***Review Article***

**A Systematic Review of Tasar Silkworm (Antheraea mylitta) Pupal Oil: Composition, Bioactivity, and Therapeutic Potential in Health and Disease Management**

**ABSTRACT**

Tasar silkworm (Antheraea mylitta) pupal oil (TPO) is emerging as a novel biofunctional lipid with significant potential in food, nutraceutical, cosmetic, and pharmaceutical sectors. This review synthesizes current knowledge on the origin, extraction methods, physicochemical properties, fatty acid composition, and therapeutic potential of TPO. Rich in alpha-linolenic acid (ALA), tocopherols, phytosterols, and phenolic compounds, TPO exhibits remarkable antioxidant, anti-inflammatory, antihyperlipidemic, and anticancer properties. Compared to other silkworm pupal oils such as Bombyx mori, Samia ricini, and Antheraea proylei, TPO contains a superior omega-3 profile and balanced omega-6 to omega-3 ratio, making it a valuable dietary lipid. Physicochemical characteristics including refractive index, specific gravity, saponification, and peroxide values further support its oxidative stability and functional performance. A recent in vivo study in streptozotocin-induced diabetic rats demonstrated that TPO supplementation significantly improved lipid profiles, reduced oxidative stress, and ameliorated hepatic and renal tissue damage. Despite its bioactivity, the underutilization of TPO and lack of clinical trials remain critical bottlenecks. This review highlights the nutraceutical potential of TPO, its role in sustainable resource valorization, and the need for future research in formulation development, clinical validation, and industrial integration.

*Keywords: Tasar silkworm, Pupal oil, Alpha-linolenic acid (ALA),* ***Polyunsaturated Fatty Acids (PUFA),*** *Omega-3 fatty acids, Bioactive lipids, Antioxidant activity,* ***Edible insect oil***

1. **INTRODUCTION**

India holds a unique position as the only country producing all major silk varieties- Mulberry, Eri, Muga, and both Tropical and Temperate Tasar. Among these, the Tasar silkworm (Antheraea mylitta), a vanya species, is particularly notable for its comparatively large body size throughout its developmental stages: egg (9–10 mg), larva (35–50 g), pupa (9–16 g), and cocoon (10–14 g or more) (Barsagade, 2017). The tropical Tasar silkworm (A. mylitta Drury) is polyphagous, thriving in forest habitats and feeding primarily on host plants such as Terminalia arjuna, Terminalia tomentosa, and Shorea robusta, among others (Ananta *et al.,* 2023). Approximately 44 distinct ecoraces of A. mylitta are found across various Indian states including Jharkhand, Odisha, Chhattisgarh, Bihar, Madhya Pradesh, Andhra Pradesh, Uttar Pradesh, West Bengal, and Maharashtra (Ojha *et al.,* 2009).

In recent years, India's Tasar silk sector has witnessed notable growth, with raw silk output of 1586 MT by 2023–2024 (Rai, 2022). This growth has significantly contributed to rural development and livelihood generation, particularly empowering women in tribal and remote areas. Simultously, silkworm pupae previously treated as waste are increasingly acknowledged for their high nutritional value and potential applications. Research indicates that they are rich in proteins, fats, carbohydrates, vitamins, minerals, and antioxidants (Sadat *et al.,* 2022).

Silkworm pupae have long been consumed as traditional food in countries such as India, China, Japan, and Thailand. Notably, China has classified them as a “novel food resource” (Lei et al., 2024). Their nutritional richness, especially the presence of proteins and fats, makes them suitable for animal feed, particularly in poultry, aquaculture, and pig farming (Sheikh *et al.,* 2018). The high levels of unsaturated fats notably omega-3 fatty acids like alpha-linolenic acid (ALA) also contribute to their recognized health benefits (Kumar *et al.,* 2020). Large volumes of spent pupae are generated during silk reeling, often discarded or marginally used as fertilizers or aquaculture feed (Dash *et al.,* 2025; Ashoka *et al.,* 1997; Wei *et al.,* 2009). However, poor disposal practices can lead to environmental concerns (Jun *et al.,* 2010). Despite being highly nutritious with protein containing all essential amino acids per FAO/WHO standards and lipids making up around 30% of dry weight the full potential of pupae remains largely untapped (Beniwal *et al.,* 2024).

Tasar silkworm pupal oil is particularly rich in unsaturated fatty acids, exceeding 75%, with ALA contributing up to 34.27% (Tao *et al.,* 2014). The composition of the oil includes α-linolenic, oleic, linoleic, palmitic, and palmitoleic acids, and it exhibits remarkable antioxidant, cholesterol-reducing, and neuroprotective properties (Wei *et al.,* 2009; Jun *et al.,* 2010). These bioactivities have encouraged its incorporation into cosmetics, soap production, and anti-aging products (Kotake-Nara *et al.,* 2002). In terms of amino acid content, pupae are rich in glutamic acid (18.3%), histidine (14.6%), and alanine (10.2%). Together with its beneficial lipid profile, this positions pupal oil as a valuable functional ingredient. Ongoing research into omega-3 polyunsaturated fatty acids (EPA, DHA, and ALA) has highlighted their effectiveness in managing conditions such as cardiovascular diseases, cancer, diabetes, and neurodegenerative disorders (Iwase *et al.,* 2015; Khan *et al.,* 2021; Srivastava *et al.,* 2021).

Recent studies have spotlighted Tasar pupal oil (TPO) as a potent source of omega-3 fatty acids, with ALA levels reaching up to 38%. Comparative research has shown that TPO offers stronger antioxidant, antibacterial, and anticancer effects than pupal oils derived from Mulberry and other silkworm species (Srivastava *et al.,* 2023, 2024a; Ramappa *et al.,* 2020; Yeruva *et al.,* 2023). Additionally, silkworm pupae are universally rich in vital nutrients like proteins, vitamins, and minerals, making pupal oil a safe candidate for human dietary use (Mahanta *et al.,* 2023; Susirirut *et al.,* 2023).

Advanced analytical techniques such as refractometry, NMR spectroscopy, and rheological assessments have been used to study TPO, confirming the presence of bioactive compounds like stearic acid and linolenic chains key to its health-promoting effects (Srivastava *et al.,* 2024b). However, research examining the medicinal efficacy of TPO, especially in diseases like diabetes, remains limited, underscoring the need for further investigation. This review endeavors to provide an in-depth overview of Tasar pupal oil, focusing on its biological source, extraction methods, biochemical profile, and therapeutic benefits. It also highlights its advantages over other silkworm pupal oils and explores its potential applications in the food, pharmaceutical, and personal care industries.

