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Microbiological, physical and sensory quality of marine shrimp (*Peneaus* spp.) sold by vendors in Trinidad, West Indies

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Abstract

The objectives of the study were: (i) to determine if the microbiological quality of fresh shrimp (*Penaeus* spp.) sold varied according to season (dry versus wet) and met international and local standards and (ii) to compare sensory quality, instrumental colour and texture profile of fresh raw shrimp to frozen shrimp stored for 9 months at -20°C. Microbial counts were determined according to the United States Food and Drug Bacteriological Analytical Manual. The aerobic plate count varied significantly ($p \leq 0.01$) with season and was higher in the dry season. *Staphylococcus* spp. incidence was in 100% shrimp and exceeded the local and international limits in seafood. According to the International Commission for the Microbiological Specification of Food limit, only 21.7%, 10% and 75% of the shrimp were of good quality for human consumption for aerobic count, *Escherichia coli* and *Salmonella* respectively. The average overall sensory score of frozen shrimp was of moderate quality (score 3) in reference to fresh shrimp (score 5). There were no significant differences ($p > 0.05$) in colour and texture of the shrimp on freezing.

Introduction

From harvest to the table, sea foods may be exposed to a range of hazards, some of which are natural to the sea food's environment and others that are introduced by handlers (Kurtzweil, 1999). Very few studies were conducted in Trinidad and Tobago (T&T) on the food safety and hygienic practices of vendors (Badrie *et al*., 2004; Benny-Ollivierra and Badrie, 2007; Balfour *et al*., 2010). There are serious safety concerns related to the consumption of raw fish and shellfish due to the presence of biological (bacteria, viruses, parasites) and chemical hazards that could pose health risks to consumers (Huss *et al*., 2000; Hosseini *et al*., 2004). Balfour *et al.* (2012) revealed that the metal concentrations namely, copper, zinc, cadmium, chromium, nickel and mercury in the marine shrimp investigated in Trinidad during 2009 were significantly lower than the permissible limits of the United States Food and Drug Administration (1993), Canada's Food Inspection Agency (2011), and T&T's Food and Drug Regulations (2007) for human consumption.

A study conducted in Trinidad in 1992 on 41 shrimp and 61 fish samples over a 12-week period from three unidentified local markets and highway vendors reported no contamination by *Salmonella* and *E. coli* (Adesiyun, 1993). Similarly, another investigation of 200 samples each of raw oysters, condiments/spices and oyster cocktails purchased from 72 oyster vendors across Trinidad detected *E. coli* in 77.0%, 44.5% and 77.0% samples respectively (Rampersad *et al.*, 1999). Of these, 73.0% of the oyster cocktails contaminated with *E. coli* had counts that exceeded the recommended standard of 16 per wet wt. gram of sample. Futhermore, in that study, *Salmonella* spp. were isolated from 3.5%, 0.5% and 1.0% of the 200 samples each of raw oysters, condiments/spices and oysters cocktails respectively. Based on the results, the authors concluded that oysters could pose a health risk to consumers in Trinidad, particularly from colibacillosis and salmonellosis. Bacterial contamination of sea food, especially above permissible limits for human consumption is a cause for concern in Trinidad.

A Caribbean Epidemiology Centre Surveillance Report on Communicable Diseases (CSR-CD, 2009) for Trinidad and Tobago reported no cases of pathogenic *E. coli* and salmonellosis during 2008 and 2009 respectively. While many cases of bacterial infection are taken into account via treatment at government and private medical institutions, some of T&T's citizens are self-treated and consequently, this has resulted in a lack of recorded statistics. Also, the CSR-CD (2009) report on bacterial infections for T&T did not state the origin of infection, which could

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have resulted from the possible consumption of any food type, including shrimp, fish, diary, livestock or vegetables with a high bacterial load. The many gaps in the literature on possible local sources of bacterial infections in foods, including shrimp, led to the undertaking of this research, to determine whether shrimp consumption could pose such health risks to consumers as a result of bacterial contamination.

