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Effect of dietary soy-lecithin on growth and body composition of Indian black tiger shrimp *Penaeus monodon* (Fabricius, 1798) reared under hyperosmotic stress condition

J. SYAMA DAYAL, R. JANNATHULLA, K. AMBASANKAR, H. IMRAN KHAN, E. P. MADHUBABU AND M. MURALIDHAR

ICAR-Central Institute of Brackishwater Aquaculture, 75 Santhome High Road, RA Puram, Chennai - 600 028 Tamil Nadu, India
e-mail: syamdayal@rediffmail.com

ABSTRACT

Sixty days feeding trial was conducted to study the effect of dietary soy-lecithin (phosphatidylcholine) as a source of phospholipids on the growth performance of *Penaeus monodon* (Fabricius, 1798) reared at hyperosmotic stress conditions (40‰) in indoor tanks. Four experimental diets *viz*., DL-1 (Control), DL-1.5, DL-2 and DL-2.5 were formulated by including soy-lecithin at the rate of 1, 1.5, 2 and 2.5%, respectively. The results revealed that the daily growth coefficient (DGC) significantly ($p<0.05$) increased from 1.44 to 1.67% day^{-1} when the inclusion levels were increased from 1 to 2.5%. The relative growth rate (RGR) was significantly ($p<0.05$) high in the groups fed on DL-2 and DL-2.5 diets than in the groups fed other diets (DL-1 and DL-1.5). Compared to DL-1, all the other diets (DL-1.5, DL-2 and DL-2.5) had increased DGC by 7.81, 11.06 and 15.89% and decreased feed conversion ratio (FCR) by 8.70, 8.83 and 9.56%, respectively. The dietary treatments had no significant difference in survival (75.56-82.22%) and carcass composition except body lipid, which was significantly ($p<0.05$) high (3.66%) in DL-2 and DL-2.5 fed groups compared to DL-1 and DL-1.5 (3.25-3.42%). Carcass phospholipids increased ($p<0.05$) from 61.96 to 69.69% with increasing dietary soy-lecithin levels, while triacylglycerides ($p>0.05$) and cholesterol ($p>0.05$) were not affected. The inclusion levels of soy-lecithin had no significant influence on the fatty acid composition of *P. monodon* except for C16:0 and C18:2c, which were high ($p<0.05$) in the groups fed DL-2 and DL-2.5 diets. Results concluded that soy-lecithin as a source of phospholipids can be more effective at hyperosmotic stress conditions and could be included at >2.5% in the diet of *P. monodon.*

Keywords: Carcass composition, Hyperosmotic stress, *Penaeus monodon,* Phospholipids, Salinity, Soy-lecithin

Introduction

The euryhaline, omnivorous Indian black tiger shrimp *Penaeus monodon* (Fabricius, 1798), is commercially important owing to its global market value. Though *P. monodon* can tolerate a wide range of salinity, it grows best at 10 to 30 ppt (Tsai *et al.,* 2002). Shrimp growth and survival are affected when ambient salinity is outside the range of ideal levels due to utilisation of adequate amount of energy to regulate their osmotic pressure. Hence, boosting the shrimp's osmoregulatory capacity is essential for the development of growth and survival when the ambient salinity is changed. Lipids are one of the vital energy producing components in the diet; especially phospholipids which play a crucial role in regulating the shrimp's osmoregulatory capacity (Chen *et al.,* 2015). Furthermore, phospholipids also play a vital role in cell growth regulation, proliferation, differentiation, metabolism, nutrient uptake, ion transport and even programmed cell death (Khan *et al.,* 2018). According to Coutteau *et al.* (1997), phospholipids have reduced the quantitative requirements of polyunsaturated fatty acids. The performance is better with high dietary phospholipids than diets high in polyunsaturated fatty acids. Phospholipids, in general, are rich in soy-lecithin (phosphatidylcholine) and have been shown to improve the growth of various penaeid shrimps such as *P. japonicus* (Kontara *et al.,* 1997), *P. monodon* (Khan *et al.,* 2018), *P. semisulcatus* (Yilmaz, 2020) and *P. vannamei* (Yan *et al.,* 2020). However, the optimised values varied in the earlier reports for aquatic species and were in the range of 1-3% in crustaceans and 1.5-12% for fish (NRC, 2011). The ability of shrimps to adjust to changes in ambient salinity can be improved by providing an adequate quantity of energy through dietary manipulation, since osmoregulation is an energy-dependent process. Otherwise, shrimp begin to withhold their energy supplies from the body, which causes a sharp decline in growth. Soy-lecithin provides phospholipids required for maintaining the cellular bilayer phospho-lipid membrane integrity, especially during stress conditions. Soy-lecithin is also one of the potent non-protein energy sources, which not only fulfil the energy demand but also contains several advantageous

