



## Potential of *Aurelia aurita* Extract in Reducing Oxidative Stress in Osteoarthritis

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### Abstract

**Background:** Oxidative stress contributes to osteoarthritis progression, supporting investigation of marine preparations as potential sources of bioactive compounds. **Objectives:** To characterize an *Aurelia aurita* preparation from Kenjeran Beach, Surabaya, and evaluate plasma malondialdehyde concentrations in rats with chemically induced osteoarthritis. **Methods:** A posttest only experimental design included an untreated osteoarthritis control and three groups receiving oral *A. aurita* preparation at 2.5, 5, or 10 mg/kg body weight for seven days. Five male Wistar rats were included per group. The preparation was characterized using gas chromatography mass spectrometry and a DPPH radical scavenging assay. **Results:** Fifteen chromatographic entries were identified. Mean plasma malondialdehyde concentrations were  $211.1 \pm 36.3$ ,  $142.0 \pm 20.3$ ,  $279.7 \pm 68.2$ , and  $320.6 \pm 14.53$  nmol/L for the control, 2.5, 5, and 10 mg/kg groups, respectively. ANOVA showed significant between group differences ( $F(3,16)=18.71$ ;  $p<0.001$ ), supported by Welch analysis. The 2.5 mg/kg group was 69.1 nmol/L lower than control, whereas higher doses showed increased concentrations. **Conclusions:** The lowest tested dose warrants further investigation. Dose optimization, chemical standardization, and safety evaluation are required before clinical translation.

**Keywords:** Antioxidants; Dose response; Lipid peroxidation; Malondialdehyde; Marine bioresources.

## Introduction

Osteoarthritis (OA) is a disorder of the whole joint involving cartilage, synovium, and subchondral bone, with pain and functional impairment as major clinical consequences<sup>1,2</sup>. In Indonesia, the Global Burden of Disease study estimated approximately 9.6 million prevalent OA cases in 2019, comprising about 5.5 million females and 4.1 million males; these figures are case counts rather than prevalence percentages<sup>3</sup>. A study at Ibnu Sina Hospital Makassar described knee pain, obesity, and radiological abnormalities among patients with knee OA, illustrating the clinical relevance of joint disease in the Indonesian setting<sup>4</sup>.

Oxidative stress provides a biochemical target for experimental OA research because excessive reactive oxygen species can participate in inflammatory signaling and cartilage matrix degradation<sup>5</sup>. Experimental work in degenerated human articular chondrocytes has connected protein kinase R activation with inflammation and matrix metalloproteinase secretion<sup>6</sup>. Plasma malondialdehyde (MDA) is used as an index of lipid peroxidation, although a systemic measurement does not identify the affected tissue or establish cartilage repair<sup>7</sup>. The unresolved question is whether an orally administered marine preparation can modify

this biochemical endpoint at a defined dose in an OA animal model.

*Aurelia aurita* is a jellyfish investigated as a marine resource for food and biomedical applications<sup>8</sup>. Studies of *Aurelia* extracts report antioxidant activity, but responses vary with species, body region, extraction conditions, and preparation type<sup>9,10</sup>. Research on *A. aurita* collagen and tuna collagen hydrolysates further indicates that processing can affect biological and antioxidant properties<sup>11,12</sup>. Jellyfish collagen peptides have also been investigated in a surgical OA model, providing a rationale for evaluating marine preparations while recognizing that purified peptides and a processed jellyfish extract are different test materials<sup>13</sup>. The novelty of this study is the combined chemical screening, radical scavenging assessment, and comparison of three oral doses of a Kenjeran Beach preparation in a chemically induced OA model.

The research question was whether rats receiving *A. aurita* at 2.5, 5, or 10 mg/kg body weight would have different final plasma MDA concentrations from an untreated OA control. The study objectives were to describe the chromatographic profile of the preparation, assess its DPPH radical scavenging activity, and compare final plasma MDA across the four experimental groups. The lowest tested dose was evaluated alongside higher doses to characterize the direction and magnitude of the observed response.

The study contributes evidence for selecting doses and analytical priorities in subsequent marine bioresource research. Indonesian laboratory studies published in Healthy Tadulako Journal demonstrate the usefulness of DPPH testing for comparing preparations, including papaya seed coffee with ginger supplementation<sup>14</sup>. Palupi and colleagues evaluated antioxidant activity alongside preliminary toxicity in *Imperata cylindrica* root extract, supporting the principle

that antioxidant screening and safety assessment address separate questions<sup>15</sup>. The present experiment therefore focuses on biochemical responses and dose selection as the next steps toward evaluating a standardized preparation.