The appearance, odour, colour and texture of shrimp are fundamental to shrimp quality. An estimate of freshness can be obtained by defining criteria related to changes in the sensory attributes like appearance, odour, colour and texture, that can be measured or quantified by sensory or instrumental methods (Olafsdottir *et al.*, 2004). Sensory evaluation is defined as the scientific discipline used to evoke, measure, analyze and interpret reactions to characteristics of food as perceived through the senses of sight, smell, taste, touch and hearing (Huss, 1995). Several shrimp quality studies have already been undertaken in countries such Turkey, Thailand, Brazil, Iceland, Greece and Mexico on the biochemical, microbiological, physical and sensory characteristic changes in shrimp (Hanpongkittikun *et al*., 1995; Noomhorm and Vongsawasdi, 1998; Meinert *et al*., 1999; Gökoğlu, 2004; Zeng *et al*., 2005; Gonçalves and Gindri Junior, 2009; Tsironi *et al*., 2009; Pardio *et al.*, 2011). To date, there is still a dearth of literature on the quality of marine shrimp species found in T&T.

The objectives of this study were to: (i) determine if the microbiological quality by aerobes (APC), *E. coli*, *Staphylococcus* spp. and *Salmonella* spp. of fresh shrimp (*Penaeus* spp.) sold according to season (dry versus wet) met international and local standards and (ii) compare sensory quality, instrumental colour and texture profile of fresh, raw shrimp (*Penaeus* spp.) at 0 storage time to frozen shrimp stored for 1, 3, 6 and 9 months at -20°C.

Materials and Methods

Source of shrimp, sampling protocol and collection

Shrimp (*Penaeus* spp.) were purchased at 4 wholesale and retail fish depots in Trinidad, located in Orange Valley, Otaheite, Sea Lots, Port of Spain and Claxton Bay, as well as from 3 road side vendors in the Tunapuna region for the period January to October 2009. Shrimp within the size range 8.5 – 11.5 cm in length were purchased seasonally, four times per year from January to February, March to April, July to August and September to October, 2009 in each of the 5 selected areas from 3 vendors respectively on site. 60 composite of shrimp samples were examined for this research: 30 composites in the dry season from January to May 2009 and 30 in the rainy season from June to October 2009.

Each shrimp composite of 908 g obtained from each vendor was placed into a sterile bag and transported to the Microbiology Lab in the Department of Food Production at the University of the West Indies, St. Augustine Campus, within 2 hours of purchase in an ice cooler to maintain a temperature of approximately 4°C. Samples were processed within 30 minutes of arrival for Aerobic Plate Count (APC), *Escherichia coli* spp., *Staphylococcus* spp. and *Salmonella* spp. using slightly modified versions of the methodologies described in the Online Bacteriological Analytical Manual of United States Food and Drug Administration (US FDA). The rest of the samples were stored for 0, 1, 3, 6 and 9 months at -20°C until it was time to conduct the sensory evaluation, instrumental colour and texture profile analyses (TPA) of the whole raw shrimp.

Methodology for determination of microbes

The determination of microbes in the raw shrimp were carried out using slightly modified versions of the method outlined by Maturin and Peeler (2001) for aerobic plate count, Benneth and Lancette (2001) for *Staphylococcus*, Feng *et al.* (2002) and Reddy *et al.* (2009) for coliforms, faecal coliforms and *E. coli*, Andrews and Hammack (2006) for *Salmonella* from the United States Food and Drug Bacteriological Analytical Manual. Water and agar controls were carried out in triplicate. Controls used in the research were *Staphylococcus aureus* ATCC 29213 (Remel, United Kingdom), *E. coli* ATCC 35218 and *Salmonella typhimurium* ATCC 14028. All media and broth used in this research were manufactured by Oxoid.

Preparation of the shrimp samples for sensorial evaluation, instrumental colour and textural profile analyses

The shrimp samples were removed from freezer (-20°C) and allowed to thaw overnight in a refrigerator at 5°C, upon which they were ready for the sensorial evaluation, instrumental colour and textural profile analyses. 5 individual chilled shrimp were placed on a clear plastic sheet for analyses. Shrimp samples were analysed fresh and after frozen storage periods of 1, 3, 6 and 9 months.

