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Nutritional properties of the invasive lionfish: A delicious and nutritious approach for controlling the invasion

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Abstract. Lionfish, *Pterois volitans* and *P. miles*, are native to the Indo-Pacific and have recently invaded the Western Atlantic Ocean. Strategies for control of this invasion have included limited removal programs and promotion of lionfish consumption at both local and commercial scales. We demonstrate that lionfish meat contains higher levels of healthy n-3 fatty acids than some frequently consumed native marine fish species. Mean lionfish fillet yield was 30.5% of the total body wet weight, a value that is similar to that of some grouper and porgy species. A sensory evaluation indicated that lionfish meet the acceptability threshold of most consumers.
Key Words: lionfish, fatty acid, invasive species, nutrition.

Introduction. The invasive Indo-Pacific red lionfish, *Pterois volitans* (Linnaeus, 1758) and *Pterois miles* (Benett, 1828), are now established along the Southeast coast of the United States and the Caribbean and is presently invading the Gulf of Mexico (Morris & Whitfield 2009; Schofield 2009; Schofield et al 2010; Whitfield et al 2002, 2006). Lionfish were first observed in South Florida waters in 1985 (Morris & Akins 2009), but were not considered established until several individuals were documented off North Carolina in 2000 (Whitfield et al 2002). Lionfish are a popular marine ornamental species, an industry that accounts for a significant proportion of the total pet trade imports (Balboa 2003; Ruiz-Carus et al 2006). Given the popularity of lionfish in the aquarium trade and the number of other non-native marine ornamentals observed in South Florida waters (Schofield et al 2010), it is largely assumed that lionfish were released intentionally or unintentionally by home aquarium hobbyists or commercial aquarists (Morris & Whitfield 2009).

Invasive lionfish pose serious threats to native coral and hard-bottom communities of the Atlantic (Morris & Whitfield 2009) and are considered to be one of the top fifteen global threats to conservation of biodiversity (Sutherland et al 2010). Densities of lionfish at some locations have far surpassed those of native reef fish occupying similar trophic levels (Green & Côté 2008; Morris & Whitfield 2009). The potential ecological impacts of lionfish are far-reaching and could include: direct consumption of key reef species; competitive exclusion of native reef fish; cascading trophic impacts such as herbivore removal causing an increase in algal growth over corals; and thwarting efforts to rebuild economically important stocks of snapper and grouper (Morris & Whitfield 2009).

The invasion of the Atlantic by a non-native fish is unprecedented; thus, lionfish control strategies or mitigative measures are untested. In many locations, researchers are working to develop control strategies for lionfish that use diver removals (Morris & Whitfield 2009). Attempts to develop trapping strategies for lionfish have been largely unsuccessful and are

problematic because of bycatch (J. Morris & L. Akins, unpublished data). A control strategy documented by Morris & Whitfield (2009) involved promoting lionfish as a food fish, especially in the Caribbean and some marine protected areas where high densities of lionfish are easily and inexpensively accessed. Indeed, lionfish are considered a food fish in their native range (Morris & Whitfield 2009) and generally speaking, the family Scorpaenidae is a delicacy in Mediterranean cuisine forming the basis for dishes such as rascasse and bouillabaisse.

Consumption of marine fish offers numerous health benefits, mostly attributed to high concentrations of n-3 polyunsaturated fatty acids, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Weaver et al. (2008) divided commonly consumed food fish into three categories based on their profile of n-3 polyunsaturated fatty acids (PUFA): Category 1 fish (highest) contained >500 mg of n-3 fatty acids per 100 g of fish; Category 2 contained 500 - 150 mg; and Category 3 contained <150 mg. The objectives of this study were to 1) document and compare the fatty acid profile of lionfish to the profiles of other marketplace fishes, 2) determine the fillet yield of lionfish, and 3) conduct a preliminary sensory comparison between lionfish and a market reef fish.

