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The migratory locust (*Locusta migratoria*) as a potential source of protein and biopolymer compounds in the future

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Abstract. *Kleden YL, Mukkun L, Ndapamuri MH, Pamatana F. 2023. The migratory locust (*Locusta migratoria *Meyen) as a potential source of protein and biopolymer compounds in the future. Biodiversitas 24: 5979-5987.* The migratory locust *Locusta migratoria* Linnaeus 1758, is an edible insect posing significant challenges to the agricultural industry in Indonesia, particularly in East Nusa Tenggara (ENT) Province. However, apart from the status of the migratory locust as a highly destructive insect pest, it has great potential as a source of protein, amino acids, and other bioactive compounds. This study aimed to determine the nutritional and other bioactive characteristics of locusts. Proximate analysis was performed using SNI 01-2891-1992 to identify protein, fat, ash, carbohydrates, and energy. The amino acid analysis was conducted using Ultra Performance Liquid Chromatography (UPLC). The chitin from the nymph and imago stages of the locust was obtained through a process including demineralization and deproteinization. Subsequently, the chitin was subjected to deacetylation in order to obtain chitosan. Proximate content analysis shows that locust has promising potential as a source of nutrients in order to address the nutritional problems of the population that are still a problem in Indonesia including in ENT Province. The protein content of locust ranged from 63.72 to 75.26% dry weight. These contents are close to those of egg protein (83%), beef protein (85%), and even most plant proteins, like soybean (81%). The imago stage exhibited the highest total amino acid content, measuring 411.41 mg/100 g, with essential amino acids such as lysine, isoleucine, leucine, valine, phenylalanine, threonine, histidine, and tryptophae. Imago contains chitin from 8.79 to 12.05% dry weight and chitosan from 59.3% to 71.26% by weight of chitin. The study suggests that locusts can be an alternative source of nutrition to dial with stunting in term of their availability of protein and amino acid. Additionally, chitin and chitosan in migratory locusts are promising nutrient sources for agriculture and health applications.

Keywords: Amino acids**,** chitin, chitosan, edible insect, protein, stunting

INTRODUCTION

The demand for food as a means of obtaining essential nutrients is steadily rising in accordance with the growth of the global population. According to projections, it is anticipated that the global population will reach approximately 10 billion individuals by the year 2050. This substantial growth in population is predicted to result in a corresponding surge in the demand for food, estimated to rise by almost 50 percent in comparison to the levels observed in 2013 (FAO 2017). Therefore, alternative sources of food are needed to meet the population's food demand needs and reduce the prevalence of malnutrition. Insects contain high levels of protein and essential amino acids; their massrearing is not difficult so they can be used as a potential source of protein and important nutrients (Amadi and Kiin-Kabari 2016; Ochiai et al. 2020; Rumpold and Schlüter 2015). Protein, fat, and bioactive compounds are found in insects (e.g., polyunsaturated fatty acids, flavonoids, and other unknown compounds with antioxidant activity) (Rumpold and Schlüter 2013; Salama 2020).

The migratory locusts (*Locusta migratoria* Linnaeus 1758) are an edible insect that causes serious problems in Indonesia's farming sector, especially in East Nusa Tenggara (NTT). Several districts on the island of Sumba, Timor, and Flores continually experience damage and losses due to locust attacks. Since 1999, it was reported that 3,254 ha of corn crops in East Sumba failed to harvest due to the locust attack, in 2007 also in North Central Timor District, and from 2009 to 2010, there was a population explosion in TTU, Belu, and West Manggarai (Mukkun 2011). From 2017 to 2021, there were reports of heavy attacks from *L. migratoria* throughout mainland Sumba, namely East Sumba, Central Sumba, West Sumba, and Southwest Sumba, and caused thousands of hectares of rice and maize crop failure (Media Indonesia 2021). On the other hand, the locusts have potential as a source of protein, amino acids, and other bioactive compounds. Previous studies have shown that Orthoptera insects such as crickets, locusts, and grasshoppers contain protein ranging from 40% to 70%, almost the same as the protein content of meat ranging from 78% to 84% (Rumpold and Schlüter 2013). *L. migratoria* is also a source of protein, micronutrients, and other bioactive compounds (Rumpold and Schlüter 2015; Salama 2020). The bioactive compounds in the locust body are also known to function as strong antioxidant compounds that can prevent various diseases in humans, such as heart disease, cancer, diabetes, and skin disorders (Nowak et al. 2016).

In addition, locusts also contain chitin and chitosan as raw materials for various industries such as the food industry, cosmetics, pharmaceuticals, wastewater treatment, paper, textile, and paint industries, and so on (Komariah 2012; Purschke et al. 2018). The nutritional content and bioactive components of locusts vary and are influenced by the type of feed consumed, the stage of development, and environmental factors (Salama 2020; Lange and Nakamura 2021). Chitin has a unique bioactivity, biodegradability, and flexibility combination, making it an attractive type of polymer used in various industrial fields. The characteristics of chitin and its derivatives derived from insects are almost the same as commercial chitin and chitosan derived from crustaceans and other aquatic invertebrates. In addition, chitin and chitosan from insects are non-toxic, safe to use, and easy to breed, so insects are a potential and inexpensive source of chitin and chitosan (Abidin et al. 2020). Based on the previous description, it is necessary to analyze the nutritional content and isolate chitin and chitosan from the migratory locusts that attack Sumba Island to develop alternative nutritional sources and industrial raw materials. Furthermore, using locusts as a source of nutrients may be employed as a strategy to manage locust populations and mitigate damage to food crops. This study aimed to determine the nutritional and other bioactive characteristics of nymphs and adult locusts to utilize them according to their potential.