## Materials and Methods

### Study Design

This laboratory experiment used a control group design with one final assessment. Chemical characterization and an in vitro radical scavenging assay were combined with an animal experiment at the Pharmacology Laboratory, Faculty of Veterinary Medicine, Airlangga University. All four animal groups underwent monosodium iodoacetate (MIA) induction. Group K received no *A. aurita* supplementation, while P1, P2, and P3 received 2.5, 5, and 10 mg/kg body weight, respectively. Final plasma MDA was the biochemical outcome. The design compares treated OA groups with an untreated OA control; it does not estimate the MDA increment caused by induction relative to healthy animals.

### Sample

*A. aurita* was collected from Kenjeran Beach, Surabaya, and its taxonomy was assessed at the Biology Service Unit, Faculty of Science and Technology, Airlangga University. Eligible animals were healthy male Wistar rats (*Rattus norvegicus*), aged 2 to 3 months and weighing 200 to 300 g. Rats with physical abnormalities before inclusion were excluded, and death during the experiment met the dropout criterion. Thirty rats were prepared: seven for each of the four groups and two held in reserve. For four groups, the Federer criterion used in the protocol yielded a planned minimum of six animals per group. This criterion is a design heuristic rather than a formal calculation of statistical power. Five rats per group contributed to the final analysis. Animals were

selected randomly, and the initial group size was seven. Animal flow and analyzed denominators are reported explicitly, in line with the reporting priorities of ARRIVE 2.0<sup>16</sup>.

### Data Collection Technique

Preparation of the test material. Whole jellyfish material was dried at 65°C and macerated in ethanol. The preparation protocol additionally describes treatment with 0.1 M sodium hydroxide for 24 hours to remove proteins other than collagen, neutralization with 0.5 M acetic acid, and fermentation for 14 days using 5% *Ganoderma lucidum* at 25°C and 120 rpm, with 2% soybean, 2% sugar, and 0.5% yeast extract. These latter processing steps follow a published jellyfish collagen peptide preparation approach<sup>13</sup>. Because the present study did not establish collagen purity or the degree of hydrolysis, the administered material is described as the processed *A. aurita* preparation, rather than purified collagen or an isolated peptide. Extraction yield was calculated as recovered preparation mass divided by starting dry material mass, multiplied by 100.

Radical scavenging assay. The DPPH reagent was prepared in ethanol using analytical grade chemicals. Reaction tubes were protected with aluminum foil and incubated at 30°C for 30 minutes in the dark; absorbance was measured at 517 nm under dim light. The assay assessed the concentration associated with 50% radical inhibition (IC<sub>50</sub>). Two replicate determinations were reported. Concentrations are expressed in mg/mL and, where comparison requires it, converted to µg/mL using 1 mg/mL = 1,000 µg/mL. DPPH assay interpretations depend on concentration, solvent, and assay conditions, as illustrated by studies using different extract matrices<sup>14,17</sup>.

Chromatographic screening. Gas chromatography coupled with mass spectrometry (GC MS) was used to examine the

chromatographic profile. The source analysis compared mass spectra and retention times with WILEY 09 and NIST library entries<sup>10</sup>. Library assignments are reported as tentative annotations rather than confirmed chemical identities, consistent with analytical identification standards<sup>18</sup>. The reported peak area percentages are instrument output descriptors and are not treated as mass concentrations or bioavailability estimates. Entries with alternative library assignments remain identified as alternatives.

Animal procedures. Rats underwent two days of acclimatization and were housed at two rats per cage. MIA was injected into the left knee under inhalation anesthesia. The source protocol reports 20 mg in 0.3 mL saline, equivalent to 66.7 mg/mL; this is presented as the recorded parameter, without assuming equivalence to a standard published induction dose. Knee circumference was compared before induction and on day 21 as a clinical indicator of joint enlargement. MIA models and clinical assessments of induced OA have been described previously<sup>19,20,21</sup>. Starting on day 24, the three treatment groups received the preparation once daily by oral gavage for seven days, while K remained without extract treatment. The groups were assessed at the same final experimental time point.

Plasma collection and measurement. Rats were fasted for 12 hours before the terminal procedure. The protocol describes ketamine injection before terminal blood collection from the abdominal aorta. Blood was centrifuged at 3,000 rpm and 4°C for 15 minutes; the supernatant was collected and stored at -20°C before analysis. Plasma MDA was measured using the thiobarbituric acid reactive substances (TBARS) approach, which has been used in rat lipid peroxidation studies<sup>22</sup>. Because TBARS can include reactions with substances other than MDA, results are interpreted as a

lipid peroxidation related biochemical endpoint<sup>7</sup>.

