CHAPTER I

INTRODUCTION

1. PROBLEMS AND RESEARCH RATIONALE

Chrysomya megacephala (Fabricius), the Oriental latrine fly, is a medically important blow fly species worldwide including Thailand. The adult adapts its way of life relatively well in the human environment; feeding and breeding on material filth. Alternate movement between filth and human food enables the adult *C. megacephala* to be a mechanical transmitter of numerous pathogens, which may cause diseases (e.g. diarrhea, gastroenteritis, ulcers, nosocomial infections, cholera, dysentery) in humans. Adult *C. megacephala* also presents itself as pestiferous not only in human dwellings, but also economic livestock. High populations of flies can lead to a pessimistic psychological impact, as a reminder of unhygienic conditions in the environment. Moreover, their larvae can cause myiasis in humans and livestock. Regarding this, a strategy to control fly populations is mandatory.

The citations on the following pages follow the style and format of the Journal of Medical Entomology

Hitherto, many methods have been implemented to suppress fly populations, with the most used being insecticidal application. In turn, the massive and regular use of these insecticides can be hazardous to humans and the environment, and generate insecticide resistance. Therefore, alternative ways that have less effect on humans, such as biological control agents or biopesticides, should be investigated.

In insects, the alimentary tract is a vital system for their life, and involves digestion and absorption of nutrients, regulation of hemolymph ionic composition and pH, detoxification, and production of semiochemical compounds such as pheromones. In recent years, some biological substances such as bacterial toxins, crude plant extracts or an active compound extracted from plants have been reported in insects as having some insecticidal property directly on the alimentary tract, or indirectly to other organs. For example, application of azadirachtin extracted from the neem tree by feeding, affects the fecundity of the fly, *Ceratitis capitata*, or mosquitoes, *Culex tarsalis* and *Culex quinquefasciatus*; while such feeding in the fly larvae, *Musca domestica* or *Stomoxys calcitrans*, inhibits development. Recently, pathology of the midgut surface of the mosquito, *Aedes aegypti*, caused by the bacterium, *Bacillus thuringiensis*, was clearly shown using scanning electron microscopy (SEM). A large hole and blister were evident in the midgut wall, according to the exposure of Cry-IVB toxin produced by this bacterium. So far, many researchers have reported the ultrastructural study of the alimentary tract in several groups of insects (e.g. mosquito, ant, bee, tick, bot fly, fruit fly, and sand fly) that are involved in pathogen transmission. As for *C. megacephala*, there is no report in the literature on the ultrastructure of the alimentary system. Therefore, the objective of this study was to gain more insight into the morphological feature of the alimentary tract of *C.*

megacephala, both in the larvae and adults, using light microscopy (LM), scanning and transmission electron microscopy (TEM). This information would establish a database of this species, which would be useful in understanding their functional role and serving as knowledge to address a strategy to control this fly species in the future.

2. LITERATURE REVIEW

2.1 Bionomic and medical importance of *Chrysomya megacephala*

Classification and distribution

Chrysomya megacephala, the Oriental latrine fly, is among the most pestiferous filth flies known, particularly in tropical countries including Thailand. This blow fly has been classified as follows: Phylum Arthropoda, Class Insecta, Order Diptera, Suborder Cyclorrhapha, Family Calliphoridae, Subfamily Chrysomyinae, Genus *Chrysomya*, Species *Chrysomya megacephala* (Fabricius, 1794).

C. megacephala has expanded its range tremendously in the last three decades, and is widely distributed throughout Asian regions, Australasia, the Pacific region and South Africa to America. It is now well established in the southern area of the United States (Kurahashi and Chowanadisai 2001). In Thailand, it is the most abundant fly species collected and among blow flies (Sucharit et al. 1976, Tumrasvin et al. 1978, Sucharit and Tumrasvin 1981).

