

Skinless V-Notched Fillet Yields of Tilapia (*Oreochromis*)

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ABSTRACT

White hybrid tilapia (*Oreochromis*) produced in an experiment that determined the effects of various management practices on growth rate and feed conversion ratios were weighed, measured, and filleted at the conclusion of the growth trials. Regression analyses produced two models to predict fillet yields—one model that used the fish weight and length and a reduced model that used only fish weight. While the full model produced a somewhat smaller error, it was found to be impractical to use fish length to estimate fillet yield due to the difficulty in obtaining a length measurement. The full model also produced unreasonable estimates when extended beyond the limits of the data set. Using a paired t-test, fillet yields of males and females of equal weights were tested and were not found to be significantly different. This model provides a means of converting market price of tilapia fillets to a price for live fish, once processing costs are considered.

INTRODUCTION

Marketed food commodities, including fish, undergo changes in product form before reaching the consumer. The objective of changing the product form of a commodity is to add value to the product. In the case of filleted fish products, changing a whole fish to a filleted product enhances the value of the product, but also significantly reduces its weight. The producer is paid not for the live weight of the fish, but for the final weight in commodity form. Producers raising fish for the fillet market need a simple means of estimating fillet yield in order to make management decisions regarding what size of live fish to harvest.

Market demand for various forms of tilapia has been created in large metropolitan areas of the United States and Canada by ethnic groups from regions including South and Central America, Southeast Asia, Africa, China, and the Philippines. Although most of the tilapia consumed in the United States is imported as fresh or frozen fillets or frozen whole fish (Harvey 2000), certain ethnic groups prefer live fish, for which they are willing to pay a significant premium. High transportation and handling costs make importation of live tilapia into the United States prohibitively expensive, and thus a domestic live tilapia industry has developed within the United States, primarily using intensive recirculating aquaculture systems. While the amount of tilapia produced domestically is rather small compared to that of catfish and trout, according to the USDA

(Harvey 2000), tilapia represents the second largest import of finfish into the United States on a live weight and value basis, trailing only Atlantic salmon. Hence, there is ample evidence of a market for tilapia.

Tilapia cannot survive in low ambient temperatures (Phippart and Ruwet 1982) and therefore, except for the southernmost regions, they cannot be produced year-round in ponds in North America. Production costs of tilapia raised in ponds have been estimated to range between \$0.88 and \$1.32/kg (Fitzsimmons and Posadas 1997), compared to an estimated production cost of \$2.79/kg for recirculating aquaculture systems (Losordo and Westerman 1994). Because of the significantly higher cost of indoor, temperature-controlled production, domestic producers generally cannot compete economically with foreign, pond-raised, processed tilapia products, which are relatively inexpensive to ship. However, they can compete for the live tilapia market due to the challenges and costs associated with transporting live fish.

Many wholesalers require a minimum size for live tilapia; producers report both 340 and 450 g (three-quarters and one pound) as minimum desired weights. Producers are tempted to retain, and grow out further fish that are too small to be marketed as live fish. However, research conducted at Virginia Tech indicates that as tilapia mature, both the growth rate and feed-conversion efficiency decrease dramatically (Kirkup *et al.* 2000), and that these decreases are primarily dependent on age rather than either size or culture conditions. Therefore it might be more economical to fillet substandard fish rather than allowing these poor performers to grow to live-market size.

Tilapia fillet yields are of interest to domestic producers for several reasons. First, fillet yield can be used to establish the value of live tilapia, once the market price and processing, handling, and carcass disposal costs are known. Secondly, fillet yield and variation are of interest to food processors and restaurateurs who are interested in a specific size fillet or portion.

In the spring and early summer of 1999 an experiment was conducted to investigate the effects of different temperature and feeding rates upon the growth and feed conversion efficiency of "Rocky Mountain" white tilapia. As a result of the experiment, there was large variation in size, length, and weight among the fish in the various treatments. At the conclusion of the experiment, the fish were weighed, measured, sexed, filleted, and the fillets were weighed.