Sensorial evaluation

A modified version of the method outlined by Ouattara *et al.* (2002) was used to carry out the sensorial evaluation of shrimp in this research. A group

Table 1. Grading description scheme on the quality of whole shrimp

5 Excellent - Fresh
Colour – Body has dark red to bright pink.
Shell – Shiny and clean. Lustrous pigmentation, difficult to remove shell from body.
Eye – Convex, bulging, returns to shape if pressed, even black colour, shiny surface.
Tail – Clean, no discoloration
Texture – Firm, body has clean defined shape.
Head – Firmly attached to body.
Odour - Strong seaweedy, marine odour
Head meat – Yellow/brown, no smell, firm texture.
4 Good
Colour - Body has natural light pink to white.
Shell – Lack luster sheen, stripes lose clear definition around edge, shell firmly attached to body, may be removed with firm pressure.
Eye – Bulging surface, no sheen.
Tail – Clean, no discoloration.
Head – Head can be moved 1mm from body with slight pressure.
Texture – Flesh has slight firmness, body still has defined shape.
Odour - Weak characteristic shrimp odour.
Head meat – Cream tinge.
3 Moderate
Colour - natural light pink with grey-greenish or yellowish discoloration.
Shell – lack luster sheen. May be peeled with firm pressure.
Eye – Slightly sunken eyes, no sheen.
Tail – Minor delamination of tail at edge.
Texture – Flesh, soft to touch, may easily be pushed in with finger.
Head – Head can be moved 1-2mm from body with slight pressure.
Odour - Marine/shrimp odour is diminishing, weak "fishy odour", even slight ammonia.
Head meat – Stained yellow.
2 Borderline - Clearly not Fresh
Colour - natural light pink with grey-greenish or yellowish discoloration.
Shell – Flat dull appearance. Shell beginning to separate between segments shell may be peeled using light pressure.
Eye – Sunken, lack luster black colour, slightly opalescent.
Tail - Blackening and discolouration around tail.
Texture – Flesh may be easily pushed with fingers.
Head - Blackening on the head can be spotted.
Odour - Weak ammonia odour.
Head meat – Heavily stained yellow or brown.
1 Unfit - Spoilt
Colour - Natural light pink with grey-greenish or yellowish discoloration. Lack defined colour.
Shell – Pale washed out colour, shell may easily be removed from the body.
Eye – Milky white colour, concave, no fixed shape.
Tail – Predominant blackening around tail.
Texture – Flesh soft and pliable.
Head - The blackening on the head is extensive and also easily removed from the body.
Odour - Ammonia odour.
Head meat – Heavily stained yellow or brown.
Source: Modified from Hanpongkittikun *et al.*, 1995; Qingzhu 2003

of 8 trained persons (students and employees of the University of the West Indies, Trinidad and Tobago) were asked to grade the appearance of the shell, eyes, tail, texture, head, odour and head meat as well as the colour of the raw chilled shrimp samples using a 5-point quality scale ranging from 5 (excellent-fresh) to 1 (unfit-spoilt). The trained panelists were also presented with a representative control sample of freshly purchased chilled shrimp of excellent quality, with its criteria outlined in Table 1. Additionally, in order to maintain inter-evaluator reliability, all panelists were trained in advance to identify shrimp of fresh, good, moderate, borderline and spoilt quality using the quality scale (Table 1) and decomposed shrimp samples at various stages of melanosis. The sensorial evaluation of the shrimp was done at the Lawrence Wilson Food Biology laboratory that was equipped with individual partitioned booths.

Instrumental colour evaluation

The instrumental colour measurements for the shrimp samples were carried out using a slightly modified version of the method outlined by Olafsdottir *et al*. (2004). A hand-held Konica Minolta Chroma Meter CR-400 was used to measure colour of the shrimp. The Konica Minolta Chroma Meter CR-400 was equipped with a pulsed xenon lamp as the light source, a silicone photo cell detector taking shrimp colour measurements at 3 second intervals (Konica Minolta Chroma Meter CR 400 Instruction Manual No.9222-1878-20, Japan). In the Konica Minolta Chroma Meter CR-400 instrument, L^* denoted the lightness value on a 0-to-100 scale from black to white; a^*, (+) red or (–) green; and b^*, (+) yellow or (–) blue. Using equations 1 and 2 below, chroma denoted 'C' and hue denoted 'H' were calculated (King 1980).

