Determination of the biometrical parameters, biochemical composition and essential trace metals of edible sea urchin (Stomopneustes variolaris) in Sri Lanka

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Determination of the biometrical parameters, biochemical composition and essential trace metals of edible sea urchin (Stomopneustes variolaris) in Sri Lanka

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Abstract: Sea urchin samples (Stomopneustes variolaris) were collected from the selected (three sampling locations) western and southern coastal area around the Sri Lanka (n = 193) from the time period of May to October, 2014. Sampled animals were measured for biometrical parameters, dissected and separated roe tissues, which were analysed for the proximate composition, fatty acid profiles (by GC), essential trace elements (by AAS), carotenoid profile and vitamin A, B1, B2, B12, C and E (By HPLC). Gonads of S. variolaris were rich in protein (11.47–18.81%), essential fatty acids (C14:0, C16:0 and C18:1 (n-9) were predominant and C12:0, C22:5 (n-6) and C22:6 (n-3) were lowest), fatty acids profiles, which revealed the higher amount of saturated fatty acids was present in the gonads of S. variolaris than the mono-unsaturated fatty acids and polyunsaturated fatty acids. Carotenoids (β carotene (9.4 mg/100 g)) and vitamin (higher amount of vitamin C (20 mg/100 g) was also rich with S. variolaris gonads. The essential trace elements like Fe, Zn and Cu also in recorded in considerable level of S. variolaris gonads. Beruwala population was recorded higher average test diameter (6.70 cm) than the other two sites and Mt. Lavinia population was showed highest GSI (5.95) value.

Keywords: gonads; test; proximate; fatty acids; trace metals; echinodermata

1. Introduction

Sea urchins which belong to the phylum Echinodermata are widely distributed in all the seas from the Arctic to Antarctic regions (James, 2008). Stomopneustes variolaris are dark-colored, omnivores, and warm-water echinoderm species and are widely distributed in the Indo-Pacific tropical and
Subtropical ocean in shady littoral areas with water depth up to 18 m (Giese, Krishnaswamy, Vasu, & Lawrence, 1964; Smith & Kroh, 2011; Kroh, 2014). *S. variolaris* are found mostly on the rocks and reefs, which are bored by their mouth and live in a cup-like depression. *S. variolaris* is one of the edible sea urchin species found in the Indian Ocean (James, 1982; Giese et al., 1964).

Gonads of sea urchins also called as roe, are in high demand and economically important food across the world as they have high nutritional value (Salon, 1985; Yokota, Matranga, & Smolenicka, 2002). Roe consists of water, protein, lipid, carbohydrate, vitamins, and minerals (Kato & Schroeter, 1985; Giese et al., 1964).

Biochemical compositions, nutritional quality, and safety of sea urchin roes are already studied for most of the edible sea urchin species using different kinds of parameters and conditions in many countries. To date in Sri Lanka, 28 sea urchin species have been recorded (Jayakody, 2012) and no species is used for human consumption, because of unexplored echinoderm resources and lack of market in tropical countries (Salon, 1985; Scheibling & Mladenov, 1987) including Sri Lanka.

This study aimed to determine the biochemical composition (including the proximate, fatty acids profile, vitamins, and carotenoids), essential trace elements (Fe, Zn, Cu, Ni, and Cr), and biometric parameters of *S. variolaris*, as that species highly inhabits the southwest region of Sri Lanka.

### 2. Materials and methods

#### 2.1. Sea urchin sampling and experimental design

Sea urchins (*S. variolaris*) were hand collected with the aid of SCUBA—diving apparatus at Mount-Lavinia (Mt. Lavinia) (*n*= 43), Beruwala (*n*= 96), and Tangalle reef (*n*= 54) in the southwest coast of Sri Lanka. This study was carried out from May to October 2014. Collected sea urchins from each location were dipped in sea water and transported to analytical chemistry lab at the Institute of Post-Harvest Technology, National Aquatic Resources Research and Development Agency within 24 h. At the laboratory, the total body weight of each individual was measured and the average horizontal test diameter was measured perpendicularly without spines using a vernier caliper (Shpigel, Mcbride, Marciano, & Lupatsch, 2004; Fabbrocini & D’Adamo, 2011; Dincer & Cakli, 2007). Individuals with a test diameter of 5–8 cm were separated to determine biochemical compositions as Giese et al. (1964) reported that larger sizes of individuals are more suitable for biochemical analysis and the rest of the samples were used to determine the essential trace metals (Fe, Zn, Cu, Ni, and Cr).

