Can the Necrophagous Blow Fly Calliphora vicina (Diptera: Calliphoridae) Be Reared on Plant-Based Meal?

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Article

Can the Necrophagous Blow Fly *Calliphora vicina* (Diptera: Calliphoridae) Be Reared on Plant-Based Meal?

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Simple Summary: The blow fly *Calliphora vicina* has shown potential as a managed pollination species to support honeybee usage in Australian horticulture. This blow fly species lays eggs onto dead animals (i.e., carrion) shortly after death, hence the larvae that hatch feed on the decomposing tissues of the dead animal. However, the use of plant-based media may reduce costs and the unpleasant odour associated with decomposing animal protein when rearing blow flies. Hence, newly hatched larvae of this fly were provided with either plant-based meals (soya bean and canola) or animal-based meatmeal; this was done to determine if plant-based meal could be used to mass rear this fly for use in horticulture as an insect pollinator of crops.. Neither pure soyabean nor pure canola meal supported the survival of any larvae through to adult emergence. However, the addition of 10% whole egg powder to the plant-based meals enabled one quarter of larvae to survive to adult emergence. This compared to over three-quarters of larvae surviving to adults when reared on animal-based meatmeal with the addition of 10% whole egg powder. Larvae fed animal-based meatmeal with 10% whole dried egg powder had the fastest development to pupal formation, the highest pupation rate, the heaviest pupae and the highest subsequent emergence of adult flies, all of which were significantly better than rearing with plant-based meals.

Abstract: The use of the blow fly *Calliphora vicina* as a potential pollination species to augment the current reliance on honeybees (*Apis mellifera*) in Australian horticulture requires the knowledge on how best to mass rear this fly species. *Calliphora vicina* lays eggs onto carrion soon after death and the resultant larvae that hatch are necrophagous and feed on the decomposing tissues of the dead animal. Newly hatched larvae of this fly were provided with plant-based meals (soya bean and canola) and compared with animal-derived meatmeal to determine if plant-based meal could be used to mass rear this blow fly species. Both soyabean and canola meal media did not support larval survival through to adult emergence. The addition of only 10% whole egg powder to the plant-based meals enabled survival to eclosion of 39% and 13% on soyabean and canola-based medias respectively compared with 76% on animal-based meatmeal with 10% whole egg powder. Larvae fed livestock meatmeal with 10% whole dried egg powder had the fastest development to the pupal stage, the highest pupation rate, the heaviest pupae and the highest subsequent adult eclosion. This study concluded that the use of plant-based meals in the mass rearing of the blow fly *C. vicina* was neither viable, nor economically viable.

Keywords: calliphorid; oviparous; larval media; food restriction; larval nutrition; pupation

1. Introduction

Flies are leading research into identifying potential new pollination species [1,2] with the Calliphoridae, Rhiniidae and Syrphidae families being identified in a review of the role of flies in Australian horticultural crops [3]. There is evidence of pollination by flies in a range of crops and coupled with this pollination evidence, their foraging behaviour, life history traits and distribution

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across Australia, eleven calliphorid species were identified as promising candidates as a managed pollination insect in Australia [3]. Two blow fly species have recently been demonstrated as being capable of pollinating avocado trees when placed inside paired-tree enclosures or larger multi-tree enclosures, namely *Calliphora dubia* Macquart 1855 [4] and *Calliphora vicina* Robineau-Desvoidy 1830 [5]. The reliance on honey bees in Australia for pollination needs carries risks associated with the use of a single species. The recent introduction of varroa mite (*Varroa destructor* Anderson & Trueman 2000) into Australia has put further pressure on managed honey bees.

As flies are the second most abundant species to visitors to flowers [4,6–9] research has focused on identifying species that could be managed to provide a pollination service. This study examined rearing of the oviparous calliphorid *C. vicina* for use as a potential managed pollination species. The mass rearing of flies has provided benefits to society across a range of biological and medical fields [10]. The European blue-bottle blow fly (*C. vicina*) (formerly known as *C. erythrocephala* [11]) has been identified as a potential insect pollination species for the horticultural industry. Having been introduced into Australia over a hundred years ago, this fly is most found in the southern half of Australia.

