & Green, D. H. (2015). The seasonal variation in the chemical composition of the kelp species *Laminaria digitate*, *Laminaria hyperborean, Saccharine latissima* and *Alaria esculenta*. *Journal of Applied Phycology,* 27, 363-373.

Shannon, E. & Abu-Ghannam, N. (2016). Antibacterial derivatives of marine algae: an overview of pharmacological mechanisms and applications. *Marine Drugs*, 14(4), 81-104.

Shannon, E., & Abu-Ghannam, N. (2019). Seaweeds as nutraceuticals for health and nutrition. *Phycologia,* 58(5), 563-577.

Simopoulos, A. P. (2016). An increase in the omega-6/omega-3 fatty acid ratio increases the risk for obesity. *Nutrients*, 8(3), 128-245.

Singh, S. P., & Singh, P. (2015). Effect of temperature and light on the growth of algae species: A review. *Renewable and Sustainable Energy Reviews,* 50, 431-444.

Stone H., Bleibaum R., & Thomas, H. (2012). *Sensory evaluation practices*. (4^{th} ed.). Boston, Massachusetts: Elsevier/Academic Press.

Talsma, P. (2018). How much sensory panel data do we need? *Food Quality and Preference,* 67, 3-9.

Thompson, S. A., Knoll, H., Blanchette, C. A., & Nielsen, K. J. (2010). Population consequences of biomass loss due to commercial collection of the wild seaweed Postelsia palmaeformis. *Marine Ecology,* 413, 17-32.

Tudoran, A., Olsen, S. O., & Dopico D. C. (2009). The effect of health benefit information on consumer health values, attitudes, and intentions. *Appetite,* 52, 568-579.

Tuorila, H., Lahteenmaki, L., Pohjalainen, L., & Lotti, L. (2001). Food Neophobia among the Finna and related response to familiar and unfamiliar foods. *Food Quality and Preference*, 21, 29-37.

United Nations (U.N.) Department of Economic and Social Affairs, Population Division. (2019). *World Population Prospects 2019: Highlights.* Retrieved from https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf.

United States (U.S.) Census Bureau. (2019a). 2014-2018 American Community Survey 1-Year Estimates (Geographic Divisions). Retrieved from https://data.census.gov/cedsci/table?q=United%20States&g=0100000US_0300000US3,6,2,8,9,1,4,5,7_0400000US72&tid=ACSDP1Y2018.DP05&hidePreview=true&t=Populations%20and%20People.

United States (U.S.) Census Bureau. (2019b). 2014-2018 American Community Survey 5-Year Estimates (Maine). Retrieved from https://www.census.gov/acs/www/data/data-tables-and-tools/data-profiles/.

United States (U.S.) Census Bureau. (2019c). 2014-2018 American Community Survey 5-Year Estimates (United States). Retrieved from https://www.census.gov/acs/www/data/data-tables-and-tools/data-profiles/.

United States Department of Agriculture (USDA). (2019, April 1). FoodData Central. Seaweed, kelp, raw. Retrieved from https://fdc.nal.usda.gov/fdc-app.html#/food-details/168457/nutrients.

United States (U.S.) Bureau of Labor Statistics. (2020). Average Retail Food and Energy Prices, U.S. and Midwest Region. Retrieved from https://www.bls.gov/regions/mid-atlantic/data/averageretailfoodandenergyprices_usandmidwest_table.htm.

United States (U.S.) Food and Drug Administration (FDA). (2012, November 19). Questions and answers on monosodium glutamate (MSG). Retrieved from https://www.fda.gov/food/food-additives-petitions/questions-and-answers-monosodium-glutamate-msg.

United States Department of Health and Human Services (HHS) and United States Department of Agriculture (USDA). (2015, December). 2015 – 2020 Dietary Guidelines for Americans. 8th Edition. Retrieved from http://health.gov/dietaryguidelines/2015/guidelines/.

