

lipids and fatty acid Analysis content`s in Pharaoh Cuttlefish *Sepia pharaonis* (Ehrenberg 1831) in the marine waters of the northwestern Arabian Gulf

Intisar M.A. Jabbar^{ID}, Amal S. Al-Sheraa^{ID}, Mahmood S. Hashim^{ID},
Ibtisam M. Abdul-Sahib^{ID}, Tariq H.Y. Al-Maliky^{ID}

Department of Marine Biology, Marine Science Center, University of Basrah, Basrah, Iraq

*Corresponding Author E-mail: intesar.jabbar@uobasrah.edu.iq

Received 13/02/2026

Accepted 10/05/2026

Published 01/06/2026

Abstract

The current study demonstrated variations in total fat content and fatty acid composition in different body parts of the *Sepia pharaonis*, including both the head and mantle, from three selected specimens weighing 700 ± 50 g, 1566.7 ± 410.9 g, and 2441.7 ± 401.9 g. Fatty acid analysis showed significant differences among weight groups ($P \leq 0.05$) between the groups based on weight for most of the fatty acids studied. Oleic acid was the most abundant fatty acid in the head and mantle tissues. Fatty acid analysis showed significant differences among weight groups ($P \leq 0.05$) eicosapentaenoic acid (EPA), linoleic acid, linolenic acid, palmitic acid, and stearic acid showed a significant increasing trend with growth, where the largest group exhibited higher values compared to the smallest group, the intermediate group presented intermediate values, statistically indistinguishable from both the lower and higher weight groups. In contrast, docosahexaenoic acid (DHA) remained relatively stable in the head with no significant differences, whereas it showed significant variation in the mantle. the higher fatty acid concentrations in the head may be due to the different nature and functions of the tissues compared to the mantle. The mantle contains lower lipid accumulation possibly because it is mostly muscular compared to the head. Overall, the results suggest a positive relationship between body weight and lipid accumulation and clear differences in fatty acid profiles between tissues. These results emphasise the effect of growth and tissue type on the biochemical composition of *S. pharaonis*, with possible implications for its nutritional value and exploitation.

Keywords: Fatty acids, Total fat, *Sepia pharaonis*, Weight groups, EPA, DHA, Marine organisms.



Introduction

Marine invertebrates are one of the most diverse and ecologically important groups of aquatic organisms, accounting for more than 90% of the known animal species worldwide. They occur in marine, freshwater and terrestrial ecosystems and play important roles in nutrient cycling, trophic interactions and energy transfer in aquatic food webs (Nikolaou and Katsanevakis, 2023; Campagne *et al.*, 2023). Squids, cuttlefish and octopuses (cephalopods) are considered to be very important marine invertebrates due to their fast growth, high nutritional value, ecological importance and increasing commercial demand (Pungor and Niell, 2023; Vidal and Shea, 2023). These organisms have unique physiological and biochemical adaptations that enable them to thrive under different environmental conditions, especially in marine ecosystems where temperature, salinity, and food availability fluctuate (Borges, 2023; Hsieh *et al.*, 2023). Furthermore, recent studies have demonstrated that cephalopods display remarkable metabolic plasticity and adaptive responses that facilitate their ecological success in dynamic marine environments (Borges, 2023; Vidal and Shea, 2023).

Sepia pharaonis is one of the commercially and nutritionally important cephalopod species found in tropical and subtropical marine waters including Arabian Gulf region. *Sepia pharaonis* was recorded for the first time in the northwestern Arabian Gulf only recently by Al-Maliky *et al.* (2024). Although ecologically and economically important, little is known about the effects of body size on fatty acid composition in this species, especially under the environmental conditions of the northwestern Arabian Gulf characterised by high temperature and salinity. Most of the previous studies on cephalopods have been mainly concerned with the general biochemical composition or total lipid content. Comparatively fewer investigations have been conducted on the variations of saturated, monounsaturated and polyunsaturated fatty acids among different weight groups. *Sepia pharaonis* was recently recorded for the first time in the northwestern Arabian Gulf by Al-Maliky *et al.* (2024).

There is limited information on the effect of body size on fatty acid composition of this species, despite its ecological and economic importance, especially in the environmental conditions of the northwestern Arabian Gulf characterised by high temperature and salinity. Previous studies on cephalopods have mainly focused on general biochemical composition or total lipid content. There are comparatively fewer studies that have looked at variations in saturated, monounsaturated and polyunsaturated fatty acids among different weight groups (Vidal and Shea, 2023; Monroig *et al.*, 2013). The hypothesis that cephalopods possess a high biochemical plasticity to deal with environmental changes has been supported in more recent ecological studies, so fatty acid profiling is an important way to understand physiological adaptation and nutritional quality (Fonseca *et al.*, 2022). Lipids are among the most important biochemical constituents in marine invertebrates, serving as primary energy reserves and structural elements of biological membranes. Lipids are triglycerides, phospholipids, sterols and other fatty substances. All lipids are insoluble in water, but are soluble in organic solvents such as acetone and ether.