properties like attractant, antioxidant, improved vitamin absorption and increased resilience to stress (Kanazawa *et al.,* 1983; Roy *et al.*, 2006). In our earlier studies (unpublished data), we investigated the impact of various water salinities on the growth performance of different species of penaeid shrimps, including *P. monodon,* to resolve the issues of decreased growth in the farmers' pond during summer near Mahabalipuram, Tamil Nadu, India. Results revealed that the growth of *P. monodon* was significantly reduced when they were exposed to beyond 40 ppt, as well as when rearing in water having <10 ppt, compared to the groups reared at 20 and 30 ppt. In support of our observation, a depressed immune response was also reported by Joseph and Philip (2020) in *P. monodon,* when reared at >35 ppt, indicating that 40 ppt might be a hyperosmotic stress condition for this shrimp species. Most of the earlier studies have focused on finding the ideal dietary level of soy-lecithin in various aquatic species in the optimal saline condition rather than at a stressed state. Hence, the present study aims to determine the optimal dietary level of soy-lecithin (phosphatidylcholine) in the practical feeds for *P. monodon* reared in hypersaline stress conditions.

Materials and methods

Experimental diets

Soy-lecithin (phosphatidylcholine), a source of phospholipids used in the present study, was obtained from Real Soy Enterprises, Indore, Madhya Pradesh, India. The quality indices and the fatty acid composition of soy-lecithin are given in Table 1. Four experimental diets were formulated with locally available ingredients listed in Table 2, with soy-lecithin as a source of phospholipids. Soy-lecithin was included in the experimental diets at rates of 1 (control), 1.5, 2 and 2.5% and named DL-1, DL-1.5, DL-2 and DL-2.5, respectively. While preparing the diets, all the solid dry sources listed in the formulae were powdered and passed through a 250 µm sieve. Feed additives and oil sources were added to the ground materials and mixed well in an electric blender for homogenisation for 20 min. Then this mash was hydrated with water at 50 ml 100 g^{-1} mash and made into dough. The dough was then steamed at atmospheric pressure for 5 min, cooled and pelletised in a tabletop pelletiser with a 2 mm diameter die (Dayal *et al.,* 2003). The pellets were dried in a forced air oven at 60ºC for 12 h and stored in a refrigerator (4°C) until use.

Table 1. Quality indices and fatty acid composition (% total fatty acids) of soy-lecithin (phosphatidylcholine) used in the present study

Particulars	Values
Moisture (%)	1.58±0.12
Acid value (mg KOH g^{-1})	35.17±2.56
Acetone insoluble (%)	58.47±3.36
Hexane insoluble (%)	0.52±0.07
Peroxide value (Meq kg^{-1})	3.81±0.55
pH	7.5
Viscosity (Poise)	80
Fatty acids (% total fatty acids)	
C16:0	14.31±0.74
C18:0	4.24±0.19
C18:1	15.11±0.28
C18:2c	58.67±2.67
C18:3c	4.82±0.61

Table 2. Ingredient and chemical composition of experimental diets containing varying levels of dietary soy-lecithin (% as fed basis)

