# Fish Inspection, Quality Control, and HACCP

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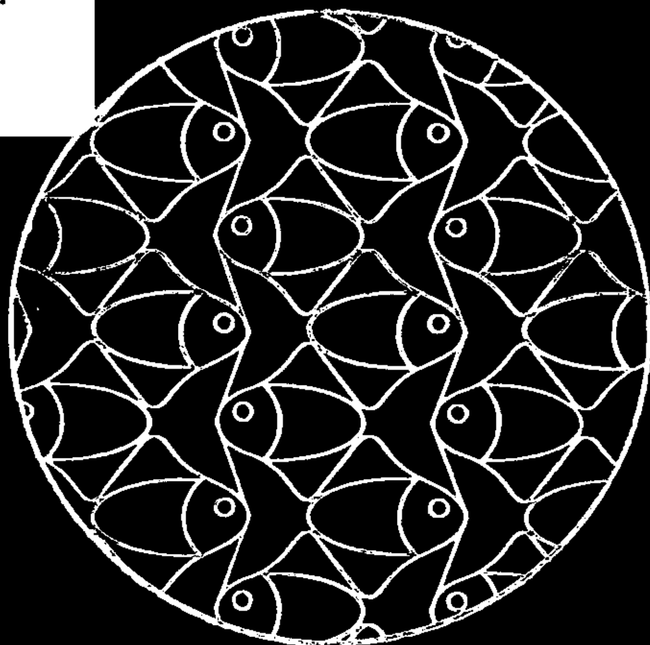

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# Automated Sensory Procedures for Shrimp

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## ABSTRACT

The current quality evaluation of shrimp involves subjective tests performed by inspectors regarding visual, texture and sensory odor attributes of a sample. This is prone to error, hard to repeat, and difficult to relate to others. The purpose of this study was to develop an automated device to quantitatively, objectively and in a repeatable manner evaluate visual, texture and sensory odor attributes of shrimp. Machine vision analysis resulted in the evaluation of count, uniformity ratio, color and melanosis. Force deformation information resulted in texture evaluation. An ammonia electrode quantified ammonia in shrimp. The total evaluation time was less than four minutes. Based on smell, "electronic nose" units can differentiate between shrimp samples aged on ice. Since results and quality parameters were stored in an integral database, this method could assist in HACCP procedures.

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## INTRODUCTION

The current evaluation of shrimp involves inspectors who judge a sample based on its visual, texture and smell attributes. Parameters such as count and uniformity ratio are also manually determined. This is subjective, hard to repeat and to relate to others. It is desirable to automate this process and to make it objective and repeatable. Use of machine vision, texture, or smell to evaluate quality has been individually studied in the literature. Prawns were automatically graded by size and packaged into a single oriented layer by combining machine vision and robotics (Kassler et al., 1993). Morphological features of shrimp were determined to find the optimum location for shrimp head removal (Ling and Searcy, 1989). However, melanosis has not been measured by machine vision, and correlation of objective and sensory results in visual analysis is lacking.

Ammonia ($NH_3$) is a major component of the decomposed odor of seafood and has been used as an objective quality index (Cobb et al., 1973a, 1973b, Ruiter and Weseman, 1976, Finne, 1982). Its concentration in shrimp was shown to increase during storage with a good correlation between concentration and traditional spoilage indicators (Cheuk and Finne, 1984; Finne, 1982). Ward et al. (1979) used an $NH_3$-electrode to show the relationship between microbial numbers and $NH_3$ concentration during refrigerated storage of fresh shrimp. $NH_3$ analysis is seldom used by the shrimp industry due to the complexity and length of the method. Therefore, a simple and rapid method of objective $NH_3$ analysis is necessary. The correlation of one chemical index with the sensory evaluation data can be insufficient. "Electronic nose" units that rely on the response of a series of electrically conducting polymers to evaluate the "smell" of a sample are becoming commercially available (Hodgins, 1995; Hodgins and Simmonds, 1995; Tan et al., 1995; Anon., 1994; Shiers and Farnell, 1995; Springett, 1991). The addition of these devices to the machine-based odor evaluation of seafood would improve their relevance.

In high quality seafood, the tissue resumes its original shape when pressure is removed. A soft texture or a slimy feel are indicators of enzymatic and/or microbial deterioration (Gorga and Ronsivalli, 1988). Few researchers have analyzed the relationship between textural properties and quality of raw seafood. Studies of simple sensory analysis were not correlated with instrumental measurements. Two methods that could be used to measure the texture of shrimp are elasticity and texture profile analysis (TPA).

