Evaluation Of Flavor Of Pacific White Shrimp *Penaeus Vannamei* Cultured In Low Salinity Water

by

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Abstract

Water quality variables and phytoplankton were monitored in five ponds with low-salinity water (2-3 ppt) for culture of Pacific white shrimp (*Pennaeus vannamei)* at a farm in West Alabama from August to October. Shrimps from these five ponds were sampled weekly from mid August until harvest and subjected to sensory evaluation. Twelve panelists were trained to evaluate the smell and appearance of raw shrimp and the smell, appearance, and taste of cooked shrimp. A testing procedure for assessing sensory characteristics of shrimp was set up with the aid of references and definitions for each of 28 sensory attributes. An intensity scale (0 to 10) was utilized for taste tests. A higher score indicated a greater intensity of each characteristic. At the end of the growing season, shrimps from all ponds on the farm were taken for organoleptic testing. In addition, shrimp samples were obtained from eight ponds at an aquaculture research station located in Gulf Shores, Alabama (average salinity = 12 ppt), three ponds at a farm near Harlingen, Texas (average salinity = 22.4 ppt), and one pond at a farm in Hawaii (full strength seawater). Four samples also were purchased from supermarkets. All samples were subjected to sensory evaluation.

Flavor and appearance of shrimp from the five ponds at the low-salinity shrimp farm in West Alabama changed over time in each individual pond and also varied among ponds. Nevertheless, no relationships were observed among sensory attributes and water variables. Although blue-green algae were abundant in ponds at the farm because of high

nutrient concentrations from feed inputs, off-flavor from algal metabolites was not detected in shrimp samples.

Few differences were reported by panelists among shrimp cultured in waters with salinities of 2 to 24 ppt. However, the panelists gave the highest overall approval to shrimp that was reared in full-strength seawater at the farm in Hawaii. Shrimp purchased from supermarkets were scored as less sweet, more bitter, and less firm than shrimp from the other sources.

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INTRODUCTION

White-leg or Pacific white shrimp *Litopenaeus vannamei* is cultured over a wide range of salinities in coastal waters. In addition, it may be grown in saline water at inland sites. Since *L.vannamei* became a popular culture species in the 1970s, its rearing area has expanded from its native habitant in North and South America to Asian countries such as China, Thailand, Vietnam, Indonesia, and Malaysia where it has surpassed the aquaculture production of domestic, black tiger shrimp *Penaeus monodon.* The production of *L.vannamei* in low salinity water has the possibility for allowing expansion of shrimp farming into inland areas of several nations.

The history of low-salinity shrimp culture has not been well documented. Boyd (1990) reported seeing *P.monodon* culture in a pond filled with saline ground water in 1989 at a site in northeastern Thailand. Smith and Lawrence (1990) conducted an experiment on inland, low salinity culture of *L.vannamei* in Texas. A major impetus to low-salinity shrimp farming was the occurrence of serious outbreaks of white spot syndrom virus (WSSV) and other viral diseases of shrimp in the mid 1990s. These diseases spread easily from farm to farm in coastal waters. Thus, it was thought that the diseases could be avoided more easily in inland areas where farm water supplies were not interconnected. Several countries, especially China, Ecuador, and Thailand have large areas of low-salinity shrimp culture. In the United States, there is limited coastal area for

shrimp farms, and inland, low-salinity shrimp culture has been introduced in several states including Alabama, Arizona, Florida, and Texas (Roy et al. 2010).

Food products to be sold in the market should meet the expectations of the consumer. In case of shrimp from low-salinity ponds, flavor is likely the issue of most concern. Several sensory tests have inferred that shrimp from low salinity water taste inferior to those from water of high salinity (Papadopondos and Finne 1986; Liang et al. 2008). In addition, off-flavor has been encountered more frequently in shrimp from low-salinity water than in those from water with salinity above 10 ppt (Boyd 2003). This is thought to results because low-salinity water is more favorable for growth of microorganism capable of producing odorous compounds responsible for off-flavor in fish and shrimp (Boyd 2003, Boyd and Tucker 1998). In addition to off-flavor of microbial origin, Armstrong et al. (1986) and Brown and Boyd (1982) reported relationships among water quality and off-flavor. However, there have been no investigations of relationships among water quality variables and off-flavor in shrimp.

The present study was conducted to determine if differences in the flavor of shrimp could be detected among ponds on the same farm or among shrimp from ponds at different locations and with different salinities.

LITERATURE REVIEW

Marine shrimp is a popular seafood product worldwide, and according to the National Fisheries Institute (http://www.aboutseafood.com/about/about-seafood/top-10-consumed-seafoods), shrimp ranked first in quantity of seafood product consumed per capita in the United States from 2001 to 2009.

Traditionally, shrimp have been captured from the sea, but the quantity of aquacultured shrimp has been increasing for several decades (Fig.1). Presently, about 52.4% of shrimp are from aquaculture, and the percentage is greater for shrimp traded internationally.

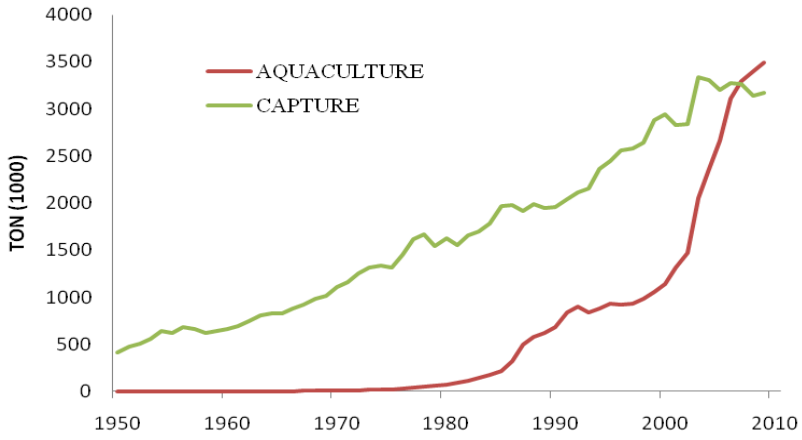

Figure.1. Aquaculture and capture production of marine shrimp from 1950-2009. Source: FAO, FishstatJ, available at http://www.fao.org/fishery/statistics/software/fishstatj/en.

Historically, two major shrimp species were cultured – black tiger prawn *Penaeus monodon* in the eastern hemisphere and Pacific white shrimp *Litopenaeus vannamei* in

the western hemisphere (Bailey-Brock and Moss 1992). Each species was native in the region where it was cultured. However, when viral diseases became problematic in shrimp aquaculture, it proved easier to develop specific pathogen free (SPF) broodstocks for *L.vannamei* than for *P.monodon.* Moreover, the feed for *L.vannamei* is less expensive than for feed for *P.monodon*, because less marine meals and oils are needed in *L.vannamei* feed (Briggs et al. 2004). As a result, Pacific white shrimp have been introduced into the major shrimp-producing countries of Asia (Liao and Chien, 2011; Briggs et al. 2004) where it has surpassed *P.monodon* as the major culture species as illustrated for Thailand (Fig.2)

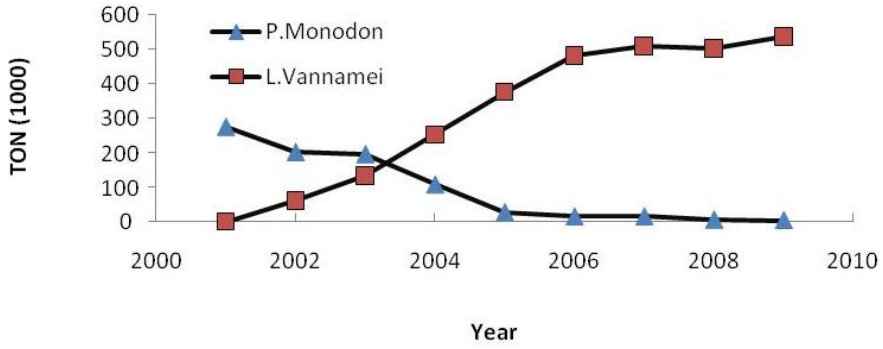

Figure 2. Annual farm-raised production of *Penaeus modnodon* and *Litopenaeus vannamei* in Thailand from 2001 – 2009. Source: FAO, FishstatJ, available at http://www.fao.org/fishery/statistics/software/fishstatj/en

Most wild caught shrimp come from marine waters, and shrimp aquaculture was initially conducted in water with salinity of 15 ppt or more (Liao 1989). Nevertheless, marine shrimp can tolerate a wide range in salinity (Bray et al. 1994, Walker et al. 2009), and both *L.vanamei* and *P.monodon* are cultured quite successfully over a wide range of

salinity (2 ppt to 40 ppt) and with some success at even lower and higher salinities (Araneda et al. 2008; Cawthorne et al. 1983; Saha et al. 1999).

Low salinity culture has allowed the expansion of marine shrimp farming into areas located considerable distances from coastlines in estuarine water that was conveyed inland via canals.

Also, shrimp farms may be sited along the most inland reaches of estuaries where water is brackish only during the dry season (Boyd 1990; Dall and Smith 1981). There is considerable saline surface and groundwater in inland, arid regions, and saline groundwater may be found even in humid regions (Roy et al. 2010; Levy 2000, Feth et al. 1965; Feth 1970, Boyd et al. 2009). It has been demonstrated that marine shrimp can be cultured in inland ponds supplied with low-salinity groundwater or surface water ranging in salinity from around 2 ppt to 15 ppt (Roy et al. 2010; Fast and Menasveta 2000). But, in some cases, low-salinity, inland water must be supplemented with magnesium and potassium to avoid negative effects of low concentrations of these two ions on shrimp survival and growth (Boyd and Thunjai 2003; Boyd et al. 2006; Roy et al. 2007). There is growing interest in inland culture of marine shrimp in several countries including the United States (Roy et al. 2007). In the United States, inland shrimp farming is currently done in several states including Alabama, Arizona, Florida, and Texas.

Although shrimp can be produced successfully in low-salinity water, this new shrimp farming technology cannot be viable unless the product is acceptable to the consumer. The flavor or taste of shrimp, like that of other fisheries products, obviously is an important variable related to consumer acceptance. The taste of prawn and lobster is influenced by free amino acid concentrations. Thus, the fact that free amino acid

concentrations in penaeid shrimp charges in response to differences in environmental salinity (McCoid et al. 1984; Papadopoulos and Finne 1986; Liang et al. 2008) suggests that the flavor of shrimp will vary with salinity.

In a review presented by Konosu (1979), glutamic acid and glycine were considered key components of the taste of crustaceans. Alanine, proline and serine may also contribute to sweet taste to some extent. In research on small boiled shrimp, almost 100 volatile components that could influence flavor were identified, and more than 40 of these components were determined to be sulfur or nitrogen-containing heterocyclic substances. Shrimp also contains various kinds of volatiles to include hydrocarbons, carbonyl compounds, alcohols and phenols (Kubota et al. 1989). Baek and Cadwallader (1997) reported 23 aroma active compounds in cooked crustaceans by using the aroma extract dilution analysis technique. A group of compounds known as bromophenols that are found in the natural marine environment of penaeid shrimps is believed to create unique flavors in wild-harvested shrimp (Miget and Haby 2007). At high concentrations, these compounds were blamed for bad odor, but at low concentrations, they are thought to enhance the intensities of the flavor recognizable as marine-like or ocean-like. Sensory analysis conducted by Whitfield et al. (1997) showed that wild-harvested shrimp had ocean-like and prawn-like flavor whereas cultured shrimp (which were presumably from full strength seawater) were described as bland. Total bromophenol content was much higher in the former than in the later.

Organoleptic testing, also called sensory analysis, utilizes the human sense for detecting taste and flavor of marine shrimp. Descriptions that could be used for the sensory characteristics of shrimp that were listed by Edmunds and Lillard (1979) include

22 terms representing three broad categories: aroma, taste and texture. Aroma characteristics were considered to be aromatic, fresh or delicate, fishy, sea-breeze, mash smelly, nutty or buttery, boiled corn (sulfury). Taste characteristics of shrimp for shrimp flesh were categorized as sweet, salty, fresh or delicate, fishy, flavorfulness, meaty, nutty or buttery. Juicy, watery, crisp, tough, soft, and meaty were the texture characteristics. Erickson et al. (2007) recently generated 30 terms to more carefully describe sensory characteristics of penaeid shrimp in both raw and cooked samples. Annotation given for each characteristic help the taster understand had to detect each sensory quality.

Some studies have shown that consumers prefer shrimp cultured in high salinity water to those from low salinity water. Research by Papadopoulos and Finne (1986) showed that free amino acid concentration of penaeid shrimp cultured in 10 ppt was much less than in shrimp reared in water of 30 ppt and 50 ppt salinity. Moreover, organoleptic testing gave a higher score (better flavor) for to shrimp cultured in 50 ppt salinity than to shrimp grown in lower salinity water. Sensory analysis conducted by Liang et al. (2008) also showed that extracts of shrimp cultured in seawater exhibited higher "umami" and sweetness and better overall flavor compared to those in low salinity water. Umami refers to taste produced by substances such as monosodium glutamate (MSG) in solution (Yamaguchi and Ninomiya 2000). Nevertheless, all studies do not agree that shrimp from high salinity water taste better than those from low-salinity water. A consumer acceptance test run by the Food Science and Human Nutrition Department of the University of Florida concluded that consumers in the United States preferred *P. vannamei* cultured in freshwater over those grown in brackish or salt water or harvested from the sea (Briggs et al. 2004).

Undesirable taste and odor – usually referred to as off-flavor – is common problem in fish, and especially Ictalurid catfish (Boyd 2003). Off-flavor is most often caused by chemicals produced by certain naturally occurring species of bacteria and algae in pond water and sediment. Geosmin (trans, 1, 10-dimethyl-9-decalol) and 2-methylisoborneol (MIB), the main compounds causing of bad taste and odor in drinking water (Juttner and Watson 2007), are the primary cause of off-flavor in fresh water fish (Howgate 2004). They are described as "earthy", "musty" or "moldy" (Boyd and Tucker 1998). Both compounds can be produced by certain species of several genera of blue-green algae and actinomyces, but blue–green algae are considered the more important contributor of odorous compounds in aquaculture ponds. Geosmin is synthesized by *Anabaena* and *Aphanizomenon* in the family Nostocaceae; *Osilatoria, Lyngbya, Symploca,* and *Schizothrix* in the family Oscillatoriaceae; and *Fischerella* in the family Stigonemataceae. MIB is produced by species of *Lyngbya, Oscillatoria*, and *Phormidium* in the family Oscillatoria (Boyd and Tucker 1998).

