Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.7, No.16, 2017

Analysing Life Cycle Stages of Indian Meal Moth, Plodia interpunctella (Hübner) on Four Different Diets

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This research was self finance

Abstract
The life cycle stages of Indian meal moth, *Plodia interpunctella* (H) was studied on four different diets: whole maize flour, whole wheat flour, breadfruit flour and a formulated diet, under ambient laboratory conditions of 28±2^{o}C and 75±5% R.H. The proximate composition of the diets, oviposition, larva instar stages, and the complete developmental duration from egg to adult of the moth were examined on the four different diets. The result showed that the percentage protein value of the formulated diet was significantly higher (14.58) than other diets. The oviposition of the moth on the diets ranges between 1-3 days and about 70% of the eggs laid were on the first day of oviposition in all the diets. The highest number of eggs laid was observed on moths reared on maize flour. Incubation of eggs examined on the diets ranges from 3-4 days. Also, there were variations in the number of larva instar stages in the four diets. The formulated diet recorded the lowest period of pupation (6.33 days) and the total developmental average period (23.50days). The study clearly showed that the formulated diet is suitable for rearing *P. interpunctella* under laboratory conditions.
Keywords: formulated; incubation; instar; oviposition; pupation.

1.0 INTRODUCTION

Indian meal moth, *Plodia interpunctella* (Hübner), is a popular insect pest of stored milled and processed cereals and it products, oilseeds, dried fruits, dried vegetables, nuts, animal feed and garlic seeds and manufactured products (Cox and Bell, 1991; Johnson *et al*., 1992 Perez-Mendoza, 2003; Rees, 2004; Ozyardimci *et al.*, 2006 Mohandass *et al.,* 2007). It is found in farms, food processing plants, houses, retail stores, granaries, and warehouses. Indian meal moth has been found to be distributed across the continent of the world and ranked as one of the most important storage pest in warm-temperate and sub-tropical climate (Rees, 2004).

The life cycle of *P. interpunctella* has been reported by many researchers to ranges from 27 -52 days depending on factors such as temperature, food odour, presence of oil, type of food, size of female, availability of drinking water, physiological state of female, food source, depth of food, temperature among others (Bell 1981; Allotey and Goswami 1990; Johnson *et al*., 1992; Nansen and Phillips 2003; Mohandass 2006). Diet (food) is the most important factor for determining the developmental period of the insect and can feed on wide range of food (Mbata 1985; Johnson *et al.,* 1992; Nansen and Phillips 2003; Silhacek, *et al*., 2003; Silhacek, and Murphy, 2005).

Analyzing and studying the growth rate and biology on a broader note of *P. interpunctella* on wide range of foods is significant since this will enable researcher to study the insect behavioral patterns and will enable pest managers to target the life stages most susceptible to control tactics and artificially simulate the effects of such a management practice on individual life stages (Hagstrum and Flinn, 1990; Flinn and Hagstrum, 1990; Flinn *et al.,* 1997).

2.0 MATERIALS AND METHODS

2.1 Insect Culture

The *P interpunctella* used to establish the culture was obtained from naturally infested maize grains obtained from Federal University of Technology, Akure (FUTA) Teaching and Research Farm, Ondo State, Nigeria. The moths larvae were reared in 2 litres plastic containers containing 300g of uninfested grains. The culture was maintained by continually replacing devoured grains and sieving out frass and fragment. The plastic containers were covered with muslin cloth, fastened with rubber band, and placed inside wire mesh cage of dimension 75cm ×50cm ×60cm (L×W×H) with it four stands dipped in water-kerosene mixture contained in a plastic

container to prevent entry of predatory ants and other insects. The culture was maintained at a temperature (28 ± 2°C) and relative humidity (70 ± 5%). The whole set up was left inside the storage research laboratory of the Department of Biology, Federal University of Technology Akure Ondo State Nigeria

2.2 Collection of Food Items

The food materials used for diet preparation were purchased from Oba market, Akure, Nigeria. The composition of food material used for diet preparation are; whole wheat grains, whole wheat flour, whole yellow maize grain, whole yellow maize flour, ground nut, bread fruit flour ,Glucose, Brewer's yeast, and glycerine. Maize grains and wheat grains used in this study were winnowed and thoroughly sorted to remove stones and other foreign materials. The seeds were then pulverized into fine powder using "Muchang grinder model No. 9FZ-300" until finely divided powder was obtained. The groundnut used was crushed using mortar and pestle. The bread fruit flour used was diced, dried in oven and milled into powdered form using "Muchang grinder model No. 9FZ-300". These food items were held in covered plastic containers at ambient tropical laboratory conditions of 30±2˚C and relative humidity of 75±5% until when used.