Under laboratory conditions, *C. vicina* females lay around 500 eggs in their lifetime (over 3–4 egg masses) [12], hence rapidly building up large numbers of this fly is feasible. Rearing of calliphorid larvae has typically used different meat-based products and tissue types primarily from a forensic context to improve the calculation of a post-mortem interval (PMI) from fly larvae collected on human remains. Variation in the tissue type that blow fly larvae develop on can produce marked differences in developmental rate and body size, which can compromise predictions of the PMI within the context of forensic entomology [13–16]. Most calliphorid larval diets have focused on different animal meats (e.g., pork, beef, lamb, chicken) [17] along with the addition of whole dried egg and milk powder [18,19] or animal fat [16]. However in an effort to reduce odour some studies have developed artificial diets [20] with varying nutritional profiles [21,22] and the addition of some plant-based sources. For example bran was added to the larval diet of *Lucilia cuprina* Wiedemann 1830 [23] and larvae of *Chrysomya megacephala* Fabricius 1794 were reared on soya flour, milk powder and egg to reduce the odour of putrefied meat [20] and their development was no different to rearing the larvae on a fish meat diet. Green et al. [21] reared black blow fly larvae (*Phormia regina* Meigen 1826) on meridic (i.e., not containing any insect components) artificial diets of agar and casein (90% protein and 10% fat) along with cellulose and yeast; the authors noted that cellulose was indigestible to *P. regina*, but did not explain how this finding was determined. Replacement of milk powder with soyabean flour in an artificial diet for rearing screwworm flies (*Cochliomyia hominivorax* Coquerel 1858) resulted in significantly smaller pupae with reduced fitness and fecundity in the emerging adults [24].

Sources of protein fed to laboratory colonies of *C. vicina* for egg development, oviposition and as a larval rearing substrate have typically used either pig or cattle tissues (e.g., liver, blood or muscle) [17,25–30]. Rearing of large numbers of calliphorid larvae requires facilities with constant air extraction and ventilation to help reduce the odour of decomposing animal protein sources and ammonia. This study aims to determine if plant- based meals such as soyabean and canola can be used to develop the larvae of a necrophagous blow fly species, in this case *C. vicina*. There is evidence of some blow fly species being capable of developing from plant material mixed with animal manures [31–33] (i.e., reject vegetables fed to cattle) as well in very rare situations from purely rotting vegetable matter associated with vegetable production [32,33].

One product of animal rendering is meatmeal, which is often used as a rearing media for calliphorid flies [34–37] and more recently in detailed studies on both *C. vicina* [38] and *C. dubia* [39]. This product is comparatively cheaper than other meat-based media and is available in large quantities with a good blend of protein (50%), carbohydrates (38%) and fat (10%). Adding either whole egg powder or whole eggs (including the shells) to meatmeal significantly increased the rate of larval development, survival and adult emergence in both *C. vicina* [38] and *C. dubia* [39]. Whole dried egg powder is in short supply globally and alternate egg-based sources such as whole eggs discarded by egg layer facilities offer a much cheaper replacement. The costs and logistics involved

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in mass rearing each fly species are a key factor in deciding what fly species to choose as a managed pollination service. Choosing the most suitable larval rearing substrate involves both the cost of the rearing media and the need to generate high levels of pupation and adult emergence (both >90%). There are multiple examples of rearing *C. vicina* in small scale laboratory trials using the liver and muscle tissue of various animals. However these materials are often costly in large volumes, require being refrigerated and produce pungent odours in a rearing facility. For these reasons, livestock derived meatmeal has often been chosen as the rearing substrate for calliphorid flies.

As opposed to house fly larvae (*Musca domestica* L. 1758) which can be reared on plant-based diets consisting of either wheat bran, poultry meal or soyabean meal [40], blow fly larvae have typically been reared on animal tissues and associated products (e.g., blood, milk powder, eggs (whole dried powder or whole eggs)). The rearing substrate can have a significant effect on the larval growth rates [41] and this study will determine the nutritional suitability of plant-based meal and livestock meatmeal on larval development of *C. vicina*. This included measuring the rate of larval growth, the size of the migrating or post-feeding larvae, the number and size (wt) of pupae formed, and the subsequent emergence of adult flies.

2. Materials and Methods

2.1. Laboratory Colony

A laboratory colony of *C. vicina* was established at the Department of Primary Industries and Regional Development in South Perth, Western Australia. Adult flies were sourced from those caught in the field using carrion-based fly traps with 250 g of beef liver and 125 mL of 1.5% sodium sulphide solution. Solar Fly Traps® from Arbico Oganics (www.arbico-organics.com) were placed at several locations in the south-west of Western Australia, namely Busselton (−33.64165 S, 115.46172 E), Capel (−33.52121 S, 115.56024 E) and Preston Beach (−32.91854 S, 115.71296 E). Sugar and water was placed within each trap so that live adult flies could survive till being collected several days later. The live flies in the trap were then chilled in a 4 °C cool room so that any adult *C. vicina* could be removed and placed into a separate unit cage (60 cm × 60 cm × 60 cm). Each cage held 500 live adults which were supplied with water and a 50:50 mixture of sugar and milk powder ad libitum. Protein was provided to the cage of flies twice per week for a period of 24 h as cubes of beef liver sprinkled with blood to enable females to develop eggs.