Finally, the roe was removed and weighed after removing excess water using blotting paper. Then, Gonado somatic index (GSI) was determined using total weight and gonad weight ratios (Vaïtilingon, Rasolofonirina, & Jangoux, 2005).

For biochemical analysis, samples were homogenized (Dincer & Cakli, 2007; Fabbrocini & D’Adamo, 2011) without adding any solvent using a mixer grinder (Sonica domestic).

#### 2.2. Determination of proximate composition

##### 2.2.1. Moisture and ash

Moisture content in 2 g of homogenized composite sample obtained using oven drying method (at 105 °C until a constant weight (3–5 h) was obtained) was determined as a percentage value. The oven-dried samples were further used to determine the ash content using the dry ashing method. The samples were subjected to 550 °C (8 h) using an ash furnace (Carbolite, Sheffield, UK) and the ash content was calculated as a percentage value (AOAC, 1998).

##### 2.2.2. Protein

Composite samples of urchins’ roe from each selected location were used to analyze protein content by taking 2 g of homogenized sample. The protein content was determined according to the AOAC
(1998) official methods, using UDK 132 (VELP Scientifica, Usmate, Italy) semi-automated Kjeltec system.

2.2.3. Lipid
The total lipids in sea urchins’ roe samples were extracted using the Bligh and Dyer (AOAC, 1998) method by taking 10 g of homogenized sample. Analyses of composite samples were performed in duplicate.

2.2.4. Carbohydrate
The presence of carbohydrates in sea urchin samples from selected locations were determined by subtraction of total moisture, ash, crude lipid, and crude protein contents of each samples from out of hundred (Mol, Baygar, Varlik, & Tosun, 2008; Pais, Saba, Rubattu, Meloni, & Montisci, 2011).

2.2.5. Energy
Energy content of each sea urchin roe sample was determined according to the AOAC (1998) official method using the PARR bomb calorimeter (MOLINE, IL USA). Analyses of dried samples were performed in duplicate for each location by taking 1 g of dried homogenized sample pellet.

2.2.6. Fatty acid profile analysis
The fat content of the each sample was determined as a percentage value. According to the fat content of the each sample of urchins’ roe, the Bligh and Dyer extraction method was used to made fatty acid methyl ester (FAME). Capillary gas chromatograph (GC) analysis was conducted in the chemistry laboratory at the Department of Physical Sciences in Rajarata University, Sri Lanka using Agilent GC, (Agilent 7890B, USA) to determine fatty acid profiles. The GC was equipped with a fused silica DB wax capillary column (30 m* 0.32 m, film 0.25 μm) and a flame ionization detector. Helium (He) gas was used as the carrier gas at 14-psi pressure. Retention times of FAME standards (Qualmix 89-5550) were used to identify chromatographic peaks.

2.2.7. Carotenoid and vitamin analysis
Carotenoid profile and vitamin A, B1, B2, B12, C, and E profiles of urchins’ roe samples were analyzed in an accredited laboratory at the Industrial Technology Institute (ITI), Sri Lanka. According to the result sheet which is issued by the ITI, vitamins A and E were analyzed by the CML/MM/03/05/01/VI.4 method and vitamin B complex (B1, B2, and B12) was analyzed using the HPLC method. Vitamin C was analyzed using the method published in US pharmacopeia. Finally, β carotene was analyzed by the method published in Roche Publication Index No: 1743 (1980).

2.2.8. Essential trace element analysis
One gram of homogenized sea urchin’s roe samples was accurately weighed into a teflon microwave digestion tube. Analyses of samples were performed in duplicate. Roe samples were acid digested using 10 mL of HNO₃ (65% nitric acid, AR) and allowed to cool for 10–15 min and the microwave digestion tubes were capped. Using the CEM/MARS XP-1500+ microwave oven (CEM, Matthews, USA) accelerated system, sea urchins’ roe samples were digested and allowed to cool to room temperature and pressure was released carefully by opening the valve. Then, the digested roe samples were transferred into a 50 mL volumetric flask and the rest of the volume was made up using de-ionized water separately. Standard solutions of Cu, Zn, Ni, and Cr at 1,000 mg/L and Fe at 10,000 mg/L were obtained from Sigma-Aldrich (Dorset, United Kingdom) which were used for the construction of calibration curve and all standards and reagents were prepared using ultra-pure water.

