CHARACTERIZATION AND BIOLOGICAL ACTIVITY OF HEMAGGLUTININS FROM DIFFERENT PARTS OF GARLIC PLANT (*ALLIUM SATIVUM*)

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Received: 19.7.2014
Accepted: 30.8.2014

SUMMARY

Aqueous extracts from bulb, leaf and root of garlic plant collected at Vanhung-Vanninh, Khanhhoa were examined for hemagglutination activity using native and enzyme-treated different animal and human erythrocytes. All extracts agglutinated at least one type of erythrocytes tested. Activity was detected in extracts from garlic bulb, leaf and root with enzyme-treated rabbit erythrocytes. The hemagglutinins of active species were examined for sugar-binding specificity with various monosaccharides and glycoproteins, pH, temperature stability, and effect of divalent cations using ammonium sulfate precipitates prepared from their extracts. Activity of the hemagglutinins was not inhibited by monosaccharides, but was inhibited by some glycoproteins tested. The inhibition profiles with glycoproteins were different depending on hemagglutinin species, activity of hemagglutinins from garlic leaf and bulb was inhibited by high-mannose type *N*-glycans, whereas activity of hemagglutinin from garlic root was inhibited by complex type *N*-glycans, indicating that each part of garlic plant contains different lectins. On the other hand, the activities of hemagglutinins were stable over a wide range of pH and temperature, and independent of the presence of divalent cations. Hemagglutinins from garlic leaf and bulb inhibited the growth of bacterium *Enterobacter cloacae*, bud did not affect other bacteria examined. These obtained results suggest that the parts of garlic plant may be good sources of useful lectins for many biological applications.

Keywords: *Allium sativum, Antibacterial activity, Carbohydrate-binding specificity, Garlic plant, Hemagglutinins, Lectins, Stability.*

INTRODUCTION

Lectins are carbohydrate-binding proteins that specifically recognize diverse sugar structures and thus mediate various biological processes, viz., cell-cell and host-pathogen interactions, and serum glycoprotein turnover besides innate immune responses (Vijayan, Chandra, 1999). Lectins are known to occur in most of the organisms ranging from viruses and bacteria to plants and animals (Lis, Sharon, 1998). They represent a heterogenous group of oligomeric proteins that vary widely in size, structure and molecular organization. Lectins are found predominantly as storage proteins in planta. Commonly plant lectins are found in abundance in seeds and bulbs, although they may also be found in the leaves of some plants. The content of lectin varies in different organisms. The high yields of lectins from different sources may facilitate mass production. Application of lectins is possible depending on their properties. The anti-fungal and anti-insect activities of lectins can be made use in the control of pathogens. The production of anti-tumor and anti-viral drugs based on lectins may also be feasible (Lam, Ng, 2011).

Most commonly consumed plant foods contain lectins, and many of these foods are eaten raw, while others contain lectins that are active even after cooking and processing. A delicate equilibrium exists within the alimentary canal between lectins, dietary saccharides, immunoglobulins, viruses, bacteria and host cells (Kilpatrick, 1999). Garlic is well known across the centuries. It was used as a medicine by early civilizations (Rivlin, 2006). Garlic is widely consumed as an important spice all over the world. The health-beneficial effects of garlic (*Allium sativum*) have long been known and garlic has a reputation for its efficacy as an anti-microbial, anti-oxidant, anti-carcinogenic, anti-mutagenic, anti-