1. **PROXIMATE AND BIOCHEMICAL COMPOSITION OF TASAR PUPAE**

The proximate composition of *Antheraea mylitta* pupae underscores their significant nutritional and industrial potential (Table 1). Proximate analysis offers critical insight into the nutritional makeup and gross energy values of feed ingredients and functional food sources (Jobling, 2001). *A. mylitta* pupae exhibit an impressive crude protein content of 60.67% on a dry weight basis (Ananta e*t al.,*2023), comparable to Muga (59.66%) and *Bombyx mori* (60.7%) (Bandy *et al.,* 2023; Sheikh *et al.,* 2018). Such high protein content is indicative of its role as a promising alternative protein supplement, surpassing even several edible insects, including *Gonimbrasia* species (79%) (Ramos-Elorduy *et al.,* 1997).

Moisture content in Tasar pupae was 11.23%, slightly exceeding that of *B. mori* pupae (7.18%) (Bose and Mazumdar, 1990), yet remaining within limits conducive for drying and oil extraction. The total ash content, reflecting mineral presence, was found to be 5.1%, marginally below that of *B. mori* (5.8%) (Sheikh *et al.,* 2018), and consistent with insect by-product standards (Rashmi *et al.,* 2023). The lipid content of Tasar pupae, recorded at 23.83%, falls within the range of 25.75% to 32.2% reported for *B. mori* pupae (Bose and Mazumdar, 1990; Tomotake *et al.,* 2010). Lipidomic analysis shows high levels of palmitic acid (6.57 mg/g), stearic acid (1.68 mg/g), and alpha-linolenic acid (0.51 mg/g), confirming its potential as a source of essential fatty acids. Importantly, the saturated fat levels were well within the permissible dietary limits recommended by the Dietary Guidelines Advisory Committee (1977), which recommends keeping saturated fat intake below 10% of total caloric intake to minimize cardiovascular risk (Astrup *et al.,* 2020).

**Table 1. Comparative Proximate Composition of Silkworm Pupae**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Proximate components** | **Tasar** | **Mulberry** | **Muga** | **Eri** |
| Moisture (%) | 8.86-11.23 | 7.18- 9.77 | 7.86 | 14.88-19.00 |
| Protein (%) | 50.82-60.67 | 55.87-60.70 | 52.65- 59.66 | 49.25-68.01 |
| Fat (%) | 23.83-28.56 | 25.75-32.2 | 16.98-28.66 | 18.37-22.91 |
| Carbohydrate (%) | 3.29 | 1.80 | 1.32- 3.99 | 1.2 |
| Ash (%) | 5.1 | 5.8 | 3.65 | 1.36 |
| Energy (kcal/ 100 gm) | 470.31- 473 | 442- 445 | 484 | 368.67  |

**(Ananta *et al.,* 2023; Mishra *et al.,* 2003; Deori *et al.,* 2016; Ghosh *et al.,* 2020)**

The chitin content in Tasar pupae was 3.87%, comparable to *B. mori* (3.5–4.7%) (Oynavod *et al.,* 2020). Tannin content, a potential anti-nutritional factor, was found to be relatively low at 0.067% compared to that of *B. mori* (2.04%) (Omotoso, 2015), enhancing its digestibility and nutritional efficiency. Carbohydrate content was recorded at 3.29%, notably higher than those in Eri (1.2%), Muga (1.32%), and *B. mori* (1.8%) (Mishra *et al.,* 2003), and energy content was found to be 470.31 kcal/100g, demonstrating its utility as a dense energy source. The amino acid profile revealed a diverse and balanced spectrum, including high levels of serine (5.28 mg/g), alanine (5.07 mg/g), glutamic acid (4.03 mg/g), leucine (3.85 mg/g), and methionine (2.18 mg/g) (Ananta *et al.,* 2023). Compared to *B. mori*, Tasar pupae demonstrated higher levels of essential amino acids such as valine, leucine, and phenylalanine (Paul and Dey, 2014), reinforcing their potential as a supplementary protein source in human and animal diets.

Micronutrient analysis confirmed the presence of essential vitamins and minerals (Table 2). Tocopherol (13.23 µg/100g) was found to be the predominant vitamin, consistent with findings by Wu *et al.* (2021), while the mineral profile included sodium (32.31 mg/100g), calcium (47.79 mg/100g), magnesium (208.7 mg/100g), iron (37.72 mg/100g), and zinc (24.88 mg/100g) (Ananta *et al.,* 2023). Mineral variability may depend on geographic, seasonal, and dietary differences, as noted in related studies on *A. pernyi* (Zhou and Han, 2006). In addition to these macro- and micronutrients, Tasar pupae are rich in phenolic acids and flavonoids. Polyphenolic compounds such as ferulic acid (1317.5 µg/g), p-coumaric acid (730.96 µg/g), and caffeic acid (55.81 µg/g), and flavonoids like catechin (40.77 µg/g), myricetin (12.47 µg/g), and quercetin (4.24 µg/g) contribute to their potent antioxidant potential (Ananta *et al.,* 2023; Tungmunnithum *et al.,* 2018). DPPH scavenging activity assays confirmed the radical-quenching capacity of Tasar pupal extracts in a dose-dependent manner (Pari and Amarnath, 2004).

These nutritional and biochemical features make Tasar pupae an ideal candidate for deriving high-value Tasar pupal oil. This oil, rich in unsaturated fatty acids and bioactive antioxidants, is increasingly recognized for its roles in modulating oxidative stress, supporting cardiovascular health, and improving metabolic function. Additionally, its application in food, pharmaceutical, and cosmetic industries exemplifies its multifunctional potential. Promoting Tasar pupal oil extraction not only supports circular bioeconomy models by valorizing sericultural by-products but also provides an opportunity for economic empowerment among rural and tribal communities, particularly women engaged in reeling and cocoon processing.

**Table 2. Comprehensive Nutrient and Bioactive Profiling of Tasar Silkworm Pupae**

|  |  |  |
| --- | --- | --- |
| **Category** | **Component** | **Content** |
| **Fatty Acids (mg /g of dry weight)** | Lauric acid (C12:0) | 0.043 |
|  | Myristic acid (C14:0) | 0.181 |
|  | Palmitoleic acid (C16:1) | 0.075 |
|  | Palmitic acid (C16:0) | 6.565 |
|  | Linolenic acid (C18:3) | 0.505 |
|  | Linoleic acid (C18:2) | 0.191 |
|  | Stearic acid (C18:0) | 1.682 |
|  | Eicosenoic acid (C20:1) | 0.053 |
|  | Behenic acid (C22:0) | 0.007 |
| **Amino Acids (mg/g)-Non essential** | Glycine | 0.146± 0.001 |
|  | Alanine | 5.066± 0.252 |
|  | Serine | 5.279± 0.092 |
|  | Proline | 3.439± 0.042 |
|  | Cysteine | 1.23± 0.011 |
|  | Asparagine | 0.164± 0.020 |
|  | Aspartic acid | 3.520± 0.280 |
|  | Glutamic acid | 4.025±0.411 |
|  | Arginine | 2.588± 0.019 |
|  | Citrulline | 0.363± 0.001 |
|  | Tyrosine | 2.741± 0.093 |
| **Amino Acids (mg/g)-Essential** | Leucine  | 3.853± 0.004 |
|  | Lysine  | 2.097± 0.009 |
|  | Valine  | 2.519± 0.092 |
|  | Threonine  | 1.060± 0.023 |
|  | Isoleucine  | 3.853± 0.004 |
|  | Methionine  | 2.178± 0.666 |
|  | Histidine  | 1.100± 0.044 |
|  | Phenylalanine  | 1.759± 0.008 |
|  | Tryptophan  | 0.036± 0.000 |
| **Vitamins (µg/100 g) - Water soluble** | Niacin | 0.43± 0.109 |
|  | Pyridoxin | 0.54± 0.010 |
|  | Pantothenic acid | 2.34± 0.143 |
|  | Biotin | 0.6± 0.016 |
|  | Thiamine | 7.68± 0.128 |
|  | Riboflavin | 1.57± 0.027 |
|  | Folic acid | 0.027± 0.002 |
|  | Cyanocobalamine | 0.032± 0.004 |
| **Vitamins (µg/100 g) - Fat soluble** | Vitamin D1 | 0.007± 0.00 |
|  | Vitamin D2 | 0.216± 0.018 |
|  | Tocopherol (Vitamin E) | 13.23± 0.794 |
|  | Vitamin K2 | 0.051± 0.005 |
|  | Vitamin K1 | 0.033± 0.004 |