Although less common than in fish culture, off-flavor can be problem in penaeid shrimp culture (Lovell and Broce 1985; Boyd 2003). Blue-green algae are usually present in water of shrimp ponds, but they seldom comprise a high percentage of the phytoplankton community unless salinity is below 10 ppt. Thus, in low-salinity shrimp farms, blue-green algae may become dominant and cause flavor problems in harvested shrimp (Boyd 2003). In 1983, some pond-cultured marine shrimp imported from South Africa into the United States were unmarketable because of an intense earthy-musty flavor (Lovell and Broce 1985). The cause of off-flavor in these shrimp was investigated. A large drop in salinity to nearly 0 ppt led to a heavy bloom of blue-green algae in the

ponds just before harvest time. It is most likely that these algae had released geosmin into the pond water that was absorbed by shrimp and imparted off-flavor to them (Lovell and Broce 1985).

Brown and Boyd (1982) conducted an experiment to explore relationship between off-flavor and water variables such as chlorophyll *a*, chemical oxygen demand (COD), and total abundance of algae. Ponds with the lowest concentrations of cholorophyll *a* and COD and the lower abundances of algae had better tasting channel catfish *Ictalurus punctatus*. Probably, a similar relationship between off-flavor and water quality would occur in shrimp ponds. For example, Boyd (2003) described a situation in Columbia where, because of nutrient enrichment from rice farming, a dense bloom of blue-green algae developed and persisted in a small estuary with a narrow, opening to the sea. Shrimp cultured in a farm that was supplied with water from the estuary developed an intense off-flavor and were unmarketable.

Off-flavor is becoming an increasingly important issue in shrimp culture as supermarkets offer an increasing variety of shrimp products with respect to country of origin and culture methods. Shrimp buyers are beginning to develop purchasing standards for farm-reared shrimp to assure consumer acceptance. Off-flavor is causing concern in countries where shrimp are cultured in low salinity water (C.E.Boyd, personal communications). It also should be noted that odorous compounds responsible for off-flavor are lipid soluble, and they tend to accumulate in the head of shrimps. Off-flavor is of greater concern in the "head-on" shrimp products than in the "shrimp tails" products. There have, however, been cases of off-flavor in shrimp tails (Lovell and Broce 1985).

MATERIALS AND METHODS

SHRIMP SAMPLES

The majority of shrimp samples were collected from the Greene Prairie Aquafarm located about 6 km north of Forkland, Alabama, on Alabama Highway 43. The farm has 17 ponds filled with low-salinity well, which typically ranges from 2 to 5 ppt (Boyd et al. 2006). In 2010, Pacific white shrimp *L.vannamei*, were stocked at 30 postlarvae/m^2 in early May. Ponds were fed twice daily with commercial, 32 % crude protein, pelleted feed. Mechanical aeration was supplied as need with floating, electric paddlewheel aerators 10.66 hp/ha. Fertilizers muriate of potash (potassium chloride) and Kmag (potassium magnesium sulfate) were occasionally added to maintain potassium concentration above 40 mg/l and magnesium concentration above 20 mg/l (McNevin et al. 2004). Shrimps were harvested in September and October 2010.

Shrimp samples (about 500 g each) were collected from 5 ponds (N4, N5, N6, N7, and N8) at weekly intervals from August through October. Shrimp samples were also obtained from 17 ponds at final harvest. Shrimp were placed temporarily in a large freezer (around -18^{0}C) at the farm, transported to Auburn University on ice in insulated chest, and then stored in a freezer (around -18^{0}C) until sensory test were made. Unfortunately, the sample from one pond was lost.

Additional shrimp samples (about 500g each) were obtained from eight ponds at the Claude Peteet Mariculture Center, Alabama Marine Resources Division, Gulf Shores,

Alabama, from the Harlingen Shrimp Farm, Bayview, Texas, and from the Sunrise Capital Shrimp Farm in Hawaii. Four samples of farmed shrimp were obtained from supermarkets: one sample of shrimp from Peru and one sample from Nicaragua were purchased from the International Market located at 5600 Buford Highway, Doraville, Georgia; one sample from Indonesia was purchased from Wal-Mart, 17 South College Street, Auburn, Al; one sample from Thailand was purchased from Publix, 2417 Moores Mill Road, Auburn, Al. These samples also were maintained on ice during transit from those stores to the laboratory and then stored at around -18^0C until used in sensory tests.

WATER ANALYSES

Water samples were collected from 5 ponds (N4-N8) at weekly intervals. Water was dipped from pond surfaces, placed in 2-L plastic bottles, and maintained on ice during transit to the laboratory at Auburn University. Upon receipt at the laboratory, all samples were analyzed for conductivity, salinity, and pH with an YSI 556 multiprobe system (Yellow Spring Instrument Company, Yellow Spring, Ohio, USA). The samples were analyzed for chlorophyll *a* by acetone-methanol extraction followed by spectrophotometer (Pechar 1987). Procedures given by Boyd and Tucker (1992) were used to measure total alkalinity, total hardness and calcium hardness, and chemical oxygen demand (by the heat of dilution option). Sodium and potassium concentration were ascertained using a Cole-Parmer Model 2655-00 flame photometer. Chloride concentration (by mercuric nitrate option), sulfate concentration (by turbidimetric option), and the standard, 5-day biochemical oxygen demand (BOD_5) were determined by protocols from Clesceri et al. (1998).

Aliquots of water sample from ponds N4-N8 were preserved with Lugol solution (Clesceri et al. 1998). Algae were identified to genus at 450X (Illuminator Model No. 1036 A, American Optical Corporation, Buffalo, New York). Taxonomic keys of Smith (1933) and Dillard (1999) were used to assist in algal identification. Algae were enumerated in Sedgwick-Rafter counting cell under 100X magnification (Clesceri et al. 1998); ten fields were counted for each sample. Numbers of individuals (single cells, colonies, or filaments) were recorded for total phytoplankton and blue-green algae.

SENSORY TEST

Reference preparation

References for organoleptic tests were prepared as described in Table 1 and 2. Most of these references were similar to references recommended by Erickson et al. (2007). Ocean/seawater and sweet solutions were changed every week, the old shrimp solution was changed every 3 weeks; the aftertaste solution and the three other solutions in the basic taste category were changed every 2 weeks. Jell-O, cheese, beef hot dog, surimi, pineapple were all kept in a refrigerator, removed just some minutes before starting a sensory test to make sure their textures were unchanged. Each described attribute was scored from 0-10 with aid of the references.

Training panelists

Sensory characteristics of the shrimps were evaluated by 12 subjects (25-71 years old, 5 male: 7 female). Training consisted of five sessions over a 1-month period. In the first session, participants were informed of the study objective, the approach of sensory testing, and definitions used in the test. Then, the references were evaluated and concentrations and scoring scales discussed.

In the second, third, and fourth sessions, panelists evaluated shrimp using the same references. But, all panelists used the same shrimp for evaluating each characteristic. For instance, one shrimp was cut into four small species and served for four participants for evaluating sweetness. The panelists would be expected to give a similar evaluation. Sheets containing descriptors of both raw and cooked shrimps were presented along with references. Participants were provided a cup of distilled water and an empty cup to rinse their mouths and to spit out when necessary.

In the fifth session, everything was set up and run as in an actual sensory test.

Descriptive analysis testing by trained panelist

Frozen shrimps were put in a refrigerator at 4^{o}C one night before the day of sensory test. About 1 hour before testing, shrimp of each sample was dehead and placed on three white paper plates that were marked clearly with the letters A, B, C to identify the samples. Shrimp cooking also was initiated 1 hour before evaluation was conducted.

Shrimps were rinsed in cool, running water and then put into boiling water. Two minutes after all shrimp rose to the surface of water, they are removed and rinsed several times with cool water, dehead and put on plates which are marked clearly with the letters A, B, C to identify samples.

Twelve panelists took turns in participating in sensory test at weekly intervals. In each test, there were six panelists. At first they were served with three plates that each contained three cooked shrimps. Then, they were provided three raw shrimp in three white plates.

Table 1. Standard references and rating used in descriptive analysis of raw shrimp sample

Attribute class	Attribute	Definition	References	Rating
Raw aroma	**Ocean/seawater**	Aromatic associated with the ocean or seawater, from slight to strong	Distilled Water	0
			50% clam juice	5
			Clam juice (Snow's bumble Bee All Natural Clam Juice, Bumble Bee Foods, LLC Sadiego, CA 92186 U.S.A.)	10
	Shrimp	Aromatic associated with raw shrimp, from slight to strong	Evaluate base on how fresh shrimps are	
	Old shrimp	Aromatic associated with old fish, from slight to strong	Distilled Water	0
			6.5% mixed - dried shrimp powder	5
			13% mixed - dried shrimp powder	10
Raw meat appearance	**Plumpness**	The appearance of being plump at the head, from flat to round	See attach reference (Appendix A1)	
	Brown color	The brownness of the meat near the head (cross-section at cut end), from white to brown	White bond paper	0
			Brown paper	10
Raw shell appearance	**Darkness**	The intensity of the shell color, from light to dark	White bond paper	0
			Black color	10
	Stripe darkness	The darkness of the stripes on the shell, from light to dark	White bond paper	0
			Black color	10
	Blotchiness	The amount of coverage of dark spots on the surface of shell, from not blotchy to blotchy	See attach reference (Appendix A2)	
	Glossiness	The amount of light reflected from the shell, from dull to glossy	White bond paper	0
			Laminated card	5
	Tail iridescence/ Rainbow color	The appearance of rainbow-like colors on the tail, from slight to extreme	Soap buble	10

Table 2. Standard references and rating used in descriptive analysis of cooked shrimp sample

Attribute class	Attribute	Definition	References	Rating
Aroma	**Ocean/seawater**	Aromatic associated with the ocean or seawater, from slight to strong	Distilled Water	0
			50% clam juice	5
			Clam juice (Snow's bumble Bee All Natural Clam Juice, Buble Bee Foods, LLC San diego, CA 92186 U.S.A.)	10
	Cooked Shrimp	Aromatic associated with fresh cooked shrimp, from slight to strong	Evaluate how fresh cooked shrimps are	
	Old shrimp	Aromatic associated with old fish, from slight to strong	Distilled Water	0
			6.5% dried shrimp powder	5
			13% dried shrimp powder	10
Appearance	**Red/orange color**	The redness of the surface, from white to red orange (peel to see)	White bond paper	0
			Salmon bond paper	4
			Orange color paper	10
	Brown color	The brownness of the meat near the head (cross-section at cut end), from white to brown (meat)	White bond paper	0
			Brown paper	10
	Blotchiness	The amount of coverage of dark spots on the surface of the meat, from not blotchy to blotchy	See attached reference (Fig.4)	
	Glossiness	The amount of light reflected from the meat, from dull to glossy	White bond paper	0
			Laminated card	5
Taste	**Bitter**		Distilled Water	0
			0.04% caffein solution	5
			0.08% caffein solution	10
	Salty		Distilled Water	0
			0.2 % NaCl solution	5
			0.4 % NaCl solution	10
	Sour		Distilled Water	0
			0.01 % acid citric solution	5
			0.02% acid citric solution	10
	Sweet		Distilled Water	0
			1.5 % sugar solution	5
			3.0 % sugar solution	10

Attribute class	Attribute	Definition	References	Rating
Mouthfeel	**Sliminess**	The feeling of a slimy film in the mouth, from not slimy to slimy	Jello (add 2 cups water in 1 bag)	10
Texture	**Firmness**	The amount of force needed to deform the head-end of the shrimp meat by first biting through skin with incisors, then chewing with molars (skin side toward molars), from not chewy to chewy	Cheddar cheese (Great Value Sliced Sharp Cheese, Wal-mart Store, Inc. Bentonville, AR 72716 ©2009)	3
			Hot dog (Hebrew National Beef Franks, ConAgra Foods, Inc. P.O. Box 3768, Dept.HN Omaha, NF 68103-0768 U.S.A)	5
	Juiciness	The amount of moisture to masticate sample to a consistency acceptable for swallowing	Surimi (Aquamar classic Leg Style Crab, Flavored Sea Food, Aquamar, Inc. Rancho Cucamonga, CA 91730)	3
			Pine apple (Dole chunk, Westlake Village, CA)	10
	Chewiness	The time required to masticate sample to a consistency acceptable for swallowing	Slight salted dry roasted peanuts (Planters, Kraft Foods Gobal, Inc, Northfield, IL 60093-2753 USA)	3
			Gummy bear (Great Value Gummy Bears, Wal-mart Store, Inc. Bentonville, AR 72716©2006, Product of Mexico)	10
	Crispness	The amount of force exerted during first incisor bite that generates a high pitched sound, from slight to high	Slight salted peanut (Planters, Kraft Foods Gobal, Inc, Northfield, IL 60093-2753 USA)	6
			Saltine cracker (Great Value Saltine Cracker, Wal-mart Store, Inc. Bentonville, AR 72716©1994)	10
	Fibrous	The presence of individual muscle fibers in the shrimp meat, from not fibrous to fibrous	Pine apple Dole chunk (Westlake Village, CA)	5
Aftertaste	**Iodine**	Aftertaste associated with the chemical iodine, from slight to strong	Distilled water	0
			0.2% iodized salt solution	10

STATISTICAL ANALYSIS

In order to evaluate the improvement of panelist during training time, mean and coefficient of variation of sensory score in each of 3 training sessions (the second, third and fourth session) were calculated.

Statistical software (SAS Institute Inc., 2004) was used to analyze the data of sensory tests. Analysis of variance (one-way ANOVA) was used to detect if significant differences occurred among shrimp samples from individual ponds during the culturing season, of different ponds on the same date, and ponds after harvest. If a difference was noted, Tukey's test was conducted to identify the differences ($P \leq 0.05$).

RESULTS AND DISCUSSION

SENSORY TRAINING

There were five training sessions, but it was not possible for all panelists to attend each session at the same time. Hence, it was necessary to duplicate some of the sessions, and only three panelists were together in all five sessions. Training results of these three panelists were used to assess the effect of training time on homogeneity of sensory assessment among panelists for the second, third, and fourth training sessions in which all panelists examined the same individual shrimp. The coefficient of variation (CV) of the results for each attribute was taken as an index of homogeneity – the lower the coefficient of variation, the greater homogeneity.

There was little improvement over time in homogeneity among panelist scores for some attributes. There were obvious improvements in score for some attributes, e.g., blotchiness, stripe darkness, darkness, plumpness and shrimp aroma for raw shrimp and crispness, juiciness, sweetness, saltiness, blotchiness, brown color, and shrimp aroma for cooked shrimp (Fig.3). Nevertheless, CVs were high and often exceeded 50%. It was noticed that one panelist would often score much lower or higher on a given attribute than other panelists in a given test. Thus, in an attempt to reduce variability in the sensory tests, the most extreme score among the six panelists was always discarded.

