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Assessment of elemental profiling for distinguishing geographic origin of aquacultured shrimp from India, Thailand and Vietnam

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ABSTRACT

Shrimp from three major exporting countries – India, Vietnam, and Thailand – were identified to country of origin by elemental profiling. Concentrations of 23 elements, including essential macro- and micro-nutrients and non-essential trace elements, in headless shell on shrimp (HLSO) samples were analyzed by ICP-AES. Elemental concentrations in shrimp showed high variation. Multivariate statistics including principal component analysis, stepwise discriminant analysis, Kernel method, and canonical discriminant analysis demonstrated the validity of elemental profiling in distinguishing aquacultured shrimp from different countries. However, it was not possible to reach definitive conclusions about which elements are the best descriptors for each region. The method was also tested as a means of differentiating shrimp produced to area of origin for two areas in Thailand, three provinces in Vietnam and India. All the multivariate statistical analysis demonstrated that the separation on a smaller scale was not as reliable as on the country scale.

1. Introduction

Food production is a major contributor to global resource use, and as a result, it causes many negative environmental impacts (Boyd & McNevin, 2015). Food safety issues also can arise from contamination of food products with pathogens and harmful chemical residues at the farm level or during processing and storage. Few if any countries are totally self-sufficient in food production, and there is a large international trade in food products (FAO, 2017). Government subsidies to different sectors in the production chain of food products may favor one country over another in international trade. Producers may not compensate workers fairly or provide safe working conditions. Thus, there is much concern over resource use, environmental stewardship, worker welfare, food safety, and fair trade within the global food system.

The government of a particular country may ban imports of food from specific countries because of food safety or other issues and impose tariffs on certain food products because of unfair trade practices (FAO, 2012; Smith & Watts, 2009). Some consumers seek food products of their own country. Others may avoid food products from specific countries on grounds of those countries' reputations for environmental stewardship, worker welfare, and food safety precautions. Thus, some countries require country of origin labeling of imported food products. In the case of fisheries products, consumers may want to know whether products are from wild-caught or aquacultured animals, and some governments require method of production labeling.

A growing number of consumers seek further assurance than provided by government regulations that their food is safe and produced by environmentally and socially responsible methods. Private certification programs have been formed that require participating producers to comply with third-party audited standards. These programs have a traceability component allowing certified products to be traced from the farm of origin to the consumer (Boyd & McNevin, 2015).

Food products may be intentionally or accidentally mislabeled

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as to country or origin, method of production, and as to whether they are certified. The high frequency of mislabeling (Jacquet & Pauly, 2008) has resulted in investigations of several methods for verifying geographic origin of food products to include elemental profiling, stable isotope analysis, lipid profiling, DNA bar coding, and near infrared spectroscopy (Li, Boyd, & Sun, 2016). Elemental profiling appears to have considerable promise for aquaculture products (Li, Boyd, & Odom, 2014; Li, Boyd, Odom, & Dong, 2013; Liu, Xue, Wang, Xue, & Xu, 2012; Smith & Watts, 2009). Moreover, elemental profiling has potential for distinguishing wild-caught from aquacultured fisheries products (Alasalvar, Taylor, Zubcov, Shahidi, & Alexis, 2002; Li, Boyd, & Dong, 2015).

Aquacultured shrimp is of particular interest in country of origin and method of production verification. A large proportion of internationally-traded shrimp are from aquaculture, shrimp are produced in many countries, shrimp aquaculture may cause severe environmental perturbations, shrimp are popular with consumers and of high economic value, and shrimp are a major component of aquaculture certification (Boyd & McNevin, 2015). For example, the USA imported 567,551 t shrimp valued at US$ 6.7 billion during 2014. These shrimp were imported from 39 countries, and a large proportion was produced by aquaculture (NOAA, 2014).

The purpose of the present study was to determine if aquacultured shrimp of the species *Litopenaeus vannamei* (Pacific white shrimp) from three major exporting countries – India, Vietnam, and Thailand – could be identified to country of origin by elemental profiling. In addition, elemental profiling was tested as a means of differentiating shrimp produced to area of origin for two areas in Thailand, three provinces in Vietnam and India. The elements included in the analyses were the ones for which the ICP-AES instrument used had the capacity to measure. These elements included the macronutrients Ca, Mg, Na, K, P, and S, the micronutrients Fe, Mn, Zn, Cu, and Se known to be essential in shrimp diets (Davis & Gatlin, 1996), Co, Ni, Cr, and Si that are possibly essential in shrimp nutrition (Tacon, 1987), and Al, As, B, Ba, Cd, Pb, Ti, and Zr for which there is no evidence of essentiality in diets for shrimp. The elements measured in this study were the same ones used in an earlier study to successfully delineate shrimp from several locations in the USA by elemental profiling (Li et al., 2014).