2.3 Insect instar and sex identification

Morphological structures of the insects were used in identifying the different instars of the insect. For instance, the colour of the outer two-thirds of adult wings is bronze to reddish brown, while the part of the wings closer to the body is grayish white (Rees, 2004). The sexes were also differentiated using their sizes, male are smaller than female when freshly emerged. Male *P.interpunctella* is tapered at the apex of the abdomen; while female the apex of the abdomen is truncated (Richard *et al*., 1932; Akinneye, 2003).

2.4 Proximate Analysis of the Food Diets

Proximate analysis of the all the diets used were carried out in order to determine the contribution of the nutrient for development and survival of larval stages of *P. interpunctella*.

2.4.1 Determination of moisture content

The moisture content was determined using the oven (Gallenkamp moisture extraction oven) drying method, which was based on weight loss. The dishes and the lids were washed with distilled water and placed in an oven at 75°C for 30 minutes to dry. The dishes were then removed and kept inside a desiccator for 30 minutes to cool. Their weights were recorded (W_1) Then 2g of the powdered food items were kept in each dish; lids were replaced and weighed accurately (W_2) (Bainbridge *et al.,* 1996). They were transferred into a desiccator immediately after weighing to prevent absorption of moisture from the atmosphere. The dishes containing the samples were transferred from the desiccator into the oven and dried at 80°C for 3 hours with the lids removed until the final constant weights were obtained. The lids were replaced and dishes containing the samples were placed inside desiccators for 30 minutes to cool. The dishes containing the dried samples were weighed (W_3) (Osborne and Voogt, 1978). Determination was in triplicate.

$$\%\ \mathrm{M.C} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

$$\%\ \text{moisture content} = \frac{\text{loss in weight due to drying}}{\text{weight of sample taken}} \times 100$$

W_1=weight of dish + lid
W_2 =weight of dish + lid + wet sample
W_3=weight of dish +lid + dry sample

2.4.2 Determination of the ash content

Clean, dried crucibles were weighed (W_1) and 2g of each sample of all the diet were placed inside crucible and reweighed (W_2). The crucibles were then heated on a Bunsen burner in order to burn the volatile organic matter off and the charred left until smoke ceased to be given off. The crucibles were then transferred to the muffled furnace at 550°C for 5h. Heating continues until a light grey or white ash was obtained. The crucibles were then removed from the furnace and transferred into desiccators to cool before reweighing (W_3) (AOAC, 1990). Cooling and weighing were continuous until constant weight was obtained.

$$\%\ \text{ash content} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where W_1=weight of empty crucibles
W_2= weight of crucible and sample
W_3=weight of crucible and ash sample

2.4.3 Determination of the crude fibre

About 1g of each defatted sample was placed inside clean, dried and well labelled conical flask and weighed (W_1). 200 ml of 1.25% H_2SO_4 were added to the samples in the conical flask and were boiled for 30 minutes. The solution were filtered (to remove the fat and sugar) and the residues were placed back into the conical flask

and distilled water was added to rinse them, 1.25% of NAOH (200ml) solution was added in each sample and heated to boil for 30 minutes. The boiled samples were filtered with ethanol and 10% HCL was added to rinse them. The residues of each sample was placed in a crucible and placed in the oven for 3 hours at 105°C, the samples were removed and weighed (W_2), and the samples were then ashed in the muffle furnace for 3 hours at 550°C. The samples were then removed, cooled in desiccators and weighed (W_3).

$$\% \text{ Crude fibre } = \frac{W_2 - W_3}{W_1} \times 100$$

Where W_1 = Weight of original sample
W_2 = Weight of residue
W_3 = Weight of the ash