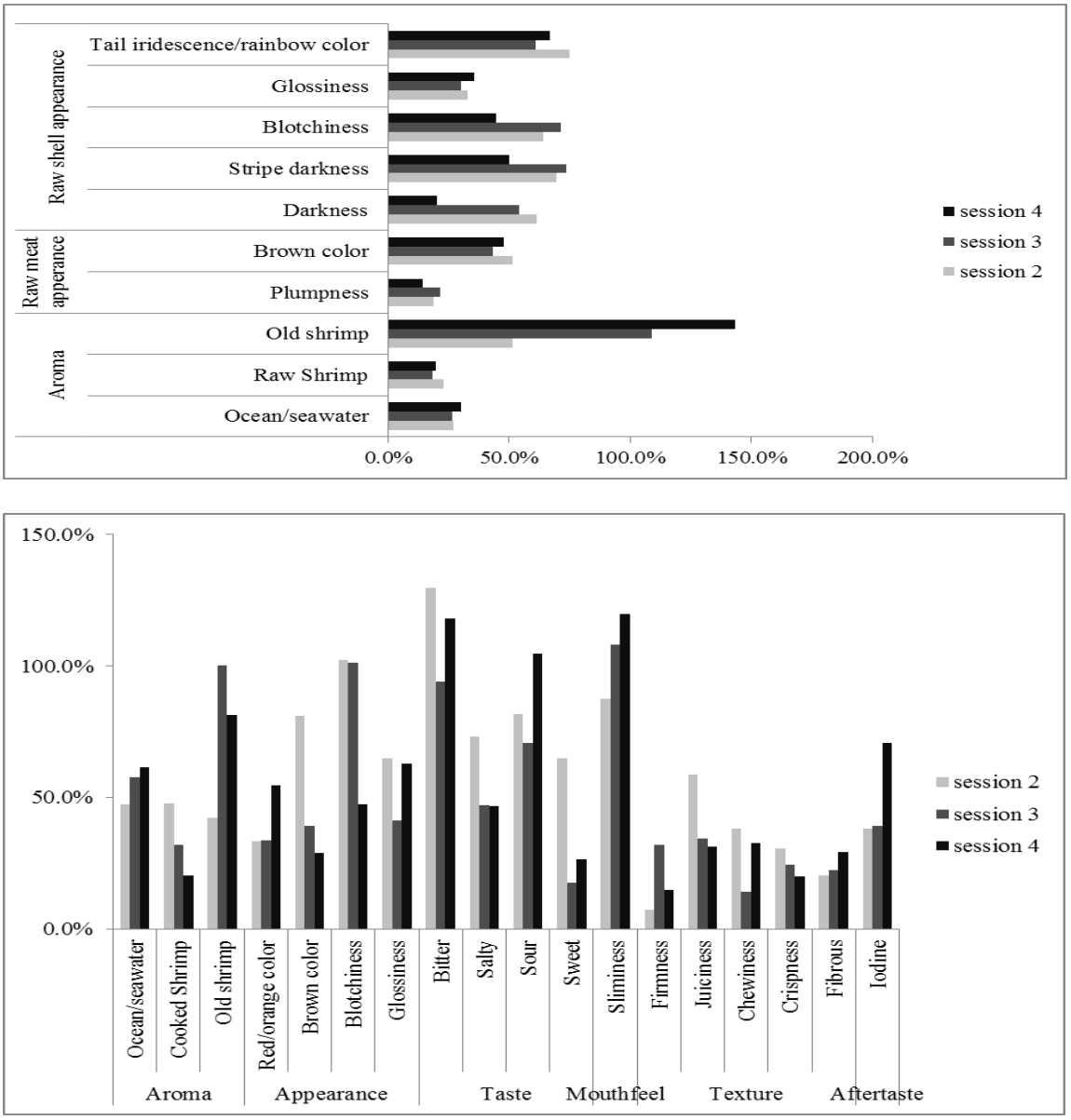

Figure 3. Upper: Coefficient of variation of evaluate score in raw shrimp over three sessions; Lower: Coefficient of variation of evaluate score in cooked shrimp over three sessions

WATER QUALITY

Water quality conditions in ponds will be described before considering the sensory test results. The five ponds selected for weekly sampling at Greene Prairie Aquafarm differed somewhat in water quality, both among ponds or among dates within the same pond. Salinity and conductivity range between 2 and 3 ppt and 3,500 and 6,000 µhmos/cm, respectively (Fig.4). The pH ranged between 7.5 and 9, while total alkalinity varied between 75 and 200 mg/l (Fig.4). Concentration of major ion exhibited the following ranges: calcium 15 to 60 mg/l; magnesium 8 to 18 mg/l; sodium 600 to 1,100 mg/l; potassium 40 to 60 mg/l; sulfate 20 to 50 mg/l; chloride 900 to 1,800 mg/l (Figs.5 and 6). These concentrations of major quality variables are typical of those reported in previous year for this farm, and they are adequate for inland production of marine shrimp.

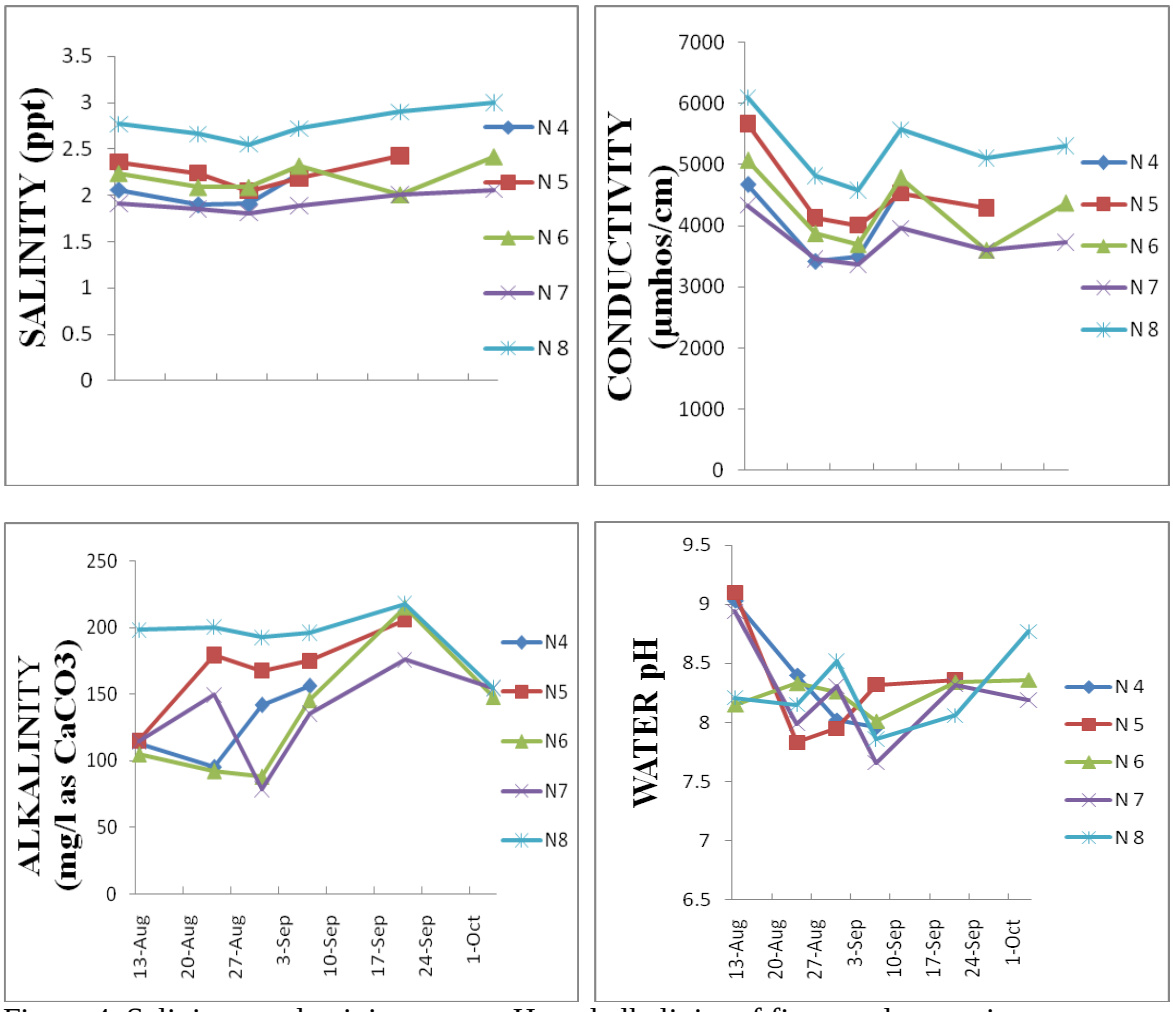

Figure 4. Salinity, conductivity, water pH, and alkalinity of five ponds over time.

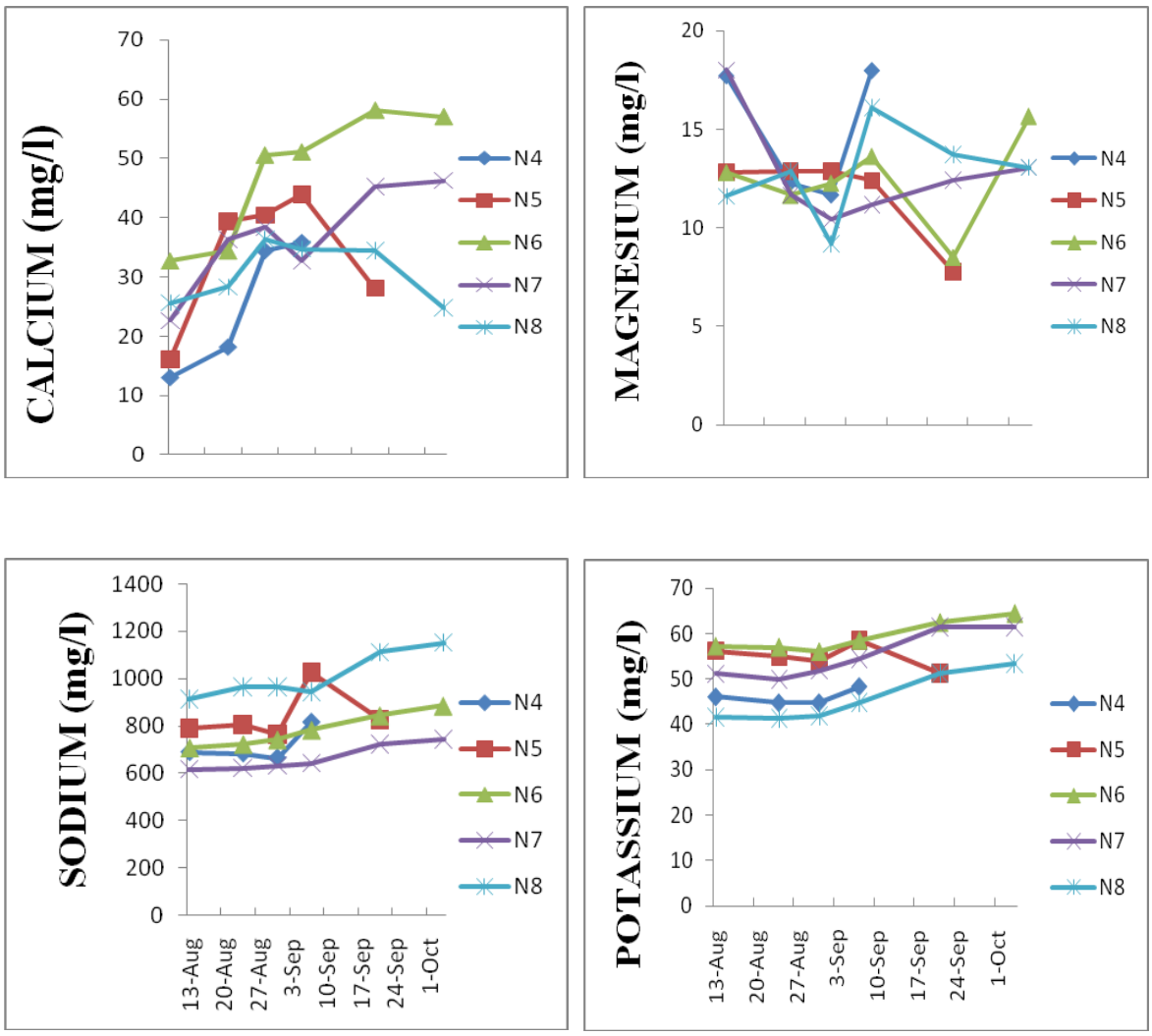

Figure 5. Concentration of calcium, magnesium, sodium and potassium in five ponds over time

