Chef Sensory Perspectives and Consumer Acceptance of Fermented Green Crab Sauce

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CHEF SENSORY PERSPECTIVES AND CONSUMER ACCEPTANCE
OF FERMENTED GREEN CRAB SAUCE

By

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B.S. University of Maine

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The European green crab (*Carcinus maenas*) is an invasive species responsible for immense ecological and economic damage along the Northeastern coast of the United States. Despite multiple population control methods explored, intensive indiscriminate trapping has been the only effective approach However, this type of trapping is currently not financially viable because of the low price and demand for hard-shell green crabs due to their small size and difficult-to-extract crabmeat.

To address this issue, researchers have investigated green crab sauce, a fermented condiment inspired by fish sauce. This umami-enhancing condiment has the potential to raise hard-shell green crab value and make green crab fisheries more economically viable. Previous research confirmed the chemical similarity of fermented green crab sauce to commercial fish sauce and garnered positive responses from New England chefs. The primary objectives of this study were to continue the product development of green crab sauce by investigating (1) chef sensory perspectives of green crab sauce and (2) consumer acceptability of green crab sauce.
A home-use test with New England chefs (n=17) revealed green crab sauce’s distinct flavor characteristics setting it apart from traditional condiments. Incorporating the sauce into various recipes demonstrated comparable likability to popular umami enhancers, highlighting its culinary potential. Consumer sensory tests (n=87) indicated a strong preference for the green crab sauce fermented at 24°C compared to 37°C in a garlic noodle recipe. Consumer comments and hedonic score correlations indicated a more pronounced crab flavor and aroma in the garlic noodle recipe with green crab sauce fermented at 24°C compared to the control (no green crab sauce), suggesting its market potential among general consumers.

This research showcases the potential of fermented green crab sauce as a sustainable means to valorize European green crabs, contributing to the conservation of coastal ecosystems while benefiting local fisheries and communities. This study emphasizes the unique taste of green crab sauce and its positive reception among both chefs and consumers when incorporated into recipes, indicating its potential for successful market entry amongst these consumer groups. To fully realize the economic and environmental benefits of green crab sauce, further investigations are needed to optimize production methods at lower temperatures and explore the addition of low-cost flavor additives to enhance its appeal.
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CHAPTER 1

LITERATURE REVIEW

1.1. Introduction

The European green crab (*Carcinus maenas*) is native to Europe and North Africa; however, its presence has been documented off the Eastern coast of North America since 1817 (Klassen & Locke, 2007). This invasive species has caused immense ecological and economic damage along the Northeastern coast of the United States. There is increasing concern about the inexorable green crab population and its potential to expand across a greater geographic range due to its biological resilience (Compton et al., 2010; Finch et al., 2021; Young & Elliott, 2020). Several methods of population control have been investigated, only intensive indiscriminate trapping has been found to be successful at reducing their population (Abt Associates, 2008; de Rivera et al., 2007; McKenzie, 2011). However, unlike many native crabs, hard-shell green crabmeat is not highly valued. Green crabs are much smaller than native species, their meat is much more difficult to extract, and the texture of the extracted meat is unfamiliar to consumers (Galetti, 2010; Kang et al., 2019). Therefore, there is a need for alternate uses for the green crab biomass.

Currently, the only lucrative market is made up of soft-shell green crabs, which comprise only a fraction of the green crab population during certain seasons (McMahan, 2021; Walter, 2021). Hard-shell green crabs are being actively used for compost and bait, while their use in animal and fish feeds is being investigated (Fulton & Fairchild, 2013; Journo & Park, 2018; Lubitz et al., 1943). To create a viable long-term industry for the indiscriminate trapping of green crabs, either by individual fishermen or green crab fisheries, there must exist greater
financial incentives for hard-shell green crabs. The fermentation of European green crabs to create an umami-enhancing green crab sauce condiment, produced similarly to fish sauce, is one such approach for the creation of a high-value product.

A popular umami enhancer, fish sauce, is a high-value, fermented condiment popular for commercial and home culinary applications (El Sheikha & Montet, 2014; Ibrahim et al., 2022). Anchovies are commonly used to produce fish sauce due to their low value and high protein content. Fish sauce is able to both extend the shelf-life and enhance the value of underutilized fish species, such as anchovies. Similarly, green crab sauce is a practical, value-enhancing approach to the utilization of green crab biomass.

However, the development of novel food products, such as green crab sauce, is accompanied by efficacy, safety, and sensory evaluation requirements. Previous research has helped to determine the efficacy and safety of green crab sauce (Greiner, 2021; Leung, 2021). Further consumer and chef sensory evaluation research is still needed to determine the feasibility and ideal market for a fermented green crab sauce. This literature review discusses the invasive species *Carcinus maenas*, efforts to control the species, umami enhancers, and previous research regarding fermented crab sauce.

### 1.2. Invasive species

Invasive species are a subsection of non-native plants and animals that can cause considerable environmental and economic costs (Tobin, 2018). Invasive noxious species are separated from non-native species due to their harmful effects on native ecosystems, cultivated ecosystems, and managed landscapes. Although some adverse ecological effects of invasive
species may appear obvious, the impact of many invasive species has a cascading ecological impact with both direct and indirect effects.

The ecological impacts of invasive species can be difficult to measure precisely. These impacts can range from invasive species’ ability to create an apparent decrease in the populations of native species to loss of biodiversity in native species, thus, creating adverse effects throughout food webs (Tobin, 2018). In the United States alone, there are approximately 50,000 foreign plant and animal species (Pimentel et al., 2005). In addition to ecological impacts, a 2021 study estimated the economic cost of biological invasions in North America increased from 2 billion dollars annually in the 1960s to over 26 billion dollars annually since 2010 (Fantle-Lepczyk et al., 2022). While many well-known adverse effects of invasive species exist, their prevalence is inevitable due to widespread global trade and interaction.

The continual increase in global travel and commerce throughout the 20th and 21st centuries has provided more channels for the human-mediated transport of exotic species across great distances (Glaesser et al., 2017; Kolar & Lodge, 2000; Padilla & Williams, 2004). The increasing speed and efficiency of travel may increase the chance at which exotic species survive long-distance transport (Havel et al., 2015). Terrestrial non-native species introductions often result from hitchhiking on trade ships or during airline travel (Tobin, 2018). Managing the introduction of marine non-native and invasive species can be especially difficult due to the interconnectedness of marine ecosystems and the prevalence of trade and travel in or over marine environments. The eradication of marine invasive species has only been possible when the invasive species have been detected and managed early and rapidly (Giakoumi et al., 2019).
1.2.1. Green Crab Invasion

The European green crab (*Carcinus maenas*) is commonly referred to as “green crab” and hereafter will be referred to as such. While the green crab is native to certain coasts of Europe and Northern Africa (Klassen & Locke, 2007), it has been referred to as among the world’s 100 most harmful invasive species (Ens et al., 2022). The earliest record of the green crab population expanding outside its native range was in the early nineteenth century, with documented discovery occurring in the Mid-Atlantic United States in 1817 (Young & Elliott, 2020). The green crab population has extended to five major regions outside its native habitat and has the capability to invade many other regions around the world. These regions are pictured in Figure 1.1 (Young & Elliott, 2020).

![Figure 1.1. The Global Distribution of Green Crabs in 2019](image)

Solid green crab icons indicate an established population of green crabs and the year they were introduced. Open green crab icons indicate areas of concern for future green crab invasions (Young & Elliott, 2020).
The introduction of green crabs to the Mid-Atlantic United States in the early nineteenth century occurred via trans-Atlantic transport ships. Although the exact method of green crab transportation is unknown, it is theorized that green crabs were transported via solid ballast or hull fouling in transport ships (Carlton & Cohen, 2003).

### 1.2.1.1. Native and Invasive Crabs on the North American East Coast

The established native, commercially harvested species of crabs on the North American East Coast include but are not limited to, the blue crab, rock crab, and Jonah crab (Rees, 1963). The two primary established species of invasive crabs are the European green crab and the Asian shore crab (*Hemigrapsus sanguineus*) (Lord & Williams, 2017). One of the distinguishing features of the commercially relevant native crabs is their large size compared to the green crab and Asian shore crabs (Table 1).
Table 1.1. Native and Invasive North American East Coast Crab Species Characteristics

<table>
<thead>
<tr>
<th>Crab Species</th>
<th>Common Name</th>
<th>Largest Carapace Width</th>
<th>Minimum Legal Harvest Carapace Width (may vary by location)</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Callinectes sapi dus</em></td>
<td>Blue Crab</td>
<td>229 mm</td>
<td>114 mm - 127 mm</td>
<td>(NOAA Fisheries, 2023), (NJ Department of Environmental Protection, 2022), (Maryland Division of State Documents, 2019)</td>
</tr>
<tr>
<td><em>Cancer borealis</em></td>
<td>Jonah Crab</td>
<td>222 mm</td>
<td>130 mm</td>
<td>(Robichaud &amp; Frail, 2006)</td>
</tr>
<tr>
<td><em>Cancer irroratus</em></td>
<td>Rock Crab</td>
<td>150 mm</td>
<td>102-108 mm</td>
<td>(Department of Marine Resources, 2022), (Robichaud &amp; Frail, 2006)</td>
</tr>
<tr>
<td><em>Carcinus maenas</em></td>
<td>Green Crab</td>
<td>79.7 mm</td>
<td>None</td>
<td>(Skonberg &amp; Perkins, 2002), (Green crabs in Maine, n.d.)</td>
</tr>
<tr>
<td><em>Chionoecetes opilio</em></td>
<td>Snow Crab</td>
<td>150 mm</td>
<td>95 mm</td>
<td>(DFO, 2016)</td>
</tr>
<tr>
<td><em>Hemigraspus sanguineus</em></td>
<td>Asian Shore Crab</td>
<td>48 mm</td>
<td>None</td>
<td>(Gilman &amp; Grace, 2009)</td>
</tr>
</tbody>
</table>

*aDesignates native, commercially important species
bDesignates invasive species

The stark size difference between the commercially important and invasive crabs are a driver of their different consumption methods. Hard-shell native crab species are commonly consumed by boiling or steaming the crab and extracting the meat. In commercial processing, most crabmeat is hand-picked, hand-packed, and ready to eat without further processing.
(Dickerson & Berry, 1976). The size of the crab and the texture of the meat plays an essential role in the cost-effectiveness of these methods of crab meat extraction.

Due to the small size of hard-shell green crabs and Asian shore crabs, the separation of the meat from the shell is much more difficult, and the yield of the crabmeat is smaller. Mechanical meat separation of hard-shell green crabs has been investigated, but poses many texture-related challenges (Galetti, 2010), creating another barrier to extracting the crab meat from hard-shell invasive crab species. Mechanical extraction of green crab meat has been investigated, but more research is needed to determine functional applications for this ingredient in commercial food systems (Galetti, 2010; Kang et al., 2019). Compared to soft-shell crabs, which are commonly cooked whole, the mechanical extraction needed for small, hard-shell crabs introduces an additional processing cost. Other methods of hard-shell invasive crab utilization, such as extraction of food ingredients and processing aids, have been investigated (Galetti, 2010; Meyers, 1994), however, more research is needed in these areas to determine their profitability and feasibility.

1.2.1.2. The Ideal Invader – Green Crab Biology

Though some physical characteristics of green crabs tend to change relative to the location of the green crab, the animals still possess many distinguishing characteristics. The green crab is a medium-sized crab with a maximum width of 9-10 cm and a lifespan of 4-7 years (Klassen & Locke, 2007). Green crabs are relatively prolific and easy to identify in many areas they have invaded. Green crabs possess a larger frontal carapace width compared to the rear (Alaska Department of Fish and Game, 2022). The front of the carapace also possesses five forward-facing anterior-lateral teeth, which are key distinguishing features of green crabs.
Additionally, male and female green crabs can be easily differentiated. Male green crabs tend to have a narrower underbelly with a triangular-shaped pattern, while females possess a broader and rounder underbelly.

Although the lifespan of green crabs is only 4-7 years, it is estimated that they molt 18 times throughout their life cycle (Souza et al., 2011). Molting is a 2-3 hour process by which green crabs shed their old shell and devote energy towards creating a new shell that will harden after approximately 3-16 days, depending on the temperature of the environment (Broekhuysen, 1936). Newly molted crabs almost always possess a green color, but as an intermolt period continues, their color may shift from green to progressively redder (Lee & Vespoli, 2015). Many red morphotype green crabs will not molt again and are in a terminal anec dysis state (Abuhagr et al., 2014). Due to their infrequent molting, many red morphotype green crabs are not considered for the soft-shell green crab industry (Bradt et al., 2022).

Medium-sized (30-55 mm), green morphotype male green crabs are most commonly being targeted for the soft-shell green crab market (Bradt et al., 2022). Soft-shell green crabs are harder to differentiate from their hard-shell counterparts compared to other species of crabs, such as blue crabs, due to their more subtle molting characteristics. However, there are several key external features that can help with the correct identification of soft-shell green crabs as shown in Figure 2 (Poirier et al., 2016).
The biological resilience of green crabs has led to their success in invading many different parts of the world. Green crabs possess phenotype plasticity due to their ability to alter many aspects of their biology to fit in with their environment (Young & Elliott, 2020). There remains no overall biological consensus for the genetic makeup of green crabs due to the extensive varying phenotypes found globally (Darling et al., 2008; Roman & Palumbi, 2004). Green crabs’ phenotypic plasticity allows for increased flexibility and adaptability to new locations, contributing to their status as ideal invaders (Young & Elliott, 2020).
In addition to the green crab being able to adapt and alter phenotypes quickly, the green crab’s resilience to a wide range of water salinities and temperatures and its diverse diet have contributed to its success as an invasive species. Green crabs have been found to survive in temperatures ranging from 0°C to 30°C and salinity levels of 4 to 52 percent (Klassen & Locke, 2007). However, larval development is more temperature dependent and they may not be able to survive temperatures greater than 22.5°C or less than 10°C (de Rivera et al., 2007). Green crabs’ salinity and temperature tolerances have contributed to their colonization of sheltered coastlines, estuaries, and semi-exposed rocky surfaces worldwide (Klassen & Locke, 2007). Countries such as Chile, China, Russia, Namibia, and New Zealand have been predicted to be the most vulnerable to future green crab invasions due to the proximity of other green crab populations and/or the characteristics of the coastal habitats as seen in Figure 1.1 (Compton et al., 2010).

Green crabs' resilience is complemented by their ability to feed on a variety of marine plants and animals, including several species of mussels, clams, scallops, algae, and marine amphipods, depending on their location (Baeta, 2006; Cordon et al., 2022; Grosholz et al., 2011; Miron et al., 2005). Additionally, green crabs have been found to possess the unique ability to uptake amino acids through their gill epithelium (Blewett & Goss, 2017). The ability of green crabs to obtain necessary nutrients for survival from a variety of sources is another factor contributing to their capacity for population persistence and expansion.

1.2.1.3. Ecological Effects of Green Crabs

The green crab’s status as a persistent invasive species has allowed its population to flourish at the expense of native species and flora. In previous research, green crabs were referred to as “ecosystem engineers” due to their ability to disrupt native marine systems to fit
their needs (Leignel et al., 2014). Green crabs are able to feed on a wide variety of organisms depending on seasonality and availability (Leignel et al., 2014). Furthermore, they exhibit the ability to show preference among their prey. Green crabs have been found to expend greater energy pursuing prey which will result in a large energy intake (Baeta, 2006). For example, green crabs will expend greater energy to pursue their preferred, high-calorie prey, such as mollusks, particularly mussels, clams, and cockles (Elner, 1981; Grosholz et al., 2011; Young & Elliott, 2020). Green crabs found on the North American East Coast have been found to prey on the following commercially and ecologically important species: soft-shell clams, scallops, juvenile American lobsters, and mud crabs (primarily *Dyspanopeus sayi*) (Gehrels, 2016; McKenzie, 2011).

Green crabs have devastated the soft-shell clam (*Mya arenaria*) population in New England. Green crabs are blamed for the soft-shell clam industry collapse in Maine in the 1950s and are a major concern due to their preference for preying on soft-shell clams (Whitlow, 2010). Since the soft-shell clam industry collapse, the most profitable years for this fishery have been those in which the green crab population suffered the most. For example, mass mortalities of green crabs were recorded in the 1950s and coincided with periods of severe cold and unusually harsh winters (Welch, 1968). The general abundance and commercial catch of soft-shell clams increased markedly during this time period.

The juvenile American lobster is another commercially relevant species that has fallen victim to green crab predation on the North American East Coast. One study attempted to determine the competitive interaction between green crabs and American juvenile lobsters (Rossong et al., 2006). In this study, the green crabs were not only able to outcompete the American juvenile lobster for food and shelter in the vast majority of the trials, but the green
crabs also consumed the juvenile lobsters in 6 of 11 trials. It has also been found that, regardless of crab species, greater overall crab presence reduces the total number of lobsters attempting to enter traps and the lobsters’ trap entry success rate (Zargarpour et al., 2011). While the extent to which green crabs are affecting the commercial lobster industry on the North American East Coast is unknown, it is clear that high densities of green crabs can outcompete lobsters and lower their catch rates.

Green crabs do not directly feed on eelgrass beds (*Zostera marina*), but they are frequently known to uproot and damage eelgrass beds during predation and foraging (Malyshev & Quijón, 2011; Neckles, 2015). Eelgrass beds are recognized as a nursery for a variety of marine species. Additionally, the presence of eelgrass beds on the North American East Coast help to support higher sediment stocks than unvegetated areas, allowing for significantly greater carbon sequestration (Novak et al., 2020). Eelgrass meadows also help to stabilize sediment, which may lead to less erosion and carbon dioxide release (Novak et al., 2020). The health of an area’s seagrass, including eelgrass, is an indicator of the overall environmental health at the land-sea interface (Short, 2006). Previous research concluded that the invasion of green crabs into new environments could damage eelgrass beds and prevent them from recovering (Garbary, 2014). The researchers added that green crabs primarily harm eelgrass shoots, with one of their studies noting a 75% reduction in eelgrass shoot density from 2001-2002 in Benoit Cove, Newfoundland, due to the presence of green crabs. Therefore, the presence of invasive green crabs can result in the destruction of eelgrass beds, which has a detrimental impact on many different levels of ecosystems.
1.2.1.4 Economic Effects of Green Crabs

The total economic losses from invasive green crabs on the North American East Coast is a complex number to estimate due to the vast ecological impact of green crabs. The losses incurred by shellfisheries reflect some of the most blatant financial impacts of green crabs. The total losses of commercial and recreational shellfisheries on the North American East Coast were estimated to be greater than $18.5 million in 2006 (Abt Associates, 2008).