**(Ananta *et al.,* 2023;** Paul and Dey, 2014**)**

1. **SOURCES AND EXTRACTION OF TASAR PUPAL OIL**

Tasar silkworm (*Antheraea mylitta*) undergoes complete metamorphosis through four distinct stages: egg, larva, pupa, and adult. The pupal stage, typically weighing between 9–16 grams, is especially significant for its lipid-rich profile and serves as the primary source for pupal oil extraction (Barsagade, 2017). After the silk has been reeled from the cocoon, the residual pupae, referred to as “spent pupae” are collected as a major by-product of the sericulture industry (Dash *et al.,* 2025). To extract oil from the pupae, it is essential to first reduce their moisture content. This is achieved through various drying methods, including traditional sun-drying, oven-drying at controlled temperatures, and modern techniques like freeze-drying. Freeze-drying, although more expensive, is particularly effective in preserving heat-sensitive bioactives and ensuring high oil stability (Habeanu *et al.,* 2023).

Oil extraction methodologies substantially influence both the yield and quality of Tasar pupal oil. Conventional Soxhlet extraction, which employs solvents such as hex or petroleum ether, is the most widely adopted technique due to its high efficiency. However, concerns regarding solvent residues have led to the growing popularity of solvent-free alternatives such as cold press and mechanical pressing methods. While these yield slightly lower quantities of oil, they are preferred for food-grade and nutraceutical purposes due to the absence of chemical contaminants (Zhao *et al.,* 2022). Supercritical CO₂ extraction is another advanced technique that offers high selectivity, minimal solvent residues, and better preservation of heat-sensitive bioactives. This method offers enhanced selectivity, leaves no solvent residue, and enables better retention of bioactive components like tocopherols, sterols, and polyunsaturated fatty acids (Tao *et al.,* 2014; Jun *et al.,* 2010). Despite its high setup costs, it is gaining traction for the extraction of high-value oils destined for pharmaceutical and cosmetic applications.

Several variables affect the oil yield from Tasar pupae, including the moisture level at the time of drying, solvent polarity, temperature, and extraction duration. Reported yields range from 20% to 32.2% of the pupal dry weight (Habeanu *et al.,* 2023). The extracted oil is typically golden-yellow with a mild nutty aroma. Its oxidative stability is attributed to its high content of antioxidants such as tocopherols and carotenoids (Srivastava *et al.,* 2023a). Continued optimization of extraction parameters and standardization across commercial scales remain vital to maximizing yield while preserving the biofunctional components of Tasar pupal oil. These improvements are crucial for elevating the economic and industrial viability of TPO in the food, health, and cosmetic sectors.

 

**Fig. 1. Flowchart Illustrating the Extraction Process of Tasar Silkworm (Antheraea mylitta) Pupal Oil**

1. **PHYSICOCHEMICAL AND NUTRITIONAL COMPOSITION**

Tasar pupal oil (TPO) possesses a unique chemical composition that imparts nutritional and therapeutic benefits. The primary constituents include triglycerides, free fatty acids, phospholipids, sterols, tocopherols, and minor bioactives such as carotenoids and phenolic compounds. These components influence its stability, health-promoting properties, and suitability for industrial applications.

### 4.1 Physicochemical Properties

The physicochemical parameters of oils are important indicators of their quality, nutritional value, and potential applications. The refractive index of TPO (1.468) is comparable to that of maize and sunflower oil, which also exhibit values of 1.468. Specific gravity, a dimensionless unit representing the ratio of the density of a substance to that of water, was measured at 0.9156 in TPO. This value aligns with the range reported for olive oil (0.915–0.928), confirming the identity and physical consistency of TPO (Ichu and Nwakanma, 2019; Yahaya *et al.,* 2012).

The saponification value (SV) indicates the amount of alkali required to saponify a given quantity of fat or oil, reflecting the average molecular weight of the fatty acids present (Ravinder *et al.,* 2016). Tasar Pupal Oil (TPO) exhibited an SV of 154.75 mg KOH/g, suggesting the predominance of long-chain fatty acids. In comparison, mulberry pupal oil displayed a higher SV (187.78–201), suggesting shorter chain lengths. The peroxide value (PV) of TPO (16.20 meq/kg) falls within acceptable oxidative stability ranges and is comparable to earlier findings (Yeasmin *et al.,* 2024). Acid value (AV), an indicator of the amount of oxidation and rancidity in oil, was 6.24 mg KOH/g for TPO, significantly lower than FAO's permissible limits for edible oils (Arasakumar *et al.,* 2021; Parthasarathy *et al.,* 2014).

Iodine value (IV), denoting the degree of unsaturation, was 40.33 g/100 g in TPO, indicating a moderate level of unsaturated bonds and oxidation potential (Sanders, 2003). Ash content, representing the mineral composition, was 0.338%, higher than that of mulberry pupae oil (0.147%). Overall, these parameters reflect the good oxidative stability and nutritional potential of TPO for industrial, dietary, and therapeutic uses.

