AMYLASE, PROTEASE, AND LIPASE ACTIVITY OF BUTTERFLY OF Junonia almana AND Junonia atlites

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ABSTRACT

Major gut digestive enzymes of butterflies are hydrolytic enzymes, i.e. amylase, protease, and lipase. Junonia is the most abundant butterfly species in the arboretum area of Universitas Padjadjaran, West Java, Indonesia. This study was aimed to determine the amylase, protease, and lipase activity of butterflies of Junonia almana and Junonia atlites. All enzyme activity was measured at the maximum wavelength of remaining substrates or products with the UV-visible spectrophotometric method. Both butterflies have higher amylase activity than protease and lipase activity. Amylase activity of J. atlites higher than J. almana at its optimum temperature and pH, i.e. 37 °C and 6.8. This study has provided the first information about amylase, protease, and lipase activity in J. atlites and J. almana butterfly.

Keywords: Arboretum, Butterfly, Hydrolytic Enzyme, Indonesia

INTRODUCTION

Enzymes have specificity in the catalyzed reaction and substrates. Enzyme activity is influenced by substrate concentration, temperature, and pH. Amylase, lipase, and protease enzymes are hydrolytic enzymes, which degraded macromolecules.1,2 Enzymes, as biocatalysts for biological reactions, help butterflies to digest their food. The butterfly life cycle is relatively short (2-6 months) and breeds rapidly.3 Butterflies are the highest number in the insect order, around 2500 species exist in Indonesia. There are 600 butterfly species in Java and Bali islands, Indonesia.4,5 This condition allows the availability of butterflies for enzyme production on a large scale.6 The genus of Junonia (Nymphalidae) is an important system model for experimental research in Lepidoptera. This system of development and evolution of this genus can be applied to all other genera. The most abundant genus of Junonia in the arboretum area of Universitas Padjadjaran, West Java, Indonesia, is Junonia almana (peacock pansies) and Junonia atlites (gray pansies).7,8 J. almana is distributed in an Asian tropical area.9 These species consume Acanthaceae, Amaranthaceae, Apocynaceae, Asteraceae, Fabaceae, and Verbenaceae. J. atlites has similar behavior to other Junonia, except when spawning.10,11 The major gut digestive enzymes of these two butterflies, the hydrolytic enzymes, have never been studied. In this study, we report the amylase, protease, and lipase activity in J. atlites and J. almana.
serum albumin (BSA), \( p \)-nitrophenol (\( p \)-NP), \( p \)-nitrophenyl palmitate (\( p \)-NPP), and tyrosine were purchased from Sigma-Aldrich, USA.

**Protein Extraction**
The butterfly wings were cut carefully. The bodies were weighed, then extracted with 0.02 M sodium phosphate buffer (pH 6.8) containing 10 mM NaCl at 4 °C for 2 h. Each extract was centrifuged at 4 °C and 13,000 G for 30 min. The supernatants were collected and stored at -20 °C.

**Determination of Total Protein Content**
Five concentrations of BSA, extracts, and blank were prepared. The Bradford reagent was added to each solution. The absorbance was measured at 573 nm after 5 min incubation.

**Amylase Activity Assay**
The starch solution (3 mL) and each butterfly extract (250 \( \mu \)L) were incubated for 8 min. Hydrochloric acid (0.5 mL) and iodine (0.5 mL) were added, the absorbance was measured at 627 nm. Amylase activity was calculated by Eqn.-1.

\[
\text{U/mg} = \frac{\text{Astd} - \text{Assampl}}{\text{Astd}} \times \frac{\text{(mg) Starch}}{\text{(mL) Enzyme in Extract} \times \text{Total Volume} \times \text{Time}}
\]  

(1)

**Protease Activity Assay**
The casein solution (1 mL) and each butterfly extract (250 \( \mu \)L) were incubated for 30 min. Ethanol (1 mL) was added, placed in a boiling water bath for 5 min, then cooled to the ambient temperature. Each mixture was centrifuged for 10 min at 13,000 G and the absorbance was measured at 277 nm. Protease activity was calculated by Eqn.-2.

\[
\text{U/mg} = \frac{\text{\( \mu \)mol Tyrosin which produce}}{\text{mg Enzyme in Extract} \times \text{Time}}
\]  

(2)

**Lipase Activity Assay**
The substrate solution (1 mL) and each butterfly extract (250 \( \mu \)L) were incubated for 15 min. The substrate solution was phosphate buffer: ethanol: \( p \)-NPP solution (95:4:1). Ethanol (1 mL) was added and the absorbance was measured at 405 nm. Lipase activity was calculated by Eqn.-3.

\[
\text{U/mg} = \frac{\text{\( \mu \)mol \( p \)-NP which produce}}{\text{mg Enzyme in Extract} \times \text{Time}}
\]  

(3)

**Statistical analysis**
Data were showed as mean and standard deviation (SD), then analyzed by single-factor ANOVA, followed by Duncan Multiple Range Test (DMRT). Data were considered to be significantly different if \( p \)-value < 0.05.