Lipids are constructed from building blocks called fatty acids, which are hydrocarbon chains with a carboxylic acid group ($-\text{COOH}$) at one end. Fatty acids are classified into saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) based on the presence or absence of double bonds. These compounds are essential for membrane fluidity, metabolic regulation, reproduction, growth and environmental adaptation of marine organisms (Yoon *et al.*, 2022; Monroig *et al.*, 2013). Marine invertebrates, especially cephalopods, are excellent sources of biologically important omega-3 polyunsaturated fatty acids, including eicosapentaenoic acid (EPA; $20:5n-3$) and docosahexaenoic acid (DHA; $22:6n-3$), which are crucial physiologically and nutritionally (Monroig *et al.*, 2013; Zhukova, 2019).

These fatty acids have been linked to a number of benefits for human health including reduced cardiovascular risk and improved neural and immune function. Therefore, the nutritional and commercial value of cephalopods is closely related to their lipid composition and fatty acid profiles (Monroig *et al.*, 2022). The fatty acid composition in marine invertebrates has been shown to differ between species, habitat, diet, reproductive stage and environmental conditions, in several studies (Parrish, 2025). Lipid composition is highly dynamic in cephalopods due to their very rapid metabolism and short life cycles. In previous studies of squids and octopuses, significant differences in DHA, EPA and saturated fatty acids were observed in developmental stages and body sizes, showing the marked influence of the growth stage on lipid accumulation and use (Andrews *et al.*, 2022). Likewise, studies on *Octopus vulgaris* showed that larger individuals have higher levels of polyunsaturated fatty acids (PUFA), especially docosahexaenoic acid (DHA), due to greater metabolic and reproductive requirements (Koven, *et al.*, 2024; Monroig *et al.*, 2022).

Environmental factors such as temperature, salinity and food availability also strongly influence fatty acid metabolism in marine invertebrates. Organisms in warm marine environments commonly exhibit adaptive changes in membrane lipid composition to sustain cellular integrity and physiological performance under thermal stress (Borges *et al.*, 2023; Yoon *et al.*, 2024). As a result, fatty acids are commonly used as trophic biomarkers for assessing nutritional relationships, ecological interactions and energy transfer in marine ecosystems (Zhukova, 2019). The present study was therefore carried out to evaluate the fatty acid composition of different size groups of *S. pharaonis* collected from the northwestern Arabian Gulf and to study the effect of body size on lipid quality and fatty acid diversity, thus providing better understanding of the nutritional value and biochemical adaptation of marine invertebrates to the extreme marine environments.

Materials And Methods

Samples of Pharaoh squid (*Sepia pharaonis*) were collected from a selected marine station in the southwestern Arabian Gulf of Iraq. After collection, the samples were placed in plastic bags with crushed ice to maintain a temperature below 20°C during storage and transport to the laboratory. The samples were sorted by weight and divided into three

weight groups, ranging from 650 g to 3000 g, for comparison. The body cavity was opened using laboratory dissecting instruments to remove the internal organs. The samples were divided into two parts: the head and the body. The sections were documented photographically after dissection into the main body parts, including the head (including the cephalothorax and tentacles) and the body (comprising the main part of the squid). Weights were taken for each dissecting section immediately after dissection using an analytical balance (± 0.001 g) and based on dry weight. The dissected tissues were placed in a Binder oven (USA) for drying at 60°C for 24 hours until resistance clock mass was reached.

Determination of Lipid Content

The percentage of fat in dried samples was estimated based on the standard method adopted by the Society of Official Analysts (AOAC, 1995) using a Soxhlet lipid recovery device. Take a weight of 10 g from the thoroughly dried sample, placed in a filter paper, then carefully drawn and inserted into the device's extraction thimble. The empty glass beaker of the Soxhlet apparatus was pre-weighed using a sensitive scale, and then 250 ml of hexane solvent was added to it. The extraction process lasted for 5 continuous hours to ensure the complete extraction of fatty substances. After the extraction process was completed, the solvent was recovered from the device, and the flask containing the extracted fat was taken out. The beaker was placed in an oven at 80 °C for 30 min to evaporate solvent residues. After that, take the beaker out of the oven, let it cool to room temperature, and then carefully reweigh it.

The percentage of fat (%) was calculated depending on the difference in the weight of the beak before and after extraction according to the following equation: **Fat percentage (%) = (Weight of flask after extraction – Weight of flask before extraction) / Sample weight × 100**. Fatty Acid Analysis: Esterification of fats: The sample was prepared according to the method approved by AOAC (1995), which is based on the esterification of fats by reacting them with methanolic potassium hydroxide prepared by dissolving 11.2 g of potassium hydroxide in 100 ml of methanol. Then 1 g of fat was taken and 8 ml of methanolic potassium hydroxide along with 5 ml of hexane were added, The mixture was shaken for 30 s and allowed to separate into two distinct layers. The upper layer (hexane layer), which contains the esterified fat, was taken and injected into the device. Chromatographic Analysis of the Sample: Fatty acid compounds were analyzed using a Fatty acid methyl esters were analyzed using a Shimadzu GC-2010 gas chromatograph equipped with a flame ionization detector (FID) and a capillary column (SE-30, 30 m × 0.25 mm), according to the following conditions: (Zhang *et al.*, 2015) (Table 1).