**Table 3. Comparative Physicochemical Indicators Reflecting the Quality and Stability of Tasar and Mulberry Silkworm Pupal Oils**

|  |  |  |
| --- | --- | --- |
| **Parameters** | **Tasar Pupal oil** | **Mulberry pupal oil** |
| Oil colour | Orange colour | Brownish tinge colour |
| pH | 6.17 | 6.28 |
| Refractive index | 1.468 | 1.452 |
| Specific gravity | 0.9156 | 0.9170 |
| Saponification value (mg KOH/g) | 154.75 | 187.78-201 |
| Peroxide value (meq/kg) | 16.20 | 6.61- 16.42 |
| Iodine value (g /100 g oil) | 40.33 | 43.61 |
| Acid value (mg KOH/g) | 6.24 | 1.97 |
| Ash content (%) | 0.338 | 0.147 |

(Arasakumar *et al.,* 2021; Yeasmin *et al.,* 2024; Suman *et al.,* 2024)

**4.2 Fatty Acid Profile**

TPO is predominantly composed of unsaturated fatty acids (UFAs), comprising more than 75% of total lipids. Alpha-linolenic acid (ALA) is the most abundant, constituting up to 38% of total fatty acids, followed by oleic acid (C18:1), linoleic acid (C18:2), palmitic acid (C16:0), and stearic acid (C18:0) (Srivastava *et al.,* 2024a; Tao *et al.,* 2014). The ALA content was determined using Gas Chromatography-Mass Spectrometry (GC-MS), a widely employed technique in food analysis for the qualitative and quantitative assessment of oils and fats (Pico, 2015). This high ALA content gives TPO a competitive advantage as a plant-based source of omega-3 fatty acids. The presence of ALA is particularly relevant for human health due to its role as a precursor to long-chain n-3 fatty acids like EPA and DHA, which contribute to cardiovascular, cognitive, and inflammatory disease prevention (Khan *et al.,* 2021; Iwase *et al.,* 2015).

**4.3 Minor Bioactive Components**

In addition to fatty acids, TPO contains a variety of minor bioactives. Tocopherols (vitamin E analogs), particularly α-tocopherol, are present in significant amounts and contribute to oxidative stability and antioxidant activity (Zhou *et al.,* 2022; Jun *et al.,* 2010). Phytosterols, including β-sitosterol and campesterol, further enhance its health-promoting potential, particularly in regulating cholesterol metabolism. Carotenoids impart a characteristic golden-yellow color to the oil and may contribute to antioxidative activity and visual health benefits. Other compounds such as flavonoids and phenolic acids have also been reported in pupal oil extracts and may synergize with fatty acids in exerting bioactivity (Mahanta *et al.,* 2023).

**4.4 Nutritional Comparison with Other Silkworm Oils**

When compared to oils from other silkworms such as *Bombyx mori* (mulberry), *Samia ricini* (eri), and *Antheraea proylei* (oak tasar), TPO stands out for its higher ALA and unsaturation index. While mulberry pupal oil is also rich in linoleic and oleic acids, it contains lower levels of ALA (~20–25%). Oak tasar pupae oil contains more saturated fatty acids and exhibits comparatively reduced oxidative stability (Beniwal *et al.,* 2024; Ramappa *et al.,* 2020). The overall nutritional value of TPO is superior due to its optimal omega-6 to omega-3 ratio, which is increasingly recommended for human dietary formulations (Yeruva *et al.,* 2023). The combined presence of high-quality proteins and bioactive lipids makes Tasar pupal oil a promising candidate for nutraceutical formulations.

1. **BIOACTIVE AND THERAPEUTIC PROPERTIES OF TASAR PUPAL OIL**

The bioactive profile of Tasar silkworm (*Antheraea mylitta*) pupal oil (TPO) reveals a potent combination of fatty acids, polyphenols, and other phytochemicals that contribute to a wide spectrum of therapeutic effects. Recent scientific interest in insect-derived oils stems from their rich unsaturated lipid content and functional health benefits, notably in oxidative stress reduction, lipid modulation, inflammation control, and disease prevention (Srivastava *et al.,* 2023a; Habeanu *et al.,* 2023).

**Fig.2. Diagrammatic Illustration of the Multidimensional Bioactivities of Tasar Pupal Oil**

**5.1 Antioxidant Potential**

The antioxidant activity of Tasar pupal oil is primarily attributed to its high levels of polyunsaturated fatty acids (PUFAs), tocopherols, and phenolic compounds. Compounds such as α-linolenic acid, p-coumaric acid, ferulic acid, catechin, and quercetin have demonstrated free radical scavenging potential through DPPH and FRAP assays (Pari and Amarnath, 2004; Tungmunnithum *et al.,* 2018). These bioactives mitigate lipid peroxidation and support cellular redox balance, which are crucial in the prevention of degenerative diseases such as diabetes, cancer, and neurodegenerative disorders (Iwase *et al.,* 2015; Srivastava *et al.,* 2021).

**5.2 Antihyperlipidemic Effects**

TPO has shown promising antihyperlipidemic properties due to its favorable ratio of unsaturated to saturated fatty acids (Table 3). Notably, the presence of omega-3 fatty acids, particularly α-linolenic acid (ALA), contributes to reduced serum triglycerides, LDL-cholesterol, and total cholesterol while improving HDL levels (Zhou *et al.,* 2022; Kumar *et al.,* 2020). These effects suggest that Tasar pupal oil could be a valuable dietary supplement in managing metabolic syndrome and cardiovascular health.

**5.3 Anticancer Activity**

Several fatty acid derivatives present in TPO, including decanoic acid, methyl linolenate, and tridecanoic acid, possess documented cytotoxicity against tumor cells through apoptosis induction and inhibition of cell proliferation (Long *et al.,* 2019; Srivastava *et al.,* 2024a). The polyunsaturated compound 9,12,15-octadecatrienoic acid (Z,Z,Z) and other phytochemicals in TPO have been shown to exert anti-proliferative effects on cancer cell lines, with potential applications in breast, liver, and colon cancers (Sharma *et al.,* 2022; Zhao *et al.,* 2022).

**Table 4. Fatty Acid Derivatives and Their Therapeutic Potentials in Tasar Pupal Oil**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sl. No.** | **Compound Name** | **Class** | **Biological Activity** | **References** |
| 1 | Tetradecanoic acid | Saturated fatty acid | Larvicidal, antifungal, antiviral, anticancer, antiparasitic, and immune-modulating activities |  (Sivakumar *et al.,* 2011; Javid *et al.,* 2020) |
| 2 | Methyl hexadec-9-enoate | Monounsaturated fatty acid | Antibacterial |  (Batalha *et al.,* 2020) |
| 3 | Pentadecanoic acid, 14-methyl-, methyl ester | Saturated fatty acid | Lubricants, antifungal, antibacterial |  (Sivakumar *et al.,* 2011; Ferdosi *et al.,* 2021) |
| 4 | Decanoic acid | Saturated fatty acid | Anticancer, antibacterial, antiviral | (Yang *et al.,* 2018) |
| 5 | n-Hexadecanoic acid | Saturated fatty acid | Antioxidant, antibacterial | (Gsan *et al.,* 2022) |
| 6 | 9,12,15-Octadecatrienoic acid, methyl ester (Z,Z,Z)- | Polyunsaturated fatty acid | Antihyperlipidemic, antioxidant, vasoprotective, tyrosinase inhibitor, anticancer, antibacterial | (Shawer *et al.,* 2022) |
| 7 | 6-Octadecenoic acid | Monounsaturated fatty acid | Anti-cancer | (Karthikeyan *et al.,* 2014) |
| 8 | 9-Hexadecenoic acid, methyl ester (Z)- | Monounsaturated fatty acid | Pesticide and antibiotic, anti-inflammatory | (Shettima *et al.,* 2013; Astudillo *et al.,* 2018) |
| 9 | Tridecanoic acid, 12-methyl-, methyl ester | Saturated fatty acid | Anthelminthic, anti-inflammatory, antimicrobial, anti-cancerous | (Chowdhury *et al.*, 2021) |
| 10 | 1-Hexadecanaminium, N,N,N-trimethyl-, octadecanoate | Saturated fatty acid | Antiseptic | (Longkumer *et al.,* 2023)  |
| 11 | Methyl stearate | Saturated fatty acid | Antimicrobial | (Nakaziba *et al.,* 2022) |
| 12 | Nonanoic acid | Saturated fatty acid | Antifungal, antibacterial | (Biswas and Jana, 2010) |