2.4.4 Estimation of the fat content

The fat was extracted with petroleum ether (40-60% boiling range from the dried residue obtained after the determination of the moisture content). The solvent was removed by evaporation and fat residue weighed. The soxhlet extraction method, which was used, could only give the approximate fat content in a sample because all the substance soluble in the chosen solvent was extracted from the sample. It is necessary to avoid the presence of water so that the water-soluble materials are not extracted along with the fat. Filter papers were weighed (W_1) and 1g of each sample as weighed into the filter papers, wrapped neatly with thread and weighed (W_2). The filter paper with the sample was inserted into the soxhlet apparatus and extraction under reflux was carried out with petroleum ether (40-60% boiling range) for 6 hours. At the end of the extraction, the filter paper and their contents were dried in the oven for about 30 minutes at 100°C to evaporate the solvent and weighed (W_3). The fat extract from a given quantity of sample was then deduced:-

$$\text{Fat (\%)(W/ w)} = \frac{\text{Weight loss by sample (extracted fat)} \times 100}{\text{Weight of sample}}$$

$$\text{Fat (\%) (W/w)} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where W_1 = Weight of filter paper
W_2 = Weight of filter paper + sample
W_3 = Weight loss of sample

2.4.5 Determination of the crude protein

The Kjeldahl method was used for this determination. The method was carried out in three steps. The first step involves digestion, a process where by about 0.6g of each sample was digested with concentrated H_2SO_4 (10ml) in a dry 500ml kjeldahl digestion flask together with on tablet of digestion catalyst (Selenium catalyst). The mixture was then swirled together and the flask was filtered with a loose pear stopper in an inclined position. It was then placed in a fume cupboard and heated gently at first but later increased. The mixture was swirled and shaken from time to time in order to wash down any charred material adhering to the flask. The mixture was heated until a clear solution was obtained. The flask was allowed to cool after which the solution was diluted with tap water to 100ml out of which 10ml was transferred into the kjeldahl distillation flask. The second step was the distillation stage where 40% NAOH solution was added to cooled and diluted digestion sample to make it alkaline. The cloudy nature of the sample solution after the addition of 40% NAOH indicates that NAOH was in excess. To the receiving flask, 25ml of 2% Boric acid solution was added and few drops of screened methyl red indicator were also added to produce a pink colour solution. The distillation was carried out with the joints tightened with the end of the delivery tube dipping below the Boric acid solution. As the distillation proceeds, the pink colour solution of the receiver turned light green indicating the presence of NH_3. Distillation continues until the distillate was 50ml after which the delivery end of the condenser was rinsed with distilled water into the receiver.

Equations: - Sample + concentrated $H_2SO_4 \longrightarrow (NH_4)_2SO_4$

$(NH_4)_2SO_4 + 2NaOH_2 \longrightarrow NH_3\,(g) + Na_2SO_4 + 2H_2O$

The received NH_3 forms a complex with Boric acid as:

$HBO_3 + NH_3 \longleftrightarrow NH_4{:}BO_2$

The final stage involves titration in which NH_3 received in the acid solution was titrated with 0.1M HCL solutions.

A blank titration was also carried out

$NH_4 + BO_2^- + HCL \longrightarrow NH_4CL + HBO_2$

Colour changed from light green to pink.

Calculations: -

$$\% \text{ Nitrogen} = \frac{\text{Volume of acid used} \times 0.0014\text{g} \times 100}{\text{Weight of sample}}$$

1ml of 0.1M HCL = 0.0014g N (Crude protein =% Nitrogen × 6.25)

Where 6.25 = Protein conversion factor

2.4.6 Determination of carbohydrate content

Carbohydrates serve as a source of energy and may be converted to fats for storage and to amino acids (Chapman, 1980). The percentage carbohydrate composition of the four media was calculated as the difference in the summation of the values for proximate analysis (moisture, ash, fat, fibre) and 100%. Thus the carbohydrate was calculated as follows:

$$CHO\% = \sum (moisture\% + ash\% + fat\% + fibre) - 100\% \text{ (AOAC, 1990)}$$

2.5 Fecundity

Newly emerged 0-24h old adult moth collected from each diet prepared in the above experiment were paired in ratio 1:1 and introduced into a 7cm diameter and 4cm deep plastic containers covered with muslin cloth held with rubber bands. In all, twelve containers of newly emerged paired male and female were prepared. After oviposition, the total number of eggs laid per female after every 24h was noted for three (3) days. The eggs were carefully separated and counted with the aid of camel hair brush. The eggs laid were examined under a dissecting microscope and the averages were determined. This was done for all the diets used for the experiment (Akinneye, 2003).