The objectives of this study were : 1) to design and build an automated quality evaluation device for shrimp including hardware and computer software, 2) to measure objective visual, $NH_3$ and texture attributes of shrimp aged on ice for up to 14 days, 3) to test the ability of an "electronic nose" unit to discriminate between odors of shrimp stored on ice for up to 14 days, and 4) to correlate visual and smell indices of shrimp with their sensory attributes.



## MATERIALS AND METHODS

A light box chamber was built of acrylic sheet with top and bottom lighting boxes. A color CCD Video Camera with an S-video output was connected to a color frame grabber. The Red-Green-Blue (RGB) color space had 256 units per axis, resulting in 16 million separate color combinations. To reduce the number of colors to be analyzed, each axis was divided into four sections, resulting in 64 cubes covering the color space. Color combinations in a given cube were lumped into the center color of that cube. Software was developed to analyze view area and color of individual objects in an acquired image using Microsoft Visual Basic Professional 3.0. Details of the experimental setup are described by Luzuriaga et al.(1996a). Ammonia was measured with an ion-selective electrode (Model 95-12, Orion Research, Inc., Boston, MA). Intact shrimp samples were placed in an air-tight box and sprayed with 5N NaOH to volatilize ammonia. Extensive experiments were conducted to determine proper amounts of sample, NaOH to be sprayed, and the effects of temperature, sample preparation and equilibration time on $NH_3$ readings. It was found that ammonia readings could be completed within 2 minutes (Luzuriaga et al., 1996b) with minimum sample preparation. The force sensing mechanism was a miniature load cell (max. capacity 9 kg), and a stepper motor driven probe. Details of the experimental setup are described by Luzuriaga et al. (1996c).

## EXPERIMENTS

### Visual Experiments

One hundred head-on, non-frozen white shrimp (*Penaeus setiferus*), from 90 to 30 count per pound were used. Intact shrimp were placed individually in the light box, an image was acquired, and the view area of the shrimp was determined in pixels. The shrimp were then weighed. For the same shrimp batch, heads were removed manually and processed as described above. The shrimp were then peeled, leaving the shell on the last segment and tail, and processed as before. The last segment of shell and tail was then removed and the same procedure was followed. The four sets of view area vs. weight data were analyzed by fitting six types of equations (Luzuriaga et al., 1996a). The three best fitting equations are shown in Table I. This allowed for prediction of weight based on view area. Count and uniformity ratios could be estimated solely from the image. The degree of melanosis in the shrimp samples stored on ice for up to 17 days was evaluated by a human expert and by the automated system at days 0, 3, 7, 9, 13, 15 , and 17. Melanosis of both sides of the shrimp were averaged. The human expert identified as melanotic areas that were black and dark. RGB colors of these darks areas were obtained. Nine color blocks from the 64 color blocks used in this system were included into melanosis calculations. At the same time that the shrimp were being evaluated for melanosis by the automated system, the color information was extracted and presented in a histogram of 64 colors. The variation of these histograms represented the change in color of the shrimp during storage on ice. The most representative colors were selected for this species of shrimp and plotted versus time.

### Ammonia measurements

Frozen, headless, shell-on, white shrimp, *Penaeus setiferus*, (40-50 count per pound) were thawed under running water, separated into nine samples of 200g each, stored in plastic bags and kept on ice for 0, 2, 4, 6, 8, 10, 14 and 21 days. Levels of $NH_3$ were measured by the procedure of Ward et al. (1979) and plotted against time. To correlate sensory odor data with the $NH_3$ probe readings, headless, peeled white shrimp (*Penaeus setiferus*) 26-30 count per pound were separated into 400g samples, aged on ice to obtain different $NH_3$ levels, and their odor evaluated by a 16 member sensory panel in two sessions. Grading was done on a scale from 0 (poor) to 10 (good). The samples were then analyzed for $NH_3$ and an equation to predict sensory odor grade from machine-read $NH_3$ levels was developed.