While not as apparent as losses in the shellfish industry, the damage to eelgrass beds requires large financial investments to restore. An analysis of seagrass restoration efforts found the median cost of one acre of seagrass restoration to be $106,782, reported in 2010 USA dollars adjusted for inflation (Bayraktarov, 2015). Green crabs have damaged many thousands of acres of seagrass. In a single bay, Casco Bay, off the coast of Maine, the highest density of eelgrass beds declined by 4,392 acres between 2001-2002 and 2013 surveys (Garbary et al., 2014).

1.2.2. Methods to Reduce the Green Crab Population

Established green crab populations are resilient. According to a report conducted by Abt Associates (2008) for the EPA, prevention strategies may be the best way to control green crab populations. These strategies include but are not limited to, determining human-mediated introduction pathways and greater education on protocols to prevent the spread of green crabs.

Once the green crab population has been introduced to a new area, the chances of eradication are much more likely to be successful the sooner control methods are implemented (Kern, 2002). Even then, complete eradication is likely to be difficult. More often, control measures have been suggested, including chemical, biological, and genetic/molecular strategies.
However, the extent to which these control strategies may influence native species and environments needs further research before these control strategies can be considered (Abt Associates, 2008). On the other hand, green crab trapping and capturing is the most common and simplest method of controlling the green crab population, but it also does not come without its challenges.

Some past green crab trapping and capturing efforts have only been moderately successful at controlling green crab populations. A 10-year-long green crab eradication effort in California, USA from 2009-2018 while monitoring the green crab population (Grosholz et al., 2021). The study took place in Seadrift Lagoon, Bolinas Lagoon, Bodega Harbor, Tomales Bay, and Elkhorn Slough. The researchers’ eradication efforts involved trapping yearly, at least 3 times between June and August. The researchers noted drastic reductions in the population of the green crabs 1-4 and 7-9 years after implementing their eradication efforts. In the fifth year, the green crab population increased to approximately three times the original population, consisting primarily of juvenile green crabs. The researchers suggested that the green crabs experienced density-dependent overcompensation, resulting in a large, short-term increase in their population. Previous research conflicts with these conclusions, suggesting that the removal of green crabs from Bodega Harbor would not result in overcompensation based on assessments made about the Bodega Harbor green crab population biology (Turner et al., 2016).

On the contrary, there is evidence that small-scale multi-year efforts can effectively reduce the green crab population. In a study conducted in Bodega Harbor, CA, researchers removed over 9,500 crabs in 66 days between July and December. Their average trap catch rate was reduced from 21.3 crabs per trap to 1.4 crabs per trap over this period of time (de Rivera et al., 2007). Similarly, a 2008-2009 trapping effort in Placentia Bay, Newfoundland, noted a
A decrease in crab catch rates (McKenzie, 2011). In July-September 2008, the researchers documented approximately 350,000 pounds of green crabs removed from the bay, resulting in the catch rates decreasing from 0.90-0.46 to 0.12-0.41 lbs/trap/hr from 2008 to 2009, respectively. While the long-term effect of green crab trapping on their population is not easily predictable, intensive year-round trapping may be an effective population control strategy.

1.2.2.1. Green Crab Fisheries

Although green crab removal has been funded for environmental and research purposes, perhaps the most effective and uncomplicated method of green crab removal is the establishment of green crab fisheries. The startup costs associated with green crab fishing are much lower than other industries. Unlike obtaining a commercial lobster fishing license in Maine, which requires significant financial and time investments, a commercial green crab fishing license can be easily obtained for $2 for a resident license and $4 for a nonresident license (Commercial green crab Only License, 2022). Current lobster and crab fishing licenses also license the fishermen to catch green crabs for no extra fee.

Green crab harvesting is complemented by a lack of seasonality. Green crabs have been found to possess a relatively constant chemical composition throughout the fishing season, suggesting that green crabs can be harvested at any time as long as the environmental conditions allow (McNive et al., 2013). The constant composition and availability of green crabs could allow them to be harvested earlier or later in the year than the shellfish harvesting season allows. Many oyster fishermen in the Northeast United States remove their trapping or fishing equipment in early winter and do not replace it until early spring (Walter, 2021). These delays in shellfish harvest present an opportunity for fishermen to supplement their business by catching
green crabs. Regardless of whether fishermen are trying to catch primarily green crabs or if green crabs are purely used to supplement fishermen’s income, the value of green crabs must be considered.

Some of the most significant obstacles to establishing green crab fisheries is the low value of hard-shell green crabs and the unreliability of the market demand (St-Hilaire et al., 2016; Walter, 2021). Hard-shell green crabs are frequently sold as bait for lobster, Tautog fish, and other marine life that prey on crabs. The green crab bait market for Tautog and lobster on the North American East Coast range from a market value of $0.30 to $1.15 per pound depending on the season and availability of other bait products (Thompson, 2014 in St-Hilaire et al., 2016; Walter, 2021).

In contrast, the soft-shell molting green crabs market is a much more high-value market. Soft-shell green crabs can be sold to restaurants in the Northeast United States for approximately $25 per pound (McMahan, 2021). This stark contrast in the value of soft-shell green crabs is due to their status as a culinary delicacy in some restaurants and regions of the North American East Coast. However, even during the peak soft-shell or molting green crab season, they only amount to approximately 25% of all the green crabs captured (Walter, 2021). Also, as stated previously, the soft-shell green crab industry is composed primarily of medium-sized male green crabs. Therefore, an increase in value and demand for hard-shell green crabs is needed to encourage greater indiscriminate fishing of green crabs and greater feasibility for green crab fisheries.

1.2.2.2. Hard-Shell Green Crab Utilization

A variety of applications have been explored to determine the potential of products from hard-shell green crabs due to their prevalence and ease of capture. While direct consumption
may sound appealing, the small size and hard shell of the crab make it extremely time-consuming to extract the meat by hand. Mechanical meat extraction has also been investigated, yielding a green crab “puree” due to the texture of the meat, which may be unfamiliar to North American consumers (Galetti, 2010). More research is needed to determine the application of recovered green crab protein, as well as mechanical optimization to improve yield (Kang et al., 2019).

Other potential uses for hard-shell green crabs include crab meal in animal and fish feed, as well as compost. Crab meal refers to a product prepared from the undecomposed, dried processing waste of the crab industry and consists of shell, viscera, and part or all of the flesh (Lubitz et al., 1943). Previous research has demonstrated promise for green crab meal in animal and fish feed for certain species (Fulton & Fairchild, 2013). Compared to crab mince, crab meal used in animal and fish feeds has significantly lower value (Gates & Parker, 1994 in Galletti, 2010). Another low-value use for green crabs has been their use as a compost ingredient due to their nitrogen, phosphorus, calcium, and chitin-rich composition (Journo & Park, 2018). To support greater harvesting of green crabs, there is a need to valorize the hard-shell green crab biomass.

1.3. Fish Sauce

Fish sauce is a nutritious, fermented condiment that not only extends the shelf-life but also enhances the value of underutilized fish species (Ibrahim et al., 2022). The United Nations Food and Agriculture Organization and World Health Organization (FAO & WHO, 2018) identify fish sauce as a translucent, not turbid liquid product with a salty taste and fish flavor obtained from the fermentation of a mixture of fish and salt. The FAO & WHO definition adds
that fish sauce is prepared by mixing fish and salt in covered containers and leaving them to ferment for, generally, six months or longer. Additional fish sauce extractions may follow the first by adding additional brine to extract the remaining protein, fish flavor, and odor (FAO & WHO, 2018). Though the conditions for fish sauce may seem simplistic, fish sauce manufacturing methods vary from country to country due to differences in culture and climatic conditions (Lopetcharat et al., 2001). Commonly characterized for its umami flavor, fish sauce is used in various dishes such as stir-fries, soups, marinades, vinaigrettes, dipping sauces, and braised meats (Nast, 2020).

1.3.1. Umami Enhancers

Umami is known as “the fifth basic taste evoking savory, full-bodied, and meaty flavor sensations” (Crowe, 2013). In 1908, a principal component of seaweed kombu was identified as glutamate, which served as the basis for the classification of “umami taste” (Ikeda, 1908 in Kurihara, 2015). That taste was distinctly different from the other four tastes. Later, the compounds 5′-inosinate from dried bonito and 5′-guanylate from dried shiitake mushrooms were identified to have umami characteristics. Additionally, it was discovered that glutamate, 5′-inosinate, and 5′-guanylate had synergistic properties when combined to produce an umami taste. The discovery of the synergistic effect of umami compounds contributed to their consideration as “flavor enhancers” (Kurihara, 2015).

While glutamate or glutamic acid elicits a sour taste when consumed on its own, the addition of a high concentration of salt (NaCl) can contribute to its umami taste (Hakimi et al., 2022). In addition to glutamic acid’s presence in kombu kelp, it is also present in a variety of umami-eliciting foods and food additives such as fish sauce, soy sauce, tomato paste, tomatoes,
oyster sauce, mushrooms, and others (Crowe, 2013; Hakimi et al., 2022; Li-Chan & Cheung, 2010). Many of these foods or food additives contain or are frequently combined with salt to produce an umami taste.

Umami flavor’s unique ability to react synergistically with salt allows for salt reduction in some recipes. In the last 15-20 years, increasing concerns about salt consumption have increased the demand for reduced-salt foods (World Health Organization, 2020). Interestingly, a 2009 study indicated that naturally brewed soy sauce was able to achieve a salt reduction in some recipes without impacting consumer acceptability (Kremer et al., 2009). The authors concluded that using naturally brewed soy sauce allowed for the reduction of 50%, 17%, and 29% salt in salad dressing, tomato soup, and stir-fried pork respectively, without affecting the consumer acceptability of the dishes. These results suggest that certain umami additives may not only be able to enhance the flavor of dishes but also allow for a salt reduction.

Umami flavors have gained popularity during the past decade, resulting in increased attention from academia and industry (Zhao et al., 2019). Some of the most popular umami-enhancing sauces include soy, fish, and oyster sauce. The global soy sauce market was valued at USD 39.7 billion in 2018, with an estimated CAGR (compound annual growth rate) of 5.9% from 2019-2025 (Grand View Research, 2019c). The global fish sauce market size was estimated to be USD 15.32 billion in 2018, with an estimated CAGR of 3.51% from 2019-2025 (Grand View Research, 2019a). Lastly, the global oyster sauce market was valued at USD 8.20 billion in 2018 and is expected to register a CAGR of 4.5% from 2019-2025 (Grand View Research, 2019b).
1.3.2. History of Fish Sauce

While the earliest records and details of fish sauce are disputed among historians, the Greek fish sauce, gàros, and Roman fish sauce, garum, are some of the oldest recorded fish sauces dating back to the 3rd-4th century BC (Grainger, 2021; Henesy, 2018). The methods for manufacturing these products involved various salt levels, fermentation times, and fish parts that affected the resulting value of the product. Broadly speaking, Roman fish sauces were made with a mixture of fish blood, viscera, and heads (Henesy, 2018). Additionally, a variety of fish or shellfish were used, including maena, murena, tunny, mullet, oysters, and sea urchins, although mackerel was the most popular (Grainger, 2021; Henesy, 2018).

Accompanying the use of fish sauce as a flavor-adding culinary ingredient, fish sauce allows for the long-term preservation and utilization of many fish species, many of which are underutilized or low-value. Due to the easy and low cost of the fermentation process, fish sauce quickly began being produced in many parts of the world (El Sheikha & Montet, 2014). The various manufacturing techniques worldwide have led to the production of many different types of fish sauce, many of which have persisted for hundreds of years (Table 1.2.).
Table 1.2. Fish Sauce Products Around the World

<table>
<thead>
<tr>
<th>Country of Origin</th>
<th>Fish Sauce Product</th>
<th>Defining Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>Uwo-shoytu</td>
<td>Malted rice and koji commonly added</td>
</tr>
<tr>
<td></td>
<td>Ikashoyu</td>
<td></td>
</tr>
<tr>
<td>Cambodia</td>
<td>Nuoc-mam</td>
<td>Ferments 3-12 months with 3:1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Thailand</td>
<td>Nam-pla</td>
<td>Ferments 5-12 months with 5:1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Pla ra</td>
<td>Fermented from sandfish, sardines, and squid</td>
</tr>
<tr>
<td>Malaysia</td>
<td>Budu</td>
<td>Includes palm sugar and tamarind</td>
</tr>
<tr>
<td>Philippines</td>
<td>Patis</td>
<td>Ferments 3-12 months with 4:1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Indonesia</td>
<td>Ketjap-ikan</td>
<td>Ferments for 6 months with 6:1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Bakasang</td>
<td>Ferments 3-6 weeks</td>
</tr>
<tr>
<td>India and Pakistan</td>
<td>Colomba cure</td>
<td>Remove guts and gills, add tamarind</td>
</tr>
<tr>
<td>Ghana</td>
<td>Momoni</td>
<td>Ferments 1-5 days with 10:3&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Greece</td>
<td>Gaross</td>
<td>Contains only liver Ferments for 8 days</td>
</tr>
<tr>
<td>France</td>
<td>Pissala</td>
<td>Ferments 2-8 weeks with 4:1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Anchovy</td>
<td>Uses beheaded and gutted fish</td>
</tr>
</tbody>
</table>

Adapted from El Sheikha & Montet, 2014 as cited in Greiner, 2021
<sup>a</sup>Fish:Salt ratio

1.3.3. Fish Sauce Fermentation

Many fish sauces are produced using the same general concept of salting, natural enzyme hydrolysis, bacterial fermentation, and extraction of the fish sauce (Hakimi et al., 2022). While the salt levels and fermentation times between fish sauces may vary (Table 1.2.), the spontaneous
process of fish sauce fermentation relies heavily on the autochthonous microbial flora and endogenous enzymes to decompose and ferment biomolecules in the fish, such as protein and fat (Xu et al., 2021). The fermentation process of fish sauce is closely tied to its quality and defining taste features (Wang et al., 2022).

Throughout the fermentation, microorganisms, enzymes, and metabolites form a complex system through a series of substance and energy exchangers (Wang et al., 2022). While the knowledge of the pathways used by the microorganisms is limited, previous research suggests that the diversity of the microorganisms present during fermentation can produce profound changes in the enzymatic and metabolic processes that affect the chemical and physical properties of the fish sauce (Xu et al., 2021). During fermentation, the metabolism of the microbes is responsible for the production of various metabolites, including amino acids (glutamic acid and aspartic acid) and organic acids (succinic acid), and secondary metabolites that are largely responsible for the taste, nutritive value, and other sensory properties of the fish sauce (Zang et al., 2020 in Xu et al., 2021). While many factors can influence the number and diversity of microbes present, the fish type, salt content, fermentation temperature, fermentation time, oxygen level, and minor ingredients of the fish sauce are some of the most relevant (Lopetcharat et al., 2001; Nguyen et al., 2020). Therefore, these variables may significantly impact the quality and sensory properties of the finished fish sauce.

1.3.4. Fish Sauce Consumer Sensory Analysis

The wide variety of processing conditions and characteristics of fish sauce (Table 2) are some of the factors that influence the sensory attributes of the fish sauce. Some of the attributes of fish sauce that represent quality are their place of origin, degrees (°N) or protein content, and
the type of fish used in the production (Chan, 2018). The degree (°N) of fish sauce is the mg of nitrogen per 100 mL of fish sauce. The higher the °N the more protein degradation has occurred, which can contribute to the aroma and taste of fish sauce. The °N of fish sauce is also largely impacted by which extraction it originated from. For example, the first extraction generally possesses the highest high protein or °N content because the later extractions require the manufacturer to add salt and water back to the fermented fish after the initial fermentation (Chan, 2018; Chongchitnant, 2022). These differences in manufacturing techniques can produce various fish sauce sensory attributes.

Thai fish sauce’s sensory attributes have been characterized in a study as possessing brown color, five aromatics (sweet, caramelized, fermented, fishy, and musty), four tastes (sweet, salty, bitter, and umami), and five aftertastes (sweet aftertaste, salty aftertaste, bitter aftertaste, caramelized flavor, and fishy flavor) (Ritthiruangdej & Suwonsichon, 2006). In their study, 12 trained sensory panelists were recruited to analyze the intensity of these attributes in 12 pure and eight mixed commercial Thai fish sauces. The pure fish sauce was characterized as a fish sauce in which fermentation is derived from anchovy fish and anchovy fish residue, while the mixed fish sauce was defined as fish sauces obtained from marinating other types of animals rather than anchovy fish. The intensities of the fish sauces were rated by the panelists using a 15-point scale in 0.5-point increments, with 0 meaning none and 15 meaning extremely strong. The resulting quantitative data allowed the researchers to conclude that there were significant differences between pure fish sauces and mixed fish sauces among the 15 sensory attributes; the pure fish sauces showed a higher degree of fishy aromatic, fish flavor, sweet flavor, caramelized flavor, and umami taste than the mixed fish sauces.
Additionally, a traditional Indonesian fermented fish sauce, *bakasang*, was analyzed by researchers using quantitative descriptive analysis (QDA) methods (Harikedua et al., 2012). The QDA analysis indicated the most prominent flavor attributes of *bakasang* to be “fishy,” “burnt,” “sweaty,” and “sulfury meaty.” While the aftertaste and mouthfeel attributes were identified most prominently as “salty,” “fishy aftertaste,” “bitter aftertaste,” and “umami.”

Another study used QDA methods to identify the sensory characteristics of *Colatura di Alici*, an Italian fish sauce (Russo et al., 2020). The researchers recruited nine trained panelists to rate the attributes of five fish sauce samples using a 6-point intensity scale, from “0 - null intensity” to “5 - extreme intensity.” The most prominent attributes among all of the samples were “cheesy” and “fishy” rating between 3-4.5 across all of the samples. These attributes were followed by medium-intensity attributes such as “meaty,” “umami,” and “roasted” in terms of intensity. The attributes rating the lowest were “rancid” and “fecal” among all of the samples. The most prominent sensory attributes of fish sauce for each study are summarized in Table 1.3.
<table>
<thead>
<tr>
<th>Fish Sauce</th>
<th>Prominent Sensory Attributes</th>
<th>Analysis</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure &amp; Mixed Thai Fish Sauce</td>
<td>salty taste</td>
<td>Descriptive Analysis</td>
<td>(Ritthiruangdej &amp; Suwonsichon, 2006)</td>
</tr>
<tr>
<td></td>
<td>brown intensity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>umami taste</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>salty aftertaste</td>
<td></td>
<td></td>
</tr>
<tr>
<td>bakasang</td>
<td>fishy</td>
<td>Quantitative Descriptive Analysis</td>
<td>(Harikedua et al., 2012)</td>
</tr>
<tr>
<td></td>
<td>burnt</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>salty</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>umami</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>bitter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colatura di Alici</td>
<td>cheesy</td>
<td>Quantitative Descriptive Analysis</td>
<td>(Russo et al., 2020)</td>
</tr>
<tr>
<td></td>
<td>fishy</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>meaty</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>umami</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>roasted</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

While there are scant studies analyzing USA consumers' preferences for fish sauce in an entree or meal, a previous study evaluated USA consumer acceptance of kimchi with varying levels of red pepper flakes and fish sauce (Park et al., 2020). In this study, researchers recruited 101 untrained citizens residing in Oregon, USA. The consumer acceptance testing for kimchi
with fish sauce was conducted using a 9-point hedonic scale. While the presence of red pepper significantly influenced USA consumers' liking of kimchi, the presence of fish sauce in kimchi at up to 1.6% (formula weight in use) did not impact consumers' liking of kimchi.