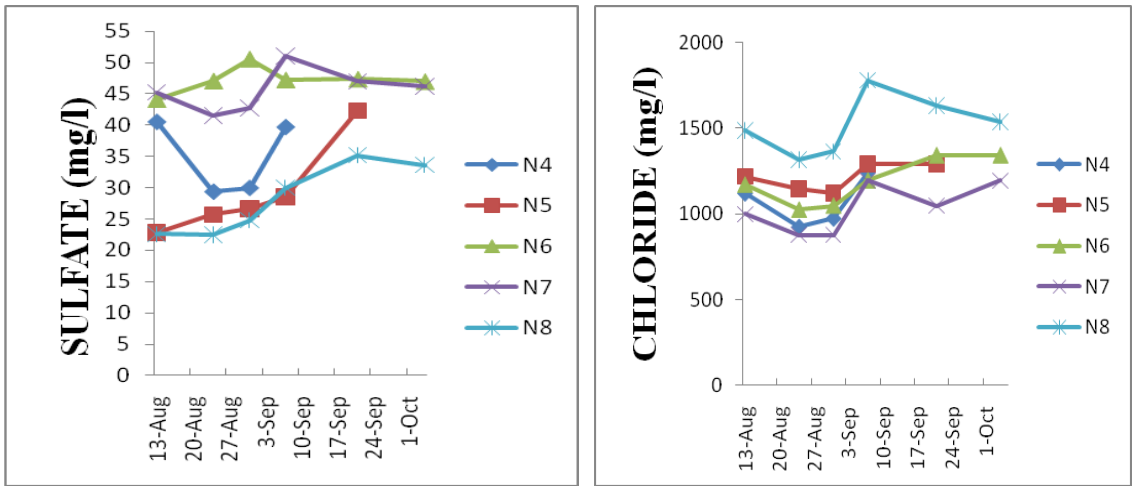

Figure 6. Concentration of sulfate, and chloride in five ponds over

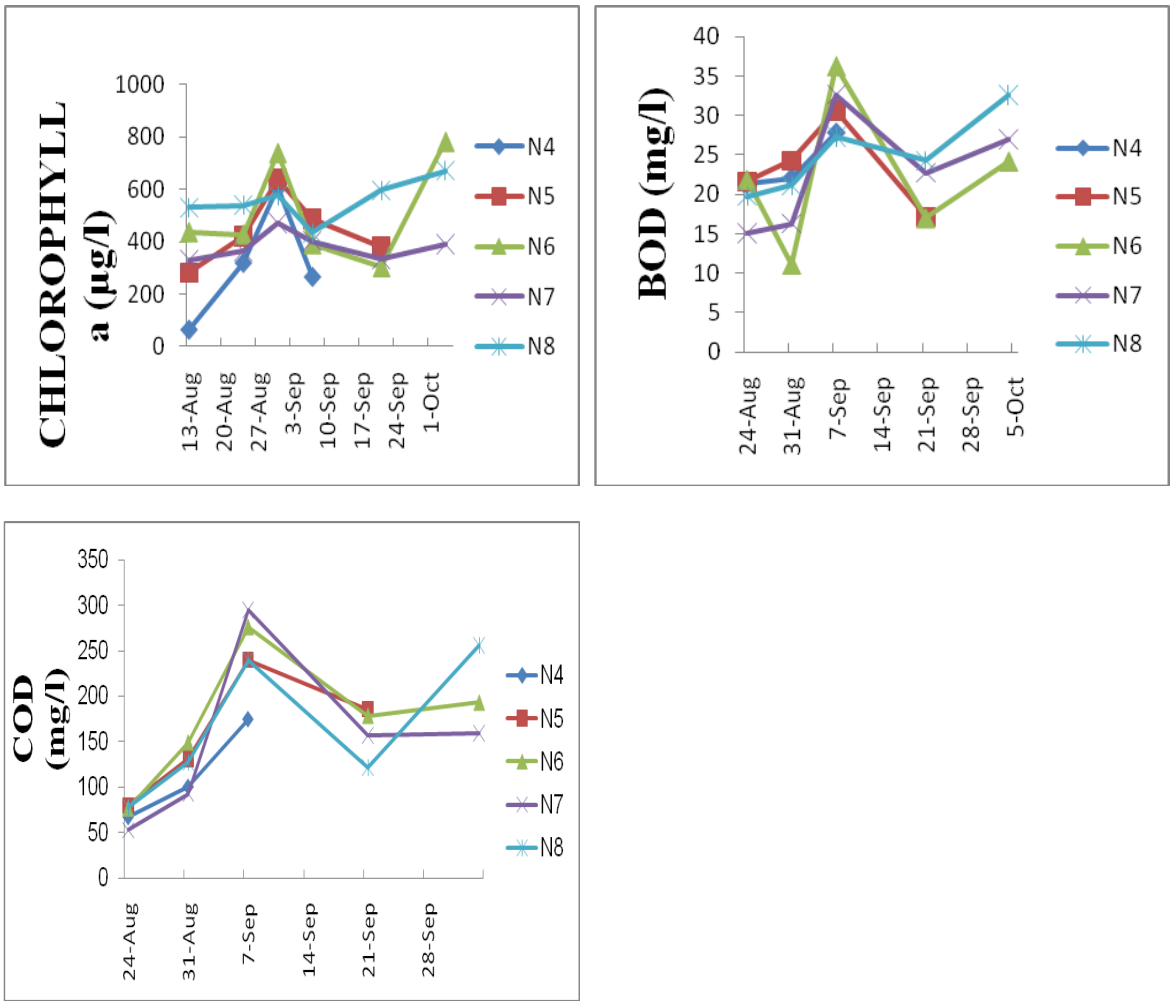

Figure 7. Concentration of chlorophyll *a*, BOD, and COD of five ponds over time

Because of high nutrient inputs in feed, ponds at Greene Prairie Aquafarm had dense phytoplankton blooms as confirmed by high concentration of chlorophyll *a* (Fig.7). Dense phytoplankton abundance also resulted in high biochemical and chemical oxygen demands in the pond water.

Taxonomic composition of algae varied among ponds and sampling dates, but blue-green algae were abundant in all ponds and made up 62.2 to 72.6% total algal abundance in ponds N4, N6, and N7 (Fig.8). The most abundant genera of blue-green algae were *Oscilatoria*, *Aphanocapsa* (*Microcystis*), *Synechocystis*, and *Raphidiopsis*, but

Anabaenopsis, *Anabaena*, *Cylindrospermum* also were observed. Three of these genera (*Osilatoria*, *Aphanocapsa,* and *Anabaena*) have been associated with off-flavor in pond-reared channel catfish (Tucker 2000; Boyd and Tucker 1998). The high abundance of blue-green algae was not surprising, because their growth is favored by high nutrient inputs to aquaculture ponds in feed (Boyd and Tucker 1998).

There also were several genera of green algae in the ponds to include *Merismopedia*, *Coelasphaerium*, *Atinastrum, Spirotaenia, Scenedesmus, Pediastrum, Tetradron, Coelastrum, Closterium, Crugenia, and Tetratrum*. Of these genera, *Spirotaenia* was found most often, but *Pediastrum*, *Scenedesmus*, and *Closterium* were also quite common. Green algae have not been implicated as source off-flavor in aquaculture species. The average abundance of phytoplankton individual range from 62,448 to 1,045,306 /ml, and like chlorophyll *a*, abundance fluctuated greatly among ponds and dates (Fig.8).

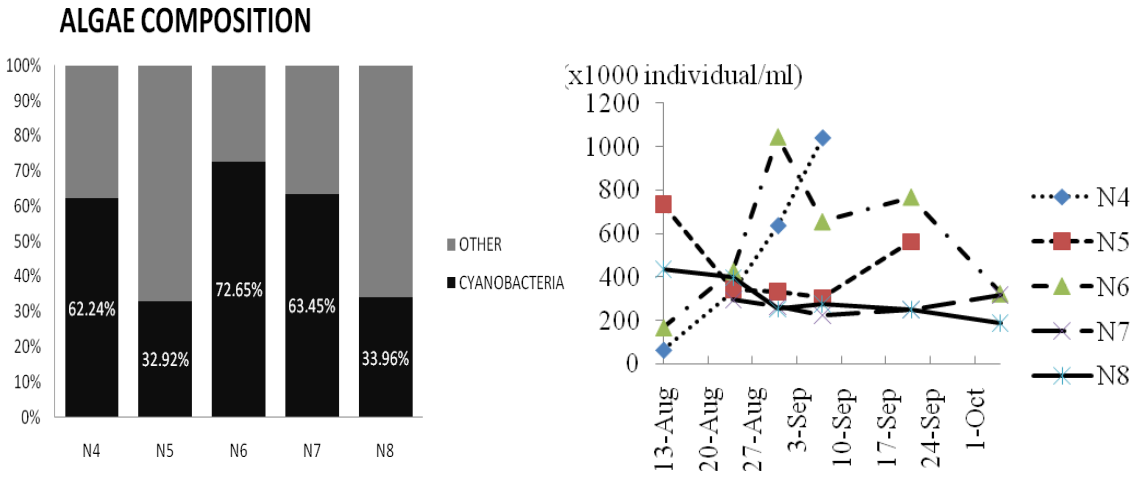

Figure 8. Left: Algae composition of five ponds; Right: Number of algae individual in five ponds

The water quality characteristics of the five ponds are thought to be representative of that in the other ponds in which water quality was not measured. The two variables of

greatest interest were the high abundance of blue-green algae and the low salinity that averaged 2.25 ppt for the five ponds.

Eight ponds at the Claude Peteet Mariculture center had pH of 6.7 to 7.87 ($\bar{x}$ = 7.09 ± 0.36), conductivity of 15,643 to 22,594 µmhos/cm ($\bar{x}$ = 17,936 ± 2,715 µmhos/cm), and salinity of 10.5 to 15.5 ppt, ($\bar{x}$ = 12.0 ± 2.1 ppt). Corresponding data for the three ponds at the Harlingen shrimp farm were pH of 6.8 to 7.02 ($\bar{x}$ = 6.88 ± 0.13), conductivity of 23,679 to 28,572 µmhos/cm ($\bar{x}$ = 26,507 ± 2,534) and salinity of 19.8 to 23.9 ppt ($\bar{x}$ = 22.4 ± 2.3 ppt). The shrimp from the farm in Hawaii were grown in the water of 35 ppt salinity (Dr. George Chamberlain, personal communications). No data were obtained for other water quality variables including phytoplankton composition.

VARIATION AMONG PONDS AND DATES

The five ponds were sampled weekly for 5 weeks before any of them were drained. The field data set is presented in Appendix B, but only the data for dates and variables where differences were noted are provided in Table 3. The differences were associated with aroma of raw shrimp (1st sampling date) and cooked shrimp (2nd sampling data), meat and shell appearance (1st, 2nd, 3rd, and 4th sampling dates), mouth feel and texture (1st sampling dates), and basic tastes (5th sampling dates).

Table 3. Significant differences were found among ponds and different sampling time

Attribute class	Sensory attribute	Pond N4	N5	N6	N7	N8
First sample						
	Raw shrimp					
Aroma	Ocean/seawater	5.8 ab	5.6 ab	7.6 a	3.4 b	4.2 b
	Shrimp	6.4 a	6.2 a	6.0 a	4.2 ab	2.8 b
Meat appearance	Plumpness	8.6 a	8.3 a	7.6 ab	7.4 ab	6.1 b
Shell appearance	Stripe darkness	3.5 b	2.9 b	4.0 ab	6.4 a	5.2 ab
	Cooked					
Mouthfeel	Sliminess	1.24 ab	1.24 ab	1.04 b	3.2 a	2.4 ab
Texture	Chewiness	4.4 b	5.0 ab	4.6 ab	6.0 ab	6.4 a
Second sample						
	Raw shrimp					
Meat appearance	Plumpness	7.6 a	7.6 a	7.4 a	5.0 b	6.2 ab
	Cooked shrimp					
Aroma	Cooked shrimp	7.6 a	5.6 ab	4.4 b	4.0 b	6.2 ab
Appearance	Glossiness	7.2 a	6.6 abc	4.8 bc	4.6 c	7.0 ab
Basic taste	Sweet	5.8 a	4.8 ab	3.2 b	4.6 ab	5.2 ab
Texture	Fibrous	6.4 a	6.0 a	3.4 bc	2.8 c	5.4 ab
Third sample						
	Cooked shrimp					
Meat appearance	Plumpness	7.6 ab	8.5 a	7.5 ab	6.0 b	7.7 a
Appearance	Stripe darkness	3.8 ab	5.5 ab	5.8 a	6.6 a	1.8 b
Texture	Fibrous	6.8 a	5.2 ab	5.6 ab	5.2 ab	2.82 b
Fourth sample						
	Raw					
No entries						
	Cooked					
No entries						
Fifth sample						
	Raw shrimp					
Meat appearance	Plumpness	8.5 a	7.5 ab	6.8 b	7.0 ab	6.4 b
	Cooked shrimp					
Basic tastes	Salty	2.6 ab	4.6 a	4.0 ab	1.8 b	4.2 ab

There were very few significant differences among sensory characteristics of shrimp at harvest from 16 ponds at the Greene Prairie Aquafarm (Appendix C). Most of the observed differences were in appearance of either raw or cooked shrimps. Significant differences were seen in plumpness, darkness, stripe darkness, and blotchiness in raw shrimp; red/orange color, blotchiness, glossiness, firmness, crispness, and fibrous in

cooked shrimp (Table 4). No differences were seen in basic tastes or after taste. There were few differences in texture (only in firmness and crispness).

Table 4. Average, standard deviation, and range of sensory scores and the number of significant differences noted of shrimp at harvest in 16 ponds at the Greene Prairie Aquafarm.

	Attribute	Sensory attribute	Average	Standard deviation	Max	Min	Number of significant differences
Raw shrimp	Aroma	Ocean/seawater	6.31	0.79	7.6	4.8	0
		Shrimp	6.56	0.79	8	5.4	0
		Old shrimp	1.57	0.81	2.8	0.28	0
	Meat appearance	Plumpness	7.68	0.65	8.6	6.3	2
		Brown color	3.46	0.78	5	2.2	0
	Shell appearance	Darkness	4.74	1.04	6.4	3	4
		Stripe darkness	5.17	1.40	7	2.2	12
		Blotchiness	3.73	1.25	6.2	1.04	1
		Glossiness	6.91	0.57	7.8	5.8	0
		Tail iridescence	4.33	0.94	6.4	2.82	0
Cooked shrimp	Aroma	Ocean/seawater	6.23	0.82	8	5	4
		Cooked shrimp	6.64	1.24	8.4	4.2	0
		Old shrimp	1.58	0.77	3.4	0.66	0
	Appearance	Red/orange color	5.96	1.01	7.2	3.4	3
		Brown color	2.85	0.68	4.2	1.8	0
		Blotchiness	2.37	1.23	4.8	0.1	2
		Glossiness	6.18	0.83	8.4	4.8	8
	Basic taste	Bitter	0.92	0.95	2.82	0.1	0
		Salty	3.28	0.81	5	2.2	0
		Sour	0.82	0.77	2.24	0.1	0
		Sweet	5.19	0.77	6	3.8	0
	Aftertaste	Iodine	3.81	0.81	5	2.4	0
	Mouthfeel	Sliminess	1.82	0.74	3.4	1.02	0
	Texture	Firmness	6.20	0.77	7.2	4	8
		Juiciness	4.66	0.64	5.4	3.6	0
		Chewiness	5.15	0.69	6.2	4.2	0
		Crispness	4.44	0.77	5.7	3	3
		Fibrous	5.33	0.59	6.4	4.4	0

Samples were taken from 13th August until ponds were harvested, and changes in sensory attributes of shrimp were observed over time in all five ponds (see Appendix D).

In pond N4, glossiness of cooked meat initially increased, but it then decreased at harvest time. The fibrous quality of meat also increased initially but then declined considerably by harvest time.

In pond N5, the ocean/seawater trait of raw shrimp, the red/orange color, salty, and juiciness of cooked shrimp fluctuated over growing season. Stripe darkness and blotchiness of raw shrimp fluctuated and decreased considerable at harvest time.

In pond N6, the ocean/seawater aroma trait of raw shrimp decreased for the first few weeks, but increased near harvest. Blotchiness of both raw and cooked shrimp tended to increase until harvest. There were fluctuations in shrimp aroma, red/orange color, and chewiness of cooked shrimp.

The most changes in attributes over time were observed in ponds N7 and N8. In pond N7, there were fluctuations in ocean/seawater aroma, plumpness, darkness, stripe darkness of raw shrimp, and in ocean/seawater aroma, old shrimp, iodine, firmness, crispness, and fibrous trait of cooked shrimp. Shrimp aroma, red/orange color, blotchiness of cooked shrimp fluctuated but increase over time while bitter attribute decreased. In pond N8, shrimp aroma, and darkness of raw shrimp, and old shrimp aroma, red/orange color, brown meat color, bitter taste, sliminess, and chewiness of cooked shrimp fluctuated during the sampling period.