hypertensive and immuno-modulatory agent (Corzo-Martinez *et al.*, 2007). The anti-cancer effects of garlic are being extensively researched and most of these effects have been attributed to the organosulfur compounds such as diallyl sulfide, diallyl disulfide, diallyl trisulfide, S-allylcysteine or S-allylmercaptocysteine (Ross, Milner, 2006). Recent findings have shown that the anti-tumor effect of allyl sulfur compounds may be related to their anti-inflammatory as well as immune-stimulatory properties (Iciek *et al.*, 2009). Furthermore, one of the most important direct defense responses in plants against the attack by phytophagous insects is the production of insecticidal peptides or proteins. One particular class of entomotoxic proteins present in many plant species is the group of carbohydrate-binding proteins or lectins (Vandenborre *et al.*, 2011). Among the plant lectins, lectins exhibiting either mannose or mannose/glucose sugar binding affinity have been interested greatly, including *Galanthus nivalis* agglutinin, Concanavalin A and *Pisum sativum* agglutinin, which revealed palpable anti-metabolic effects towards members of the homopteran insects both under *in vitro* (Rahbe *et al.*, 1995) as well as in planta conditions (Powell *et al.*, 1995; Gatehouse *et al.*, 1996). Among the mannose-binding lectins, *G. nivalis* agglutinin (GNA) has been widely studied and introduced into different plants, viz., rice, wheat and tuber crops (Nagadhara *et al.*, 2003, 2004; Gatehouse *et al.*, 2003). Transgenic plants expressing GNA showed significant entomotoxic effects as evidenced by insect bioassays under controlled conditions (Couty *et al.*, 2001). Similarly, bioassays based on artificial-diet-feeding system, using mannose-specific lectin from *Allium sativum* agglutinin showed anti-metabolic effects towards green leafhopper and brown planthopper insects (Majumder *et al.*, 2004). Expression of garlic lectins in tobacco conferred resistance against tobacco aphid and cotton leaf worm, respectively (Sadeghi *et al.*, 2007, 2008). The transgenic rice lines expressing garlic leaf lectin gene was also reported for exhibiting increased resistance against green leafhopper and brown planthopper pests (Saha *et al.*, 2006). Recently, the gene encoding lectin from garlic leaf was introduced into transgenic indica rice and exhibited surpassing resistance against green leafhopper, brown planthopper and whitebacked planthopper insects (Yarasi *et al.*, 2008). Thus, garlic plant may be a dominant sources of useful lectins for basic research and application in biomedicine and transgenic plants.

Garlic plant *Allium sativum* has been cultivate in many countries as the valuable sources of foo and medicine. In Vietnam, garlic plant has bee cultivating extensively at Bacninh, Vinhphu Haiduong, Lyson-Quangngai, Ninhhoa-Khanhho Ninhhai-Ninhthuan with the production of 2,000 ton per year. Those garlic species may contribute as source of not only attractive spice but also othe bioactive compounds for biochemical and medicina uses. On the other hand, in the harvested process, th garlic bulbs were only collected, whereas their lea and root were nearly all removed, where they may contain useful bioactive compounds for various applications. The objective of this research was t biochemically characterize the hemagglutinins and biological activity obtained from different parts of garlic plant for future applications.

MATERIALS AND METHODS

Materials

Garlic plants *Allium sativum* were collected a Vanninh District, Khanhhoa Province, Vietnam in March, 2014. After collection, the bulb, leaf and root was cut, separately, and were kept at – 20 °C until being used to extract protein. Blood from rabbit and chicken was obtained from the Institute of Vaccine-Nhatrang, Vietnam, and human A-, B-, and O-type blood was obtained from Khanhhoa General Hospital, Vietnam. Transferrin, fetuin, asialo-fetuin, porcine stomach thyroglobulin and bovine submaxillary mucin were purchased from Sigma (St. Louis, MO). Yeast mannan was from Nakarai Chemical (Kyoto, Japan). All other chemicals used in this study were of the highest purity available. Six species of human pathogenic bacteria *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Escherichia coli*, *Enterobacter cloace*, *Bacillus cereus* and *Streptococcus facalis* were obtained from Institute of Pasteur-Nhatrang. Three species of shrimp pathogenic vibrios, *Vibrio alginolyticus*, *Vibrio parahaemolyticus* and *Vibrio harveyi* were obtained from Institute of Aquaculture Research No 3, Nhatrang, Vietnam.