2.2. Larval Extraction

Cages of adult *C. vicina* (≈1 week old and having had two liver feeds at days 2 and 6 after emergence) were presented with beef liver cubes sprinkled with blood on day 9 to elicit oviposition. The liver was checked >26–28 h later to determine the presence of newly hatched, 1st instar larvae. If present, then fifty (50) larvae were removed using a fine camel-hair paintbrush and placed onto each of five (5) replicates of 200 g of media (i.e., 4 g of media/larvae).

2.3. Larval Rearing Media Composition

Two plant-based products, soya bean meal and canola meal were compared to livestock based meatmeal as larval media for cohorts of newly hatched larvae. The meatmeal (livestock derived) was sourced from Talloman Rendering, Hazelmere, WA, Australia and combined with whole dried egg powder (Farm Pride Foods, Keysborough, VIC, Australia). The soyabean meal (Full Fat Soy Meal; 34% protein and 14% fat) and canola meal (34% protein and 10% fat) were sourced from PBA Feeds, Toowoomba, QLD, Australia. Larvae were reared on either 100% livestock based meatmeal (T1), 90% livestock based meatmeal and 10% whole egg powder (T2), 100% soyabean meal (T3), 90% soyabean meal and 10% whole egg powder (T4), 100% canola meal (T5) or 90% canola meal and 10% whole egg powder (T6) in a laboratory-based study.

The dry ingredients of each media treatment were first combined (*v*/*v*) and then sufficient water added to make them all up to the same consistency. The mixture was then divided across each replicate with 200 g placed into rectangular plastic containers (20 cm × 10 cm wide). Once prepared,

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fifty (50) newly hatched larvae were extracted from the liver and placed onto each larval media blend. The edges of each media tray were cut down to the height of the media so that post-feeding or migrating larvae could easily leave the food source.

2.4. Larval Development, Pupation and Adult Emergence

Each tray of larval media was placed onto a 5 cm deep bed of dry sand within a 2 L plastic box. These were kept in a vertical rearing cabinet in the laboratory held at 24.5 °C ± 0.5 °C, 30–40% RH and 14 h light: 10 h dark continuous cycle. Each media tray was sprayed daily with 25 mL of water to keep the media moist. Larval migration (i.e., they had left the media and were either under the tray or in the sand), along with newly formed pupae and adult emergence were recorded every day from every replicate media treatment. The weight (mg) of any migrating larvae and newly formed pupae was recorded from each media treatment.

2.5. Statistical Analysis

All the data collected on larval development to the wandering phase and pupation was analysed using R (version 4.1.1) with the "*nlme*" package [42]. If the data was normally distributed an analysis of variance (ANOVA) was performed using the function "*aov*" [formula: *response variable ~ treatment*] to evaluate the effects of each treatment (larval media composition) on fly development (% larval wanderers, % pupation; dependent variables). Bartlett's test was used to determine homogeneity of variances across treatments. If the variances were not homogenous, then the non-parametric Kruskal-Wallis test was used to compare group means and Tukey's Multiple Comparison test used to determine which means are significantly different from one another [43].

3. Results

Livestock Meatmeal, Soyabean Meal and Canola Meal (T1–T6)

There was a significant difference between treatments (larval rearing media) in development through to post-feeding or migrating larvae ($F = 21.139$, $df = 4$, $p < 0.001$) (Figure 1A); larval development was most rapid on 90% meatmeal and 10% whole egg powder (T2) where within 7 days peak larval migration of over 80% had occurred. No larvae successfully developed through to the migration stage when fed pure soyabean meal (T3) and <5% of larvae migrated from pure canola meal (T5). The addition of 10% whole egg powder to both plant-based meals significantly increased the level of larval migration to 29% when added to canola meal (T6) and 49% when added to soyabean meal (T4).