In addition to flavor, color is the most important factor in the product-intrinsic sensory cue for establishing consumers’ initial reactions to a product (Spence, 2015). For example, researchers analyzing the consumer acceptance of the degrees of brown color in commercial soy sauce found that brown color is an essential factor in the initial saltiness expectations, emotional response, and purchase intention (Ketkaew et al., 2021). Furthermore, it has been found that consumers expected greater saltiness in soy sauces with a darker brown color, even though the association may not concur with the actual salt content (Wongthahan et al., 2020). In Thai fish sauces, it has been reported that sensory evaluators generally preferred a dark brown color (Wang et al., 2017).

1.4. Crab Sauce

Fermented crab sauce is a traditional umami seasoning in the coastal cities of Southeast China, especially Beihai (Liu et al., 2019). Due to the prevalence of soldier crabs (*Mictyris brevidactylus*) in this region and their umami flavor (Liu & Chen, 2020), they are used to make crab sauce. The crabmeat is cured with approximately 30% salt and fermented for approximately 30-40 days (Liu et al., 2019). Similar to the manufacturing of fish sauce, this process relies on the activity of endogenous enzymes and microorganisms to break down the crabmeat into a protein-rich liquid.

While few studies have been conducted on crab sauce, researchers have used various methods, including equivalent umami concentration (EUC), to investigate the non-volatile taste-
active components of crab sauce made from fermented soldier crabs (Liu et al., 2019). When manufacturing the crab sauce, the researchers removed the crab viscera, mashed the remaining crabmeat, mixed it with 30% salt, and allowed it to ferment for 35 days. A EUC (equivalent umami concentration) analysis was performed to evaluate the synergistic effect of the flavor nucleotides and umami amino acids. The EUC analysis yielded a monosodium glutamate concentration of 19.3g/100 mL, exhibiting the intense umami taste of the crab sauce.

1.4.1. Green Crab Sauce

The idea for green crab sauce was theorized to create a viable product from hard-shell green crabs to encourage greater efforts toward large-scale fishing of green crabs on the North American East Coast (Greiner, 2021). Previous research demonstrated that hard-shell green crabs fermented with 20-30% salt at 24°C, 30-37°C, and 50°C for 90 days could produce a condiment chemically similar to commercially-available fish sauce products (Greiner et al., 2021). The manufacturing process for green crab sauce differs slightly from Southeast China’s crab sauce. Green crab sauce manufacturing involves chopping whole green crabs, mixing them with salt, fermenting the mixture, and straining the final product.

An additional two-study experiment on green crab sauce evaluated the effects of enzyme-assisted fermentation and the perspectives of chefs residing in New England, USA (Leung, 2021). The researcher concluded that longer fermentation time significantly increased the pH, nonenzymatic browning, amine nitrogen, and total volatile base nitrogen and decreased the moisture content; however, there were few significant differences among the enzyme-assisted green crab sauces. In the second study, survey responses from 59 New England chefs were collected regarding their preferences for fish sauce and feedback about a green crab sauce
concept. When rating their preferences for fish sauce attributes, chefs were given three options for color (light brown, medium brown, dark brown), aroma (sweet, fishy, savory), appearance (transparent, opaque, unfiltered), and flavor (umami, salty, caramel). Of these survey options, most chefs preferred medium brown color, savory aroma, transparent appearance, and umami flavor attributes. The chefs’ feedback for the green crab sauce product concept involved rating their “likeliness to use” and “willingness to purchase” on a 9-point scale, with 1 meaning “Not at all likely/willing” and 9 meaning “Extremely frequently/willing.” The mean ratings for this survey question were 8.0 for “likeliness to use” and 7.5 for “willingness to purchase,” indicating positive concept feedback for commercially available green crab sauce.

1.5. Food Safety

Similar to fish sauce, bacterial pathogen risk in green crab sauce formulations of 20% salt or greater is low. In anchovies, long-term exposure to high levels of salt can create an environment in which pathogens are inactivated (Verdos et al., 2018). In previous research, green crab sauce with a salt concentration of 20% or greater achieved water activity levels of 0.765 or lower (Greiner, 2021). This product is well below the 0.85 water activity level for food safety regulations and suggests a safe product unlikely to harbor common pathogens.

In both crab sauce and fish sauce, histamine levels are a concern due to their formation during protein decomposition, especially at higher temperatures (Visciano et al., 2014; Arulkumar et al., 2023). In the United States, histamine levels are regulated to be no more than 200 ppm (20 mg 100 mL⁻¹) in fish sauce, lowered from 500 ppm (50 mg 100 mL⁻¹) in 2021 (FDA, 2022). All process variations of the green crab sauce in previous research have been under
this new limit, suggesting there are unlikely to be chemical hazards associated with this process (Greiner, 2021).

1.6. Conclusions and Experimental Objectives

Long-term indiscriminate fishing of green crabs has the potential to reduce their population, helping to mitigate their ecological and environmental damage. In order for this to be a viable option, a more lucrative financial market must exist for hard-shell green crabs. The creation of a high-value green crab sauce has the potential to enhance the value of green crabs and extend their shelf-life. However, the development of a novel food product comes with efficacy, safety, and consumer sensory requirements. Previous research has determined a safe green crab sauce condiment that is chemically similar to fish sauce can be produced and the product concept has been positively received by chefs across New England (Greiner, 2021; Leung, 2021). Consumer and chef sensory evaluation research is still needed to determine the sensory acceptability and ideal market for a fermented green crab sauce condiment.

The objectives of this research are to (i) investigate potential markets for green crab sauce, (ii) determine New England chefs’ sensory acceptance of green crab sauce, and (iii) determine the consumer acceptability of green crab sauce in a recipe.

1.7. References


Compton, T. J., Leathwick, J. R., & Inglis, G. J. (2010). Thermogeography predicts the potential global range of the invasive European green crab (*Carcinus maenas*). *Diversity and Distributions*, 16(2), 243–255. https://doi.org/10.1111/j.1472-4642.2010.00644.x


CHAPTER 2

CHEF HOME-USE SENSORY TEST OF FERMENTED GREEN CRAB SAUCE

2.1. Abstract

To help control the population of invasive green crabs, chefs’ acceptance and sensory perspectives of a fermented green crab condiment were investigated. To produce the green crab sauce, finely chopped, whole green crabs were mixed with 20% (w/w) salt and fermented at 37°C for 90 days using recommendations from previous research. A remote, home-usage test was conducted by 17 chefs in Maine and Rhode Island. The chefs were asked to rate sensory attributes of green crab sauce on its own and in a recipe on a 9-point hedonic scale. They were also asked to compare green crab sauce to an umami enhancer of their choice and provide comments regarding their preferences. The most common critique of appearance was its lack of transparency. The mean hedonic scores for appearance, taste, and aroma were 5.9 ± 1.5, 6.1 ± 2.2, and 5.1 ± 2.2, respectively. These scores were equivalent to “neither like nor dislike” or “like slightly.” The chefs’ mean hedonic scores and comments indicated a greater liking of the green crab sauce’s taste compared to its aroma. The chefs’ comments supported the researcher’s hypothesis that green crab sauce possessed a novel, unique taste and may not be appropriate as a direct substitute for existing condiments such as fish sauce. The green crab sauce performed best in soup dishes (n=3) and worst in salad dishes (n=3) when compared to the chef-chosen umami enhancers. New England chefs’ comments regarding green crab sauce’s performance in a recipe were primarily positive, suggesting their status as a target consumer for future fermented green crab sauce condiments. Further experimentation is needed to determine the recipes green crab sauce is most appropriate for and its likability by a larger consumer audience.
2.2. Introduction

The European green crab (*Carcinus maenas*) is native to Europe and North Africa; however, its presence has been documented off the Eastern coast of North America since 1817 (Klassen & Locke, 2007). Numerous studies have shown the potential for green crabs to adversely affect many ecosystem components, directly and indirectly, through predation, competition, and habitat modification (Klassen & Locke, 2007). Green crabs found on the North American East Coast have been shown to prey on the following commercially and ecologically important species: soft-shell clams, scallops, juvenile American lobsters, and mud crabs (primarily *Dyspanopeus sayi*) (Gehrels, 2016; McKenzie, 2011). It has been estimated that their population was responsible for more than 23 million USA dollars of losses annually from 1975-2005 (Abt Associates, 2008).

Previous research has demonstrated successful reductions of the green crab population through intensive indiscriminate trapping (Abt Associates, 2008; de Rivera et al., 2007; McKenzie, 2011). The potential for green crab fisheries has been investigated, however, the industry requires a significant increase in the value and demand for hard-shell green crabs (McNiven et al., 2013). Hard-shell green crabs, or non-molting green crabs, comprise the majority of the green crab population at any given time. Currently, there are few, low-value options for green crabs, such as compost and bait (Fulton & Fairchild, 2013; Journo & Park, 2018). On the other hand, soft-shell green crabs may be sold to New England restaurants for up to $25/lb but may be dependent on demand and seasonality (McMahan, 2021). Thus, there is a need for a high-value option to increase the demand for green crabs.
Fish sauce has been a staple condiment in many cultures for thousands of years, dating back to the 3rd-4th century B.C. (Grainger, 2021; Henesy, 2018). It may be used in recipes to add an “umami kick” or add “funky, complex flavors” (Kruse, 2017). Due to the ease and low cost of the fermentation process, fish sauce quickly began being produced in many parts of the world (El Sheikha & Montet, 2014). Fish sauce production involves the spontaneous fermentation of many low-value and underutilized fish species to a condiment with much higher value and a much longer shelf-life (El Sheikha & Montet, 2014; Hakimi et al., 2022). Due to the similar low value and underutilization of hard-shell green crabs, their use in a fermented green crab sauce condiment is being investigated.

Previous research has determined that whole green crabs fermented at a temperature of 24°C, 30-37°C, or 50°C with a salt content of 20% and a fermentation time of 90 days can produce a viable green crab fermented condiment that is chemically comparable to commercially available fish sauce products (Greiner et al., 2021). Additionally, a green crab sauce concept was perceived positively by chefs in New England (Leung, 2021). In that study, New England chefs were surveyed, and scored “likeliness to use” and “willing to purchase” a commercially available green crab sauce very positively. The survey indicated that the target consumers for green crab sauce could include of head chefs who focus on Asian cuisine and are familiar with fish sauce. Sensory evaluation of green crab sauce is still needed to ensure its palatability to consumers. This project aims to conduct a home-usage test to gain greater insight into the acceptability and sensory aspects of the use of crab sauce as a unique umami flavor enhancer in recipes prepared by chefs.
2.3. Materials and Methods

2.3.1. Preparation of Crab

Green crabs were trapped off the coast of Georgetown, Maine, and transported on ice to the University of Maine (Orono, ME, USA). Live crabs were blast frozen (Southeast Cooler, Lithia Springs, CA, USA) for 1 hr at $-30^\circ$C, then stored at $-20^\circ$C until use. Frozen whole crabs were thawed for 36–48 h at 4$^\circ$C before being finely chopped in a Kolsch bowl cutter (UltraSource, Kansas City, MO, USA) and combined with uniodized kosher salt (Morton Salt, Chicago, IL, USA) at 200 mg g$^{-1}$ (w/w). The treatment was prepared and packed into clean, 0.95 L canning jars covered with a double layer of cheesecloth (Pyrm Consumer USA, Spartanburg, SC, USA).

2.3.2. Fermentation

The treatment was incubated at 37$^\circ$C for 90 days. The sauce was separated from the solid residue for testing by straining through two layers of non-sterile cheesecloth into 250 mL centrifuge tubes. The filtrate was clarified by centrifugation in an Avanti J-E Beckman Coulter centrifuge ((Brea, CA, USA) 706 $\times$ g, 10 min). The filtrate was centrifuged a second time for greater clarification (706 $\times$ g, 15 min). Finally, the filtrate was filtered through Whatman #1 filter paper. The green crab sauce was stored for up to 1 year at 4$^\circ$C until pasteurization.

2.3.3. Pasteurization

The green crab sauce was pasteurized by heating it to 93.3$^\circ$C for 5 minutes. This value was obtained from the FDA’s Fish and Fishery Products Hazards and Control Guidance (FDA, 2011) to target non-proteolytic Clostridium botulinum type B for a 6D reduction. The green crab sauce
was bottled in 50 mL glass bottles with plastic caps (Nakpunar, Hamilton Township, New Jersey, USA) prior to pasteurization. The bottles were placed in a metal rack, immersed in simmering water within a stainless steel pot, and heated over a gas stovetop. The temperature of the green crab sauce was monitored using a K-type thermocouple probe (Omega, Stamford, CT, USA) inserted snugly into the plastic bottle cap and secured using masking tape. The probe was positioned to remain submersed without making contact with the sides of the glass bottle. The come-up-time for green crab sauce to reach 93.3°C was between 6-7 minutes.

2.3.4. Chef Home-Use Test

The protocol for this study was approved by the University of Maine Institutional Review Board for the Protection of Human Subjects (Approval number: 2022-10-04). The remote sensory analysis of green crab sauce was performed by New England chefs and was administered using Qualtrics software (Qualtrics, Provo, UT). All chefs gave their informed consent before participating in this study (Appendix A). The target population for this survey was professional working chefs located throughout the Northeast United States who were at least 18 years old and did not have an allergy to any form of seafood. Chefs were recruited through personal networks via email (Appendix B).

Before the survey was administered, a 50 mL bottle of crab sauce was labeled as “Green Crab Sauce, University of Maine, 50 mL” on label paper. The sauce was then shipped to each of the participants’ addresses for remote analysis. The samples were refrigerated at 4°C prior to shipping and shipped using express 2-day shipping. Once shipped, the Qualtrics survey was administered, consisting of 21 questions, and taking approximately 20 minutes to complete (Appendix C). The participants had approximately two weeks to complete the survey once the
crab sauce had been shipped. The survey questions were split into 3 blocks. The first block consisted of questions regarding the chefs’ state of residence and their experience in the culinary industry. The second block asked the participants to assess the appearance, aroma, and taste of the crab sauce on its own. The third block asked the participants to cook and assess a recipe of their choice with green crab sauce. The chefs rated the attributes of the crab sauce on its own and in their recipe using a 9-point hedonic scale. The chefs were also asked to prepare the same recipe of their choice with an umami enhancer of their choice for comparison to their green crab sauce recipe. This recipe was also rated on a 9-point hedonic scale. Lastly, the chefs provided optional qualitative feedback for the green crab sauce’s attributes and performance in the recipe of their choice.

2.3.5. Statistical Analysis

The data were coded and analyzed using IBM SPSS 27 (International Business Machines – Statistical Package for Social Sciences) at a significance level of p < 0.05. Significant differences between mean hedonic scores were determined by one-way analysis of variance (ANOVA), followed by an LSD test. For some qualitative data, a six-phase reflexive thematic analysis was conducted (Braun & Clarke, 2006; Braun & Clarke, 2019).

2.4. Results

2.4.1. Chef and Cuisine Classification

A total of 17 chefs participated in this study, 15 from Maine and 2 from Rhode Island. The chefs were asked to classify their professional experience to help researchers gauge their level of culinary expertise. The terminology used to classify chefs was recommended by a
professional working executive chef. The chef classification can be rated by experience as executive chef > chef de cuisine > consulting chef > cook. Chefs were also given the option of “Other” which includes examples such as chefs in education or professional home chefs. Most of the chefs classified themselves as executive chef (41.2%), followed by other (29.4%), chef de cuisine (11.8%), cook (11.8%), and consulting chef (5.9%) (Table 2.1).

Chefs were also asked about their cuisine of focus and allowed to select multiple cuisines. The majority of chefs selected American cuisine (31.9%), followed closely by Asian (25.5%) and European (25.5%). Few chefs also selected Latin American (12.8%), Other (2.1%), and African (2.1%) (Table 3.1).

<table>
<thead>
<tr>
<th>Table 2.1. Chef-Selected Classification and Cuisine of Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category</strong></td>
</tr>
<tr>
<td><strong>Chef Classification</strong></td>
</tr>
<tr>
<td>Executive Chef</td>
</tr>
<tr>
<td>Chef de Cuisine</td>
</tr>
<tr>
<td>Consulting Chef</td>
</tr>
<tr>
<td>Cook</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td><strong>Cuisines of Focus</strong>*</td>
</tr>
<tr>
<td>American</td>
</tr>
<tr>
<td>Asian</td>
</tr>
<tr>
<td>European</td>
</tr>
<tr>
<td>Latin American</td>
</tr>
<tr>
<td>African</td>
</tr>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>

*Chefs were able to select multiple cuisines of focus, so responses do not sum 17.
2.4.2. Chef Umami Enhancer Use

Initial tastings of the green crab sauce by the research team suggested a different taste and aroma compared to other umami enhancers, such as fish sauce (Appendix D). From the initial tasting, we hypothesized that its sensory qualities may make crab sauce an inappropriate as a direct substitute for fish sauce in existing recipes. Thus, the chefs were asked to evaluate their use of umami enhancers, such as crab sauce, fish sauce, etc., as well as to classify their frequency of umami enhancer use. Of the 17 chefs, most participants selected “Greater than 4 times a week” (9), followed by “2-3 times a week” (4), “weekly” (2), “1-2 times a month” (1), and “less than once a month” (1) (Figure 2.1).

![Figure 2.1. Approximately How Often Do You Use Umami Flavor Enhancers (Soy Sauce, Tamari, Fish Sauce, Garum, Anchovy Paste, Shrimp Paste, Worcestershire Sauce, MSG, Miso, Etc.) When Cooking?](image-url)

The chefs were also asked about the type of dishes they prepare most often with umami enhancers. This question served to gauge the chefs’ experience cooking with certain dishes as well as to determine which dishes chefs most often prepare with umami enhancers. The chefs
could select multiple types of dishes. The results were spread throughout the available categories of dishes. The dishes with greater than 10 responses were dressing (15.7%), marinade (15.7%), soup (14.5%), stir fry (10.8%), and dipping sauce (10.8%) (Table 2.2).

Table 2.2. What Type of Dishes, That Contain an Umami Flavor Enhancer, Do You Prepare Most Often at Your Restaurant or Place of Work?