Atomic absorption spectrophotometer (AAS) (Varian 240 FS, Springvale, Australia) was used to determine essential trace metals in the prepared sea urchins’ roe sample. Fe and Zn concentration of sea urchins’ roe sample were determined using flame atomic absorption spectrometry (AAS–240 FS) and a graphite tube atomizer (Varian GTA-120) was used for Cu, Ni, and Cr determination. Analyses of samples were done in duplicate and spiked sample recovery was used as a quality control of the study (80–120%).
2.3. Statistical analysis
Data were analyzed using Microsoft excel 2010 version and Minitab 16.0 Statistic package. ANOVA statistical analyses for parametric test and Mann-Whitney test for non-parametric test were conducted with the level of significance at $p < 0.05$ (5%).

3. Results and discussion

3.1. Biometrical parameters
The average test diameters (Table 1) recorded for Beruwala, Tangalle, and Mt. Lavinia samples were 6.7 (±1.3), 6.5(±2.7), and 5.6(±1.0) cm, respectively. According to Giese et al. (1964), S. variolaris with a 10-cm diameter was found from the Madras harbor, India.

Average GSI value (Table 1) for Beruwala, Tangalle, and Mt. Lavinia samples was 3.2 (±1.6), 3.4 (±1.9), and 6.0 (±3.3), respectively. The reasons for the change in the GSI value may be due to the effect of water temperature. According to the study done by Shpigel et al. (2004), that the higher water temperature can lower the GSI significantly and independently of the light regimes. Also, GSI may change due to sea urchin origin (Arafa, Chouaibi, Sadok, & El Abed, 2012). However, in this study, the samples collected from Mt. Lavinia reef’s individuals visibly showed a higher percentage of gonads (test diameter) in their body cavity than the individuals collected from other two locations compare with their test diameter.

3.2. Proximate composition of S. variolaris roe
Proximate composition values of S. variolaris showed a somewhat higher percentage of crude protein, crude fat, carbohydrate, and energy (Table 2) than Paracentrotus lividus, (Mol et al., 2008) but a lower percentage of ash and moisture. Mol et al. (2008) reported P. lividus percentage of proximate composition: crude protein, crude fat, moisture, ash, and carbohydrate contents of sea urchin gonads’ mean values as 12.03, 3.05, 79.87, 2.25, and 2.80 respectively; also, energy value was 107.81 kcal/100 g.

Table 1. S. variolaris average total weight, average gonad weight, test diameter, and GSI values at each selected location

| Locations     | Parameters                  | Average total weight/g | Average gonad weight/g | Average test diameter/cm | Average GSI  |
|---------------|-----------------------------|------------------------|------------------------|--------------------------|--------------|
| Beruwala      | 96                          | 147.9 (±50.4)          | 4.8 (±2.7)             | 6.7 (±1.3)               | 3.2 (±1.6)   |
| Tangalle      | 54                          | 131.5 (±66.6)          | 5.5 (±3.2)             | 6.5 (±2.7)               | 3.4 (±1.9)   |
| Mt. Lavinia   | 43                          | 101.4 (±57.8)          | 7.0 (±6.3)             | 5.6 (±1.0)               | 6.0 (±3.3)   |

Table 2. Proximate analysis of Beruwala, Tangalle, and Mt. Lavinia samples

| Constituents    | Female + Male (n = 96) | Female + Male (n = 54) | Female + Male (n = 43) | Mean Values |
|-----------------|------------------------|------------------------|------------------------|-------------|
| Moisture (%)    | 71.31 (±0.04)          | 67.90 (±0.10)          | 68.64 (±0.11)          | 69.28 (±0.08) |
| Ash (%)         | 02.95 (±0.05)          | 01.91 (±0.08)          | 01.99 (±0.07)          | 02.28 (±0.07) |
| Crude Lipid (%) | 08.37 (±0.41)          | 07.94 (±0.05)          | 07.65 (±0.08)          | 07.99 (±0.18) |
| Crude Protein (%)| 11.47 (±0.15)          | 14.70 (±0.30)          | 18.81 (±2.13)          | 14.99 (±0.93) |
| Carbohydrate (%)| 05.92 (±0.25)          | 07.55 (±0.36)          | 02.90 (±2.16)          | 05.46 (±0.92) |
| Energy (kJ/g)   | 24.94 (±1.03)          | 26.40 (±0.32)          | 25.65 (±0.07)          | 25.66 (±0.47) |
In Red sea urchins (S. franciscanus) and Purple sea urchins (Strongylocentrotus purpuratus), protein (%) values varied from 7.7 to 9.6 and 9.5 to 12.3, respectively (Kato & Schroeter, 1985), but in S. variolaris, which was collected from all the selected locations, the mean value of protein (%) was 14.99 (±0.93) (Table 2). These values were higher than the protein (%) value of S. franciscanus and S. purpuratus, but the values revealed no significant difference among the selected locations as p = 0.420. This value was also somewhat higher than the protein (%) value of P. lividus (12.03%) (Mol et al., 2008). The lipid content (%) of gonads of S. franciscanus and S. purpuratus was 7.6–8.3 and 5.4–5.2, respectively (Kato & Schroeter, 1985). However, the mean value (%) of lipid of S. variolaris was 07.99 (±0.18) which is mostly similar to the findings of Kato and Schroeter (1985). Kato and Schroeter (1985) reported ash (%) content also of S. franciscanus and S. purpuratus to be 1.6–1.5 and 1.3–1.7 respectively, and mean ash values (%) of S. variolaris were 02.28 (±0.07) in all the selected locations (Table 2).

