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Lipid Reserves of *Scomberoides lysan* (Pisces: Carangidae) from the Sri Lankan Waters

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ABSTRACT

The present investigation was carried out to quantify the lipid reserves and to find out the correlation with standard length and water content for total lipid content in different body tissues of *Scomberoides lysan*. Energy allocation of lipid reserves into liver, gonad and muscle were analyzed for the first time for different gonad maturation stages of *S. lysan* from the Sri Lankan waters. Relationships of energy storage with body size and gonad maturation stages and percentage of water content and lipid content of muscle, liver and gonad were computed and compared. Results showed that lipid content in the liver varied between 4.54 and 66.96% (Mean 31.11±14.10%) and revealed liver is the major energy storage site in *S. lysan*. Mean values for percentage of lipid reserve in ovary and liver for maturing female was 20.42 and 41.35% whereas for pre-spawning female was 44.2 and 30.79%, respectively. Similar trend was also obtained for males and it emphasize that the lipid stored in the liver during the maturing stage is mobilized towards the gonad during pre-spawning for gonad development, gamete production and other reproductive purposes. Regression analysis showed that the percentage of lipid of liver, gonad and muscle for all individuals showed a significant curvilinear relationship with standard length. Moreover, a curvilinear relationship was obtained between standard length and lipid hepatosomatic index but linear relationship was obtained between standard length and lipid gonadosomatic index. Interestingly, inverse linear relationship was obtained between percentage of water content and lipid content of muscle, liver and gonad. The results gained from the present study provide information on nutritional status of different maturity stages, reproductive potential and broodstock nutrition of *S. lysan*.

Key words: Energy allocation, lipid hepatosomatic index, lipid gonadosomatic index, lipid content, muscle, liver, gonad, pre-spawning

INTRODUCTION

Energy storage in animals is typically in the form of lipids. Lipid storage and dynamics are particularly important aspects of fish health and population success (Lloret *et al*., 2008) because they have a large influence on growth, reproduction and survival (Sutharshiny and Sivashanthini, 2011). Now-a-days, fish lipids have been highlighted as being beneficial for human health (Hedayatifard and Yousefian, 2010). Quantity of energy reserves in a fish influence the metabolic activities of it. When energy reserves becomes low, it will lead to a situation of increased natural mortality, less survival, low fecundity, low quality of eggs, belated maturation and inferior hatching

rates and fertilization (Sogard and Olla, 2000; Lambert *et al*., 2003; Koops *et al*., 2004; Wanless *et al*., 2005). This concept has not only been studied in temperate fish but also in other vertebrates and invertebrates. For example, a study on changes in the concentrations of liver total lipids and serum total lipids during the development has been performed by Ali *et al*. (2011) for broiler chicks. Another study on lipid changes specifically fatty acid variation was carried out seasonally in bivalve mollusc *Saccostrea cucullata* by Sajjadi *et al*. (2009).

Lipid content of fish is highly variable and provides indications on the fish quality (Van der Lingen and Hutchings, 2005; Shamsan and Ansari, 2010), affected by habitat characteristic and the food supply (Levi *et al*., 2005; Shulman *et al*., 2005). Usually a lipid content of 2-12% in live weight was recorded for majority of fish and fish related organisms (Mahin *et al*., 2011; Farhoudi *et al*., 2011; Tawfik, 2009) and 21% in crab, *Portunus sanguinolentus* eggs (Sounndarapandian and Dey, 2008). In a study with sturgeon fish (*Huso huso*). Ebrahimnezhadarabi *et al*. (2011) reported that fat incorporated in juvenile's diet increase the growth and enhance the nutritional indices.

In a fish once the lipid content exceeds the needed quantity of metabolizable energy the balance will be deposited in its tissues. As a result the fish will show high lipid content and categorised as high lipid content fish. Generally, when lipids are stored only in the liver of fish they are termed as lean fish. If the lipids are stored in other body tissues they are termed as fatty fish (Huss *et al*., 2003).

Lipid storage sites are primarily liver, muscle in the mesentery and along the lateral line or at the base of fish (Arrington *et al*., 2006). In most cases energy is stored in the liver of the fish and therefore, liver indices becoming as an important indication of the overall fish condition (Lambert and Dutil, 1997).

During breeding, lipid reserves stored in the body of fish will be significantly reduced. This is because energy and essential nutrients has to be supplied to the ovary for its rigorous generative synthesis (Morris and Culkin, 2000; Okuda, 2001).

As a fish mature, gonad development takes place and the fish must produce gametes. The related processes are very energy intensive and require lipids. During these phases, lipid levels decrease in the liver and muscle tissue and increase in the gonads (James and Elizabeth, 2003; Zaboukas *et al*., 2006).