The % survival of larvae to pupation was significantly different across treatments (T1 = 32.8 ± 1.81; T2 = 82.0 ± 4.54; T3 = 0 ± 0; T4 = 46.8 ± 1.91; T5 = 1.6 ± 0.37; T6 = 24.4 ± 5.68) (Figure 1B). The variances across the media treatments were not homogenous (Bartlett's $T = 13.64$, $df = 4$, $p = 0.0085$) and there was a significant difference between the survival of larvae through to pupation across the treatments (Kruskal–Wallis, $H_c = 23.26$, $p = 0.0003$); Tukey's HSD procedure indicate that significantly more larvae reared on meatmeal and egg powder (T2) survived to pupation compared with pure soyabean (T3) and pure canola meal (T5) ($p < 0.05$). Survival to pupation on soyabean meal and egg powder (T4) was significantly higher than on pure soyabean meal (T3) ($Q = 3.05$, $p < 0.005$) media treatments T1, T4 and T6 were not significantly different from each other ($p > 0.05$) (Figure 1B).

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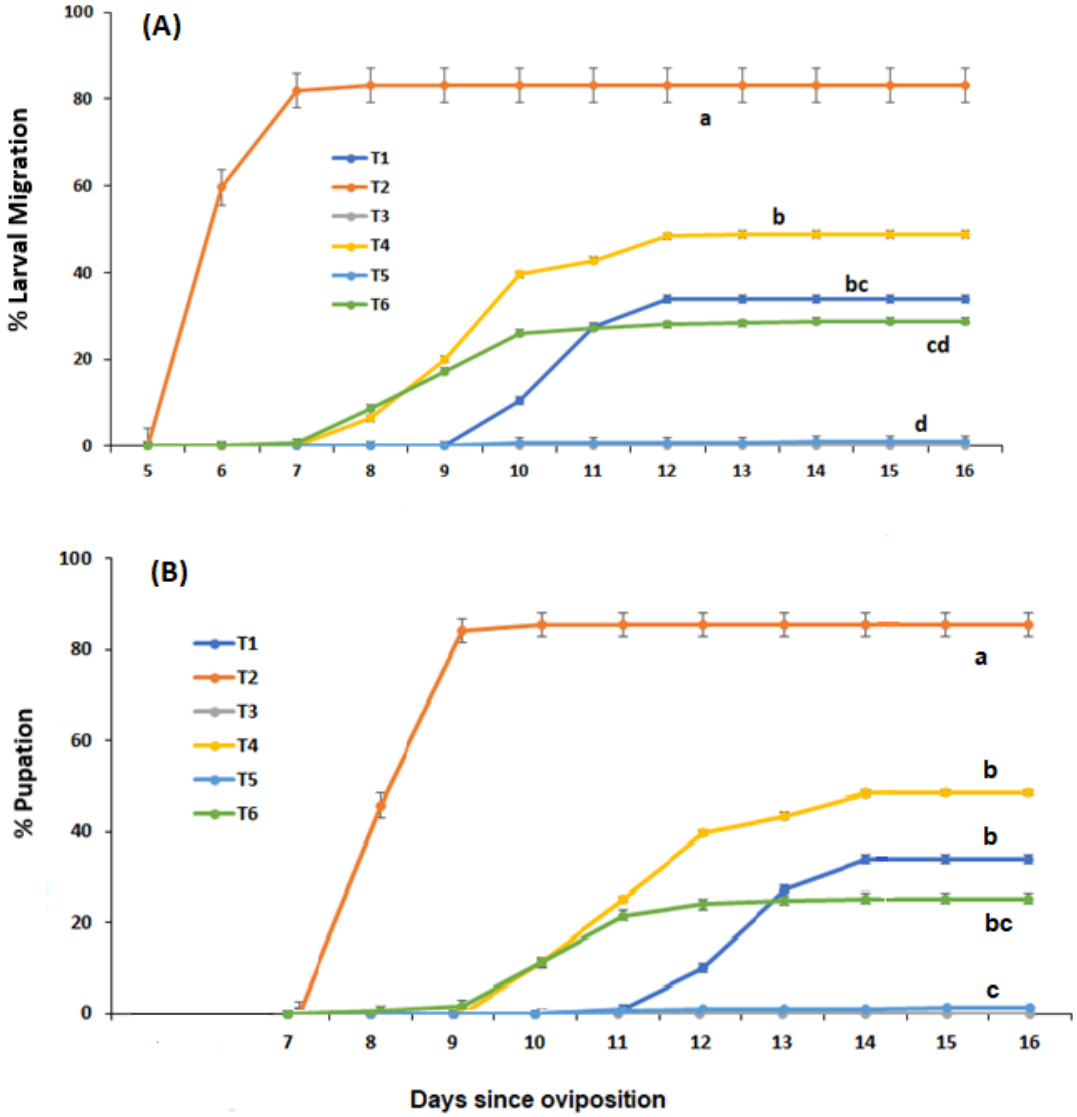