<table>
<thead>
<tr>
<th>Type of Dish</th>
<th>Number of Responses (n=17)*</th>
<th>Percent of Responses (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dipping Sauce</td>
<td>10</td>
<td>10.8</td>
</tr>
<tr>
<td>Dressing</td>
<td>13</td>
<td>15.7</td>
</tr>
<tr>
<td>Marinade</td>
<td>13</td>
<td>15.7</td>
</tr>
<tr>
<td>Glaze</td>
<td>6</td>
<td>7.2</td>
</tr>
<tr>
<td>Soup</td>
<td>12</td>
<td>14.5</td>
</tr>
<tr>
<td>Stew</td>
<td>6</td>
<td>7.2</td>
</tr>
<tr>
<td>Chili</td>
<td>3</td>
<td>3.6</td>
</tr>
<tr>
<td>Stir Fry</td>
<td>9</td>
<td>10.8</td>
</tr>
<tr>
<td>Curry</td>
<td>6</td>
<td>7.2</td>
</tr>
<tr>
<td>Other</td>
<td>6</td>
<td>7.2</td>
</tr>
</tbody>
</table>

*Chefs were able to select multiple types of dishes, so responses do not sum 17.

2.4.3. Chef Sensory Evaluation of Green Crab Sauce by Itself

In block 2 of the survey, the chefs rated their liking of the appearance, aroma, and taste of the green crab sauce on its own on a 9-point hedonic scale (n=17). On average, the chefs’ rated the appearance of the experimental green crab sauce $5.9 \pm 1.5$, the aroma $5.1 \pm 2.2$, and the taste $6.1 \pm 2.2$ (Figure 2.2).
Figure 2.2. Chef Rankings of Green Crab Sauce’s Appearance, Aroma, and Taste on a 9-Point Hedonic Scale (n=16)

The chefs were also asked to comment on the appearance, aroma, and taste of the crab sauce on its own. The comments for the appearance consisted of 2 positive, 5 neutral, and 3 negative comments (Appendix E). A positive comment included “Looked more natural than fish sauce,” while a negative comment included “not completely clarified… some brown residue settles at the surface.”

The chef comments regarding aroma consisted of 1 positive, 7 neutral, and 4 negative comments (Appendix F). An example of a negative comment was “it has an intense aroma… would likely be off-putting to the average or even adventurous consumers…,” while the positive comment was “the aroma made me want to cook with it.”

The chef comments regarding taste were more positive than those for aroma, including 5 positive, 7 neutral, and 3 negative comments (Appendix G). An example of a positive comment was “Nice crab flavor, good balance of umami and salt” and a negative comment was “Very salty. Kind of a mushy sort of flavor.”
2.4.4. Chefs Sensory Evaluation of Green Crab Sauce in a Recipe

In the third and final block of the questionnaire, the chefs (n=17) were asked to cook with the green crab sauce (n=17) in a recipe of their choice and were given the option to compare their recipe prepared with the green crab sauce and separately with an umami enhancer of their choice (n=14). The chefs rated their liking using a 9-point hedonic scale and provided detailed comments about their liking of green crab sauce in their dish. This section of the survey was performed to get more information on the types of dishes the green crab sauce could be effectively incorporated into and its viability to replace different umami enhancers in a recipe.

The chefs incorporated green crab sauce in various dishes (Appendix H). Some of the most common recipe categories include pasta with shellfish, salads, and soups (Appendix H). The most common umami enhancer used to compare to green crab sauce in a recipe was fish sauce (Table 2.3). To minimize variables, the chefs’ overall liking of the green crab sauce and umami enhancers of their choice in recipes were split into recipe categories in Figure 2.3. While figure 2.3. had a low sample size, the mean hedonic scores of green crab sauce incorporated in a soup were highest and salads were lowest among the dish categories.

<table>
<thead>
<tr>
<th>Umami Enhancer</th>
<th>Number of Responses*</th>
<th>Percentage of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish Sauce</td>
<td>14</td>
<td>59.1</td>
</tr>
<tr>
<td>Garum</td>
<td>2</td>
<td>9.1</td>
</tr>
<tr>
<td>Shrimp Paste</td>
<td>2</td>
<td>9.1</td>
</tr>
<tr>
<td>Soy Sauce</td>
<td>1</td>
<td>4.6</td>
</tr>
<tr>
<td>Anchovy Essence</td>
<td>1</td>
<td>4.6</td>
</tr>
<tr>
<td>MSG</td>
<td>1</td>
<td>4.6</td>
</tr>
<tr>
<td>Crab Head Fat Butter</td>
<td>1</td>
<td>4.6</td>
</tr>
</tbody>
</table>

*Chefs were able to select multiple umami enhancers, so responses do not sum 17.
Chefs were also given the option to provide detailed comments regarding their liking of green crab sauce in their recipe (Appendix I). Of the comments, 6 were positive, 2 were neutral, and 2 were negative. An example of a positive comment was “I was able to replace with equal amounts for fish sauce in Beef Pho. Still have the umami taste without the off smell of fish sauce.” The negative comment was given by a chef who prepared shrimp fried rice and commented “The musky sort of flavor did not help the dish.” Themes and descriptors, generated from the panelist comments, are displayed in Figure 2.4 to visualize the qualitative feedback more easily.
Figure 2.4. Themes of Chefs’ Evaluation of Green Crab Sauce in a Chef-Made Dish

2.4.5. Green Crab Sauce Price Information

Chefs were given the option to record how much they would spend on a 16-ounce bottle of green crab sauce using a sliding scale. Fifteen of 17 chefs responded to this survey question. The average of the amounts selected was $12.87 with a standard deviation of $4.87, a maximum of $24, and a minimum of $7 (Figure 2.5). Any additional comments provided by the chefs were recorded in Appendix H.
2.5. Discussion

2.5.1. Chef Demographic Information

The goal of this study was to receive chef feedback on green crab sauce to determine its likeability and applicability as an umami enhancer in a recipe. A remote sensory analysis was conducted by 17 New England chefs to determine their sensory perspectives of the crab sauce on its own and in a recipe of their choice. The results of this study can be used by green crab sauce producers and consumers to aid in the product development of green crab sauce as an umami-enhancing condiment.

New England chefs were selected due to the prevalence of green crabs throughout the New England coast. Additionally, a previous survey concluded that New England head chefs focusing on Asian cuisine would be effective target consumers for green crab sauce (Leung, 2021). Of the chefs surveyed (n=17), the most popular chef classification was “head chef,”
consisting of 8 of the 17 chef participants. Hierarchically, head chefs understand the most about their culinary practices and have the most control over their restaurant’s menu (Wellton et al., 2016). American, Asian, and European were the most common cuisines of focus by chefs. Of the chefs surveyed, 12 indicated a focus on Asian cuisine. Asian cuisine is most recognized for its use of fish sauce (Curtis, 2009). The high frequency of Asian cuisine focus may indicate chefs’ familiarity with cooking with fish sauce. Additionally, more than half of chefs selected use fish sauce more than four times per week, indicating a high familiarity with fish sauce (56.3%). Only one chef indicated fish sauce usage of less than once a month.

2.5.2. Chef Sensory Evaluation of Green Crab Sauce By Itself

Most fish sauces are produced using the same general methods of salting, natural enzyme hydrolysis and bacterial fermentation, and extraction of the fish sauce (Hakimi et al., 2022). The fermentation process of fish sauce is closely tied to its quality and defining taste features (Wang et al., 2022). While few consumer acceptance studies have been performed on fish sauce, a previous survey conducted by Leung (2021) concluded that most New England chefs believe flavor is the most important characteristic of fish sauce. The survey also indicated that the ideal green crab sauce would be medium brown in color, transparent, and possess a rich umami flavor.

The first sensory attribute of green crab sauce assessed was its appearance in a clear 50 mL bottle. As stated, the most common critique of appearance was its lack of clarification (Appendix E). These statements agree with New England chefs’ previous indication of their preference for a “transparent” green crab sauce in a previous survey (Leung, 2021). The addition of finer filtration during the processing of green crab sauce will likely be more costly, time-consuming, and would reduce yield. However, color and appearance are some of the most crucial
factors in the product-intrinsic sensory cue for establishing consumers’ initial reactions to a product (Spence, 2015). Finer filtration methods should be explored to reduce negative chef perceptions of the appearance of green crab sauce.

The next attributes investigated were the aroma and taste of the green crab sauce on its own. The mean hedonic liking of the aroma was less than the taste. Additionally, more negative comments were used to describe the aroma compared to the taste of the green crab sauce. Similarly, previous research on fish sauce has described the compounds responsible for its taste more positively than its aromatic compounds. The aroma of volatile compounds in fish sauce have been described as fishy, fecal, rancid, cheesy, meaty, and burnt (Russo et al., 2020), while the sensory peptides responsible for the taste of many Asian fish sauces have been shown to exhibit sweet, sour, bitter, umami, and kokumi tastes (Hakimi et al., 2022). The results in this study support a greater liking of the taste of green crab sauce compared to its aroma. Therefore, green crab sauce may be more efficacious as a recipe ingredient, enabling its interaction with other flavors and aromas in a dish, rather than its use as a finishing ingredient.

Fish sauce is known for its inclusion in a variety of recipes, rather than its consumption on its own (Hill, 1936; Huynh et al., 2015). Previous research also highlights fish sauce’s use as a replacement for sodium chloride (NaCl) in recipes to lower the recipes’ overall NaCl content without impacting consumer acceptability or palatability (Huynh et al., 2015). The umami enhancing compounds present in fish sauce, such as l-glutamate and 5’-ribonucleotides, react synergistically with salt in recipes to influence consumer preference and overall liking (Park et al., 2020; Yamaguchi & Ninomiya, 2000). Similarly to fish sauce, crab sauce’s use in a recipe is of greater importance than its sensory qualities when assessed independently, due to its role as a flavor-enhancing ingredient in a recipe.
2.5.3. Chef Sensory Evaluation of Green Crab Sauce in a Recipe

Umami is known as “the fifth basic taste evoking savory, full-bodied, and meaty flavor sensations” (Crowe, 2013). Umami flavors have gained popularity during the past decade, resulting in increased attention from academic and industry sources (Zhao et al., 2019). Some of the most popular umami-enhancing sauces include soy, fish, and oyster sauce. As stated earlier, umami enhancers, such as fish sauce, can be used in recipes to add an “umami kick” or “funky” flavors to dishes (Kruse, 2017). When combined with other foods, umami enhancing ingredients may elicit a synergistic umami taste (Schmidt et al., 2020). While there is some sensory research on fish sauce and crab sauce on its own, no research is currently available on the acceptance or sensory evaluation of fish sauce or crab sauce in a recipe.

The researchers' initial taste testing of green crab sauce (Appendix D) revealed more “marine” flavors and “crabby” aromas that differ from the sensory attributes of fish sauces described in the previous discussion section (Hakimi et al., 2022; Russo et al., 2020). Therefore, green crab sauce may be more well liked as a recipe ingredient, enabling its interaction with other flavors and aromas in a dish, rather than its use as a finishing ingredient. Moreover, it is likely to be best suited to dishes in which crab and/or seafood flavors are prominent.

Chefs compared a variety of umami enhancers to green crab sauce (Table 2.3); however, fish sauce was the most common. Thus, while fish sauce may be the most similar fermented umami-enhancing condiment to green crab sauce, it may also be comparable to other umami enhancers and differ in its incorporation in recipes. The researchers’ hypothesis was also supported by qualitative feedback comments such as: “It's just different…”, “It has a distinct flavor…”, and “It was great in a dish with crab, but I am not sure how versatile of an ingredient
it can be due to its particular crabby flavor” (Appendix I). Green crab sauce’s status as a unique umami enhancer, could benefit its marketability, however, greater information regarding its versatility in recipes and user-friendliness is needed.

The chef participants incorporated green crab sauce and their umami enhancers into a wide variety of dishes (Appendix H), providing the researchers with the means to assess the performance of green crab sauce in different recipes. In general, the salad dishes that were cold or uncooked and incorporated with green crab sauce received the lowest overall hedonic liking scores (Figure 2.3.). Some participant comments reflected their criticism of the green crab sauce in a salad recipe. For example, one chef commented: “… It worked fairly well in the Larb which is meant to be a heavily seasoned dish with powerful aromatics. But the more neutral rice and lettuce salad was made too strong” (Appendix I). Green crab sauce, fermented at 37°C, may not be able to serve as a substitute ingredient for other umami enhancers in uncooked, cold, or salad dishes due to its powerful, unique aromatic properties.

On the contrary, green crab sauce was enjoyed in many other dishes such as soup and pasta with shellfish. There was positive feedback indicating it was a great or effective replacement for fish sauce or other umami enhancers in dishes (Appendix I). Its pleasant and umami taste when combined with other ingredients in a dish was commented on by several chefs (Appendix I). Though the aroma of green crab sauce may differ from fish sauce, these comments indicate that it can still be used as an effective umami enhancer in chef-made recipes. This data suggests New England chefs should remain a target consumer base for green crab sauce production.
2.5.4. Green Crab Sauce Bottle Price

In the last section of the home-use test survey, the chefs were asked how much they would pay for a 16-ounce bottle of crab sauce. According to prices posted on Amazon (2023), some of the most popular fish sauces include a 17-ounce bottle of Red Boat fish sauce that costs $14.95, a 24-ounce bottle of Three Crabs Brand fish sauce that costs $11.93, and a 24-ounce bottle of Squid Brand fish sauce that costs $8.99. The average price selected was $12.87 (n=15) (Figure 2.6), which would position green crab sauce as an above-average-priced fermented condiment when comparing it to popular fish sauces on Amazon.

2.5.5. Limitations

This research includes a home-use test of a green crab sauce product formulation. The chef questionnaire (Appendix C) was formulated to allow the chefs to choose their own umami enhancers to compare to green crab sauce. The sample size consisted of 17 chefs, which may not have been large enough to represent all chefs in New England. Additionally, their freedom regarding their recipe choice was essential to gaining insight from the home-use test. The researchers of this study possessed limited knowledge regarding the chef-chosen umami enhancers and recipes (Appendix H & Table 2.3). While 14 chefs chose fish sauce to compare to green crab sauce in a recipe (Table 2.3), the researchers have no information regarding the brand or ingredients of the fish sauce. Fish sauces are frequently combined with other ingredients such as sugar, colorants, and preservatives (Greiner et al., 2021). Future green crab sauce formulations should consider the application of additional ingredients to optimize consumer liking. Additionally, another limitation includes the lack of labeling, packaging, branding, and marketing of green crab sauce. These aspects of a product play a large role in consumer liking.
and purchasing habits and, if present, may have altered chef perceptions of the product (Martinho, 2020).

2.6. Conclusions

The results of this study provide valuable insights into New England chefs' opinions and the sensory acceptability of green crab sauce, both on its own and in comparison to other umami-enhancing ingredients. The feedback from the chefs regarding the appearance of the sample bottle of green crab sauce highlighted its lack of transparency. To address this issue, further exploration of finer filtration methods should be considered in future processing to enhance the sauce's transparency. The chefs expressed a preference for the flavor of the green crab sauce over its aroma, suggesting that the sauce is more effective when used in dishes that emphasize its taste rather than its aroma. Furthermore, when incorporated into recipes, the chefs noted the unique flavor of the green crab sauce, using descriptors such as "different," "distinct," and "crabby.” This feedback supports our initial hypothesis that the green crab sauce should not be promoted as a direct replacement for fish sauce but rather as a novel umami-enhancing ingredient. The sensory attributes of green crab sauce, when considered independently, provide valuable insights into its role as a flavor-enhancing ingredient in a recipe.

Overall, green crab sauce was liked less in uncooked, cold, or salad dishes and most in soup dishes compared to the chef-chosen umami enhancers (Figure 2.3.). The chefs’ comments regarding green crab sauce’s performance in their recipes were primarily positive and indicated its use as an effective umami enhancer. New England chefs should continue to be target consumers for a fermented green crab sauce condiment. Additionally, 15 of the 17 chefs indicated they would spend an average of $12.87 on a 16-ounce bottle of green crab sauce, an
above-average price point compared to other popular fish sauces available on the market. However, the price-point of green crab sauce could likely be increased by more complete labeling, packaging, branding, and marketing of green crab sauce that play a large role in consumer liking and purchasing habits.

In summary, this study has shed light on New England chefs' perspectives on green crab sauce and its role as an umami-enhancing ingredient. By addressing the concerns raised about transparency and continuing to investigate its applications in various dishes, further advancements can be made to initiate the use of green crab sauce in culinary settings.

2.7. References


CHAPTER 3

CONSUMER ACCEPTANCE TESTING OF GREEN CRAB SAUCE IN A GARLIC NOODLE RECIPE

3.1. Abstract

We investigated consumer liking of green crab sauce as a means to develop a value-added product from invasive green crabs (*Carcinus maenas*). Green crab sauces fermented at 24°C and 37°C were chemically analyzed and incorporated in garlic noodles for consumer acceptance testing. The total volatile base nitrogen (TVBN), nonenzymatic browning, and amine nitrogen values determined in this study were all significantly higher in the 37°C fermented green crab sauce compared to the 24°C fermented green crab sauce, which aligns with findings in previous research. During consumer testing, 87 consumers rated their liking of three garlic noodle samples prepared with either a 20% salt solution as a control, green crab sauce fermented at 24°C, or green crab sauce fermented at 37°C, all added at approximately 7.1% (w/w). The liking of aroma, flavor, and overall liking of the control and the 24°C crab sauce treatment were rated significantly (p < 0.05) higher than the 37°C crab sauce treatment, suggesting consumers liked the green crab sauce fermented at 24°C to a greater degree than the 37°C-fermented green crab sauce in a recipe. Consumer comments further revealed that the 24°C crab sauce treatment exhibited a pronounced crab flavor and aroma, appealing to some panelists, while the control had a milder, buttery taste that appealed to others. Conversely, the 37°C crab sauce treatment garnered comments highlighting the intensity of its seafood or crab flavor and aroma, possibly contributing to its lower hedonic scores. The difference in consumer perceptions of the samples were supported by a low correlation between overall liking and aroma in the control formula, a
moderate correlation in the 24°C crab sauce treatment, and a strong correlation in the 37°C crab sauce treatment. Consumers’ positive comments and mean overall liking score of 7.2 for the sample containing green crab sauce fermented at 24°C suggests its ability to be marketed to New England consumers.

3.2. Introduction

The green crab (*Carcinus maenas*), referred to as among the world’s 100 most harmful invasive species (Ens et al., 2022), has an established invasive population on the North American East and West coasts (Young & Elliott, 2020). Previous research has referred to green crabs as “ecosystem engineers” due to their ability to disrupt native marine systems to fit their needs (Leignel et al., 2014). Green crabs' resilience is complemented by their ability to feed on a variety of marine plants and animals, including several species of mussels, clams, scallops, algae, and marine amphipods, depending on their location (Baeta, 2006; Cordon et al., 2022; Grosholz et al., 2011; Miron et al., 2005). In particular, their preference for soft-shell clams is blamed for the soft-shell clam industry collapse in Maine, USA during the 1950s and continues to suppress soft-shell clam populations, representing a loss of over $20 million USA per year (Lovell, S. et al., 2007; Whitlow, 2010).