### Data Analysis Technique

The initial statistical analysis used SPSS, one way analysis of variance (ANOVA), and a least significant difference (LSD) procedure following the omnibus test. The significance threshold was 0.05. With five animals per group, distributional assumption tests have limited diagnostic power. Therefore, group differences were also evaluated with a sensitivity analysis that allows unequal variances, and statistical reporting emphasizes effect estimates and uncertainty rather than a binary assessment of significance.

ANOVA and pairwise comparisons were reconstructed from the reported group sizes, means, and SDs. Within group and between group sums of squares were calculated from these summaries. Pooled variance mean differences and 95% confidence intervals (CIs) accompany the exploratory LSD comparisons; the intervals are not simultaneous intervals. Holm adjustment was added across the six pairwise comparisons to assess multiplicity. A Welch ANOVA was calculated as a sensitivity analysis allowing unequal group variances<sup>23</sup>. Group mean CIs use the t distribution with four degrees of freedom. These reconstructed statistics are approximate because the available summaries are rounded. Individual values were not reconstructed, and distribution dependent tests were not repeated without original observations.

### Ethical Consideration

The Ethics Committee of the Faculty of Medicine, Hang Tuah University, approved this study under permit I/178/UHT/KEPK.03/XII/2023. The experimental procedures are described above, and the study is reported with attention to the ARRIVE 2.0 requirements for animal

characteristics, allocation, analyzed sample sizes, and experimental procedures<sup>16</sup>.

### Result

The experimental animals were male Wistar rats meeting the specified age and body weight eligibility criteria. Seven rats were initially assigned to each group, with two additional animals held in reserve. Twenty animals were analyzed, comprising five in each group. Thus, two initially assigned animals per group did not contribute to the final analysis. The reserve animals were not included in the reported final group denominators. The extraction used 500 g of dry jellyfish material and yielded 76.32 g of preparation, corresponding to 15.264%.

The reported DPPH IC<sub>50</sub> was approximately 27 mg/mL, corresponding to approximately 27,000 µg/mL. The replicate relative percent difference was reported as 1.1%. The chromatographic report listed 15 entries (Table 1). Ethanol accounted for 10.53% of reported peak area, while the largest reported fatty acid related entry was palmitic acid at 1.45%. Final plasma MDA means ranged from 142.0 nmol/L in P1 to 320.6 nmol/L in P3 (Table 2).

ANOVA reconstructed from the reported summaries showed a difference across groups,  $F(3,16) = 18.71$ ,  $p \approx 0.0000175$ . The Welch sensitivity analysis also indicated a group difference,  $F(3,8.21) = 75.92$ ,  $p \approx 0.00000254$ . Pairwise estimates are presented in Table 3. The reconstructed comparisons were consistent with the rounded p values in the source analysis. After Holm adjustment across six comparisons, P1 versus K and P2 versus K remained below 0.05, while P3 versus P2 did not.

Mean differences are the first group minus the second group, in nmol/L. Estimates use  $n = 5$  per group and the pooled ANOVA residual variance. CIs are unadjusted; Holm p values adjust the six comparisons. Values are

approximate calculations from rounded summaries, not a repeat analysis of individual observations. Therefore, these estimates should

be interpreted cautiously, as rounding and the absence of individual level data may affect their numerical precision.

**Table 1.** Tentative chromatographic annotations of the *A. aurita* preparation

| No. | Retention time | Peak area (%) | Tentative library annotation                                                                |
|-----|----------------|---------------|---------------------------------------------------------------------------------------------|
| 1   | 2.022          | 10.53         | Ethanol (extraction solvent)                                                                |
| 2   | 5.803          | 0.02          | Propenal (acrolein)                                                                         |
| 3   | 14.118         | 0.14          | Tetradecanoic acid (myristic acid)                                                          |
| 4   | 15.294         | 0.07          | Octisalate                                                                                  |
| 5   | 17.015         | 0.04          | Phthalic acid ester (heptan 3 yl and isobutyl)                                              |
| 6   | 18.914         | 0.47          | Methyl hexadecanoate or pentadecanoic acid (alternative annotations)                        |
| 7   | 20.578         | 1.45          | Hexadecanoic acid (palmitic acid)                                                           |
| 8   | 21.933         | 0.17          | Ethyl hexadecanoate                                                                         |
| 9   | 27.912         | 0.45          | Methyl octadecadienoate (11,14)                                                             |
| 10  | 28.398         | 0.32          | Methyl octadecenoate (9)                                                                    |
| 11  | 31.090         | 0.12          | Octadecadienoic acid (9,12): (Z,Z) assignment or linoelaidic acid (alternative annotations) |
| 12  | 31.618         | 0.20          | Octadecenoic acid (9)                                                                       |
| 13  | 33.475         | 0.12          | Ethyl linoleate                                                                             |
| 14  | 33.944         | 0.41          | Octadecanoic acid (stearic acid)                                                            |
| 15  | 60.279         | 0.11          | Phthalic acid bis(2 propylpentyl) ester                                                     |