Male and female gonads are the only organs in sea urchins, which are used to store the nutrients for reproduction. Protein is the main constituent of the gonads of urchins (except moisture) (Verachia et al., 2012). Higher amount of proteins are presence in sea urchin gonads is an advantage as they are get low protein diet (Fabbrocini & D’Adamo, 2011) and gonads can be used for substitutes as an alternative protein sources instead of fish supplements. According to Shpigel et al. (2004), the proximate composition has been strongly influenced by food quality, which is present in living environment. Also Shpigel et al. (2004) reported lipid and carbohydrate levels decreased with the maturation of the gonad under natural conditions.

3.3. Fatty acid analysis

In this study some fatty acid such as C14:0, C16:0, and C18:1 (n-9) were predominant and C12:0, C22:5 (n-6), and C22:6 (n-3) were found in lowest in the gonads of S. variolaris (shown in Table 3). But, C16:0 and C20:5 n3 were predominant in the gonad of P. lividus species (Mol et al., 2008). In this study, C14:0 and C16:0 amounts were higher than also C22:5 (n-6) and C22:6 (n-3) were lower than the P. lividus, which conducted by Mol et al. (2008) and similar to value of Psammechinus miliaris and P. lividus (Hughes, Cook, Orr, Kelly, & Black, 2011). Fatty acids C10:0 and C12:0 were recorded in P. lividus species during the study period, which was conducted by Mol et al. (2008).

Fatty acid composition of S. variolaris gonads is shown in Table 3. This study revealed that S. variolaris had the highest total saturated fatty acid (SFA) content of 54.84% in the Beruwala sample, 51.65% in the Tangalle sample and 61.46% in the Mt. Lavinia sample. The total amount of monounsaturated fatty acids (MUFA) was 14.99% in the Beruwala sample, 14.45% in the Tangalle sample and 11.58% in the Mt. Lavinia sample, and the lowest values of polyunsaturated fatty acids (PUFA) were 9.97% in the Beruwala sample, 14.91% in the Tangalle sample, and 11.16% in the Mt. Lavinia sample (Table 3). Fatty acid composition among the selected locations revealed that the total amount of SFA was significantly higher (p < 0.005) than the total amount of MUFA and PUFA, but in P. lividus fatty acid composition showed total amounts of MUFA and PUFA were significantly higher (p < 0.05) than those of SFA. In addition, the PUFA content of the samples was also significantly higher (p < 0.05) than SFA and MUFA contents (Mol et al., 2008). However, in S. variolaris the amount of SFAs was higher than that of MUFA and PUFA. Another study revealed that among isolated fatty acids of P. lividus PUFAs were more abundant (44.7%) than SFAs (35.0%) and MUFAs (20.3%) (La Cruz-García, López-Hernández, González-Castro, Rodríguez-Bernaldo De Quirós, & Simal-Lozano, 2000).

According to Table 3, the ω3/ω6 ratio of S. variolaris was 0.57 in the Beruwala sample, 1.27 in the Tangalle sample, and 0.61 in the Mt. Lavinia sample. However, the ω3/ω6 ratio of P. lividus is about 1.55 (Mol et al., 2008); this value is similar to that of the Tangalle sample, and higher than that of the Beruwala and Mt. Lavinia samples. A high ω3/ω6 ratio (6.7) was found in P. lividus (La Cruz-García et al., 2000), which is higher than that reported before the study conducted by Mol et al. (2008). ω3 was the highest in the Tangalle sample when compared with other selected locations. The ω3/ω6 ratio is an indicator of great importance for human nutrition because several studies have shown...
that diets high in \(\omega_6\) fatty acids are related to an increased incidence of breast, prostate, and colon cancer, whereas diets high in \(\omega_3\) fatty acids have beneficial effects against several types of malignant tumors (La Cruz-Garcia et al., 2000).