2.6 Determination of Head Capsule Width and Larval Instars

Freshly laid **e**ggs were collected from the diets and same were introduced into freshly prepared diets in plastic container 8 cm wide and 4 cm deep and the eggs were allowed to hatch after incubation period of 3 days. Ten larvae from the diets were taken daily and placed on glass slides containing drops of 70% ethanol; this was done separately for the ten larvae. The larvae were subsequently measured for determination of head capsule width (at the vertex), body length (from the tip of the head to the tip of the abdomen), and the body width (at the prothorax). Young larvae were measured under a stereomicroscope fitted with an ocular micrometer (×4).

2.7 Determination of Developmental periods *P interpunctella* on different diets

Four diets: whole wheat flour (100%), whole maize flour (100%), breadfruit flour (100%) and the formulated diet which is composed of whole wheat (20%), + whole wheat flour (20%), + whole maize (20%), + whole maize flour (20%), + groundnut (10%), + glycerine (3%) + yeast (5%), + glucose (2%) were evaluated in the laboratory under ambient conditions of temperature (28 $\pm 2^0$C) and relative humidity (70 ± 5%) for suitability *P interpunctella* mass rearing. Eggs of the insect were obtained from the maintained culture. Thirty eggs were introduced into each diet in a plastic container 8.0 cm diameter and 4.0 cm depth with the lid punctured with hot iron rod and sealed with muslin cloth to allow aeration. Each diet / set up was replicated three times in completely randomized design. The following parameters were studied: duration of development from egg to larva, larva to pupa, pupa to adult stages and the total developmental periods of *P.interpunctella* on each diet.

2.8 Morphometric measurement of adult *P. interpunctella*

Emerged adults were separated by sex and 15 males and 15 females were selected from each diet for measurement of body length and width using plastic metric rule. The weight were also taken using the sensitive weighing balance (Model Mettler LG 501)

2.9 Statistical Analysis

All the experimental set up were replicated three times. The data collected were subject to analysis of variances (ANOVA) and means were separated using New Duncan Multiple Range Test at 95% degree of confidence.

3.0 RESULTS

3.1 Proximate Analysis of the Diets used as Growth Media for *P. interpunctella*

The proximate composition of formulated diet, whole wheat flour, whole maize flour, and breadfruit flour were presented in Table 1. The moisture content value of formulated diet was the lowest (9.38%), whereas the highest moisture content value of (12.50%) was observed on whole wheat flour. The highest ash content was recorded on breadfruit flour (2.06%). The formulated diet, recorded the highest fat content of 11.5% and these were significantly different ($P<0.05$) from the fat content recorded on other diets evaluated.

The formulated diet had the highest protein content (14.58%) while breadfruit flour had the lowest protein content (5.49%). The protein content of formulated diet, was significantly higher ($P<0.05$) from other diets (wheat flour, maize flour, bread fruit flour) when compared. Breadfruit flour has the highest fibre content (2.93%), while maize has the lowest (1.20%). Breadfruit flour recorded the highest carbohydrate content (76.61%).

3.2 Fecundity of *P. interpunctella* Reared on Different Diets

The fecundity of *P. interpunctella* is presented in Table 2. The adult female *P. interpunctella* started laying eggs

within 24h of emergence. On all the diets, eggs laid on Day 1 were significantly higher than eggs laid on Day 2 and Day 3. *P. interpunctella* reared on formulated diet laid more eggs on the Day 1 of oviposition. Number of eggs laid by adult female reared on the diets of breadfruit flour, wheat flour, and formulated diet are 31, 131 and 161 respectively for the first day of oviposition. In all the diets used for rearing the insect, over 70% of the eggs were laid on the first day of oviposition except for *P. interpuntella* reared and breadfruit flour, where 68% and 20% of the eggs were recorded on day1 and day 2 respectively.