Van den Berg, H., Dagnelie, P. C., & Van Staveren, W. A. (1988). Vitamin B_{12} and seaweed. Lancet, 1, 242-243.

Vilg, J. V., Nylund, G. M., Werner, T., Qvirist, L., Mayers, J. J., Pavia, H., … Albers, E. (2015). Seasonal and spatial variation in biochemical composition of *Saccharina latissima* during a potential harvesting season for Western Sweden. *Botanica Marina*, 58(6), 435-447.

Violi, F., Lip, G. Y. H., Pignatelli, P., & Pastori, D. (2016). Interactions between dietary vitamin K intake and anticoagulation by vitamin K antagonists: Is it really true? *Medicine (Baltimore)*, 95, 1-7.

VitaminSea Seaweed. (2018, March 8). USDA SBIR phase II project narrative. Technical and market feasibility of kelp meal as a nutritional supplement in low-moisture foods.

VitaminSea Seaweed. (2019). About Us. Retrieved from http://www.vitaminseaseaweed.com /about-vitaminsea.html.

Wells, M., Potin, P., Craigie, J., Raven, J., Merchant, S., Helliwell, K., … Brawley, S. (2017). Algae as nutritional and functional food sources: Revisiting our understanding. *Journal of Applied Phycology,* 29, 949–982.

Wiber, A., & Atchley, C. (2018). Understanding the millennial mindset. *Food Business News.* Retrieved from https://www.foodbusinessnews.net/articles/11122-understanding-the-millennial-mindset?page=2.

Williams, A. N., & Woessner, K. M. (2009). Monosodium glutamate ‘allergy’: menace or myth? *Clinical and Experimental Allergy*, 39(5), 640-646.

Witman, S. (2017). World’s biggest oxygen producers living in swirling ocean waters. *Journal of Geophysical Research: Oceans*, Eos, 98. Retrieved from https://doi.org/10.1029/ 2017EO081067.

World Health Organization (WHO). (2013). Micronutrient deficiencies. Retrieved from https://www.who.int/nutrition/topics/idd/en/.

Yamaguchi, S., & Ninomiya, K. (2000). Umami and food palatability. *The Journal of Nutrition,* 130(4), 921S-926S.

Zanfirescu, A., Ungurianu, A., Tsatsakis, A. M., Nițulescu, G. M., Kouretas, D., Veskoukis, A., … Margină, D. (2019). A review of the alleged health hazards of monosodium glutamate. *Comprehensive reviews in food science and food safety*, 18(4), 1111–1134.

Zarate, R., el Jaber-Vazdekis, N., Tejera, N., Perez, J. A., & Rodriguez, C. (2017). Significance of long chain polyunsaturated fatty acids in human health. *Clinical and Translational Medicine,* 6(25), e1-e19.

Zhao, Y., Zhang, M., Devahastin, S., & Liu, Y. (2019). Progresses on processing methods of umami substances: A review. *Trends in Food Science & Technology,* 93, 125-135.

Zuckerbrot, T. (2014, February 24). Edible seaweed. Food and Nutrition Magazine. Retrieved from http://www.foodandnutrition.org/March---April---2014/Edible--- Seaweed/.

APPENDIX A: ADVERTISEMENT FOR SENSORY EVALUATION TEST

You are invited to participate in a research study. The research is being conducted by graduate student Laurel Simone and Professor Mary Ellen Camire of the School of Food & Agriculture at the University of Maine. You must be at least 18 years old to participate and not be allergic to or dislike wheat, gluten, yeast, or seaweed.

We are conducting a research study about consumer liking for bread made with Maine seaweed. If you agree to take part, you will be asked to taste three samples of bread and answer questions about yourself and how much you like the bread. The test will take no more than 20-30 minutes.

You will receive $10.00 for completing the questionnaire, but no compensation will be given if you do not answer all the questions about the bread samples.

The test will be held at the Westin Hotel in Portland, Maine, on July 14, 2019, between 11:00 am – 4:30 pm.