MATERIALS AND METHODS

Study area

The samples of migratory locusts were obtained from Palanggai Village, Pahunga Lodu Sub-district, and Watupuda Village, Umalulu Sub-district, East Sumba District, East Nusa Tenggara, Indonesia. (Figure 1).

Procedures

Sample collection and preparation

Instar stage 3, 4, and 5 of nymph were obtained from Palanggai Village, Pahunga Lodu Sub-district, East Sumba District, while adults were obtained from Watupuda Village, Umalulu Sub-district, East Sumba District. Nymph and imago samples were taken from different locations because no adult insects were found at the sampling site of nymph. However, the sampling locations exhibit similar characteristics, since they both consist of savannah fields where grasses are the predominant vegetation. The samples were collected from the areas that had not previously been treated with pesticide. Furthermore, samples of locusts were collected at nymph and imago stage, with the assumption that the chemical makeup of these stages would alter due to variations in both the quantity and quality of their diet. Previous studies have demonstrated a significant correlation between diet types and the chemical composition of locusts (Nik et al. 2021; Wang et al. 2022). Kuntadi et al. (2018) also stated that the type and stage of the insect as well as climate factors are involved in determining the nutritional content of the edible insect including migratory locust.

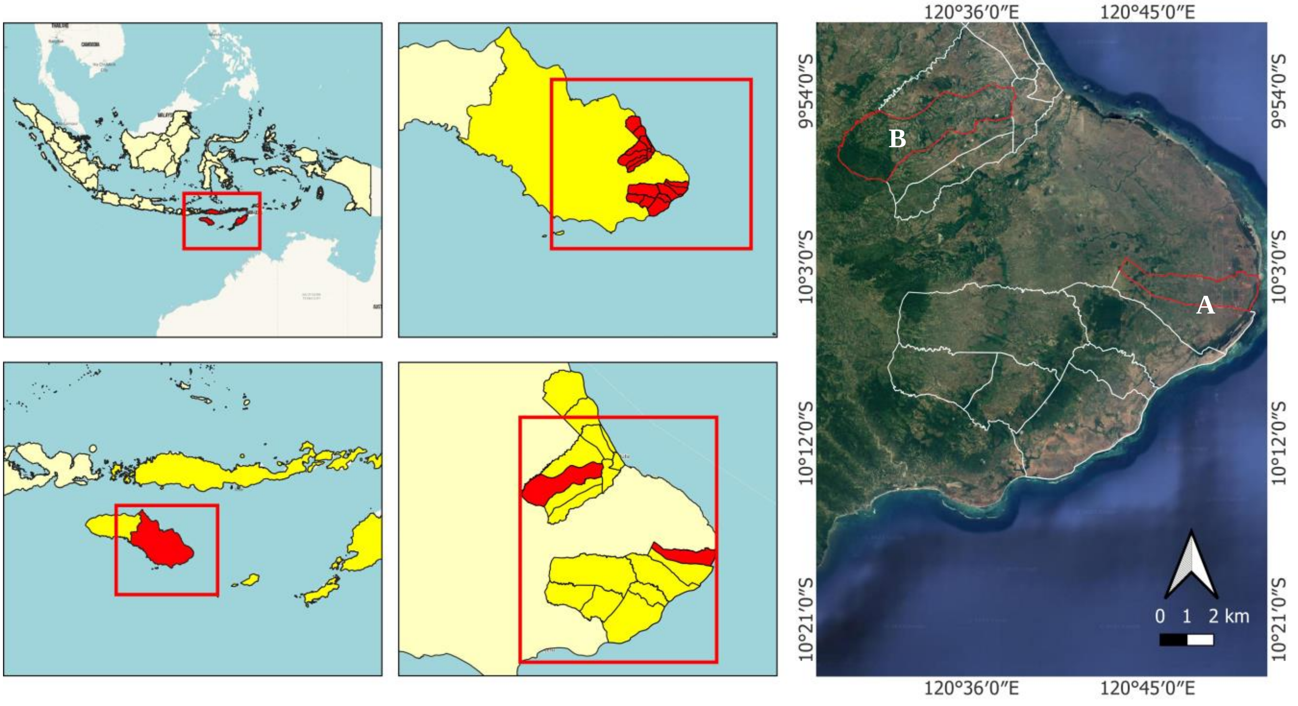

Figure 1. Location of sample collection at A. Palanggai Village, Pahunga Lodu Sub-district and; B. Watupuda Village, Umalulu Sub-district, East Sumba District, East Nusa Tenggara, Indonesia

Insects were captured during nocturnal hours in maize fields and pastures that have not had pesticide application, utilizing nets as the primary method of capture. The captured insects undergo a cleaning process followed by sun drying, which aims to reduce their moisture content to a range of 12 to 14 percent. Subsequently, the desiccated arthropods were pulverized, filtered via a sieve, and subsequently preserved in a freezer for subsequent study.