**RESULTS AND DISCUSSION**

**Protein Extraction**
The butterflies of \( J. \) almana and \( J. \) atlites were collected from December 2014 to February 2015, due to the highest rainfall in arboretum area, which increases butterfly populations associated with the plant fertility level as the butterfly host plant. The rainfall level affected the nectar availability. High water availability causes an increase in plants releasing nectar through the flowers. This study collected 72 \( J. \) almana butterflies (8.67 g) and 53 \( J. \) atlites butterflies (5.22 g). Butterfly’s body produces a crude extract with a concentration was 14.29 mg/mL for \( J. \) almana and 14.28 mg/mL for \( J. \) atlites. All crude extract was stored at -20 °C, to stop all enzymatic reactions that cause protein degradation or produce adverse substances.

**Determination of Total Protein Content**
Bradford's method with BSA as a standard was used to determine the total protein content. In the Bradford method, the amount of protein-CBBG complex is proportional to the positive charge on the protein.
maximum wavelength of the protein-CBBG complex was 573 nm, which corresponds to its complementary or transmitted color, i.e. orange wavelength (570-620 nm). The correlation coefficient of the BSA calibration curve was 0.995, which met the ICH criteria. It showed that instrument response is equal to the concentration. The absorbance of crude extract of J. alilites and J. almana was 0.78 ± 0.01 and 0.85 ± 0.01, respectively. The calculated total protein content of J. alilites and J. almana with a linear regression equation was 83.30 ± 0.10 and 90.21 ± 0.09 μg/mL, respectively. The total protein content of J. alilites was lower than J. almana, which significantly different (p = 1.76 x 10⁻⁷). These values were higher than the total protein content of Catopsilia pomona butterfly (71.98 ± 0.18 μg/mL). Crude extract of J. almana and J. alilites contain 58.30% and 60.63% of protein, respectively. This result showed that the crude extracts contain non-protein compounds which soluble in phosphate buffer.

In this study, the optimum pH and temperature of amylase, protease and lipase were determined. At optimum pH, the enzyme three-dimensional structure is the most convenient to binding to the substrate. When the hydrogen ion concentration change, the enzyme activity is progressively lost until the enzyme became denatured. pH alteration occurs in amino acid residues to maintain the tertiary and the quaternary structure of the active enzyme. Increased temperature causes increased kinetic energy, thereby increased the collision intensity between the substrate and the enzyme. Further increased temperature will decrease enzyme activity, due to denaturation. Enzymes encounter conformational changes at high temperatures, causes the substrate inhibition to enter the active site of the enzyme.

**Amylase Activity Assay**

The sensitivity of amylase activity which determines with iodimetry by the Fuwa method (mg of starch equivalents consumed/min) was five times higher than the activity units (mg of glucose equivalents produced/min) measured with the dinitrosalysilic acid method. The starch type with the glucose number difference affects the formed starch-iodine complex. Butterflies need monosaccharides as an energy source of nectar. When a butterfly flies, the needed energy increase, so there will be increased amylase activity. The butterflies are dependent on the amylase endurance, cause when fly, the butterfly’s temperature is more than 30 °C or 5-10 °C higher than normal body temperature. In insects, most amylase is active at neutral or slightly acidic pH.

**Table-1: Amylase Activity in Various Temperature and pH**

| Parameter | Amylase activity (U/mg) | p-value |
|-----------|-------------------------|---------|
|           | J. alilites | J. almana |         |
| Temperature (°C) |               |           |         |
| 27        | 6.41 ± 0.01 | 6.28 ± 0.01 | 5.46 x 10⁻⁵ |
| 37        | 8.08 ± 0.01 | 7.61 ± 0.01 | 8.36 x 10⁻⁷ |
| 47        | 6.60 ± 0.06 | 6.82 ± 0.01 | 4.42 x 10⁻⁵ |
| pH        |               |           |         |
| 5.8       | 3.16 ± 0.01 | 2.93 ± 0.01 | 4.42 x 10⁻⁵ |
| 6.8       | 6.41 ± 0.01 | 6.28 ± 0.01 | 5.46 x 10⁻⁵ |
| 7.8       | 1.98 ± 0.02 | 0.78 ± 0.01 | 3.64 x 10⁻⁶ |

The optimum temperature and pH of J. alilites and J. almana amylase were 37 °C and 6.8. Amylase activity of J. alilites was better than J. almana at optimum temperature and pH. The amylase activity of both butterflies was significantly different (Table-1). The optimum temperature and pH of J. alilites and J. almana were similar to the stomach amylase of hemiptera insects, i.e. 25-40 °C and 6.5, respectively. The butterflies are active at 16-42 °C and 28-30 °C is requiring for flight. The decreased amylase activity at 47 °C caused by exposure of the hydrophobic residues to the enzyme surface which important to stabilize the amylase structure. Amylase activity at 47 °C was higher than 27 °C, which indicates amylase has a high resistance to extreme environments. The charge of amino acid residues at the optimum pH is in an appropriate state, so the enzyme activity is efficient. The amylase activity of J. alilites and J. almana was higher than C. pomona butterfly at 27 °C, i.e. 5.85 ± 0.01 U/mg, but lower than C. pomona butterfly, at 37 and 47 °C, i.e. 8.21 ± 0.01 and 7.74 ± 0.11 U/mg,
referred to. These results showed that amylase of C. pomona was more stable than J. atlites and J. almana in different temperatures. The amylase activity of J. atlites and J. almana was higher than C. pomona butterfly at the studied pH. These results showed that amylase of J. atlites and J. almana more active than C. pomona in different pH.

