Purification and Characterization of Midgut $\alpha$-Glucosidase from Larvae of the Rice Green Caterpillar, *Naranga aenescens* Moore

N. Memarizadeh$^1$, P. Zamani$^2$, R. H. Sajedi$^2$, and M. Ghadamyari$^{1*}$

**ABSTRACT**

Application of chemical pesticides has increased significantly worldwide and has raised serious concerns about environmental pollutions. One of the encouraging trends to minimize pesticide risk is production of resistant plants containing toxic proteins against insect pests. Considering the importance of purification and characterization of digestive enzymes in the production of resistant plants, in this study an $\alpha$-glucosidase from the *Naranga aenescens* Moore's midgut was purified by ammonium sulfate precipitation, ion exchange chromatography on DEAE-sepharose, and concentrating through ultrafiltration. The apparent molecular mass of the enzyme was 48 kDa determined by SDS-PAGE. The optimum pH and temperature of the enzyme were 6.0 and 45°C, respectively. The irreversible thermoinactivation of the enzyme showed that it was highly stable at 35°C but moderately stable at 40 and 45°C. Zn$^{2+}$, Hg$^{2+}$, Co$^{2+}$ at 10 and 20 mM, and Ba$^{2+}$ only in 20 mM strongly inhibited the $\alpha$-glucosidase activity. Ba$^{2+}$ and Ca$^{2+}$ only at 10 mM, EDTA and Hg$^{2+}$ only at 20 mM and Mg$^{2+}$ at 10 and 20 mM significantly increased the enzyme activity. The $K_m$ and $K_{cat}$ values for the $\alpha$-glucosidase were 0.54 mM and 3.62 min$^{-1}$, respectively, when p-Nitrophenyl-$\alpha$-D-glucopyranoside (pN$\alpha$G) was used as a substrate.

**Keywords:** Ion exchange chromatography, Enzyme activity, Kinetic parameters, Thermostability, Kinetic parameters, Toxic proteins.

**INTRODUCTION**

The *Naranga aenescens* Moore (Lepidoptera: Noctuidae), known as rice green caterpillar, is a defoliator pest of the rice crop in Northern provinces of Iran. This pest also feeds on developing panicle rachis near the developing kernels resulting in huge loss of the crop. In 1986, this pest was reported from Iran at Guilan and Mazandaran provinces and was widely distributed in all paddy fields. “*N. aenescens* outbreak in paddy fields in Guilan province and 30,000 hectares of paddy fields were sprayed with synthetic insecticides against this pest annually” (Abivardi, 2001; Asadi et al., 2010). Chlorpyrifos and fenitrothion are widely used to control this pest. Since the Guilan and Mazandaran provinces have a very high water table, application of pesticide against *N. aenescens* is extremely hazardous not only to farmers and consumers via drinking polluted water, but also to the environment. Therefore, characterization of purified digestive enzymes can be first step of production of resistant plants as an encouraging research field to decrease usage of chemical pesticides.

---

1 Department of Plant Protection, Faculty of Agricultural Sciences, University of Guilan, Rasht, Islamic Republic of Iran.
2 Corresponding author: e-mail: ghadamyari@guilan.ac.ir
3 Department of Biochemistry, Faculty of Biological Sciences, Tarbiat Modares University, Tehran, Islamic Republic of Iran.
Carbohydrates are normally converted into monosaccharides, which can be absorbed through the midgut of insects. Glucosidases have crucial role in final stages of carbohydrates digestion. These enzymes constitute a group of glycoside hydrolase that are involved in the metabolism of oligosaccharides. Furthermore, glucosidases were used for biosynthesis and modification of glycoproteins (Melo et al., 2006). Alpha-glucosidase (EC 3.2.1.20) is an enzyme that acts upon α(1→4) glycosidic bonds and liberates the glucose from non-reducing ends of α-glucoses, α-glucans and α-linked oligosaccharides. In some insects, α-glucosidases seem to be an essential tool for the partitioning of carbohydrates from the diet into carbon nutrition and osmoregulation (Ashford et al., 2000). Alpha-glucosidases show diverse substrate specificities in plants, fungi and insects (Frandsen and Svensson, 1998; Wongchawalit et al., 2006; Carvalho et al., 2010). Some α-glucosidases preferentially hydrolyze α-linked di-, oligo-, and/or polyglucans as substrate, while others preferentially cleavage heterogeneous substrates such as aryl glucosides and sucrose (Chiba, 1988; Frandsen and Svensson, 1998). This enzyme was also capable of catalyzing transglycosylation to produce alpha-1,4 linked maltotriose and alpha-1,6 linked isomaltooligosaccharides (Johnson et al., 2010) and some α-glucosidases show clear transglycosylation activity (Kato et al., 2002).