Table 1: The Fatty acid compounds analyzing using a Gas Chromatography.

	Parameters	Temperature
1	Injection port temperature	280°C

2	Detector temperature	310°C
3	Column temperature	120 – 290°C (10°C / MIN)
4	Gas flow rate	100 KPa

Statistical Analysis

Data were analyzed using SPSS software. One-way ANOVA was performed to test differences among weight groups, and Duncan's multiple range test was applied for post-hoc comparisons. Statistical significance was considered at $P \leq 0.05$.

Results

Table 2 presents the mean total wet weight of *S. pharaonis* specimens, ranging from 650 to 750 g, with an average of 700 ± 50 g., and the mean total Dry weight was (151.155 ± 43.38) g. And total Fat% were (10.96 ± 0.23) %. While an average of Fatty acids in the head was (8.66 ± 0.23) also an Average of Fatty acids in the mantle was 2.46 ± 0.14 and the average of Oleic acid %, Eicosapentaenoic acid (EPA)%, Docosahexaenoic acid (DHA)%, Linoleic acid %, Linolenic acid %, and Palmitic acid % were $(11.38 \pm 0.55, 8.65 \pm 0.61, 13.71 \pm 0.62, 14.28 \pm 0.62, 12.55 \pm 0.7, 5.99 \pm 0.21$ and $3.32 \pm 0.32)$ %. respectively.

Table 2: Mean values of wet weight, dry weight, fat percentage, and fatty acid composition in *S. pharaonis* specimens (650-750 category).

Parameters	Values
Total average Wet weight (g)	700 ± 50
Total dry weight (g)	151.155 ± 43.38
Total Fat%	10.96 ± 0.23
Fatty acids in head%	8.66 ± 0.23
Fatty acids in mantle%	2.46 ± 0.14
Oleic acid %	11.38 ± 0.55
Eicosapentaenoic acid (EPA, %)	8.65 ± 0.61
Docosahexaenoic acid (DHA)%	13.71 ± 0.62
Linoleic acid (%)	14.28 ± 0.62
Linolenic acid %	12.55 ± 0.7
Palmitic acid %	5.99 ± 0.21
Stearic acid	3.32 ± 0.32

Table 3: Mean values of wet weight, dry weight, fat percentage, and fatty acid composition in *S. pharaonis* specimens (1000–1900 g category).

Parameters	Values
Total average Wet weight (g)	1566.7 ± 410.9
Total dry weight (g)	236.807 ± 39.9

Total Fat%	11.24±0.7
Fatty acids in head%	8.7±0.46
Fatty acids in mantle%	2.6 ± 0.39
Oleic acid %	12.45±1.98
Eicosapentaenoic acid (EPA, %)	9.77±1.7
Docosahexaenoic acid (DHA)%	14.51±1.7
Linoleic acid (%)	14.51±1.89
Linolenic acid %	13.45±1.98
Palmitic acid %	6.56±1.15
Stearic acid	4.07±1.15

The total average Wet weigh (1566.7 ± 410.9) g, and the mean total Dry weight was 236.807 ± 39.9 g, and total Fat% were (11.24 ± 0.7) %. While an average of Fatty acids in the head was (8.7 ± 0.46) also an Average of Fatty acids in the mantle was 2.6 ± 0.39 and the average of Oleic acid %, Eicosapentaenoic acid (EPA)%, Docosahexaenoic acid (DHA)%, Linoleic acid %, Linolenic acid %, and Palmitic acid %% were (12.45 ± 1.98 , 9.77 ± 1.7 , 14.51 ± 1.7 , 14.51 ± 1.89 , 13.45 ± 1.98 , 6.56 ± 1.15 , and 4.07 ± 1.15).

Table 4: Mean values of wet weight, dry weight, fat percentage, and fatty acid composition in *S. pharaonis* specimens (2000–3000 g category).

Parameters	Values
Total average Wet weight (g)	2441.7 ± 401.9
Total dry weight (g)	423.875 ± 112.9
Total Fat%	12.36 ± 0.23
Fatty acids in head%	9.36 ± 0.66
Fatty acids in mantle%	2.9 ± 0.59
Oleic acid %	12.94 ± 0.61
Eicosapentaenoic acid (EPA, %)	10.33 ± 0.49
Docosahexaenoic acid (DHA)%	14.84 ± 0.23
Linoleic acid (%)	15.503 ± 0.43
Linolenic acid %	13.96 ± 0.33
Palmitic acid %	6.79 ± 0.42
Stearic acid	4.28 ± 0.42

Table 4 presents the mean wet and dry weights, fat percentage, and fatty acid composition of *S. pharaonis* specimens in the 2000–3000 g weight category. The total average Wet weigh (2441.7 ± 401.9) gm, and the mean total Dry weight was 423.875 ± 112.9 gm, and total Fat% were (12.36 ± 0.23) %. While an average of Fatty acids in the head

was (9.36± 0.66) also an Average of Fatty acids in the mantle was 2.9 ± 0.59. The relative average of eicosapentaenoic acid (EPA) reached 10.33 ± 0.49%, while docosahexaenoic acid (DHA) recorded 14.84 ± 0.23%. The combined value of EPA and DHA reached 25.17%. Linolenic acid was detected at 13.96 ± 0.33%. Among other fatty acids, oleic acid accounted for 12.94 ± 0.61%, linoleic acid for 15.503 ± 0.43%, palmitic acid for 6.79 ± 0.42%, and stearic acid for 4.28 ± 0.42%.