Figure 1. Proportion of *C. vicina* larvae that had (**A**) migrated off the media, and (**B**) pupated up to 16 days since oviposition when reared on either: T1 = 100% meatmeal; T2 = 90% meatmeal and 10% whole egg powder; T3 = 100% soyabean meal; T4—90% soyabean meal and 10% whole egg powder; T5 = 100% canola meal; T6 = 90% canola meal and 10% whole egg powder. Different letters indicate significant differences between treatments ($p \leq 0.05$, Tukey HSD test).

The variances in larval weight (mg) were homogeneous across treatments (Bartlett's T = 8.86, p = 0.065) and a one-way ANOVA indicated a significant difference between larval media treatments (F = 72.48, $p < 0.0001$). Mean larval weight was not significantly different ($p > 0.05$) between meatmeal alone (T1) and meatmeal with whole egg powder (T2) but was significantly different between all other media treatments ($p < 0.05$) (Figure 2A). The variances in pupal weight (mg) were also homogeneous across treatments (Bartlett's T = 1.86, p = 0.761 and a one-way ANOVA indicated a significant difference between media treatments in pupal size (weight in mg) (F = 103.05, $p < 0.0001$). Mean pupal weight was significantly different ($p < 0.05$) between each media treatment with the heaviest pupae in T2, followed by T1, T4, T5 and T6 (Figure 2B).

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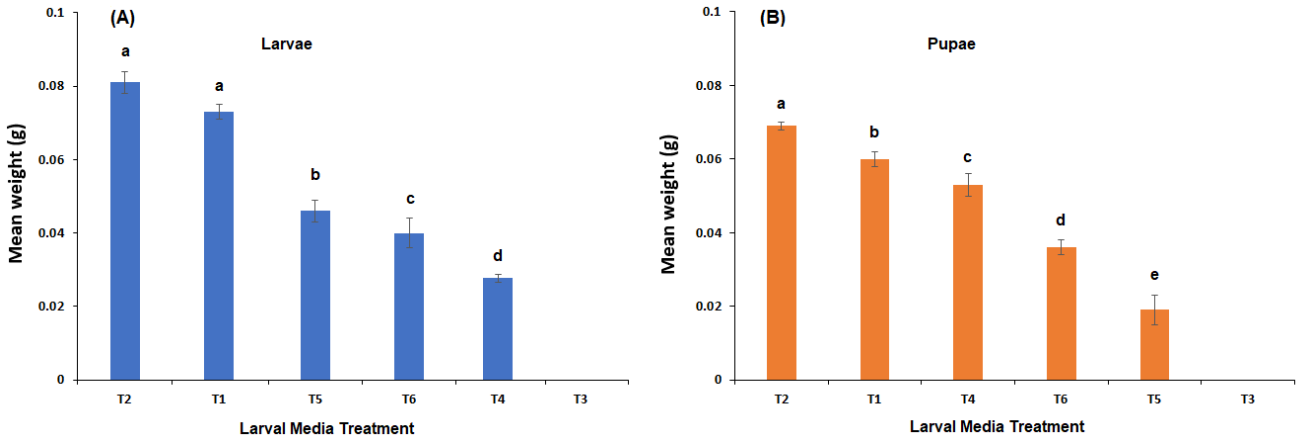

Figure 2. Mean weight ± s.e. of *C. vicina* migrating larvae (**A**) and pupae (**B**) from newly hatched larvae being fed either: 100% meatmeal (T1); 90% meatmeal and 10% whole egg powder (T2); 100% soyabean meal (T3); 90% soyabean meal and 10% whole egg powder (T4); 100% canola meal (T5); or 90% canola meal and 10% whole egg powder (T6). Different letters indicate significant differences between treatments ($p \leq 0.05$, Tukey HSD test).

The variances in adult eclosion across the four (4) media treatments where adult eclosion occurred (T1, T2, T4 and T6) were not homogenous (Bartletts T = 19.12, $p = 0.00026$), hence a one-way Kruskal-Wallis test indicated that adult eclosion was significantly different across media regimes ($\chi^2 = 14.18$, $p = 0.0027$) (Figure 3). The lowest adult emergence was from the canola meal and whole egg powder (52%, T6), which a multiple comparison indicated was significantly less than both pure livestock meatmeal (90%, T1; Q = 2.889, $p = 0.004$) and meatmeal with 10% whole egg powder (93%, T2; Q = 3.477, $p = 0.0005$) (Figure 3).