External morphology and life cycle

C. megacephala is a holometabolous insect, having 4 distinct stages in its life cycle: egg, larva, pupa and adult. Its egg is creamy-white banana shaped, 1.5-1.6 mm in length. Under natural temperature in Thailand, the egg stage lasts within 1 day and becomes larva (maggot), which is creamy-muscoid shaped, with a worm-like appearance. During the larval stage, flies pass through 3 different stages or instars by moulting. In the third instar, the anterior spiracle has 11-13 branches on the second segment or prothorax (Sukontason et al. 2004). In the caudal segment, there are two posterior spiracles, each having three straight slits. Mature larvae are up to 16 mm long. All three instars take ~100 hours to develop. The larval stage is very active and ravenous, and competitors are crowded out. After post-feeding, the pre-pupae migrate from the breeding site to reach a dry area to pupate. After that, the skin of the third instar becomes rigid, hardened and darkened before contracting to a barrel-like form. This surrounding hardened skin is called a puparium, which is mahogany brown when mature. Then, the newly emerged fly breaks out from the pupal case. The adult fly has a stout body with a noticeably large head. The eyes are unusually large and very prominent in shades of red. The body of the adult is relatively large, being 8-11 mm in length, metallic greenish blue with purple reflections. In males, the head has two compound eyes touching in the middle of the frons. The facets of the upper two-thirds are greatly enlarged and sharply demarcated from the small facets in lower third. In females, two compound eyes are separated by a broad fron and the upper facets are not strikingly enlarged and not demarcated from the lower ones. The development of *C. megacephala* at 27°C and various developmental events were completed by all larvae at the following ages: egg hatch, 18 hr; first moult, 30 hr; second moult, 72 hr; pupariation, 144 hr; and adult emergence, 234 hr (Wells and Kurahashi 1994). Adult longevity is dependent on temperature and humidity. At temperatures of 25-29°C and 75% relative humidity, flies live an average of 54 days (90 days maximum); while at lower humidity they appear to live longer (Greenberg 1973).

Biological behavior

Adult *C. megacephala* adapts its life to the human environment by feeding and breeding on almost anything with nutritional value, such as organic waste and excrement. Thus, it is a hemisynanthropic to eusynanthropic exophilous species. It has a pronounced activity peak during the heat of the afternoon, and is one of the first species to become active in the early morning and one of the last to depart carrion at nightfall. At night it normally rests, although it adapts to artificial light to some extent. Adults are commonly found near human dwellings and they are a nuisance in slaughterhouses, and on meat, fish, sweets, fruits and other foodstuffs in market places. They are strongly attracted to carrion and excrement for breeding purposes (Greenberg 1973), and once they have settled on carrion, they are not easily disturbed. Adults have a habit of entering dwellings in search of suitable oviposition sites such as garbage, high humid areas, decaying animals or corpses; but they seldom oviposit in isolated human excrement. Females lay 150-300 eggs in each oviposition. The larvae need high humidity and temperature for good development. They breed equally well in carrion and human feces in cesspits; however, larvae have been reported from isolated patches of cow dung. As for their behavior, adult flies are mainly active during the day when they feed and mate. Adult activities have been reported to associate with age; the young have quite active movement, including mating; while in the old or those more than 30 days are sluggish and/or clumsy (Methanitikorn 2005).

Medical importance

C. megacephala is a ubiquitious fly that has impact on humans and animals in many ways, and it acts as a mechanical carrier of various pathogens to both. Factors promoting this fly as a good carrier are (i) eusynanthropy (ii) feeding habit and (iii) dispersal and great flight activity (Greenberg 1971). Other factors such as unhygienic sanitation, availability of food, breeding place and proper climatic conditions are also involved. Thus, adults visit different food sources, and make contact with microbe-rich substrates, such as manure, carcass, and human or livestock food. Their alternate movement between filth and human food may make them ideally mechanical vectors for transmitting pathogens (e.g. bacteria, virus, protozoa, and helminth eggs) (Greenberg 1973, Sulaiman et al. 2000, Sukontason et al. 2007), which may cause diseases (e.g. gastroenteritis, ulcers, nosocomial infections, cholera, and dysentery). In Thailand, several species of bacteria were isolated from adult *C. megacephala*, including *Aeromonas hydrophila*, *Edwardsiella tarda* and *Vibrio cholerae* non-01, which are the causative agents of diarrheal disease. Five other possible bacterial species are included, i.e. *Aeromonas sorbia*, *Citrobacter freundii, Escherichia coli, Providencia alcalifaciens* and *Pseudomonas aeruginosa* (Sukontason et al. 2007).