The distribution and area of food crops affected by *L. migratoria*

The analysis of the distribution and area of food crops caused by the migratory locusts in East Sumba District in 2022 was conducted utilizing secondary data obtained from the Department of Agriculture and Food Resilience. East Sumba District. The compiled data pertains to the magnitude of the locust infestation on agricultural crops such as rice, maize, and peanut. Data on crop damage caused the migratory locust is generated by dividing the percentage of crop area affected and the total planting area. The total area of corn, rice, and nuts affected by the migratory locusts is the sum of the area affected of each village on the same plantation and is presented in the form of a graph. The severity of damage is classified into four distinct categories: mild attack, which encompasses damage ranging from 0 to 25 percent; moderate, which includes damage ranging from 26 to 50 percent; heavy, which encompasses damage ranging from 51 to 80 percent; and vary heavy or severe with damage above 80 percent. The spatial analysis of locust attacks was conducted utilizing the ArcMap 10.8.2 program. The coordinate points of each site were subsequently overlaid onto the administrative territory established by the Indonesian RBI in 2017.

Protein content analysis

Nymph and imago protein content was analyzed using the Kjeldahl method with a N to protein conversion factor of 5.33 (Thiex and Manson 2002). 1 g of the locst's sample was put into a Kjeldahl tube and selenium was added. Following this, 12 mL of concentrated H_2SO_4 were introduced into the tube. The resulting mixture was subjected to digestion within a KjelDigester, maintained at a temperature of 420°C. The results of the digestion were then distilled using 40% NaOH, while the results of the distillation were collected in an erlenmeyer containing 25 mL of 4% H_3BO_3. The distillation results were titrated with 0.2 N HCl until the color changed from green to red.

Fat content analysis

Fat content was analyzed by the gravimetric method (Weibull). A 1 (one) g of sample was added with 15 mL of 25% HCl and 10 mL of distilled water, then boiled for 3 hours. The residue that had been dried was then extracted in a soxlet using hexane. The extraction results were dried and weighed (AOAC 2011).

Ash content analysis

The porcelain cup was dried in an oven at 105ºC for 3 hours and then weighed. Then, 1-2 g of the prepared sample was added to the cup. The cup and sample were dried in an electric furnace at 600°C for 18-24 hours. The sample that was turned into ash was then placed in a desiccator for 1 hour, then the cup's and ash's weight was weighed (AOAC 2011).

Water content analysis

The water content of locusts at different life stages was analyzed using the thermogravimetric method (AOAC 2011). Approximately 1 g sample was put in a weighed Petri dish and then heated in an oven at 105ºC until the weight was constant (24 hours). The difference between the initial and after-drying weights was calculated as dry basis moisture content (% DM).

Carbohydrate calculation

The carbohydrate content is calculated using the by-difference method (AOAC 2011) with the formula:

$$Carbohydrate\ (\%) = 100 - (water\ content + protein + ash + fat)$$

Amino acid content analysis

The total and individual amino acids from the flour of the migratory locust were analyzed using the UPLC (Ultra Performance Liquid Chromatography) method according to Meussen et al. (2014) with modification. As much as 1 g of sample was put into the vialn and HCl was added for hydrolysis purposes. The hydrolysis results were then homogenized by adding aquabides, and then the sample was filtered to accommodate the filtrate. The filtrate obtained was then added to the standard solution and derivatized before being injected into the UPLC. The column employed in this study was C18, whereas the detector was photodiode array detector (FDA). The mobile phase employed was Eluent accq. ultra tag, Aquabides, and it was delivered through a pump system in the form of a gradient. The column temperature was maintained at 49°C. The amino acid levels in the sample were calculated using the ratio of the analyte area to the internal standard, with the following formula:

$$\text{Ration analyte area to internal standard} = \frac{ASpl}{AIs}$$

$$Amino\ acid = \left(ratio\ sample\ and\ standard\ x\ \frac{C\ standard}{1000000}\ x\ \frac{MW\ x\ Vf\ x\ DF}{Wspl\ or\ Vspl}\right)$$

Where:
Aspl : area of amino acid analyte
Ais : internal standard area
MW : amino acid molecular weight (g/mol)
C standard : concentration of amino acid standard solution (pmol/µL)
Vf : final volume of test solution (µL)
DF : dilution factor
Wspl : weight of sample (g)
Vspl : volume of sample

Chitin and chitosan analysis

Chitin and chitosan analysis was carried out using the method described by Puvvada et al. (2012) with modification. Initially, the migratory locust samples were washed and dried at 65°C until their weight remained constant. After drying, samples were immersed in a boiling 4% sodium hydroxide solution for an hour to dissolve proteins and sugars. The samples were then further ground using a blender. The next step was demineralization to remove minerals, especially calcium carbonate. The milled samples were soaked in 1% HCl solution with a ratio of 1:4 for 24 hours. After drained off, 50 mL of 2% NaOH was added to the sample to dissolve the albumen into water-soluble amino acids. The precipitate obtained was washed with distilled water until the pH was neutral, dried in an oven at 50-60°C for 24 hours, and weighed. The chitin yield was calculated by comparing the weight of the chitin obtained to the initial sample weight. Furthermore, the resulting chitin was deproteinated using 3N NaOH solution with a sample and NaOH ratio of 1:10, heated at 90ºC for 60 minutes, and then washed with distilled water until the pH was neutral and dried. The deproteinization results were decolorized by adding 4% NaOCl solution for 10 minutes at room temperature. The resulting chitin was deacetylated into chitosan by removing the acetyl group by adding 50% NaOH at 130°C while stirring for 60 minutes. The dry precipitate obtained is chitosan.