$$\text{Chroma (C)} = (a^2 + b^2)^{1/2} \ldots \text{Equation (1)}$$

$$\text{Hue (H°)} = \cos^{-1}[a/(a^2 + b^2)^{1/2}] \ldots \text{Equation (2)}$$

Table 2. Glossary of textural parameters of shrimp

Hardness - Effort required to bite through the sample with front teeth or maximum peak force during first compression cycle (first bite)
Fracturability – The ease at which the sample fracture, crumbles, crunches or becomes brittle under increasing compression load
Adhesiveness – Degree to which samples sticks to the mouth
Springiness – Height that the food recovers during the time that elapses between the end of the first bite and the start of the second bite
Cohesiveness – Strength of the internal bonds making up the body of the sample before rupture
Gumminess – The product of hardness × cohesiveness; or perception of the dimensions and shape of sample's particles
Chewiness – The product of gumminess × springiness (which equals hardness × cohesiveness × springiness)
Resilience – Associated with the elastic recovery of a sample in terms of speed and force
Source: TA.XT Plus Texture Analyzer Stable Micro System (Texture Exponent 32 Version 4.0.9.0, Surrey, United Kingdom); Meinert *et al.*, 1999

Instrumental texture profile evaluation

Modified versions of the Texture Profile Analyses (TPA) methods outlined by Meinert *et al.* (1999), Qingzhu (2003) and Mbarki *et al.* (2008) were used in this research. The TPA of the raw, whole shrimp samples were carried out using the TA.XT Plus Texture Analyzer Stable Micro System (Texture Exponent 32 Version 4.0.9.0, Surrey, United Kingdom) that was calibrated using a 5Kg load cell and then fitted with a cylindrical compression probe of radius 36 mm. The shrimps were compressed on their sides to approximately 50% of the sample's width to avoid cracking, on the basis of preliminary trials. The height of the probe was set at a return distance of 15.0 mm and return speed of 10.0 mm/s. Overall, the texture analyzer was set at a pre-test speed of 2.0 mm/s, test speed of 2.0 mm/s, post test speed at 2.0 mm/s and trigger force of 5 *g*. Data was collected for hardness, fracturability, adhesiveness, springiness, cohesiveness, gumminess, chewiness and resilience for each of the 5 replicates and the average values were reported. Refer to Table 2 for definitions of the texture profile parameters used in this study.

Statistical analyses

Statistical analyses were carried out using Statistical Package for Social Sciences (SPSS) version 17 software at the 5% level of significance. Case summaries provided the average level of

Staphylococcus spp. obtained for the shrimp sampled in Trinidad. Cross tabulation and chi-square was used to determine if *E. coli* and APC levels varied significantly in fresh shrimp by season, and also for the sensory quality attributes of the frozen shrimp. Pearson's correlation coefficient was used to determine the relationship between *E. coli* and faecal coliform. Binary logistic regression was used for determining if season was a factor for determining the presence *Salmonella* spp. in this research with the dependent variable being coded for '1' or '0' for *Salmonella*'s presence or absence and the covariates being season. Analysis of variance at a 95% level of confidence was used to show if there were significant differences between instrument colour and texture profile parameters of fresh versus frozen shrimp.

Results and Discussion

Quality of shrimp in relation to local and international standards

APC

In this research, only 21.70% of the shrimp sampled in Trinidad in 2009 had APC levels of good quality according to ICMSF (1986) standards while the remaining shrimp were marginally acceptable (62.8%) and unacceptable (15.6%) for human consumption as shown in Figure 1. Those findings were in contrast to T&T's APC Food and Drug Regulation (2007) for fish and fishery product which suggested that 51.7% of the shrimp were safe for human consumption having $\leq 1\times10^6$ colony forming units per gram (cfu/g) while the remaining 48.3% exceeded the limit of 1×10^6 cfu/g, rendering almost half of local shrimp unfit for human consumption in 2009. The variation in the APC findings in relation to the T&T and ICMSF codes could be due that fact that T&T's APC limit was specific to fresh and frozen crustaceans while the ICMSF's APC standard (1986) used in this research was ideally suited for fresh and frozen fish and cold smoked as well as precooked breaded fish and frozen cooked crustaceans. APC levels also exceeded the ICMSF standard for the edible portion of frozen shrimp, quick frozen cooked brown peeled and undeveined shrimp from Bangladesh (Pinu *et al.*, 2007; Ahmed and Anwar 2007). Similarly, in India, individually quick-frozen (IQF) shrimp products made from aquacultured tiger shrimp (*Penaeus monodon*) showed that 2.5% of raw, peeled, tail-on, 6.4% of raw, peeled tail-off, and 7.5% of headless shell-on shrimp samples exceeded APC levels of 10^5 colony forming units per gram (cfu/g) (Mohamed *et al*., 2003).