### "Electronic Nose" Experiments

The Neotronics "Electronic Nose" was used (NOSE). This instrument uses a battery of 12 sensors made of electrically conductive polymers. The response of the polymers that change as a result of the adsorption of chemicals in a sample atmosphere is measured with time. The system is calibrated with deionized water. In the first series of experiments, ammonia, trimethylamine (TMA) and dimethylamine (DMA) solutions of known concentrations (30, 100, 300, and 1000 ppm) were analyzed with the NOSE unit. 50 ml of solution was placed in a 140 ml glass beaker and placed inside the sample vessel. Prior to data acquisition, the glass sample chamber was purged with compressed air for 2 minutes. The sensor head was purged for 4 minutes and at the same time the sample's volatile components equilibrated in the head space. Three replicates of each sample were analyzed.

In the second series of experiments, frozen headless shell-on pink shrimp (*Penaeus notialis)* 31-40 count per pound, imported from Indonesia, were thawed under running water. Shrimp were aged on ice for 14 days. The change in odor of shrimp was evaluated with the NOSE unit at days 0, 2, 4, 6, 8, 10, 12 and 14. 65g of shrimp were placed in a 140 ml glass beaker and placed inside the glass sample vessel. The same analytical conditions were used as before. The data was processed using Multiple Discriminant Analysis. The ammonia level of samples were also measured (Table II).



### Texture measurements

Elasticity of raw shrimp stored on ice was measured with the Instron equipped with a 50 kg load cell and a spherical indenter, and with our device. The yield point of raw shrimp was measured. The effects of shrimp size, cross head speed, sample temperature, degree of deformation on the measured elasticity values were determined. To measure the TPA parameters, two successive compression decompression cycles at the center of the first segment at various deformation levels was performed at different crosshead speeds. Results were analyzed statistically to evaluate differences in results at different treatments

## RESULTS AND DISCUSSION

### Visual attributes

Table I shows that estimation of weight by the view area is reliable, and that count and uniformity ratio can be accurately measured by machine vision.

Table I. Experimentally determined and estimated total weight, count and uniformity ratio values for different forms of white shrimp.

| | Total weight (g) | count / lb | Uniformity Ratio |
|---|---|---|---|
| Intact | | | |
| Experimental | 867.0 | 50.9 | 3.11 |
| $y = a+b^{x}$ | 867.5 | 50.8 | 2.98 |
| $y = a+b^{1.5}$ | 865.7 | 50.9 | 2.95 |
| $y = a+be^{x/c}$ | 867.0 | 50.9 | 2.96 |
| Headless | | | |
| Experimental | 593.6 | 75.8 | 3.17 |
| $y = a+b^{x}$ | 592.2 | 76.0 | 2.89 |
| $y = a+b^{1.5}$ | 593.5 | 75.8 | 3.08 |
| $y = a+be^{x/c}$ | 593.7 | 75.8 | 3.12 |
| Peeled | | | |
| Experimental | 509.4 | 90.1 | 3.23 |
| $y = a+b^{x}$ | 505.6 | 90.8 | 3.12 |
| $y = a+b^{1.5}$ | 508.7 | 90.3 | 3.22 |
| $y = a+be^{x/c}$ | 509.6 | 90.1 | 3.19 |
| Tail off | | | |
| Experimental | 461.1 | 98.6 | 3.32 |
| $y = a+b^{x}$ | 460.2 | 98.8 | 2.93 |
| $y = a+b^{1.5}$ | 462.0 | 98.4 | 3.22 |
| $y = a+be^{x/c}$ | 462.1 | 98.4 | 3.17 |

### Melanosis and Color

Melanosis scores of shrimp stored on ice increased with time up to 15 days, but was lower on day 17. Both the human expert and machine readings detected this decrease Luzuriaga et al., 996a). Figure I shows the color change in shrimp stored on ice for up to 17 days. Melanotic colors (a) showed an increase in color 2 (R =96, G = 32, B =32) and 4 (160, 96, 32). Others stayed the same or fluctuated without a definite pattern. Non-melanotic colors (b) showed drastic decreases in colors 61 (224, 224, 160) and 57 (160, 160, 96), and an increase in color 6 (224, 160, 32). The change in these colors could be monitored, and quality related information extracted. The computer program also evaluated the color spectrum of the samples and compared it to the minimum and maximum values of colors considered "normal" for that species, stored in a database. These values would be different for different species, but the evaluation method would be identical.