This enzyme can be found in the midgut and salivary glands of insects (Lagadic and Chararas 1988; Ghadamyari et al., 2010; Ramzi and Hosseininave 2010; Saberi et al., 2012; Asadi et al., 2012) as well as hypopharyngeal glands of Apis mellifera L. (Baker and Lehner 1972; Terra et al. 1996). Characterization of α-glucosidases from the crude of alimentary canal, salivary glands and hemolymph of N. aenescens, which was carried out by Asadi et al. (2012), showed that the specific activity of α-glucosidases in the alimentary canal was more than the other segments. Till now, α-glucosidases have been isolated and characterized from many insects including Dysdercus peruvianus Guerin-Meneville (Hemiptera: Pyrrhocoridae), Sitophilus zeamais Motschulsky (Coleoptera: Curculionidae), A. mellifera; A. cerana japonica; A. cerana indica (Hymenoptera: Apidae), Drosophila melanogaster (Diptera: Drosophilidae), Glyphodes pyloidis Walker (Lepidoptera: Pyralidae) and N. aenescens (Huber and Mathison 1976; Tanimura et al. 1979; Baker 1991; Silva and Terra 1995; Ghadamyari et al. 2010; Asadi et al., 2012).

There are few researches on the purification of α-glucosidases in the digestive system of insects and our knowledge about this enzyme in the digestive system of lepidopteran insects is still rudimentary. Moreover, representation of a universal protocol for purification of different isoforms of α-glucosidase from different insect sources may require affinity of substrate (ligand) based chromatography to the target site (Chanchao et al., 2008). In A. mellifera, the purification of α-glucosidase has involved CM-cellulose and on Sephadex G-100 (α-glucosidase I), DEAE-cellulose, CM-cellulose, and Bio-Gel P-150 (α-glucosidase II), or DEAE-sepharose CL-6B, Bio-Gel P-150, and CM-Toyopearl 650M (α-glucosidase III) (Takewaki et al., 1980; Nishimoto et al., 2001). In addition, Kubota et al. (2004) purified α-glucosidase from honey of A. mellifera using salting-out chromatography, CM-cellulose, Bio-Gel P-150, and DEAE-Sephadex CL-6B.

Glucosidases inhibitors can serve as plant defense mechanisms, particularly against attack by insects and α-glucosidase inhibitors can be used as new insecticide by preventing the digestion of carbohydrates. Therefore, in this study, as the first step of this encouraging field, a novel α-glucosidase was purified from larval midgut of N. aenesccens and then it was characterized.

**MATERIALS AND METHODS**

**Chemicals**

p-Nitrophenol and bovine serum albumin were purchased from Merck (Darmstadt,
Germany). $p$-Nitrophenyl-$\alpha$-D-glucopyranoside (pNaG) and 4-methylumbelliferyl-$\alpha$-D-glucopyranoside (4-MU$\alpha$G) were obtained from Sigma (St. Louis, USA). DEAE-sepharose was purchased from GE healthcare (UK).

**Insect and Enzyme Preparation and Purification**

*N. aenescens* larvae were collected from rice seedling *Oryza sativa* L. ‘variety of Hashemi’ in the northern provinces of Iran. The 5$^{th}$ instar larvae were randomly selected for purification and enzyme characterization. Last larval instars were immobilized on ice, dissected under a stereoscopic microscope, and their alimentary canals were removed. Then, the alimentary canals were cleaned of the malpighian tube and adhering lipids. Finally, midgut was separated from foregut and hindgut and used for $\alpha$-glucosidase purification.