Preparation of extracts and ammonium sulfate precipitates

A 100 g sample of each part of garlic plant (bulb, leaf and root) was homogenized for 1 min in a blender with 6 volumes of 0.02 M phosphate buffer, pH 7.2 containing 0.85% NaCl (PBS), and kept a

4°C for 12 h with occasionally stirring. After filtration through a cheese cloth, the filtrate was centrifuged at 8,000 rpm for 10 min. The supernatants were stored at −20 °C until used. Hemagglutination tests were carried out with erythrocytes from human and various animals in a native state or enzyme-treated with trypsin and papain. To the supernatant (extract), solid ammonium sulfate was slowly added to attain 75% saturation. The mixture was gently stirred and then kept at 4°C for 18 h. The precipitates were recovered by centrifugation at 6,000 rpm for 30 min, dissolved in a small volume of PBS, and thoroughly dialyzed against the same buffer overnight. The nondialyzable fraction was recovered as ammonium sulfate precipitates used for hemagglutination–inhibition, stability and biological activity tests.

Preparation of a 2% suspension of native and enzyme-treated erythrocytes

Each blood sample was washed three to five times with 50 volumes of saline. After washing, a 2% erythrocyte suspension (v/v) was prepared in saline and used as native erythrocytes. Trypsin- or papain-treated erythrocytes were prepared as follows. One-tenth volume of 0.5% (w/v) trypsin or papain solution was added to a 2% native erythrocyte suspension, and the mixture was incubated at 37°C for 60 min. After incubation, the erythrocytes were washed three to five times with saline and a 2% suspension (v/v) of trypsin- or papain-treated erythrocytes was prepared in saline (Hung *et al.*, 2009a).

Hemagglutination assay

Hemagglutination assays were carried out using a microtiter method in a 96-well microtiter V-plate (Hung *et al.*, 2009a). First, 25 µL of serially two-fold dilutions of a test solution were prepared in saline on a microtiter V-plate. To each well, 25 µL of a 2% erythrocyte suspension was added and the mixtures gently shaken and incubated at room temperature for 2 h. Hemagglutination was observed macroscopically and judged as positive in the case that more than 50% of erythrocytes in the well were agglutinated. Hemagglutination activity was expressed as a titer, the reciprocal of the highest two-fold dilution exhibiting positive hemagglutination. The assay was carried out in triplicate for each test solution.

Hemagglutination-inhibition test

Hemagglutination-inhibition tests were carried out using ammonium sulfate-precipitates according to the method previously described (Hung *et al.*, 2009a). First, 25 µL of serially two-fold dilutions of sugar or glycoprotein were prepared in saline. To each well, an equal volume of a hemagglutinin solution with a hemagglutination titer of four was added, and the plate was mixed gently and allowed to stand at room temperature for 1 h. Finally, 25 µL of a 2% suspension of trypsin-treated rabbit erythrocytes was added to each well, and the plate gently shaken and incubated for a further 1 h. Inhibition was observed macroscopically and inhibition activity was expressed as the lowest concentration of sugar or glycoprotein at which complete inhibition of hemagglutination was achieved. The assay was performed in duplicate per sugar compound. The following sugars and glycoproteins were tested: the monosaccharides D-glucose, D-mannose and N-acetylneuraminic acid (sialic acid); and the glycoproteins transferrin, asialo-transferrin, fetuin, asialo-fetuin, yeast mannan, porcine stomach thyroglobulin, bovine submaxillary mucin, and asialobovine submaxillary mucin. Asialo-transferrin and asialobovine submaxillary mucin were prepared by hydrolyses of their parent sialoglycoproteins with 0.05 M HCl for 1 h at 80°C followed by dialysis against saline overnight.

Effects of divalent cations, pH, and temperature on hemagglutination activity

To examine the effects of divalent cations on hemagglutination activity, a 1 mL aliquot of a hemagglutinin solution was dialyzed at 4°C overnight against 100 mL of 50 mM EDTA in PBS. The non-dialyzable fraction was recovered and hemagglutination activity in the presence or absence of divalent cations (10 mM $CaCl_2$ or $MgCl_2$) was determined.