Material and Method

Fatty acid analyses

A lipid profile was obtained through a fatty acid analysis (FAA) on four lionfish (mean total length = 120 mm ± 20.6 standard error) collected from the Bahamian Archipelago. Samples were shipped frozen to Roger Williams University where they were maintained at -80°C. Muscle tissue samples were removed from the dorsal side of each fish, ensuring that no bones, skin or spines were present in the sample. The samples were then massed and lyophilized for 48 hours. Total lipids were extracted from lyophilized samples with chloroform/methanol (2:1 v/v) as described by Folch et al. (1957). Between 20 and 50 mg of the dried muscle tissue were weighed and ground in a tissue grinder with 10 mL of a chloroform/methanol (2:1 v/v) mixture, vacuum filtered and rotovapped to dryness. Fatty acid methyl esters (FAMES) were prepared by trans-esterification following the method of Drillet et al. (2005). After extraction lipids were reconstituted in 2 mL of toluene/methanol/acetyl chloride mixture (40:50:10 v/v/v) and 0.5 mL of 1.6 mg mL^{-1} heptadecanoic acid (C17:0) was added as an internal standard. The mixture was then heated in a water bath at 60°C for 60 min. Aqueous sodium bicarbonate (1 mL or 5% by weight) was then added and the upper organic layer was removed and saved. The original solution was washed twice with heptane and the upper organic layers were combined. The solvent was then evaporated by a gentle stream of warm nitrogen and then re-suspended in 1 mL of chloroform. A 1.0 µL aliquot of the FAMEs was analyzed on an Agilent 6850 Gas Chromatograph (GC) coupled with an Agilent 5975B mass sensitive detector. The GC was equipped with an Agilent, J&W DB-23 column (60 m long, 0.250 mm ID with a 0.25 µm film thickness). The inlet temperature was 250°C, and helium was used as the carrier gas, with a 2.1 mL min^{-1} flow rate and splitless injection. The oven temperature was initially set to 50°C for 1 min and was increased to 175°C at a rate of 25°C min^{-1} and then increased to 235°C at a rate of 4°C min^{-1} and held for 5 min (David et al 2002). The concentration of FAMES in each sample was determined by using the quantization feature on the ChemStation (Agilent Technologies) and comparing the peak areas of known FAMEs standards (Supelco Inc. CAT No 18919-1AMP) to those observed from the lionfish samples. FAMES peaks were identified by comparing retention times and mass spectrographs to those of known FAMEs and corroborating with the NIST MS Search 2.0 mass spectral library. The concentration of each fatty acid was only included if there was a 90% or better certainty on the concentration from the ChemStationQuantitation Software.

Fillet yield

To determine mean fillet yield, lionfish (n = 49; mean total length = 346 mm ± 5.3 standard error; mean weight = 637 g ± 31.03) were collected from the offshore waters of North Carolina. Lionfish were scaled and fillet by hand while paying careful attention to removing the maximum amount of meat from the flank. Total fish weight and fillet yield was recorded for each fish and the percent fillet yield calculated.

Sensory Evaluation

Red porgy *Pagrus pagrus* (Linnaeus, 1758) were selected for a sensory comparison with lionfish owing to its comparable size and texture. Both species were obtained from the central coastal waters of North Carolina, filleted, scaled, and vacuum packed in 20 x 25 cm, 3-millimeter thick, VAK poly bags (Shippers Warehouse, Morrow, Georgia) to minimize lipid oxidation during cold storage. Fillets were frozen to -20°C in a convection freezer. Twenty-four hours prior to the sensory evaluation, the fillets were removed from frozen storage and allowed to thaw at 4.4°C in a convection cooler.

A kitchen-tested recipe was selected from a number of recipes developed specifically for snapper and grouper species by specialists with the North Carolina Sea Grant Extension Program and North Carolina Cooperative Extension. Fillets were arranged on broiler pans according to size and were brushed with butter to prevent moisture loss during cooking and then lightly salted. The lionfish and red porgy fillets were broiled simultaneously in separate ovens until the flesh at the center of the fillets appeared opaque, indicating they had been adequately cooked. A semi-solid, garlic and basil-flavored butter was applied to and allowed to melt over each fillet. The fillets were then sized into two to three ounce portions, coded, and served to 20 randomly selected panelists from the central coast of North Carolina. Panelists were screened to ensure that they occasionally dined on snapper and grouper and did not dislike garlic, basil, or butter flavorings. In addition to the coded samples of lionfish and red porgy, panelists were provided a cup of distilled water, and a score sheet. After receiving the fish, panelists were instructed to rinse their palates with distilled water before tasting the first sample and again before evaluating the second sample.