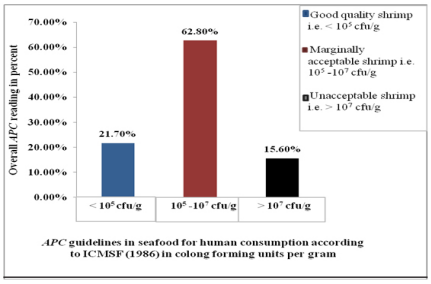

Figure 1. Overall Aerobic Plate Count (APC) for shrimp sampled in 2009

Staphylococcus spp.

One hundred percent (100%) of the *Staphylococcal* findings in the shrimp sampled in Trinidad in 2009 had an overall average of 5.12×10^8 cfu/g, which drastically exceeded the maximum permissible human consumption limit of 10^3 colony forming units per gram for good quality shrimp according to the T&T (2007) and ICMSF (1986) guidelines. This finding suggested equally high levels of poor sanitation practices during harvesting and post-harvest handling of the shrimp. Balfour *et al*. (2010) revealed that while most of the vendors (66.7%) in Trinidad used a sanitizing agent (also referred to as disinfectants) and a supply of potable water to clean tables and storage bins before and after use with sea foods, as a common practice to reduce the number of microorganisms to acceptable levels in the sea food industry, and all the seafood vendors wore clean clothes and had no visible open wounds, in accordance with the guidelines of Kurtzweil (1999), only few vendors used hair nets and gloves, possibly resulting in contamination of shrimp also from hair and hands. The *Staphylococcus* spp. pathogen is not only a matter of public health concern to shrimp consumers in Trinidad, but, has also been reported in a variety of foods worldwide consisting of street-foods, fresh, raw and frozen ready-to-eat fish and shrimp, raw poultry from other countries such as Iran, Egypt and Cyprus (EI-Sherbeeny *et al*., 1985; Eleftheriadou *et al.*, 2002; Zarei *et al*., 2012). In Brazil, Ayulo *et al.* (1994) isolated *S. aureus* in 60% shellfish meat of which 43.4 % exceeded the levels of 10^4 colony forming units per gram resulting in potentially hazardous levels to consumers. Measures must be put in place to reduce the contamination of Trinidad's shrimp from the *Staphylococcus* spp. bacteria. Shrimp is a highly popular delicacy in Trinidad that is sometimes served barely cooked usually less than 5 minutes in a wide range of oriental-influenced recipes such as sushi, shrimp fry rice, pepper shrimp as well as shrimp wantons, kababs and cocktails; the implication of which could possibly be gastroenteritis to consumers with symptoms that

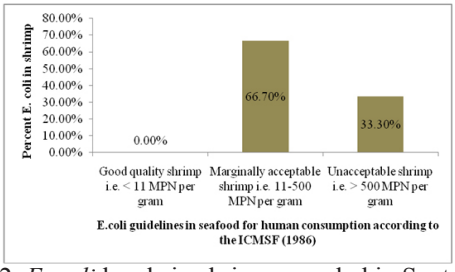

Figure 2. *E. coli* levels in shrimp sampled in September-October 2009

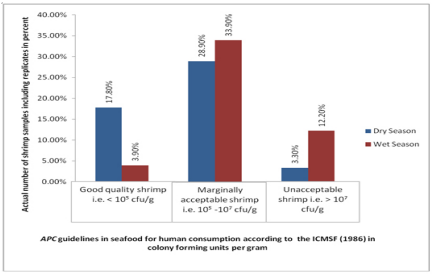

Figure 3. Distribution of APC in shrimp between the dry and wet seasons

include nausea, vomiting, diarrhoea and abdominal pains (Le Loir *et al*., 2003).