If you would be interested in participating in this study, please contact us at sensory.evaluation@maine.edu or 207-581-1733.

If you would like to reserve an appointment for the study, please scan the QR code that will take you to a website with the list of open seating times. Otherwise, you may visit the appointment website at https://doodle.com/poll/x3wgwk4zk89ggqwv.

Thank you.

APPENDIX B: RECRUITMENT EMAIL FOR SENSORY EVALUATION TEST

Will you be in the Portland area this summer?

Graduate student Laurel Simone and Professor Mary Ellen Camire of the School of Food & Agriculture at the University of Maine will be conducting a research study in downtown Portland. You must be at least 18 years old to participate and not be allergic to or dislike wheat, gluten, yeast, or seaweed.

We are conducting a research study about consumer liking for bread made with Maine seaweed. If you agree to take part, you will be asked to taste three samples of bread and answer questions about yourself and how much you like the bread. The test will take no more than 20-30 minutes.

You will receive $10.00 for completing the questionnaire, but no compensation will be given if you do not answer all the questions about the bread samples.

The test will be held at the Westin Hotel in Portland, Maine, on July 14, 2019, between 11:00 am – 4:30 pm.

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If you would like to reserve an appointment for the study, please scan the QR code that will take you to a website with the list of open seating times. Otherwise, you may visit the appointment website at https://doodle.com/poll/x3wgwk4zk89ggqwv.

Thank you.

APPENDIX C: INFORMED CONSENT FORM FOR SENSORY EVALUATION TEST

You are invited to take part in a research project led by graduate student Laurel Simone and her advisor Professor Dr. Mary Ellen Camire of the University of Maine School of Food and Agriculture. The goal of this project is to determine consumer liking of seaweed in bread. You must be at least 18 years of age to take part. Do not take part if you cannot eat gluten or have other reasons to not eat wheat, yeast, or seaweed.

What Will You Be Asked to Do?
If you choose to take part in this study, you will be asked to answer a few questions about yourself, such as your age and gender. You will be served samples of bread that contains seaweed. After taking at least two bites of each sample, you will be asked to give us your opinion of the bread. The sensory evaluation should not take longer than 20-30 minutes to complete.

Risks:
There are no risks to you from participating in this study.

Benefits:
There are no direct benefits to you for taking part in this test. The overall benefit of this research may help seaweed farmers and food companies develop new food products containing seaweed, may create a new market for their products, and possibly a new revenue source for their companies.

Compensation:
You will receive $10.00 for completing the questionnaire, but no compensation will be given if you do not answer all the questions about the bread samples.

Confidentiality:
Your answers will be collected anonymously. Copies will be stored indefinitely on the researcher's password-protected computer at the University of Maine and made available to other researchers. No one will be able to connect your answers to your identity.

Voluntary:
Participation in this survey is voluntary. If you do not feel comfortable answering a question, you do not need to answer it. You may stop at any time, but you will not be given the $10.00 if you do not complete all the questions about the bread samples.

Your participation in this test implies your consent.

Contact Information:
If you have any questions about this study, please contact Laurel or her faculty advisor at (207-581-1733, sensory.evaluation@maine.edu). If you have any questions about your rights as a research participant, please contact the Office of Research Compliance, University of Maine, 207/581-2657 (or e-mail umric@maine.edu).

APPENDIX D: SENSORY EVALUATION TEST QUESTIONNAIRE

Thank you for participating. Please answer some questions about yourself, then evaluate all three samples in the order shown on your computer screen.