Ingredient composition	Dietary soy-lecithin			
	DL-1	DL-1.5	DL-2	DL-2.5
Fishmeal[1]	25	25	25	25
Acetes[2]	8	8	8	8
Squid meal[3]	3	3	3	3
Shrimp head meal[4]	4	4	4	4
Soybean meal[5]	20	20	20	20
Wheat[6]	24	23.5	23	22.5
Broken rice[6]	10	10	10	10
Fish oil[1]	2	2	2	2
Soy-lecithin[5]	1	1.5	2	2.5
Vit-min mix[7]	2	2	2	2
Binder[8]	1	1	1	1
Proximate composition				
Moisture	8.22	9.05	9.16	8.78
Crude protein	38.12	37.36	38.44	38.18
Ether extract	5.85	6.21	6.59	6.98
Crude fibre	2.23	2.34	2.28	2.26
NFE[9]	30.47	30.78	28.99	29.75
Total ash	15.11	14.26	14.54	14.05

[1]Bismi Fisheries, Mayiladuthurai, Tamil Nadu, India; [2]Om-Sai Aqua, Dandi, Gujarat, India; [3]Blueline Foods India Pvt. Ltd, Mangalore, Karnataka, India; [4]Khaja Mohammed Store, Chennai, Tamil Nadu, India; [5]Real Soy Enterprises, Indore, Madhya Pradesh, India; [6]Local market. [7]Thiamine hydrochloride (25.50 g), Riboflavin (25.00 g), Pyridoxine hydrochloride (50.00 g); Cyanocobalamin (0.10 g); Menadione (5.00 g); All-trans tocopherol acetate (99.00 g); Retinyl acetate (10.00 g); Vitamin D (50 g); Nicotinic acid (101.00 g); D-Ca-pantothenate (61.00 g); Biotin (25.00 g); Folic acid (6.25 g); Inositol (153.06 g); Ferric citrate (13.70 g); $ZnSO_4.7H_2O$ (28.28 g); $MgSO_4.7H_2O$ (0.12 g); $MnSO_4.H_2O$ (12.43 g); $CuSO_4.5$ H2O (19.84 g); CoC12.6H_2O (4.07 g); KIO_4 (0.03 g); KCl (15.33 g); Na_2SeO_3 (0.02 g); [8]Pegabind (Synthetic resin), Bentoli Agri-Nutrition Asia Pvt. Ltd., Singapore; [9]Nitrogen free extract

Growth trial

P. monodon juveniles were procured from a local farm near Mahabalipuram, Chennai, India. They were stocked in 500 l (1.30 x 0.64 x 0.73 m) oval-shaped fibreglass reinforced plastic (FRP) tanks with constant aeration for a week before the experiment. The present

study was conducted in an indoor facility of the Muttukadu Experimental Station, ICAR-CIBA, Chennai, India. A total of 240 healthy shrimps with an average body weight of 3.13±0.26 g were used in the present study. The juveniles were randomly transferred into 12 FRP experimental tanks. They were further divided into four treatments (60 shrimps per treatment), each with three replicates (20 shrimps per replicate). All shrimps in the treatment groups were acclimatised to an experimental salinity of 40 ppt by gradually increasing the water salinity at the rate of 2 ppt per day by using common crude salt obtained from Kelambakkam Salt Pans, Chennai, India (Jannathulla *et al.,* 2017). Following that, an initial sampling for growth measurement was carried out in each replicate, individually, and the experiment was conducted for 60 days. The shrimps were hand-fed thrice a day (@ 6% of the body weight) and the given rate was adjusted based on their intake. Uneaten feed pellets (if any) were collected after feeding time (1 h) and were washed with deionised water and then dried (@ 60°C) to calculate the daily feed intake. UV-treated water, after filtering *via* a 5 m cartridge filter, was used in the present study. The water quality indices were monitored at weekly intervals and were analysed using the standard method of APHA (2012). The natural photoperiods of 12 h light and 12 h dark were maintained throughout the experimental periods. At the end of the study, the growth performance, including relative growth rate (RGR), daily growth coefficient (DGC), weight gain (WG%), feed conversion ratio (FCR), protein efficiency ratio (PER), apparent protein utilisation (APU) and survival were determined.