For glucosidase isolation from midgut of *N. aenescens*, 300 midgut were homogenized in 6 ml cold phosphate buffer 0.02M (pH 6.0) using a hand-held glass homogenizer and centrifuged at 15,000xg for 15 minutes at 4°C. The supernatants were passed through a filter paper and used in purification process. Ammonium sulfate was added to the crude extract to 85% saturation at 4$^{\circ}$C for 4 hours. Ammonium sulfate was added gradually to the raw extract in Erlenmeyer flasks with a magnetic stirrer at low speed. The precipitate was centrifuged at 7,000xg for 30 minutes at 4$^{\circ}$C; dissolved in 20 mM phosphate buffer (pH 7.0); and dialyzed overnight against 50 mM Tris-HCl buffer (pH 7.0). The concentrated protein solution was applied onto a DEAE-Sepharose column previously equilibrated with 50 mM Tris, pH 7.0. Proteins were then eluted with a step wise gradient of 0 to 0.5M NaCl in the same buffer. The active fractions were pooled and concentrated by ultrafiltration (Amicon, Beverly, MA). All of these works were performed in a cold room maintained at 4±1°C.

**Measurements of Enzyme Activity and Protein Concentration**

The enzymatic activity was determined by measuring the increase in absorbance at 405 nm caused by the hydrolysis of pNaG. 10 $\mu$L of homogenate were incubated for 20 minutes at 37°C with 45 $\mu$L of substrate solution (20 mM) and 115 $\mu$L of 20 mM phosphate-acetate-citrate mixed buffer (Ghadamyari *et al.*, 2010). The reaction was stopped by addition of 600 $\mu$L of NaOH (0.25 M). Optical density was measured at 405 nm using microplate reader (Stat Fax 3200, Awareness Technology, USA) after 10 minutes. Controls without enzyme or without substrate were included. A standard curve of absorbance against amount of $p$-Nitrophenol was constructed to enable calculation of the amount of $p$-Nitrophenol released during the $\alpha$-glucosidase assays. One unit enzyme is defined as the amount of the enzyme that catalyzes the production of 1 micro mole of $p$-Nitrophenol per minute. The protein concentration was measured by the method of Bradford (1976) using bovine serum albumin (BSA) as a standard.

**Electrophoresis**

Sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) was carried out by the method of Laemmli (1970), using a 10% (w/v) polyacrylamide gel and the gel was stained with Coomassie Brilliant Blue R-250. For zymogram analysis, the above procedure was performed but the samples were loaded onto the gel without heating according to the semi-denaturing procedure (Gabriel and Wang, 1969). Briefly, the gel was immersed in 3 mM 4-MU$\alpha$G in 0.1M sodium acetate (pH 5.0) for 10 minutes at room temperature to develop bands showing $\alpha$-glucosidase.
activity. The blue-fluorescent bands appear in a few minutes under UV.

Effect of pH and Temperature

The activity of α-glucosidase was determined at several pH values using 20 mM glycine-phosphate-acetate-citrate buffer, adjusted to various pHs. The activity of the enzyme at different temperatures was determined by incubating the reaction mixture at different temperatures in this buffer (pH 6.0). Thermal stability of the enzyme was examined by incubating the enzyme at 35, 40 and 45°C in the buffer, pH 6.0 for a series of time intervals, followed by cooling on ice, and determining residual activity under standard assay conditions.

Kinetic Parameters and the Effects of Metal Ions and EDTA

The enzyme activities were determined at different substrate concentrations under optimum conditions. $K_m$, $V_{max}$ and $K_{cat}$ values were determined by Lineweaver–Burk plots.

The effects of chloride salts of various metal ions and EDTA on the activity of the enzyme were evaluated at concentrations of 10 and 20 mM of each in the reaction mixture.

Statistical Analysis

Three replicates were conducted for all the biochemical assays and data were subjected to analysis of variance (ANOVA). Statistical analyses were performed at $P=0.05$ by Tukey’s test using the SAS software.