3.3 Larva Instars

Table 3 shows the head capsule width of the various larval instars of *P. interpunctella.* Based on the observed average mean for the head capsule width obtained, there were seven larva instars identified on maize and wheat flour, while on breadfruit flour and formulated diet five larva instar of the insect were observed. In all the diet there were progressive increases in the head capsule width in all the *P. interpuntella* reared on the different diets. The Developmental periods of *P. interpunctella* on the different diets are presented on table 4. The incubation period of the eggs ranged from 3-4 days in all the diets examined with mean incubation period of 3.5 days. The total developmental period of moths reared on formulated diet, was the lowest 23.50±0.3 as it ranges between 23– 24 days, The total developmental period of moths reared on formulated diet, was highly significantly ($P<0.05$) than the total developmental period obtained of moths reared on the other diets.

3.4 DISCUSSION

3.4.1 Proximate Composition of Different Diet used for Life History

The moisture contents recorded for all the diets used in this study were within the safe moisture range as reported by Hayma (1995). On the formulated diet, an average moisture content of 9.38% was observed been the lowest moisture content of the diets examined. The adaptation of Lepidoptera and other stored product insects to produce which are best preserved at low moisture content might have enhance the feeding and rapid development of the *P. interpunctella*, reared on formulated diet. This agrees with the findings of Levinson and Levinson (1978) who reported that due to low water content of dried food products, stored product insects have characteristically adapted to require less water in their diets. In addition, the modification of insect body especially with the presence of cuticle helps to conserve water within its body.

The crude protein content of formulated diet is 14.58%. This was the highest protein content recorded on all the diets used. Also, on the formulated diet, the highest fat content of 11.50% was recorded. Concurrently, the *P. interpunctella* reared on the formulated diet recorded the shortest developmental period of 23.5 days. This agreed with the findings of Silhacek and Murphy, (2006) which concluded that diets rich in protein and glycerol/glucose-supplement reduce the developmental duration of moth, particularly wheat germs supplemented with glycerol/glucose. Additional illustration of preferences to diet containing proteins and fats by *P. interpunctella* larvae is noticed in the granary, in which the larvae eat exactly the reproductive (germ) part of seeds (Almaši, 1984; Silhacek and Murphy, 2005). In this study, it was discovered that diets that is rich in fat of about 11.50% supports the growth of this insect.

The carbohydrate content of diets used for this study makes the diets suitable for the growth and development of *P. interpunctella.* Carbohydrates could serve as a source of energy and the excess of it may be converted to fats for storage and to amino acids (Chapman, 1980). Behmer (2006) reported that the flour beetle, *Tenebrio* exhibits optimal growth on diets containing 70% carbohydrate and that *Tenebrio* fails to develop if the carbohydrate concentrations drop below 40%.

3.4.2 Fecundity of *P. interpunctella* Reared on Different Diets

The adult female *P. interpunctella* have pre- oviposition period of less than 24h after emergence at normal ambient temperature of 28±2^{0}C and 75±5% relative humidity, the fast rate of oviposition may be due to the high protein content in the diets used. Furthermore, Ashamo (2005) has earlier reported that the female *Dasyses rugosella* (Stainton) started laying eggs within 24hrs of emergence. Across the diets, eggs laid on Day 1 were significantly higher ($P<0.05$) than the eggs laid on Day2 and Day3 respectively. On maize grain, significantly higher numbers of eggs were laid on the Day1. This may be because the newly emerged adult female *P. interpunctella* might have dissipated large proportion of the energy stored (during the larva stage) for laying more eggs on first day, hence laying fewer eggs on other days since the adult moth doesn't feed.

The egg in the diets was 0.36±0.00mm (range 0.36-0.37mm) long and 0.26±0.05 mm wide (range 0.26-0.29 mm) the colour of the eggs changes from light yellow to brownish yellow as the embryo develops. This size that is a liitle bit larger than the earlier reported sizes. The incubation period of the eggs ranged from 3-4 days in all the diets examined with mean incubation period of 3.5 days. This observation was similar to the findings of Akinneye and Ashamo (2009) on studies on of *Ephestia cautella* (Walker).

On the formulated diet, the least development period of total larval stage of 13.67±0.26 days (range13-14 days) was observed.