1. Please indicate the gender that you identify with:
   Female
   Male
   Other
   Prefer not to answer

2. Which of the following ranges contains your age?
   18 - 24 years
   25 - 34 years
   35 - 44 years
   45 - 54 years
   55 - 64 years
   65 - 74 years
   75 years or older
   Prefer not to answer

3. Please indicate the racial group that you identify with:
   American Indian or Alaska Native
   Asian or Pacific Islander
   Black or African American
   White or Caucasian
   Other
   More than one race
   Prefer not to answer

4. Are you Hispanic?
   Yes
   No
   Prefer not to answer

5. Which state is your primary residence?
   [pull-down list of states, District of Columbia, Puerto Rico, outside the United States, and prefer to not answer as options]

6. What is your household’s annual income?
   Less than $25,000
   $26,000 - $50,000
   $51,000 - $75,000
   $76,000 - $100,000
   $101,000 - $125,000
   $126,000 - $150,000
   More than $150,000
   Prefer not to answer or not sure

7. Approximately how much of your household’s food shopping do you do?
   None at all
   25%
   50%
   75%
   100%
   I prefer not to answer

8. Which type of bread do you usually buy? (You may mark all that apply).
   Artisanal
   Home-made
   Mass-produced
   Refined flour
   Whole grain
   Sliced
   I do not know, or I prefer not to answer

9. Where do you usually buy bread?
   Grocery store
   Local independent bakery
   Bakery store chain
   Big box store (such as Target, Walmart)
   Club store (such as BJ’s, Sam’s Club, Costco)
   Bakery outlet
   Online store
   Do not buy- bake at home
   None of the above or do not buy bread

10. How much do you agree with the statement, “I prefer to buy local foods instead of mass-produced foods.”
    Strongly disagree
    Slightly disagree
    Neither agree nor disagree
    Slightly agree
    Strongly agree

11. How often do you eat seaweed or food containing seaweed?
    Never
    1-4 times a year
    5-10 times a year
    1-2 times a month
    1-2 times a week
    More than 2 times a week
    Prefer not to answer

12. Would you consider buying bread that contained seaweed?
    Yes
    No

13. What would make you consume bread containing seaweed more often? (Select all that apply)
    Greater availability where I shop
    Longer shelf-life
    Sustainably grown
    Minimally processed
    Higher nutritional content
    Sold fresh

[Page Break]

Please evaluate all three samples in order from left to right. Take a sip of water before tasting each sample. Please take at least two bites of each sample. Make check that the sample code matches the code on the computer screen.

14. How much do you like or dislike the appearance of this bread?
    Dislike Extremely
    Dislike Very Much
    Dislike Moderately
    Dislike Slightly
    Neither Like nor Dislike
    Like Slightly
    Like Moderately
    Like Very Much
    Like Extremely

15. How do you like the size of the seaweed pieces in this bread?
    Much too small
    Slightly too small
    Just about right
    Slightly too large
    Much too large

16. How much do you like or dislike the color of this bread?
    Dislike Extremely
    Dislike Very Much
    Dislike Moderately
    Dislike Slightly
    Neither Like nor Dislike
    Like Slightly
    Like Moderately
    Like Very Much
    Like Extremely

17. How much do you like or dislike the aroma of this bread?
    Dislike Extremely
    Dislike Very Much
    Dislike Moderately
    Dislike Slightly
    Neither Like nor Dislike
    Like Slightly
    Like Moderately
    Like Very Much
    Like Extremely

18. How much do you like or dislike the taste of this bread?
    Dislike Extremely
    Dislike Very Much
    Dislike Moderately
    Dislike Slightly
    Neither Like nor Dislike
    Like Slightly
    Like Moderately
    Like Very Much
    Like Extremely

19. How much do you like or dislike the texture of this bread?
    Dislike Extremely
    Dislike Very Much
    Dislike Moderately
    Dislike Slightly
    Neither Like nor Dislike
    Like Slightly
    Like Moderately
    Like Very Much
    Like Extremely

20. How much do you like or dislike the sample overall?
    Dislike Extremely
    Dislike Very Much
    Dislike Moderately
    Dislike Slightly
    Neither Like nor Dislike
    Like Slightly
    Like Moderately
    Like Very Much
    Like Extremely

21. Would you consider buying this bread?
    Yes
    No

22. How much would you be willing to pay for a full loaf of this bread? (Choose one answer)
    $3.00
    $4.00
    $5.00
    $6.00
    $7.00
    $8.00
    I would not buy this bread

23. For which occasions or uses would you buy this bread? Please select all that apply.
    Sandwiches
    With cheese or spreads like hummus
    As a bread bowl
    With soup
    Parties
    Every day
    Picnics
    As a gift
    I would not buy this bread.