RESULTS

Purification of the α-glucosidase and Determination of Its Molecular Mass

A crude extract of N. aenescens containing the α-glucosidase specific activity (1.675 U ml$^{-1}$ or 1.675 µmol min$^{-1}$ mg$^{-1}$ protein) was purified through a three-step purification procedure. At first, homogenized and filtered sample was subjected to ammonium sulfate precipitation and then it was dialyzed and resulted in an increase of 1.25-fold in enzyme purity (Table 1). Precipitation was then followed by fractionation through a DEAE-sepharose anion exchange resin, in which six protein peak were visualized, one peak with each salt concentration. The fifth peak, eluted around 0.4M salt, corresponded to the α-glucosidase activity (Figure 1). After this step, a single band of protein was detected in SDS-PAGE. The molecular mass estimated on the gel was 48 kDa. Moreover, a single band was also detected in zymogram obtained by SDS-PAGE (Figure 2).

Kinetic Parameters

The $K_m$ and $V_{max}$ values for the α-glucosidase when pNαG was used as a substrate were estimated to be 0.54 mM and 3.55 mM min$^{-1}$, respectively. The $K_{cat}$ was calculated at 3.62 min$^{-1}$ from the $V_{max}$ and purified enzyme concentration.

Table 1. Summary of the purification of N. aenescens α-glucosidase.

<table>
<thead>
<tr>
<th>Step</th>
<th>Total activity (U)</th>
<th>Specific activity (U mg$^{-1}$)</th>
<th>Yield (%)</th>
<th>Purification fold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude enzyme</td>
<td>2314.88</td>
<td>1.675</td>
<td>100</td>
<td>1</td>
</tr>
<tr>
<td>Ammonium sulphate</td>
<td>884.26</td>
<td>2.095</td>
<td>38.198</td>
<td>1.25</td>
</tr>
<tr>
<td>(DEAE)-sepharose</td>
<td>348.83</td>
<td>24.67</td>
<td>15.06</td>
<td>14.72</td>
</tr>
</tbody>
</table>
Midgut α-Glucosidase Purification

Figure 1. Elution profile of *N. aenescens* α-glucosidase on DEAE-sepharose column. The active peak is indicated. Arrow is pointing to the fifth peak, eluted around 0.4M salt, corresponding to the α-glucosidase activity.

![Figure 1](image1.png)

**Figure 2.** Analysis of purified α-glucosidase by SDS-PAGE. Lanes 1 and 2: Active fraction after ion exchange chromatography stained with histochemical and general staining, respectively; Lane 3: Molecular weight markers.

**Effect of pH and Temperature on the Enzyme Activity**

A typical bell-shaped pH activity curve was obtained for the α-glucosidase hydrolyzing pNaG substrate in a 40 mM glycine-phosphate-acetic-citric mixed buffer system. Maximum activity was observed at pH 6.0 (Figure 3-a). The optimum temperature for α-glucosidase purified from *N. aenescens* was obtained as 45°C (Figure 3-b).

**Thermostability**

The irreversible thermoinactivation of the enzyme was recorded in 20 mM phosphate-acetate-citrate buffer, pH 6.0, at 35, 40 and 45°C. As shown in Figure 4, *N. aenescens* α-glucosidase retained more than 80% and 75% of its original activity after 30 and 60
minutes of incubation at 35°C, respectively. However, the enzyme activity lost 40 and 10% of its original activity after 20 minutes of incubation at 40 and 45°C, respectively, as depicted in Figure 4; and after 30 minutes, a complete inactivation of the α-glucosidase occurred, but the enzyme was still active at 40°C after 60 minutes. Furthermore, activation was obtained for the enzyme in the initial times of incubation, particularly at 45°C.

**Effect of Metal Ions and EDTA on Enzyme Activity**

The α-glucosidase activity was measured at optimum pH in the presence of various metal ions and EDTA. As shown in Table 2, Zn$^{2+}$, Hg$^{2+}$, Co$^{2+}$ in each concentrations of 10 and 20 mM and Ba$^{2+}$ only in 20 mM strongly inhibited the α-glucosidase activity. Enzyme activity could not be affected by K$^+$.
Table 2. Effects of metal ions and EDTA on the activity of α-glucosidase from *N. aenescens*. All metal ions were added as chloride salts.