Total coliform, Faecal coliform and E.coli

All (100%) of the shrimp sample analyzed in Trinidad had total coliform levels exceeding 24 MPN per gram which may not only be attributed to the possibility of faecal contamination but could also be the result of other pathogens affected by vendors' hygiene (Okonko *et al.*, 2009), poor sanitation practices (Smooth and Pierson, 1997), cross contamination during storage, handling and processing of the shrimp with other seafood (Fraser and Sumar, 1998). The majority of shrimp (90%) in this research had *E. coli* levels that were unfit for human consumption having exceeded 11 MPN per gram according to ICMSF (1986) code. The levels of *E. coli* in the shrimp were also directly proportional to the percent faecal coliform (r = 1) in the sampled shrimp which had exceeded T&T's maximum acceptable limit of 10 MPN per gram. Therefore, these findings indicated that the possible source of the bacteria was sewage and faecal contamination which was directly responsible for the quantity of *E. coli* in Trinidad's shrimp sampled in 2009. This was also evident at the Mucuripe seafood market, in Fortaleza, Northeastern Brazil, where 14 potentially hazardous strains of *E. coli* were isolated from red snapper (*Lutjanus purpureus*) and from seabob shrimp (*Xiphopenaeus kroyeri*) respectively, that produced exotoxins, of which seven were thermolabile and seven were thermostable (Teophilo *et al*., 2002). The remaining 10 percent of the shrimp samples had *E. coli* levels that were of good quality (i.e. less than 11 MPN per gram) according to ICMSF (1986) standard, thus making those shrimp samples safe for consumption.

More specifically, for the final batch of shrimp that was sampled at Port of Spain, Orange Valley, Otaheiti, Claxton Bay and Tunapuna during September to October 2009, further dilutions showed that two-thirds (66.7%) were found to be only marginally acceptable ranging within 11-500 MPN per gram while the remaining 33.3% of the samples in that batch were unacceptable for human consumption having more than 500 MPN per gram (Figure 2); and were of public health concerns according to the ICMSF (1986) standards. Figure 2 indicated the acceptability of shrimp in 2009 with respect to ICMFS guidelines for good, marginal and unacceptable quality shrimp. None of the shrimp in this batch were of good quality and therefore were not considered safe to consume as they all had more than 11 MPN per gram (Figure 2). A previous study by Balfour *et al.* (2010) observed at each of the fishing depots used for this research that low-temperature storage facilities were inadequate. In addition, not all of the shrimp on display were iced, since it was a customary practice of the vendors in Trinidad to have a portion of shrimp for sale openly displayed on stainless steel or tiled counter-tops, in order to attract customers. This could have resulted in temperature abuse of the shrimp and a food safety risk by exposure to flies. Such conditions could have enhanced rapid microbial growth on the shrimp and in turn, posed health risks to consumers, as reflected in results of the bacterial levels. Unrefrigerated seafood dishes have been incriminated in two gastrointestinal outbreaks from the visit of cruise ship passengers to Haiti (1976) and Mexico (1981) where several species of *Vibrion*, *Salmonella*, toxigenic *Escherichia coli* and *Shigella* were isolated from the stools of the ill passengers (Berkelman *et al*., 1983). In Japan (1998), enterohemorrhagic *E. coli* (EHEC) O157:H7 was implicated in the gastrointestinal outbreak from the consumption of salmon roe in sushi (Terajima *et al.*, 1999).

Salmonella spp.

Salmonella was present in 25% of the sampled shrimp. *Salmonella* should be absent in shrimp according to ICMSF (1986), CFIA (2011) and TT (2007) seafood consumption codes. Its presence was also reported in prawns, fish and oriental shrimp from the United States, Cyprus and Malaysia (Arumugaswamy *et al*., 1995; Heinitz *et al.*, 2000; Eleftheriadou *et al.*, 2002). These findings could be attributed to post-harvest contamination (Shabarinath *et al.*, 2007) since *Salmonella* is not generally