Source: Primary data, 2025. Peak area percentages are reproduced from the analytical report. The listed entries are not a closed composition totaling 100%. Ethanol is interpreted as an extraction solvent related peak. Alternative assignments at retention times 18.914 and 31.090 are not counted as separately confirmed compounds.

**Table 2.** Final plasma MDA concentrations in the four experimental groups

| Group | Dose (mg/kg) | n | Mean $\pm$ SD     | Minimum | Maximum | 95% CI of mean |
|-------|--------------|---|-------------------|---------|---------|----------------|
| K     | None         | 5 | 211.1 $\pm$ 36.3  | 164     | 242     | 166.0 to 256.2 |
| P1    | 2.5          | 5 | 142.0 $\pm$ 20.3  | 108     | 161     | 116.8 to 167.2 |
| P2    | 5            | 5 | 279.7 $\pm$ 68.2  | 204.5   | 388.5   | 195.0 to 364.4 |
| P3    | 10           | 5 | 320.6 $\pm$ 14.53 | 302     | 337     | 302.6 to 338.6 |

Source: Primary data, 2025. MDA, malondialdehyde; SD, standard deviation; CI, confidence interval. All concentrations are in nmol/L. K is the untreated OA control. CIs were calculated from the reported summaries using the *t* distribution; all four groups have five analyzed rats.

**Table 3.** Exploratory pairwise differences in final plasma MDA

| Comparison   | Mean difference | 95% CI          | LSD p   | Holm adjusted p |
|--------------|-----------------|-----------------|---------|-----------------|
| P1 versus K  | -69.1           | -123.5 to -14.7 | 0.016   | 0.048           |
| P2 versus K  | 68.6            | 14.2 to 123.0   | 0.017   | 0.048           |
| P3 versus K  | 109.5           | 55.1 to 163.9   | < 0.001 | 0.002           |
| P2 versus P1 | 137.7           | 83.3 to 192.1   | < 0.001 | < 0.001         |
| P3 versus P1 | 178.6           | 124.2 to 233.0  | < 0.001 | < 0.001         |
| P3 versus P2 | 40.9            | -13.5 to 95.3   | 0.131   | 0.131           |

Figure 1 presents group mean plasma MDA with 95% CIs. The lowest mean was observed in P1, and higher means were observed in P2 and P3. The intervals show the precision of each mean, including the wider

interval in P2. No individual observations are depicted because the available data consist of group summaries.

The preparation yielded 76.32 g from 500 g of dry jellyfish, with 15 chromatographic

entries and a reported DPPH IC<sub>50</sub> of approximately 27 mg/mL. P1 had a mean MDA concentration 69.1 nmol/L below K, while P2 and P3 had means 68.6 and 109.5 nmol/L above K. The observed group differences were supported by both the reconstructed ANOVA and the Welch sensitivity analysis.

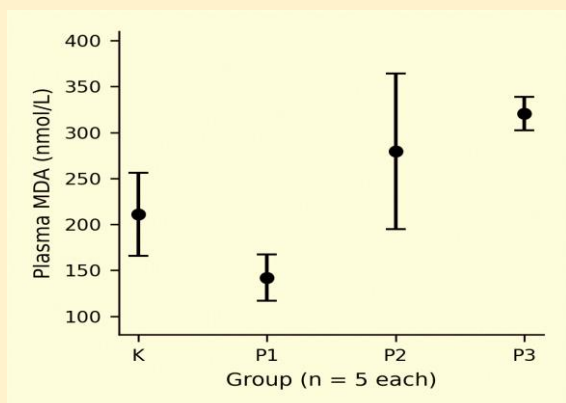


**Figure 1.** Plasma MDA means and 95% CIs (n = 5 per group). K: untreated OA; P1/P2/P3: 2.5/5/10 mg/kg. CIs calculated from reported summaries.