The changes that take place in the tissue of fish, at the onset of maturation, are often different in males and females. Generally in several fishes, male gonad is smaller than the female. This is caused by difference in size of the fish, fish behaviour and the size of the gonads (Andrew, 2011). Lipids stored in the ovary of fish is the principal source of energy as it provide the energy for larval stages before first feeding and persuade the survival of fish larva (Rainuzzo *et al*., 1997). For estimating the energy reserves of fishes determination of lipid content has been extensively used among the biochemical parameters (Adams, 1999). Meffe and Snelson (1993) studied the partitioning of the total lipid budget in muscle, liver and ovary in mosquito fish. Reznick and Brown (1987) proposed that somatic lipid storage is an adaptation that by shifting stored energy into the ovary.

The doublespotted queenfish *Scomberoides lysan* (Forsskal 1775) is an economically important food fish in coastal as well as offshore fisheries in Sri Lanka included under family Carangidae. The flesh of the fish is meaty and flesh: carcass ratio is high so that these fish have high consumer demand and market potential. The species is popular for dry fish production with export demands and especially consumed by mothers during pregnancy and immediately after delivery. Therefore, it's highly prized and continues to maintain a high market demand. It is found along the Indian

and Pacific oceans with the reefs. Juveniles are found in shallow waters whereas adults in clear waters (De Bruin *et al*., 1994). Vary rarely form small groups, usually found as single individuals. *S. lysan* is a popular sport fish. Their tough skin is often stripped off, dried and used for trolling lures (Honebrink, 2000).

Several studies on lipid changes of different organs of fish have been studied for different temperate fishes (MacFarlane *et al*., 1993; Fiorin *et al*., 2007; Lloret *et al*., 2007) whereas no such study is available for tropical fishes, so far. Size-based variation for the level of stored lipids, reporting a positive relationship between body size and lipid content was studied by various researchers (Cargnelli and Gross, 1997; Jonsson and Jonsson, 1997; Saito *et al*., 1999; Mackereth *et al*., 1999). The strategy of the energy allocation among different body compartments and the relationships of energy storage with body size and Gonad Maturation Stages (GMS) could change according to their reproductive potential and status.

Information on the energy reserves of *S. lysan* is still lacking and the present investigation was originated as a consequence of it in order to find out the nutritional status and also to understand the energy allocation for reproductive strategies. In the present investigation three different aspects were studied in detail: (1) total lipid content in liver, muscle and gonad was quantified and compared between immature, maturing and pre-spawning stages, (2) relationships between standard length and total lipid content in different organs were computed and compared and (3) relationships between percentage of water content and lipid content in different organs were computed and compared.

MATERIALS AND METHODS

Sample collection: Fishes were collected at monthly regular intervals from January 2010 to December 2010 by means of 7" 21 ply mesh size drift gill nets set in the Point Pedro and Puttalam Sea, Sri Lanka with the help of Federation of Fishermen Cooperative Society's Union of the respective district. Every month, sub samples from the catch were taken to the laboratory for further analysis. Selected fishes representing the full size range of each sex and different GMS were taken for the analysis (Table 1), every month. Standard length (L_S) and total wet weight (M) were measured to the nearest 0.1 mm and 0.01 g using calipers and an electronic balance, respectively.

The fish samples were dissected, sex was determined and sexual maturity of gonads was examined macroscopically. Immature stages were very small, flat and thread like. Maturing and pre-spawners were first classified according to sex by visual inspection of the gonads, through an incision made in the ventral mid line. All males and females included in the analysis were then classified microscopically (Mackie and Lewis, 2001). Maturing stage ovaries were signified with the following characters: pinkish in colour, oocytes present, cortical alveoli and oil droplets are distinct and zona radiata well formed. Late pre-spawning stages were distinguished by observing the following characters: Ovaries were large with blood capillaries, yellow or orange coloured and with visible but still non hydrated oocytes and sometimes (if previously spawned) with postovulatory follicles. The maturing males were classified microscopically to be in the maturing stage: Yellow brown bodies, connective and muscle tissues prominent, spermatocytes were the dominant tissue and pre-spawning maturity stage: abundance of spermatozoa and central sperm sinus was present.

Observations of the present study showed that all size classes as well as all GMS were found in the collection of every month's sample which emphasizes *S. lysan* is a multi spawner and spawns throughout the year in Sri Lankan waters perhaps have a peak spawning period. For carangids Thresher (1984) reported repeated, periodical spawning pattern in Hawaiian waters whereas

Griffiths *et al.* (2005) emphasized talang queenfish *Scomberoides commersonnianus* have a protracted spawning season.