Figure 1. Variation in total fat percentage (Total%), head fat percentage (Head%) and mantle fat percentage (Mantle%) in three weight categories of *S. pharaonis* of 650–750 g, 1000–1900 g and 2000–3000 g. The results show a gradual increase in the percentage of total fat as body weight increases. The lowest value (≈11%) was observed in the 650–750 g category followed by 11.5% in the 1000–1900 g category. The highest value (≈12–13%) was observed in the 2000–3000 g category. Head fat percentage also increased slightly from 8.5% in the smallest category to almost 9.5% in the largest group. Mantle fat percentage remained relatively low in all categories but showed a slight upward trend, between 2.3% and 2.8%. These results suggest a positive association of body weight with lipid accumulation in different body parts.

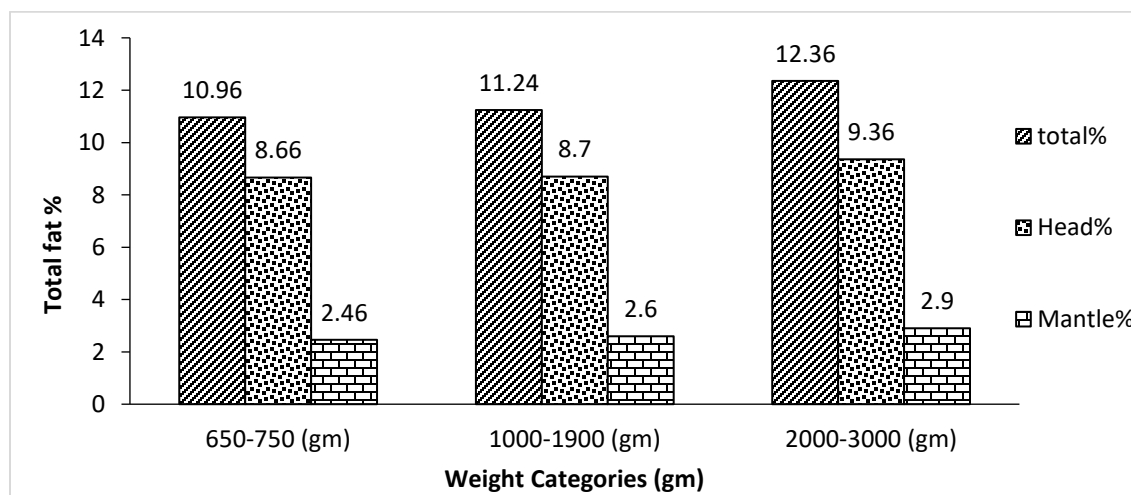


Figure 1: The percentage of total fat (%) between the three body segments according to weight.

Table 5 summarizes the fatty acid composition in the head of *S. pharaonis* across three weight categories, a significant increase ($P \leq 0.05$) in Oleic, Eicosapentaenoic, Linoleic, Linolenic, Palmitic and Stearic acids with increasing body weight. However, no significant differences were observed in Docosahexaenoic acid among the studied weight groups.

Table 5. Fatty acid composition (%) in the head of *S. pharaonis* across different weight groups (Means ± SD).

Fatty acid	700 ± 50 g	1566.7±410.9	2441.7± 401.9
Oleic acid %	11.38 ± 0.56 a	12.45 ± 1.99 ab	12.95 ± 0.62 b

Eicosapentaenoic acid (EPA)%	8.65 ± 0.61 a	9.78 ± 1.71 ab	10.33 ± 0.50 b
Docosahexaenoic acid (DHA)%	13.71 ± 0.63 a	14.51 ± 1.71 a	14.84 ± 0.23 a
Linoleic acid %	14.29 ± 0.62 a	15.17 ± 1.90 ab	15.50 ± 0.44 b
Linolenic acid %	12.55 ± 0.71 a	13.45 ± 1.98 ab	13.96 ± 0.34 b
Palmitic acid %	5.99 ± 0.21 a	6.56 ± 1.16 ab	6.79 ± 0.42 b
Stearic acid %	3.33 ± 0.33 a	4.07 ± 1.16 ab	4.28 ± 0.43 b

Table 6 presents the fatty acid composition in the mantle of *S. pharaonis* across three weight categories, significant increase in all studied fatty acids with increasing fish weight. Fish weighing 3000 g recorded the highest values compared to those weighing 700 g, while the 1900 g group had intermediate values (ab), indicating no clear significant difference between them and the other two groups in some cases. Oleic acid increased from 10.17% at 700 g to 11.38% at 3000 g. Eicosapentaenoic acid (EPA) also increased from 7.00% to 7.85%. Docosahexaenoic acid (DHA) showed an increase from 10.62% to 11.50%. Similarly, the proportions of Linoleic and Linolenic acids increased significantly with weight gain. Regarding saturated fatty acids, both Palmitic and Stearic acids increased with weight gain. Overall, the results suggest that an increase in fish weight leads to an improvement in fatty acid content.