Data analysis

Quantitative data such as chemical properties, chitin, and chitosan composition of locusts w are analyzed by ANOVA, using SPSS IBM 23 followed by the Tukey's least significant difference (LSD) tests at $P<0.05$ level to determine the differences among the different stages. The normality test of the data was performed using the Shapiro-Wilk test at significant difference of 0.05. Meanwhile, the distribution of locusts' attack data is presented in the pictures using the ArcMap 10.8.2 program. The coordinate points of each site were subsequently overlaid onto the administrative territory established by the Indonesian Earth map (Rupa Bumi Indonesia) in 2017.

RESULTS AND DISCUSSION

The distribution and area of food crops caused by migratory locust (*L. migratoria*) in East Sumba District

According to secondary data obtained from the Ministry of Agriculture and Food Sustainability of East Sumba District, it was revealed that the migratory locusts significantly affected plantations across the entirety of the East Sumba District during 2022. The severity of the damage to such crops is classified into the categories of mild attack (0-25%), moderate (25-50%), heavy (51-80%), and very heavy or severe (>80%). Villages Haharu and Kanatang experienced the most severe attacks, which resulted in the destruction of over 80 percent of their maize and rice crops. Waingapu City, Pinupahar, and Kambata Mahambuhang, meanwhile, sustained 50 to 80 percent damage to their food crops (Figure 2 and Figure 3).

Based on extensive data on the area of food crops affected by locusts (Figure 4), it is seen that the locust is a serious threat to the food security system of the population on the island of Sumba. A total of 3,316 hectares of food crops have been negatively impacted by locust, with maize crops experiencing the most severe destruction. Numerous initiatives have been implemented together by the government and agricultural practitioners, encompassing the utilization of pesticides. However, the efficacy of pesticide spraying has been hindered by technical limitations and financial constraints.

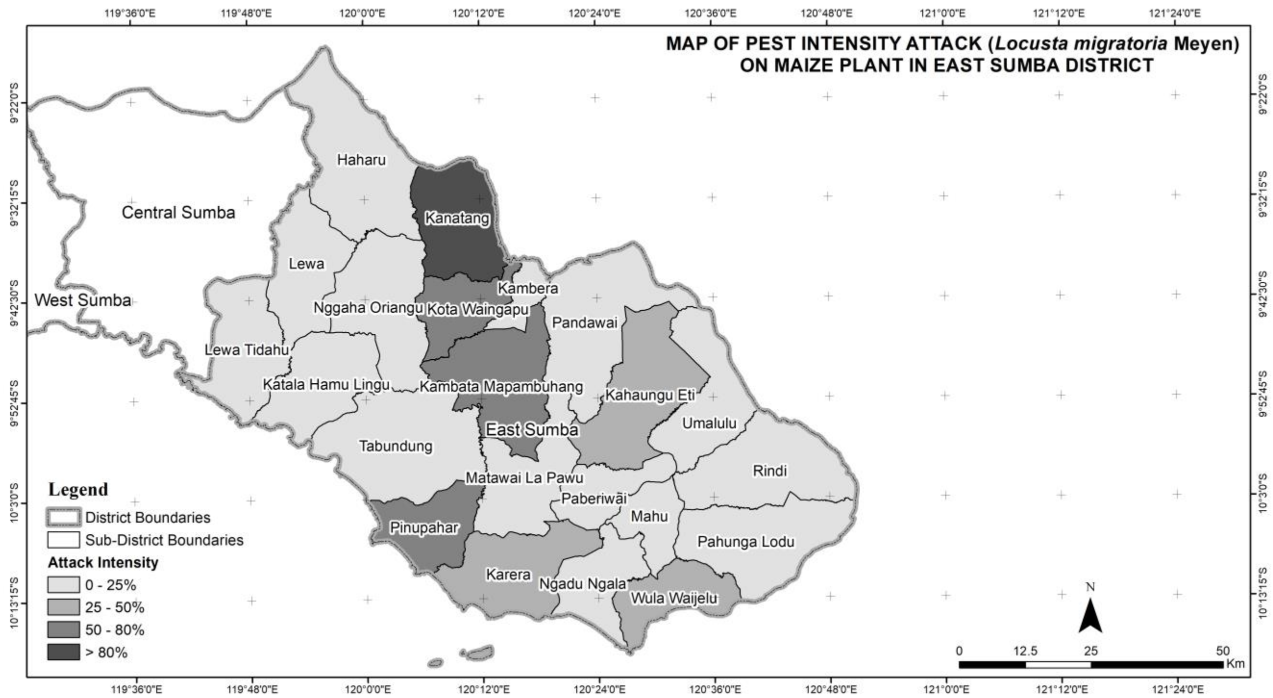

Figure 2. Intensity of migratory locust attacks on maize plantations in East Sumba District, Indonesia