Individuals were thawed and eviscerated and muscle, liver and gonads were removed. These sections were chosen because of their reported potential as storage sites for lipids (Shulman, 1974; Sheridan, 1988). Eviscerated weight (W_E) and muscle weight were measured to the nearest 0.01 g the gonad and liver were blotted dry and weighed to nearest 0.001 g. Each specimen's sex, L_S, M, W_E and weight of muscle, liver and gonad were recorded.

Lipid determination and estimation of lipo-somatic indices: Percentage of lipid content in muscle, liver and gonad were analyzed as a measure of energy reserves. The whole liver and gonad were taken for lipid analysis, whilst for the muscle a portion or sub sample of 10 g was taken dorsally directly under the anterior dorsal fin and well above the lateral line. The collected tissues were cleaned by removing skin, scales and bones. They were rinsed with distilled water. Total lipid content of *S. lysan* in muscle, liver and gonad were extracted using chloroform, methanol and water (2: 2: 1.8) according to the method of Bligh and Dyer (1959).

Lipid content in liver and gonad expressed as a percentage of dry mass were given and lipid hepatosomatic index (LI_{HS}) and lipid gonadosomatic index (LI_{GS}) were computed with the following formula (Lloret *et al.*, 2008):

$$LI_{HS} = \frac{ABSLL}{W_E} \times 100$$

$$LI_{GS} = \frac{ABSLG}{W_E} \times 100$$

Where:
ABSLL = Absolute lipid content in the liver
ABSLG = Absolute lipid content in the gonad

Absolute lipid content was computed by multiplying the respective lipid contents by total tissue weights.

Data analysis: Data obtained for total lipid content in liver, muscle and gonad tissues for immature, maturing and pre-spawning male and female were first analyzed by two way Analysis of Variance (ANOVA). When the results of the two way ANOVA show the mean values of the samples are significantly different, ANOVA was followed by Post hoc comparison of means: Duncan's Multiple Range Test (DMRT) using STATISTICA 6.0 software. The level of statistical significance was set at $p<0.05$.

Regression analysis was performed for the pooled data of *S. lysan*, irrespective of sex. Cumulative lipid content in liver, muscle and gonad tissues for different GMSs were computed and plotted as a graph to compare the lipid compartmentalization.

Data obtained for total lipid content in the muscle, liver and gonad against L_S for all individuals were tested for regression statistics. The relationship between lipid content and L_S was investigated by least square linear regression analysis using MINITAB 14 software. Similar regression analysis was also performed for the LI_{HS} and LI_{GS} data with L_S. The whole fish lipid levels were compared

in terms of LI_{HS} and LI_{GS} index of condition to access whether these indices are a diagnostic measure of nutritional status.

Regression analysis of percentage of water content and lipid content of muscle, liver and gonad of mature and pre-spawning individuals were also computed, irrespective of sexes.

RESULTS

Three hundred and sixteen specimens were collected from January 2010 to December 2010 from the Point Pedro and Puttalam Sea, Sri Lanka. Among the sub sample collected 42 maturing male, 57 maturing female, 16 pre-spawning male and 7 pre-spawning female were distinguished and recorded whilst the immature remained unsexed since it was difficult to distinguish their sex.

Mean values (Mean±Standard deviation (SD)) of L_S, M, LI_{HS}, LI_{GS} and percentage of lipid content of muscle, liver and gonad for different GMS of male and female *S. lysan* individuals are presented in Table 1. The total extractable lipid content was determined from the differences between the dry mass before extraction and the dry mass following extraction.

Partitioning of lipid content in different tissues: Two way ANOVA revealed significant interaction between lipid content in liver, muscle and gonad of male and female (ANOVA, n = 205, $p<0.05$) and therefore, differences between liver, muscle and gonad of male and female were examined in detail.

No significant difference (DMRT, $p>0.05$) was observed for lipid content of the liver, muscle and gonad among the maturing male and maturing female. Pre-spawning and maturing individuals exhibited no significant differences (DMRT, $p>0.05$) for lipid content of liver in both sexes. Pre-spawning male showed no significant differences (DMRT, $p>0.05$) for lipid content of gonad with that of maturing male and maturing female. These results are given in Table 1.