Panelists were instructed to evaluate the flavor, texture, color, and appearance of both species according to a hedonic scale where 7 = Excellent, 6 = Very Good, 5 = Good, 4 = Fair, 3 = Poor, and 1 = Completely Unacceptable. We define the "acceptability threshold" as 5 or above for any of the aforementioned sensory attributes. Scores lower than 5 indicate a recipe or a new product formulation must be refined to enhance consumers' expectations for consumption quality. In addition, panelists were requested to circle the code of their preferred choice. Panelists were not required to make a choice on the score sheets, but were encouraged to include written comments. Mean scores for each comparison were evaluated statistically using a Student's t-test (Microsoft Excel) with $p<0.05$ considered significantly different.

Table 1. Fatty acid analysis results for lionfish.

Fatty Acid Methyl Ester (FAME)	mg FAME/100 g Wet Lionfish Muscle Tissue	Percentage of total FAME
C14:0	4.02 (1.73)	2.04 (0.56)
C14:1	0.24 (0.40)	0.17 (0.21)
C15:0	1.09 (0.79)	0.49 (0.31)
C15:1	0.39 (0.68)	0.27 (0.31)
C16:0	64.67 (9.09)	27.54 (1.85)
C16:1	5.01 (3.27)	2.34 (1.23)
C17:1	1.02 (1.38)	0.89 (0.47)
C18:0	23.41 (3.98)	9.94 (0.88)
C18:1n9trans	21.43 (3.63)	9.28 (1.05)
C18:1n9cis	4.79 (0.95)	2.08 (0.24)
C18:2n6cis	2.37 (1.68)	1.06 (0.62)
C18:3n3	1.50 (1.89)	0.97 (0.77)
C20:1n9	0.29 (0.52)	0.27 (0.25)
C20:4n6	20.32 (3.86)	8.34 (1.29)
C20:5n3	14.17 (3.83)	5.79 (0.67)
C22:6n3	73.01 (15.65)	30.03 (3.20)
DHA/EPA	5.15	5.19
Total n-3	88.69	36.79
Total n-6	22.69	9.40

Results

Fatty acid analysis and fillet yield

The FAA revealed that lionfish tissue contained primarily 13 fatty acids: C14:0, C14:1, C15:0, C15:1, C16:0, C18:0, C20:0, C18:1n9trans, C18:1n9cis, C18:3n3, C20:4n6, C20:5n3 and C22:6n3 (Table 1). The fatty acid C22:6 or Docosahexaenoic acid (DHA) was the most concentrated. The total concentration of n-3 fatty acids in lionfish (EPA and DHA) were less than 150 mg fatty acid/g muscle tissue, which qualifies lionfish as a Category 3 fish (Weaver et al., 2008).

When arranged as a percentage of fatty acid/total fatty acid composition, the n-3 fatty acids (DHA and EPA) ranked highest. Lionfish contain a higher percentage of healthy n-3 fatty acids than species groups such as snapper, grouper, and bluefin tuna. Lionfish contain a relatively low concentration of the less-desirable fatty acids (Weaver et al 2008) (Figure 1). The mean lionfish fillet yield was 30.5% ± 0.002 standard error.

Sensory Evaluation

The overall sensory characteristics of both lionfish and red porgy scored in the range of "Good" to "Very Good" indicating that the panelists found both species appealing. The sensory comparison resulted in similar scores between the two species for appearance ($p = 0.83$) and color ($p = 0.35$) and higher scores for red porgy for flavor ($p = 0.01$) and texture ($p = 0.02$). When asked to make an overall preference, 10 panelists (50%) chose red porgy while only three (15%) favored the lionfish. The remaining panelists (35%) did not indicate a preference. Based on the who preferred the red porgy indicated that the texture of the meat was firmer than the lionfish, while one panelist indicated that the softer texture of the lionfish was more appealing. Texture seemed to be the deciding factor when panelists rated the flavor of the red porgy higher than that of the lionfish.