**5.4 Antibacterial Properties**

TPO exhibits antibacterial activity against a wide range of gram-positive and gram-negative bacteria. Fatty acids such as palmitic, oleic, and lauric acids interfere with bacterial membr integrity and metabolic pathways, leading to growth inhibition (Zhou and Han, 2006; Srivastava *et al.,* 2024a). Studies on methyl hexadecenoate and decanoic acid from Tasar oil demonstrate strong antibacterial activity with measurable inhibition zones and low MIC values, indicating potential use in pharmaceutical formulations and wound healing products.

1. **INDUSTRIAL AND NUTRACEUTICAL APPLICATIONS**

Tasar pupal oil (TPO) presents versatile opportunities in industrial and nutraceutical domains due to its rich content of essential fatty acids, tocopherols, and phytosterols. Its high oxidative stability and balanced fatty acid profile make it a suitable alternative to conventional edible oils. TPO has been proposed for use in the formulation of dietary supplements, functional foods, cosmetics (anti-aging creams, moisturizers), biodegradable lubricants, and even bio-based surfactants.

In the food industry, TPO’s high α-linolenic acid content (up to 38%) positions it as a sustainable omega-3 source suitable for cholesterol management and inflammation control. In cosmetics, its natural tocopherols and carotenoids protect skin cells against oxidative stress and UV damage. In pharmaceuticals, the oil’s unsaturated fatty acids and phenolics contribute to anti-inflammatory, antioxidant, and hepatoprotective effects.

**Fig. 3. Overview of the Health Benefits of α -Linolenic Acid**

1. **CASE STUDY: ANTI-DIABETIC POTENTIAL OF TPO IN RAT MODEL**

A recent study by Srivastava *et al.* (2024b) explored the dietary and therapeutic effects of TPO in a streptozotocin-induced diabetic rat model. The study employed various biophysical and analytical techniques to assess the oil’s physicochemical characteristics and bioactivity. Nuclear Magnetic Resonance (NMR) spectroscopy confirmed the presence of stearic acid and linolenic chains in TPO. When administered to diabetic rats, TPO significantly reduced serum glucose, total cholesterol, triglycerides, and LDL-C levels, while increasing HDL-C. Additionally, hepatic antioxidant enzyme levels, such as catalase and superoxide dismutase improved markedly in TPO-treated groups, suggesting its efficacy in mitigating oxidative stress. Histological analysis of liver and kidney tissues demonstrated reduced inflammation and structural preservation, further supporting its protective role. These findings reinforce TPO’s potential as a novel dietary lipid source with functional and therapeutic value.

1. **CONCLUSION**

Tasar pupal oil (TPO), derived from the wild silkworm Antheraea mylitta, represents a promising and sustainable lipid resource with multifaceted applications. Rich in unsaturated fatty acids, particularly alpha-linolenic acid (ALA) alongside a spectrum of antioxidants, vitamins, and bioactive compounds, TPO has demonstrated notable therapeutic potential in preclinical studies. Its antioxidant, antihyperlipidemic, anti-inflammatory, and cytoprotective properties render it a compelling candidate for functional foods, nutraceuticals, pharmaceuticals, and cosmeceuticals. Despite these attributes, TPO remains an underexploited by-product of sericulture. With increasing global interest in insect-based foods and oils for sustainable health and nutrition, there is an urgent need to elevate awareness, develop regulatory clarity, and validate health claims through human clinical trials. The valorization of Tasar pupae through scientific innovation and industrial integration can contribute to tribal livelihoods, women's empowerment, and the broader goal of sustainable resource utilization. By consolidating current knowledge and highlighting its comparative advantages over other silkworm pupal oils, this review underscores the need for focused research, standardization, and commercialization strategies. With further scientific validation and policy support, Tasar pupal oil has the potential to transition from a niche extract to a mainstream functional lipid source in the global bioeconomy.

1. **LIMITATIONS AND FUTURE PROSPECTS**

Despite its promising properties, Tasar pupal oil (TPO) remains underutilized in mainstream applications due to several limitations. Firstly, variability in oil yield and composition due to silkworm species, rearing conditions, and extraction methods may affect its consistency. Standardized protocols for oil processing and quality control are necessary to ensure reproducibility and market viability.

Secondly, most of the reported therapeutic effects are based on in vitro or animal studies. Clinical validation through human trials is crucial to establish the safety, efficacy, dosage guidelines, and long-term impacts of TPO consumption. Regulatory frameworks for edible insect oils are still evolving in many countries, creating uncertainty around commercialization. There is also a lack of awareness and technical expertise among rural producers to harness TPO for high-value markets. Empowering tribal and women sericulture workers through training, technology transfer, and policy support could transform pupae from a low-value by-product into a profitable commodity. Future research should explore nano-formulation, microencapsulation, and emulsion-based delivery systems to enhance TPO’s bioavailability and functional performance. Investigations into its synergistic interactions with other bioactives, and its potential use in metabolic syndrome, neurodegeneration, and immune modulation, will open new frontiers. Overall, integrating TPO into food, health, and industrial systems aligns with the global push toward sustainable, circular bioeconomy models.