2. Materials and methods

2.1. Sample collection and pretreatment

Thirty shrimp samples each for India and Vietnam and 60 samples for Thailand were collected. Shrimp samples from India were from one pond each at 30 farms in Andhra Pradesh state. In Vietnam, shrimp were collected from one pond on each of 10 farms in three adjacent provinces in the Mekong Delta region – Soc Trang, Bac Lieu, and Ca Mau. There were two sampling areas in Thailand – one in southern Thailand and the other in eastern Thailand. Shrimp were obtained from 30 ponds representing 25 farms in southern Thailand and another 30 ponds representing 27 farms in eastern Thailand. The locations of these farms are depicted in Fig. 1. The ponds were filled with water directly from the sea or from canals fed by sea water. Ponds were operated for intensive production with daily inputs of manufactured feed equal to about 2% of the estimated body weight of shrimp daily. Mechanical aeration to avoid low dissolved oxygen concentration was applied 18–24 h/day.

Shrimp were collected from each pond on a single date between May and August 2016. Shrimp were captured with cast nets. The collectors wore disposable latex gloves and selected exactly 16 shrimp by hand from one or more cast net hauls in each pond. Shrimp had individual weights of 10–20 g, but most were 12–16 g. Each sample of shrimp was placed in a separate zip-lock bag and stored on ice in an insulated chest for up to 6 h before being prepared for dehydration. In order to avoid possible elemental contamination, shrimp in each sample were deheaded by an individual wearing disposable latex gloves. However, the shells were not removed from the shrimp tails. This provided samples that were prepared in the same way as is the major shrimp product imported by the USA. After deheading all shrimp in one sample, the waste was cleaned up and the gloves were changed.

The shrimp tails were dehydrated in an ABC Electro Food Dehydrator, Model ABC-728.002, Hong Kong. Shrimp from each sample were placed on a separate shelf in the dehydrator and held at about 20 °C for 12–15 h. After dehydration, each sample was divided into two equal, subsamples of each shrimp, placed in zip-lock bags, and stored in a freezer at −4 °C. After all shrimp samples were collected and dried. One set of the subsamples was shipped by air-courier to Auburn University, Auburn, Alabama USA. The other set was kept as a backup in case of loss during shipment or preparation for analyses.

The shrimp were further dried to a constant weight at 80 °C in a mechanical convection oven. Dried shrimp samples were ground with a IKA Economical Analytical Mill (Cole-Palmer, Vernon Hills, Illinois USA). The steel blade of the mill was replaced with a carbide-coated one to avoid metal contamination.

2.2. Elemental analysis

A 2.0-g aliquot of each dried, ground shrimp sample was weighed into a 125-mL Erlenmeyer flask, and 40 mL of a 7:3 solution prepared from concentrated, high purity nitric and perchloric acids (BDH ARISTAR PLUS from VWR International, Radnor, PA, USA), respectively, was added. Flasks were covered with watch glasses and held overnight at room temperature in a perchloric fume hood before being digested on hot plates at 190 °C. The acid solution was added as necessary to avoid the flask from going dry. Digestion was considered complete when the contents were light yellow. The residues in the flasks were treated with 5.0 mL of 1.0 mol/L hydrochloric acid (BDH ARISTAR PLUS), transferred to 50-mL volumetric flasks, and made to volume with glass-distilled water. The flask contents were thoroughly mixed and filtered through Whatman No. 42, acid-washed filter paper into 50-mL plastic tubes, capped, and stored in a freezer at −4 °C until analyzed.

2.3. Apparatus

The elemental analysis was done with an inductively coupled plasma atomic emission spectrometer [ICP-AES] (Spectro Ciros CCD, SPECTRO analytical Instruments, Inc. Mahwah, New Jersey, USA). The ICP-AES has an axial plasma observation and operates from 125 to 770 nm at 27 MHz. Additional parameters are: plasma power 1400 W, coolant flow 14 L/min, auxiliary flow 1 L/min, nebulizer flow 0.95 L/min, preflush parameter 20 s, and total analysis time 60 s.

The instrument has internal standards for all elements. But, in order to verify precision and accuracy, certified standards for each element were obtained from Spex CertiPrep, Metuchen, New Jersey USA. These standards were diluted with ultrapure distilled water to provide five concentrations within the expected ranges of the samples. The internal standards were checked against the prepared external standards that were analyzed in duplicate. It was verified that agreement within 5% or less was achieved between standard concentrations and instrument results for each element. The standard verification process was repeated after each batch of 40 samples. The analyses included Al, As, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Pb, S, Se, Si, Ti, Zn, and Zr.