<table>
<thead>
<tr>
<th>Metal ion (mM)</th>
<th>Relative activity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>100&lt;sup&gt;de&lt;/sup&gt;</td>
</tr>
<tr>
<td>10</td>
<td>128.95±2.78&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>20</td>
<td>141.94±2.85&lt;sup&gt;de&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ba&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>128.95±2.78&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>10</td>
<td>62.75±2.40&lt;sup&gt;ef&lt;/sup&gt;</td>
</tr>
<tr>
<td>20</td>
<td>113.32±1.91&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>K&lt;sup&gt;+&lt;/sup&gt;</td>
<td>141.94±2.85&lt;sup&gt;de&lt;/sup&gt;</td>
</tr>
<tr>
<td>10</td>
<td>113.32±1.91&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>20</td>
<td>121.21±0.01&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mn&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>121.21±0.01&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>10</td>
<td>121.70±2.92&lt;sup&gt;ef&lt;/sup&gt;</td>
</tr>
<tr>
<td>20</td>
<td>121.70±2.92&lt;sup&gt;ef&lt;/sup&gt;</td>
</tr>
<tr>
<td>Co&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>21.76±1.19&lt;sup&gt;kl&lt;/sup&gt;</td>
</tr>
<tr>
<td>10</td>
<td>113.32±1.91&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>20</td>
<td>113.32±1.91&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mg&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>150.66±2.31&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>10</td>
<td>138.34±1.54&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>20</td>
<td>128.28±1.22&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hg&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>12.28±1.22&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>10</td>
<td>10.84±0.71&lt;sup&gt;ef&lt;/sup&gt;</td>
</tr>
<tr>
<td>20</td>
<td>9.14±0.31&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ca&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>138.34±5.71&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>10</td>
<td>107.06±0.92&lt;sup&gt;de&lt;/sup&gt;</td>
</tr>
<tr>
<td>20</td>
<td>95.81±4.56&lt;sup&gt;de&lt;/sup&gt;</td>
</tr>
<tr>
<td>Zn&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>113.96±3.83&lt;sup&gt;def&lt;/sup&gt;</td>
</tr>
<tr>
<td>10</td>
<td>119.86±1.56&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>EDTA</td>
<td>113.96±3.83&lt;sup&gt;def&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

and Mn<sup>2+</sup>. However, Ba<sup>2+</sup> and Ca<sup>2+</sup> only in 10 mM, EDTA and Hg<sup>2+</sup> only in 20 mM, and Mg<sup>2+</sup> in each concentration of 10 and 20 mM increased the enzyme activity significantly.