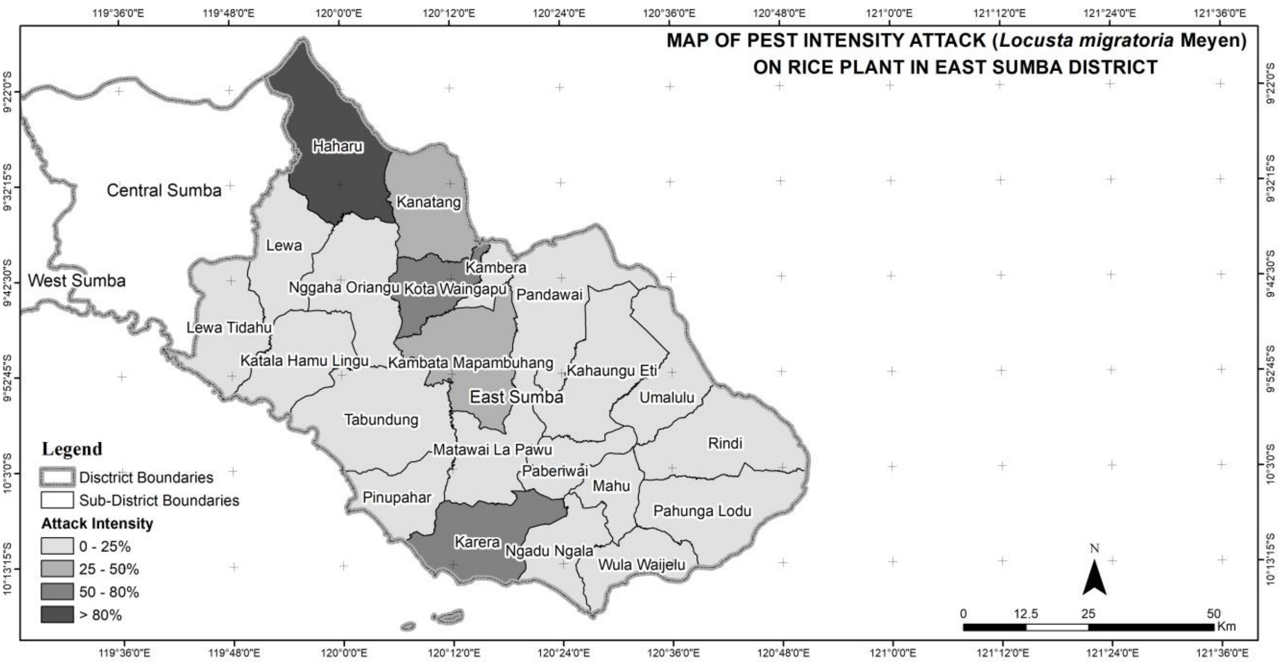

Figure 3. Migratory locust attack intensity on rice plants in East Sumba District, Indonesia

Apart from being a threat, migrating locust insects have the potential to be a source of nutritions and other bioactive compounds useful to human health. The study of the nutritional characteristics and bioactive content, as well as the safety aspects of locusts, needs to be further studied in order to be exploited and, at the same time, become one of the population control techniques.

Protein content

The macro-nutrient content of migratory locusts from East Sumba is presented in Table 1. Based on the results of the normality analysis using Shapiro-Wilk, it can be assumed that the protein content of the locust has a normal distribution, with the significant value of 3th, 4th, and 5th instar of nymph, as well as imago are 0.739, 0.060, 0.054, 0.298, respectively. Therefore, the test continued with a parametric test using ANOVA, followed by a Tukey Least Significant Different. An ANOVA analysis at $P<0.05$ showed that the stage of locust development (nymph and imago stage) had a significant influence on the macro-nutrient content of the locust, with a sifnificant value (p-value) of 0.001. Protein was the most abundant nutrient, followed by fat, carbohydrate, and ash. According to Kinyuru (2021), the nutritional content of insects is influenced by developmental stages, types of food, and the geographical conditions of the areas where they grow. In addition, the flying activity in a swarm could impact the balance of specific nutrients such as protein, fats, and carbohydrates, as these nutrients might have been used to produce energy for flight.

Table 1. Mean nutritional content of nymphs and imago from migratory locusts

Nutrition (dry weight)	3rd nymph	4th nymph	5th nymph	Imago
Protein (%)	63.72^{a}	66.41^{c}	64.21^{b}	75.26^{d}
Fat (%)	7.15^{b}	7.40^{c}	7.68^{d}	6.41^{a}
Carbohydrate (%)	15.51^{c}	12.54^{b}	13.74^{b}	6.72^{a}
Ash (%)	4.87^{b}	4.84^{b}	5.55^{c}	4.69^{a}
Water Content (%)	8.75^{b}	8.81^{c}	8.82^{c}	6.92^{a}
Energy from fat (Kcal/100g)	64.35^{b}	57.60^{a}	69.12^{c}	57.69^{a}
Total Energy (kcal/100g)	381.85^{b}	377.44^{a}	380.94^{b}	385.65^{c}

Notes: Numbers followed by different letters in columns are significantly different at $P<0.05$

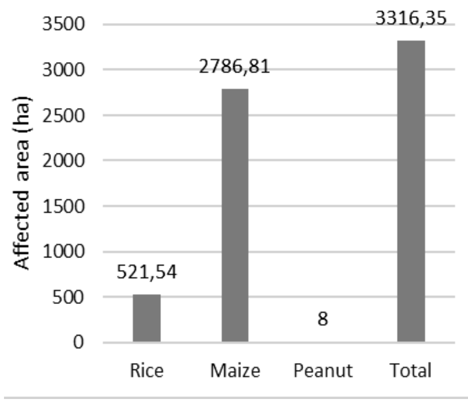

Figure 4. Area of food crops affected by locust in East Sumba District, Indonesia