MATERIALS AND METHODS

The fish used for the experiment are commonly called “Rocky Mountain White Tilapia”, although a best guess is that they are a white inter-specific species of the genus *Oreochromis*, primarily *O. niloticus*, *O. aureus*, and *O. mossambicus*. This hybrid has been selectively bred at Blue Ridge Aquaculture Inc., (Martinsville, VA, USA) for its color and growth rate. The white hybrids are desirable in the live fish market because of their generally attractive external appearance. This hybrid grows rapidly and has other physiological attributes that make it well suited to culture in high-density aquaculture systems. Although predominantly white, the fish ranged in color from a bright white to a bluish and golden white to a few that were colored a reddish brown. As fry, the fish were given methyltestosterone mixed with their feed to chemically sex reverse the females. Prior to delivery to Virginia Tech, the fish were graded twice at Blue Ridge Aquaculture, Inc. to obtain a relatively uniform size by removing the runts.

The fish were raised in 660.7 L (150 gallon) agricultural watering troughs (Rubbermaid, Winchester, VA, USA). The experiment was a three (temperatures) by four (feeding levels) factorial design having two replicates. The nominal culture temperatures were 26, 29, and 32°C and the feeding levels for each temperature, conducted four times a day, were saturation feeding, 87, 73, and 60% of the daily saturation feed rate. The average fish weight at the beginning of the experiment was approximately 53g, and the growth experiment lasted 20 weeks. At the conclusion of the experiment, the fish were taken off feed for three days prior to harvesting. The tanks were completely drained and the live fish from each tank were placed in an ice-filled chest. The fish were kept on ice for several hours prior to being filleted to anesthetize them and increase rigor, making them easier to fillet and reducing the amount of blood in the fillet. Prior to processing, the fish were weighed to the nearest gram using a digital scale, and measured to the nearest millimeter using a measuring board. Fish weighing 300g or more were then filleted; smaller fish were dissected to determine sex but were not filleted. A total of 407 fish were filleted. As noted, the fish used in this experiment were chemically sex reversed, i.e., from female to male, and thus, during the filleting process, only 10% were identified as females. Of that 10%, a disproportionate number of females did not reach the 300g minimum cut-off weight for filleting; thus only 24 fish identified as females were filleted.

The filleting was conducted by two competent fish cutters with extensive experience in filleting tilapia for a small Midwestern tilapia producer. The v-notched skinless filleting was primarily accomplished with electric carving knives. One individual cut across the torso just behind the gill, and then cut horizontally, down along the backbone through the ribcage to the tail. While still attached to the tail, the side of the fish was then flipped over and another horizontal cut was made along the skin to separate the meat from the skin and scales. The sex of the fish was then determined based upon the internal sex organs. The procedure was repeated on the other side of the fish. The other individual cut the ribcage out of the fillet with an electric knife and removed the pectoral fin with a v-shaped cut. The combined weights of the fillets for each fish were determined to the nearest gram on a digital scale.

RESULTS

Fillet Weight Model

A mathematical model of the fillet weight (W_f) in grams was fitted using the linear regression procedure (SAS, Cary, NC, USA). Considered in the model were polynomials of weight and length, condition factor, temperature and feeding rate, sex, and interaction terms of the primary factors. Only fish weight (W) in grams and length (L) in millimeters were found to be significant at the 95% confidence level, and the resulting model was $W_f = 65.0 - 0.403L + 0.401W$, with a coefficient of determination (r^2) of 0.913. The reduced model, $W_f = -16.7 + 0.336W$, produced an r^2 of 0.906. The fillet weight versus fish weight data and the regression line are shown in Figure 1. It appears that weight is a

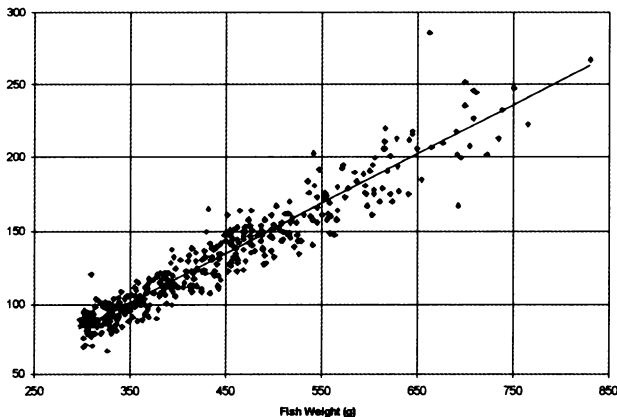


Figure 1. Relationship between fish weight and total fillet weight.

very good predictor of fillet yield, and that for a given weight, shorter, fatter fish produce a slightly higher yield. Although losing some predictive power, the reduced model is more appropriate for several reasons. Fish length and weight are highly correlated, and therefore most of the predictive capability of length can be accounted for in the weight measurement. The large positive intercept and the large negative coefficient for length in the full model are intuitively illogical. Beyond the limits of the data set, the full model produces unreasonable predictions. For example, predicted fillet weight of fingerlings would exceed the entire weight of the fish. On the other hand, the coefficients of the reduced model are intuitively logical, and produce reasonable estimates of the fillet weights even beyond the limits of the data collected. For the reduced model, the 95% confidence interval for the y-intercept is -21.5 to -11.9, and the 95% confidence interval for the weight coefficient is 0.326 to 0.347. Considering the variation in yield introduced by the filleting process, the linear correlation between fillet yield and weight is good.