Laboratory analysis

About ten shrimps at the inter-moult stage from each replicate were collected at the end of the growth trial. They were washed using deionised water to remove the adhering contamination and then dried with clean tissue paper. The whole shrimp of each replicate were homogenised using a blender and were stored at -80°C until analysis. The proximate composition of experimental diets and shrimp carcasses in terms of moisture, crude protein, ether extract, crude fibre and total ash was determined as per the AOAC (1997) method. The level of nitrogen-free extract was calculated using the formula, (NFE) = [100 - (% of moisture + crude protein + ether extract + crude fiber + total ash)]. The lipid classes such as phospholipids, triacylglycerides and cholesterol in shrimp were estimated by Fiske and Subbarow (1925), Rice (1970) and Parekh and Jung (1970) method, respectively in a UV-visible spectrophotometer (UV1800-Shimadzu, Japan). Fatty acid methyl esters were prepared according to Metcalfe *et al.* (1966) and were subsequently injected into a gas chromatograph (GC-2014, Shimadzu) equipped with RTX-wax capillary column (100 m length × 0.25 mm I.D × 0.2 µm film thickness) and flame ionisation detector (FID) according to Jannathulla *et al.* (2019a).

Statistical analysis

One-way ANOVA (SPSS ver.16.0 for Windows) with Tukey's test was performed to compare the mean differences with a probability of $p<0.05$. Regression analysis coefficient was determined to assess the effect of dietary soy-lecithin on the weight gain of *P. monodon*.

Results and discussion

Generally, shrimps reared beyond the optimal salinity, need more energy which can be achieved by a high protein diet (Shiau *et al.,* 1991). Though increased protein content promotes growth, it also enhances the excretion of ammonia due to increased protein catabolism, which is detrimental to cultured species. As a result, non-protein energy sources like lipids, particularly phospholipids, are often used to provide additional energy (Yan *et al.,* 2020). This is corroborated by Hu *et al.* (2008), who found that the supplementation of phospholipids to penaeid shrimps enhanced the growth compared to a diet devoid of phospholipids. The growth performance of *P. monodon,* fed diets containing varying levels of dietary soy-lecithin as a source of phospholipids is presented in Table 3. The results revealed that the group fed DL-1 diet which contained 1% soy-lecithin showed a significantly ($p<0.05$) lower growth than the other dietary treatments, suggesting that 1% soy-lecithin might not have satisfied the dietary requirement of *P. monodon* at hypersaline conditions. Furthermore, the lipid (ether extract) content of our experimental diets ranged from 5 to 8% on fed basis (Table 2), with the diet DL-1 containing 1% soy-lecithin having a lower lipid (ether extract) content. Though it was within the recommended range, it performed poorly than the others, suggesting that more than the lowest lipid content may be required for *P. monodon* when reared under hyperosmotic stress. However, the dietary soy-lecithin significantly ($p<0.05$) increased the DGC from 1.44% day^{-1} to 1.67% day^{-1} when the inclusion levels increased from 1 to 2.5%. But the RGR was significantly ($p<0.05$) high in the groups fed on DL-2 and DL-2.5 diets (6.01-6.20%) than the groups fed diets DL-1 (5.04%) and DL-1.5 (5.75). Jannathulla *et al.* (2019b) stated that shrimp utilises most of the energy gained from the diet for the osmoregulation process to balance the body fluid with their environment. Hence it exhibits hypo-osmotic regulation when reared at high salinity. Gong *et al.* (2004) documented that the supplementation of phospholipids increased the osmoregulatory capacity of the shrimps. Furthermore, soy-lecithin is not only a source of energy but also has a considerable quantity of essential fatty acids, phosphorus

Table 3. Growth performance of *P. monodon* fed diets containing varying levels of dietary soy-lecithin