To examine the effect of temperature, a 1 mL aliquot of a hemagglutinin solution was heated at various temperatures (from 30 to100 °C) for 30 min, then immediately cooled on ice, and hemagglutination activity was determined as above. To examine the effect of pH, a 1 mL aliquot of a hemagglutinin solution was dialyzed at 4°C overnight against 0.05 M buffers of various pH (from 3 to10) and then dialyzed against saline to eliminate the pH effect. The non-dialyzable fractions were assayed for hemagglutination activity. The following buffers were used; acetate buffer for pH 3, 4 and 5, phosphate buffer for pH 6 and 7, Tris-HCl buffer for pH 8 and carbonate buffer for pH 9 and 10. Hemagglutination activity was determined with trypsin-treated rabbit erythrocytes (Hung *et al.*, 2009a).

Protein contents

Protein contents were determined by the method of Lowry *et al.* (1951) using bovine serum albumin as a standard.

Screening on antibacterial activity

The antibacterial assay of ammonium sulfate-precipitates from each part of garlic plant was performed by the agar disc diffusion method (Parekh, Chanda, 2006). The bacteria were grown in medium containing nutrient broth and yeast malt broth, and incubated overnight in a shaker 37 °C. The cell concentration of bacteria was determined by measuring the suspension turbidity at 600 nm, and converted to colony forming units (10^5-10^6 CFU/ml) using a calibration curve. As a positive reference, ampicillin solution (1.0 mg/mL) in a medium was examined in the same way. As a negative control without both precipitate and ampicillin was incubated in the similar way. The disc (0.6 cm) was saturated with 20 µL of the test compound or ampicillin, allowed to dry and then placed on the upper layer of the seeded agar plate. The plates were incubated overnight at 37°C. Antibacterial activity was determined by measuring the diameter of the zone of inhibition (mm) surrounding bacterial growth.

RESULTS AND DISCUSSION

Hemagglutination activity from different parts of garlic plant

Extracts from three parts of garlic plant showed relatively strong activities with enzyme-treated rabbit erythrocytes, but no hemagglutination with the other types of erythrocytes irrespective of treatment with enzymes (Table 1).

Sugar-binding specificities

From the 3 species, carbohydrate-binding specificity of each hemagglutinin was examined for hemagglutination–inhibition test with a series of sugars and glycoproteins
using ammonium sulfate precipitates prepared from each extract. The hemagglutination activities of these hemagglutinins were not inhibited by any of the monosaccharides examined. On the other hand, their hemagglutination activities were inhibited by glycoproteins bearing high mannose *N*-glycans and complex *N*-glycans. The hemagglutination–inhibition profiles with a variety of glycoproteins differed depending on hemagglutinin species (Table 2). The hemagglutination activity of garlic bulb and leaf was inhibited by yeast mannan and asialo-porcine thyroglobulin, both have high mannose *N*-glycans in molecular structures. Porcine thyroglobulin did not exhibit any inhibitory activity even at concentration of 2 mg/mL. This glycoprotein bears both high-mannose type (unit A-type) and complex type (unit B-type) oligosaccharides. Among the unit B-type, the major *N*-glycans contain at least 9 different structures consisting of mono- and disialylated (α1–6) fucosylated bi-, triantennary structures terminated either with (α2–3) or (α2–6)-linked sialic acid or (β1-4)-linked galactose residues (Yamamoto *et al.*, 1981). The elimination of sialic acid residues of porcine thyroglobulin enhanced inhibitory potential of parental glycoprotein, clearly indicating that the presence of sialic acid as a terminal residue affected the activity of the carbohydrate toward these hemagglutinins. The yeast mannan, which bears high mannose *N*-glycans with the (α1-6) linkage in its backbone and (α1-3) linkage in this side chains, showed strong inhibitory activity toward three hemagglutinins. The data indicate that the garlic bulb and leaf each contain, at least, a lectin specific for high-mannose type *N*-glycans, especially hemagglutinin from the garlic leaf showed the strongest high-mannose binding specificity among three hemagglutinins examined (Table 2). Practically, the mode of molecular recognition toward high mannose type *N*-glycans has also been intensively reported for lectins from various sources, such as lectin from bacterium *Pseudomonas fluorescens* (Sato *et al.*, 2012), the legume lectin ConA (Naismith, Field, 1996), the monocot mannose-binding lectins (Barre *et al.*, 1996), lectins from garlic bulb and leaf (Dam *et al.*, 1998), lectins from the cultivated macroalgae (Hori *et al.*, 2007; Hung *et al.*, 2009b, 2011, 2014), and lectins from cyanobacteiria (Ziółkowska, Wlodawer, 2006). All them showed the different binding affinity in the structures of branched oligomannosides of high-mannose type *N*-glycans. In contrast, the hemagglutinin from garlic root showed distinct carbohydrate binding specificity compared with that of the hemagglutinins from the garlic bulb and leaf. The hemagglutination activity of hemagglutinin from garlic root was inhibited by asialo-fetuin, porcine thyroglobulin and its derivative, but was not inhibited by yeast mannan even at concentration of 2 mg/mL. Fetuin bearing both complex type *N*-glycans and *O*-glycans and porcine stomach mucin bearing *O*-glycans were no inhibitory, whereas asialo-fetuin was moderately inhibitory, indicating that that the