Effect of Sex on Fillet Yields

As noted previously, fillet yield is a function of size and on average, the females were only 66.6% as heavy as their male counterparts for a given treatment. The question to be answered is whether the fillet yields of males and females of similar weights are different. Once this is known, it can be determined whether unisex production should be priced differently than mixed-sex production. As noted above, gender was not a significant factor in the construction of the fillet model, but a paired t-test is a stronger statistical test. For each of the 24 filleted females, a male was selected at random that had the same or nearly the same body weight. A paired t-test was used to compare the fillet weights and fish lengths of equal-sized males and females. At the $p = 0.05$ level, the differences in fillet yields were not significant, but the males were found to be significantly longer. F tests were used to compare the variance of the fillet weights and the lengths. At the $p = 0.05$ level, no statistical difference could be detected in the variance of the fillet weights or lengths.

Table 1. Comparison of length, weight, fillet weight, and yield of males and females of comparable weight.

		Length (mm)	Weight (g)	Fillet Weight (g)	Yield (%)
Males	Average	267.0	375.8	108.7	0.29
	(SD)	14.7	64.7	24.4	0.024
Females	Average	261.8	376.0	110.3	0.29
	(SD)	15.3	64.7	21.9	0.02

DISCUSSION

Weight is a good predictor of fillet yield. The full model regression formula that included both fish weight and fish length produced a model with slightly greater predictive power than the reduced model that used only fish weight, and could thus be of interest from an academic perspective. Its predictive power is only slightly better than that of the reduced model. From a practical perspective, weight is relatively easy to measure, whereas length is not, and thus for commercial applications, the reduced model is a more valuable tool than the full model.

The wholesale price per kilogram for tilapia is generally based upon fish weight—fish heavier than 600g bring a premium price, those between approximately 350 and 600g an intermediate price, and those less than 350g a lesser price (Fitzsimmons and Posadas 1997). The reduced model predicts yields of 28.8% and 30.8% for 350g and 600g fish respectively, which would justify a price premium of approximately 7% based strictly upon the increase in yield, but which does not include any reduction in processing costs. The yields obtained from this experiment are lower than both the 33% yield figure cited as a rule of thumb by Fitzsimmons and Posadas (1997) and the average fillet yield of 33.5% from *O. niloticus* averaging 207.4g, cited by Obanu and Ikeme (1988). In contrast, Clement and Lovell (1994) obtained only a 25.4% fillet yield from *O. niloticus* that weighed an average of 585g. Several factors could account for the discrepancies, including tilapia species and the skill of the fish cutter. However, the largest source of variation is likely to be the methods and procedures used in filleting, which unfortunately are generally not reported in the literature. Variability introduced by fillet technique and skill of the cutter is not included in this model, because only one set of cutters was used.

Fillet yield is important information for making management decisions in pricing fish products, selecting species, specifying feed rations, and controlling production costs. Muscle yield of fish species has a big impact on the profitability of the aquaculture firm and on the survival of a specific marketing channel. The fish producer is the last claimant to the consumer's market price for fish and fish products. The more handlers there are operating in a marketing channel, the smaller the margins for each handler. Gross retail margins for fresh fish usually command between 30 and 50% of the total profit, depending on the marketing season and the fish species. Producers are accustomed to marketing whole fish, while customers are used to purchasing fish fillets. When the useable flesh is separated from the whole fish, the result is the fillet and a by-product. Typically, these by-products of the fish filleting process do not have significant value and their production cost has already been factored into the fish value. The higher the yield ratio of muscle to by-product and the higher the market price the greater the chance a producer has of receiving a higher return on the aquaculture product. Documentation of fillet yields, coupled with market price, indicate the value of the fish products in a marketing channel. The better the yield, the better the survival of a species in the marketplace.

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