Previous research has demonstrated successful reductions of the green crab population through intensive indiscriminate trapping (Abt Associates, 2008; de Rivera et al., 2007; McKenzie, 2011). Green crab fisheries have been investigated to help reduce the green crab population, but require significant increases in the value of hard-shelled green crabs in order to be profitable (McNiven et al., 2013). While soft-shell green crabs can be sold to restaurants in the Northeast United States for approximately $25 per pound (McMahan, 2021), hard-shell green
crabs are predominately used as compost or bait and sold for less than $1 a pound (St-Hilaire et al., 2016; Fulton & Fairchild, 2013; Journo & Park, 2018; Lubitz et al., 1943). Moreover, the bulk of captured green crabs year-round are hard-shelled, while the soft-shell green crabs, that are molting or soon-to-molt, make up a fraction of the population (Walter, 2021). Exploring the development of a high-value product utilizing hard-shell green crabs is essential to command a high value for hard-shell green crabs.

A popular umami enhancer, fish sauce, is a high-value, fermented condiment popular for commercial and home culinary applications (El Sheikha & Montet, 2014; Ibrahim et al., 2022). Anchovies are commonly used to produce fish sauce due to their low value and high protein content. The production of fish sauce is able to both extend the shelf-life and enhance the value of underutilized fish species, such as anchovies. Similarly, green crab sauce aims to be a practical, value-enhancing approach to the utilization of hard-shell green crab biomass.

Previous research has investigated the potential for the production of a fermented hard-shell green crab sauce due to green crabs’ low value (Skonberg & Perkins; Greiner, 2021). Green crabs, when chopped whole and fermented at 24-50°C with a salt content of 20-30% produced a viable product that is chemically comparable to commercially available fish sauce products (Greiner, 2021). Additionally, a green crab sauce product concept was perceived very positively by New England chefs in an online survey (Leung, 2021). The ease of production and low startup costs associated with fermented green crab sauce production may contribute to the accessibility of small-scale processing operations. However, consumer sensory acceptability testing is needed to ensure the palatability and viability of green crab sauce. The purpose of this work was to assess the consumer acceptance of fermented green crab sauce manufactured using whole green crabs.
3.3. Materials and Methods

3.3.1. Preparation of Green Crabs

Green crabs were trapped off the coast of Georgetown, Maine, and transported on ice to the University of Maine (Orono, ME, USA). Live crabs were blast frozen (Southeast Cooler, Lithia Springs, CA, USA) for 1 hr at −30°C, then stored at −20°C until use. Frozen whole crabs were thawed for 36–48 h at 4°C before being finely chopped in a Kolsch bowl cutter (UltraSource, Kansas City, MO, USA) and combined with uniodized Kosher salt in the bowl cutter (Morton Salt, Chicago, IL, USA) at 200 mg g⁻¹ (w/w). Both treatments were prepared separately and packed into clean, 0.95 L and 3.79 L canning jars covered with a double layer of cheesecloth (Pyrm Consumer USA, Spartanburg, SC, USA).

3.3.2. Fermentation

The samples were split into two groups with one group being fermented at 24°C for 90 days and the other at 37°C for 90 days at the University of Maine (Orono, ME, USA). After fermentation, the sauce was separated from the solid residue for testing by straining through two layers of non-sterile cheesecloth into 250 mL centrifuge tubes. The filtrate was centrifuged in an Avanti J-E Beckman Coulter centrifuge (Brea, CA, USA) (706 × g, 10 min). The filtrate was centrifuged a second time to increase the clarity of the filtrate (706 x g, 15 min). Finally, both filtrates were filtered through a Whatman #1 filter paper to further increase the filtrate clarity. The filtrate was refrigerated at 4°C until pasteurization.
3.3.3. Pasteurization

The clarified green crab sauce was pasteurized by heating it to 93.3°C for 5 minutes. This value was obtained from the FDA’s Fish and Fishery Products Hazards and Control Guidance (FDA, 2011) to target non-proteolytic Clostridium botulinum type B for a 6D reduction. The green crab sauce was bottled in 50 mL glass bottles with plastic caps (Nakpunar, Hamilton Township, New Jersey, USA) prior to pasteurization. The bottles were placed in a metal rack, immersed in simmering water within a stainless steel pot, and heated over a gas stovetop. The temperature of the green crab sauce was monitored using a K-type thermocouple probe (Omega, Stamford, CT, USA) inserted snugly into the plastic bottle cap and secured using masking tape. The probe was positioned to remain submersed without making contact with the sides of the glass bottle. The green crab sauce took between 6-7 minutes after being exposed to heat to reach 93.3°C.

3.3.4. Determination of Nonenzymatic Browning

Nonenzymatic browning was measured using the methods of Zhao et al., 2019 with modifications as described in Greiner et al., 2021. One mL of sauce was stirred using a magnetic stir bar and plate with 10 mL of ethanol (500 mL L−1 v/v Fisher Scientific, Waltham, MA, USA) for one hour. The mixture was then filtered through a 0.45 μm syringe filter (MDI Membrane, Harrisburg, PA, USA) and subjected to an absorbance measurement at 420 nm with a DU 530 spectrophotometer (Beckman Coulter, Brea, CA, USA) (n=3).
3.3.5. Determination of Total Volatile Basic Nitrogen (TVBN) and Amine Nitrogen

*Total Volatile Basic Nitrogen*

Total volatile basic nitrogen was measured according to Botta et al. (1986) as cited by Leung (2021) with slight modifications. Fermented crab sauce (5 mL) was diluted 1:1 with deionized water (5 mL) and vortexted until homogenous. This 10 mL mixture was added to a micro-Kjeldahl distillation unit (Rapid distillation unit, Labconco, Kansas City, MO) followed by 4 mL of 10% sodium hydroxide solution. The samples were distilled into an Erlenmeyer flask containing 15 mL of 4% boric acid solution and 8 drops of indicator (0.2% methyl red and 0.2% methylene blue, 2:1 in ethanol) to constitute a final volume of approximately 45 mL. The distillate was then titrated with 0.05 N hydrochloric acid (HCl) until the mixture turned from a light green to a constant blue color. The volume (mL) of titrant used was recorded to calculate TVBN using the following equation:

\[
TVBN = [(Volume \text{ (mL)} HCl \text{ used for titrating the sample}) \times \text{Normality of HCL} \\
\times \text{Molecular weight of N}] \times \frac{100 \text{ mL}}{\text{Undiluted sample volume (mL)}}
\]

TVBN values were expressed as mg/100 mL (n=3).

*Amine Nitrogen*

Amine nitrogen was measured using an N-formol titration method described by Joung and Min (2018) as cited by Leung (2021) with slight modifications. Each sample was analyzed once, and replicates (n=3) were averaged for mean amine nitrogen concentration for each treatment. Sauce samples were diluted with distilled water (1:10, sauce to water) and pH was
adjusted to 8.5 with 0.1 N sodium hydroxide (NaOH) solution. Next, 8 mL of 37% w/v formaldehyde solution was adjusted to a pH of 8.5 with 0.05 N NaOH. The adjusted sample and formaldehyde mixtures were combined which dropped the overall pH. This mixture was titrated with 0.05 N NaOH until a pH of 8.5 was reached. The amount of 0.05N NaOH used to titrate was recorded and used to calculate amine nitrogen using the following equation:

\[
\text{Amine Nitrogen} = 14 \times mL \text{ of NaOH titrant} \times N \text{ of NaOH} \times 10 \times \frac{100}{10}
\]

Amine nitrogen was expressed as mg/100 mL (n=3).

3.3.6. Consumer Acceptance Testing

All subjects gave their informed consent for inclusion before they participated in the study (Appendix K). The protocol for this study was approved by the University of Maine Institutional Review Board for the Protection of Human Subjects (Approval number: 2023-03-18). Recruitment of panelists willing to try green crab sauce and garlic noodles was conducted via email (Appendix L), paper flier recruitment (Appendix M), and a University of Maine news notice (Appendix N). Persons under the age of 18, who do not like pasta, or are allergic to shellfish, gluten, wheat, or dairy were not allowed to participate. Sensory evaluation was conducted in the University of Maine Sensory Evaluation Testing Center (Orono, ME), which is equipped with 12 individual assessment booths for private assessment and SIMS 2000 sensory evaluation software (version 6.0, Sensory Computer Systems LLC, Berkeley Heights, NJ, USA). The evaluation rooms were climate-controlled with positive-pressure air flow to prevent odors from the food preparation area to bias judgments. A combination of fluorescent and incandescent lighting was used. Each participant was provided with $5 as compensation for their participation.
The samples were presented simultaneously in small ceramic white ramekins labeled with randomly assigned 3-digit codes assigned by SIMS. Samples of the three formulations were given to subjects in a random sequence predetermined with the SIMS program. During testing, the panelists used a 9-point hedonic scale (1 = dislike extremely; 5 = neither like nor dislike; 9 = like extremely) for overall acceptability, aroma, color, texture, and taste (Peryam and Pilgrim 1957) (Appendix O). Demographic data was also collected, as well as panelists’ grocery shopping frequency, meal preparation frequency, and interest in cooking with new food ingredients. A Five-point just-about-right scale was used to evaluate sample saltiness. Optional comments were also collected for each sample.

3.3.7. Consumer Testing Sample Preparation

Three separate samples of garlic noodles were prepared using a modification of the recipe described by Park (2022). The ingredients of each sample are summarized in Table 3.1. The garlic noodle preparation methods were as follows: three large pots were filled with water, placed over high heat, and brought to a boil. In each pot, Barilla brand linguini noodles (12 ounces) were boiled for approximately 10 minutes until soft. The cooked noodles were strained. Meanwhile, three large skillets were placed over medium heat, and diced garlic (8 g), Kikkoman brand soy sauce (60 mL), butter (42 g), brown sugar (12 g), and green crab sauces or 20% salt solution (30 mL) were added to each skillet and boiled for approximately 2 minutes. The cooked noodles were added to each skillet and tossed until evenly coated for 1 minute. The resulting garlic noodles were placed in a steam bath to keep them warm. During testing, this process was repeated every 30 - 45 minutes in order to maintain consistent quality and temperature. Additionally, the noodles were mixed for uniformity before each sample was placed into the
small white ramekin to be served. Approximately 10 cooked noodles were served at approximately 140°F in each small white ramekin.

Table 3.1. Sample Recipe Ingredients for Consumer Testing

<table>
<thead>
<tr>
<th></th>
<th>24°C Crab Sauce Treatment</th>
<th>37°C Crab Sauce Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>170g raw linguini pasta</td>
<td>170g raw linguini pasta</td>
<td>170g raw linguini pasta</td>
</tr>
<tr>
<td>4g minced garlic</td>
<td>4g minced garlic</td>
<td>4g minced garlic</td>
</tr>
<tr>
<td>30 mL soy sauce</td>
<td>30 mL soy sauce</td>
<td>30 mL soy sauce</td>
</tr>
<tr>
<td>7g brown sugar</td>
<td>7g brown sugar</td>
<td>7g brown sugar</td>
</tr>
<tr>
<td>21g unsalted butter</td>
<td>21g unsalted butter</td>
<td>21g unsalted butter</td>
</tr>
<tr>
<td>15 mL salt solution</td>
<td>15 mL green crab sauce</td>
<td>15 mL green crab sauce</td>
</tr>
</tbody>
</table>

3.3.8. Statistical Analysis

The chemical analyses and sensory evaluation data were coded and analyzed using IBM SPSS 27 (International Business Machines - Statistical Package for Social Sciences) at a significance level of p < 0.05. The chemical analysis data was evaluated using a t-test. Significant differences between mean hedonic ratings were determined by one-way analysis of variance (ANOVA), followed by Tukey’s honest significant difference (HSD) post hoc test was used to separate treatment means. Pearson’s bivariate correlational analyses were also conducted on hedonic ratings.

3.4. Results

3.4.1. Chemical Analyses

Amine nitrogen, TVBN, and nonenzymatic browning were all significantly higher in the green crab sauce sample fermented at 37°C than the green crab sauce fermented at 24°C (Table 3.2.).
Table 3.2. Chemical Analyses of Green Crab Sauce Samples

<table>
<thead>
<tr>
<th>Chemical Analysis</th>
<th>24°C Fermented Green Crab Sauce</th>
<th>37°C Fermented Green Crab Sauce</th>
</tr>
</thead>
<tbody>
<tr>
<td>TVBN (mg 100 mL⁻¹)</td>
<td>136.3 ± 3.2a</td>
<td>161.5 ± 1.46b</td>
</tr>
<tr>
<td>Amine N (mgN 100 mL⁻¹)</td>
<td>900.7 ± 17.6a</td>
<td>998.7 ± 8.1b</td>
</tr>
<tr>
<td>Nonenzymatic Browning (Absorbance)</td>
<td>0.30 ± 0.00a</td>
<td>0.95 ± 0.17b</td>
</tr>
</tbody>
</table>

Lowercase letters designate significant differences between attributes (t-test, p < 0.05). Data are expressed as mean ± standard deviation (n = 3).

3.4.2. Panelist Characteristics

The consumer acceptance testing was conducted on April 20th, 2023 from 10 am to 5 pm. Eighty-eight participants finished the study. Participants were primarily female (n = 46), 18-25 years old (n = 38), and Caucasian (n = 76) (Table 3.3.).

Table 3.3. Gender, Age, & Ethnicity of Consumer Panelists

<table>
<thead>
<tr>
<th>Gender</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>41</td>
<td>46.6</td>
</tr>
<tr>
<td>Female</td>
<td>46</td>
<td>52.3</td>
</tr>
<tr>
<td>Prefer not to answer</td>
<td>1</td>
<td>1.1</td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-25</td>
<td>38</td>
<td>43.2</td>
</tr>
<tr>
<td>26-35</td>
<td>17</td>
<td>19.3</td>
</tr>
<tr>
<td>36-45</td>
<td>11</td>
<td>12.5</td>
</tr>
<tr>
<td>46-55</td>
<td>9</td>
<td>10.2</td>
</tr>
<tr>
<td>56-65</td>
<td>7</td>
<td>8.0</td>
</tr>
<tr>
<td>66 or older</td>
<td>6</td>
<td>6.8</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black or African American</td>
<td>4</td>
<td>4.5</td>
</tr>
<tr>
<td>Asian</td>
<td>4</td>
<td>4.5</td>
</tr>
<tr>
<td>Caucasian (White)</td>
<td>76</td>
<td>86.5</td>
</tr>
<tr>
<td>Native Hawaiian or Other</td>
<td>1</td>
<td>1.1</td>
</tr>
<tr>
<td>Pacific Islander</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prefer not to answer</td>
<td>5</td>
<td>5.6</td>
</tr>
</tbody>
</table>

72
Panelists were asked food purchasing and preparation questions that may pertain to their likelihood of purchasing a new food ingredient (Table 3.4.). The majority of participants conducted approximately 81-100% of their household’s grocery shopping (50.6%), prepared their main meal at home more than 5 times per week (48.3%), and were very to extremely interested in new and innovative food ingredients (75.3%).

**Table 3.4.** Panelists’ Grocery Shopping Frequency, Meal Preparation Frequency, and Interest in Cooking with New Food Ingredients

<table>
<thead>
<tr>
<th>Food Purchasing &amp; Preparation Habits</th>
<th>Response</th>
<th>Number of Panelists (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household grocery shopping frequency</td>
<td>0-20%</td>
<td>13 (14.6)</td>
</tr>
<tr>
<td></td>
<td>21-40%</td>
<td>8 (9.0)</td>
</tr>
<tr>
<td></td>
<td>41-60%</td>
<td>12 (13.5)</td>
</tr>
<tr>
<td></td>
<td>61-80%</td>
<td>11 (12.4)</td>
</tr>
<tr>
<td></td>
<td>81-100%</td>
<td>45 (50.6)</td>
</tr>
<tr>
<td>Main meal preparation frequency</td>
<td>Never or rarely</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1-2 times per week</td>
<td>13 (14.6)</td>
</tr>
<tr>
<td></td>
<td>3-5 times per week</td>
<td>33 (37.1)</td>
</tr>
<tr>
<td></td>
<td>More than 5 times per week</td>
<td>43 (48.3)</td>
</tr>
<tr>
<td>Interest in cooking with new food ingredients</td>
<td>Not interested at all</td>
<td>1 (1.1)</td>
</tr>
<tr>
<td></td>
<td>Slightly interested</td>
<td>6 (6.7)</td>
</tr>
<tr>
<td></td>
<td>Moderately interested</td>
<td>15 (16.9)</td>
</tr>
<tr>
<td></td>
<td>Very interested</td>
<td>37 (41.6)</td>
</tr>
<tr>
<td></td>
<td>Extremely interested</td>
<td>30 (33.7)</td>
</tr>
</tbody>
</table>
3.4.3. JAR Saltiness Testing

Further analysis of the saltiness of each recipe was recorded to determine its impact on consumers’ hedonic scores. Greater than 70% of consumers indicated “Just about right” (JAR) for all of the samples (Table 3.5.).

Table 3.5. JAR Saltiness Scores for Garlic Noodle Recipes (n=87)

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>24°C Crab Sauce Treatment</th>
<th>37°C Crab Sauce Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not salty enough</td>
<td>19</td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>JAR</td>
<td>64</td>
<td>76</td>
<td>64</td>
</tr>
<tr>
<td>Too salty</td>
<td>4</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

The samples were rated at a 5-point “Just About Right” scale. “Not salt enough” refers to the bottom two ratings of “not nearly salty enough” and “not salty enough.” “Too salty” refers to the top two ratings of “too salty” and “much too salty.” Control refers to a 20% (w/w) salt water garlic noodle treatment.

3.4.4. Hedonic Testing

There were no significant differences in consumer liking of color, aroma, flavor, and overall liking between the control and the 24°C crab sauce treatment (Table 3.6.). The overall acceptability of samples 1 and 2 averaged greater than 7.0, indicating highly acceptable sensory quality (Everitt, 2009). The aroma, flavor, and overall liking of the 37°C crab sauce treatment was liked significantly less than two other samples. There were no significant differences in the liking of the color for any of the samples.
### Table 3.6. Hedonic Scores for Garlic Noodle Recipes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Control</th>
<th>24°C Crab Sauce Treatment</th>
<th>37°C Crab Sauce Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>6.6 ± 1.4a</td>
<td>6.6 ± 1.4a</td>
<td>6.7 ± 1.5a</td>
</tr>
<tr>
<td>Aroma</td>
<td>7.1 ± 1.2a</td>
<td>6.9 ± 1.4a</td>
<td>6.3 ± 1.8b</td>
</tr>
<tr>
<td>Flavor</td>
<td>7.3 ± 1.2a</td>
<td>7.2 ± 1.3a</td>
<td>6.6 ± 1.7b</td>
</tr>
<tr>
<td>Overall Liking</td>
<td>7.2 ± 1.2a</td>
<td>7.2 ± 1.3a</td>
<td>6.6 ± 1.7b</td>
</tr>
</tbody>
</table>

Samples were rated on the 9-point scale, where 9 is “like extremely” and 1 is “dislike extremely.” Data are expressed as mean ± standard deviation (n = 87). Control refers to a 20% (w/w) salt water garlic noodle treatment.