Despite of the high abundance of blue-green algae, off-flavor caused by geosmin or MIB was not observed in any for the shrimp from Greene Prairie Aquafarm. Of course, earlier studies on channel catfish have reported that the presence of a high density of blue-green algae does not always cause off-flavor (Boyd and Tucker 1998).

VARIATION AMONG ORIGINS OF SHRIMP

A nested design model was used to explore differences associated with origin (source) of shrimp. The sources of variation in the model were: source (Greene Prairie Aquafarm, Claude Peteet Mariculture Center, Harlingen Shrimp Farm, Sunrise Capital Shrimp Farm and supermarkets) and pond (ponds nested within source). In each pond, the five shrimp tested were considered as replications. The design was unbalanced because the number of ponds in each source was different. If a difference was indicated by the F-test, then Tukey' test that was utilized to further explore what the differences were.

Supermarket shrimp has less color in shell and meat (brown color, darkness and stripe darkness) and less blotchiness and glossiness than shrimp from other sources. Shrimp from the three farms (Greene Prairie Aquafarm, Harlingen Shrimp Farm, and Sunrise Capital Shrimp Farm) were almost identical in appearance, but shrimp from the Claude Peteet Mariculture Center had less blotchiness than shrimp from these farms.

In terms of taste, shrimps bought in the supermarket were inferior to shrimp from other sources. For instance, they were less sweet and more bitter than the others. There were few significant differences in texture attributes (chewiness and fibrous). Shrimp from the farm in Hawaii had the highest score in chewiness, followed by shrimp from West Alabama, Gulf Shores, supermarkets, and Harlingen, respectively. In the fibrous trait, shrimp from Hawaii also had the highest score, and for this feature they were different to shrimp from all sources.

To provide an overall assessment of the panel's opinion of shrimp from the different sources, each characteristic evaluated in sensory tests was assigned a weighting

factor. The weighting factors (-1, 0, 0.5, 1, and 2) were decided upon by the degree to which individual traits were thought to contribute to overall approval by the panelists (Table 5). Some attributes (brown color, darkness, stripe darkness in raw shrimp and brown color, in cooked shrimp) were considered to be neutral (weighting factor = 0), because these features are used for describe shrimp appearance and probably do not make people feel good or bad about shrimp. Among sensory attributes evaluated, sweet and salty tastes were considered to be the most important ones, and a weighting factor of 2 was assigned.

Table 5. Weighting factors for each sensory attribute considered in shrimp taste tests

	Attribute class	Sensory attribute	Weighting factor
Raw shrimp	Aroma	Ocean/seawater	1
		Shrimp	1
		Old shrimp	-1
	Meat appearance	Plumpness	1
		Brown color	0
	Shell appearance	Darkness	0
		Stripe darkness	0
		Blotchiness	-1
		Glossiness	0.5
		Tail iridescence	0.5
Cooked shrimp	Aroma	Ocean/seawater	1
		Cooked shrimp	1
		Old shrimp	-1
	Appearance	Red/orange color	0.5
		Brown color	0
		Blotchiness	-1
		Glossiness	0.5
	Basic taste	Bitter	-1
		Salty	2
		Sour	-1
		Sweet	2
	Aftertaste	Iodine	-1
	Mouthfeel	Sliminess	-1
	Texture	Firmness	1
		Juiciness	1
		Chewiness	1
		Crispness	1
		Fibrous	-1

The score for each attribute was multiplied by its weighting factor, and the resulting products were summed. The sums for each sample were averaged to generate one score for each shrimp source (West Alabama, Gulf Shores, Harlingen, Hawaii, and supermarket) (Table 6). Shrimps from Hawaii had the highest acceptability score, followed by West Alabama, Gulf Shores, and Harlingen. Supermarket shrimp had the lowest score.

Table 6. Acceptance score of shrimp from West Alabama, Gulf Shores, Harlingen, Hawaii, and supermarket.

	Source				
	West Alabama	Gulf Shores	Harlingen	Hawaii	Supermarket
Acceptability scores	10.09	10.08	9.61	12.16	9.34

In summary, there were considerable differences both within individual ponds and among ponds for some attributes of both raw and cooked shrimp from 13 August until harvest 5 to 9 weeks later at Greene Prairie Aquafarm. Both the appearance, taste, and other sensory attributes of shrimp harvested from different ponds on the farm can be expected to vary. However, no relationship was observed among sensory attributes and salinity or other water quality variables. Despite ponds having a high abundance of blue-green algae, none of the samples exhibited off-flavor characteristics of geosmin or methylisoborneol.

Shrimps from ponds with salinities of 2-24 ppt had some differences in appearance and texture but not in taste. The panelists expressed the greatest overall satisfaction for the shrimp that were reared in full-strength seawater (≈ 35 ppt) at the Sunrise Capital Shrimp Farm. Shrimp from supermarkets were considered by the panelists to have inferior taste as compared to shrimp from the farms and the research

station. However, it should be mentioned that shrimp from the supermarket were labeled as farmed shrimp.

Conclusion:

Under the reported conditions, shrimp flavor varied among ponds of the same farm and changed over the growing season in individual ponds. Flavor of shrimp raised in low salinity water (2-3 ppt) was similar to that of shrimp cultured in brackish water (10-24 ppt). However, the taste panel found that shrimp from a pond with full-strength seawater had the best flavor. In this study, imported, farmed shrimp purchased in the supermarket was given lower score as compare to those from domestic farms. However, methods of preserving, transporting and processing shrimp may have negatively affected flavor of shrimp from supermarket. Base on the report results, the differences in flavor and texture were found to shift with time and to certain extent culture (salinity) but all shrimp at the acceptable quality.

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APPENDICES

APPENDIX A

Plumpness and blotchiness references for sensory test

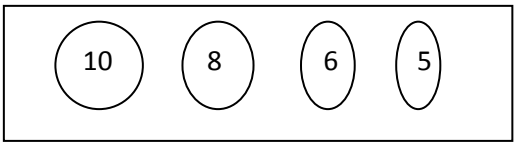
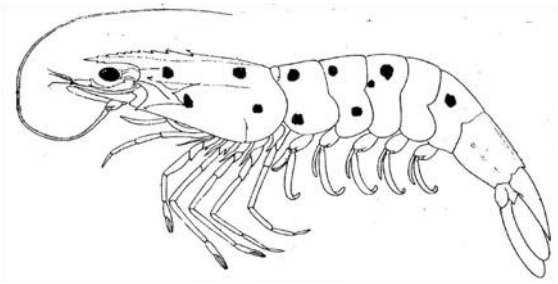


Figure A1. Plumpness



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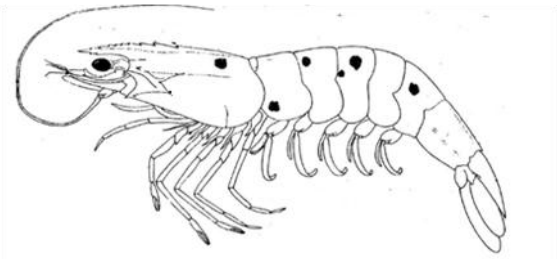

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Figure A2. Blotchiness

APPENDIX B

Statistical tables for sensory scores of shrimp from five ponds (N4, N5, N6, N7, N8) at Greene Prairie Aquafarm in West Alabama on different sampling dates

Table B1. The first sampling (August 13th, 2011)

Attribute class	Sensory attribute	Pond				
		N4	N5	N6	N7	N8
Raw shrimp						
Aroma	**Ocean/seawater**	**5.8 ab**	**5.6 ab**	**7.6 a**	**3.4 b**	**4.2 b**
	Shrimp	**6.4 a**	**6.2 a**	**6.0 a**	**4.2 ab**	**2.8 b**
	Old shrimp	2.42 a	1.4 a	1.6 a	2.6 a	2.4 a
Meat appearance	**Plumpness**	**8.6 a**	**8.3 a**	**7.6 ab**	**7.4 ab**	**6.1 b**
	Brown color	3.4 a	3.8 a	4.2 a	4.2 a	3.8 a
Shell appearance	Darkness	3.6 a	3. 6 a	3.4 a	3.4 a	2.0 a
	Stripe darkness	**3.5 b**	**2.9 b**	**4.0 ab**	**6.4 a**	**5.2 ab**
	Blotchiness	2.42 a	2.62 a	2.0 a	2.0 a	2.2 a
	Glossiness	7.8 a	7.2 a	7.0 a	6.0 a	7.6 a
	Tail iridescence	4.6 a	4.9 a	4.8 a	1.24 a	3.0 a
Cooked shrimp						
Aroma	Ocean/seawater	5.0 a	4.8 a	5.2 a	5.0 a	5.0 a
	Cooked shrimp	5.6 a	5.4 a	5.4 a	4.6 a	5.2 a
	Old shrimp	1.8 a	2.8 a	1.8 a	2.22 a	2.22 a
	Red/orange color	3.4 a	3.0 a	4.8 a	3.2 a	5.4 a
Appearance	Brown color	3.0 a	2.8 a	3.6 a	1.64 a	1.24 a
	Blotchiness	0.46 a	0.46 a	1.02 a	2.12 a	2.04 a
	Glossiness	4.6 a	4.6 a	5.2a	6.8 a	6.4 a
Basic taste	Bitter	2.6 a	0.84 a	2.8 a	3.24 a	4.24 a
	Salty	3.0 a	3.4 a	3.4 a	3.2 a	3.8 a
	Sour	2.2 a	1.02 a	1.02 a	2.64 a	1.06 a
	Sweet	4.8 a	4.8 a	4.4 a	6.2 a	5.2 a
Aftertaste	Iodine	2.6 a	3.6 a	3.6 a	3.8 a	4.2 a
Mouthfeel	**Sliminess**	**1.24 ab**	**1.24 ab**	**1.04 b**	**3.2 a**	**2.4 ab**
Texture	Firmness	6.2 a	5.4 a	6.6 a	7.2 a	7.2 a
	Juiciness	4.6 a	4.0 a	4.4 a	5.2 a	5.2 a
	Chewiness	**4.4 b**	**5.0 ab**	**4.6 ab**	**6.0 ab**	**6.4 a**
	Crispness	5.0 a	4.8 a	4.6 a	4.2 a	4.0 a
	Fibrous	4.2 a	5.0 a	5.2 a	5.6 a	5.8 a

Noted: Means within the same row not followed by the same letters are significantly different ($P \leq 0.05$)

Table B2. The second sampling (August 20th, 2011)

Attribute class	Sensory attribute	Pond				
		N4	N5	N6	N7	N8
Raw shrimp						
Aroma	Ocean/seawater	6.0 a	6.4 a	5.6 a	7.0 a	6.8 a
	Shrimp	6.4 a	5.8 a	4.8 a	4.4 a	4.4 a
	Old shrimp	2.4 a	1.62 a	2.8 a	2.62 a	2.04 a
Meat appearance	Plumpness	**7.6 a**	**7.6 a**	**7.4 a**	**5.0 b**	**6.2 ab**
	Brown color	3.2 a	4.2 a	4.4 a	2.3 a	3.6 a
Shell appearance	Darkness	4.8 a	4.8 a	5.4 a	3.8 a	3.6 a
	Stripe darkness	5.6 a	5.2 a	3.4 a	3.4 a	4.9 a
	Blotchiness	3.5 a	4.0 a	3.2 a	3.0 a	4.4 a
	Glossiness	6.2 a	7.2 a	7.0 a	6.8 a	7.2 a
	Tail iridescence	5.6 a	5.2 a	3.44 a	3.04 a	5.2 a
Cooked shrimp						
Aroma	Ocean/seawater	7.6 a	6.0 a	6.4 a	7.0 a	7.6 a
	Cooked shrimp	**7.6 a**	**5.6 ab**	**4.4 b**	**4.0 b**	**6.2 ab**
	Old shrimp	3.0 a	3.8 a	3.42 a	3.8 a	3.4 a
	Red/orange color	3.6 a	3.0 a	4.4 a	4.0 a	3.2 a
Appearance	Brown color	3.6 a	4.0 a	2.2 a	2.4 a	3.6 a
	Blotchiness	3.42 a	2.24 a	0.84 a	0.46 a	3.02 a
	Glossiness	**7.2 a**	**6.6 abc**	**4.8 bc**	**4.6 c**	**7.0 ab**
Basic taste	Bitter	1.8 a	3.82 a	1.06 a	1.44 a	1.62 a
	Salty	3.8 a	3.4 a	3.8 a	3.2 a	2.6 a
	Sour	1.06 a	1.26 a	1.04 a	0.86 a	0.86 a
	Sweet	**5.8 a**	**4.8 ab**	**3.2 b**	**4.6 ab**	**5.2 ab**
Aftertaste	Iodine	3.8 a	5.4 a	4.4 a	3.6 a	4.8 a
Mouthfeel	Sliminess	2.82 a	3.22 a	1.82 a	2.64 a	4.82 a
Texture	Firmness	6.6 a	5.6 a	5.2 a	5.8 a	5.2 a
	Juiciness	4.4 a	3.8 a	4.4 a	4.0 a	3.6 a
	Chewiness	4.4 a	4.4 a	3.4 a	3.8 a	3.2 a
	Crispness	4.4 a	4.2 a	3.4 a	2.6 a	3.0 a
	Fibrous	**6.4 a**	**6.0 a**	**3.4 bc**	**2.8 c**	**5.4 ab**

Noted: Means within the same row not followed by the same letters are significantly different ($P \leq 0.05$)

Table B3. The third sampling (August 27th, 2011)