Protease Activity Assay
Insects need protein for structural proteins, enzymes, receptors, transporters, and storage. The protease activity was determined based on the amount of producing tyrosine from casein hydrolysis, then measured at 277 nm, i.e. the maximum wavelength of the aromatic amino acids.

| Parameter | Protease activity (U/mg) | p-value |
|-----------|-------------------------|---------|
| Temperature (°C) | J. atlites | J. almana | p-value |
| 27 | 0.76 ± 0.02 | 1.27 ± 0.01 | 1.42 x 10^-6 |
| 37 | 0.29 ± 0.01 | 1.11 ± 0.01 | 5.34 x 10^-7 |
| 47 | 0.20 ± 0.01 | 0.45 ± 0.01 | 7.88 x 10^-8 |
| pH | | | |
| 5.8 | 0.39 ± 0.01 | 0.64 ± 0.01 | 4.62 x 10^-5 |
| 6.8 | 0.76 ± 0.02 | 1.27 ± 0.01 | 1.42 x 10^-6 |
| 7.8 | 0.43 ± 0.01 | 0.65 ± 0.01 | 4.45 x 10^-8 |

The optimum temperature and pH of J. atlites and J. almana protease were 27 °C and 6.8. Protease activity of J. almana was better than J. atlites at optimum temperature and pH. The amylase activity of both butterflies was significantly different (Table-2). The optimum temperature of J. atlites and J. almana were similar to the stomach protease of Ectomyelois ceratoniae, i.e. 30 °C with casein as the substrate. The optimum pH of J. atlites and J. almana were classified as neutral protease, correspond to the general body pH of the insect and in the range of protease, i.e. 7.0 to 9.0, due to serine protease in the extract. Both protease activities decreased with increasing temperature. This result showed that amylase work more dominant than protease, when a butterfly flies, due to nectar degradation as an energy source.

At the optimum temperature and pH, protease activity of both butterflies was higher than C. pomona, i.e. 0.59 ± 0.01 U/mg. These results showed that protease of J. atlites and J. almana more active than C. pomona in studied temperature and pH.

Lipase Activity Assay
Lipase activity was determined based on hydrolysis ester bonds in the oil as the substrate into glycerol and its fatty acids.

| Parameter | Lipase activity (U/mg) | p-value |
|-----------|-------------------------|---------|
| Temperature (°C) | J. atlites | J. almana | p-value |
| 27 | 2.46 ± 0.06 x 10^4 | 21.43 ± 0.02 x 10^-4 | 1.12 x 10^-12 |
| 37 | 1.79 ± 0.04 x 10^4 | 4.38 ± 0.03 x 10^-4 | 1.11 x 10^-8 |
| 47 | 2.15 ± 0.03 x 10^4 | 5.68 ± 0.02 x 10^-4 | 1.85 x 10^-9 |
| pH | | | |
| 5.8 | 3.75 ± 0.04 x 10^4 | 5.88 ± 0.02 x 10^-4 | 1.0 x 10^-7 |
| 6.8 | 2.46 ± 0.06 x 10^-4 | 21.43 ± 0.02 x 10^-4 | 1.12 x 10^-12 |
| 7.8 | 1.22 ± 0.02 x 10^-4 | 9.71 ± 0.02 x 10^-4 | 2.05 x 10^-11 |

The optimum temperature of J. atlites and J. almana lipase activity was 27 °C, while pH optimum was 5.8 for J. atlites and 6.8 for J. almana. Lipase activity of J. almana was higher than J. atlites at optimum temperature and pH. The lipase activity of both butterflies was significantly different (Table-3). The optimum temperature of J. atlites and J. almana were similar to lipase activity in Ectomyelois ceratoniae, i.e. 30 °C. The optimum pH of J. atlites and J. almana were in the range of lipase activity in insects, i.e. 5.5-7.5. Both lipase activities decreased with increasing temperature. When flying, the dominant enzyme was amylase, due to energy production from nectar degradation. At the optimum temperature and pH, lipase activity of both butterflies was higher than C. pomona, i.e. 0.59 ± 0.01 U/mg. These results showed that lipase of J. atlites and J. almana more active than C. pomona in studied temperature and pH.
CONCLUSION

*Junonia atlites* and *Junonia almana* have higher amylase activity than protease and lipase activity at optimum temperature and pH.

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