Table 6: Fatty acid composition (%) in the mantle of *S. pharaonis* across different weight groups (Means ± SD).

Fatty acid	700 ± 50 g	1566.7±410.9	2441.7± 401.9
Oleic acid %	10.17 ± 0.31 a	11.26 ± 1.81 ab	11.38 ± 0.53 b
Eicosapentaenoic acid (EPA)%	7.00 ± 0.11 a	7.81 ± 1.18 ab	7.85 ± 0.40 b
Docosahexaenoic acid (DHA)%	10.62 ± 0.24 a	11.46 ± 1.29 ab	11.50 ± 0.44 b
Linoleic acid %	12.74 ± 0.27 a	13.54 ± 1.34 ab	13.66 ± 0.30 b
Linolenic acid %	9.53 ± 0.23 a	10.41 ± 1.21 ab	10.49 ± 0.42 b
Palmitic acid %	5.54 ± 0.35 a	6.22 ± 1.16 ab	6.46 ± 0.47 b
Stearic acid %	2.62 ± 0.28 a	3.39 ± 1.11 ab	3.62 ± 0.45 b

Discussion

The present results show clear differences in wet weight, dry weight, total lipid content, and fatty acid composition among the different weight groups of *S. pharaonis*. Wet weight increased from approximately 700 g in the first group to 1566.7 g in the second group and 2441.7g in the third group. Dry weight also increased with body size, indicating continuous tissue growth and biochemical accumulation during development. Similar findings were reported by Monroig *et al.* (2013) and Rey *et al.* (2025), demonstrated growth in

cephalopods is associated with increased biochemical reserves and tissue development. Total lipid percentage increased gradually from 10.96% in the first group to 11.24% in the second group and 12.36% in the third group. This slow increase suggests a better lipid accumulation with body size and may be indicative of higher energetic demands related to growth, tissue maintenance, swimming activity and preparation for reproduction in larger individuals. Fast growth and high metabolic activity are hallmarks of cephalopods, and larger groups often require more biochemical energy reserves to support physiological functions (Vidal and Shea, 2023). Similar results were reported by Sieiro *et al.* (2020), who observed higher lipid reserves in larger marine molluscs compared with smaller ones.

Dinh Thi *et al.* (2023) showed that the composition of fatty acids changed depending on body size and developmental stage. In contrast, Özogul *et al.* (2008) reported small differences in lipid percentage between different size groups of some cephalopod species, indicating that lipid accumulation might be species and habitat dependent. The differences in fatty acid composition between the weight groups studied may reflect metabolic changes occurring during growth and development. Lipids are not only energy stores but are also vital structural components of biological membranes and regulators of cell metabolism. The progressive increase of oleic acid, EPA, linoleic acid, linolenic acid, palmitic acid and stearic acid suggests that larger specimens have increased capacity for lipid biosynthesis and storage.

Wu *et al.* (2024) reported that long chain fatty acids are closely associated with growth and metabolic activity of marine organisms. Similarly, Li *et al.* (2023) reported EPA and DHA as key biochemical markers linked to physiological development and nutritional quality. In all groups studied, the head tissue has higher lipid content than the mantle. Lipids in the head ranged from 8.66–9.36% while mantle values ranged from 2.46–2.90%. The difference could be related to tissue-specific physiological and biochemical functions. Neural tissues, sensory organs and complex nervous structures in the head region require higher concentrations of structural lipids, particularly phospholipids and long-chain polyunsaturated fatty acids, to preserve the integrity of the membranes and the efficiency of the neural signalling. Navarro and Villanueva (2000) have shown that neural tissues of cephalopods are especially rich in phospholipids and essential fatty acids because of their structural and functional importance in neuronal membranes. Similar observations were reported by (Ponte *et al.*, 2022) emphasising the advanced neural organisation and functional specialisation of cephalopod nervous tissues characterised by intensive membrane-associated biochemical activity and elevated requirements for structural lipids and long-chain polyunsaturated fatty acids.

On the other hand, the mantle consists mainly of muscular tissue responsible for swimming and locomotion, which might explain its relatively low lipid content. Muscle cells use energy rapidly for contraction and movement and do not store large amounts of lipids. This pattern is consistent with the functional specialisation of cephalopod tissues. It is in agreement with Kim (2011) who reported that the neural and structural tissues have higher proportions of lipids than muscular tissues. Unsaturated fatty acids prevailed

in all weight groups, particularly oleic acid, linoleic acid, linolenic acid, EPA and DHA. The high abundance of polyunsaturated fatty acids emphasises the nutritional value of *S. pharaonis* as a marine source of omega-3 fatty acids. The EPA values ranged from 8.65% to 10.33% and the DHA values ranged from 13.71% to 14.84%.