To explore potential variations in the liking of green crab sauce attributes based on demographic information, hedonic scores were further analyzed by age (Table 2) and participants' responses to the question regarding their interest in cooking with new food ingredients (Table 3). Statistical analysis revealed no significant differences in hedonic scores between consumers aged 18-25 (43.2%) and those aged 26 and older (56.8%). Similarly, no significant differences were found between consumers who indicated being "extremely interested" (33.7%) in cooking with new food ingredients and those who did not indicate such interest (66.3%).

#### 3.4.5. Intra-Sample Correlations Between Hedonic Ratings

Intra-sample correlations between participants’ hedonic ratings were performed to determine whether liking of certain attributes were related (Tables 3.7., 3.8., & 3.9.). In all samples, color had a moderate correlation with overall liking ranging from 0.489 to 0.510. Flavor possessed strong correlations with overall liking ranging from 0.885 to 0.931. Interestingly, aroma possessed varying correlations with overall liking ranging from 0.357 for the control to 0.595 for the 24°C crab sauce treatment and 0.767 for the 37°C crab sauce treatment.
Table 3.7. Intra-Control Pearson’s Correlations Between Hedonic Attributes (n=87)

<table>
<thead>
<tr>
<th>Hedonic Attributes</th>
<th>Color</th>
<th>Aroma</th>
<th>Flavor</th>
<th>Overall Liking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>1</td>
<td>0.452</td>
<td>0.495</td>
<td>0.510</td>
</tr>
<tr>
<td>Aroma</td>
<td>0.452</td>
<td>1</td>
<td>0.353</td>
<td>0.357</td>
</tr>
<tr>
<td>Flavor</td>
<td>0.495</td>
<td>0.353</td>
<td>1</td>
<td>0.885</td>
</tr>
<tr>
<td>Overall Liking</td>
<td>0.510</td>
<td>0.357</td>
<td>0.885</td>
<td>1</td>
</tr>
</tbody>
</table>

All correlations are highly significant (p < 0.01). Control refers to a 20% (w/w) salt water garlic noodle treatment.

Table 3.8. Intra-24°C Crab Sauce Treatment Pearson’s Correlations Between Hedonic Attributes (n=87)

<table>
<thead>
<tr>
<th>Hedonic Attributes</th>
<th>Color</th>
<th>Aroma</th>
<th>Flavor</th>
<th>Overall Liking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>1</td>
<td>0.419</td>
<td>0.341</td>
<td>0.489</td>
</tr>
<tr>
<td>Aroma</td>
<td>0.419</td>
<td>1</td>
<td>0.593</td>
<td>0.595</td>
</tr>
<tr>
<td>Flavor</td>
<td>0.341</td>
<td>0.593</td>
<td>1</td>
<td>0.922</td>
</tr>
<tr>
<td>Overall Liking</td>
<td>0.489</td>
<td>0.595</td>
<td>0.922</td>
<td>1</td>
</tr>
</tbody>
</table>

All correlations are highly significant (p < 0.01)

Table 3.9. Intra-37°C Crab Sauce Treatment Pearson’s Correlations Between Hedonic Attributes (n=87)

<table>
<thead>
<tr>
<th>Hedonic Attributes</th>
<th>Color</th>
<th>Aroma</th>
<th>Flavor</th>
<th>Overall Liking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>1</td>
<td>0.498</td>
<td>0.393</td>
<td>0.507</td>
</tr>
<tr>
<td>Aroma</td>
<td>0.498</td>
<td>1</td>
<td>0.756</td>
<td>0.767</td>
</tr>
<tr>
<td>Flavor</td>
<td>0.393</td>
<td>0.756</td>
<td>1</td>
<td>0.931</td>
</tr>
<tr>
<td>Overall Liking</td>
<td>0.507</td>
<td>0.767</td>
<td>0.931</td>
<td>1</td>
</tr>
</tbody>
</table>

All correlations are highly significant (p < 0.01)

3.4.6. Consumer Comments

Consumer comments were collected to provide more data regarding sample preference and differentiation, wherein a total of 40 consumer comments were collected for the control, 43 comments for the 24°C crab sauce treatment, and 41 comments for the 37°C crab sauce treatment. Data were separated into comments with any mention of flavor (Table 3.10.) and comments with any mention of aroma (Table 3.11.). The control was described as having mild or subtle flavor more frequently than the 24°C and 37°C crab sauce treatments (Table 3.10.). The
24°C and 37°C crab sauce treatments were described as having a “crab” or “fishy” flavor more frequently than the control. The intensity of crab or seafood flavor was commented on most frequently in the 37°C crab sauce treatment.
### Table 3.10. All Consumer Comments Referencing Flavor Separated by Sample in Hedonic Testing

<table>
<thead>
<tr>
<th>Sample</th>
<th>Flavor Comment</th>
</tr>
</thead>
</table>
| Control                       | “I like the flavor, very mild…”  
“subtler flavor than (sample with 37°C fermented green crab sauce)”  
“Compared to (sample with 37°C fermented green crab sauce), (this sample) wasn’t as salty or flavorful, but it had a butteriness to the taste that made it more mild…”  
“it has a nice, mild flavor… didn’t taste like seafood, tasted like pasta with butter”  
“Tasted of buttered noodles and garlic. Did not taste any crab.” |
| 24°C Crab Sauce Treatment     | “tastes like i dipped a piece of crab in butter”  
“… There is a nice salty/seafood/unami balance”  
“The first couple of bites had a fishy aftertaste. That being said, after chewing for a bit, the fishy aftertaste went away and it tasted fine.”  
“This sample had a more intense flavor than (garlic noodles with 20% salt solution)... very delicious”  
“good balance, maybe a little more crab flavor” |
| 37°C Crab Sauce Treatment     | “Definitely tastes more like seafood than the others…”  
“This has a stronger crab flavor than (garlic noodles with green crab sauce fermented at 24°C)”  
“… more of a seaweed or miso flavor but I still detect a crabby flavor…”  
“The flavor was bolder than (garlic noodles with 20% salt solution)...”  
“This one tastes the ‘fishiest’ of them all. Or I guess crabby?...”  
“It has an interest aftertaste that is exceptionally seafoody (in a great way)”  
“Too much shellfish taste for me” |

Control refers to a 20% (w/w) salt water garlic noodle treatment.

Comments regarding the aroma of the recipes also yielded differences in consumer perceptions. The control only had one mention of aroma in all of the feedback. The feedback on aroma for the garlic noodles with green crab sauce (Samples 2 & 3) were more frequent.
Panelists frequently described the aromas of Samples 2 & 3 as intense, however, feedback varied greatly (Table 3.11.).

**Table 3.11. All Consumer Comments Referencing Aroma Separated by Sample in Hedonic Testing**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Aroma Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>“Aroma still off-putting like (both of the other samples)”</td>
</tr>
<tr>
<td>24°C Crab Sauce Treatment</td>
<td>“Less of the crab aroma on the nose but more present than the (garlic noodles with 20% salt solution)”</td>
</tr>
<tr>
<td></td>
<td>“Nice color and aroma”</td>
</tr>
<tr>
<td></td>
<td>“… I might say that (garlic noodles with 20% salt solution) has a slight edge over (this sample) in terms of aroma…”</td>
</tr>
<tr>
<td></td>
<td>“Aroma was more pronounced than (both of the other samples)…”</td>
</tr>
<tr>
<td></td>
<td>“the smell was so moderate in a good way”</td>
</tr>
<tr>
<td></td>
<td>“I like the aroma very much”</td>
</tr>
<tr>
<td></td>
<td>“The aroma is a little off-putting…”</td>
</tr>
<tr>
<td>37°C Crab Sauce Treatment</td>
<td>“More of a crab aroma than the (garlic noodles with 20% salt solution)”</td>
</tr>
<tr>
<td></td>
<td>“Great color, texture, and aroma”</td>
</tr>
<tr>
<td></td>
<td>“…the crab smell was overpowering”</td>
</tr>
<tr>
<td></td>
<td>“Had a certain musky smell to it that was off-putting”</td>
</tr>
<tr>
<td></td>
<td>“Aroma is not great…”</td>
</tr>
</tbody>
</table>

Control refers to a 20% (w/w) salt water garlic noodle treatment.
3.5. Discussion

3.5.1. Chemical Analyses

The fermentation of both fish sauce and crab sauce is a result of enzyme-catalyzed hydrolysis, especially of proteins, by endogenous and microbially-derived enzymes. The result of this process is the production of various taste-active and volatile compounds that influence the taste of fish sauce on its own and in a recipe. Higher TVBN and amine nitrogen values are indicators of fermentation progression and production of amines (Castro et al., 2006; Hill and Stewart, 2019). Nonenzymatic browning is commonly impacted by Maillard browning reactions in fish sauce (Tungkawachara et al., 2003). The production of amines and enzymatic browning are some of the most important factors influencing the taste, aroma, and color of a fermented fish sauce (Altissimi et al., 2018; Liu et al., 2022).

In this study, TVBN, amine nitrogen, and nonenzymatic browning were analyzed in crab sauces fermented at 24°C and 37°C for 90 days. The TVBN, nonenzymatic browning, and amine nitrogen values determined in this study were all significantly higher in the 37°C fermented green crab sauce compared to the 24°C fermented green crab sauce, which agrees with previous findings (Greiner, 2021). These findings suggest that the crab sauce fermented at 37°C possessed a stronger taste, aroma, as well as a darker color than the crab sauce fermented at 24°C (Altissimi et al., 2018; Liu et al., 2022). After chemical analyses, the crab sauces were incorporated into garlic noodle recipes for consumer acceptance evaluations.
3.5.2. Panelist Characteristics

To investigate the consumer acceptance of green crab sauce as a commercial product, demographic questions were needed to target potential customers. In this study, the median age was between 26 and 35 years old. While seafood liking was not assessed in this study, a previous survey indicated the lowest prevalence of seafood consumption among the young adult age group (19-30 years old) (Jahns et al., 2014). The most frequent seafood intake recorded in that survey was amongst adults aged 31-70 years old. Therefore, the recruitment of older panelists may be a more accurate population for potential consumers of green crab sauce.

Additionally, of the consumer panelists, approximately 76% were responsible for their household grocery shopping, 85% prepared their main meal at home at least 3 times a week, and 75% were very to extremely interested in cooking with new food ingredients. Overall, the panelists’ food purchasing and preparation habits support the likelihood that they may be future consumers of a green crab sauce product. If advertised to consumers, green crab sauce would likely be sold at specialty grocery stores and occupy a niche in the market. Insufficient research exists concerning the demographic traits of consumers who exhibit a preference for shopping at specialty, non-traditional food stores. Greater research in this area can assist researchers in better understanding the target consumer groups of green crab sauce.

3.5.3. Consumer Acceptance

There is no previous research on the sensory perspectives of volatile compounds in fermented crab sauce condiments. However, volatile compounds in a similarly manufactured product, fish sauce, have been described as fishy, fecal, rancid, cheesy, meaty, and burnt (Russo et al., 2020). The flavor of crab sauce manufactured from soldier crabs in China has been
described as possessing an intense umami taste (Liu et al., 2019). Sensory peptides in a variety of fish sauces produced throughout Asia have been shown to exhibit sweet, sour, bitter, umami, and kokumi tastes (Hakimi et al., 2022). In general, more positive, desirable descriptors are used to describe the flavor compounds responsible for fish sauce’s taste, while less desirable descriptors are used to describe its aroma. Therefore, fermented condiments such as fish sauce and likely crab sauce, are added to recipes to highlight their taste rather than their aroma. In this study, garlic noodles were chosen due to their simplicity, popularity, and strong garlic aroma, which may pair well with less desirable aromas of green crab sauce.

In this study, three garlic noodle samples were prepared with the only difference being the presence of a 20% salt solution (control), green crab sauce fermented at 24°C, and green crab sauce fermented at 37°C. All of the samples were accepted by consumers, with the 37°C crab sauce treatment scoring over 6 (like slightly) for overall liking and the control and the 24°C crab sauce treatment scoring over 7 (like moderately). The aroma, flavor, and overall liking of the control and the 24°C crab sauce treatment were greater than the 37°C crab sauce treatment, suggesting that consumers liked the green crab sauce fermented at 37°C less than the 20% salt solution (control) and green crab sauce fermented at 24°C in a recipe. Therefore, consumers preferred green crab sauce fermented at 24°C when applied to a garlic noodle recipe at an approximate concentration of 7.1% (w/w).

The researchers aimed to control the perceived saltiness of the samples, ensuring each recipe contained very similar salt levels (Table 3.1.), to assess consumer liking while minimizing confounding variables. There were no significant differences in the consumer liking of color with sample means ranging from 6.6 to 6.7. Consumers’ perceptions of the intensity and acceptability of saltiness were evaluated using a JAR (Just About Right) test for all three samples.
Approximately 70% of responses are expected in the JAR category to conclude that a specific attribute is at its optimal level (Rothman, 2007 & Zhi et al., 2016). In this study, 74-87% of consumers indicated “just about right” for the saltiness of the samples. Therefore, the color and saltiness of the samples were likely not significant variables impacting overall consumer liking, and were unlikely to have been perceived as notably different across treatments.

The consumer comments regarding aroma and taste (Tables 3.10. & 3.11.) revealed differences in the consumer perceptions of each sample. There were no significant differences in hedonic scores between the control and the 24°C crab sauce treatment, suggesting consumers liked these recipes equally. However, both correlations and consumer comments for each sample indicated they were able to detect a greater aroma and flavor in the 24°C crab sauce treatment compared to the control (Tables 3.7. - 3.11.). Consumer comments indicated that they were able to detect more crab flavor and aroma in the 24°C crab sauce treatment compared to the control (Tables 3.10. & 3.11.). The comments suggested some panelists tended to enjoy the more crab-forward flavor of the 24°C crab sauce treatment, while others preferred the mild, butter-forward flavor of the control. On the other hand, the 37°C crab sauce treatment had the most comments claiming it had the strongest seafood or crab flavor and aroma which may have contributed to its lower hedonic scores for taste, aroma, and overall liking (Table 3.10. & 3.11.). This is reflected in the fact that the correlation between liking of aroma and overall liking was highest for the 37°C fermented crab sauce treatment. The consumers’ preference for the garlic noodles with green crab sauce fermented at 24°C indicates the consumers liking of less intense crab flavor and aroma compared to the garlic noodles with green crab sauce fermented at 37°C. Therefore, the green crab sauce fermented at 24°C may be a more consumer-friendly option due to its less-
intense flavor and aroma. However, recipe choice likely plays a large role in the effectiveness of green crab sauce.

The garlic noodles containing green crab sauce were described as having a “crab” aroma (Table 3.11.), while the taste was described as containing umami, crab, and shellfish flavors (Table 3.10.). The crab and shellfish flavors were also likely influenced by the aroma of the green crab sauce due to the interconnectedness of the recipes’ taste and aroma (Araujo et al., 2020). Previous research describes fish sauce as possessing salty and umami tastes, and particular aromas of ammoniacal, meaty, and cheesy odor attributes (Dougan & Howard, 1975). The differences in the characteristics used to describe fish sauce and those used to describe the garlic noodles seasoned with green crab sauce suggest its distinct taste and aroma, indicating probable variance in its ideal usage. This stance is further supported by one chef’s quote: “…Currently this product is probably not a ‘finishing sauce’ but more something you would incorporate into larger sauces, marinades, curries, etc.” It is important to note a limitation of this conclusion includes that the aroma and taste descriptors of fish sauce were used to describe it on its own, whereas those for the green crab sauce were observed in a garlic noodle recipe. Additionally, the study by Dougan & Howard (1975) pertains to a single type of fermented fish sauce, which may differ in flavor and aroma when compared to other fish sauces.

However, these conclusions are further reinforced by correlations between the samples’ aroma and overall liking. Garlic noodle recipes with green crab sauce had greater correlations between aroma and overall liking, compared to the garlic noodle sample with the 20% salt in water solution (Tables 3.7. - 3.9.). Using the definitions of the intensity of correlation coefficients determined by Weber and Lamb (1970) as cited in Kwak et al. (2013), garlic noodles with 20% salt solution possessed a low positive correlation (Table 3.7.), garlic noodles with
green crab sauce fermented at 24°C possessed a moderate positive correlation (Table 3.8.), and garlic noodles with green crab sauce fermented at 37°C possessed a high positive correlation (Table 3.9.) between aroma and overall liking. These results indicate that the aroma of the recipes played a greater role in consumers’ overall liking of the recipes.

3.5.4. Limitations and Recommendations

Some limitations of this study include the predominantly white ethnicity of the panelists (Table 3). Although this demographic is emblematic of numerous regions in New England (U.S. Census Bureau, 2022), an ethnically heterogeneous panelist population would hold pertinence for additional areas across the United States. Moreover, the majority of participants were found to belong to the 18-25 age group, which may not align with the target consumer base for a premium green crab fermented condiment. Additionally, the researchers did not ask for information from the participants regarding their seafood preferences or umami enhancer usage, which may have contributed to the researchers’ ability to discern more significant differences in the hedonic score data.

Furthermore, the evaluation of green crab sauce was confined to its incorporation at an approximate concentration of 7.1% (w/w) in a garlic noodle recipe. Further investigation is warranted to determine whether lower concentrations of 37°C fermented green crab sauce or its application in different recipes can elicit a more favorable sensory experience. Commercial fish sauces are frequently combined with sugar, preservatives, and colorants to produce more desirable flavors (Greiner et al., 2021; Nakano et al., 2017). Additional ingredients may effectively lower the intensity of the “crab” flavor and aroma, which may have contributed to lower consumer overall liking of the recipe with green crab sauce fermented at 37°C. Further
market analysis research should also be conducted to determine the profitability of green crab sauce fermented at 24°C versus 37°C in New England. Reduced cost savings are typically linked to lower fermentation temperatures. However, if a green crab sauce undergoes fermentation at 37°C and achieves a comparable flavor profile with the addition of cost-effective additives, such additives may contribute to a reduction in the overall manufacturing cost of the sauce.