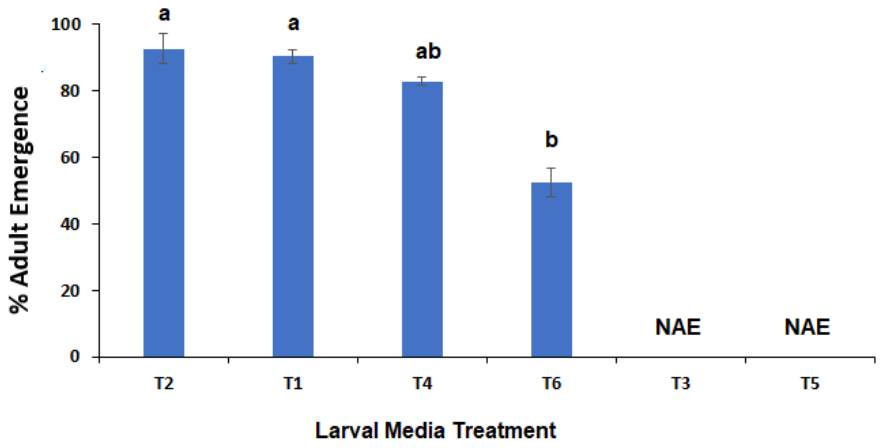

Figure 3. Mean % adult emergence of *C. vicina* from newly hatched larvae fed either: 100% meatmeal (T1); 90% meatmeal and 10% whole egg powder (T2); 100% soyabean meal (T3); 90% soyabean meal and 10% whole egg powder (T4); 100% canola meal (T5); or 90% canola meal and 10% whole egg powder (T6). Different letters indicate significant differences between treatments ($p \leq 0.05$, Tukey HSD test). NAE = No adult emergence.

No adults emerged from either pure soya bean meal (T3) or pure canola meal (T5), even though there were 11 pupae formed from T5 (mean wt. 19.3 ± 2.87 mg). The highest adult emergence was from meatmeal and whole egg powder (T2), which was significantly higher ($p < 0.05$) than canola meal and whole egg powder (T6) (Figure 3).

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4. Discussion

This primary focus of this study was to optimize the rearing of the calliphorid blow fly *C. vicina*, with the larval rearing media being the most critical phase in this process. Numerous studies in the laboratory have demonstrated that adding whole egg powder to livestock derived meatmeal resulted in rapid larval migration and pupal formation along with consistently larger pupae and high rates of adult eclosion [38]. The addition of only 10% whole egg powder to the meatmeal increased pupation by 38%, pupal weight by 16% and adult emergence by 25%. Rearing the larvae of another calliphorid, *Calliphora dubia* had similar improvements in the same parameters [39]. Several quality control points are measured during mass rearing, which typically include larval migrant weight, percent pupation and size (wt) and rates of adult eclosion [44]. Other parameters measured post-eclosion include adult flight ability, lifespan and lifetime fecundity, which were not assessed in this study.

The ingredients tested in the present work were from three sources, livestock meatmeal, soyabean meal and canola meal. Both soyabean and canola meal have a very similar amino acid profile [45] and are both one of the few vegetable foods that contain all 9 essential amino acids (Table 1). The amino acids in both soyabean and canola meal protein are close to that of livestock meatmeal, in particular their levels of each essential amino acid [46]. Canola meal is a major protein source for animal feeding in Australia with high concentrations of protein and a well-balanced amino acid profile [47]. Variation in canola meal protein is a limiting factor in the value of canola meal, where according to Seberry et al. [48] total crude protein can vary from 36–47%. Protein alone is not a good indicator of canola meal quality, as heat treatment by processes to extract canola oil from seed results in a loss in protein digestibility (see references in [47]).

Table 1. Amino acid profile of animal-derived meatmeal and both soyabean and canola meal *.

	Livestock Meatmeal	Soyabean Meal	Canola Meal
Essential amino acids			
Arginine	4.80	7.20	5.80
Histidine	1.44	2.60	2.70
Iso-leucine	1.87	4.00	4.00
Leucine	4.16	7.80	7.00
Lysine	3.64	6.40	5.80
Methionine	1.11	1.30	1.90
Phenylalanine	2.29	5.00	3.80
Threonine	2.31	4.00	4.50
Valine	2.69	4.80	5.00
Non-essential amino acids			
Alanine	5.16	4.30	4.30
Aspartic acid	5.18	11.70	7.00
Cystine	1.03	0.64	
Glutamic acid	8.83	18.70	17.50
Glycine	9.33	4.20	4.90
Proline	6.04	5.10	6.00
Serine	2.66	5.10	4.60
Tyrosine	1.57	3.20	3.10

* Livestock meatmeal data sourced from [49] and plant-based meal data sourced from [45]. Values are expressed as % of crude protein.