### 3.4. Vitamin and carotenoid analysis

Vitamins in trace amounts are well-known organic nutritional compounds found in foods which are essential for the health of humans. According to their solubility, vitamins can be classified as water soluble and fat soluble. Vitamins B and C are water soluble and except these two, all others are fat soluble. Sea foods are a source of some vitamins. Fatty species are generally rich in fat-soluble vitamins and among water-soluble vitamins the amount of B12 is particularly high (Gokulakrishnan, Roja, & Eswar, 2015). According to the results, sea urchin roes are rich in vitamins C, E, A and \(\beta\) carotene. The highest concentration recorded was for vitamin C (20 mg/100 g), followed by \(\beta\) carotene (9.4 mg/100 g), vitamin E (1.9 mg/100 g), and vitamin A (386 \(\mu\)g/100 g). Vitamins B1, B2, and B12 were tested, but the results were below the limit of detection (0.30, 0.25, and 0.15 mg/100 g, respectively).

Ascorbic acid (vitamin C) and vitamin A are considered antioxidants essential for human health as they provide necessary immune responses, wound healing, non-heme iron absorption, reduction in allergic responses, development of connective tissue components such as collagen, etc. Both have the ability to reduce the risk of cardiovascular disease through reducing free radical production and free radical damage to the vessels of the heart.

When considering vitamin E, it is one of the fat-soluble antioxidants which are essential to promote cardiovascular health, boost immune function, and contribute to proper blood flow and clotting as well as repairing skin damages (FAIRF, NSEC, NSA, & Nofima, 2010). Daily requirement of the vitamins is in trace amounts. But, if we cannot meet our needs through our diet, we have to use dietary supplements. But, sea urchin roes are rich in some vitamins like C, E, A, and \(\beta\) carotene. The reality is we can obtain much more vitamins from these kinds of underutilized seafood species in Sri Lanka.

### 3.5. Trace metal accumulation

Essential trace metal (Fe, Zn, Cu, Ni, and Cr) accumulation in gonads of *S. variolaris* was analyzed in individuals collected from the selected locations \((n = 30)\) (Tables 4). The essential trace metal accumulation of Fe was higher in Beruwala reef samples than in the other sites in the following order: Beruwala > Tangalle > Mt. Lavinia reefs; Zn was higher in Tangalle reef samples in the following order: Tangalle > Mt. Lavinia > Beruwala; Cu was higher in Beruwala reef samples in the following order: Beruwala > Tangalle > Mt. Lavinia; Ni was higher in the Beruwala reef sample in the following order: Beruwala > Tangalle > Mt. Lavinia. Finally, Cu, Ni, and Cr were higher in the Beruwala sample than the other two selected sites. A study on *P. lividus* of the Algerian coastal environment revealed Cd and Zn concentrations were significantly higher in female than in male gonads, while Cu concentration was more in male gonads (Soualili, Dubois, Gosselin, Pernet, & Guillou, 2008), but in this study Cu and Fe concentrations in the gonads differ according to the sampled sites. Therefore, contaminations of trace metals in sea urchin gonads reveal their environment conditions including seaweeds.

*S. variolaris* accumulated an average concentration of trace metals in the following order: Fe > Zn > Cu > Ni > Cr in Beruwale samples, Zn > Fe > Cu > Ni > Cr in Tanagalle samples and Zn > Fe > Cr > Ni > Cu in Mt. Lavinia samples. According to the above order, a higher average concentration of Zn in Tangalle and Mt. Lavinia samples than in Beruwala samples can be seen. The overall accumulation of essential trace metals, which was analyzed in *S. variolaris* gonads from the selected sites, can be used as a bio-indicator to identify trace metal pollution of that particular area of coastal regions in Sri Lanka. Because many sea urchin species, namely *P. lividus* and other species were used as bio-indicators in the world (Mostafa & Collins, 1995; Soualili et al., 2008).
The Mt. Lavinia population of *S. variolaris* yielded higher amount of proximate composition, SFA, \(\omega_6\) and less metal accumulation than the other two selected locations, according to the previous studies, the high amount of nutrients with less amount of non-essential metals in gonads of *S. variolaris* are suitable for human consumption to reduce the health risk. But due to high amount of SFA and \(\omega_6\) were could be caused severe problem for human health. This is a good source to start sea urchin fishery in Sri Lanka for export due to the low degree of contamination of gonads of both male and female *S. variolaris*.