Percentage of lipid content in the gonad tissues of immature fish was significantly (DMRT, $p<0.05$) lower than the lipid content in the other stages. It clearly express that low lipid level present in immature fish due to small sized gonads present. The percentage of lipid reserve in ovary

Table 1: Mean values of standard length (L_S), body weight (M), Lipid hepato somatic index (LI_{HS}), Lipid gonado somatic index (LI_{GS}) and percentage of lipid content of muscle, liver and gonad for different maturity stages of *S. lysan* individuals

Sex	Description	LS (cm)	M (g)	Muscle (%)	Liver (%)	Gonad (%)	LI_{HS}	LI_{GS}
IM	Mean±SD	19.67±2.84	104.88±40.70	3.42±1.13a	19.27±8.16a	1.51±1.08a	0.63±0.02	2×10^{-4}±3.0×10^{-4}
		n = 143	n = 143	n = 83	n = 70	n = 10	n = 70	n = 10
		(10.7-26.8)	(21.1-225.53)	(0.51-5.45)	(4.54-38.09)	(0.23-3.33)	(0.002-0.11)	(5×10^{-4}-4.4×10^{-5})
MM	Mean±SD	30.11±4.10	343±142	4.95±1.02^{bd}	44.19±9.07^{bd}	19.36±8.64^{bcd}	0.13±0.08	0.013±0.014
		n = 71	n = 71	n = 42	n = 33	n = 23	n = 33	n = 23
		(23.0-38.0)	(139.0-728.0)	(1.95-6.85)	(30.84-61.31)	(8.33-37.61)	(0.02-0.44)	(0.001-0.052)
PSM	Mean±SD	53.25±0.99	1409±126.8	9.81±1.77^{c}	25.96±4.44^{ce}	20.37±1.414^{bcd}	0.035±0.005	0.008±0.002
		n = 26	n = 26	n = 16	n = 16	n = 16	n = 16	n = 16
		(51.5-55.0)	(1286.0-1531.0)	(6.84-13.0)	(18.81-34.88)	(17.76-23.16)	(0.026-0.047)	(0.005-0.011)
MF	Mean±SD	9.15±3.78	310.2±138.6	4.94±0.91^{bd}	41.35±11.30^{bd}	20.42±7.21^{bcd}	0.12±0.09	0.017±0.019
		n = 65	n = 65	n = 57	n = 47	n = 36	n = 47	n = 36
		(23.0-38.5)	(136.2-900.0)	(1.95-6.85)	(11.62-66.96)	(9.09-33.33)	(0.01-0.51)	(0.0008-0.09)
PSF	Mean±SD	61.16±0.46	1641±54.76	6.68±0.08^{e}	30.79±0.62^{ce}	44.2±1.35^{e}	0.038±0.01	0.09±0.003
		n = 11	n = 11	n = 7	n = 7	n = 7	n = 7	n = 7
		(60.5-61.5)	(1548.0-1689.0)	(6.57-6.8)	(30.25-32.1)	(42.02-46.39)	(0.01-0.038)	(0.08-0.09)

IM: Immature, MM: Maturing male, MF: Maturing female, PSM: Pre-spawning male, PSF: Pre-spawning female, SD: Standard deviation, n: Sample size, range given in parenthesis

of pre-spawning female exhibited a significantly (DMRT, $p<0.05$) higher value (mean 44.2%, ±1.35) than the pre-spawning male (mean 20.37%, ±1.41). Similarly the percentage of lipid reserve in the liver of pre-spawning female (mean 30.79±0.621) was significantly (DMRT, $p<0.05$) higher than the pre-spawning male (mean 25.96±4.44). Respective results explained in this paragraph are tabulated in Table 1.

Lipid compartmentalization for the cumulative percentage of lipid content in liver, muscle and gonad tissues for all individuals revealed lipid content in the muscle (as percentage of dry weight) constituted between 0.51 and 13.00% (mean = 4.76%, ±2.02) whereas lipid content in the liver between 4.54 and 66.96% (mean 31.11%, ±14.10). LI_{HS} ranged between 0.002 and 0.512 (mean = 0.07±0.08), lipid content in gonads varied between 0.22 and 46.39% (mean = 20.03%, ±10.85) and LI_{GS} ranged between 5×10^{-42} and 0.09 (mean = 0.02±0.01). Highest variation for lipid content in liver suggests that liver is the major energy storage site in *S. lysan*. The results explained in this paragraph are given in Table 1.

There is a progressive accumulation of liver lipid content of maturing fish (42.52%±10.47) than the muscle (4.95%, ±0.95) (Table 1) but the absolute amount of lipid stored in this organ was small (0.077 g, ±0.08) compared to that stored in the muscle (1.056 g, ±0.573).