Besides, *C. megacephala* can cause annoyance to humans and livestock. Either small or large numbers of adults are pestiferous, by disturbing humans during work or at leisure. Their presence can lead to a negative psychological impact as a reminder of unhygienic conditions in the environment. High populations of flies, particularly in the summer, emerge from livestock farms to neighbouring domestic settlements and may result in considerable social problems for humans. Adults can also bother economically important animals by disturbing their rest, which could lead to a decrease in production, thereby causing economic loss in poultry or dairy farms (WHO 1986). Furthermore, the maggot of *C. megacephala* can induce myiasis in both humans and animals, and such cases have been reported (Zumpt 1965, Kumarasinghe et al. 2000).

2.2 General alimentary system of insects (Romoser and Stoffolano 1994, Chapman 1998)

The alimentary system of insects is involved in the initial steps of nutrient transportation to individual cells. Ingestion, tritulation (chewing), digestion, absorption into the hemolymph, and egestion are all associated with this system. Insects possess a tubular (often coiled) alimentary canal, which extends from the anterior oral opening (the mouth) to the posterior anus. The gut is formed by a one-cell-thick layer of epithelial cells, and a noncellular basement membrane (basal lamina) is present on the haemocoel side of this layer of cells. This anatomy is one of the major reasons for the biological success of insects in their ability to eat, digest and utilize an enormous diversity of food, and it provides a better appreciation of the extreme diversity observed in the modifications and specializations of the alimentary system of insects. The structural and biochemical modifications of the alimentary system of a particular species reflect the type of food eaten. Because of the variety in dietary requirements among the different life stages and the differences between the sexes, one finds both structural and functional variations in the way food is obtained, stored, processed and absorbed. For example, adult blow flies living in a natural environment have a diversity of consumption behavior, which is different from that in laboratory flies fed with high-protein diets, such as fresh pork liver for the larvae and mixed sucrose solution and multivitamin syrup for the adults. Butterfly larvae chew up plant material, whereas adults may suck up only floral nectar. Female mosquitoes bite and suck up a vertebrate blood meal, whereas males do not.

Morphology and physiology of the gut relate to the dietary differences in the following ways. Insects that take solid food typically have a wide, straight, short gut with strong musculature and obvious protection from abrasion (especially in the midgut, which has no cuticular lining). These features are most obvious in solid-feeders with a rapid throughput of food, for example the plant-feeding caterpillars. In contrast, insects feeding on blood, sap or nectar usually have long, narrow, convoluted guts to allow maximal contact with the liquid food; here, protection from abrasion is unnecessary. From a nutritional viewpoint, most plant-feeding insects need to process large amounts of food because nutrient levels in leaves and stems are often low. Their gut is usually short and without storage areas, as food is available continuously. By comparison, a diet of animal tissue is nutrient-rich and, at least for predators, well balanced. However, the food may be available only intermittently (such as times when a predator captures prey or a blood meal is obtained) and the gut normally has a large storage capacity.

Morphologically, the alimentary canal of insects is divided into three distinct regions; the anterior foregut or stomodaeum, the midgut or mesenteron, and the posterior hindgut or proctodaeum, with sphincters (valves) controlling food-fluid movement between regions. The foregut is concerned with ingestion, storage, grinding and transportation of food to the midgut. Here, the digestive enzymes are produced and secreted; and absorption of the products of digestion occurs. The material remaining in the gut lumen together with urine from the Malpighian tubules then enters the hindgut, where absorption of water, salts and other valuable molecules occurs prior to elimination of the feces through the anus. The gut epithelium is one cell layer thick throughout the length of the canal and rests on a basement membrane surrounded by a variably developed muscle layer. Both the foregut and hindgut have a cuticular lining, whereas the midgut does not. The foregut and hindgut arise as invaginations of the ectoderm, which also gives rise to the integument, and the gut epithelial cells are continuous with the epidermal cells. The midgut is generally believed to be of endodermal origin. Longitudinal and circular muscles are usually associated with each of the three regions and, by means of rhythmical peristaltic contractions, move food along the alimentary canal. Each region of the gut displays several local specializations, which develop differently in different insects, depending on diet. The alimentary canal tends to be shorter in species that exist on high-protein diets and longer in those with high-carbohydrate diets, but there are many exceptions.