Attribute class	Sensory attribute	Pond				
		N4	N5	N6	N7	N8
Raw shrimp						
Aroma	Ocean/seawater	6.8 a	5.4 a	6.0 a	5.8 a	4.8 a
	Shrimp	5.2 a	7.4 a	7.4 a	6.0 a	5.0 a
	Old shrimp	1.4 a	1.64 a	1.64 a	2.0 a	1.02 a
Meat appearance	**Plumpness**	**7.6 ab**	**8.5 a**	**7.5 ab**	**6.0 b**	**7.7 a**
	Brown color	3.2 a	4.4 a	4.2 a	4.2 a	2.6 a
Shell appearance	Darkness	3.4 a	5.0 a	4.9 a	5.8 a	2.6 a
	Stripe darkness	**3.8 ab**	**5.5 ab**	**5.8 a**	**6.6 a**	**1.8 b**
	Blotchiness	4.8 a	2.62 a	2.42 a	4.0 a	2.64 a
	Glossiness	7.2 a	8.0 a	7.8 a	6.8 a	6.0 a
	Tail iridescence	3.8 a	6.2 a	5.6 a	4.62 a	3.42 a
Cooked shrimp						
Aroma	Ocean/seawater	7.8 a	7.0 a	6.0 a	6.0 a	5.8 a
	Cooked shrimp	5.4 a	7.4 a	6.2 a	6.0 a	5.6 a
	Old shrimp	2.6 a	2.2 a	2.02 a	2.2 a	1.44 a
	Red/orange color	3.8 a	4.8 a	5.4 a	4.2 a	3.0 a
Appearance	Brown color	1.9 a	3.3 a	3.4 a	3.6 a	3.2 a
	Blotchiness	0.84 a	3.0 a	2.14 a	2.02 a	2.02 a
	Glossiness	5.0 a	6.2 a	6.6 a	6.6 a	6.4 a
Basic taste	Bitter	2.62 a	1.64 a	1.42 a	1.64 a	2.62 a
	Salty	3.4 a	3.2 a	2.8 a	3.0 a	2.4 a
	Sour	1.46 a	1.64 a	1.44 a	1.24 a	0.86 a
	Sweet	4.0 a	5.4 a	5.0 a	4.8 a	4.4 a
Aftertaste	Iodine	4.2 a	3.2 a	3.0 a	4.0 a	3.0 a
Mouthfeel	Sliminess	1.24 a	2.82 a	2.22 a	3.62 a	1.26 a
Texture	Firmness	7.0 a	6.0 a	5.4 a	4.8 a	6.2 a
	Juiciness	4.4 a	5.0 a	4.0 a	4.2 a	5.0 a
	Chewiness	5.4 a	4.4 a	5.0 a	4.2 a	5.0 a
	Crispness	4.6 a	5.4 a	5.4 a	4.0 a	5.0 a
	Fibrous	**6.8 a**	**5.2 ab**	**5.6 ab**	**5.2 ab**	**2.82 b**

Noted: Means within the same row not followed by the same letters are significantly different ($P \leq 0.05$)

Table B4. The fourth sampling (Sep 3rd, 2011)

Attribute class	Sensory attribute	Pond				
		N4	N5	N6	N7	N8
Raw shrimp						
Aroma	Ocean/seawater	5.6 a	5.0 a	5.4 a	5.4 a	6.8 a
	Shrimp	7.2 a	5.2 a	6.0 a	5.6 a	6.6 a
	Old shrimp	0.84 a	1.64 a	0.68 a	0.66 a	1.02 a
Meat appearance	Plumpness	7.6 a	7.3 a	6.3 a	7.9 a	7.8 a
	Brown color	3.0 a	3.2 a	3.2 a	3.4 a	3.0 a
Shell appearance	Darkness	5.0 a	5.2 a	5.4 a	4.2 a	4.4 a
	Stripe darkness	4.0 a	5.3 a	5.4 a	4.2 a	3.3 a
	Blotchiness	2.02 a	4.0 a	3.6 a	3.4 a	3.8 a
	Glossiness	6.8 a	5.8 a	5.8 a	6.6 a	6.8 a
	Tail iridescence	2.04 a	4.2 a	3.82 a	3.62 a	2.44 a
Cooked shrimp						
Aroma	Ocean/seawater	7.2 a	6.7 a	5.4 a	5.2 a	6.4 a
	Cooked shrimp	5.0 a	6.0 a	5.2 a	4.8 a	5.0 a
	Old shrimp	0.86 a	1.4 a	1.0 a	1.04 a	1.06 a
	Red/orange color	4.2 a	3.4 a	4.2 a	3.2 a	2.8 a
Appearance	Brown color	3.02 a	2.4 a	2.4 a	2.0 a	2.8 a
	Blotchiness	2.8 a	2.8 a	2.4 a	2.42 a	3.02 a
	Glossiness	6.4 a	5.4 a	6.0 a	6.0 a	5.8 a
Basic taste	Bitter	2.84 a	0.68 a	1.06 a	0.68 a	1.84 a
	Salty	3.4 a	1.8 a	1.8 a	2.8 a	2.4 a
	Sour	0.86 a	1.82 a	1.82 a	0.86 a	0.86 a
	Sweet	4.0 a	5.4 a	5.0 a	5.4 a	4.0 a
Aftertaste	Iodine	3.6 a	2.8 a	3.6 a	2.2 a	3.22 a
Mouthfeel	Sliminess	1.36 a	1.66 a	1.84 a	1.84 a	1.24 a
Texture	Firmness	6.4 a	5.6 a	6.2 a	5.8 a	5.6 a
	Juiciness	5.0 a	4.4 a	4.0 a	4.2 a	4.8 a
	Chewiness	5.8 a	4.2 a	3.8 a	4.6 a	5.4 a
	Crispness	4.6 a	3.6 a	4.8 a	5.0 a	3.8 a
	Fibrous	3.4 a	5.4 a	5.2 a	5.4 a	2.64 a

Noted: Means within the same row not followed by the same letters are significantly different ($P \leq 0.05$)

Table B5. The fifth sampling (Sep 10th, 2011)

Attribute class	Sensory attribute	Pond				
		N4	N5	N6	N7	N8
Raw shrimp						
Aroma	Ocean/seawater	8.2 a	5.8 a	5.4 a	7.9 a	5.8 a
	Shrimp	7.4 a	6.8 a	6.2 a	7.0 a	6.0 a
	Old shrimp	0.82 a	1.66 a	1.66 a	0.84 a	1.46 a
Meat appearance	**Plumpness**	**8.5 a**	**7.5 ab**	**6.8 b**	**7.0 ab**	**6.4 b**
	Brown color	3.0 a	3.2 a	3.0 a	2.0 a	2.6 a
Shell appearance	Darkness	3.2 a	5.2 a	4.7 a	3.4 a	4.1 a
	Stripe darkness	4.4 a	5.1 a	5.2 a	4.2 a	4.1 a
	Blotchiness	4.2 a	2.7 a	4.62 a	2.6 a	4.0 a
	Glossiness	7.4 a	7.2 a	6.6 a	7.2 a	7.4 a
	Tail iridescence	2.02 a	2.72 a	3.22 a	3.4 a	3.02 a
Cooked shrimp						
Aroma	Ocean/seawater	7.6 a	6.6 a	6.8 a	6.8 a	7.2 a
	Cooked shrimp	7.0 a	7.4 a	7.2 a	5.8 a	8.4 a
	Old shrimp	1.8 a	2.62 a	2.64 a	1.4 a	2.44 a
	Red/orange color	5.6 a	4.3 a	3.4 a	5.7 a	5.2 a
Appearance	Brown color	2.4 a	4.2 a	4.2 a	3.2 a	3.02 a
	Blotchiness	4.2 a	3.04 a	2.24 a	2.12 a	2.02 a
	Glossiness	7.0 a	6.6 a	6.2 a	6.8 a	6.8 a
Basic taste	Bitter	1.22 a	2.66 a	2.46 a	0.46 a	2.06 a
	Salty	**2.6 ab**	**4.6 a**	**4.0 ab**	**1.8 b**	**4.2 ab**
	Sour	0.84 a	2.66 a	2.26 a	0.46 a	1.86 a
	Sweet	6.0 a	5.4 a	5.4 a	5.4 a	4.6 a
Aftertaste	Iodine	6.0 a	5.2 a	5.2 a	6.3 a	5.0 a
Mouthfeel	Sliminess	1.04 a	1.84 a	1.66 a	2.62 a	1.44 a
Texture	Firmness	6.4 a	6.6 a	5.8 a	7.2 a	6.6 a
	Juiciness	5.2 a	4.0 a	4.2 a	5.6 a	4.2 a
	Chewiness	6.1 a	5.4 a	5.2 a	5.2 a	5.2 a
	Crispness	4.8 a	4.6 a	5.6 a	4.6 a	5.0 a
	Fibrous	6.8 a	5.6 a	5.2 a	6.3 a	6.4 a

Noted: Means within the same row not followed by the same letters are significantly different ($P \leq 0.05$)

APPENDIX C

Statistical tables for sensory scores of shrimp from 16 ponds from Greene Prairie Aquafarm in West Alabama

Raw shrimp

Attribute class	Sensory attribute	Pond															
		N1	N2	N3	N4	N5	N6	N7	N8	N9	S2	S3	S4	S5	S6	S7	S8
Aroma	Ocean/ seawater	6.0a	6.6a	7.0a	6.0a	5.8a	7.0a	7.0a	5.8a	6.2a	5.2a	7.6	6.8a	4.8a	6.6a	5.4a	7.2a
	Shrimp	6.6a	6.6a	6.4a	6.2a	5.6a	8.0a	6.6a	6.0a	6.8a	5.4a	7.8a	6.8a	5.8a	7.2a	5.6a	7.6a
	Old shrimp	2.0a	1.82a	2.6a	0.46a	1.0a	1.4a	0.5a	2.8a	0.3a	0.8a	1.2a	2.2a	1.6a	1.4a	2.4a	2.4a
Meat appearance	**Plumpness**	**7.8ab**	**6.3b**	**6.5ab**	**7.8ab**	**7.0ab**	**7.6ab**	**8.0ab**	**8.0ab**	**7.6ab**	**8.5a**	**8.6a**	**8.3 ab**	**7.6ab**	**7.2ab**	**7.8ab**	**8.2ab**
	Brown color	3.2a	4.0a	3.8a	5.0a	2.2a	3.4a	3.8a	2.4a	4.0a	2.8a	2.6a	4.6 a	3.6a	3.0a	4.0a	3.0a
Shell appearance	**Darkness**	**5.2abc**	**6.4a**	**6.2ab**	**4.0abc**	**3.4bc**	**3.9abc**	**3.8abc**	**5.2abc**	**4.4abc**	**4.2abc**	**6.0ab**	**5.2abc**	**3.0c**	**5.8abc**	**4.0abc**	**5.2abc**
	Stripe darkness	**4.9ab**	**7.0a**	**6.4a**	**5.4a**	**2.2b**	**7.0a**	**4.6ab**	**5.0ab**	**5.2ab**	**4.6ab**	**6.4a**	**5.2 ab**	**2.7b**	**6.4a**	**3.8ab**	**6.2a**
	Blotchiness	**3.4ab**	**3.8ab**	**3.0ab**	**3.2ab**	**1.0b**	**6.2a**	**3.0ab**	**5.0ab**	**3.2ab**	**3.2ab**	**2.8ab**	**5.0 ab**	**4.8ab**	**4.2a**	**5.0ab**	**2.8ab**
	Glossiness	6.8a	6.6a	6.6a	7.4a	6.8a	7.2a	7.4a	6.4a	7.8a	6.2a	7.4a	6.2 a	5.8a	7.4a	7.2a	7.4a
	Tail iridescence	6.4a	4.0a	5.2a	3.4a	4.6a	5.0a	3.4a	5.4a	2.8a	3.6a	4.4a	3.82a	4.8a	5.0a	3.4a	4.0a

Noted: Means within the same row not followed by the same letters are significantly different ($P \leq 0.05$)

Cooked shrimp

Attribute class	Sensory attribute	Pond															
		N1	N2	N3	N4	N5	N6	N7	N8	N9	S2	S3	S4	S5	S6	S7	S8
Aroma	**Ocean/ seawater**	**6.4ab**	**6.0ab**	**5.2b**	**5.2b**	**5.2b**	**7.0ab**	**6.8ab**	**6.0ab**	**6.2ab**	**5.0b**	**8.0a**	**6.8ab**	**6.7ab**	**7.0ab**	**6.0ab**	**6.2ab**
	Cooked shrimp	6.8a	7.2a	6.6a	6.2a	4.2a	7.8a	6.8a	4.8a	6.8a	4.6a	8.4a	7.2 a	5.8a	8.2a	7.4a	7.4a
	Old shrimp	1.62a	1.22a	2.62a	1.2a	1.4a	0.9a	0.7a	1.6a	1.1a	1.2a	1.2a	3.4a	1.8a	1.0a	1.4a	3.0a
	Red/orange color	**6.0ab**	**6.2ab**	**5.6ab**	**4.6ab**	**5.6ab**	**6.6ab**	**7.2a**	**6.4ab**	**7.2a**	**7.0a**	**6.6ab**	**4.8ab**	**3.4b**	**6.0ab**	**6.2ab**	**6.0ab**
Appearance	Brown color	3.2a	2.0a	2.0a	3.4a	3.2a	4.2a	2.2a	3.2a	2.6a	3.4a	3.2a	3.4 a	1.8a	2.0a	2.8a	3.0a
	Blotchiness	**1.7ab**	**1.46ab**	**0.1b**	**2.2ab**	**2.4ab**	**4.8a**	**3.6ab**	**4.4a**	**2.2ab**	**3.8ab**	**1.2ab**	**1.8ab**	**2.0ab**	**2.4ab**	**2.0ab**	**1.6ab**
	Glossiness	**6.2ab**	**5.4b**	**4.8b**	**6.4ab**	**6.4ab**	**6.2ab**	**6.8ab**	**6.0ab**	**6.8ab**	**5.8ab**	**8.4a**	**5.8ab**	**5.0b**	**6.6ab**	**6.0ab**	**6.2ab**
Basic taste	Bitter	2.24a	1.84a	2.64a	0.1a	0.7a	0.3a	0.1a	0.9a	0.3a	0.8a	0.1a	0.28a	1.3a	0.1a	2.8a	0.3a
	Salty	4.4a	5.0a	4.0a	2.8a	3.2a	3.4a	2.6a	2.8a	2.6a	2.8a	3.8a	4.0 a	3.8a	2.2a	2.6a	2.4a
	Sour	2.24a	2.04a	1.64a	0.1a	1.2a	0.5a	0.1a	1.4a	0.1a	1.1a	0.1a	0.1 a	1.1 a	0.1a	1.3a	0.1a
	Sweet	4.0a	4.8a	5.0a	5.6a	6.0a	5.8a	4.4a	5.8a	4.4a	6.0a	6.0a	6.0 a	4.6a	5.6a	3.8a	5.2a
Aftertaste	Iodine	4.4a	4.6a	4.4a	4.4a	3.2a	5.0a	2.8a	2.4a	3.6a	2.4a	4.2a	3.8 a	4.2a	3.8a	4.6a	3.2a
Mouth feel	Sliminess	3.4 a	1.6a	2.6a	1.2a	1.4a	1.2a	1.0a	1.62a	1.3a	1.2a	1.82a	2.6 a	2.4a	1.2a	3.0a	1.4a

Noted: Means within the same row not followed by the same letters are significantly different ($P \leq 0.05$)