**REFERENCES**

1. Barsagade, D.D. (2017). Tropical Tasar Sericulture. In: Omkar (eds) Industrial Entomology. Springer, Singapore. <https://doi.org/10.1007/978-981-10-3304-9_10>.
2. Ananta, S., Jena, K., Das, S., Singh, J., Sinha, A., & Sathyanarayana, K. (2023). Evaluation of proximate compositions and profiling of nutritional aspects in pupae of tasar silkworm *Antheraea mylitta* (Drury) as potential for food and feed resources. Journal of Environmental Biology, 44, 485-490. [http://doi.org/10.22438/jeb/44/3(SI)/JEB-13](http://doi.org/10.22438/jeb/44/3%28SI%29/JEB-13)
3. Ojha, N. G., Reddy, R. M., Hansda, G., Sinha, M. K., Suryanarayana, N., & Prakash, N. V. (2009). Status and potential of Jata, a new race of Indian tropical tasar silkworm (*Antheraea mylitta* Drury). Academic journal of entomology, 2(2), 80-84.
4. Rai, S. (2022). TREND OF TASAR SILK INDUSTRY IN INDIA-A STATISTICAL APPROACH. Plant Archives, 22(Special issue), 265-273. <https://doi.org/10.51470/PLANTARCHIVES.2022.v22.splecialissue.048>
5. Sadat, A., Biswas, T., Cardoso, M. H., Mondal, R., Ghosh, A., Dam, P., et al. (2022). Silkworm pupae as a future food with nutritional and medicinal benefits. Current Opinion in Food Science, 44, 100818. <https://doi.org/10.1016/j.cofs.2022.100818>
6. Lei, X., Qian, Z., Zhu, X., Zhang, N., He, J., Xiao, J., et al. (2024). Fitness effects of synthetic and natural diet preservatives on the edible insect *Bombyx mori*. npj Science of Food, 8(1), 39. <https://doi.org/10.1038/s41538-024-00284-9>
7. Sheikh, I. U., Banday, M. T., Baba, I. A., Adil, S., Nissa, S. S., Zaffer, B., & Bulbul, K. H. (2018). Utilization of silkworm pupae meal as an alternative source of protein in the diet of livestock and poultry: A review. Journal of Entomology and zoology Studies, 6(4), 1010-1016.
8. Kumar, R., Srivastava, D., Kumar, U., Kumar, M., & Singh, P. (2020). Bioprospecting of omega 3 fatty acid from silkworm pupal oil: from molecular mechanism to biological activities*.*Journal of Biologically Active Products from Nature, 10(6), 495-506. <https://doi.org/10.1080/22311866.2020.1862704>
9. Dash, S., Baig, M. M., Bhoi, T. K., Lagoriya, D. S., & KS, R. (2025). Strategies for Diversifying By-Product Utilisation in Mulberry and Tasar Sericulture: Current Scenario and Future Prospects. Entomological News, 132(3), 290-310. <https://doi.org/10.3157/021.132.0304>
10. Ashoka, J., & Sivashankar, N. (1997). Use of silkworm rearing waste in freshwater prawn culture. Indian Journal of Sericulture, 36(2),161-163.
11. Wei, Z. J., Liao, A. M., Zhang, H. X., Liu, J., & Jiang, S. T. (2009). Optimization of supercritical carbon dioxide extraction of silkworm pupal oil applying the response surface methodology. Bioresource Technology, 100(18), 4214-4219. <https://doi.org/10.1016/j.biortech.2009.04.010>
12. Wang Jun, W. J., Wu FuAn, W. F., Liang Yao, L. Y., & Wang Meng, W. M. (2010). Process optimization for the enrichment of α-linolenic acid from silkworm pupal oil using response surface methodology. African Journal of Biotechnology, 9(20), 2956-2964.
13. Beniwal, A., Mahapatara, D., Das, M., Acharjee, S., Sarma, J., Shome, A., & Baruah, A. M. (2024). A comprehensive review on the multifaceted applications of mulberry silkworm pupae: A sustainable resource. *Journal of Asia-Pacific Entomology*, *27*(4), 102312. <https://doi.org/10.1016/j.aspen.2024.102312>
14. Tao, L. T., Pan WenJuan, P. W., Zhang JianGuo, Z. J., & Wei ZhaoJun, W. Z. (2014). Microencapsulation and properties of the silkworm pupal oil with soybean protein isolate/β-cyclodextrin. Journal of Chemical and Pharmaceutical Research, 6 (7), 295-301.
15. Kotake-Nara, E., Yamamoto, K., Nozawa, M., Miyashita, K., & MURAKAMI, T. (2002). Lipid profiles and oxidative stability of silkworm pupal oil. Journal of Oleo Science, 51(11), 681-690. <https://doi.org/10.5650/jos.51.681>
16. Iwase, Y., Kamei, N., & Takeda-Morishita, M. (2015). Antidiabetic effects of omega-3 polyunsaturated fatty acids: from mechanism to therapeutic possibilities. Pharmacology & Pharmacy, 6(3), 190-200. <http://dx.doi.org/10.4236/pp.2015.63020>
17. Khan, S. U., Lone, A. N., Khan, M. S., Virani, S. S., Blumenthal, R. S., Nasir, K., et al. (2021). Effect of omega-3 fatty acids on cardiovascular outcomes: a systematic review and meta-analysis*.*EClinicalMedicine, 38 (2021), 100997. <https://doi.org/10.1016/j.eclinm.2021.100997>
18. Srivastava, D., Singh, V., Kumar, U., & Venkatesh, K. R. (2021). Alpha-linolenic acid: a pharmacologically active ingredient from nature. The Indian Journal of Nutrition and Dietetics, 58(4), 534–553. <https://doi.org/10.21048/IJND.2021.58.4.28086>
19. Srivastava, D., Singh, V., & Kumar, M. (2023a). Isolation of Alpha-linolenic acid (ALA) from tasar, *Antherea mylitta* pupal oil and its anticancer activity. Journal of Drug Delivery & Therapeutics, 13(5), 53-59. <http://dx.doi.org/10.22270/jddt.v13i5.5823>
20. Srivastava, D., Tripathi, D. K., Singh, V., & Poluri, K. M. (2024). Insights into the characterization and therapeutic potential of Tasar silkworm pupal oil. Biocatalysis and Agricultural Biotechnology, 55, 102985. <https://doi.org/10.1016/j.bcab.2023.102985>
21. Ramappa, V. K., Singh, V., Srivastava, D., Kumar, D., Verma, A., Verma, D. et al. (2023). Fabrication of mulberry leaf extract (MLE)-and tasar pupal oil (TPO)-loaded silk fibroin (SF) hydrogels and their antimicrobial properties. 3 Biotech, 13(2), 37. <https://doi.org/10.1007/s13205-022-03443-5>
22. Yeruva, T., Jayaram, H., Aurade, R., Shunmugam, M. M., Shinde, V. S., Venkatesharao, S. R. B., & Azhiyakathu, M. J. (2023). Profiling of nutrients and bioactive compounds in the pupae of silkworm, *Bombyx mori*. Food Chemistry Advances, 3, 100382. <https://doi.org/10.1016/j.focha.2023.100382>
23. Mahanta, D. K., Komal, J., Samal, I., Bhoi, T. K., Dubey, V. K., Pradhan, K. et al. (2023). Nutritional aspects and dietary benefits of “Silkworms”: Current scenario and future outlook. Frontiers in Nutrition, 10, 1121508. <https://doi.org/10.3389/fnut.2023.1121508>