## Discussion

**Interpretation of Key Findings.** The principal finding is a response that varies across the tested doses. The 2.5 mg/kg group had a lower final mean plasma MDA than the untreated OA control, whereas the 5 and 10 mg/kg groups had higher means. This pattern identifies the lowest tested dose as a candidate for further study, without establishing an optimal dose. MDA is relevant to lipid peroxidation, but systemic TBARS measurements should be interpreted within the broader oxidative stress framework rather than as direct evidence of cartilage recovery<sup>5,7</sup>. The absence of a healthy group means that these comparisons concern differences within the induced model; they do not establish restoration to a physiological baseline.

**Comparison with Previous Studies.** Studies of *A. aurita* and *A. coerulea* have described antioxidant activity, with differences

related to extract type and body region<sup>9,10</sup>. An *A. aurita* study in a diabetic experimental setting also supports investigation of responses to free radical related injury, although its disease model differs from OA<sup>24</sup>. The collagen preparation examined by Barzkar and colleagues and hydrolysates evaluated by Wirayudha and colleagues further illustrate why extraction and processing should be considered when comparing antioxidant findings<sup>11,12</sup>. Here, the reported IC<sub>50</sub> of approximately 27,000 µg/mL falls above commonly applied 200 µg/mL thresholds and is consistently described as very weak DPPH activity. The much lower IC<sub>50</sub> values reported in the HTJ papaya seed coffee study illustrate a difference in assay potency across matrices, rather than a direct comparison of therapeutic efficacy<sup>14</sup>. Solvent dependent differences have also been examined in *Kopsia arborea* extracts<sup>17</sup>. Antioxidant assays involving polar and nonpolar fractions measure different aspects of activity, supporting the use of complementary assays in future characterization<sup>25</sup>.

**Clinical and Public Health Implications.** The present observations support further experimental dose evaluation rather than immediate clinical supplementation. Clinical knee OA assessment includes symptoms and radiological severity, as shown in the Makassar HTJ study, and these outcomes are distinct from a plasma biochemical marker<sup>4</sup>. Fatty acid related annotations in the present chromatographic profile offer hypotheses for fractionation and subsequent testing. Elwekeel and colleagues investigated antioxidant and inflammatory responses in *Salsola* extracts and included molecular docking, but that evidence concerns a different biological material<sup>26</sup>. Likewise, Felim and colleagues measured inflammatory and cartilage related outcomes in a surgical OA model after collagen treatment<sup>13</sup>. These studies provide mechanistic context;

they do not show that a specific annotated compound, cyclooxygenase pathway, or collagen peptide caused the MDA difference observed here. Safety evaluation remains a separate priority, illustrated by Palupi and colleagues through concurrent antioxidant and preliminary toxicity testing<sup>15</sup>.

Advantages and Limitations of the Research. Combining chemical screening, an in vitro assay, and three animal treatment doses allowed the study to identify a dose pattern that would be missed by testing one dose alone. Effect estimates and uncertainty are reported, and the Welch sensitivity analysis supports the overall difference without requiring equal group variances. The final five animals per group were fewer than the planned minimum, reducing precision and making attrition relevant to interpretation. The design did not include a healthy control, baseline plasma MDA, joint histology, functional outcomes, or direct pathway measurements. Chemical assignments remain tentative because library matching is not equivalent to confirmation with authentic standards<sup>18</sup>. Ethanol is interpreted as a solvent related peak and is excluded from claims about jellyfish bioactive constituents. Processing may also affect the final material, so any response should be attributed to the tested preparation as a whole.

Recommendations for Future Research. A confirmatory experiment should use a standardized batch, prespecified effect based sample size planning, documented allocation and blinding, and a healthy comparison group. Studies should evaluate doses around and below 2.5 mg/kg, measure joint structure and function alongside oxidative endpoints, and include a defined toxicological assessment. Chemical characterization should establish peptide or collagen content, quantify selected constituents with standards, and use solvent blanks and explicit library identification criteria<sup>18</sup>. Complementary radical scavenging

and reducing capacity assays can strengthen characterization across extract fractions<sup>25</sup>. These steps will establish whether the lowest dose response is reproducible and whether it accompanies meaningful joint outcomes.

## Conclusion

The processed *A. aurita* preparation produced a very weak response in the reported DPPH assay and 15 tentative chromatographic entries. In the induced OA model, the 2.5 mg/kg group had lower final mean plasma MDA than the untreated control, while the two higher dose groups had higher means. These findings identify a specific dose for further experimental evaluation and emphasize the need for chemical standardization, confirmation of joint outcomes, and safety assessment before clinical application.

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#### Conflict of Interest Statement

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