Cooked shrimp

Attribute class	Sensory attribute	Pond															
		N1	N2	N3	N4	N5	N6	N7	N8	N9	S2	S3	S4	S5	S6	S7	S8
Texture	**Firmness**	**5.2ab**	**6.0ab**	**4.0b**	**6.6a**	**6.6a**	**6.6a**	**6.4a**	**6.4a**	**6.2ab**	**6.0ab**	**7.2a**	**5.8 ab**	**6.8a**	**6.8a**	**6.8a**	**5.8ab**
	Juiciness	4.4a	4.4a	4.4a	4.6ab	5.4a	5.4a	4.8a	5.2a	5.4a	5.2a	4.2a	3.6 a	5.0a	5.2a	3.8a	3.6a
	Chewiness	4.8a	4.4a	4.2a	5.4a	4.6a	6.2a	5.6a	5.8a	5.8a	5.0a	6.2a	4.6 a	5.2a	5.8a	4.6a	4.2a
	Crispness	**4.4abc**	**5.4ab**	**3.6abc**	**4.2abc**	**4.8abc**	**5.0abc**	**3.8abc**	**4.2abc**	**3.2bc**	**3.0c**	**4.4abc**	**5.2abc**	**5.7a**	**4.8abc**	**5.0abc**	**4.4abc**
	Fibrous	4.8a	5.0a	5.2a	5.2a	6.0a	5.6a	4.8a	6.4a	4.4a	5.2a	6.4a	5.2a	5.9a	4.6a	5.2a	5.4a

Noted: Means within the same row not followed by the same letters are significantly different ($P \leq 0.05$)

APPENDIX D

Statistical tables for sensory score of each pond (N4-N8) in West Alabama farm over time

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Table D1. Statistical table for sensory score of pond N4 over time

Raw shrimp							
Attribute class	Sensory attribute	Time					
		week 0	week 1	week 2	week 3	week 4	HV
Aroma	Ocean/seawater	5.8 a	6.0 a	6.8 a	5.6 a	8.2 a	6.0 a
	Shrimp	6.4 a	6.4 a	5.2 a	7.2 a	7.4 a	6.2 a
	Old shrimp	2.42 a	2.4 a	1.4 a	0.84 a	0.82 a	0.46 a
Meat appearance	Plumpness	8.6 a	7.6 a	7.6 a	7.6 a	8.5 a	7.8 a
	Brown color	3.4 a	3.2 a	3.2 a	3.0 a	3.0 a	5.0 a
Shell appearance	Darkness	3.6 a	4.8 a	3.4 a	5.0 a	3.2 a	4.0 a
	Stripe darkness	3.5 a	5.6 a	3.8 a	4.0 a	4.4 a	5.4 a
	Blotchiness	2.42 a	3.5 a	4.8 a	2.02 a	4.2 a	3.22 a
	Glossiness	7.8 a	6.2 a	7.2 a	6.8 a	7.4 a	7.4 a
	Tail iridescence	4.6 a	5.6 a	3.8 a	2.04 a	2.02 a	3.42 a
Cooked shrimp							
Aroma	Ocean/seawater	5.0 a	7.6 a	7.8 a	7.2 a	7.6 a	5.2 a
	Cooked shrimp	5.6 a	7.6 a	5.4 a	5.0 a	7.0 a	6.2 a
	Old shrimp	1.8 a	3.0 a	2.6 a	0.86 a	1.8 a	1.22 a
Appearance	Red/orange color	3.4 a	3.6 a	3.8 a	4.2 a	5.6 a	4.6 a
	Brown color	3.0 a	3.6 a	1.9 a	3.02 a	2.4 a	3.4 a
	Blotchiness	0.46 a	3.42 a	0.84 a	2.8 a	4.2 a	2.24 a
	Glossiness	**4.6 b**	**7.2 a**	**5.0 ab**	**6.4 ab**	**7.0 a**	**6.4 ab**
Basic taste	Bitter	2.6 a	1.8 a	2.62 a	2.84 a	1.22 a	0.1 a
	Salty	3.0 a	3.8 a	3.4 a	3.4 a	2.6 a	2.82 a
	Sour	2.2 a	1.06 a	1.46 a	0.86 a	0.84 a	0.1 a
	Sweet	4.8 a	5.8 a	4.0 a	4.0 a	6.0 a	5.6 a
Aftertaste	Iodine	2.6 a	3.8 a	4.2 a	3.6 a	6.0 a	4.4 a
Mouth feel	Sliminess	1.24 a	2.82 a	1.24 a	1.36 a	1.04 a	1.22 a
Texture	Firmness	6.2 a	6.6 a	7.0 a	6.4 a	6.4 a	6.6 a
	Juiciness	4.6 a	4.4 a	4.4 a	5.0 a	5.2 a	4.6 a
	Chewiness	4.4 a	4.4 a	5.4 a	5.8 a	6.1 a	5.4 a
	Crispness	5.0 a	4.4 a	4.6 a	4.6 a	4.8 a	4.2 a
	Fibrous	**4.2 ab**	**6.4 ab**	**6.8 a**	**3.4 b**	**6.8 a**	**5.2 ab**

Noted: Means within the same row not followed by the same letters are significantly different ($P \leq 0.05$)

Table D2. Statistical table for sensory score of pond N5 over time

Raw shrimp

Attribute class	Sensory attribute	Time								
		week 0	week 1	week 2	week 3	week 4	week 5	week 6	week 7	HV
Aroma	**Ocean/seawater**	**5.6 ab**	**6.4 ab**	**5.4 ab**	**5.0 ab**	**5.8 ab**	**8.0 a**	**5.6 ab**	**4.4 b**	**5.8 ab**
	Shrimp	6.2 a	5.8 a	7.4 a	5.2 a	6.8 a	7.0 a	6.0 a	5.8 a	5.6 a
	Old shrimp	1.4 a	1.62 a	1.64 a	1.64 a	1.66 a	0.84 a	1.44 a	2.4 a	1.0 a
Meat appearance	Plumpness	8.3 a	7.6 a	8.5 a	7.3 a	7.5 a	8.6 a	7.8 a	7.8 a	7.0 a
	Brown color	3.8 a	4.2 a	4.4 a	3.2 a	3.2 a	3.4 a	2.2 a	3.4 a	2.2 a
Shell appearance	Darkness	3.6 a	4.8 a	5.0 a	5.2 a	5.2 a	4.6 a	3.7 a	4.2 a	3.4 a
	Stripe darkness	**2.9 ab**	**5.2 a**	**5.5 a**	**5.3 a**	**5.1 ab**	**3.6 ab**	**4.3 ab**	**4.3 ab**	**2.2 b**
	Blotchiness	**2.62 ab**	**4.0 ab**	**2.62 ab**	**4.0 ab**	**2.7 ab**	**4.2 ab**	**3.9 ab**	**6.8 a**	**1.04 b**
	Glossiness	7.2 a	7.2 a	8.0 a	5.8 a	7.2 a	7.6 a	7.0 a	7.2 a	6.8 a
	Tail iridescence	4.9 a	5.2 a	6.2 a	4.2 a	2.72 a	3.42 a	3.62 a	3.8 a	4.6 a

Cooked shrimp

Attribute	Sensory attribute	Time								
		week 0	week 1	week 2	week 3	week 4	week 5	week 6	week 7	HV
Aroma	Ocean/seawater	4.8 a	6.0 a	7.0 a	6.7 a	6.6 a	6.6 a	5.4 a	5.4 a	5.2 a
	Cooked shrimp	5.4 a	5.6 a	7.4 a	6.0 a	7.4 a	6.0 a	6.4 a	4.0 a	4.2 a
	Old shrimp	2.8 a	3.8 a	2.2 a	1.4 a	2.62 a	1.4 a	1.02 a	1.8 a	1.4 a
Appearance	**Red/orange color**	**3.0 b**	**3.0 b**	**4.8 ab**	**3.4 ab**	**4.3 ab**	**6.0 ab**	**5.6 ab**	**6.4 a**	**5.6 ab**
	Brown color	2.8 a	4.0 a	3.3 a	2.4 a	4.2 a	2.0 a	2.6 a	3.2 a	3.2 a
	Blotchiness	0.46 a	2.24 a	3.0 a	2.8 a	3.04 a	4.6 a	2.42 a	2.44 a	2.42 a
	Glossiness	4.6 a	6.6 a	6.2 a	5.4 a	6.6 a	6.6 a	6.0 a	5.6 a	6.4 a
Basic taste	Bitter	0.84 a	3.82 a	1.64 a	0.68 a	2.66 a	1.24 a	1.04 a	2.42 a	0.66 a
	Salty	**3.4 ab**	**3.4 ab**	**3.2 ab**	**1.8 b**	**4.6 a**	**2.2 ab**	**2.6 ab**	**3.2 ab**	**3.2 ab**
	Sour	1.02 a	1.26 a	1.64 a	1.82 a	2.66 a	1.04 a	0.46 a	2.24 a	1.24 a
	Sweet	4.8 a	4.8 a	5.4 a	5.4 a	5.4 a	5.6 a	5.2 a	5.0 a	6.0 a
Aftertaste	Iodine	3.6 a	5.4 a	3.2 a	2.8 a	5.2 a	6.0 a	4.2 a	5.0 a	3.2 a
Mouth feel	Sliminess	1.24 a	3.22 a	2.82 a	1.66 a	1.84 a	2.84 a	1.64 a	3.8 a	1.42 a
Texture	Firmness	5.4 a	5.6 a	6.0 a	5.6 a	6.6 a	6.8 a	5.8 a	6.0 a	6.6 a
	Juiciness	**4.0 b**	**3.8 b**	**5.0 ab**	**4.4 b**	**4.0 b**	**6.8 a**	**4.6 b**	**4.0 b**	**5.4 ab**
	Chewiness	5.0 a	4.4 a	4.4 a	4.2 a	5.4 a	4.6 a	5.2 a	4.8 a	4.6 a
	Crispness	4.8 a	4.2 a	5.4 a	3.6 a	4.6 a	4.2 a	4.6 a	5.2 a	4.8 a
	Fibrous	5.0 a	6.0 a	5.2 a	5.4 a	5.6 a	6.7 a	5.4 a	5.4 a	6.0 a

Noted: Means within the same row not followed by the same letters are significantly different ($P \leq 0.05$)

Table D3. Statistical table for sensory score of pond N6 over time

Raw shrimp

Attribute class	Sensory attribute	Time									
		week 0	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	HV
Aroma	**Ocean/seawater**	**7.6 a**	**5.6 ab**	**6.0 ab**	**5.4 ab**	**5.4 ab**	**5.2 b**	**6.0 ab**	**6.2 ab**	**6.2 ab**	**7.0 ab**
	Shrimp	6.0 a	4.8 a	7.4 a	6.0 a	6.2 a	6.0 a	6.8 a	7.8 a	5.6 a	8.0 a
	Old shrimp	1.6 a	2.8 a	1.64 a	0.68 a	1.66 a	1.02 a	1.46 a	0.28 a	2.6 a	1.44 a
Meat appearance	Plumpness	7.6 a	7.4 a	7.5 a	6.3 a	6.8 a	6.7 a	8.0 a	8.1 a	7.8 a	7.6 a
	Brown color	4.2 a	4.4 a	4.2 a	3.2 a	3.0 a	2.8 a	2.4 a	3.8 a	3.2 a	3.4 a
Shell appearance	Darkness	3.4 a	5.4 a	4.9 a	5.4 a	4.7 a	5.0 a	4.1 a	5.0 a	3.0 a	3.9 a
	Stripe darkness	4.0 a	3.4 a	5.8 a	5.4 a	5.2 a	5.3 a	4.2 a	6.0 a	4.3 a	7.0 a
	Blotchiness	**2.0 b**	**3.2 ab**	**2.42 ab**	**3.6 ab**	**4.62 ab**	**3.6 ab**	**2.5 ab**	**1.9 b**	**5.0 ab**	**6.2 a**
	Glossiness	7.0 a	7.0 a	7.8 a	5.8 a	6.6 a	7.0 a	7.0 a	7.6 a	7.4 a	7.2 a
	Tail iridescence	4.8 a	3.44 a	5.6 a	3.82 a	3.22 a	4.6 a	3.6 a	4.8 a	5.6 a	5.0 a

Cooked shrimp

Aroma	Ocean/seawater	5.2 a	6.4 a	6.0 a	5.4 a	6.8 a	7.0 a	7.0 a	6.6 a	4.2 a	7.0 a
	Cooked shrimp	**5.4 abc**	**4.4 c**	**6.2 abc**	**5.2 bc**	**7.2 abc**	**8.4 a**	**7.6 ab**	**8.4 a**	**6.4 abc**	**7.8 ab**
	Old shrimp	1.8 a	3.42 a	2.02 a	1.0 a	2.64 a	1.22a	2.0 a	0.46 a	0.84 a	0.86 a
	Red/orange color	**4.8 ab**	**4.4 ab**	**5.4 ab**	**4.2 ab**	**3.4 b**	**4.6 ab**	**6.2 ab**	**7.4 a**	**4.4 ab**	**6.6 ab**
Appearance	Brown color	3.6 a	2.2 a	3.4 a	2.4 a	4.2 a	4.2 a	3.0 a	2.6 a	4.6 a	4.2 a
	Blotchiness	**1.02 b**	**0.84 b**	**2.14 ab**	**2.4 ab**	**2.24 ab**	**2.82 ab**	**3.8 ab**	**1.44 ab**	**4.2 ab**	**4.8 a**
	Glossiness	5.2 a	4.8 a	6.6 a	6.0 a	6.2 a	5.8 a	5.4 a	7.0 a	6.2 a	6.2 a
Basic taste	Bitter	2.8 a	1.06 a	1.42 a	1.06 a	2.46 a	0.88 a	1.44 a	0.1 a	1.64 a	0.28 a
	Salty	3.4 a	3.8 a	2.8 a	1.8 a	4.0 a	3.0 a	3.0 a	2.4 a	2.6 a	3.4 a
	Sour	1.02 a	1.04 a	1.44 a	1.82 a	2.26 a	0.48 a	0.86 a	0.1 a	1.44 a	0.46 a
	Sweet	4.4 a	3.2 a	5.0 a	5.0 a	5.4 a	5.2 a	5.6 a	5.6 a	5.0 a	5.8 a
Aftertaste	Iodine	3.6 a	4.4 a	3.0 a	3.6 a	5.2 a	4.4 a	4.6 a	3.6 a	3.6 a	5.0 a
Mouth feel	Sliminess	1.04 a	1.82 a	2.22 a	1.84 a	1.66 a	0.64 a	1.64 a	0.66 a	1.22 a	1.22 a
Texture	Firmness	6.6 a	5.2 a	5.4 a	6.2 a	5.8 a	7.0 a	6.2 a	6.6 a	7.0 a	6. 6 a
	Juiciness	4.4 a	4.4 a	4.0 a	4.0 a	4.2 a	4.2 a	5.0 a	4.6 a	3.6 a	5.4 a
	Chewiness	**4.6 ab**	**3.4 b**	**5.0 ab**	**3.8 ab**	**5.2 ab**	**4.6 ab**	**5.6 ab**	**6.2 a**	**5.4 ab**	**6.2 a**
	Crispness	4.6 a	3.4 a	5.4 a	4.8 a	5.6 a	4.2 a	4.4 a	4.6 a	5.8 a	5.0 a
	Fibrous	5.2 a	3.4 a	5.6 a	5.2 a	5.2 a	4.4 a	6.0 a	5.6 a	5.2 a	5.6 a