24. Susirirut, P., Thitipramote, N., & Chaiwut, P. (2023). Simultous Extraction of Oil and Protein from Silkworm (*Bombyx mori* L.) Pupae (*Lueng Parroj* var.) and Their In Vitro Skin Moisturization. Molecules, 28(20), 7032. <https://doi.org/10.3390/molecules28207032>
25. Srivastava, D., Pandey, P., Tripathi, D. K., Yadav, J. P., Ali, B., Singh, V. et al. (2024b). Tasar Silkworm Pupae oil: A potential therapeutic and edible lipid source to mitigate the oxidative stress and cholesterol complications associated with diabetes. Food and Humanity, 3, 100418. <https://doi.org/10.1016/j.foohum.2024.100418>
26. **Jobling, M.** (2001). Feed composition and analysis. In D. Houlihan, T. Boujard, & M. Jobling (Eds.), Food intake in fish (pp. 1-24), Blackwell Science. <http://dx.doi.org/10.1002/9780470999516>
27. Banday, M. T., Adil, S., Sheikh, I. U., Hamadani, H., Qadri, F. I., Sahfi, M. E. et al. (2023). The use of silkworm pupae (*Bombyx mori*) meal as an alternative protein source for poultry. World's Poultry Science Journal, 79(1), 119-134. <https://doi.org/10.1080/00439339.2023.2163955>
28. Ramos‐Elorduy, B. J. (1997). The importance of edible insects in the nutrition and economy of people of the rural areas of Mexico. Ecology of food and nutrition, 36(5), 347-366. <https://doi.org/10.1080/03670244.1997.9991524>
29. Bose, P. C., & Majumder, S. K. (1990). Biochemical composition of pupae waste and utilization. Indian silk, 29(2), 45-46.
30. Rashmi, K. M., Chandrasekharaiah, M., Soren, N. M., Prasad, K. S., David, C. G., Thirupathaiah, Y., & Shivaprasad, V. (2022). Defatted silkworm pupae meal as an alternative protein source for cattle. Tropical Animal Health and Production, 54(5), 327. <https://doi.org/10.1007/s11250-022-03323-3>
31. Tomotake, H., Katagiri, M., & Yamato, M. (2010). Silkworm pupae (*Bombyx mori*) are new sources of high quality protein and lipid. Journal of nutritional science and vitaminology, 56(6), 446-448. <https://doi.org/10.3177/jnsv.56.446>
32. Astrup, A., Magkos, F., Bier, D. M., Brenna, J. T., de Oliveira Otto, M. C., Hill, J. O. et al. (2020). Saturated fats and health: a reassessment and proposal for food-based recommendations: JACC state-of-the-art review. Journal of the American College of Cardiology, 76(7), 844-857. <https://doi.org/10.1016/j.jacc.2020.05.077>
33. Mishra, N., Hazarika, N. C., Narain, K., & Mahanta, J. (2003). Nutritive value of non-mulberry and mulberry silkworm pupae and consumption pattern in Assam, India. Nutrition Research, 23(10), 1303-1311. [https://doi.org/10.1016/S0271-5317(03)00132-5](https://doi.org/10.1016/S0271-5317%2803%2900132-5)
34. Deori, G., Khanikor, D. P., & Sarkar, C. R. (2016). Evaluation of proximate composition of eri silkworm pupae fed on *Ailanthus grandis* and *Ailanthus excels* leaves. Journal of Experimental Zoology, 19 (1), 515-516.
35. Ghosh, A., Ray, M., & Gangopadhyay, D. (2020). Evaluation of proximate composition and antioxidant properties in silk-industrial byproduct. *Lwt*, *132*, 109900. <https://doi.org/10.1016/j.lwt.2020.109900>
36. Oynavod, A., Sveta, Y., & Sayora, R. (2020). Effective oil extraction from *Bombyx mori* silkworm pupae and its structural characteristics. CHEMISTRY AND CHEMICAL ENGINEERING, 18(1), 5. <https://doi.org/10.70189/1992-9498.1246>
37. Omotoso, O. T. (2015). An Evaluation of the Nutrients and Some Anti-nutrients in Silkworm, *Bombyx mori* L.(Bombycidae: Lepidoptera). Jordan Journal of Biological Sciences, 8(1), 45-50.
38. Paul, D., & Dey, S. (2014). Essential amino acids, lipid profile and fat-soluble vitamins of the edible silkworm *Bombyx mori* (Lepidoptera: Bombycidae). International Journal of Tropical Insect Science, 34(4), 239-247. <https://doi.org/10.1017/S1742758414000526>
39. Wu, X., He, K., Velickovic, T. C., & Liu, Z. (2021). Nutritional, functional, and allergenic properties of silkworm pupae. Food Science & Nutrition, 9(8), 4655-4665. <https://doi.org/10.1002/fsn3.2428>
40. Zhou, J., & Han, D. (2006). Proximate, amino acid and mineral composition of pupae of the silkworm *Antheraea pernyi* in China. Journal of Food Composition and Analysis, 19(8), 850-853. <https://doi.org/10.1016/j.jfca.2006.04.008>
41. Tungmunnithum, D., Thongboonyou, A., Pholboon, A., & Yangsabai, A. (2018). Flavonoids and other phenolic compounds from medicinal plants for pharmaceutical and medical aspects: An overview. Medicines, 5(3), 93. <https://doi.org/10.3390/medicines5030093>
42. Pari, L., & Satheesh, M. A. (2004). Antidiabetic activity of *Boerhaavia diffusa* L.: effect on hepatic key enzymes in experimental diabetes. Journal of ethnopharmacology, 91(1), 109-113. <https://doi.org/10.1016/j.jep.2003.12.013>
43. Hăbeanu, M., Gheorghe, A., & Mihalcea, T. (2023). Nutritional value of silkworm pupae (*Bombyx mori*) with emphases on fatty acids profile and their potential applications for humans and animals. Insects, 14(3), 254. <https://doi.org/10.3390/insects14030254>
44. Zhao, L., Wu, B., Liang, S., Min, D., & Jiang, H. (2022). Insight of silkworm pupa oil regulating oxidative stress and lipid metabolism in *Caenorhabditis elegans*. Foods, 11(24), 4084. <https://doi.org/10.3390/foods11244084>
45. Ichu, C. B., & Nwakanma, H. O. (2019). Comparative Study of the physicochemical characterization and quality of edible vegetable oils. International Journal of Research in Informative Science Application & Techniques (IJRISAT), 3(2), 1-9. <https://doi.org/10.46828/ijrisat.v3i2.56>
46. Yahaya, A. T., Taiwo, O., Shittu, T. R., Yahaya, L. E., & Jayeola, C. O. (2012). Investment in cashew kernel oil production; cost and return analysis of three processing methods. American Journal of Economics, 2(3), 45-49. <http://dx.doi.org/10.5923/j.economics.20120203.04>
47. Ravinder, T., Kaki, S. S., Kunduru, K. R., Kanjilal, S., Rao, B. V. S. K., Swain, S., & Prasad, R. B. N. (2016). Physico-chemical characterization and oxidative stability studies of eri silkworm oils. International Journal of Modern Chemistry and Applied Science, 3 (1), 293-300.