An interesting observation during this study was a temporary rise in temperature of the plant-based meal treatments, and in particular the soya bean meal at days 3–5 after placing the larvae onto them (Figure 4) where temperatures were 5–6 °C warmer in the soyabean meal media. This did not translate into faster larval development as no larvae survived to pupation on pure soyabean meal and <5% survived to pupation on canola meal (of which none resulted in subsequent adult emergence). The rate of development of an insect including blowflies is primarily governed by

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temperature [50] and can differ between even closely related species of blow flies [51]. Soyabean meal is often fermented to breakdown the proteins into smaller peptides, which are more easily absorbed by animals and in the process generates heat [52].

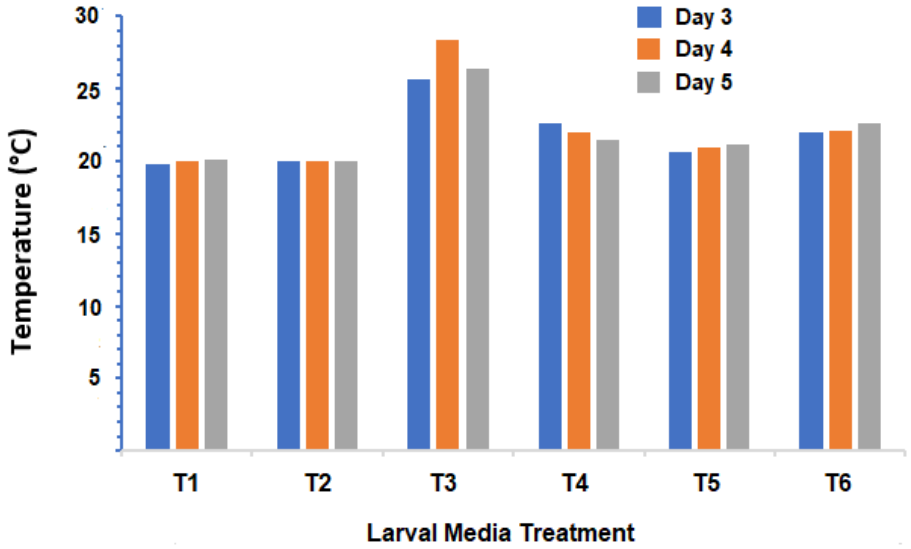

Figure 4. Mean temperature of media at days 3–5 after placing newly hatched larvae of *C. vicina* onto the media where: T1 = 100% meatmeal; T2 = 90% meatmeal and 10% whole egg powder; T3 = 100% soyabean meal; T4 = 90% soyabean meal and 10% whole egg powder; T5 = 100% canola meal; and T6 = 90% canola meal and 10% whole egg powder.

Newly hatched larvae of house fly (*Musca domestica* L. 1758) fed on soyabean meal had over three-quarters survive to larval migration, of which 95% pupated and all resulted in adult eclosion [40]. By contrast in this study, no larvae of *C. vicina* survived to the larval migration phase on soyabean meal and only 4.4% of larvae fed canola meal migrated from the food source and formed very small pupae, with no subsequent adult emergence. One reason for the poor development of *C. vicina* larvae on soya bean meal could be that soybean has been reported as lacking in the amino acids cysteine and methionine [53] (see Table 1), which are required for animal growth [54]. Canola meal however is reported in the literature as having higher levels of cysteine and methionine than soyabean meal [55] but being limiting in lysine [56]. Methionine and cysteine are the highest sulphur containing amino acids, whose oxidation results in pungent, volatile sulphur compounds [57] The fact that no adult flies developed from larvae fed either pure plant meal (soyabean or canola) suggests that some component(s) of animal protein are essential for their development. This was highlighted by the addition of whole egg powder to the plant meals at only 10% of the total larval media resulting in adult emergence of *C. vicina* (50–80%) from pupae that were formed. This may be a simplistic reason for the lack of development through to adult eclosion when larvae were fed plant-based meals, as [58] showed an interaction between amino acid composition and the microbial population present in larval development of the blow fly *Lucilia sericata* Meigen 1826.