Noted: Means within the same row not followed by the same letters are significantly different ($P \leq 0.05$)

Table D4. Statistical table for sensory score of pond N7 over time

Raw shrimp

Attribute class	Sensory attribute	Time									
		week 0	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	HV
Aroma	**Ocean/seawater**	**3.4 b**	**7.0 a**	**5.8 ab**	**5.4 ab**	**7.9 a**	**5.4 ab**	**5.6 ab**	**6.4 ab**	**6.4 ab**	**7.0 a**
	Shrimp	4.2 a	4.4 a	6.0 a	5.6 a	7.0 a	5.8 a	6.6 a	8.0 a	6.2 a	6.6 a
	Old shrimp	2.6 a	2.62 a	2.0 a	0.66 a	0.84 a	1.22 a	1.26 a	0.28 a	2.2 a	0.46 a
Meat appearance	**Plumpness**	**7.4 ab**	**5.0 c**	**6.0 bc**	**7.9 a**	**7.0 ab**	**6.6 abc**	**7.2 ab**	**7.7 ab**	**7.8 ab**	**8.0 a**
	Brown color	4.2 a	2.3 a	4.2 a	3.4 a	2.0 a	3.2 a	2.0 a	2.0 a	3.2 a	3.8 a
Shell appearance	**Darkness**	**3.4 ab**	**3.8 ab**	**5.8 a**	**4.2 ab**	**3.4 ab**	**3.0 ab**	**4.1 ab**	**4.8 ab**	**2.8 b**	**3.8 ab**
	Stripe darkness	**6.4 a**	**3.4 ab**	**6.6 a**	**4.2 ab**	**4.2 ab**	**3.0 b**	**4.3 ab**	**5.6 ab**	**4.6 ab**	**4.6 ab**
	Blotchiness	2.0 a	3.0 a	4.0 a	3.4 a	2.6 a	4.2 a	2.82 a	2.2 a	4.6 a	3.0 a
	Glossiness	6.0 a	6.8 a	6.8 a	6.6 a	7.2 a	6.4 a	7.2 a	8.0 a	7.4 a	7.4 a
	Tail iridescence	1.24 a	3.04 a	4.62 a	3.62 a	3.4 a	3.6 a	3.42 a	4.8 a	4.0 a	3.42 a
Cooked shrimp											
Aroma	**Ocean/seawater**	**5.0 ab**	**7.0 ab**	**6.0 ab**	**5.2 ab**	**6.8 ab**	**7.2 ab**	**5.8 ab**	**7.4 a**	**4.8 b**	**6.8 ab**
	Cooked shrimp	**4.6 a**	**4.0 b**	**6.0 ab**	**4.8 ab**	**5.8 ab**	**6.2 ab**	**6.8 ab**	**8.0 a**	**7.0 ab**	**6.8 ab**
	Old shrimp	**2.22 ab**	**3.8 a**	**2.2 ab**	**1.04 ab**	**1.4 ab**	**1.8 ab**	**1.6 ab**	**0.66 b**	**2.4 ab**	**0.66 b**
Appearance	**Red/orange color**	**3.2 b**	**4.0 ab**	**4.2 ab**	**3.2 b**	**5.7 ab**	**4.0 ab**	**6.8 a**	**6.0 ab**	**5.4 ab**	**7.2 a**
	Brown color	1.64 a	2.4 a	3.6 a	2.0 a	3.2 a	3.6 a	3.2 a	1.4 a	4.2 a	2.22 a
	Blotchiness	**2.12 ab**	**0.46 b**	**2.02 ab**	**2.42 ab**	**2.12 ab**	**4.2 a**	**2.8 ab**	**2.22 ab**	**4.4 a**	**3.62 ab**
	Glossiness	6.8 a	4.6 a	6.6 a	6.0 a	6.8 a	5.2 a	5.0 a	6.8 a	6.2 a	6.8 a
Basic taste	**Bitter**	**3.24 a**	**1.44 ab**	**1.64 ab**	**0.68 ab**	**0.46 ab**	**0.68 ab**	**1.06 ab**	**0.18 ab**	**0.46 ab**	**0.1 b**
	Salty	3.2 a	3.2 a	3.0 a	2.8 a	1.8 a	2.4 a	3.2 a	2.6 a	1.8 a	2.62 a
	Sour	2.64 a	0.86 a	1.24 a	0.86 a	0.46 a	0.68 a	0.84 a	0.1 a	1.64 a	0.1 a
	Sweet	6.2 a	4.6 a	4.8 a	5.4 a	5.4 a	4.6 a	5.4 a	5.0 a	4.8 a	4.4 a
Aftertaste	**Iodine**	**3.8 ab**	**3.6 ab**	**4.0 ab**	**2.2 b**	**6.3 a**	**4.0 ab**	**4.6 ab**	**3.2 ab**	**2.6 ab**	**2.8 ab**
Mouth feel	Sliminess	3.2 a	2.64 a	3.62 a	1.84 a	2.62 a	0.84 a	1.84 a	1.64 a	4.0 a	1.02 a
Texture	**Firmness**	**7.2 a**	**5.8 ab**	**4.8 b**	**5.8 ab**	**7.2 a**	**7.2 a**	**6.8 ab**	**6.6 ab**	**6.4 ab**	**6.4 ab**
	Juiciness	5.2 a	4.0 a	4.2 a	4.2 a	5.6 a	4.4 a	5.0 a	4.6 a	4.6 a	4.8 a
	Chewiness	6.0 a	3.8 a	4.2 a	4.6 a	5.2 a	5.2 a	6.0 a	5.2 a	4.8 a	5.6 a
	Crispness	**4.2 ab**	**2.6 b**	**4.0 ab**	**5.0 ab**	**4.6 ab**	**4.8 ab**	**5.0 ab**	**4.8 ab**	**5.8 a**	**3.8 ab**
	Fibrous	**5.6 ab**	**2.8 b**	**5.2 ab**	**5.4 ab**	**6.3 ab**	**4.6 ab**	**6.6 a**	**5.4 ab**	**6.4 a**	**4.8 ab**

Noted: Means within the same row not followed by the same letters are significantly different ($P \leq 0.05$)

Table D5. Statistical table for sensory score of pond N8 over time

Raw shrimp

Attribute class	Sensory attribute	Time									
		week 0	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	HV
Aroma	Ocean/seawater	4.2 a	6.8 a	5.4 a	6.8 a	5.8 a	5.4 a	7.6 a	7.4 a	7.4 a	5.8 a
	Shrimp	**2.8 b**	**4.4 ab**	**5.8 ab**	**6.6 ab**	**6.0 ab**	**5.2 ab**	**8.2 a**	**7.4 ab**	**8.2 a**	**6.0 ab**
	Old shrimp	2.4 a	2.04 a	1.02 a	1.02 a	1.46 a	0.82 a	0.66 a	0.64 a	1.24 a	2.8 a
Meat appearance	Plumpness	6.1 a	6.2 a	7.3 a	7.8 a	6.4 a	7.0 a	8.2 a	7.6 a	7.8 a	8.0 a
	Brown color	3.8 a	3.6 a	2.8 a	3.0 a	2.6 a	1.8 a	3.2 a	3.2 a	2.8 a	2.4 a
Shell appearance	**Darkness**	**2.0 b**	**3.6 ab**	**2.8 ab**	**4.4 ab**	**4.1 ab**	**3.0 ab**	**4.7 ab**	**4.6 ab**	**4.4 ab**	**5.2 a**
	Stripe darkness	5.2 a	4.9 a	2.2 a	3.3 a	4.1 a	2.6 a	5.8 a	5.1 a	4.9 a	5.0 a
	Blotchiness	2.2 a	4.4 a	2.44 a	3.8 a	4.0 a	5.4 a	4.8 a	4.2 a	6.8 a	5.0 a
	Glossiness	7.6 a	7.2 a	6.2 a	6.8 a	7.4 a	6.4 a	7.8 a	6.8 a	7.6 a	6.4 a
	Tail iridescence	3.0 a	5.2 a	2.24 a	2.44 a	3.02 a	3.22 a	4.8 a	4.0 a	4.82 a	5.4 a
Cooked shrimp											
Aroma	Ocean/seawater	5.0 a	7.6 a	5.4 a	6.4 a	7.2 a	7.2 a	7.8 a	7.2 a	7.6 a	6.0 a
	Cooked shrimp	5.2 a	6.2 a	5.2 a	5.0 a	8.4 a	7.6 a	7.2 a	8.0 a	7.8 a	4.8 a
	Old shrimp	**2.22 ab**	**3.4 a**	**0.66 ab**	**1.06 ab**	**2.44 ab**	**1.62 ab**	**0.84 ab**	**0.48 b**	**1.04 ab**	**1.6 ab**
Appearance	**Red/orange color**	**5.4 ab**	**3.2 ab**	**3.2 ab**	**2.8 b**	**5.2 ab**	**4.2 ab**	**5.4 ab**	**6.2 ab**	**5.6 ab**	**6.4 a**
	Brown color	**1.24 b**	**3.6 ab**	**2.8 ab**	**2.8 ab**	**3.02 ab**	**2.2 ab**	**4.8 a**	**1.8 ab**	**3.6 ab**	**3.2 ab**
	Blotchiness	2.04 a	3.02 a	2.02 a	3.02 a	2.02 a	1.24 a	4.02 a	3.4 a	3.8 a	4.4 a
	Glossiness	6.4 a	7.0 a	6.8 a	5.8 a	6.8 a	5.4 a	7.4 a	7.0 a	6.6 a	6.0 a
Basic taste	**Bitter**	**4.24 a**	**1.62 ab**	**1.64 ab**	**1.84 ab**	**2.06 ab**	**0.68 ab**	**0.1 b**	**0.1 b**	**0.28 b**	**0.86 ab**
	Salty	3.8 a	2.6 a	2.6 a	2.4 a	4.2 a	2.22 a	3.4 a	1.8 a	3.4 a	2.8 a
	Sour	1.06 a	0.86 a	0.86 a	0.86 a	1.86 a	0.48 a	0.28 a	0.1 a	0.28 a	1.42 a
	Sweet	5.2 a	5.2 a	4.6 a	4.0 a	4.6 a	5.4 a	5.6 a	4.8 a	5.8 a	5.8 a
Aftertaste	Iodine	4.2 a	4.8 a	3.0 a	3.22 a	5.0 a	3.2 a	4.6 a	3.2 a	4.0 a	2.4 a
Mouth feel	**Sliminess**	**2.4 ab**	**4.82 a**	**0.66 b**	**1.24 b**	**1.44 b**	**0.64 b**	**1.22 b**	**0.68 b**	**1.82 ab**	**1.62 ab**
Texture	Firmness	7.2 a	5.2 a	6.2 a	5.6 a	6.6 a	6.2 a	6.8 a	6.6 a	5.8 a	6.4 a
	Juiciness	5.2 a	3.6 a	5.0 a	4.8 a	4.2 a	4.4 a	5.4 a	4.2 a	5.2 a	5.2 a
	Chewiness	**6.4 a**	**3.2 b**	**5.0 ab**	**5.4 ab**	**5.2 ab**	**4.8 ab**	**6.0 ab**	**4.2 ab**	**5.6 ab**	**5.8 ab**
	Crispness	4.0 a	3.0 a	5.0 a	3.8 a	5.0 a	6.1 a	5.1 a	3.4 a	5.6 a	4.2 a
	Fibrous	5.8 a	5.4 a	2.82 a	2.64 a	6.4 a	5.4 a	5.4 a	5.8 a	6.2 a	6.4 a

Noted: Means within the same row not followed by the same letters are significantly different ($P \leq 0.05$)

APPENDIX E

Statistical results of sensory score of shrimp from different origins (West Alabama, Gulf Shores, Harlingen, Hawaii, and supermarket)

Attribute class	Sensory attribute	Source				
		West Alabama	Gulf Shore	Harlingen	Supermarket	Hawaii
Raw shrimp						
Aroma	Ocean/seawater	6.31a	6.28a	5.10a	6.03a	7.20a
	Shrimp	6.56a	6.63a	6.33a	6.50a	8.20a
	Old shrimp	1.57a	1.26a	1.55a	1.77a	1.44a
Meat appearance	**Plumpness**	**7.68b**	**7.03ab**	**5.47a**	**6.7ab**	**8.6b**
	Brown color	**3.46a**	**2.85ab**	**2.35ab**	**1.9b**	**2.4ab**
Shell appea01rance	**Darkness**	**4.74ab**	**5.44ab**	**4.80ab**	**3.4a**	**7.4b**
	Stripe darkness	**5.17b**	**5.51b**	**4.57ab**	**2.83a**	**7.4ab**
	Blotchiness	**3.73a**	**1.91b**	**3.47ab**	**1.87ab**	**4.00ab**
	Glossiness	6.91a	7.03a	7.33a	6.23a	8.2a
	Tail iridescence	4.33a	3.83a	4.94a	2.73a	4.40a
Cooked shrimp						
Aroma	Ocean/seawater	6.23a	6.14a	5.80a	6.80a	7.00a
	Cooked shrimp	6.64a	6.83a	6.40a	6.78a	8.00a
	Old shrimp	1.58a	1.20a	1.41a	0.99a	1.02a
	Red/orange color	**5.96b**	**6.29b**	**3.80a**	**5.10ab**	**8.00b**
Appearance	Brown color	2.85a	2.65a	2.33a	1.61a	3.22a
	Blotchiness	**2.37b**	**0.52a**	**1.78ab**	**1.19ab**	**0.66ab**
	Glossiness	6.18a	6.80a	6.00a	6.13a	7.20a
Basic taste	Bitter	0.92a	0.50a	0.54a	0.95a	0.10a
	Salty	3.28a	2.85a	4.00a	3.76a	3.00a
	Sour	0.82a	0.48a	0.88a	0.24a	0.10a
	Sweet	**5.19b**	**5.28b**	**5.87b**	**3.3a**	**5.80b**
Aftertaste	Iodine	3.81a	3.78a	3.21a	3.45a	2.80a
Mouth feel	Sliminess	1.82a	2.20a	2.67a	2.71a	1.02a
Texture	Firmness	6.20a	6.29a	5.20a	5.25a	7.20a
	Juiciness	4.67a	4.48a	4.67a	3.65a	3.60a
	Chewiness	**5.15b**	**4.85ab**	**3.70a**	**3.83a**	**5.6ab**
	Crispness	4.44a	4.93a	4.20a	3.75a	4.60a
	Fibrous	**5.33b**	**5.05ab**	**4.47ab**	**4.30a**	**7.40c**

Noted: Means within the same row not followed by the same letters are significantly different ($P \leq 0.05$)