**Future development and export market for echinoderm fishery in Sri Lanka**

Considering the global production, there are three main countries which share the highest production, namely Japan (*Strongylocentrotus intermedius* and *Strongylocentrotus nudus*), Chile (*Loxechinus albus*), and the United State of America (*Strongylocentrotus franciscanus* and *Strongylocentrotus droebachiensis*) and in Japan, sea urchin gonads are high-price food items, which are eaten raw (sashimi), with rice as shushi or preserved with brine, salt, and alcohols (Siikavuopio, 2009). But in Sri Lanka, there is no

| Fatty acids | Beruwala (%) | Tangalle (%) | Mt.Lavinia (%) |
|-------------|--------------|--------------|---------------|
| C12:0       | 0.13         | 0.14         | 0.47          |
| C14:0       | 26.77        | 23.91        | 31.36         |
| C15:0       | 0.62         | 0.71         | 0.53          |
| C16:0       | 21.86        | 21.71        | 24.06         |
| C18:0       | 5.53         | 5.17         | 5.05          |
| Total SFA   | 54.84        | 51.65        | 61.46         |
| C16:1       | 1.68         | 2            | 1.37          |
| C18:1 (n-9) | 7.17         | 6.4          | 5.27          |
| C18:1 (n-7) | 1.29         | 1.68         | 1.11          |
| C20:1 (n-9) | 3.82         | 3.51         | 2.66          |
| C22:1 (n-9) | 1.03         | 0.86         | 1.16          |
| Total MUFA  | 14.99        | 14.45        | 11.58         |
| C18:2 (n-6) | 0.65         | 0.93         | 0.92          |
| C18:3 (n-3) | 0.69         | 1.28         | 0.9           |
| C18:4 (n-4) | 0.82         | 0.71         | 0.76          |
| C20:4 (n-6) | 4.14         | 4.49         | 4.7           |
| C20:5 (n-3) | 2.17         | 6.11         | 2.53          |
| C22:4 (n-6) | 0.76         | 0.53         | 0.6           |
| C22:5 (n-6) | 0.30         | 0.29         | 0.21          |
| C22:6 (n-3) | 0.44         | 0.57         | 0.53          |
| Total PUFA  | 9.97         | 14.91        | 11.16         |
| C18:3 (n-3) | 0.69         | 1.28         | 0.9           |
| C20:5 (n-3) | 2.17         | 6.11         | 2.53          |
| C22:6 (n-3) | 0.44         | 0.57         | 0.53          |
| \(n_3\) (\(\omega_3\)) | 3.29         | 7.95         | 3.96          |
| C18:2(n-6)  | 0.65         | 0.93         | 0.92          |
| C20:4(n-6)  | 4.14         | 4.49         | 4.7           |
| C22:4(n-6)  | 0.76         | 0.53         | 0.6           |
| C22:5(n-6)  | 0.30         | 0.29         | 0.21          |
| \(n_6\) (\(\omega_6\)) | 5.85         | 6.24         | 6.45          |
| (\(\omega_3/\omega_6\)) | 0.57         | 1.27         | 0.61          |
Table 4. Trace metal (Cu, Ni, Fe, Zn, and Cr) concentration and total amount of particular trace metals present in *S. variolaris* (n = 30) Be = Beruwala, Mt. = Mt. Lavinia, Ta = Tangalle