3.6. Conclusions

The chemical analyses revealed that TVBN, nonenzymatic browning, and amine nitrogen values were all significantly higher in the 37°C fermented green crab sauce compared to the 24°C fermented green crab sauce, confirming previous findings. The consumer hedonic test, comparing three garlic noodle samples differing only in the presence of a 20% salt solution, green crab sauce fermented at 24°C, and green crab sauce fermented at 37°C, indicated that all samples were generally accepted, with the 37°C crab sauce treatment receiving a slightly lower score for overall liking compared to samples 1 and 2. The aroma, flavor, and overall liking of the control and 2 were rated higher than those of the 37°C crab sauce treatment, suggesting that consumers preferred the green crab sauce fermented at 24°C and the 20% salt solution over the one fermented at 37°C. Analysis of consumer comments further revealed that the 24°C crab sauce treatment exhibited a pronounced crab flavor and aroma, appealing to some panelists, while the control had a milder, buttery taste that appealed to others. Conversely, the 37°C crab sauce treatment garnered comments highlighting its intense seafood or crab flavor and aroma, possibly contributing to its lower hedonic scores. Spearman’s correlation matrices supported these claims regarding aroma, indicating a greater correlation between the consumers’ hedonic ratings of aroma and overall liking in Samples 2 and 3 compared to the control. Further research is needed to determine the manufacturing costs associated with green crab sauce fermented at
lower temperatures, as well as the effectiveness of the addition of low-cost flavor additives to green crab sauce to improve its overall liking.

3.7. References


CHAPTER 4

OVERALL CONCLUSIONS

This work, as well as previous research on fermented green crab sauce reveals its promising potential as a sustainable and economically viable solution to address the ecological and economic damage caused by the invasive green crab along the Northeastern coast of the United States. Despite exploring multiple population control methods, intensive indiscriminate trapping remains the only verified effective approach. However, this method is not financially viable due to the low price and demand for hard-shell green crabs, primarily attributed to their small size and difficult-to-extract crabmeat.

To address this issue, researchers have investigated the development of green crab sauce, a fermented condiment inspired by fish sauce, known for its umami-enhancing properties. This unique condiment presents an opportunity to raise the value of hard-shell green crabs, making green crab fisheries more economically viable while contributing to the conservation of coastal ecosystems. Previous research conducted by UMaine graduate students has determined the appropriate fermentation temperature and time to produce green crab sauce that is chemically similar to commercial fish sauce and has demonstrated positive responses regarding the product concept from New England chefs, identifying them as a target consumer group for a future, commercially-produced green crab sauce. These studies also identified the need for a greater sensory understanding of green crab sauce in a recipe by two potential consumer groups: chefs and general consumers.

The primary objectives of this study were (1) to investigate chef sensory perspectives of green crab sauce and (2) to determine consumer acceptability of green crab sauce in a finished recipe. A home-use test involving New England chefs revealed distinct flavor characteristics that
set green crab sauce apart from traditional condiments. Incorporating the sauce into various recipes demonstrated its comparable likability to popular umami enhancers, further highlighting its culinary potential. Consumers accepted green crab sauce fermented at 24°C in a garlic noodle recipe and indicated a strong preference for green crab sauce fermented at 24°C over sauce fermented at 37°C. Consumer liking of green crab sauce in a recipe indicates its significant market potential among general consumers, especially in New England.

In the first study, the home-use test and survey provided the researchers with insight regarding green crab sauce’s performance and useability in recipes. Chefs were selected as a target research group due to the need for culinary expertise to evaluate green crab sauce’s attributes and performance in a recipe. Additionally, chefs were chosen due to their previous positive responses to the green crab sauce product concept and their likeliness to purchase the product.

In this study, green crab sauce fermented at 37°C for 90 days was shipped to the chefs’ residences. The sauce was evaluated on its own and in a recipe and the chefs provided both qualitative and quantitative feedback. Chefs’ evaluation of the sauce on its own yielded greater liking of the sauce’s taste compared to its aroma. Chefs’ comments related to the appearance of green crab sauce suggested a need for greater clarification and filtration to eliminate fine particulate matter.

The chefs cooked the green crab sauce in a variety of recipes, with some of the most popular categories being soup, salad, and pasta with shellfish. Additionally, the chefs cooked an identical recipe with the substitution of an umami enhancer of their choice for comparison. The quantitative and qualitative feedback received regarding the green crab sauce in a recipe was primarily positive, indicating chefs' potential to remain target consumers for a green crab sauce.
product. The chefs provided insight into the attributes of green crab sauce in a recipe, such as its difference from other umami enhancers.

Some limitations of this study include its reliance on less-structured qualitative data with various confounding variables. However, there was a need for greater qualitative data collection for this product due to its novelty and unfamiliarity among consumers. Additional limitations include the lack of current branding, packaging, and marketing that may impact consumers' liking of green crab sauce.

In the second study, a consumer acceptance test was conducted. Assessing general consumers' liking of green crab sauce in a recipe can aid in understanding the effectiveness of marketing green crab sauce to consumers. Two green crab sauce treatments were tested in this study. These comprised green crab sauce fermented at 24°C and 37°C for 90 days. The additional, lower fermentation temperature was selected due to its demonstrated viability in previous research, lower manufacturing costs associated with lesser energy inputs (especially in New England's cold winter months), and to provide greater information on fermentation temperatures' impact on green crab sauce's sensory profile. A fermentation temperature of 24°C is considered close to "ambient temperature," thus if the condiment is effective at this fermentation temperature, it would greatly improve the ease of production.

Chemical and color testing were conducted and compared to previous research to ensure replicability across studies. These values confirm previous findings and suggest a stronger aroma, stronger flavor, and darker color in the green crab sauce fermented at 37°C compared to 24°C. For consumer acceptance testing, both sauces were incorporated into a garlic noodle recipe, with an additional control sample containing 20% (w/w) salt solution instead of green crab sauce in order to deliver parity of saltiness. Consumer acceptance testing indicated a greater
overall liking of the control garlic noodle sample and the sample containing 24°C fermented green crab sauce compared to the sample containing 37°C fermented green crab sauce. Greater correlations between aroma and overall liking were found in the garlic noodle samples containing green crab sauce. Additionally, consumer comments referenced the taste and aroma of “crab” or “seafood” in the samples containing green crab sauce, indicating that some consumers were able to differentiate between the samples containing green crab sauce, but that the difference in flavor did not negatively impact liking. The comments for noodles containing green crab sauce fermented at 24°C suggested it was liked more for its mild “crab” and “seafood” flavor compared to the much stronger aroma and flavor of the sample with 37°C fermented sauce. These findings suggest green crab sauce fermented at 24°C is likely suitable to be marketed as an ingredient to general consumers.

Overall, these findings progress the development process for a green crab sauce condiment product concept and have uncovered more areas for exploration. While the initial investment and yield have been discussed in previous work, there is a need for greater research into the manufacturing costs associated with the fermentation of green crab sauce at different temperatures. There is also a need to explore the addition of low-cost flavor additives to enhance its appeal.

Greater consumer-liking of green crab sauce fermented at 24°C complements its lower manufacturing costs, however, the use of the raw crab sauce in a formulated product has not been investigated. The stronger aroma and flavor of the green crab sauce fermented at 37°C could allow it to be utilized in smaller quantities to enhance the flavor of low-cost products in conjunction with ingredients. The inclusion of green crab sauce fermented at 37°C into an umami enhancer, such as soy sauce, may lessen the robustness of its aroma and flavor. The
dilution of 37°C fermented green crab sauce with water may also be warranted to provide a condiment that is more user-friendly and would allow for a greater overall volume to be produced.

Previous research has determined the development of green crab sauce is feasible at laboratory scale and that the finished product is desired by New England chefs. This research furthers product development by demonstrating the liking of green crab sauce in a recipe by both New England chefs and general consumers. More research is needed to determine the requirements and costs for upscaling the manufacturing of green crab sauce. Marketing, packaging, and branding are also needed for the successful launch of a green crab sauce product. By leveraging effective marketing strategies that communicate its novelty, sustainability, and locality, the sauce’s market potential can be further strengthened.

Fermented green crab sauce holds the promise of being a sustainable and economically viable contributor to a multipronged solution to the challenges posed by the invasive green crab species. By transforming this ecological threat into a valuable culinary resource, the sauce contributes to the conservation of coastal ecosystems and the economic well-being of local fisheries and communities. The acceptance of green crab sauce in recipes by both consumers and chefs signifies its promising potential among both of these consumer groups. Effective marketing of this sustainable, innovative product will help to further its likeability and success as an umami-enhancing condiment. Continued research and development efforts will be crucial in optimizing its production, enhancing its appeal, and successfully introducing this innovative condiment to the market. This work and the product development of green crab serve to support the commercial production of a high-value fermented green crab sauce condiment to provide a solution to the resilient, invasive green crab populations.


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https://doi.org/10.1007/s10750-014-2166-0


Maryland Division of State Documents. 08.02.03.14. (2019). [https://2019-dsd.maryland.gov/regulations/Pages/08.02.03.14.aspx](https://2019-dsd.maryland.gov/regulations/Pages/08.02.03.14.aspx)


Informed Consent
You are invited to participate in a research project conducted by Bryson McDonough, a M.S. student of Food Science and Human Nutrition in the School of Food and Agriculture at the University of Maine. The faculty advisor is Dr. Jennifer Perry, an Associate Professor of Food Microbiology at the University of Maine School of Food and Agriculture. The purpose of the research is to conduct a sensory evaluation of a new product concept: green crab sauce. You must be at least 18 years of age to participate. Please do not take part if you have an allergy to seafood.

What Will You Be Asked to Do?
If you decide to participate you will be asked to provide an address for mailing the crab sauce. Next, the green crab sauce will be mailed to you. The questionnaire will be split into 3 blocks. Block 1 will consist of basic questions regarding your state of residence and your experience in the culinary industry. Block 2 will ask you to assess the appearance, aroma, and taste of the crab sauce. Block 3 will ask you to cook a recipe of your choice with the green crab sauce. The questionnaire will take about 20 minutes to complete, however, the total time spent will vary based on the cooking of the dish chosen in Block 3. After receiving the crab sauce, you will have approximately two weeks to complete all 3 blocks of the anonymous questionnaire.

Risks:
The main risks for you are the loss of time and inconvenience.

Benefits:
There are no benefits to you but you may enjoy tasting the crab sauce. Your feedback could help researchers to formulate a food product that benefits the sustainability of New England’s aquaculture and coastal environments.

Compensation:
Once you reach the end of the survey you will be sent to a separate page, not connected to your survey responses, to provide your email address. If you provide your email address you will be entered into a randomized drawing to win one of four $25 Amazon gift cards that will be sent to
you electronically if your email address is selected. Your email address will not be connected to your responses. You must reach the end of the questionnaire to enter the raffle.

Confidentiality:
The names and addresses required for shipping the crab sauces will remain confidential and will be deleted immediately following the shipping of the crab sauce. The survey responses are anonymous. The survey responses will be collected and stored until May 10, 2025, and will then be archived in the Digital Commons at Fogler Library indefinitely. The email addresses collected for the raffle will not be associated with the data. If you wish to have your email address stored for future contact it will be kept on a password-protected computer until August 31, 2025. All other email addresses will be deleted no later than December 31, 2023 once the raffle winners are selected.

Voluntary:
Participation in this survey is voluntary. If you choose to take part in this study, you may stop at any time. You may skip any questions you do not wish to answer.

Contact Information:
If you have any questions about this study, please contact me at bryson.mcdonough@maine.edu or the faculty sponsor at jennifer.perry@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 B. RECRUITMENT EMAIL FOR CHEF HOME-USE TEST

University of Maine’s Green Crab Sauce At-Home Study

Dear Chef,

Thank you for expressing your interest in participating in the At-Home Green Crab Sauce Study conducted by the University of Maine’s Green Crab Research Team. We truly appreciate you spending your valuable time assisting us with this important and exciting project.

You are invited to participate in an anonymous research study regarding the at-home tasting of fermented green crab sauce. **To participate, you must provide an accurate mailing address for mailing the crab sauce (linked at the end of the email).** Next, you will be mailed a sealed, glass container containing green crab sauce. You will be asked to cook a dish using green crab sauce in place of fish sauce, taste the dish, and respond to an anonymous questionnaire.

- **Purpose:** To understand the preferences of chefs and culinary professionals located in or near the New England area regarding a fermented sauce made with green crabs found off the coast of Maine.

- **Study Details:** To participate, you must be at least 18 years of age. **Please do not take part if you have any allergies to shellfish.** The Green Crab Sauce will be mailed to you. The questionnaire will take approximately 20 minutes, however, the time spent cooking will vary based on the dish chosen. The questionnaire will consist of background information regarding chef experience and experience with fish sauce, as well as questions asking you to compare our provided green crab sauce to a fish sauce of your choice. Upon submission of the questionnaire, you will have the opportunity to enter a randomized drawing to win one of four $25 Amazon gift cards that will be sent to you electronically.

- **More Information:** This research is being conducted by Bryson McDonough, a graduate food science student in Food Science and Human Nutrition at the University of Maine, and his graduate advisor, Associate Professor Jennifer Perry of the University of Maine School of Food and Agriculture. For more information about the study please see the attached Informed Consent Form or email Bryson McDonough at bryson.mcdonough@maine.edu. Please click the link below if you wish to participate. [Link to Consent & Mailing Information Qualtrics Form](#)
APPENDIX C. CHEF HOME-USE SURVEY QUESTIONNAIRE

Start of Block: Block 1

Q1 In which state do you currently reside?
   - Connecticut (1)
   - Maine (2)
   - Massachusetts (3)
   - New Hampshire (4)
   - Rhode Island (5)
   - Vermont (6)
   - New York (7)
   - New Jersey (8)
   - Delaware (9)
   - Maryland (10)
   - Other (11) _________________________________________
   - I do not want to answer (12)

Q2 Identify your current position in the culinary industry:
   - Executive Chef (1)
   - Chef de Cuisine (2)
   - Consulting Chef (3)
   - Corporate Chef (4)
   - Private Chef (5)
   - Sous Chef (6)
   - Cook (7)
   - Other (8) ___________________________________________
   - I do not want to answer (9)

Q3 Please identify which cuisines you typically prepare:
   Please select all that apply
   - American (1)
   - Asian (Thai, Vietnamese, Japanese, Korean, etc.) (2)
   - European (French, Italian, Greek, Spanish, etc.) (3)
   - Latin American (4)
Q4 Approximately how often do you use umami flavor enhancers (Soy Sauce, Tamari, Fish Sauce, Garum, Anchovy Paste, shrimp paste, Worcestershire sauce, MSG, Miso, etc) when cooking?
   o Less than once a month (1)
   o 1-2 times a month (2)
   o Weekly (3)
   o 2-3 times a week (4)
   o Greater than 4 times a week (5)
   o I do not want to answer (6)

Q7 What type of dishes, that contain an umami flavor enhancer, do you prepare most often at your restaurant or place of work?
   □ Dipping Sauce (1)
   □ Dressing (2)
   □ Glaze (3)
   □ Soup (4)
   □ Stew (5)
   □ Chili (6)
   □ Marinade (7)
   □ Stir Fry (8)
   □ Curry (9)
   □ Other (10)  ____________________________________________
   □ I do not want to answer (11)

End of Block: Block 1
Start of Block: Block 2

E1 The next part of the questionnaire will require the crab sauce provided.
Description of Crab Sauce: A fermented seafood sauce made using invasive green crabs harvested in New England. This condiment provides powerful umami flavors and aromas. This product exemplifies sustainability and most importantly, high quality. This locally produced, fermented seafood condiment can be used to transform any savory dish and enhance the dining experience.

E2 Please place your crab sauce in an area where you can assess its appearance.

Q9 Please rate the appearance of both the crab sauce:

Q10 Optional: Explain your preference regarding the appearance of the crab sauce.

E3 Please smell the crab sauce.

Q11 Please rate the aroma of the crab sauce:

Q12 Optional: Explain your preference regarding the crab sauce aroma.

E4 Optional: Please try a few drops of the crab sauce on its own. If you do not wish to taste the sauce on its own, please select “Prefer not to answer” or skip this question.

Q14 Optional: Please rate the taste of the crab sauce:
Q15 Optional: Explain your preference regarding the taste of the crab sauce.

End of Block: Block 2

Start of Block: Block 3

E5 Based on your understanding of the aroma and/or taste of the crab sauce, please use the crab sauce provided in a recipe you are familiar with.

OPTIONAL: You may also cook an equal portion of your typical recipe using an umami flavor enhancer (ie. Soy Sauce, Tamari, Fish Sauce, Garum, Anchovy Paste, shrimp paste, Worcestershire sauce, A-1 sauce, MSG, Miso, etc.) of your choice for comparison.

Q16 Please briefly describe the dish you made using the crab sauce.

________________________________________________________________________

Q17 OPTIONAL: What umami flavor enhancer did you choose to use to compare the crab sauce to?

- o Fish Sauce (1)
- o Soy Sauce (2)
- o Tamari Sauce (3)
- o Oyster Sauce (4)
- o Garum (5)
- o Shrimp paste (6)
- o Worcestershire Sauce (7)
- o A-1 Sauce (8)
- o Anchovy Essence (9)
- o MSG (10)
Soy Sauce, Tamari, Fish Sauce, Garum, Anchovy Paste, shrimp paste, Worcestershire sauce, A-1 sauce, Aji No Moto, MSG, Miso, and Bean Paste

Q18 Please rate the taste of both the Crab Sauce and Umami Flavor Enhancer (if relevant) in your dish:

<table>
<thead>
<tr>
<th></th>
<th>Prefer not to answer</th>
<th>Dislike extremely</th>
<th>Dislike Very Much</th>
<th>Dislike Moderately</th>
<th>Dislike Slightly</th>
<th>Neither like nor dislike</th>
<th>Like slightly</th>
<th>Like moderately</th>
<th>Like very much</th>
<th>Like extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crab Sauce</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Umami Flavor Enhancer</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

Q19 Optional: Explain in detail your preference of the crab sauce in your dish.

Q20 Approximately how much would you pay for a 16-ounce bottle of Crab Sauce? Please select "Would not purchase" if you would not wish to buy the Crab Sauce.

Q21 Optional: Please provide any additional comments you would like to add about the crab sauce.

End of Block: Block 3

Thank you very much for providing our team with your valuable time and opinions. If you have any follow-up comments please feel free to email me at bryson.mcdonough@maine.edu.
APPENDIX D. RESEARCHERS’ INITIAL GREEN CRAB SAUCE OBSERVATIONS

Methods
The pasteurized green crab sauce was tasted and smelled by the research team before the creation of survey. The words used to describe the aroma and taste were recorded.