Particulars	Dietary soy-lecithin				SEM (±)	CV (%)	p-value
	DL-1	DL-1.5	DL-2	DL-2.5			
Initial wt. (g)	3.14^{a}	3.06^{a}	3.07^{a}	3.28^{a}	0.014	4.876	0.330
Final wt. (g)	12.69^{c}	13.59^{bc}	14.12^{ab}	15.52^{a}	0.295	5.115	0.015
RGR (%)[1]	5.04^{c}	5.75^{b}	6.01^{a}	6.20^{a}	0.008	2.075	<0.001
DGC (% day^{-1})[2]	1.44^{c}	1.56^{b}	1.60^{b}	1.67^{a}	0.001	2.036	0.001
FCR[3]	2.33^{a}	2.13^{b}	2.12^{b}	2.11^{b}	0.001	2.274	0.004
PER[4]	1.38^{b}	1.57^{a}	1.53^{a}	1.54^{a}	0.001	2.417	0.003
APU[5]	26.49^{b}	29.97^{a}	31.09^{a}	30.36^{a}	0.297	2.433	0.001
Survival	75.56^{a}	75.56^{a}	82.22^{a}	82.22^{a}	42.777	10.911	0.638

All the values are the mean of three replications; Means bearing the same superscripts within the row do not differ significantly ($p>0.05$).
[1]Relative growth rate; [2]Daily growth coefficient; [3]Feed conversion ratio; [4]Protein efficiency ratio; [5]Apparent protein utilisation

and vitamins that would help to stabilise cell membranes and improve digestion, absorption and consumption of nutrients, especially lipids (Yilmaz, 2020). Similarly, Sanchez *et al.* (2014) found that *P. vannamei* fed 4% soy-lecithin grew faster than those fed 1% soy-lecithin, who suggested that this beneficial effect was due to increased lipid deposition and energy availability for growth, which might be attributed to increased transport and mobilisation of lipids from the hepatopancreas to the haemolymph and other tissues. All these could be possible reasons for obtaining higher growth with the higher inclusion levels of soy-lecithin as a source of phospholipid in our study.

All experimental diets had a positive response in growth indices when compared to the diet DL-1, as shown in Fig. 1. The DGC gradually increased by 7.81% in DL-1.5, 11.06% in DL-2 and 15.89% in DL-2.5 and FCR decreased by 8.70, 8.83 and 9.56%, respectively. This indicates that the dietary soy-lecithin (phosphatidylcholine) effectively regulates both the limiting processes acting on permeability properties of epithelial structure and the compensatory process during the active movement of water and ions. Our results are in agreement with the findings of earlier studies when soy-lecithin was supplemented at 3% in *Penaeus japonicus* (Teshima *et al.,* 1986) and 2% in *Fenneropenaeus chinensis* (Kanazawa *et al.,* 1983). In contrast, *P. vannamei* fed 1% phospholipids had no impact when reared in freshwater (Li *et al.,* 2016), while *P. vannamei* needs 6.5% soy-lecithin at the post-larval stage (Coutteau *et al.,* 1997). The authors suggested that the efficacy, type and source of phospholipids and the species, age and rearing condition would be a reason for obtaining the differences mentioned above. The dietary treatments had no significant difference in survival and ranged from 75.56-82.22%. On the contrary, significant effect was reported in *P. vannamei* fed with varying levels of phospholipids (Coutteau *et al.,* 1996). Similarly, Niu *et al.* (2011) found lower survival of *P. vannamei* with 2.72% of phospholipids (62.6%) than the diet containing 10.16% of phospholipids (89.1%). Maintaining required water quality parameters such as temperature (26.15±2.17°C), pH (7.81±0.29), DO (7.57±0.77 mg l^{-1}) and total ammonia (0.04±0.01 mg l^{-1}) throughout the experimental periods irrespective of the dietary treatments may have led to higher survival and no differences among them in our study.