Mean values for percentage of lipid reserve in ovary and liver for maturing female was 20.42 and 41.35%, respectively. For pre-spawning female lipid reserve in ovary and liver was 44.2 and 30.79%, respectively. Similar trend was also obtained with male gonads (Table 1). These results clearly explain that the lipid stored in the liver during the maturing stage is mobilized towards the gonad during pre-spawning for gonad development, gamete production and other reproductive purposes.

Relationships between L_S and lipid content: Relationships obtained by regression analysis for L_S against LI_{HS}, LI_{GS}, total lipid content in the muscle, liver and gonad for all individuals are shown in Fig. 1. In all individuals, muscle lipid, liver lipid and gonad lipid and the value of LI_{HS} and LI_{GS} were size dependent with small individuals have less lipid in all tissues than the larger individuals (Fig. 1).

The percentage of lipid of all individuals (Dry Weight, DW) is positively related to the L_S showed a significant curvilinear relationship (Fig. 1) between them that is better in the muscle than liver and gonad. Regression analysis of standard length versus percentage of muscle lipid, liver lipid and gonad lipid gave significant ($p<0.01$) curvilinear equations of $Y = -0.002x^2 + 0.292x-1.708$, $Y = -0.062x^2 + 4.958x-51.04$ and $Y = -0.011x^2 + 1.515x-18.30$, respectively. A significant ($p<0.01$) curvilinear relationship of $Y = -0.847x^2 + 12.116x-3.952$ was also obtained between percentage of muscle lipid content and percentage of liver lipid content of all individuals of *S. lysan*. Moreover, a significant ($p<0.01$) curvilinear relationship was obtained between L_S value of LI_{HS} with the equation of $Y = -0.000x^2 + 0.024x-0.319$ but a significant ($p<0.01$) linear relationship was obtained between L_S and value of LI_{GS} with the equation of $Y = 0.001x-0.023$.

Relationships obtained by regression analysis between percentage of water content and lipid content of muscle, liver and gonad of mature and pre-spawning individuals irrespective of sexes are illustrated in Fig. 2. Regression analysis of water content versus percentage of muscle lipid, liver lipid and gonad lipid gave linear equations of $Y = -0.105x + 12.62$, $Y = -0.73x + 8.42$ and $Y= -0.493x + 57.85$, respectively.

Water is one of the most important components for the quality of food matrices including fish muscle. Water influences quality attributes such as appearance, texture and storage stability