- **Foregut**

The foregut is commonly differentiated into the pharynx, esophagus, crop and proventriculus. Although there is considerable variation in the foregut, several morphological regions can usually be recognized. The true mouth lies at the base of the hypopharynx within the cibarium (preoral cavity) formed by the mouthparts. The true mouth communicates directly with the pharynx, a structure that varies greatly among different insects. The pharynx is concerned with the ingestion and backwards passage of food. The cibarium or pharynx or both may be highly modified, forming pumps with well-developed extrinsic visceral musculature. The esophagus is next to the pharynx, and commonly enlarged posteriorly to form the crop. In some insects, the posterior enlargement may be in the form of one or more blind sacs, or diverticula. This distensible crop found in the Diptera, Lepidoptera and Hymenoptera is an important evolutionary adaptation because it permits the adults to store carbohydrates. The walls of the crop are folded longitudinally and transversely. The folds become flattened as the crop is filled, usually permitting a very large increase in volume. The proventriculus is immediately posterior to the crop. The luminal side of this structure often bears sclerotized denticles (teeth) or spines. The proventriculus typically communicates with the midgut by means of an intussusception, which consists of both foregut and midgut tissue. This structure is called the stomodael valve. Midgut tissue (cardial epithelium) surrounds the foregut portion of the stomodael valve.

The foregut, with its morphological divisions, serves mainly as a conducting tube, carrying food from the cibarial cavity to the midgut. The enlarged crop functions, at least in part, as a site of temporary food storage and partial digestion in some cases. The proventriculus, when armed with denticles, may serve as a grinding structure in addition to the mouthparts. Spines in the proventricular region may act together as a food sieve or filter. The differences in the proventriculus structure of various insect groups are related to the type of food eaten. For example, Hemiptera, a fluid-feeder insect, lacks a proventriculus. The stomodael valve is developed to varying degrees in different insects. Whether this structure actually acts as a valve in most insects is not known. In addition to the sac-like diverticula of some insects (e.g. crop in flies), some species whose larvae feed on resinous plants may have diverticula in the esophagus that store resins. With the aid of powerful circular muscles around these diverticula, the insect is able to defend itself by ejecting the resins onto a predator. The resins act as deterrents and are extremely effective in protecting the larva. Although the foregut is not the major digestive region of the alimentary canal, some digestion may occur in the crop by the action of salivary enzymes and enzymes regurgitated from the midgut; for example, in some Orthoptera. The foregut intima is impermeable, except for the possible passage of small amounts of lipid in certain insects. Thus, the foregut probably plays no major role in the absorption of materials into the hemolymph.

- **Midgut**

The midgut is the chief site for the production and secretion of digestive enzymes, digestion and absorption. Depending on the species and dietary intake, the midguts of various insects may differ considerably with respect to regions of secretion and absorption. The midgut typically begins with the cardial epithelium (cardia) associated with the stomodael valve. There is a common group of diverticula, the gastric caeca, immediately posterior to the cardia. The number of these caeca varies in different species, and similar pouches may be present in other sections of midgut. The remainder of the midgut, the ventriculus, is usually a somewhat enlarged sac and serves as the insect's stomach. In some insects, the midgut is divided into distinct regions; for example, two, three and four regions have been identified among various true bugs (Hemiptera).

The midgut epithelium of most insects is comprised of three basic cell types: columnar digestive, regenerative and endocrine. The principal cell type is the digestive cell, which is typically columnar with a striated border formed by microvilli on the luminal side. On the hemocoelic side, the basal plasma membrane is characteristically infolded, and mitochondria are associated with these folds. These cells usually contain extensive rough endoplasmic reticulum, much of which is probably involved in the synthesis of digestive enzymes. When they are synthesizing enzymes, the principal cells are characterized by the presence of rough endoplasmic reticulum stacks and Golgi bodies. In most insects, synthesis appears to occur at the time of secretion into the gut lumen so that stores of enzymes do not accumulate in the cells. The microvilli and folded basal plasma membrane provide the extensive surface area, which is expected to be in actively absorbing and secreting cells. Recently, considerable attention has been given to the ultrastructure of the midgut because it serves as the principal site for enzyme induction processes against toxic substances that are either in the natural diet or applied by humans as insecticides. It is also the major site where many pathogens and/or parasites gain entrance to either the insect host or vector, and it may prove to be the largest endocrine organ of the insect.

The principal cells of the midgut have a limited life and, in most insects, they are continually replaced from regenerative cells at the base of the midgut epithelium. These cells replace the actively functioning gut cells that die or degenerate as a result of holocrine secretion. Regenerative cells may be dispersed individually among the epithelial cells or concentrated in discrete groups as nidi or crypts. When present, the gastric caeca function to increase the surface area for either secretion of digestive enzymes or absorption of water, ions, glucose, amino acids and other nutrients. Digestion in certain insects also takes place in the gastric caeca. However, the evolutionary trend in holometabolous insects is toward the loss of the caeca.