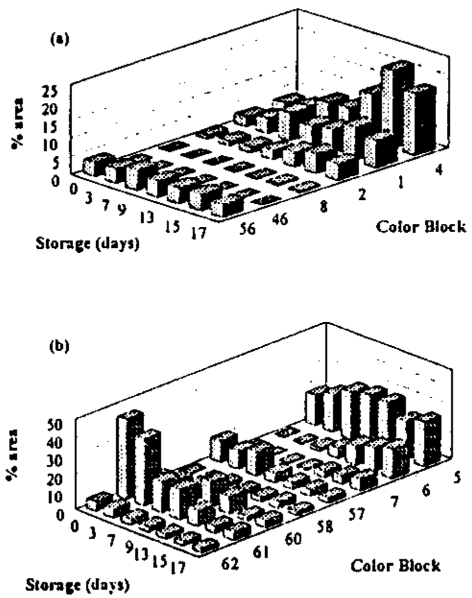


FIGURE 1. Color change in white shrimp stored on ice. a) Melanotic colors; b) Non-melanotic colors.



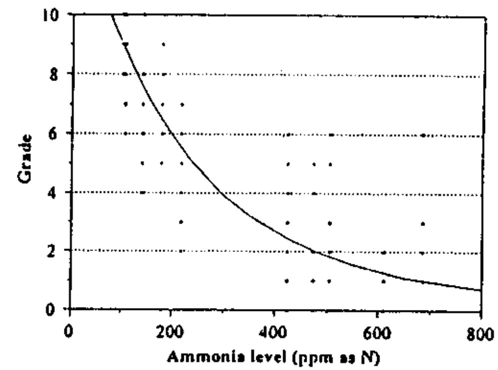


FIGURE 2. Correlation of sensory results with machine-read ammonia levels in shrimp stored on ice.

### Ammonia Measurements

Figure 2 shows the change in the ammonia levels of shrimp stored on ice, and the grades given to samples by the sensory panelists. The variability in the sensory panel data is expected, An exponential equation was fitted to the data where y = grade (from 0 to 10) and x =$NH_3$ level.

$$y = 0.3338 + 13.363\ e\ -x/229\text{-}93 \qquad (1)$$

The fitted curve showed an exponential decrease of grade with an increase in the $NH_3$ levels. Based on these results a grade of 10 could be given to samples with 75 ppm of $NH_3$ or less. An intermediate score of 5 was represented by 230 ppm of $NH_3$. During sensory evaluation, panelists expressed that they considered a grade of 5 the limit between accepting or rejecting a sample, which confirms the results of Cheuk and Finne (1984).

### "Electronic Nose" Results

The results of the response of DMA, TMA and ammonia at different concentrations is shown in Figure 3.

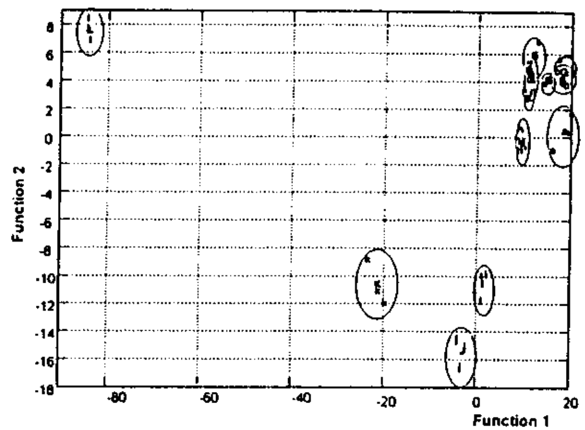


Figure 3.Multiple discriminant analysis of shrimp samples stored on ice for 14 days, where a=o, b=2, c=4, d=6, e=8, f=10, g=12, h=14 days. "Electric Nose" results of the response of DMA, TMA and ammonia at different concentrations.

Multiple discriminant analysis is a statistical method that enables the reduction of multi-dimensional data into two or three dimensions, which can be viewed in a single plot. Significant differences between samples are shown by the spatial separation between clusters.

The results from the multiple discriminant analysis showed that the odor profile from the ammonia, TMA and DMA solutions are different and can be grouped in clusters. Also, the concentrations of each solution has also been differentiated in smaller clusters within the main cluster.

From Figure 4, it can be seen that the different stages of decomposition in shrimp are clearly grouped in distinct regions of the plot. Therefore, the NOSE unit was capable of differentiating the change in odor profile of the shrimp samples during storage. This, combined with the objective attributes from visual and texture measurements, can be used to evaluate the quality of shrimp.