These results are in line with the findings of Monroig *et al.* (2013) and Tan *et al.* (2025) who reported that the cephalopods are good sources of long chain omega-3 fatty acids in particular DHA and EPA. For all groups, the DHA concentrations were always higher than EPA, suggesting the important structural role of DHA for membrane stability, neural tissues and physiological regulation. The relatively stable values of DHA among the studied groups may be a reflection of its essential physiological role in maintaining membrane fluidity and neural function. Unlike some other fatty acids that can vary with metabolic activity and energy need, DHA is generally preserved conservatively because of its vital importance in cellular membranes and nervous tissues.

The predominance of polyunsaturated fatty acids observed in the present study may be partially related to the environmental characteristics of the northwestern Arabian Gulf, including elevated temperature and salinity, which have been previously reported to influence lipid metabolism in marine invertebrates, (Yoon *et al.*, 2022; Borges *et al.*, 2023) demonstrated that marine organisms living in warm and fluctuating environments may modify membrane lipid composition by increasing the proportion of unsaturated fatty acids in order to maintain membrane fluidity and physiological stability under environmental stress conditions. Consequently, the relatively high concentrations of EPA and DHA in *S. pharaonis* might also indicate physiological and biochemical adaptation mechanisms besides their nutritional value. Moderate levels of saturated fatty acids, especially palmitic and stearic acids, were found and their concentrations were slightly increased with body weight. Lourenço *et al.* (2024) reported similar results and Batista *et al.* (2022) found that cephalopods generally have lower proportions of saturated fatty acids compared to unsaturated fatty acids. However, some marine molluscs were found to have higher levels of saturated fatty acids (Zhukova, 2019), indicating that the composition of fatty acids can be influenced by species, tissue type and environmental conditions.

Conclusions

The present study gives a detailed biochemical characterisation of *S. pharaonis* from different body weight groups from north-western Arabian Gulf. The results showed that growth was related to increases in wet and dry weight and a gradual and clear increase in the overall lipid content of the whole body (10.96%-12.36%) and a progressive accumulation of energy reserves throughout development. The fatty acids profile indicated that the most abundant fatty acids were the unsaturated ones, mainly oleic, linoleic, linolenic acids, EPA and DHA, confirming the high nutritional value of *S. pharaonis* as a natural source of omega-3 long-chain fatty acids. DHA was consistently high in all size groups, indicating the critical structural role of DHA in cell membranes and

neural tissues. Generally, whole body lipid content expressed the highest values relative to tissue level fractions, suggesting that lipid accumulation is most conspicuous at the level of the organism. Furthermore, tissue-specific differences were found, with higher concentrations of lipids in the head than in the mantle, suggesting functional specialisation between neural and muscular tissues.

References

- Al-Maliky, T.H.; Hashim, M.S.; Abdul Karim, Z., and Jabbar, I. M. (2024). New Record of the Squid *Sepia pharaonic* Ehrenberg, 1831 from NW Arabian Gulf. *Am. J. Sci. Eng. Res.*, 7(4): 148-151. www.iarjournals.com.
- Andrews, P.L.R.; Ponte, G. and Rosas, C. (2022). Methodological considerations in studying digestive system physiology in octopus: limitations, lacunae and lessons learnt. *Front. Physiol.* 13:928013. <https://doi.org/10.3389/fphys.2022.928013>
- AOAC Association of Official Analytical Chemists. (2019). Official Methods of Analysis. <https://www.aoac.org/official-methods-of-analysis/>
- Batista, I.; Ramos, C., and Nunes, M. L. (2022). Nutritional composition and lipid quality of cephalopods from Atlantic waters. *J. Food Comp. Anal.*, 103, 104216. <https://doi.org/10.1016/j.jfca.2021.104216>
- Borges, F.O., Sampaio, E.; Catarina P Santos, C.P., and Rosa, R. (2023). Climate-Change Impacts on Cephalopods: A Meta-Analysis, *Integr. Comp. Biol.*, Volume 63, Issue 6: 1240–1265, <https://doi.org/10.1093/icb/icad102>
- Campagne, C.S.; Roy, L.A.; Langridge, J.; Claudet, J.; Mongruel, R.; Beillouin, D., and Thiébaud, E. (2023). Existing evidence on the impact of changes in marine ecosystem structure and functioning on ecosystem service delivery: a systematic map. *Envi. Evid* 12, 13 <https://doi.org/10.1186/s13750-023-00306-1>
- Dinh Thi, H.; Doan Lan, P.; Pham Van, C.; Nguyen Van, Q., and Nguyen, D. T. (2023). The Composition and content of fatty acid, lipid classes of two octopus species: and from Ha Long bay, Quang Ninh province, Vietnam. *Vietnam J. Mar. Sci. Tech.*, 23(3), 303–310. <https://doi.org/10.15625/1859-3097/18184>
- Fonseca, V.F.; Duarte, I.A.; Feijão, E.; Matos, A.R., and Duarte, B. (2022). Fatty acid-based index development in estuarine organisms to pinpoint environmental contamination. *Mar. Poll. Bull.*, 180, 113805. <https://doi.org/10.1016/j.marpolbul.2022.113805>
- Hsieh, H.Y.; Tew, K.S., and Meng, P. J. (2023). The Impact of Changes in the Marine Environment on Marine Organisms. *J. Mar. Sci. Eng.* 11(4), 809. <https://doi.org/10.3390/jmse11040809>
- Kim, H.Y. (2011). Docosahexaenoic acid: membrane modification and neurotrophic mechanisms. *Oléagineux, Corps gras, Lipides*, 18(5), 237-241.
- Koven, W.; Yanowski, E., and Gardner, L. (2024). Docosahexaenoic acid (DHA) is a driving force regulating gene expression in bluefin tuna (*Thunnus thynnus*) larvae development. *Sci Rep* 14, 23191. <https://doi.org/10.1038/s41598-024-74152-7>