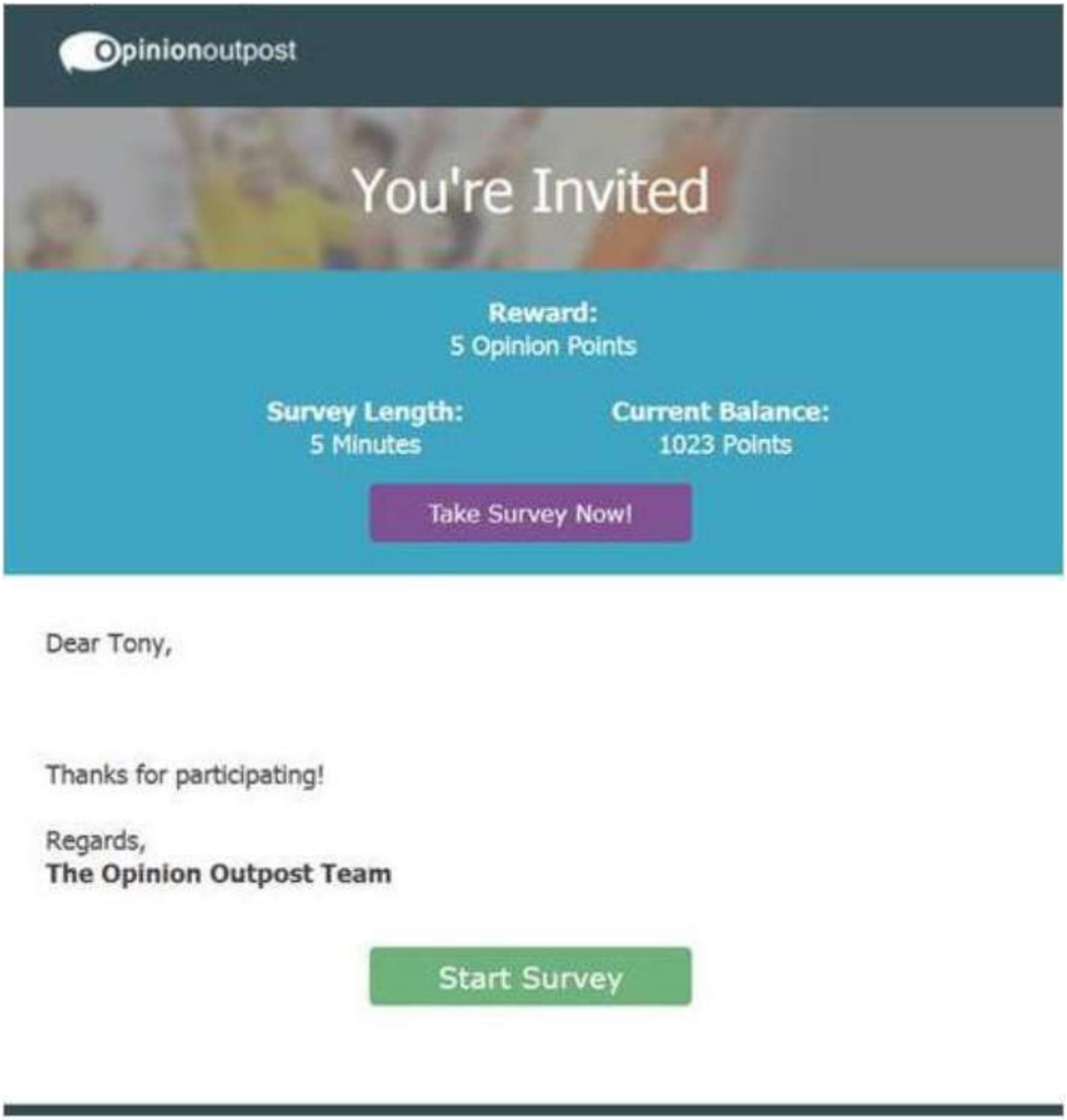
Please add any additional comments that you may have about this bread sample. If you compare this bread with other ones, please use the sample code numbers. Everyone gets the samples in a different order, so please do not say "the first one…" etc.