The analysis showed that the nutritional content varied in the nymph and imago stages. Protein is the locust's most important nutrient, ranging from 63.72% in the 3rd instar nymph to 75.26% in the adult insect (imago). Protein in the imago stage is significantly higher than in the nymph stage. There is only a slight difference between these values and those of egg protein (83%) or beef (85%) and even a little difference between these values and those of most plant proteins such as soybean (81%) (Ochiai et al. 2020). Since some nitrogen is bound in the exoskeleton, measured nitrogenous substances of insects may be higher than their actual protein contents (Kouřimská and Adámková 2016). Despite locusts' high crude protein levels, chitin can impair their solubility. However, this can be improved six-fold under alkaline pH conditions (Brogan 2018) and through chitin extraction (Clarkson et al. 2018). As a result of the high chitin content of migratory locusts and other insects, the nitrogen-to-protein conversion factor of 6.25 has been shown to underestimate their protein contents by 17% (Boulos et al. 2020). Therefore, in calculating the contents of locust protein, a correction factor of 5.33 was used instead of 6.25. According to Boulos et al. (2020), a nitrogen-to-protein conversion factor of 5.33 should be used to quantify the actual protein content of locusts and other edible insects. In general, edible insects are rich in protein, particularly species from the order Orthoptera (grasshoppers, crickets, and locusts), representing a valuable alternative protein source. Compared to plant protein sources like dry soybeans, with 35.8% protein, insects have great potential as an alternative protein source (Rumpold and Schlüter 2015; Henchion et al. 2017). However, insect protein food's nutrient quality, digestibility, and availability must be assessed. Studies have shown that insects have superior protein quality regarding their accessibility and digestibility compared with casein and soy. Still, the chitin can be removed to improve the protein quality (Clarkson et al. 2018). In this study, the results suggest that adult locusts contain 76.89% protein, indicating that they are a cheap source of protein in the future. Furthermore, using migratory locusts as a protein source can alleviate malnutrition and stunting in East Nusa Tenggara Province. Additionally, it can be used to control locusts, which have been a serious problem on Sumba and other islands.

Fat content

The data on the fat content of the locust have been subjected to a normality test using Shapiro-Wilk, to determine their distribution. The results show that all data for the three stages of nymphs and imago have a normal distribution, with significant values of 0.253, 0.510, 0.220, and 0.346, respectively. To investigate possible differences in fat composition between the nymph and imago stage, the analysis of variance (ANOVA) test was conducted at a significance level of 5 percent. The fat content exhibited a statistically significant (p-value =0.00) increase during the final period of nymph development (4th instar) in comparison to the imago stage. The lipid composition of nymphs exhibits a range of 7.15% to 7.68%, however in the imago stage, the lipid content shows a decline to 6.41%. In line with the fat content, the carbohydrate content was also higher in the nymph phase, namely 12.54 to 15.51%, compared to the imago phase, which was only 5.17%. the migratory locusts from East Sumba have a lower fat content than previously reported by Yin et al. (2012), which is 10 to 13.41%. An insect's fat content can vary even within the same developmental stage, depending on its diet and age (Rutaro et al. 2018). Fat is an important source of energy, as well as serving several other biochemical functions. Additionally, food products must enhance their taste and appeal, contributing to developing distinct flavors during the processing phase (Yin et al. 2012). Insect fat contains lecithin and fat-soluble vitamins (A, D, and E). Many important benefits are associated with these active natural products regarding their physiological and biological functions (Yin et al. 2012). In addition, locust oil contained 66.47% unsaturated fatty acids compared to 33.56% saturated fatty acids (Kinyuru 2021). In locusts, polyunsaturated fatty acids (omega-3 and omega-6) may help prevent heart disease (Egonyu et al. 2021).

Ash content

To determine the normality of the data of ash content, a Shapiro-Wilk test was performed. The results show that all ash content data for the three instar of nymphs and imago have a normal distribution, with significant values of 0.385, 0.253, 0. 253, and 0. 253, respectively. At a significance level of 0.05, variant analysis (ANOVA) revealed that the ash content of the imago and nymph differs significantly (p=0.00). It can be seen in Table 3 that the 3rd instar nymph exhibited the highest overall ash level (5.55%), which was observed to be significantly different from the ash content of other developmental stages. In contrast, the imago stage exhibits the lowest total ash content at 4.69%. This indicates that locusts can also function as an important source of minerals, especially minerals that are bioavailable and easily absorbed by the human body. A study by Köhler et al. (2019) found that the bombay locust (*Patanga succincta* Johannson, 1763) contains the minerals iron (Fe) and zinc (Zn). As far as mineral bioavailability is concerned, Latunde-Dada et al. (2016) found that grasshoppers, crickets (*Gryllodes sigillatus* Walker 1869), and mealworms (*Tenebrio molitor* Linnaeus 1758) have much more chemically available calcium, copper, magnesium, manganese, and zinc than sirloin steaks, while buffalo worms (*Alphitobius diaperinus* Panzer 1797) have iron bioavailability comparable to $FeSO_4$. According to the study, insects could be good sources of bioavailable minerals, especially iron, and could serve as dietary mineral supplements (Latunde-Dada et al. 2016). Edible insects are high in mineral elements, such as calcium, phosphorus, iron, and zinc, which our bodies need as supplements (Yin et al. 2012). The locusts contain 27 mineral elements, such as Mn, Fe, Cu, Zn, etc. Yellow powder insects and Chinese rice locusts have Se contents of 4.62 and 4.75 mg/kg, respectively. Among its benefits, Se accelerates detoxification, inhibits mutagenic activity, destroys the carcinogen, and prevents cancer cell development (Rumpold and Schlüter 2015).