| Test Diameter/cm | Total Gonad Weight/g | Ave Cu/µg/kg (±sd) | Ave Ni/µg/kg (±sd) | Ave Fe/µg/kg (±sd) | Ave Zn/µg/kg (±sd) | Ave Cr/µg/kg (±sd) |
|------------------|----------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| 3.70**           | 1.77                 | 0.00 (±0.00)       | 250.48 (±133.17)   | 14.67 (±7.30)      | 0.00 (±0.00)       | 413.39 (±2249.03)  | 0.73               |
| 4.10**           | 0.80                 | 943.73 (±73.87)    | 1472.64 (±133.19)  | 57.40 (±13.84)     | 0.05 (±1.13)       | 481.63 (±2457.08)  | 0.39               |
| 4.10**           | 0.75                 | 0.00 (±0.00)       | 0.00 (±0.00)       | 14.57 (±3.15)      | 0.01 (±2.35)       | 216.01 (±663.73)   | 0.16               |
| 4.50**           | 1.92                 | 0.00 (±0.00)       | 226.95 (±29.60)    | 12.04 (±4.86)      | 0.02 (±7.12)       | 204.12 (±70.18)    | 0.39               |
| 4.80**           | 1.12                 | 2724.19 (±230.57)  | 476.25 (±587.56)   | 16.60 (±10.32)     | 0.02 (±151.47)     | 1153.7 (±365.84)   | 0.13               |
| 4.90**           | 1.15                 | 1582.53 (±257.60)  | 2213.92 (±1926.32) | 495.26 (±300.06)   | 0.57 (±8.93)       | 1900.89 (±440.29)  | 2.22               |
| 5.00**           | 1.46                 | 2940.13 (±142.39)  | 512.88 (±39.07)    | 31.50 (±14.81)     | 0.05 (±63.71)      | 310.17 (±305.26)   | 0.45               |
| 5.10**           | 3.10                 | 0.00 (±0.00)       | 82.11 (±100.05)    | 16.19 (±4.43)      | 0.02 (±192.66)     | 192.66 (±49.37)    | 0.60               |
| 5.30**           | 2.13                 | 2076.23 (±110.42)  | 595.67 (±19.50)    | 51.25 (±10.26)     | 0.11 (±15.69)      | 380.57 (±70.05)    | 0.81               |
| 5.70**           | 3.31                 | 1543.87 (±41.48)   | 443.05 (±66.98)    | 28.14 (±3.49)      | 0.09 (±9.71)       | 147.71 (±58.77)    | 0.49               |
| 5.80**           | 4.94                 | 1102.90 (±181.14)  | 605.38 (±100.46)   | 120.57 (±120.30)   | 0.60 (±1.73)       | 985.96 (±883.62)   | 4.87               |
| 5.90**           | 2.91                 | 3246.59 (±48.33)   | 855.38 (±533.18)   | 6.74 (±8.49)       | 0.02 (±20.78)      | 1582.98 (±2020.69) | 4.61               |
| 6.00**           | 1.73                 | 1102.06 (±126.42)  | 680.54 (±16.83)    | 97.90 (±79.84)     | 0.17 (±3.08)       | 596.63 (±71.94)    | 1.03               |
| 6.00**           | 3.59                 | 2759.31 (±36.53)   | 640.50 (±173.56)   | 80.54 (±21.76)     | 0.29 (±23.01)      | 305.49 (±29.58)    | 1.10               |
| 6.20**           | 10.07                | 200.0 (±0.00)      | 190.52 (±42.84)    | 24.41 (±1.82)      | 0.25 (±3.35)       | 530.21 (±432.7)    | 5.34               |
| 6.30**           | 3.00                 | 1266.82 (±151.33)  | 862.23 (±257.10)   | 53.69 (±64.44)     | 0.16 (±1.12)       | 862.51 (±404.02)   | 2.59               |
| 6.40**           | 4.04                 | 1641.76 (±52.06)   | 525.28 (±131.10)   | 69.02 (±25.20)     | 0.28 (±5.99)       | 296.82 (±45.85)    | 1.20               |
| 6.50**           | 5.59                 | 1100.60 (±358.24)  | 945.73 (±79.44)    | 26.07 (±11.61)     | 0.15 (±0.00)       | 584.85 (±98.45)    | 3.27               |
| 6.50**           | 8.73                 | 1591.53 (±25.72)   | 462.22 (±49.64)    | 23.39 (±6.00)      | 0.20 (±8.92)       | 128.25 (±183.3)    | 1.12               |
| 6.50**           | 7.71                 | 0.00 (±0.00)       | 523.40 (±0.01)     | 21.28 (±3.99)      | 0.16 (±3.24)       | 270.10 (±128.39)   | 2.08               |
| 6.70**           | 3.86                 | 2943.60 (±548.30)  | 488.06 (±45.36)    | 32.66 (±2.05)      | 0.13 (±10.66)      | 247.63 (±11.89)    | 0.96               |
| 7.00**           | 8.81                 | 1488.70 (±97.26)   | 525.18 (±31.10)    | 36.89 (±14.35)     | 0.33 (±10.67)      | 276.80 (±72.79)    | 2.44               |
| 7.10**           | 8.63                 | 0.00 (±0.00)       | 402.22 (±313.11)   | 14.16 (±1.94)      | 0.12 (±2.86)       | 297.70 (±76.32)    | 2.57               |
| 7.20**           | 11.80                | 891.71 (±65.90)    | 531.15 (±19.83)    | 21.97 (±2.51)      | 0.26 (±90.16)      | 214.04 (±286.63)   | 2.53               |