3.4.3 Larva instars development

The larva instar stages of 5-7 were observed in this study which has been reported by many researchers (Almaši, 1984; Baxter, 2008). The last instar larva spins a silken cocoon which protects the pupae from predator during development. This corroborated with report of Ashamo (2005) that *D. rugusella* larva also spins a silken cocoon that protects the pupae from predator during development. The pupa is a stage in which the major development such as wings, flight muscles, and tissue occurs (Rees, 2004). The colour of the pupa was uniformly light brown but became dark brown before adult emergence. Pupa development ranges between 6.33-10.33 days in the entire diet used. Insects emerged at night or early in the morning. This observation was similar to the findings of Akinneye and Ashamo (2009) on studies of *Ephestia cautella* (Walker).

3.4.4 Developmental periods of *P. interpunctella* on selected diets

The total developmental period of moths from egg to adult reared on formulated diet recorded the shortest developmental duration of 23.50±0.3 which ranges between 23– 24 days. The variations in the developmental duration on different diets may be due to the proximate composition of the diets. Jonfla-Essien (2006) reported that emergence of adult insect can be enhanced by the diet chemical composition. The total developmental period of moths from egg to adult reared on formulated diet, was shortest (23.5days), having a nutrients (chemical) composition of 14.58% protein, 11.5% fat, 9.38% moisture and 61.41% carbohydrate when compared with other diets used in this study.

The body length of adult moth in all the diets used ranges between 6.0 -8.0 mm. This agreed with the report of Rees (2004) that the body length of *P. interpuntella* is 6-10mm long. The upper one third of the forewings is silvery-white to grey colour. The lower two thirds are reddish-bronze with a copper sheen and irregular dark bands. Hind wings are silvery-grey with a long fringe of hairs. At rest, the wings are held roof-like over the body. The head and thorax are grey and the posterior brown, with a coppery sheen. The body length of adult male ranges between 6.0-7.5mm while that of female ranges between 7.0-8.5mm. Females are generally larger than males and have an expanded abdomen. This is in agreement with the findings of Akinneye (2009) on his studies on *E. cautella*. Adult moth reared on the formulated diet produced the highest body length that ranges between 6.5-7.0mm for male insect and 7.5-8.0mm for female. Male *P. interpunctella* is tapered at the apex of the abdomen; while female the apex of the abdomen is truncated.

3.4.5 CONCLUSION

In this research, it was discovered that the moth exhibited different larva instar stages with respect to diets. Five larval instar stages was observed on *P. interpunctella* reared on combined diets + glucose + yeast + glycerine and bread fruit flour, while larva instar stages of seven was observed on maize flour and wheat flour.

Also, all the diets were suitable for the growth of *P. interpunctella.* As those reared on combined diets + glucose + yeast + glycerine, exhibited short developmental duration however, on whole maize flour more eggs were laid when compared with other diets. Thus, among all the diets examined, the best diet for rearing *P. interpunctella* for production of eggs, or egg parasitoids used for bio-control are combined diets + glucose + yeast + glycerine, and whole maize flour.

ACKNOWLEDGEMENTS

I knowledge Pastor Olawumi Emmanuel A. and Mrs. Olawumi Janet my parents for their financial support and encouragement during the research work. I also acknowledge Mrs Toyin Alade the Chief Technologist, Department of Biology, FUTA for making some of the materials available during the research work.

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Table 1: Proximate analysis of the diets used as growth media for *P. interpunctella*

Diets	Moisture	Ash	Fat	Protien	Fibre	CHO
A	9.63±0.13^{a}	1.42±0.24^{a}	5.67±0.25^{c}	9.92±1.17^{b}	1.20±0.06^{a}	72.16±0.0^{c}
B	9.38±0.121^{a}	1.92±0.09^{b}	11.5±0.32^{d}	14.58±0.58^{c}	1.21±0.09^{a}	61.41±0.00^{a}
C	12.50±0.76^{b}	1.48±0.61^{a}	4.32±0.24^{b}	9.52±0.28^{b}	1.21±0.001^{a}	70.97±0.5^{c}
D	11.42±0.62^{a}	2.06±0.20^{c}	1.49±0.08^{a}	5.49±0.22^{a}	2.93±0.11^{b}	76.61±1.26^{d}

Note: Each value is Means ± Standard deviation of three replicates. Values followed by the same letter in the same column are not significantly different using New Duncan Multiple Range Test at *($P < 0.05$)
KEY: A=maize flour, B=formulated diet C=wheat flour, D=breadfruit flour and CHO = Carbohydrate