**DISCUSSION**

Purification of α-glucosidase from *N. aenescens* by DEAE-cellulose chromatography, showed a relatively high specific activity of 24.67 U mg<sup>-1</sup> with a 14.72-fold purification. The specific activity of α-glucosidase was higher than those obtained for two α-glucosidases purified previously from *A. cerana indica* larval midgut (Chanchao et al., 2008). Purification of α-glucosidase from *A. cerana indica* by DEAE-cellulose and Superdex 200 columns resulted in a relatively high specific activity of 2.2 and 1.8 U mg<sup>-1</sup> and with a purification fold of 3.1 and 2.6, respectively (Chanchao et al., 2008). The specific activity of crude α-glucosidase from whole alimentary canal of *N. aenescens* reported by Asadi et al. (2012) was 3.08 U mg<sup>-1</sup> which was obtained in the present work. Considering that α-glucosidase in whole alimentary canal of *N. aenescens* showed two isoforms (Asadi et al., 2012), we succeeded to purify one isoform by DEAE-cellulose chromatography. Zymogram analysis in the present study showed homogeneity and revealed only a single band (Figure 2) for the fraction corresponding to the active peak of ion-exchange chromatography (Figure 1). This means that under purification processes, only one isoform could be purified. The molecular mass of *N. aenescens* α-glucosidase estimated by SDS-PAGE was 48 kDa which is different from that reported for purified α-glucosidases from *A. cerana indica* (68 kDa) (Chanchao et al., 2008), *A. mellifera* L (98 kDa) (Nishimoto et al., 2001) and *A. cerana japonica* (76 kDa) (Wongchawalit et al., 2006), but it is within the range of the majority of other α-glucosidases (22-120 kDa) (Anindyawati et al., 1998; Kashiwabara et al., 2000; Nashiru et al., 2001; Nishimoto et al., 2001; Kato et al., 2002; Faridmoayer and Scaman, 2004; Torre-Bouscoullet et al., 2004; Yamamoto et al., 2004; Okuyama et al., 2005; Ezeji and Bahl, 2006; Naested et al., 2006; Wongchawalit et al., 2006; Chanchao et al., 2008; Carvalho et al., 2010). Alpha-glucosidase purified from whole *A. mellifera* adult by ammonium sulfate gave two α-glucosidase fractions with different solubility considered as α-glucosidase-I (highly soluble) and α-glucosidase-II (less soluble) (Huber and Mathison, 1976). SDS-
PAGE of these purified α-glucosidases showed relative molecular masses of 93 and 78 kDa for α-glucosidase-I and α-glucosidase-II, respectively. Our result showed that the relative molecular mass of α-glucosidase purified from N. aenescens midgut was less than those obtained for α-glucosidases purified previously from different species of Apis larval midgut (Nishimoto et al., 2001; Wongchawalit et al., 2006; Chanchao et al., 2008). An α-glucosidase was isolated from the midgut of larval sugar cane stalk borer, Diatrea saccharalis using mild-denaturing electrophoresis and it was further purified to near homogeneity by gel filtration (Carneiro et al., 2004). The results showed that this α-glucosidase appeared to have a relative molecular mass of 54 kDa. The membrane bound α-glucosidase in Quesada gigas (Hemiptera: Cicadidae) was solubilized using Triton X-100 and purified to homogeneity by means of gel filtration and ion-exchange chromatography. The results showed that the purified α-glucosidase was a protein with a pH optimum of 6.0 against the synthetic substrate pNpG and molecular weight of 61 kDa (Fonseca et al., 2010).

The $K_m$ value of crude α-glucosidases in the N. aenescens's alimentary canal was 3.96 mM (Asadi et al., 2012) and α-glucosidase in the whole alimentary canal of N. aenescens showed two isoforms. However, the $K_m$ value of purified α-glucosidase from midgut for pNpG substrate was calculated at 0.54 mM and it showed much higher affinity of purified enzyme to substrate over crude enzyme. Furthermore, the $K_m$ value is within the range of the majority of other α-glucosidases. For instance, the $K_m$ values of purified α-glucosidases from A. mellifera L. and A. cerana japonica were 0.31 and 1 mM, when pNpG was used as a substrate (Nishimoto et al., 2001; Wongchawalit et al., 2006).

Alpha-glucosidase purified from N. aenescens midgut showed appropriate activity at acidic pH conditions and maximum activity was observed at pH 6.0 for this α-glucosidase (Figure 3-a). Optimum pH for activity of crude α-glucosidase from N. aenescens's alimentary canal was also at pH 6.0 (Asadi et al., 2012). The pH of 5.0 was reported as optimal pH for the purified α-glucosidase from A. cerana indica (Chanchao et al., 2008). The effects of pH on the activity of α-glucosidase III from A. mellifera using maltose as the substrate showed that the pH optimum of the enzyme was 5.5, which did not differ greatly from α-glucosidase I and II showing pH optima of 5.0 (Nishimoto et al., 2001). Most of α-glucosidase, extracted from insects, exhibits pH optima ranging from 4.5 to 7.0 (Frandsen and Svensson, 1998; Ghadamyari et al., 2010; Ramzi and Hoseininaveh, 2010; Saberi et al., 2012). Nakonieczny et al. (2006) reported that optimal pH for α-glucosidase in the larvae of Apollo butterfly, P. apollo ssp. Frankenbergeri was between 4.9 and 5.6.