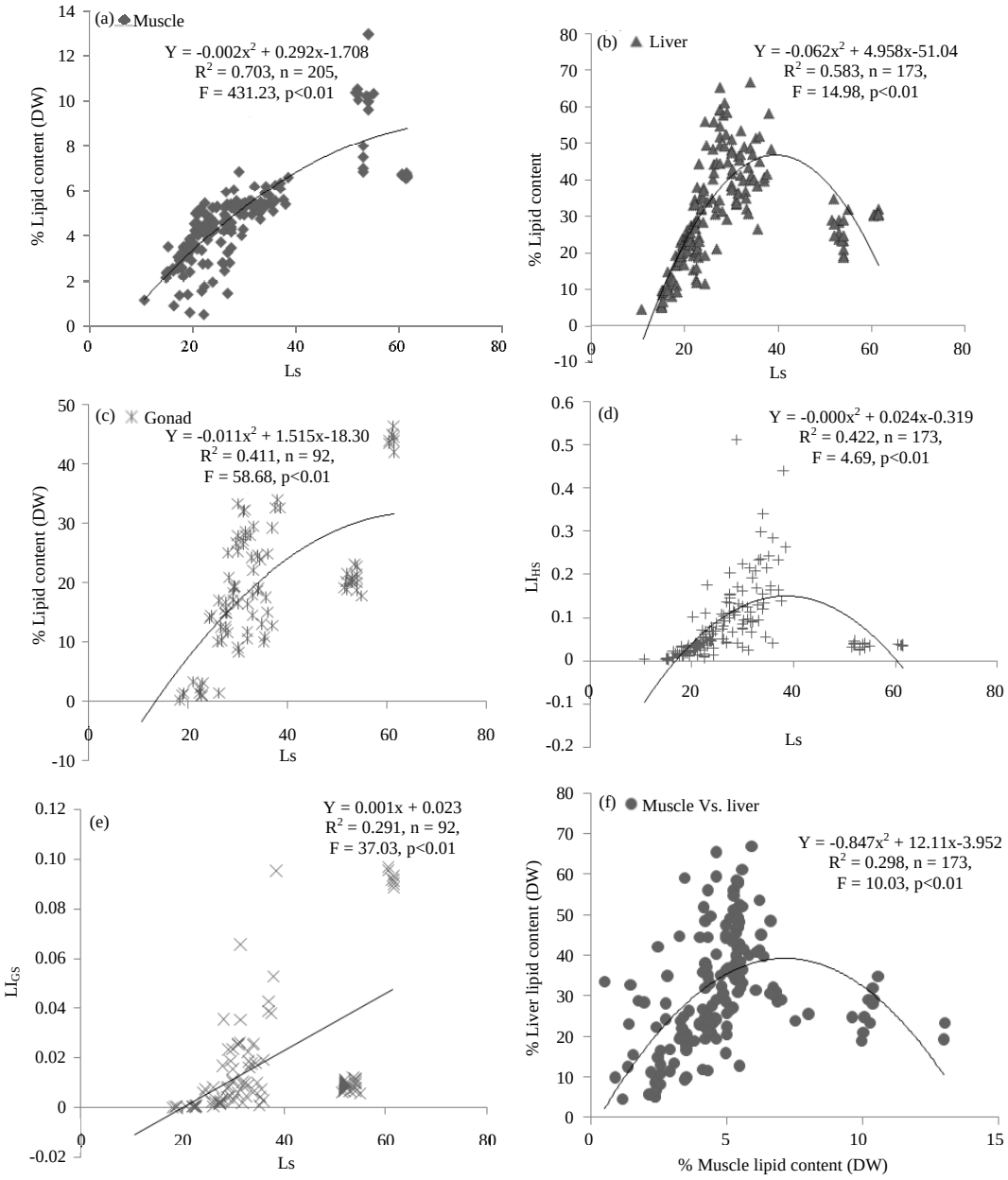

Fig. 1 (a-f): Relationships between standard length (L_s) of all individuals and lipid content (% dry weight, DW) in (a) muscle (b) liver (c) gonad (d) LI_{HS} + and (e) LI_{GS} x and (f) relationship between the muscle lipid content (% dry weight, DW) and the liver lipid content (% dry weight, DW)

(Andersen and Rinnan, 2002). A correlation can be noted from the results where a decrease in percentage of water content in liver, muscle and gonad of maturing individuals is linked to an increase in fat content, even though the relationship is better in gonad than in the liver and muscle.