presence of sialic acid as a terminal residue prevented interaction between hemagglutinin and fetuin (Figure 1). The data indicate that the garlic root contains, at last, a lectin specific for complex type *N*-glycans that can recognize the terminal Gal (β1-4) residues. The hemagglutination–inhibition profiles are diverse, depending on the originating species. The results suggest the presence of lectins specific for high mannose *N*-glycans and complex *N*-glycans in parts of garlic plant.

Table 1. Hemagglutination activities of extracts from parts of garlic plant. The hemagglutination activity is expressed as a titer that is the reciprocal of the highest two-fold dilution exhibiting positive agglutination.

Species	Rabbit			Chicken			Human A			Human B			Human O		
	Na	Tb	Pc	N	T	P	N	T	P	N	T	P	N	T	P
Garlic bulb	-	16	4	-	-	-	-	-	-	-	-	-	-	-	-
Garlic leaf		32	4							-					
Garlic root	-	128	512	-	-	-	-	-	-	-	-	-	-	-	-

[a] Native erythrocytes. [b] Trypsin-treated erythrocytes. [c] Papain-treated erythrocytes. - No hemagglutination.

Table 2. Hemagglutination-inhibition test of the hemagglutinins from parts of garlic plant. Values indicate the lowest concentration of sugar (mM) and glycoprotein (μg/mL) at which complete inhibition of hemagglutination (titer 4) was achieved.

Sugar & glycoprotein	Garlic bulb	Garlic leaf	Garlic root
Sugar (mM)			
Monosaccharides [a]			
Glucose			
Mannose			
Sialic acid			
Glycoprotein (μg mL^{-1})			
Transferrin			
Fetuin			
Asialo-fetuin			250.0
Porcine thyroglobulin			125 0
Asialo-porcine thyroglobulin	500.0	125 0	166 6
Yeast mannan	500 0	62.5	
Porcine stomach mucin			
Asialo-Porcine stomach mucin			

[a] The monosaccharides examined are described in Materials and methods.
- Indicates no inhibition at 100 mM for monosaccharides and at 2000 μg/mL for glycoproteins.

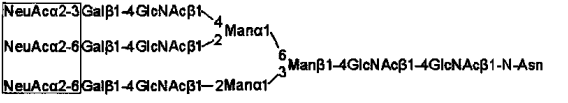

Figure 1 The sialic acid residues (Squars) of fetuin affected negatively to activity of hemagglutinin from garlic root

Effects of divalent cations, pH, and temperature on hemagglutination activity

The effects of pH and temperature on hemagglutination activity of the hemagglutinins from some active species shown in Figure 2. Most of the hemagglutination activities of these hemagglutinins were unchanged after being dialyzed against 50 mM EDTA and in the presence of 10 mM $CaCl_2$ or $MgCl_2$. Addition of $CaCl_2$ or $MgCl_2$ at 10 mM concentration restored almost the total hemagglutination activity initially. The hemagglutination activities of hemagglutinin from garlic bulb was also thermostable because its activity was unchanged by heating at 90 °C for 30 min, however, the activity slightly decreased as incubation temperature exceeded 90 °C (Figure 2a). On the other hand, the hemagglutination activities of hemagglutinin from garlic leaf and root were heat labile because the activities was significantly decreased as the incubation temperature exceeded 50 °C and 60 °C, respectively (Figure 2a).