The dietary treatments had no significant impact on the carcass composition of *P. monodon* fed varying levels of dietary soy-lecithin except for body lipids (Table 4). The lipid content of the body gradually increased with increase in the inclusion levels of dietary soy-lecithin, as phospholipids affected lipid deposition and retention (Niu *et al.,* 2011). Of all the dietary treatments, the diets DL-2 and DL-2.5 had significantly ($p<0.05$) higher body lipid content (3.66% wet weight basis) while it was 3.25% in DL-1 and 3.42% in DL-1.5 fed groups. Our results corroborated with the findings of Sanchez *et al.* (2014), who found increased body lipid in both cephalothorax and muscle of *P. vannamei* reared on 1 and 4% of dietary soy-lecithin with three different fish oil levels (1, 2 and 3%). However, no significant difference was observed in *P. vannamei* fed 0, 2 and 4% phospholipids with 0, 0.2 and

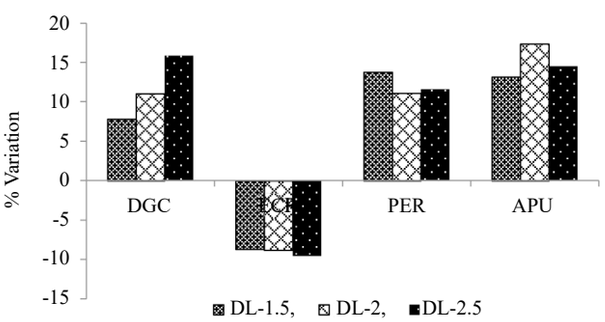

Fig. 1. Percentage variations among the experimental diets in comparison with the diet DL-1 (control)

Table 4. Carcass composition (% wet weight) of *P. monodon* fed diets containing varying levels of dietary soy-lecithin

Particulars	Dietary soy-lecithin				SEM (±)	CV (%)	p-value
	DL-1	DL-1.5	DL-2	DL-2.5			
Moisture	72.58[a]	72.12[a]	71.55[a]	71.97[a]	0.949	1.779	0.804
Crude protein	19.22[a]	19.16[a]	19.19[a]	19.12[a]	0.001	0.235	0.139
Ether extract	3.250[c]	3.420[b]	3.660[a]	3.660[a]	0.002	1.555	<0.001
Crude fibre	0.90[a]	0.93[a]	0.81[a]	0.94[a]	0.002	6.086	0.088
NFE	0.44[a]	0.78[a]	1.22[a]	0.66[a]	0.974	167.561	0.898
Total ash	3.61[a]	3.59[a]	3.56[a]	3.66[a]	0.001	1.071	0.087

All the values are the mean of three replications. Means bearing the same superscripts within the row do not differ significantly (p>0.05)

0.4% dietary cholesterol (Yan *et al.,* 2020). *P. monodon* fed a diet containing 1% soy-lecithin (DL-1) had significantly (p<0.05) lower level of phospholipids (61.96%) which gradually increased (p<0.05) with increase in the inclusion levels of dietary soy-lecithin (Fig. 2). In contrast, other lipid classes such as triacylglycerides (p>0.05) and cholesterol (p>0.05) were not affected due to the dietary modification. Similarly, dietary effects had no significant influence on the fatty acid composition of *P. monodon* in our study (Table 5), suggesting that *P. monodon* can balance its body fatty acid composition even when reared at varied levels of dietary soy-lecithin. Similar results were reported by Sanchez *et al.* (2014), who found no difference in the fatty acid composition of *P. vannamei* reared with 4% dietary soy-lecithin. However, both C16:0 and C18:2c were found to be significantly (p<0.05) high in the groups fed on a diet containing >2% soy-lecithin (DL-2 and DL-2.5), which could be attributed to the preferential utilisation of fatty acids by *P. monodon*. Sparing and retention of fatty acids had previously been demonstrated in various shrimp species such as *F. chinensis* (Xu *et al.,* 1994), *P. monodon* (Deering *et al.,* 1997) and *P. vannamei* (Gonzalez-Felix *et al.,* 2002).