(Continued)
Table 4. (Continued)

| Test Diameter/ cm | Total Gonad Weight/g | Ave Cu/ µg/kg (±mg) | Total Cu/ mg (±µg/kg) | Ave Ni/ µg/kg (±mg) | Total Ni/ mg (±µg/kg) | Ave Fe/ mg/kg (±µg) | Total Fe/ mg/ kg (±µg) | Ave Zn/ µg/kg (±mg) | Total Zn/ mg (±µg) | Ave Cr/ µg/kg (±mg) | Total Cr/ mg (±µg) |
|-------------------|----------------------|---------------------|-----------------------|---------------------|-----------------------|---------------------|----------------------|---------------------|-------------------|---------------------|-------------------|
| 7.30**            | 3.48                 | 6063.33 (±136.76)   | 21.10                 | 749.24 (±84.98)     | 2.61                  | 6.39 (±8.49)        | 0.02                 | 16.98 (±0.32)      | 0.06              | 421.86 (±6.62)     | 1.47              |
| 7.30**            | 3.66                 | 1355.52 (±47.34)    | 4.96                  | 1048.70 (±57.48)    | 3.84                  | 79.03 (±0.08)       | 0.29                 | 15.62 (±0.15)      | 0.06              | 654.84 (±30.60)    | 2.40              |
| 7.70**            | 8.72                 | 894.03 (±3.74)      | 7.80                  | 1031.07 (±13.86)    | 8.99                  | 7.05 (±3.54)        | 0.06                 | 0.01 (±0.07)       | 0.01x10^-2        | 685.91 (±55.36)    | 5.98              |
| 7.70**            | 6.61                 | 648.56 (±724.19)    | 4.29                  | 504.50 (±16.83)     | 3.33                  | 18.92 (±1.00)       | 0.13                 | 57.49 (±1.27)      | 0.38              | 250.03 (±23.65)    | 1.65              |
| 8.30**            | 10.72                | 3272.29 (±91.16)    | 35.08                 | 585.71 (±35.01)     | 6.28                  | 117.33 (±12.78)     | 1.26                 | 74.19 (±1.21)      | 0.80              | 361.77 (±24.33)    | 3.88              |
| 8.90**            | 18.69                | 114.46 (±89.61)     | 21.4                  | 139.30 (±42.69)     | 2.60                  | 31.69 (±0.53)       | 0.59                 | 23.57 (±1.41)      | 0.44              | 191.80 (±9.42)     | 3.58              |
| Average           | 1445.48 (±1410.97)   | 6.26 (±2.05)        | 616.95 (±429.63)      | 2.72                  | 54.25 (±88.48)       | 0.21 (±0.25)        | 27.35 (±37.76)      | 0.13 (±0.24)       | 471.29 (±408.43)   | 2.03              | 1.60              |

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Fishery established on sea urchin to date, according to this study, which revealed there is a positive trend to establish sea urchin fishery and increase local and export markets of roe of sea urchin.

4. Conclusion
The population of sea urchins varied with study area, where the highest population was observed at the Beruwala reef; the population of S. variolaris showed a higher average test diameter (6.70 cm) than that of the other two sites and Mt. Lavinia population was showed a higher GSI (5.95) than the other site populations. The highest amount of protein (%), lipid (%), and energy (kJ/g) was found in S. variolaris in the selected sites in Sri Lanka. The value of protein (%) and lipid (%) recorded was higher in the Mt. Lavinia sample than in the other selected samples. Fatty acid profiles, which were identified in S. variolaris species, revealed a higher amount of SFA was present in the gonads of S. variolaris than that of the MUFA and PUFA. Therefore, there is no considerable health benefit for humans when consuming more SFA than the MUFA and PUFA. Also, the fatty acids C14:0, C16:0, and C18:1 (n-9) were predominant and C12:0, C22:5 (n-6), and C22:6 (n-3) were the lowest in the gonads of S. variolaris. Essential trace metals like Fe, Zn, and Cu were highly concentrated in S. variolaris in the selected sites in Sri Lanka. The value of protein (%) and lipid (%) recorded was higher in the Mt. Lavinia sample than in the other selected samples. Fatty acid profiles, which were identified in S. variolaris species, revealed a higher amount of SFA was present in the gonads of S. variolaris than that of the MUFA and PUFA. Therefore, there is no considerable health benefit for humans when consuming more SFA than the MUFA and PUFA. Also, the fatty acids C14:0, C16:0, and C18:1 (n-9) were predominant and C12:0, C22:5 (n-6), and C22:6 (n-3) were the lowest in the gonads of S. variolaris. Essential trace metals like Fe, Zn, and Cu were highly concentrated in S. variolaris gonads, which improve the health and biochemical activities and functions in the human body.
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