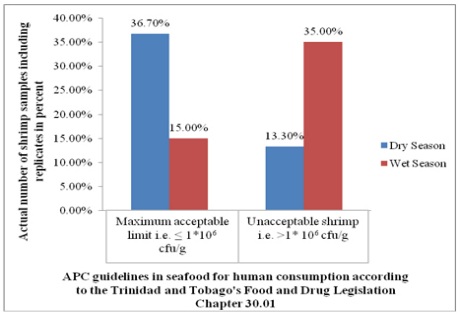

Figure 4. Distribution of APC in shrimp between dry and wet seasons according to T&T guidelines

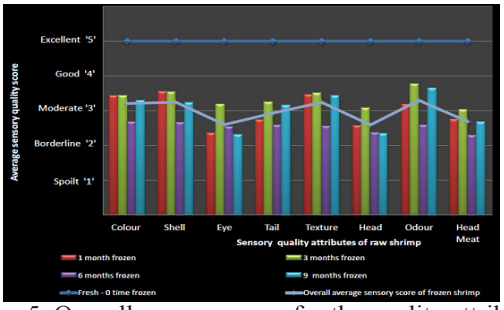

Figure 5. Overall average score for the quality attributes of raw shrimp during storage

recognized as a part of the normal bacterial flora in a marine environment (Dalsgaard *et al*., 1995) and, therefore, not haboured naturally in marine shrimp.

In New York from 1980 to 1994, shellfish accounted for 64% seafood-associated outbreaks (Wallace *et al.*, 1999). From the literature, *Salmonella* was found to be the main aetiological agent from shrimp and seafood consumption for foodborne disease outbreaks in England and Whales between the period 1992 to 1996 (Panisello *et al.*, 2000). For passenger ship outbreaks, a review by Rooney *et al.* (2004) suggested that seafood was the most (28%) implicated food; with *Salmonella* spp. being the most frequently (30%) associated with outbreaks and the factors included inadequate temperature control, infected food handlers, contaminated raw ingredients, cross-contamination, inadequate heat treatment and onshore excursions. They are highly infectious bacteria that cause a variety of symptoms in people including 'gastroenteritis' characterized by nausea and vomiting within 8-48 hours, fever, abdominal cramps and diarrhoea that may vary from a few loose stools, to profuse watery stools, to rarely dysentery (bloody stools) with much straining (Cornell University, 1997).

Seasonal effects of shrimp (dry vs. wet)

When the wet and dry season values were separated for the APC findings, as shown in Figures 3 and 4, the effects of season on quality emerged. Cross tabulation and chi-square showed that APC levels in the local shrimp sampled in 2009 varied significantly ($p = 0.000$) with season according to international and local standards. In relation to ICMSF (1986) standards for good quality shrimp, almost one-fifth (17.8%) were collected in the dry season (Figure 3) which suggested that it had been safer to consume shrimp in Trinidad from January to May of 2009.

The distribution of APC findings in the local shrimp according to the ICMSF (1986) code showed that 33.9% of the marginally acceptable shrimp and 12.2% of unacceptable shrimp were obtained in the wet season (Figure 3), both of which could have resulted in public health concerns. This would have been attributed to the higher average rainfalls in Trinidad and Tobago from May to December that can range from approximately 129 mm to 269 mm (Trinidad and Tobago Climate Guide, 2011), therefore, resulting in larger runoffs from households entering the rivers and ultimately the marine environment where the shrimp were harvested and possibly caused higher microbial loads. According to T&T's maximum acceptable limit of APC levels in shrimp for human consumption, 36.7% were obtained from the dry season while 35.0% of shrimp in the unacceptable range were reported in the wet season (Figure 4). The presence of *Salmonella* and levels of *E. coli* in the shrimp were not significant ($p > 0.05$) according to season.