Three hemagglutinins from parts of garlic plant examined maintained their activities over a range of pH values between 5 and 8 with a slight decrease in activity in more acidic and alkaline media. The activity of hemagglutinin from garlic bulb was unchanged at a pH range between 3 and 9 (Figure 2b).

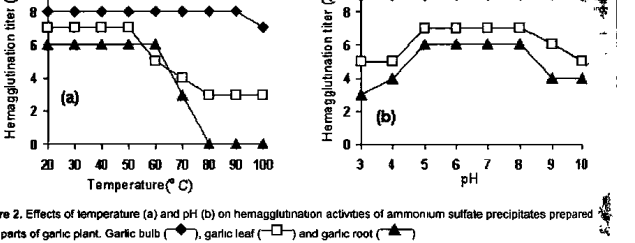

Figure 2. Effects of temperature (a) and pH (b) on hemagglutination activities of ammonium sulfate precipitates prepared from parts of garlic plant. Garlic bulb (◆), garlic leaf (□) and garlic root (▲)

Antibacterial activity

The antibacterial activity of hemagglutinins from parts of garlic plant was examined with six species of human pathogenic bacteria *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Escherichia coli*, *Enterobacter cloace*, *Bacillus cereus* and *Streptococcus facalis* and 3 species of shrimp pathogenic marine bacteria *Vibrio harveyi* *V. alginolyticus* and *V. parahaemolyticus*. Hemagglutinin from garlic bulb inhibited the growth of *Enterobacter cloacae* with the diameter of the inhibitory zone was 11 mm at 74.76 mg/mL concentration, whereas hemagglutinin from garlic leaf showed the inhibitory zone of 12 mm at 10.82 mg/mL concentration, which was much lower than that of hemagglutinin from garlic bulb (Figure 3). Three hemagglutinins did not affect the growth of other bacteria tested. Standard ampicillin (1.0 mg/mL) was also used along with the hemagglutinins for comparison, where it showed the diameter of the inhibitory zone was 12 mm. The degrees of inhibition at 10.82 mg/mL concentrations of hemagglutinin from garlic leaf was comparable to that of ampicillin (1.0 mg/mL), although the chemical structures of these compounds are clearly distinct. The antibacterial activities have been reported for lectins from various biological sources, such as lectin from *Araucaria angustifolia* seed showed antibacterial activity against Gram-negative and Gram-positive strains (Santi-Gadelha *et al.*, 2006), lectin from *Bufo arenarum* skin had strong activity against Gram negative bacteria (*Escherichia coli K12*

4100 and wild strains of *Escherichia coli* and *Proteus morganii*) and Gram positive bacteria (*Enterococcus faecalis*) (Riera *et al.*, 2003) or lectin from *Archidendron jiringa* seed showed activity against *Bacillus subtilis*, *Staphylococcus aureus*, and *Candida albicans* (Charungchitrak *et al.*, 2011). Therefore, the mode of bacteria-agglutination lectins are diverse, depending on the originating species. The result suggests that bacterium *E. cloacae* have mannoside or mannoside-like structure(s) on the cell surface which might respond as a receptor(s) for hemagglutinins. Thus, the garlic leaves are promising natural antimicrobial agents with potential applications in pharmaceutical industry for controlling the pathogenic bacteria.