A peritrophic matrix, more correctly termed the peritrophic membrane or peritrophic envelope, forms a delicate lining layer to the midgut, separating the food from the midgut epithelium. It is usually made up of a number of separate laminae, which are extracellular secretions. In some insects, the peritrophic matrix comprises two different types of lamina. Each consists of a network of microfibrils, usually chitin, which may be randomly oriented or regularly arranged to produce an open lattice structure. The microfibrils are embedded in a matrix of proteins and glycoproteins. The peritrophic matrix occurs in most insects, although it apparently is not present in most Hemiptera. These insects have a membranous covering of the microvilli, which may be analogous to a peritrophic matrix. In adult Diptera, a peritrophic matrix is absent from those unfed, but forms within hours of one taking a meal. Only a blood meal induces the formation of the peritrophic matrix in adult mosquitoes; a nectar meal is not followed by its production in either females or males. In some beetle larvae, just before pupation, the peritrophic matrix continues production after feeding has ceased and the gut emptied of undigested material. This peritrophic matrix is extruded from the anus and collapses and dries, forming a thread that is used like silk to form a cocoon. The peritrophic matrix performs a number of different functions. As it is positioned between the food and midgut epithelium, it plays key roles in the intestinal biology of insects. It can protect the midgut epithelium from mechanical damage and insult from pathogens, toxins and other damaging chemicals. Moreover, it acts as a semipermeable membrane regulating the passage of molecules between the different midgut compartments.

- **Hindgut**

The hindgut is composed of cuboidal epithelial cells. It commences with the pylorus, which is associated with a variable number of typically slender, elongated excretory structures, and the Malpighian tubules, which usually contain a valvular structure, the pyloric valve. The Malpighian tubules are used for indicating the begining of the hindgut. The hindgut is divisible into a tubular anterior intestine, just posterior to the Malpighian tubules, and a highly muscularized, enlarged rectum, which terminates at the anus. The anterior intestine may be differentiated into an anterior ileum and posterior colon. The ileum of most insects is a narrow tube running back to the rectum. Only a single cell type is present in the ileum of many insects. The rectum is usually an enlarged sac with a thin epithelium except for certain regions, the rectal pads, in which the epithelial cells are columnar. There are usually six rectal pads arranged radially round the rectum. They may extend longitudinally along the rectum or be papilliform as in Diptera. These structures receive an extensive supply of tracheae and are metabolically very active. They play an especially important role in the excretory system.

The hindgut is the major region of the insect involved in recycling. Here, required materials are reclaimed while excess or waste materials are trashed. Functions of the hindgut include (1) water and ion absorption from urine and feces, (2) a cryptonephridial system for water conservation (the Malpighian tubules come into close contact with the hindgut, thus facilitating water and ion regulation of the hemolymph), (3) pheromone or sex attractant production, (4) respiration in the larva of some insects, such as dragonflies, and (5) modifications in structure for housing symbiotic microorganisms.

Generally, little or no digestion occurs in the hindgut. It serves principally to carry undigested food material away from the midgut, ultimately egesting it from the insect. In the case of insects housing symbionts in the hindgut, however, digested products produced by the symbionts, such as short-chain fatty acids, acetate and butyrate are absorbed by the hindgut. Unlike the foregut intima, the hindgut intima is permeable and allows the passage of at least relatively small molecules. Before egestion, the hindgut absorbs, to varying degrees, water, salts and amino acids previously removed from the hemolymph by the Malpighian tubules; thus, it plays a major role in the water and salt balance of an insect.