- Li, C.; Lin, H.; Guo, Y.; Yu, G.; Ma, Z.; Pei, K., and Qin, C. (2023). Fatty acid analysis reveals the trophic interactions among organisms in the Zhelin Bay Marine Ranch. *Front. Mar. Sci.* 10:1132246. doi: [10.3389/fmars.2023.1132246](https://doi.org/10.3389/fmars.2023.1132246)
- Lourenço, H.M.; Anacleto, P.; Afonso, C., and Bandarra, N.M. (2024). Fatty acid composition and nutritional quality of cephalopods: Implications for human health. *Mar. Drugs*, 22(3), 145. <https://doi.org/10.3390/md22030145>
- Monroig, O.; Tocher, D.R., and Navarro, J.C. (2013). Biosynthesis of polyunsaturated fatty acids in marine invertebrates: Recent advances in molecular mechanisms. *Mar. Drugs*, 11 (10), pp. 3998-4018. <https://doi.org/10.3390/md11103998>
- Navarro, J.C., and Villanueva, R. (2000). Lipid and fatty acid composition of early stages of cephalopods: An approach to their lipid requirements. *Aquac.*, 183(1–2), 161–177. [https://doi.org/10.1016/S0044-8486\(99\)00290-2](https://doi.org/10.1016/S0044-8486(99)00290-2)
- Nikolaou, A.; Katsanevakis, S. (2023). Marine extinctions and their drivers. *Reg Environ Change* 23, 88 <https://doi.org/10.1007/s10113-023-02081-8>
- Ozogul, Y.; Duysak, O.; Ozogul, F.; Özkütük A.S., and Türeli, C. (2008). Seasonal effects in the nutritional quality of the body structural tissue of cephalopods. *Food Chem.* 110(3):847-52. <https://doi.org/10.1016/j.foodchem.2007.11.048>
- Parrish, C.C. (2025). Production, Transport, Fate and Effects of Lipids in the Marine Environment. *Mar. Drugs*, 23(2), 52. <https://doi.org/10.3390/md23020052>
- Ponte, G.; Chiandetti, C.; Edelman, D.B.; Imperadore, P.; Pieroni, E.M., and Fiorito, G. (2022). Cephalopod Behavior: From Neural Plasticity to Consciousness. *Frontiers in Systems Neuroscience*, 15, 787139. <https://doi.org/10.3389/fnsys.2021.787139>
- Pungor, J.R., and Niell, C.M. (2023). The neural basis of visual processing and behavior in cephalopods. *Current Biology*, 33(20), R1106-R1118. <https://doi.org/10.1016/j.cub.2023.08.093>
- Rey, F.; Gaspar, L.; Ricardo, F.; Pita, C.; Domingues, M.R., and Calado, R. (2025). Lipidomic signatures in *Octopus vulgaris* arm muscle reveal geographic variation along the Iberian Atlantic Coast. *npj Sci Food* 9, 173. <https://doi.org/10.1038/s41538-025-00520-w>
- Sieiro, P.; Otero, J., and Aubourg, S.P. (2020). Biochemical Composition and Energy Strategy Along the Reproductive Cycle of Female *Octopus vulgaris* in Galician Waters (NW Spain). *Front Physiol.* 15; 11:760. doi: 10.3389/fphys.2020.00760. PMID: 32760287; PMCID: PMC7373806.
- Tan, K.; Xu, P.; Huang, L.; Luo, C.; Choong, K.; Li, Z.; Guo, Y., and Cheong, K.L. (2025). Quantitative evaluation of essential amino acids and omega-3 long-chain polyunsaturated fatty acids from global marine bivalve aquaculture. *Food Chem X.* 23; 25:102181. doi: 10.1016/j.fochx.2025.102181. PMID: 39925763; PMCID: PMC11803897.
- Vidal, E.A.G., and Shea, E.K. (2023). Cephalopod ontogeny and life cycle patterns. *Front. Mar. Sci.* 10:1162735. doi: [10.3389/fmars.2023.1162735](https://doi.org/10.3389/fmars.2023.1162735)