Comparing sensory quality, instrumental colour and texture profile of fresh raw shrimp to frozen shrimp

The average overall sensory score of the fresh shrimp was referenced as excellent in quality and denoted by 5 (Figure 5). The overall quality attribute of the raw frozen shrimp was moderate in quality and given a score of 3 out of 5 (Figure 5). More specifically, cross tabulation and chi square of the sensory quality attributes of the frozen shrimp showed significant differences ($p < 0.05$) by storage time and season respectively. The average sensory score for up to 9 months of storage showed that the eye, tail, head and headmeat of the shrimp were borderline '2' or clearly not fresh while the colour, shell, texture and odour were moderate '3' in quality (Figure 5). The shrimp were moderate in quality in the third month of storage and borderline in the sixth month of storage. This may have been the result of shrimp melanosis, commonly known as 'blackspot' which is a harmless but objectionable surface discoloration caused by polyphenoloxidase enzyme systems that remain active during refrigeration, ice storage and post freeze-thawing (Otwell and Marshall, 1986). In shrimp, a black discolouration or "black spot" starts in the head and then spreads to the tail, where it forms black bands outlining the sections of the tail region (Faulkner *et al.*, 1954). Such discoloration

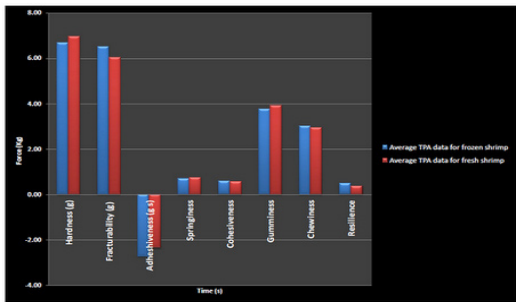

Figure 6. Average TPA data for fresh versus frozen shrimp in Trinidad

lowers the value of shrimp and is prevented by de-heading of freshly caught shrimp. Most of the shrimp vendors (93.3%) in T&T recommended de-heading the shrimp, followed by freezing until ready for use (Balfour *et al*., 2010). However, since de-heading is time-consuming and leads to a reduction in the overall weight of the shrimp, most shrimp sold by vendors at local depots retain their heads at the points of sale.

During the dry season, the colour, texture and odour of the shrimp as well as the tail and shell in the wet season were moderate in quality; the eye, head and head meat were of borderline quality in both seasons. The sensory quality findings in this study suggested one critical factor that greater care must be taken to preserve the freshness of the shrimp from harvest to consumption all year round. Montero *et al.* (2004) showed that the use of 4-hexylresorcinol proved effective at extending shelf life of shrimp (*Parapenaeus longirostris*) and the addition of ethylenediaminetetraacetic acid (EDTA) and sodium pyrophosphate to the formulation enhanced melanosis inhibition at all times of year. Other suggested treatments from the literature for delaying the occurrence of melanosis and extending the shelf-life of shrimp included the use of sulphite agents and vacuum packaging, freezing and modified atmosphere packaging, inhibition by grape seed extract, and organic acid treatments (Bono *et al.*, 2012; Vijay Kumar Reddy *et al.*, 2012; Gokoglu and Yerlikaya, 2008; Gökoğlu, 2004).

Shrimp undergo rapid spoilage and can lead to wastage of a catch, unless processed adequately (Chandrasekaran, 1994). Analysis of variance showed no significant differences ($p > 0.05$) in the instrumental colour and texture profile properties of shrimp at 0, 1, 3, 6 and 9 months of storage. The finding suggested that freezing shrimp at -20°C for up to 9 months did not affect the instrumental colour and textural profile properties of the raw shrimp. This finding was supported by Dalgaard and Jørgensen (2000) which showed that freezing or combined use of brining and chilling can be a useful preservation method for the shelf-life extension of shrimp products for greater than seven months. Figure 6 showed the average texture profile values of fresh versus frozen shrimp from analyses conducted in Trinidad.

Conclusion

The microbiological analyses of the shrimp sampled in Trinidad in 2009 revealed that only 21.7%, 10%, 0% and 75% were of good quality for human consumption in relation to APC, *E. coli*, *Staphylococcus* spp. and *Salmonella* respectively, according to the International Commission for the Microbiological Specification of Food (ICMSF) limit. Season was only significant in relation to APC levels in the marine shrimp in Trinidad, with the dry season (January to May) being the safer period of the year for shrimp consumption. Sensory evaluation showed that the raw frozen shrimp were moderate in quality in reference to the control fresh shrimp. Instrumental colour and texture profile properties of shrimp were unaffected by frozen storage for up to 9 months. Bacteriological and sensory evaluations showed that greater care must be taken improve the overall quality of shrimp from harvest to consumption.

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