[After all of the samples are evaluated]

This is the end of the test. Thank you for your time and opinions.

APPENDIX E: RECRUITMENT EMAIL INVITATION

FOR ONLINE CONSUMER SURVEY



APPENDIX F: INFORMED CONSENT FORM FOR ONLINE CONSUMER SURVEY

You are invited to participate in a research project being conducted by graduate student Laurel Simone and her advisor Professor Mary Ellen Camire of the School of Food and Agriculture at the University of Maine. The purpose of the research is to learn about consumer preferences for seaweed in bread and other food products. You must be at least 18 years of age to participate.

What Will You Be Asked to Do?
If you decide to participate, you will be asked to take a confidential survey. It should take you about 20 minutes to complete.

Risks:
Except for your time and inconvenience, there are no risks to you from participating in this study.

Benefits:
While this study will have no direct benefit to you, the overall benefit of this research may be the documentation of consumer acceptance of bread containing dried seaweed that may help a small Maine company encourage bakeries to buy their products. Increased demand for dried seaweed could benefit seaweed farmers.

Compensation:
If you agree to take part in this survey, you will receive the standard compensation in your Dynata account.

Confidentiality:
This study is confidential. There will be no records linking you to your answers. Although Dynata has participants' names and email addresses, the email addresses or any other identifying information will not be shared with the researchers. Data will be kept on a password-protected computer indefinitely. Information for the compensation is not connected to survey responses.

Voluntary:
Participation is voluntary. If you choose to take part in this study, you may stop at any time. While you may skip the occasional question, it would be very helpful if you completed the survey. You may skip any questions that you do not wish to answer.

Submission of the survey implies consent to participate.

Contact Information:
If you have any questions about this study, please contact Laurel or her faculty advisor at (207-581-1733, sensory.evaluation@maine.edu). If you have any questions about your rights as a research participant, please contact the Office of Research Compliance, University of Maine, 207/581-2657 (or e-mail umric@maine.edu).

I agree to participate in the survey.

Yes □
No □

[Persons who indicate yes will be directed to the survey; those who say no will receive a thank you message.]

APPENDIX G: ONLINE CONSUMER SURVEY QUESTIONAIRE

1. Please indicate which gender you identify with:
   Female
   Male
   Other
   I prefer not to answer

2. Please indicate your age based on your last birthday:
   18 - 24 years old
   25 - 34 years old
   35 - 44 years old
   45 - 54 years old
   55 - 64 years old
   65 - 74 years old
   75 years or older
   I prefer not to answer

3. In which U.S. state or other district do you live?
   [pull-down menu of state names]

4. In which region of the U.S. do you primarily reside?
   New England (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont)
   Mid-Atlantic (New Jersey, New York, Pennsylvania)
   East North Central (Illinois, Indiana, Michigan, Ohio, Wisconsin)
   West North Central (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota)
   South Atlantic (Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia)
   East South Central (Alabama, Kentucky, Mississippi, Tennessee)
   West South Central (Arkansas, Louisiana, Oklahoma, Texas)
   Mountain (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming)
   Pacific (Alaska, California, Hawaii, Oregon, Washington)
   I do not reside in the United States