- Wu, J.; Xiong, W.; Liu, W.; Wu, J.; Ruan, R.; Fu, P.; Wang, Y.; Liu, Y.; Leng, X.; Li, P.; Zhong, J.; Zhang, C., and Du, H. (2024). The Effects of Dietary n-3 Highly Unsaturated Fatty Acids on Growth, Antioxidant Capacity, Immunity, and Oxylipin Profiles in *Acipenser dabryanus*. *Antioxidants*, 13(4), 421.
<https://doi.org/10.3390/antiox13040421>
- Yoon, D.S.; Kim, D.H.; Kim, J.H.; Sakakura, Y.; Hagiwara, A.; Park, H.G.; Lee, M.C., and Lee, J.S. (2024). Interactions between lipid metabolism and the microbiome in aquatic organisms: A review. *Mar. Pollut. Bull.* [https://doi: 10.1016/j.marpolbul](https://doi.org/10.1016/j.marpolbul)
- Yoon, G.R.; Earhart, M.; Wang, Y.; Suh, M., and Anderson, W.G. (2022). Effects of temperature and food availability on liver fatty acid composition and plasma cortisol concentration in age-0 lake sturgeon: Support for homeoviscous adaptation. *J. Therm. Bio.*, 105, 103210. <https://doi.org/10.1016/j.jtherbio.2022.103210>
- Zhang, H.; Zhenyu Wang, Z., and Liu, O. (2015). Development and validation of a GC-FID method for quantitative analysis of oleic acid and related fatty acids, *J. Pharm. Anal.* Volume 5, Issue 4, Pages 223-230, ISSN 2095-1779,
<https://doi.org/10.1016/j.jpha.2015.01.005>.
- Zhukova, N.V. (2019). Fatty Acids of Marine Mollusks: Impact of Diet, Bacterial Symbiosis and Biosynthetic Potential. *Biomolecules*. 11;9(12):857. doi:
<https://doi.org/10.3390/biom9120857>

تحليل محتوى الدهون والأحماض الدهنية في الحبار *Sepia pharaonis* (Ehrenberg 1831)

في المياه البحرية/ شمال غرب الخليج العربي

انتصار محمدعلي جبار ^{ID}*, امال سوادى الشرع ^{ID}, محمود شاكر هاشم ^{ID}, ابتسام مهدي عبد الصاحب ^{ID},طارق حطاب ياسين المالكي ^{ID}

قسم الاحياء البحرية، مركز علوم البحار، جامعة البصرة، البصرة، العراق

*Corresponding Author E-mail: intesar.jabbar@uobasrah.edu.iq

تاريخ الإستلام: 2026/02/13 تاريخ القبول: 2026/05/10 تاريخ النشر: 2026/06/01

المستخلص

أظهرت الدراسة الحالية اختلافات في محتوى الدهون الكلية وتركيب الأحماض الدهنية في أجزاء مختلفة من جسم الحبار *Sepia pharaonis* (الرأس والجبة)، وقد اختبرت ثلاث مجموعات وزنية مختلفة تراوحت بين (401.9 ± 2441.7, 410.9 ± 1566.7, 50 ± 700) غم. بينت نتائج التحليل الاحصائي لمعظم الأحماض الدهنية المدروسة تحت مستوى احتمالية (P ≤ 0.05) فروقات معنوية بين المجموعات الوزنية. اظهرت الاحماض الدهنية فروقات معنوية واضحة تحت مستوى احتمالية (P ≤ 0.05) كان حامض Oleic acid هو الحامض الدهني الأكثر وفرة في أنسجة الرأس والجبة.

كما أظهر حامض Eicosapentaenoic acid (EPA), linoleic acid, linolenic acid, Palmitic acid و Stearic acid زيادة ملحوظة مع النمو، كما أظهرت المجموعة (401.9 ± 2441.7 غم) قيماً أعلى بالمقارنة مع المجموعة (700 ± 50 غم)، في حين سجلت المجموعة (410 ± 1566.7 غم) قيماً متوسطة لا يمكن تمييزها إحصائياً عن باقي المجاميع. في المقابل، ظل حامض Docosahexaenoic acid (DHA) مستقراً نسبياً ولم تسجل فروقات معنوية في الرأس في جميع المجموعات في حين أظهر تفاوتاً كبيراً في الجبة. قد يكون ارتفاع تراكيز الأحماض الدهنية في الرأس ناتجاً عن الوظائف المختلفة للأنسجة مقارنة بالجبة وكذلك تميزت الجبة بتراكم أقل للدهون مقارنة بالرأس وذلك يعود لكونها من الأنسجة العضلية. بشكل عام، تشير النتائج إلى وجود علاقة إيجابية بين وزن الجسم وتراكم الدهون واختلافات واضحة في الأحماض الدهنية بين الأنسجة. تؤكد هذه النتائج على ان تأثير النمو ونوع النسيج في التركيب الكيميائي الحيوي لـ *S. pharaonis*، مع تداعيات محتملة على قيمتها الغذائية واستغلالها.

الكلمات المفتاحية: الأحماض الدهنية، الدهون الكلية، *S. pharaonis*، المجموعات الوزنية، EPA، DHA، الكائنات البحرية.