The optimum temperature for activity of purified α-glucosidase was obtained as 45°C (Figure 3-b) which was equal to crude α-glucosidase (Asadi et al., 2012). The irreversible thermoinactivation of the enzyme showed that it was highly stable at 35°C but moderately stable at 40 and 45°C (Figure 4). Wongchawalit et al. (2006) showed that α-glucosidase from Japanese honeybee was stable in a temperature-range up to 40°C. The optimal temperature for the purified α-glucosidase from A. cerana indica was 50°C (Chanchao et al., 2008). A. mellifera α-glucosidase III was stable up to 40°C, but it lost the activity completely by incubation at 60°C for 15 minutes (Nishimoto et al., 2001). Several purified α-glucosidases from various sources showed optimum temperature ranging from 50 to 70°C (Anindyawati et al., 1998; Martino et al., 2001; Tanaka et al., 2002; Zdzieblo and Synowiecki, 2002; Iwata et al., 2003; Bravo-Torres et al., 2004; Yamamoto et al., 2004; Okuyama et al., 2005; Ezeji and Bahl, 2006; Giannesi et al., 2006; Zhou et al., 2009).

Results of the present study indicated that Zn$^{2+}$, Hg$^{2+}$, and Co$^{2+}$ in each concentrations of 10 and 20 mM and Ba$^{2+}$ only in 20 mM strongly inhibited the α-glucosidase activity
and K⁺, Mn²⁺, Mg²⁺ and EDTA in each concentrations of 10 and 20 mM, Ba²⁺ and Ca²⁺ only in 10 mM and Hg²⁺ only in 20 mM significantly increased the enzyme activity. Asadi et al. (2012) showed that in the presence of Fe³⁺, Mn²⁺, Hg²⁺, and Zn²⁺ (10, 20 mM) and Hg²⁺ (20 mM), crude α-glucosidase from alimentary canal were completely inactivated. Carvalho et al. (2010) reported that in the presence of Na⁺, Ba²⁺, Co²⁺, Ni²⁺, Mg²⁺, Mn²⁺, Al³⁺, Zn²⁺ and Ca²⁺, α-glucosidase from Thermoascus aurantiacus CBMAI-756 maintained 90-105% of its maximum activity and was inhibited by Cr³⁺, Ag⁺, and Hg²⁺ (Carvalho et al., 2010). Alpha-glucosidase Purified from Chaetomium thermophilum var. coprophilum was completely inhibited by 1 mM Hg²⁺ and Ag⁺, while Al³⁺, Zn²⁺, Co²⁺ and Cu²⁺ inhibited 35, 70, 51, and 46%, respectively. Most of other ions, such as Mg²⁺, Ca²⁺, Ba²⁺, K⁺, Fe²⁺, NH⁴⁺ and Mn²⁺, tested at 1 mM concentration, or EDTA were without effect (Giannesi et al., 2006).

The effect of metal ions and other chemical reagents were examined on the G. pylolalis α-glucosidase activity. The results showed that CaCl₂ (40 mM) increased α-glucosidase activity and, also, the α-glucosidase activity was enhanced with increase in concentration of EDTA. Different concentrations of MgCl₂ and KCl (5, 10, 20 and 40) did not have any effect on α-glucosidase activity in this insect (Ghadamyari et al., 2010).

In conclusion, this work was done on the purification and characterization of digestive enzymes and it is possible to create plants that are resistant to pest.

ACKNOWLEDGEMENTS

The authors express their gratitude to the Research Council of the University of Guilan.

REFERENCES


لالوهای در پژوهشگاه نارنگا مور

ن. ممکنی زاده، پ. زمانی، ر. ح. ساجدی، و م. قدیمیاری

چکیده

کاربرد آف تنظیم یک های شبیه‌پی و طیف ویژگی‌های پیوست‌مایه آنزیم آلفا-گلکوزیداز روده میانی

Naranga aenescens Moore

ن. ممکنی زاده، پ. زمانی، ر. ح. ساجدی، و م. قدیمیاری

چکیده

کاربرد آف تنظیم یک های شبیه‌پی و طیف ویژگی‌های پیوست‌مایه آنزیم آلفا-گلکوزیداز روده میانی

Naranga aenescens Moore

ن. ممکنی زاده، پ. زمانی، ر. ح. ساجدی، و م. قدیمیاری

چکیده

کاربرد آف تنظیم یک های شبیه‌پی و طیف ویژگی‌های پیوست‌مایه آنزیم آلفا-گلکوزیداز روده میانی