Carbohydrate content

The Shapiro-Wilk test for normality determined that the carbohydrate content data of the migratory locust are normally distributed, with consecutive p-values of 0.849, 0.780, 0.157, and 0.762 for the 3^{th}, 4^{th}, 5^{th} instar nymph, and imago, respectively. At a significance level of 0.05, variant analysis (ANOVA) revealed that the carbohydrate content of the imago and nymph differs significantly (p=0.00). The carbohydrate content in nymphs ranged from 13.55 to 15.51%, significantly higher than that found in imago, which was only 6.72%. However, the carbohydrates in edible insects are easily digested and absorbed, with a low total sugar content (1 to 10%), so carbohydrates in insects are good for health (Ochiai et al. 2020). This study reported lower carbohydrate values than Salama (2020), who reported 19.0 grams/100 grams. The differences may be due to dietary differences and swarming age (Zhang et al. 2019).

Total energy

Based on the results of the normality analysis using Shapiro-Wilk, it can be assumed that the total energy content of the locust has a normal distribution, with p-value of 0.380, 0.724, 0.125, and 0.129 for the 3th, 4th, 5th instar nymph, and imago, respectively. The energy contained in locusts varies depending on their life stage, ranging from 377.44 to 385.65 kcal/100 g. The imago insects provide the highest energy (385.65 kcal/100g) and are significantly different from others (Table 2). This is thought to be due to the influence of the type of food consumed during their life. Rumpold and Sc hlüter (2013) reported that the mean energy contents of edible insects range from 409.78 to 508.89 kcal/100 g (based on dry matter). While locusts may not be a major energy source in terms of calories, they can be a valuable source of protein, fat, minerals, and other nutrients for health benefits.

Amino acid content

The content of amino acids of migratory locusts in the nymph and imago stage is presented in Table 2. Normality tests on total and individual amino acid data have been performed using the Shapiro-Wilk test. The results showed that most of the amino acids data have a normal distribution. Therefore, the test continued with a parametric test using ANOVA, followed by Tukey LSD with significance of P<0.05. The table presents data indicating substantial variations in the amino acid composition across various developmental stages of locusts. As an example, it is important to emphasize that the imago stage exhibits a notably elevated amino acid composition, particularly with respect to amino acids such as L-Asam glutamate, Valine, Alanine, Glycine, and Leucine. The imago stage exhibited the highest total amino acid content, measuring 411.41 mg/100 g, which was significantly greater than that observed in the nymph stage. Essential amino acids such as lysine, isoleucine, leucine, valine, phenylalanine, threonine, histidine, and tryptophan are present in locusts in varying amounts, with a total EAA of 37.89%. This result is slightly lower than the World Health Organization (WHO) standard, which is 40% of total amino acids. Table 2 shows that the essential amino acids such as leucine, valine, and threonine are quite high; however, tryptophan and histidine are low, so these amino acids become limiting amino acids in the locust. Lysine and threonine are amino acids that often become limiting amino acids in some cereals, so locust acid can be an alternative to fulfill this deficiency (Kouřimská and Adámková 2016).

The E/N ratio, also known as the Essential to Non-Essential ratio, serves as an indicator of the balance between essential and non-essential amino acids within a given protein. The measurement holds significant value as an indicator of protein quality (Köhler et al. 2019; Huis 2021). The data shown in the table indicates that there is a minor variation in the ratio over the several stages, with the 5^{th} nymph exhibiting the greatest ratio of 0.64.

Chitin and chitosan

Chitin and chitosan are a group of carbohydrates that are often found in insects including the migratory locust. Table 3 shows the findings of the chitin and chitosan content analysis conducted on nymph and imago locust. The Shapiro-Wilk test was employed to assess the normality of the chitin and chitosan data, which indicated that the distribution of the chitin and chitosan contents in the locust was normal (p-value ranged from 0.414 to 0.985). Table 3 demonstrated that the chitin content in the nymph and imago stages ranges from 8.64% to 12.33% of the dry weight of the insect samples. The 3^{rd} instar nymph exhibited the highest chitin concentration, which was not significantly different from that of the 5^{th} instar nymph and the imago.