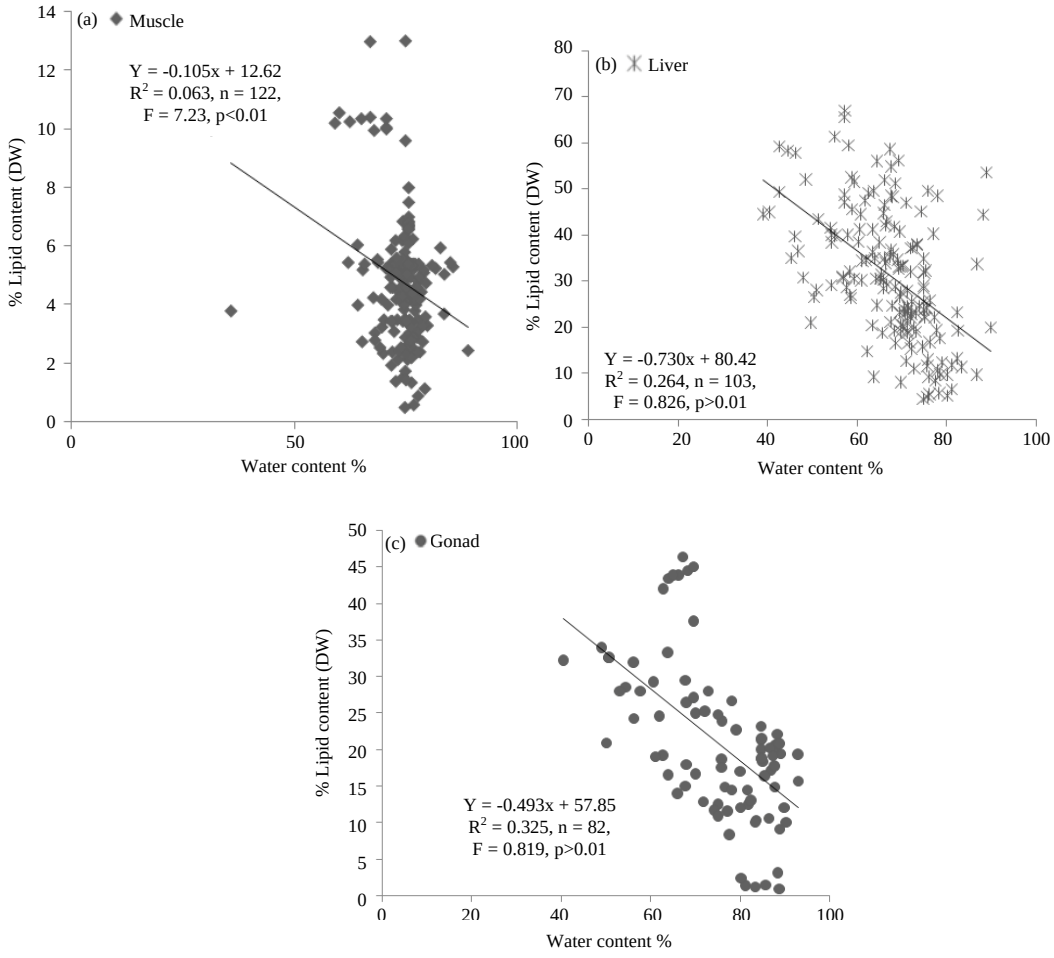

Fig. 2 (a-c): Relationships between % water content and lipid content (% dry weight, DW) of maturing and pre-spawning individuals in (a) muscle, (b) liver and (c) gonad

DISCUSSION

Even though lipid concentrations varied greatly among individuals, results show that in the *S. lysan* lipids are stored mainly in the liver, varied between 18.81 and 61.31% dry weight in males and between 11.62 and 66.96% dry weight in females. Shao-Ning *et al.* (2010) identified from their research that the liver is an important energy storage organ in *Trachinotus ovatus* (Family: Carangidae). Seiichi and Yusuke (1993) reported that liver lipid and muscle lipid of matured striped jack (Family: Carangidae) was 18.78 and 4.86% and of wild puffer was 76.79 and 1.36%, respectively. These results are in consistent with the values obtained in the present study for *S. lysan*. These findings also confirming the important role of the liver for energy reserve in family Carangidae fishes.

Previous records of lipid content of some other species of family Carangidae are shown in Table 2. Present study revealed muscle lipid content of 0.51-13.00% (mean = 4.76%, ±2.02) for *S. lysan*. Most of the earlier studies provide information only on muscle lipid of other carangid fishes. For *Parastromateus niger*, Chedoloh *et al.* (2011) reported muscle lipid of 2.58% whereas,

Table 2: Mean values obtained for percentage of lipid of fish species included under family Carangidae from the world

Fish	Muscle	Liver	Gonad	Region	Source
Striped jack	-----	18.78%	4.86%	Japan	Seiichi and Yusuke (1993)
Parastromateus niger	2.58±0.51	--	--	Southern Thailand	Chedoloh *et al.* (2011)
Parastromateus niger	2.33	--	--	Malaysia	Nurnadia *et al.* (2011)
Atule mate	2.13±0.27	--	--	Southern Thailand	Chedoloh *et al.* (2011)
Selar crumenophthalmus	3.31±0.25	--	--	Southern Thailand	Chedoloh *et al.* (2011)
Carangoides gymnostethus	2.12±0.35	--	--	Southern Thailand	Chedoloh *et al.* (2011)
Pampus argenteus	3.22±0.67	--	--	Southern Thailand	Chedoloh *et al.* (2011)
Pampus argenteus	2.09	--	--	Malaysia	Nurnadia *et al.* (2011)
Elagatis bipinnulata	2.74±0.74	--	--	Southern Thailand	Chedoloh *et al.* (2011)
Selaroides leptolepis	2.12	--	--	Malaysia	Nurnadia *et al.* (2011)

Nurnadia *et al.* (2011) reported 2.33%. Further Chedoloh *et al.* (2011) reported a muscle lipid content of 2.13% for *Atule mate*, 3.31% for *Selar crumenophthalmus*, 2.12% for *Carangoides gymnostethus*, 2.74% for *Elagatis bipinnulata* and 3.22% for *Pampus argenteus*. However, Nurnadia *et al.* (2011) reported 2.09% for *Pampus argenteus* and 2.12% for *Selaroides leptolepis*. All these values fall well within the range recorded in the present study.

In the present study during pre-spawning lipids represented between 42.02-46.39% of the dry ovary weights of *S. lysan*. This high value in pre-spawning females may reflect high reproductive potential of individuals of that particular population.

The increase of the relative lipid content in the liver of maturing *S. lysan* with size indicates a progressive accumulation of energy in the liver as fish grows till sexual maturation.