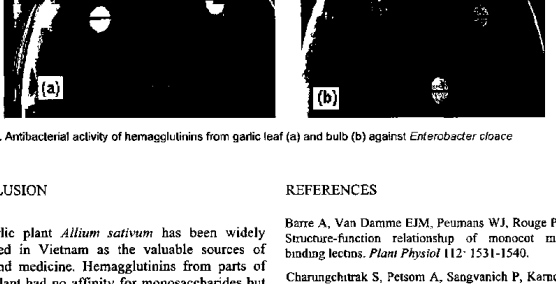

Figure 3. Antibacterial activity of hemagglutinins from garlic leaf (a) and bulb (b) against *Enterobacter cloace*

CONCLUSION

Garlic plant *Allium sativum* has been widely cultivated in Vietnam as the valuable sources of spice and medicine. Hemagglutinins from parts of garlic plant had no affinity for monosaccharides but instead for glycoproteins bearing *N*-glycans. Their hemagglutination activity was stable over a wide range of pH and temperature and was not affected by divalent cations. Carbohydrate binding specificity of hemagglutinins from parts of garlic plant showed distinction among them, hemagglutinins from garlic leaf and bulb recognized high-mannose type *N*-glycans, whereas hemagglutinins from garlic root bond to complex type *N*-glycans, indicating that each part of garlic plant contains different lectins. Hemagglutinin from garlic leaf and bulb inhibited the growth of bacterium *Enterobacter cloace*, but did not affect other bacteria examined. These obtained results suggest that the parts of garlic plant may be good sources of useful lectins for many biological applications including as an anti-bacterial reagent.

Acknowledgements: *This research was supported from the grant of Department of Science and Technology of Khanhhoa Province in the period of 2013-2015.*

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MÔ TẢ ĐẶC TÍNH VÀ HOẠT TÍNH SINH HỌC CỦA HEMAGGLUTININ TỪ CÁC BỘ PHẬN CỦA CÂY TỎI (*ALLIUM SATIVUM*)

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TÓM TẮT

Dịch chiết từ các phần củ, lá và rễ của cây tỏi được thu ở Huyện Vạn Ninh, Tỉnh Khánh hòa đã được kiểm tra hoạt tính ngưng kết máu với hồng cầu người và động vật ở cả dạng tự nhiên và dạng đã được xử lý enzyme. Tất cả dịch chiết thu được đã ngưng kết với ít nhất một dạng hồng cầu được sử dụng. Hoạt tính mạnh đã được phát hiện trong các dịch chiết từ củ, lá và rễ của tỏi với hồng cầu thỏ được xử lý enzyme. Dùng các kết tủa với ammonium sulfate thu được từ các dịch chiết để kiểm tra đặc tính liên kết đường với các đường đơn và các glycoprotein khác nhau, khả năng bền với nhiệt độ, pH và ảnh hưởng của cation hóa trị hai đến hoạt tính ngưng kết hồng cầu. Hoạt tính của các hemagglutinin không bị ức chế bởi các đường đơn, nhưng đã bị ức chế bởi một số glycoprotein khác nhau, phụ thuộc vào mẫu hemagglutinin. Hoạt tính của hemagglutinin từ lá và rễ cây tỏi đã bị ức chế bởi *N*-glycan dạng high-mannose, trong khi đó hoạt tính của hemagglutinin từ rễ tỏi lại bị ức chế *N*-glycan dạng phức đã chỉ ra rằng mỗi bộ phận của cây tỏi chứa các lectin khác nhau. Hoạt tính của các hemagglutinin bền trong một phạm vi của nhiệt độ, pH và không phụ thuộc vào cation hóa trị hai. Các hemagglutinin từ lá và củ tỏi đã ức chế sự phát triển của vi khuẩn *Enterobacter cloacae*, nhưng không ức chế sự phát triển của các vi khuẩn khác đã được kiểm tra. Kết quả thu được trong nghiên cứu đã cho thấy rằng các bộ phận của cây tỏi có thể là một nguồn lectin hữu ích cho nhiều sử dụng trong sinh học.

Từ khóa: *Allium sativum, Cây tỏi, Đặc tính liên kết Carbohydrate, Đồ bền, Hoạt tính kháng khuẩn, Hemagglutinin, Lectin*

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