48. Yeasmin, M. S., Ferdousi, L., Dey, S. S., Uddin, M. J., Chowdhury, T. A., Rana, M. et al. (2024). Sustainable production of liquid phenyl using oil extracted from discarded pupae of mulberry silk worms (*Bombyx mori*). Journal of the Indian Chemical Society, 101(9), 101248. <https://doi.org/10.1016/j.jics.2024.101248>
49. Arasakumar, E., Manimegalai, S., & Priyadharshini, P. (2021). Extraction of Oil from Mulberry and Eri Silkworm Pupae and Analyzing the Physio-Chemical Properties for Commercial Utilization. Madras Agricultural Journal, 108 (7-9), 389- 392. <http://dx.doi.org/10.29321/MAJ.10.000523>
50. Parthasarathy, U., & Nandakishore, O. P. (2014). Morphological characterisation of some important Indian *Garcinia* species. Dataset Papers in Science, 2014(1), 823705. <https://doi.org/10.1155/2014/823705>
51. Sanders, T. H. (2003). Groundnut (peanut) oil. In GUNSTONE, F. D. (Ed), Vegetable Oils in Food Technology. Composition, Properties, and Uses, Blackwell Publishing Ltd, Oxford, UK, 231-243.
52. Suman, K. (2024). A comparative analysis of the characterization, antibacterial and antioxidant properties of oak tasar (*Antheraea proylei*) and mulberry (*Bombyx mor*i) pupae oils. Pharmacological Research-Natural Products, 4, 100086. <https://doi.org/10.1016/j.prenap.2024.100086>
53. **Pico, Y.** (2015). Chemical analysis of food: Techniques and applications (348 pp.). Rio de Jiro, Elsevier.
54. Sivakumar, R., Jebsan, A., Govindarajan, M., & Rajasekar, P. (2011). Larvicidal and repellent activity of tetradecanoic acid against *Aedes aegypti* (Linn.) *and Culex quinquefasciatus* (Say.)(Diptera: Culicidae). Asian Pacific journal of tropical medicine, 4(9), 706-710. [https://doi.org/10.1016/S1995-7645(11)60178-8](https://doi.org/10.1016/S1995-7645%2811%2960178-8)
55. Javid, S., Purohit, M. N., Yogish Kumar, H., Ramya, K., Mithuna, N. F. A., Salahuddin, M. D., & Prashantha Kumar, B. R. (2020). Semisynthesis of myristic acid derivatives and their biological activities: A critical insight. Journal of Biologically Active Products from Nature, 10(6), 455-472. <https://doi.org/10.1080/22311866.2020.1865836>
56. Batalha, M. D. M., Goulart, H. F., Santana, A. E., Barbosa, L. A., Nascimento, T. G., da Silva, M. K., et al. (2020). Chemical composition and antimicrobial activity of cuticular and internal lipids of the insect *Rhynchophorus palmarum*. Archives of Insect Biochemistry and Physiology, 105(1), e21723. <https://doi.org/10.1002/arch.21723>
57. Ferdosi, M. F., Khan, I. H., Javaid, A., Hafiz, M. S., Butt, I., & Munir, A. (2021). GC-MS analysis and bioactive components of flowers of *Bergenia ciliata*, a weed of rock crevices in Pakistan. Pakistan Journal of Weed Science Research, 27(4), 527. <https://doi.org/10.28941/pjwsr.v27i4.1012>
58. Yang, C., Lim, W., Bazer, F. W., & Song, G. (2018). Decanoic acid suppresses proliferation and invasiveness of human trophoblast cells by disrupting mitochondrial function. Toxicology and Applied Pharmacology, 339, 121-132. <https://doi.org/10.1016/j.taap.2017.12.009>
59. Gsan, T., Subban, M., Christopher Leslee, D. B., Kuppannan, S. B., & Seedevi, P. (2024). Structural characterization of n-hexadecanoic acid from the leaves of *Ipomoea eriocarpa* and its antioxidant and antibacterial activities. Biomass Conversion and Biorefinery, 14(13), 14547-14558. <https://doi.org/10.1007/s13399-022-03576-w>
60. Shawer, E. E. S., Sabae, S. Z., El-Gamal, A. D., & Elsaied, H. E. (2022). Characterization of Bioactive Compounds with Antioxidant Activity and Antimicrobial Activity from Freshwater Cyanobacteria. Egyptian Journal of Chemistry, 65(9), 723-735. <http://dx.doi.org/10.21608/ejchem.2022.127880.5681>
61. Karthikeyan, S. C., Velmurugan, S., Donio, M. B. S., Michaelbabu, M., & Citarasu, T. (2014). Studies on the antimicrobial potential and structural characterization of fatty acids extracted from Sydney rock oyster *Saccostrea glomerata*. Annals of Clinical Microbiology and Antimicrobials, 13(1), 332. <https://doi.org/10.1186/s12941-014-0057-x>
62. Shettima, A. Y., Karumi, Y., Sodipo, O. A., Usman, H., & Tijjani, M. A. (2013). Gas Chromatography-Mass Spectrometry (GC-MS) analysis of bioactive components of ethyl acetate root extract of *Guiera senegalensis* JF Gmel. Journal of Applied Pharmaceutical Science, 3(3), 146-150. <https://dx.doi.org/10.7324/JAPS.2013.30328>
63. Astudillo, A. M., Meana, C., Guijas, C., Pereira, L., Lebrero, P., Balboa, M. A., & Balsinde, J. (2018). Occurrence and biological activity of palmitoleic acid isomers in phagocytic cells. Journal of lipid research, 59(2), 237-249. <http://dx.doi.org/10.1194/jlr.M079145>
64. Chowdhury, S. K., Dutta, T., Chattopadhyay, A. P., Ghosh, N. N., Chowdhury, S., & Mandal, V. (2021). Isolation of antimicrobial Tridecanoic acid from *Bacillus sp*. LBF-01 and its potentialization through silver nanoparticles synthesis: a combined experimental and theoretical studies. Journal of Nanostructure in Chemistry, 11(4), 573-587. <https://doi.org/10.1007/s40097-020-00385-3>
65. Longkumer, N., Richa, K., Karmaker, R., Singha, B., & Sinha, U. B. (2023). Experimental and Theoretical Investigations on the Antibacterial Activity of Some Bromoaniline Compounds. Anti-Infective Agents, 21(3), 12-25. <https://doi.org/10.2174/2211352521666230126123021>
66. Nakaziba, R., Amanya, S. B., Sesaazi, C. D., Byarugaba, F., Ogwal-Okeng, J., & Alele, P. E. (2022). Antimicrobial bioactivity and GC‐MS analysis of different extracts of *Corchorus olitorius* L leaves. The Scientific World Journal, 2022(1), 3382302. <https://doi.org/10.1155/2022/3382302>
67. Biswas, S. M., & Jana, A. (2010). Bioactivity of 2-amino-9-(4-oxoazetidin-2-yl) Nonanoic Acid from the Root Exudates of *Cleome viscosa* L. Bio-Research, 8(1), 651-656. <https://doi.org/10.4314/br.v8i1.62552>
68. Sharma, A., Gupta, R. K., Sharma, P., Duwa, A. K., Bandral, R. S., & Bal, K. (2022). Silkworm as an edible insect: A review. The Pharma Innovation Journal, 11(2), 1667-74.