There are marked differences in developmental rate and body size of resultant adults when blow fly larvae are fed different tissue types [17,59,60], which includes *C. vicina*. Larvae of *Ch. megacephala* fed diets high in fat showed increased larval development rates but resulted in smaller adult flies [16]. The type of larval rearing substrate in this study had a significant effect on the proportion and size of post-feeding larvae, their ability to pupate (along with pupal weight) and successful adult eclosion. Larvae of the calliphorid *Aldrichina grahami* Aldrich 1930 fed pure pork liver paste were significantly heavier than larvae fed a diluted and poorer quality pork liver paste [61]. The odour of decomposing protein when rearing calliphorid flies can be an occupational hazard for workers in a rearing facility. To overcome this, Reddy et al. [20] developed an artificial diet of soyabean flour, milk powder and whole egg to rear large numbers of *Ch. megacephala* in an effort to reduce the unpleasant odour from the putrefied meat. All life history stages rate of development and the resultant size of

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adults that were produced was no different after rearing this blow fly on the artificial diet as compared to the fish meat diet.

The ability of necrophagous flies to develop from only plant material is limited and rarely reported in the literature, where they represented <1% of all fly species that emerged. The only known examples of flies developing from plant-based material include: *C. dubia* from rotting snow peas *Pisum sativum* var. *macrocarpum* [32], celery (*Apium graveolens* L.) and cauliflower (*Brassica oleracea* von Plenck) [33]; *Chrysomya rufifacies* Macquart 1842 from rotting cauliflower [32] and leek (*Allium ampeloprasum* L.) [33] and *L. cuprina* from rotting celery [33]. *C. vicina* has previously been reared from rotting residues of beetroot (*Beta vulgaris* L.) [33]. The blow fly species *C. dubia*, *Ch. rufifacies* and *L. cuprina* are capable of developing in animal manures mixed with plant material. For example, poultry litter (poultry manure and either jarrah (*Eucalyptus marginata* Donn x Smith) or pine (*Pinus radiata* Don. Monterey P.) sawdust) when applied to soil as a fertiliser in vegetable production, [31] where they represented <0.2% of all flies developing from this substrate. *C. dubia* adults developed from reject vegetables when fed to livestock and mixed with animal manure [32], in particular reject cauliflowers fed to cattle (17.3%), but also carrots fed to cattle (<0.01%).

Mass rearing of house flies (*Musca domestica* L. 1758) can be achieved using plant-based substrates (i.e., 50% wheat bran, 30% alfalfa meal, and 20% corn meal). This substrate mixture produced the highest survival to pupation and heaviest pupal weights compared with animal wastes (e.g., diary, swine or poultry manure) [62]. Pérez et al. [12] reared larvae of *C. vicina* on several different artificial diets; the shortest developmental time (egg to pupae) was on pig's liver (18.8 days) compared with milk powder and egg (24.6 days) and powdered liver. Our studies showed C. *vicina* development from egg to pupae took only 9-10 days on meatmeal and whole egg powder, which is less than half the duration recorded by Pérez et al. [12]. *Calliphora vicina* has been described by Pérez et al. [12] as highly adaptable to being reared in a laboratory setting with artificial nutritional diets. The study reported here only partly supports this description, where larval media consisting of 90% meatmeal and 10% whole egg powder ensured rapid larval development to pupation, the highest pupation rate and subsequent adult emergence. When reared on plant-based meal and whole egg powder, both larval development and survival of pupae to adult eclosion was significantly impaired.

This study demonstrated that the larvae of *C. vicina* are not capable of developing through to pupation when reared on pure canola meal. Although there was some level of pupal formation on pure soyabean meal (<5%), no adults emerged from these pupae. The addition of just 10% whole egg powder to the plant-based meals enabled between 30–50% of larvae to migrate from the media and 20–40% to then pupate with some adult emergence from the soyabean meal and 10% whole egg powder (T4) (39% of initial larvae) and less so from canola meal and 10% whole egg powder (T6) (13% of initial larvae). Hence, the use of plant-based meal as an ingredient to rear *C. vicina* larvae in any mass rearing scenario has not been supported by this study, where neither pure plant meals supported larval development through to adult eclosion. Even when blended with 10% whole egg powder, the plant meal media resulted in lighter weight larvae (26% soyabean meal and 50% canola meal), lighter weight pupae (22% soyabean meal and 52% canola meal) and a reduced adult emergence (51% soyabean meal and 83% canola meal) when compared with livestock meatmeal and whole egg powder.

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