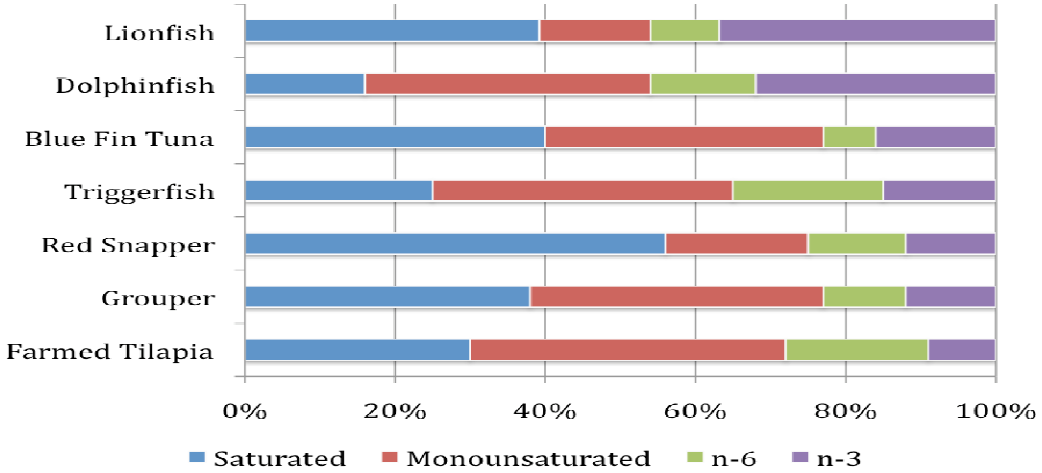

Figure 1. Percent saturated and monosaturated fats and Omega-3 and Omega-6 fatty acids for lionfish and other commonly harvested marine species. Values for farmed tilapia, a widely available freshwater species, are provided for comparison (Weaver et al 2008).

Discussion. Control efforts for lionfish in the U.S. South Atlantic are desirable to reduce the potential ecological harm of this invasion (Morris & Whitfield 2009; Morris et al 2010). Past harvest pressure and market demand for resident reef fish suggest that lionfish harvesting could be a promising local control strategy. Given bycatch issues associated with hook and line and trap gears, targeted efforts for lionfish will likely be most successful by spearfishing or by collecting live fish with hand nets. Lionfish may, however, be harvested as a bycatch in some trap fisheries. Lionfish bycatch in traps is significant as some operations in Florida and Bermuda are reporting catches of multiple lionfish in single traps and upwards of 50-100 lionfish have been landed per day (J. Morris, unpublished data).

When compared to some other marine reef fish species (e.g., red snapper, dolphinfish etc., see Figure 1) of the Southeast U.S. and Caribbean, lionfish are higher in n-3 fatty acids and contain a relatively low amount of saturated fatty acids. According to the fillet yield and sensory results, lionfish were found to produce a mean % fillet yield of 30.5%, a value that is similar to that of groupers red hind *Epinephelus guttatus* (30.1%), graysby *Cephalopholis cruentatus* (34.18%), and coney *Cephalopholis fulva* (34.69%), porgies *Calamus* sp. (32.93%), and larger than grunts white grunt *Haemulon plumier* (24.69%) and French grunt *Haemulon flavolineatum* (26.52%) (Coblentz 1997). This fillet yield is significant but also emphasizes the importance of fish processing (i.e., filleting) prior to shipping as this will reduce shipping costs per unit of edible lionfish meat.

Like snapper, the flesh of lionfish is white and the flavor is mild, making it suitable for a variety of culinary preparations. Several chefs have developed lionfish recipes and have participated in demonstrations depicting the proper and safe way to prepare a lionfish (J. Morris, personal observations). Efforts are currently underway by the National Oceanic and Atmospheric Administration and the Reef Environmental Education Foundation to introduce lionfish to the menus of restaurants. The success of this program will likely depend on identifying a consistent source of lionfish with similar harvest costs as native reef fish species. It should be noted that the same seafood safety advisories promulgated for native reef fishes, such as ciguatera poisoning, should also be observed for lionfish.

These results indicate that the palatability of lionfish makes it a good candidate for human consumption and thus a viable incentive for removal of the lionfish. Outreach focused on educating the public on lionfish handling and cleaning is needed to minimize the risk of envenomation to fishers and processors. The novelty of lionfish as a food item will likely spur extensive public interest, especially regarding the ecological benefits of removing this invasive species.

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References

Balboa C. M., 2003 The consumption of marine ornamental fish in the United States: a description from the U.S. import data. In: J.C. Cato, and C.L. Brown, (Eds.), Marine Ornamental Species. Collection, Culture and Conservation. pp. 65–76. Iowa State Press, Ames, Iowa.