Results
Aroma Descriptors: Marine, Seafood, Earthy
Taste Descriptors: Umami, Salty, Crabby

Hypothesis
Green crab sauce is not a direct replacement for fish sauce, but rather a novel umami enhancing ingredient.
<table>
<thead>
<tr>
<th>Comment</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Very similar in color and viscosity to other fish sauces I have used.</td>
<td></td>
</tr>
<tr>
<td>It's muddy but that doesn't really matter as it won't be the primary liquid in anything it is added to.</td>
<td></td>
</tr>
<tr>
<td>The appearance doesn't matter to me, no preference</td>
<td></td>
</tr>
<tr>
<td>Provided a small amount of umami I background in the dish I prepared</td>
<td></td>
</tr>
<tr>
<td>I like the color, but I am little put off by the sediment settling in the bottle.</td>
<td></td>
</tr>
<tr>
<td>It needed to be shaken after sitting, as it had settled slightly</td>
<td></td>
</tr>
<tr>
<td>It is murky and unappealing when compared to fish sauce, however there are many other products on the market that aren't clear i.e. shoyu, fermented shrimp paste, miso etc</td>
<td></td>
</tr>
<tr>
<td>It is quite cloudy. This is not a problem with fermented sauces and extractions per se, but I know from making many types of &quot;fish sauces&quot; at work and home that it should be possible to clarify this product beyond what has been done, whether through allowing more particulate matter to settle over time and carefully decanting, straining through superfine filters, or both. This will provide a cleaner taste and a more product-typical appearance. Most if not all commercially available fish sauce products have been strained to the point of clarity and I think its a customer expectation whether amateur or professional.</td>
<td></td>
</tr>
<tr>
<td>Looked more natural than fish sauce</td>
<td></td>
</tr>
<tr>
<td>It resembles other fish sauce I use</td>
<td></td>
</tr>
<tr>
<td>It is not completely clarified the is some brown residue the settles at the surface</td>
<td></td>
</tr>
<tr>
<td>The appearance is inoffensive; looks like soy sauce. It would be enhanced by an attractive label on the bottle and/ or a dark colored glass</td>
<td></td>
</tr>
</tbody>
</table>
### APPENDIX F. CHEF GREEN CRAB SAUCE AROMA SURVEY COMMENTS

<table>
<thead>
<tr>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXTREMELY crabby and not in a good way. Almost overpowering.</td>
</tr>
<tr>
<td>Very strong aroma, almost too strong that it smells burnt.</td>
</tr>
<tr>
<td>Smells exactly like overcooked crab--lots of ammonia. Crab is delicious, though takes on a bad smell when overcooked, this only highlights this aroma and really none of the pleasant aspects of crab/crab broth.</td>
</tr>
<tr>
<td>It’s pretty strong but I think that is how it should be.</td>
</tr>
<tr>
<td>This crab sauce had a familiar, but disagreeable aroma. It reminded me of the smell (and sorry to be graphic about this) of my dogs anal glands. This did not stop me from cooking with it.</td>
</tr>
<tr>
<td>It’s funkier than a traditional fish sauce</td>
</tr>
<tr>
<td>Understanding that this is made of fermented crustaceans, it has an intense aroma that is extremely powerful and would likely be off-putting to the average or even adventurous consumers. This stuff is loud!</td>
</tr>
<tr>
<td>The aroma made me want to cook with it.</td>
</tr>
<tr>
<td>The aroma is very strong, but I wouldn't say that is positive or negative. Currently this product is probably not a &quot;finishing sauce&quot; but more something you would incorporate into larger sauces, marinades, curries etc.</td>
</tr>
<tr>
<td>Mild smelling, not artificial or strong smelling</td>
</tr>
<tr>
<td>It's has a rich smell</td>
</tr>
<tr>
<td>Pretty intense crab smell but that can be said for most fish sauces</td>
</tr>
<tr>
<td>The aroma tends heavily toward decay. I don’t mind a fishy smell but this one is extreme</td>
</tr>
</tbody>
</table>
## APPENDIX G. CHEF GREEN CRAB SAUCE TASTE SURVEY COMMENTS

<table>
<thead>
<tr>
<th>Comment</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>might be a bit on the salty side</td>
<td></td>
</tr>
<tr>
<td>Way too salty as a fish sauce replacement</td>
<td></td>
</tr>
<tr>
<td>At first it’s very aggressive and might need salt levels adjusted but the finish is a lovely oceanic crab flavor.</td>
<td></td>
</tr>
<tr>
<td>Same as aroma--its pungent and funky in an unpleasant way. Fish sauce can be pungent and funky while still having a clean flavor, this tasted muddy/murky/the unpleasant side of crab</td>
<td></td>
</tr>
<tr>
<td>Very salty. Kind of a musky sort of flavor</td>
<td></td>
</tr>
<tr>
<td>It has a very savory flavor and is less funky than it smells.</td>
<td></td>
</tr>
<tr>
<td>The sauce tastes less strongly then it smells.</td>
<td></td>
</tr>
<tr>
<td>It’s intense.</td>
<td></td>
</tr>
<tr>
<td>It delivers a mountain of crab flavor</td>
<td></td>
</tr>
<tr>
<td>After tasting the sauce my mind started to think of the multiple applications one could use this sauce for.</td>
<td></td>
</tr>
<tr>
<td>I believe with further ageing and straining this could mellow and develop some very good and nuanced flavors. Currently I would compare this to a moonshine level of fermentation. Raw and powerful, but needing more time and specialized aging conditions to really shine. The flavor is so strong I couldn't use it in my recipes in normal concentrations.</td>
<td></td>
</tr>
<tr>
<td>Mild fresh ocean taste</td>
<td></td>
</tr>
<tr>
<td>It has a fermented flavor of umami I enjoy, a key background component in flavor</td>
<td></td>
</tr>
<tr>
<td>Nice crab flavor, good balance of umami and salt</td>
<td></td>
</tr>
<tr>
<td>Taste is very salt forward and not as fishy as the aroma would suggest</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX H. CHEF-CHOSEN RECIPES FOR GREEN CRAB SAUCE

INCORPORATION

<table>
<thead>
<tr>
<th>pasta with crab meat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risotto with mixed shellfish, finished with crab sauce</td>
</tr>
<tr>
<td>Farro and tomato salad with fish sauce vinaigrette</td>
</tr>
<tr>
<td>Crab Spaghetti, preserved tomato, crab fat butter, calabrian chili</td>
</tr>
<tr>
<td>A very spicy and pungeant vietnamese style salad</td>
</tr>
<tr>
<td>Shrimp fried rice</td>
</tr>
<tr>
<td>Thai Green Curry with tofu.</td>
</tr>
<tr>
<td>Cold soba noodle salad</td>
</tr>
<tr>
<td>Dipping sauce for egg roll</td>
</tr>
<tr>
<td>Pot Stickers / Dipping Sauce</td>
</tr>
<tr>
<td>Thai Pork Larb with lettuce salad</td>
</tr>
<tr>
<td>Beef Pho</td>
</tr>
<tr>
<td>Tom Kha</td>
</tr>
<tr>
<td>Kimchi and fried rice</td>
</tr>
<tr>
<td>Pasta with a tomato sauce, picked crab meat, braised greens</td>
</tr>
<tr>
<td>Shrimp Tom Yum soup</td>
</tr>
</tbody>
</table>
Once incorporated into the dish, the pungency dissipated quite a bit and was very pleasant when tasted with the other ingredients.

It's just different and will take some more tinkering to get used to. I do feel that the salt levels might need adjusting so it isn't as salt forward and maybe diluted a bit before packaging.

We used lots of pungent spice and herbs to mask/stand up to the crab sauce. They helped mask the aroma and the dish was tasty. However, it would have been better with a cleaner tasting fish sauce. I would love to have a green crab "fish sauce" that I want to reach for (and I think its a really good idea too), but this one isn't it, I think/hope with a little tweaking maybe a recipe could be developed that is a bit cleaner and I think it would be a big hit.

The musky sort of flavor did not help the dish

I think it was comparable to Vietnamese fish sauce. It had a different aroma and wasn't as salty.

There was a less of an intense flavor then regular fish sauce. Once combined with the other dressing ingredients (soy, lime, ginger, garlic, sesame, calola), the odor was less disagreeable.

The flavor and aroma are simply too strong right now. For me. It worked fairly well in the Larb which is meant to be a heavily seasoned dish with powerful aromatics. But the more neutral rice and lettuce salad was made too strong.

I was able to replace with equal amounts for fish sauce in Beef Pho. Still have it the umami taste without the off smell of fish sauce

It has a distinct flavor that works quite well as a replacement for fish sauce. I can see using it for wings, marinades, soups, dressings etc.

It was great in a dish with crab but I am not sure how versatile of an ingredient it can be due to its particular crabby flavor. Would be good with any crustacean dish, probably all shellfish

I found the crab sauce to be an excellent replacement for fish sauce in Tom yum soup. There was virtually no difference in taste between the two. I used 32 of seafood stock as a base and 2.5 T of crab/ fish sauce. The fish sauce i used was slightly thicker, so there was a bit of viscosity difference, but I enjoyed them both equally. I would use crab sauce as a replacement for fish sauce in the future.
APPENDIX J. ADDITIONAL CHEF SURVEY COMMENTS

<table>
<thead>
<tr>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compared to the prices of fish and shellfish-based sauces $24/lb does not seem exorbitant, although lower retail prices may induce diners to try it. I used it in modest amounts where its effect was subtle but apparent.</td>
</tr>
<tr>
<td>If marketed as a sustainable product that provides a solution to an invasive species problem, you could easily sell this product, especially if you had taste testing where it was incorporated into a balanced dish.</td>
</tr>
<tr>
<td>For an expertly made version, I would pay $12 or so for a 16 oz bottle--in line with really nice fish sauce (red boat for example) pricing, or higher. I would love to support an expertly/locally made fish sauce. But I would not buy the sauce in its current iteration.</td>
</tr>
<tr>
<td>I think this a great project and a very good use of the invasive crabs. Although it is not my preference in flavor I hope that somebody finds a use for it.</td>
</tr>
<tr>
<td>During shipping, the lid cracked, and some of the crab sauce leaking into the packaging. The odor was extremely strong on opening the package. Overall, the flavor was a positive addition, but lacked the complexity of fish sauce.</td>
</tr>
<tr>
<td>I think it would be better if it could be clarified more. The color makes a huge difference if using it uncooked in a dish.</td>
</tr>
<tr>
<td>I see numerous applications for the Green Crab Sauce: Asian style substitute for Fish Sauce or Tamara or Soy Sauce. Vinaigrettes. Asian Slaw Dipping Sauce Stir fry enhancer. Add to a dumpling filling for flavor.</td>
</tr>
<tr>
<td>Very user friendly and enjoyed using a local, sustainable product</td>
</tr>
<tr>
<td>I think it’s a great use of this invasive species</td>
</tr>
</tbody>
</table>
APPENDIX K. INFORMED CONSENT FORM FOR CONSUMER ACCEPTANCE TEST

You are invited to take part in a research project conducted by Bryson McDonough, a Master’s student in the Food Science and Human Nutrition department, and his advisor, Associate Professor Jennifer Perry. The purpose of this research is to evaluate a novel and sustainable product: green crab sauce.

You must be at least 18 years old to take part in this project. If you have never eaten pasta, do not like pasta or crab, or if you are allergic to shellfish, gluten, wheat, or dairy, please do not take part.

What will you be asked to do?

If you choose to participate in this study, you will be asked to come to the Sensory Evaluation Center in Hitchner Hall (Room 158 A and 158 B) at the University of Maine Orono campus. You will be asked to answer a few questions about yourself followed by tasting three different pasta recipes with green crab sauce and complete a questionnaire about how much you like the samples. Testing and evaluation will take approximately 15-20 minutes.

Risks

The risks associated with this testing are minimal with loss of your time and inconvenience.

Benefits

There are no direct benefits involved to you, but you may enjoy eating the pasta. The overall benefit of this research is to evaluate people’s opinions on green crab sauce.

Confidentiality

Your name and email addresses, collected for time slot organization, will be stored on a password protected computer and deleted by April 30, 2023. Your answers will be collected anonymously. Your name will not be on any files that contain your answers to our questions. Data will be kept indefinitely on the University's Digital Commons site.

Voluntary

Taking part in this study is voluntary. If you choose to take part in this study, you may stop at any time. However, you must complete the questionnaire to get the compensation

Compensation

Upon completion of today's evaluation, you will receive $5. No compensation will be provided if you decide not to answer all of the questions.

Contact Information

If you have any questions about this study, please contact Bryson McDonough at bryson.mcdonough@maine.edu or Dr. Perry at jennifer.perry@maine.edu. If you have any questions about your rights as a research participant, please contact the Office of Research Compliance, University of Maine, at (207)581-2657 (or email umric@maine.edu).
APPENDIX L. CONSUMER ACCEPTANCE EMAIL RECRUITMENT LETTER

Pasta with Green Crab Sauce Recruitment Notice

Your opinion of novel & sustainable food product, green crab sauce, is needed.

If you are 18 years old or older and you like eating pasta, you are invited to evaluate pasta enhanced with green crab sauce. You are receiving this email because your email is enlisted in the Sensory Evaluation Center email notification list. If you have never eaten pasta, do not like pasta, or if you are allergic to gluten, wheat, shellfish, or dairy, we request you not to participate in the testing.

The evaluation of green crab sauce is a part of a research project at the University of Maine. The purpose of the research is to learn if consumers like green crab sauce. This research will be conducted by Bryson McDonough, a Master’s student in Food Science & Human Nutrition at the University of Maine.

Evaluation/testing will take about 15 - 20 minutes. You will be asked to evaluate three different pasta recipes. Participants will receive a $5.00 reward for tasting pasta and completing the questionnaire.

The testing will be held in the Fall at the Sensory Evaluation Center located in Hitchner Hall (Room 158 A and 158 B).

For more information about the study, please see the attached Consent Form. If you are interested in participating in this study, please schedule a time to participate using the link or QR code below:

Link to Google Forms
Would you like to support the development of a sustainable food product, by trying pasta enhanced with green crab sauce?

If you are 18 years old or older and you like eating pasta, you are invited to evaluate pasta enhanced with green crab sauce. If you have never eaten pasta, do not like pasta, or if you are allergic to gluten, wheat, shellfish or dairy, we request you not to participate in the testing.

Evaluation/testing will take about 15 - 20 minutes. You will be asked to evaluate three different pasta recipes. Participants will receive a $5.00 reward for tasting pasta and completing the questionnaire. The testing will be held in the Fall at the Sensory Evaluation Center located in Hitchner Hall (Room 158 A and 158 B).

For more information about the study, please contact Bryson McDonough at bryson.mcdonough@maine.edu.

To schedule a time to participate, please click the link below or scan the QR code below:

QR code and link to Google Form
APPENDIX N. CONSUMER ACCEPTANCE PRESS RELEASE RECRUITMENT LETTER

Adults needed for a new research project support sustainable green crab sauce

Researchers at the University of Maine School of Food and Agriculture are searching for new food uses for invasive green crabs to prevent ongoing ecological and economic damage to Maine’s coasts. Graduate student Bryson McDonough and associate professor Dr. Jennifer Perry at the UM School of Food and Agriculture hope to get feedback on this product. He is recruiting people who are at least 18 years old to come to the Orono-based Sensory Evaluation Center in Hitchner Hall 158A & 158B to taste three different pasta recipes with green crab sauce [dates and times to be determined]. The study will take 15-20 minutes, and research volunteers will receive $5.00 for their time and opinions. If you have never eaten pasta, do not like pasta, or if you are allergic to shellfish, gluten, wheat, or dairy, please do not take part. For more information please contact Bryson McDonough at bryson.mcdonough@maine.edu or Dr. Jennifer Perry at jennifer.perry@maine.edu.

Please make an appointment to participate in the sensory testing using the link or QR code below:

*QR Code and link to Google form*
APPENDIX O. CONSUMER ACCEPTANCE SURVEY QUESTIONNAIRE

Green Crab Sauce Pasta questionnaire

Thank you for participating in this study. Please answer some questions about yourself, then evaluate all three samples from left to right. Make sure that the sample code on the sample you are trying matches the code on the computer screen. Take a sip of water before tasting each sample.

What is your current gender identity?

- Female (Cis or trans)
- Male (Cis or trans)
- Non-binary, genderqueer, or genderfluid
- Prefer not to reply

Please indicate your age.

- 18-25
- 26-35
- 36-45
- 46-55
- 56-65
- 66 years or older
- Prefer not to answer

How do you describe yourself? (Please select all that apply)

- Black or African American
- American Indian/Alaska Native
- Asian
- Caucasian (White)
- Native Hawaiian/Other Pacific Islander
- Prefer not to answer
Approximately what percentage of your household grocery shopping do you do?

- Less than 25%
- 26-50%
- 51-75%
- 76-100%
- Prefer not to answer

When preparing your main meal at home, how often do you usually prepare home cooked meals?

- Never or rarely
- 1-2 times per week
- 3-5 times per week
- More than 5 times per week
- Prefer not to answer

How interested are you in cooking with new and innovative food ingredients?

- Not interested at all
- Slightly interested
- Moderately interested
- Very interested
- Extremely interested

Please evaluate the first sample. [Note: These questions will be repeated for each sample.]

How much do you like the overall appearance of this sample?

- Dislike Extremely
- Dislike Very Much
- Dislike Moderately
How much do you like the aroma of the sample?

- Dislike Extremely
- Dislike Very Much
- Dislike Moderately
- Dislike Slightly
- Neither Like nor Dislike
- Like Slightly
- Like Moderately
- Like Very Much
- Like Extremely

Please take a bite and evaluate the texture questions below.

How much do you like the flavor of this sample?

- Dislike Extremely
- Dislike Very Much
- Dislike Moderately
- Dislike Slightly
- Neither Like nor Dislike
- Like Slightly
- Like Moderately
- Like Very Much
- Like Extremely

How would you rate the saltiness of this sample?
o Not nearly salty enough
o Not salty enough
o Just about right
o Too salty
o Much too salty

How much do you like the sample overall?

o Dislike Extremely
o Dislike Very Much
o Dislike Moderately
o Dislike Slightly
o Neither Like nor Dislike
o Like Slightly
o Like Moderately
o Like Very Much
o Like Extremely

Is there anything else that you would like to say about this sample? Please type the sample’s three-digit code in your comments.

Comment box

[The last screen after all three samples are evaluated:] Thank you for your time and opinions. Please raise the window slightly to let the kitchen staff know that you are done.
BIOGRAPHY OF THE AUTHOR

Bryson McDonough was born in Highpoint, North Carolina on March 16, 2000. He was raised in Bangor, Maine and graduated from Bangor High School in 2018. He attended the University of Maine and graduated in 2022 with a Bachelor’s degree in Food Science and Human Nutrition. His studies continued at the University of Maine where he enrolled in the accelerated M.S. program in Food Science and Human Nutrition in 2022. After receiving his degree, Bryson will be working at Mori, an innovative food packaging company, to begin his work in research and development of sustainable food packaging. Bryson is a candidate for the Master of Science degree in Food Science and Human Nutrition from the University of Maine in August 2023.