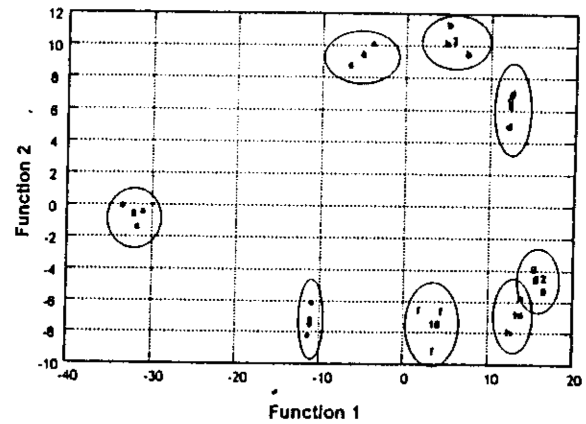


FIGURE 4. Multiple discriminant analysis of shrimp samples stored on ice for 14 days. a=0, b=2, c=4, d=6, e=8, f=10, g=12, h=14.

TABLE II. Ammonia levels in shrimp during storage on ice, in NOSE experiments.

| Days on ice | Ammonia levels (ppm as N) | Standard deviation (ppm as N) |
|---|---|---|
| 0 | 132 | 13.0 |
| 2 | 158 | 31.9 |
| 4 | 388 | 31.3 |
| 6 | 488 | 38.3 |
| 8 | 687 | 48.9 |
| 10 | 786 | 37.8 |
| 12 | 796 | 43.4 |
| 14 | 972 | 17.9 |

### Texture Measurement

Table III shows the elasticity measurement results for shrimp stored on ice. Elasticity did not change significantly during the first 6 days. Between day 6 and 9, there was a significant decrease in elasticity. This corresponded well with the onset of melanosis, and the ammonia levels that the panelists considered as unacceptable. Therefore elasticity could be used as a texture attribute in evaluating overall quality. Elasticity values did not change significantly after day nine.

Texture Profile Analysis (TPA) was also performed (Bourne, 1978). The data obtained were not of great value for the purpose of correlation with the quality of shrimp. Most of the TPA parameters showed little difference over time, and in most cases no significant differences were observed. The cohesiveness, hardness, fracturability, gumminess and chewiness parameters did not show any trend or significant change during storage. Springiness and adhesiveness showed some significant differences. Springiness at day 0 was higher and significantly different from that at the other storage times. After day 3 the value of springiness remained constant. Similar behavior was observed for adhesiveness. At day 0 the adhesiveness was low compared to that at the rest of the storage times. After day 3 adhesiveness increased four times from day 0, and remained constant up to day 18. This increase was confirmed subjectively: shrimp were sticky on and after the third day.

Table 3. Measurement of elasticity of peeled white shrimp during storage on ice. Deformation level 27%, crosshead speed = 100 mm/minute.

| Storage Time (days) | n (shrimp) | Degree of Elasticity (%) | Std. Deviation (%) | Difference[a] $p<0.05$ |
|---|---|---|---|---|
| 0 | 20 | 45.6 | 4.90 | a |
| 3 | 20 | 45.3 | 7.67 | a |
| 6 | 20 | 44.7 | 4.51 | a |
| 9 | 20 | 40.8 | 5.39 | b |
| 12 | 20 | 40.3 | 4.86 | b |
| 15 | 20 | 41.0 | 4.11 | b |
| 18 | 20 | 38.5 | 4.46 | b |

[a]: Same letter indicates no significant difference at $p<0.05$.



## FUTURE WORK

We are currently working on the integration of the Neotronics Electronic Nose unit into our existing system. The capabilities of this unit will enhance the automated quality evaluation of seafood. Other shrimp species, and eventually other seafood will be evaluated with this system to develop a database of quality attributes at different degrees of decomposition.

## ACKNOWLEDGMENTS

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## Session 11—SENSORY MONITORING—DISCUSSION

*Anon.* Why was tilapia added to Thailand shrimp farming?

*Sophonphong (Thailand)* In order to eat the algae.

*Anon.* Electronic nose is good, however, it is not as sensitive as the human nose. If 34% of sensory variation is in individuals, why can't there be more consistency?

*Balaban (U.S.A.)* In some cases, this is true. In shrimp, nitrogen changes to ammonia and the nose is better because several odors are detected. There is lack of consistency often because of difficulty in standardizing methods across the world. More attention has to be given to standardization. Sensory is a starting point for determining product quality.