Female pre-spawners seem to expend much energy on reproductive activities since they presented lower liver lipid reserves than those of maturing individuals. Therefore, it could be emphasized that lipids stored in the liver of *S. lysan* during the maturing stage are mobilized towards the gonad during pre-spawning for gonad development, gamete production and other reproductive purposes. Generally various authors (Chelappa *et al.*, 1989; Adams, 1999; Morris and Culkin, 2000) emphasized that lipid reserves stored in the body of fishes greatly reduced during breeding as it had been supplied to the ovary in the form of energy. The present study has detected differences in the lipid content of *S. lysan* tissues in different maturation stages.

The quantity of lipid has been used as biochemical index of trophic condition for fresh water and marine fish (Novotony and Beeman, 1990). Fish can be grouped into four categories according to their fat contents: lean fish (<2%), low fat (2-%), medium fat (4-8%) and high fat (>8%) (Ackman, 1989). Accordingly *S. lysan* having a cumulative average of 4.76% muscle lipid in DW (1.281% in wet weight) can be classified under the first category, lean fish. This finding is in consistent with the previous study for other carangids (Chedoloh *et al.*, 2011). From the inferences of the present study being a lean fish *S. lysan* can be recommended as a good nutritional source of food fish for the human health. In all maturation stages lipids are stored chiefly in the liver except pre-spawning female than that of muscle and gonad further confirms liver is the major energy depot in *S. lysan*. This finding could be supported by the earlier observations reported by Huss *et al.* (2003).

Ramadan (2003) reported that the fat content was affected by maturation and the depletion of fat reserve in muscle accompanied by a rise of fat content in gonad for gilthead seabream *Sparus aurata* along the Tunisian coast.

The change in percentage of gonad lipid from maturing to pre-spawning stage is higher in female than the male imply that the energy expended for gamete production in female was higher than male. The gender related differences in lipid depletion reveal the different energy expenditure for gamete production between the sexes.

In a previous study for *Trachinotus ovatus* (Assem *et al*., 2005) minimal value of ovarian lipid (in dry weight) of 7.868±1.081% was obtained for immature stage and the lipid storage increased progressively and a maximum value of 14.021±3.697% was obtained for mature stage. Similar trend was also recorded in the present study with tropical *S. lysan*.

Ali *et al*. (2001) identified a linear relationship between log total length and log total body lipid of *Channa* fish. Dumas *et al*. (2007) showed that the body weight chemical composition of rainbow trout can be expressed mathematically and these equations show the linear link between fish size and lipid content of body. Peters (2003) observed a positive curvilinear relationship between percent lipid in the muscle and percent of lipid content in the whole fish. The present results are also in support with the earlier studies.

A negative correlation obtained between the concentration of water and lipid in the liver, muscle and gonad can be supported by the earlier studies by Shulman and Love (1999) and Shulman *et al*. (2005). The negative correlation could be a substitute to specify the condition of fish indirectly if the water content is known and it could be a rapid indicator of lipid reserve of this species. This phenomenon can be referred as the fat water line and is common in many fish species (Love, 1988).

One previous study proved that post larvae of *Macrobrachium rosenbergii* fed with cod liver oil enriched feed had the highest weight gain (225.72±9.05%), highest specific growth rate (2.95±0.07%) and highest survival (77.14±4.28%) as well as low food conversion ratio (0.87±0.03) compared to the post larvae fed with the vitamin E, Vitamin D and astaxanthin (Parakarma *et al*., 2009). The liver of *S. commersonnianus* had high amount of omega-3-fatty acids followed by muscle and head, respectively (Zibaee-Nezhad *et al*., 2010). It would be useful to carry out further studies on the composition of fatty acids and other lipid profile in the liver of *S. lysan* as the results gained could be utilized in the preparation of formulated nutritional feeds for cultured species. Moreover, the knowledge gained on lipid dynamics in relation to gonad maturation stages for *S. lysan* provides information for diet formulation during culture trials as it endow with parallel evidence for broodstock nutrition.

CONCLUSION

S. lysan having a cumulative average of 4.76% muscle lipid (in dry weight) can be classified as lean fish. Being a lean fish it can be recommended as a good nutritional source of food fish for the human health. From the present study it can be inferred that lipids are stored mainly in the liver of *S. lysan*. High value of lipids in ovary of pre-spawning females reflects high reproductive potential. Female pre-spawners possessed lower liver lipid reserves than maturing individuals confirm that lipids stored in the liver of *S. lysan* during the maturing stage are mobilized towards the gonad during pre-spawning for gonad development. The percentage of lipid of *S. lysan* individuals positively related to the size of the fish showed a significant curvilinear relationship. Negative correlation was observed between percentage of water content and lipid content. Findings obtained from the pilot study are good indication on energy allocation and broodstock nutrition.

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