Table 2. Amino acid content of locusts

Amino acid (dry weight)	3^{rd} nymph	4^{th} nymph	5^{th} nymph	Imago
Amino acids (mg/100g)	315.86a	332.27b	323.54c	411.41d
Amino acids (%)				
L-Serin	5.26b	5.35c	5.47d	4.58a
L-Asam glutamate	12.14c	12.31d	11.82b	10.36a
Fenil Alanin*	3.70c	3.44b	3.95d	2.83a
Isoleucine*	4.79b	4.76a	4.81b	5.02c
Valin*	7.43c	7.30a	7.32b	8.17d
Alanine	11.86b	11.97c	11.45a	13.13d
Arginine	4.71b	4.77c	5.01d	4.63a
Glisine	7.16a	7.16a	7.33b	8.25c
Lisin*	6.24b	6.62c	5.99a	6.84d
Asam Aspartate	6.89b	6.97c	6.66a	7.09d
Leusin*	8.62a	8.81b	8.64a	8.90c
Tirosin	5.32c	4.95b	5.51d	4.49a
Proline	6.93b	7.06c	6.83a	7.85d
Treonin*	5.49c	5.26b	5.48c	5.07a
Histidine*	2.50c	2.32b	2.63d	2.02a
Triftofan*	0.96b	0.93b	1.10c	0.79a
Total	100	100	100	100
Essential Amino Acid (EAA. %)	35.43a	37.44b	38.24d	37.89c
Non Essential Amino Acid (NEAA. %)	60.27	60.55	60.08	60.37
E/N	0.59	0.62	0.64	0.63

Notes: *Numbers followed by different letters in columns are significantly different at P<0.05

Table 3. Content of chitin and chitosan on dry weight

Stadia	Chitin (% dry weight)				Chitosan (% dry weight)			
	1	2	Mean	SD	1	2	Mean	SD
Nymph 3	12.60	12.05	12.33[b]	0.39	65.55	69.30	67.43[b]	2.65
Nymph 4	8.48	8.79	8.64[a]	0.22	58.60	59.30	58.95[a]	0.49
Nymph 5	13.15	9.91	11.53[b]	2.29	59.20	73.45	66.33[b]	10.08
Imago	10.79	10.44	10.62[ab]	0.25	68.23	71.26	69.75[b]	2.14

In comparison, chitosan ranged from 58.95 to 69.75% of total chitin. The imago stage exhibits a greater chitosan content compared to other stages, with a statistically significant difference seen solely in comparison to the 4th instar nymph. The presence of chitin and chitosan in locusts is a potential compound that needs to be studied further. These compounds are reported to be widely used in agriculture, food, cosmetics, pharmaceuticals, wastewater treatment, and industry sectors (Komariah 2012; Purschke et al. 2018). Chitin is a biopolymer composed of N-acetyl-D-glucosamine units linked to β (1-4) that are most commonly found in nature after cellulose. Chitosan is a product of the deacetylation of chitin through a chemical reaction process using sodium hydroxide base or through an enzymatic reaction using the enzyme chitin deacetylase. Chitosan is a biopolymer resistant to mechanical stress (El Knidri et al. 2018; Komariah 2012). Chitin is a linear polysaccharide consisting of (1-4)-linked 2-acetamido-2-deoxy-b-D-glucopyranose. Chitosan is a linear polysaccharide consisting of (1-4)-linked 2-amino-2-deoxy-b-D-glucopyranose (Casadidio et al. 2019; Malerba and Cerana 2019). Chitin and its deacetylated derivative, chitosan, have recently been widely used as outstanding natural biopolymers. Using these chemicals has been particularly beneficial for industries such as pharmaceuticals, cosmetics, biotechnology, and food, (Puvvada et al. 2012; Aranaz et al. 2018; Malerba and Cerana 2019); wastewater treatment, agriculture, and medical applications, paper production. and textiles (Casadidio et al. 2019). In the agricultural sector, chitin powder and its deacetylated derivative, chitosan, have been used by farmers as biopesticides, biofertilizers, and agricultural film in seeds and fruit coatings since the 1980s. Both chitin and chitosan exhibit various biological properties such as anticholesterolemic, wound-healing agents, anticancer, fungistatic, hemostatic, analgesic, antiacid, antiulcer, and immunoadjuvant (Casadidio et al. 2019). Based on the properties and characteristics of chitin and chitosan, the chitin and chitosan extracted from the migratory locust have promising future prospects. It is necessary to conduct further studies on the biological properties of chitin and chitosan from migratory locusts, such as antimicrobial properties, antioxidants, potential use as medicinal ingredients, cosmetics, and other functions for future development.

In conclusion, the migratory locust (*Locusta migratory*) from East Sumba has potential as food and a source of nutrition, especially protein and amino acids. The nymph and imago of locusts contain protein ranging from 63,72% to 75.26% dry weight. Meanwhile, the imago stage exhibited the highest total amino acid content, measuring 411.41 mg/100 g, with essential amino acids such as lysine, isoleucine, leucine, valine, phenylalanine, threonine, histidine, and tryptophane. The lipid composition of nymphs exhibits a range of 7.15% to 7.68%, however in the imago stage, the lipid content experiences a decline to 6.41%. Consistent with the observed fat level, the carbohydrate content in the nymph stage was also found to be greater, ranging from 13.55% to 15.51%, in contrast to the imago stage when it was just 5.17%. The chitin content in the nymph and imago stages ranges from 8.64% to 12.33% of the dry weight of the insect samples, whereas chitosan ranges from 58.95 to 69.75% of total chitin. This preliminary research indicates that the migratory locust can be used as a source of nutritions such as protein and amino acids, in order to solve nutrition and health problems in the future. By utilizing the migratory locusts as protein source can alleviate malnutrition and stunting in East Nusa Tenggara. Additionally, it can be used as a control method of migratory locusts, which have been a serious problem in Sumba and other islands of East Nusa Tenggara.

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