Table 2: Fecundity of *P. interpunctella* on different diets

	No of Eggs Laid Per Female			
Days	A	B	C	D
1	161.00 ± 3.61^{c}	131.00 ± 3.61^{b}	160.33 ± 2.08^{c}	31.00 ± 3.61^{a}
2	29.33 ± 1.16^{b}	28.67 ± 4.16^{b}	9.33 ± 1.15^{a}	9.00 ± 1.00^{a}
3	21.67 ± 2.08^{c}	10.00 ± 2.00^{b}	11.67 ± 1.53^{b}	5.67 ± 2.08^{a}

Note: Each value is Means ± Standard deviation of three replicates. Values followed by the same letter in the same roll are not significantly different using New Duncan Multiple Range Test at *($P < 0.05$)
Key: A= formulated diet, B= whole wheat flour C= whole maize flour, and D=breadfruit flour.

Table 3: Head capsule width for larval instars reared on all the diet combinations and t-test for conformity to Dyar's rule

Food media	Instars	Observed average	Growth ratio	Growth rate	Calculated average	Differences
Maize flour	1st	0.096	$.67	-	0.115	+0.02
	2nd	0.144	0.80	1.50	0.119	-0.03
	3rd	0.170	0.70	1.21	0.120	-0.05
	4th	0.240	0.50	1.41	0.322	+0.08
	5th	0.480	0.67	2.00	0.540	+0.06
	6th	0.720	0.75	1.50	0.654	-0.07
	7th	0.960	-	1.33		
Wheat flour	1st	0.084	0.70	-	0.06	- 0.02
	2nd	0.120	0.50	1.43	0.12	0.00
	3rd	0.240	0.50	2.0	0.38	0.14
	4th	0.480	0.80	2.0	0.49	0.02
	5th	0.600	0.83	1.25	0.54	-0.06
	6th	0.720	0.75	1.20	0.65	-0.07
	7th	0.960		1.33		
Bread flour	1st	0.057	0.530	-	0.06	-0.003
	2nd	0.108	0.512	1.89	0.113	-0.005
	3rd	0.210	0.540	1.99	0.23	0.02
	4th	0.390	0.60	1.86	0.72	0.03
	5th	0.660		1.69		
	6th					
	7th					
Formulateddiet	1st	0.057	0.527	-	0.06	-0.003
	2nd	0.108	0.512	1.89	0.113	-0.005
	3rd	0.210	0.540	1.99	0.230	0.02
	4th	0.390	0.590	1.86	0.71	0.03
	5th	0.660		1.69		
	6th					
	7th					

Note: Growth ratio= observed mean head capsule width (mm) of a larval instar divided by the observed mean headcapsule (mm) of the succeeding larval instar.Calculated mean = observed mean head capsule width (mm) of a succeeding larval multiplied by the mean of growth ratio. Growth rate=the mean head capsule width of a succeeding instar divided by the mean. Differences= observed mean head capsule width (mm) minus the calculated mean of insect.

Table 4: Developmental periods of *P. interpunctella* (in days) on selected diets (M±SE)

Diets	Incubation(days)	Larva	Pupa	Total Developmental Period
A	3.5 ± 0.00^{a} (3-4)	18.67 ± 0.3^{b} (18 - 19)	8.3 ± 0.3^{bc} (8 - 9)	30.47 ± 0.2^{c} (29 - 31)
B	3.5 ± 0.00^{a} (3 - 4)	13.67 ± 0.26^{a} (13-14)	6.33 ± 0.28^{b} (6 – 7)	23.50 ± 0.3^{a} (23 – 24)
C	3.5 ± 0.00^{a} (3-4)	15.33 ± 0.25^{a} (15-16)	9.3 ± 0.6^{c} (8 - 10)	28.13 ± 0.28^{b} (28– 29)
D	3.5 ± 0.00^{a} (3-4)	18.67 ± 0.29^{b} (18 – 19)	8.3 ± 0.3^{bc} (8 – 9)	30.33 ± 0.25^{c} (30-31)

Note: Each value is Means ± Standard deviation of three replicates. Values followed by the same letter in the same column are not significantly different using New Duncan Multiple Range Test at *($P < 0.05$) Values in parentheses are range.

KEY: A= whole maize flour, B=formulated diet, C= whole wheat flour and D=breadfruit flour.