Coblentz B. E., 1997 Subsistence consumption of coral reef fish suggests non-sustainable extraction. Conserv Biol **11**:559-561.

David F., Sandra P., Wylie P. L., 2002 Improving the Analysis of Fatty Acid Methyl Esters Using Retention Time Locked Methods and Retention Time Databases. Agilent Technologies-Application. Agilent Technologies, Palo Alto, CA. 11 pp.

Drillet G., Iversen M. H., Sørensen T. F., Ramløv H., Lund T., Hansen B. W., 2006 Effect of cold storage upon eggs of a calanoid copepod, *Acartiatonsa* (Dana) and their offspring. Aquaculture **254**:714–729.

Folch J., Lees M., Sloane-Stanley G. H. 1957 A simple method for the isolation and purification of total lipids from animal tissues. J Biol Chem **226**:497-509.

Green S. J., Côté I. M., 2008 Record densities of Indo-Pacific lionfish on Bahamian coral reefs. Coral Reefs **28**:107.

Kimball M. E., Miller J. M., Whitfield P. E., Hare J., 2004 Thermal tolerance and potential distribution of invasive lionfish (*Pterois volitans/miles* complex) on the East Coast of the United States. Mar Ecol Prog Ser **283**:269–278.

Morris J. A. Jr., Akins J. L., 2009 Feeding ecology of invasive lionfish (*Pterois volitans*) in the Bahamian archipelago. Environ Biol Fish **86**:389–398.

Morris J. A. Jr., Whitfield P. E. 2009 Biology, ecology, control and management of the invasive Indo-Pacific lionfish: an updated integrated assessment. NOAA Tech Memo NOSNCCOS **99**, 57 pp.

Morris J. A. Jr., Shertzer K. W., Rice J. A., 2010 A stage-based matrix population model of invasive lionfish with implications for control. Biol Invas **13**:7-12. DOI 10.1007/s10530-010-9786-8.

Ruiz-Carus R., Matheson R. E., Roberts D. E. Whitfield P. E., 2006 The western Pacific red lionfish, *Pterois volitans* (Scorpaenidae), in Florida: Evidence for reproduction and

parasitism in the first exotic marine fish established in state waters. Biol Conserv **128**:384-390. DOI:10.1016/j.biocon.2005.10.012
Schofield P. J., 2009 Geographic extent and chronology of the invasion of non-native lionfish *Pterois volitans* [Linnaeus 1758] and *P. miles* [Bennett 1828] in the Western North Atlantic and Caribbean Sea. Aquat Invas **4**:473–479.
Schofield P. J., Morris J. A. Jr., Langston J. N., Fuller P. L., 2010 *Pterois volitans/miles*. USGS Nonindigenous Aquatic Species Data Base, Gainesville, Florida: http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=963. Accessed 25 Oct 2010.
Sutherland W. J., Clout M., Côté I.M., Daszak P., Depledge M. H., Fellman L., Fleishman E., Garthwaite R., Gibbons D. W., De Lurio J., Impey A. J., Lickorish F., Lindenmayer D., Madgwick J., Margerison C., Maynard T., Peck L. S., Pretty J., Prior S., Redford K. H., Scharlemann J. P. W., Spalding M., Watkinson A. R., 2010 A horizon scan of global conservation issues for 2010. Trends Ecol Evol **25**:1–7.
Weaver K. L., Ivester P., Chilton J. A., Wilson M. D., Pandey P., Chilton F. H., 2008 The content of favorable and unfavorable polyunsaturated fatty acids found in commonly eaten fish. J Am Diet Assoc **108**:1178-1185.
Whitfield P. E., Gardner T., Vives S. P., Gilligan M. R., Courtenay W. J., Ray G. C., Hare J. A., 2002 Biological invasion of the Indo-Pacific lionfish *Pteroisvolitans* along the Atlantic coast of North America. Mar Ecol Prog Ser **235**:289-297.
Whitfield P. E., Hare J. A., David A. W., Harter S. L., Munoz R. C., Addison C. M., 2006 Abundance estimates of the Indo-Pacific lionfish *Pteroisvolitans/miles complex* in the Western North Atlantic. Biol Invas **9**:53-64.

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