Based on the present study, it can be concluded that the supplementation of soy-lecithin (phosphatidylcholine) as a source of phospholipids through the diet had a positive effect on growth performance in the juveniles of *P. monodon.* Results of the study indicated that soy-lecithin could be included ≥2.5% in the diet of *P. monodon* when they are reared at hyperosmotic stress conditions.

Table 5. Fatty acid composition (% total fatty acids) of *P. monodon* fed diets containing varying levels of dietary soy-lecithin

Fatty acid	Dietary lecithin				SEM (±)	CV (%)	p-value
	DL-1	DL-1.5	DL-2	DL-2.5			
C14:0	0.65[a]	0.66[a]	0.61[a]	0.64[a]	0.001	4.442	0.259
C15:0	5.44[a]	0.15[a]	0.15[a]	0.16[a]	12.062	309.528	0.454
C16:0	17.77[b]	17.52[b]	18.47[a]	19.09[a]	0.071	1.926	0.006
C17:0	0.66[a]	0.71[a]	0.67[a]	0.65[a]	0.001	6.058	0.352
C18:0	6.59[a]	7.58[a]	7.76[a]	7.68[a]	0.192	7.790	0.140
C20:0	0.10[a]	0.17[a]	0.17[a]	0.14[a]	0.001	20.670	0.095
C22:0	0.14[a]	0.21[a]	0.26[a]	0.20[a]	0.006	49.308	0.562
C24:0	0.19[a]	0.23[a]	0.23[a]	0.27[a]	0.012	63.498	0.925
C16:1	0.90[a]	0.84[a]	0.76[a]	0.65[a]	0.005	12.167	0.078
C17:1	0.31[a]	0.43[a]	0.46[a]	0.36[a]	0.003	18.111	0.139
C18:1c	11.73[a]	11.64[a]	12.15[a]	12.14[a]	0.104	3.570	0.388
C18:1t	2.32[a]	2.21[a]	1.89[a]	2.42[a]	0.111	19.837	0.526
C20:1	0.43[a]	0.36[a]	0.39[a]	0.30[a]	0.008	32.727	0.628
C24:1	0.14[a]	0.13[a]	0.19[a]	0.20[a]	0.002	35.529	0.455
C18:2c	16.93[b]	16.42[b]	18.45[a]	19.07[a]	0.139	2.767	0.002
C20:2	0.84[a]	0.92[a]	0.92[a]	0.85[a]	0.043	30.930	0.974
γc18:3	0.13[a]	0.19[a]	0.24[a]	0.15[a]	0.004	45.093	0.430
αC18:3	0.61[a]	0.64[a]	0.53[a]	0.42[a]	0.010	23.388	0.244
C20:4	3.31[a]	3.73[a]	3.30[a]	3.30[a]	0.052	8.830	0.308
C20:5	11.57[a]	12.01[a]	11.58[a]	11.50[a]	0.110	3.741	0.518
C22:6	10.60[a]	11.54[a]	11.09[a]	10.69[a]	0.110	3.973	0.122

All values are the mean of three replications. Means bearing the same superscripts within the row do not differ significantly (p>0.05)

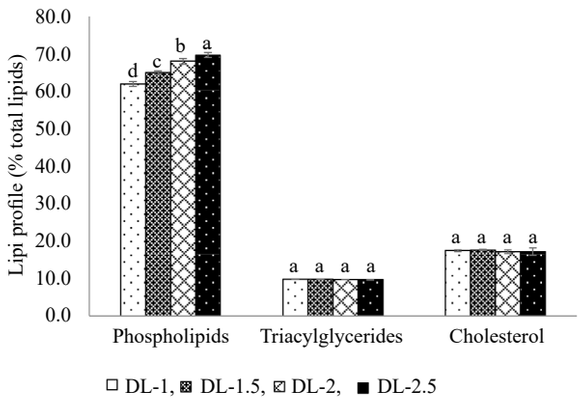

Fig. 2. Lipid profiles (% total lipids) of *P. monodon* fed diets containing varying levels of dietary soy-lecithin

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