5. Which racial group do you identify with?
   American Indian or Alaska Native
   Asian
   Black or African American
   White or Caucasian
   Native Hawaiian or Pacific Islander
   More than one group
   I prefer not to answer

6. Are you Hispanic?
   Yes
   No
   I prefer not to answer

7. What is your annual income?
   Less than $20,000
   $20,000 - $29,999
   $30,000 - $39,999
   $40,000 - $49,999
   $50,000 - $59,999
   $60,000 - $69,999
   $70,000 - $79,999
   $80,000 - $89,999
   $90,000 - $99,999
   $100,000 - $149,999
   More than $150,000
   I prefer not to answer

8. Please select the highest level of education that you have completed:
   Up to high school or GED
   2 year degree
   4 year degree
   Graduate degree
   Doctorate
   I prefer not to answer

9. How much of your household's food shopping are you responsible for?
   0% - 25%
   26% - 50%
   51% - 75%
   76% - 100%
   I prefer not to answer

10. Which type of grain products do you usually buy? (Select all that apply)
   Sliced bread
   Unsliced bread
   Rolls
   Muffins
   Bagels
   Pizza crusts
   Flatbreads
   English muffins
   Croissants
   Crackers
   Pasta
   None of the above products

11. Which type of bread do you usually buy? (Select all that apply)
    Artisanal
    Mass-produced
    Refined flour
    Whole grain
    Organic
    Non-GMO
    I do not know

12. Where do you usually buy bread? (Select all that apply)
    Grocery store
    Local independent bakery
    Bakery store chain
    Big box store (such as Target, Walmart)
    Club store (such as BJ's, Sam's Club, Costco)
    Bakery outlet
    Online store
    Do not buy - bake at home
    None of the above or do not buy bread

13. How often do you eat seaweed or food containing seaweed?
    Never
    1-4 times a year
    5-10 times a year
    1-2 times a month
    1-2 times a week
    2 or more times a week
    Daily
    I prefer not to answer

14. Would you consider buying bread that contained seaweed? [If yes, branch to additional questions #15-19]
    Yes
    No
    Not sure

15. How much would you be willing to pay for a one-pound loaf of bread that contained seaweed?
    Less than $4.00
    $4.00
    $5.00
    $6.00
    $7.00
    $8.00
    More than $8.00

16. How much would you be willing to pay for a one-pound loaf of bread that contained seaweed from Maine?
    Less than $4.00
    $4.00
    $5.00
    $6.00
    $7.00
    $8.00
    More than $8.00

17. Which type of packaging would you prefer for a bread containing seaweed? (Select all that apply)
    Paper
    Paper with a clear window to view the bread
    Resealable plastic
    Clear plastic
    No package at all

18. How often do you think that you would buy a loaf of bread containing seaweed?
    More than once a week
    Once a week
    1-3 times per month
    Several times a year

19. Please tell us on which occasions you might buy bread containing seaweed. (Select all that apply)
    Sandwiches
    With cheese
    Parties
    Snacks
    Picnics
    Other [fill-in]

20. What would make you consume seaweed bread more often? (Select all that apply)
    More availability
    Natural preservatives
    More seaweed flavor
    Sustainably-grown
    Minimally processed
    Lower calories
    Good source of iodine
    Less seaweed flavor
    Vegan source of vitamin B12
    Organic
    Local
    Grown in Maine

Source of antioxidants
Good source of calcium
I have no interest in purchasing bread containing seaweed
None of the above motivates me

21. Which of these products would you try if they contained seaweed? (Select all that apply)
Bagels
Breads
Crackers
Flatbreads
Rolls
Croissants
Muffins
English muffins
Pasta
None of the above