2.3 Ultrastructural study on the alimentery organs of insects

The alimentary tract of insects is an extremely important area, interfacing between the inside and outside of insects. It is the "front line" for contact with toxins in food, insecticides ingested orally and various pathogens that enter via the oral route. Therefore, information of the ultrastructure of the alimentary system of insects is specialized. So far, many researchers have investigated the ultrastructure, function or physiology of insect alimentary organs, particularly those of medical, veterinary and agricultural importance. The literature on ultrastructural studies of the alimentary tract of insects could be roughly divided into 2 categories. The first group was the basic ultrastructural morphology, as follows: peritrophic matrix in adult fly *Stomoxys calcitrans* (Diptera: Muscidae) using TEM (Lehane 1997); foregut and cardia of adult fruit fly *Bactocerca dorsalis* (Diptera: Tephridae) using LM, TEM (Lee et al. 1998); midgut structure of adult fruit fly *Bactocerca dorsalis* (Diptera: Tephridae) using LM, TEM (Hung et al. 2000); midgut surface of adult mosquito *Aedes aegypti* (Diptera: Culicidae) using SEM, TEM (Zieler et al. 2000); midgut of adult female sand fly *Lutzomyia intermedia* (Diptera: Psychodidae) using LM, SEM, TEM (Andrade-Coelho et al. 2001); endocrine cell from midgut epithelium of adult female sand fly *Lutzomyia longipalpis* (Diptera: Psychodidae) using TEM (Leite and Evangelista 2001); midgut of larva brown house moth *Hofmannophila pseudospretella* (Lepidoptera: Oecophoridae) using LM (Gerard, 2002); midgut and hindgut of 8 species of adult beetles, *Dendroctonus* (Coleoptera: Scolytidae) using LM, TEM (Silva-Olivares et al. 2003); midgut of larvae and adult female of tick *Haemaphysalis longicornis* (Acari: Ixodidae) using LM, SEM, TEM (Matsuo et al. 2003); midgut of third instar of human bot fly *Dermatobia hominis* (Diptera: Cuterebridae) using TEM (Evangelista and Leite 2003); midgut endocrine cells in adult bee *Melipona quadrifasciatua anthidioides* (Hymenoptera: Apidae) using LM, TEM (Neves et al. 2003); midgut epithelium formation in embryo and larva of wingless insect *Thermobia domestica* (Insecta: Zygentoma) using TEM (Rost et al. 2005); midgut of adult sand fly *Lutzomyia longipalpis* (Diptera: Psychodidae) using SEM, TEM (Secundino et al. 2005); peritrophic matrix structure of adult female mosquitoes *Aedes aegypti*, *Ochlerotatus triseriatus*, *Culex nigripalpus*, *Psorophora columbiae* (Diptera: Culicidae) using LM, TEM (Moncayo et al. 2005); midgut and salivary gland of first instar fly *Dermatobia hominis* (Diptera: Oestridae) using LM, TEM (Evangelista and Leite 2005); midgut of adult female mosquito *Anopheles darlingi* (Dipter: Culicidae) using LM, TEM (Okuda et al. 2005); Malpighian tubules of fire ant *Solenopsis saevissima* (Myrmicinae) using SEM, TEM (Arab and Caetano 2002); salivary gland of adult female mosquito *Culex quinquefasciatus* (Diptera: Culicidae) using LM, TEM (Sais et al. 2003); salivary gland of larva of ant *Pachycondyla villosa* (Hymenoptera: Formicidae) using LM, SEM, TEM (Zara and Caetano 2003); Infrabuccal cavity and anterior pharynx in adult ant *Monomorium pharoanis* (Hymenoptera: Formicidae) using using LM, TEM (Eelen et al. 2004); origin of alimentary tract of larval tick *Ixodes ricinus* (Acari: Ixodidae) using LM, TEM (Jasik and Buczek 2005). The second group of ultrastructural studies on alimentary organs, involved in the application of some pathogens against insects, was limited in the literature as follows; histopathological and ultrastructural effects of endotoxins of bacterium *Bacillus thuringiensis israelensis* in midgut of black fly *Simulium pertinax* larvae (Diptera: Simuliidae) using LM, TEM (Cavados et al. 2004); pathogenesis of West Nile virus in midgut epithelium of mosquito *Culex pipiens* (Dipter: Culicidae) using TEM (Girard et al. 2005); effects of *Bacillus thuringiensis* endotoxin on midgut of larval mosquito *Aedes aegypti* (Diptera: Culicidae) using SEM (Clark et al. 2005).

3. PURPOSE OF THIS STUDY

To describe thoroughly the ultrastructure of alimentary organs of larva and adult *C. megacephala* using LM, SEM and TEM.

4. SIGNIFICANCE OF THE RESEARCH

This study was the first to investigate the ultramorphology of the alimentary organs of *C. megacephala* in detail. The information obtained would increase knowledge on the basic biology of this blow fly, which may be useful for applied research such as fly control in the future.