Naranga aenescens Moore

ن. ممکنی زاده، پ. زمانی، ر. ح. ساجدی، و م. قدیمیاری

چکیده

کاربرد آف تنظیم یک های شبیه‌پی و طیف ویژگی‌های پیوست‌مایه آنزیم آلفا-گلکوزیداز روده میانی

Naranga aenescens Moore

ن. ممکنی زاده، پ. زمانی، ر. ح. ساجدی، و م. قدیمیاری

چکیده

کاربرد آف تنظیم یک های شبیه‌پی و طیف ویژگی‌های پیوست‌مایه آنزیم آلفا-گلکوزیداز روده میانی

Naranga aenescens Moore

ن. ممکنی زاده، پ. زمانی، ر. ح. ساجدی، و م. قدیمیاری

چکیده

کاربرد آف تنظیم یک های شبیه‌پی و طیف ویژگی‌های پیوست‌مایه آنزیم آلفا-گلکوزیداز روده میانی

Naranga aenescens Moore

ن. ممکنی زاده، پ. زمانی، ر. ح. ساجدی، و م. قدیمیاری

چکیده

کاربرد آف تنظیم یک های شبیه‌پی و طیف ویژگی‌های پیوست‌مایه آنزیم آلفا-گلکوزیداز روده میانی

Naranga aenescens Moore

ن. ممکنی زاده، پ. زمانی، ر. ح. ساجدی، و م. قدیمیاری

چکیده

کاربرد آف تنظیم یک های شبیه‌پی و طیف ویژگی‌های پیوست‌مایه آنزیم آلفا-گلکوزیداز روده میانی

Naranga aenescens Moore

ن. ممکنی زاده، پ. زمانی، ر. ح. ساجدی، و م. قدیمیاری

چکیده

کاربرد آف تنظیم یک های شبیه‌پی و طیف ویژگی‌های پیوست‌مایه آنزیم آلفا-گلکوزیداز روده میانی

Naranga aenescens Moore

ن. ممکنی زاده، پ. زمانی، ر. ح. ساجدی، و م. قدیمیاری

چکیده

کاربرد آف تنظیم یک های شبیه‌پی و طیف ویژگی‌های پیوست‌مایه آنزیم آلفا-گلکوزیداز روده میانی

Naranga aenescens Moore

ن. ممکنی زاده، پ. زمانی، ر. ح. ساجدی، و م. قدیمیاری

چکیده

کاربرد آف تنظیم یک های شبیه‌پی و طیف ویژگی‌های پیوست‌مایه آنزیم آلفا-گلکوزیداز روده میانی

Naranga aenescens Moore

ن. ممکنی زاده، پ. زمانی، ر. ح. ساجدی، و م. قدیمیاری

چکیده

کاربرد آف تنظیم یک های شبیه‌پی و طیف ویژگی‌های پیوست‌مایه آنزیم آلفا-گلکوزیداز روده میانی

Naranga aenescens Moore

ن. ممکنی زاده، پ. زمانی، ر. ح. ساجدی، و م. قدیمیاری

چکیده

کاربرد آف تنظیم یک های شبیه‌پی و طیف ویژگی‌های پیوست‌مایه آنزیم آلفا-گلکوزیداز روده میانی

Naranga aenescens Moore

ن. ممکنی زاده، پ. زمانی، ر. ح. ساجدی، و م. قدیمیاری

چکیده

کاربرد آف تنظیم یک های شبیه‌پی و طیف ویژگی‌های پیوست‌مایه آنزیم آلفا-گلکوزیداز روده میانی

Naranga aenescens Moore

ن. ممکنی زاده، پ. زمانی، ر. ح. ساجدی، و م. قدیمیاری

چکیده

کاربرد آف تنظیم یک های شبیه‌پی و طیف ویژگی‌های پیوست‌مایه آنزیم آلفا-گلکوزیداز روده میانی

Naranga aenescens Moore

ن. ممکنی زاده، پ. زمانی، ر. ح. ساجدی، و م. قدیمیاری

چکیده

کاربرد آف تنظیم یک های شبیه‌پی و طیف ویژگی‌های پیوست‌مایه آنزیم آلفا-گلکوزیداز روده میانی

Naranga aenescens Moore

ن. ممکنی زاده، پ. زمانی، ر. ح. ساجدی، و م. قدیمیاری