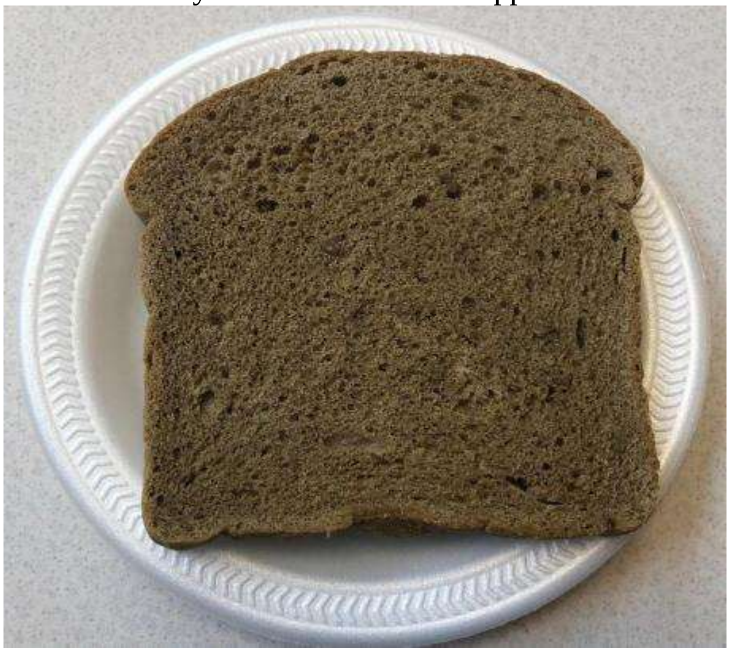
22. How much do you like or dislike the appearance of the seaweed in this bread?

Dislike extremely
Dislike very much
Dislike moderately
Dislike slightly
Neither like nor dislike
Like slightly
Like moderately
Like very much
Like extremely

23. How much do you like or dislike the appearance of the seaweed in this bread?

Dislike extremely
Dislike very much
Dislike moderately
Dislike slightly
Neither like nor dislike
Like slightly
Like moderately
Like very much
Like extremely

24. How much do you like or dislike the appearance of the seaweed in this bread?



Dislike extremely
Dislike very much
Dislike moderately
Dislike slightly
Neither like nor dislike
Like slightly
Like moderately
Like very much
Like extremely

25. Do you consider seaweed or seaweed products healthful?
    Yes
    No
    Maybe

26. Which characteristics would prevent you from buying bread containing seaweed?
    Appearance
    Flavor
    Price
    Aroma
    Texture
    None of the above

27. Are you concerned that seaweed, like other seafood products, may contain heavy metals?
    Yes
    No
    Maybe
    Not sure

This is the end of the survey. Please click the End button to close the survey. Thank you for your time and opinions. You will receive the standard compensation in your account.

BIOGRAPHY OF THE AUTHOR

Laurel Simone was born and raised in Wolfeboro, New Hampshire. She graduated from Kingswood Regional High School. She pursued an undergraduate degree in Environmental Science at Denver University. She graduated in 2012 with a B.S. in Environmental Science and a minor in Business Administration. After college, she moved back to the east coast to pursue a career in environmental education. It is here where Laurel learned her passion for teaching gardening, cooking, and food systems curriculum. She began to pursue a second Bachelor of Science degree in Food Science and Human Nutrition at The University of Maine. She graduated in 2018 with a B.S. in Food Science and Human Nutrition. She is currently pursuing her M.S. in Food Science and Human Nutrition at the University of Maine in the coordinated Dietetic Internship program. She will complete the majority of her dietetic internship at Maine Medical Center in Portland, Maine.

Laurel is the former president of the Kappa Omicron Nu Honor Society and a current member of the Academy of Nutrition and Dietetics. She represented the state of Maine at the Academy's nationwide annual conference for nutritional advocacy in Washington, D.C., in July of 2019. Laurel's desire to pursue a career in nutrition is broad, and she cannot predict what aspects of the internship will interest her the most; however, she is driven by a strong interest to treat nutrition-related diseases, conduct clinical research to prevent such diseases, and to understand the policy that shapes the profession. Laurel is a candidate for the Master of Science degree in Food Science and Human Nutrition from The University of Maine in August 2020.