Insects reared for food use – a comparison of greenhouse gas production in *Tenebrio molitor* with other livestock animals

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Abstract

The breeding of edible insects is still a matter of peripheral interest in the Czech Republic, though its gradual development can be expected. The rearing of a large number of living organisms is associated with the production of waste and greenhouse gases. In this experiment, the production of greenhouse gases was determined in the species *Tenebrio molitor*. Production of carbon dioxide, ethane and ethylene was measured. A gas chromatograph was used to measure the production of greenhouse gases. The measured values were converted into production in $g{\cdot}kg^{-1}$ of live weight and compared to the production of greenhouse gases in livestock animals. The results show that the difference in greenhouse gas production between *Tenebrio molitor* and livestock animals ranged between 0.822 and 26.548 $g{\cdot}kg^{-1}$ of live weight $LW{\cdot}h^{-1}$ for carbon dioxide, which are values as much as 1664.52 times higher. For other greenhouse gases, the difference ranged from 0.009 to 1.375 g CO_2-eq$\cdot kg^{-1}$ $LW{\cdot}h^{-1}$, indicating that these values are as much as 3.82 times higher than in livestock animals.

Carbon dioxide, edible insects, greenhouse gases, livestock animals

Introduction

Edible insects can be defined as all species of insect whose consumption does not have a negative effect on the health of the consumer. This usually involves species of insect that are abundant and widespread at a given place and whose harvesting or breeding is undemanding. Species of insect used in the Czech Republic include the yellow mealworm beetle, the giant mealworm beetle, the steppe cricket, the house cricket, the desert locust and the migratory locust (Borkovcová et al. 2009). The yellow mealworm beetle (*Tenebrio molitor*) is one of the most frequently bred species. It is a readily available and easily bred species (Plate V, Fig. 1). The adult has a dark brown to black body 14 – 18 mm long. Its wing cases are shiny with longitudinal ribbing. The larvae are around 30 mm long and are golden brown in colour, with the head and the final segments of the body being darker in colour (Bruins 2005).

Breeding for food use remains of peripheral interest to date in the Czech Republic, though development in this area can be expected in the future in line with global trends. The mass breeding of insects, like the rearing of any livestock animal, will be accompanied by the production of organic waste and greenhouse gases. The most significant greenhouse gases include carbon dioxide, methane and nitrous oxide (Oonincx 2010). Emissions of these gases from animal production represent 14.5% of all anthropogenic emissions (Gerber et al. 2013). The aim of this experiment was to measure and monitor production of greenhouse gases produced by the breeding of the yellow mealworm.

Materials and Methods

The subjects of the experiment were yellow mealworm larvae which were closed in infusion bottles, from which a sample of air was taken with a tuberculin needle. Ethane and ethylene were determined during the experiment

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in view of the fact that nitrous oxide and methane are produced at the limit of measurability. Measurements were taken for a period of 3 hours at 60 min intervals. The measured values were converted into equivalent carbon dioxide for the purpose of comparison with the results stated by other authors.

The content of ethane and ethylene in 1 ml of air collected with a tuberculin syringe was determined in a gas chromatograph (FISSONS INSTRUMENT) with an HP-PLOT/Al_2O_3 capillary column 24 m long. The temperature of the detector was 200 °C, the injection temperature 230 °C and the column temperature 40 °C (Fišerová and Hradilík 1994; Fišerová et al. 2001 and Fišerová et al. 2008). The carbon dioxide content was determined on a CHROM 5 gas chromatograph with a katharometer with a 1.5 meter packed column with PORAPAK Q.

The measured values were converted into CO_2-eq by means of the GWP (global warming potential) of individual greenhouse gases. This means that the general procedure for calculation is as follows: production of the monitored greenhouse gas multiplied by the pertinent GWP value. The following equation was used in our case for the calculation of total production of greenhouse gases: production of GHG (greenhouse gases) = (production of CO_2 x 1) + (production of ethane x 8.4) + (production of ethylene x 6.3). For the production of gases by insects, the concentration of gases was converted to the weight of animal material.

Results and Discussion

The results of measurement of greenhouse gas production in the yellow mealworm are given in Tables 1 and 2. The measured values in $\mu g \cdot g^{-1}$ of live weight are given in Table 1. Table 2 shows values converted into grams of equivalent carbon dioxide per kilogram of live weight. Values for the production of greenhouse gases by livestock animals, with which the values we measured for the production of greenhouse gases in the yellow mealworm are compared, are given in Table 3.

Table 1. Measured values of greenhouse gases in the yellow mealworm in $\mu g \cdot g^{-1}$

	Yellow mealworm		
	Hour 1	Hour 2	Hour 3
Ethylene	66.91 ± 1.35	64.62 ± 3.94	53.85 ± 8.35
Ethane	15.93 ± 0.98	16.1 ± 1.27	14.36 ± 2.26
CO_2	12.5 ± 0.29	14.26 ± 1.12	21.27 ± 1.03

Table 2. Measured values of greenhouse gas production in the yellow mealworm converted into g CO_2-eq$\cdot$kg^{-1} LW

	Yellow mealworm				
	Hour 1	Hour 2	Hour 3	Average	Total
Ethylene	0.422	0.407	0.339	0.389	0.503
Ethane	0.100	0.101	0.090	0.097	
CO_2	0.013	0.014	0.021	0.016	

The highest production was measured for ethylene, with a value of 0.389 g CO_2-eq$\cdot$kg^{-1} LW. The lowest production was found for carbon dioxide, for which a value of 0.016 g CO_2-eq$\cdot$kg^{-1} LW was determined. Total production of all greenhouse gases during the experiment was 0.503 g CO_2-eq$\cdot$kg^{-1} LW.

When we compared the values we measured for the production of carbon dioxide by *Tenebrio molitor* with the results of other authors, we found that our values are of the order of 10 times lower than those given in the study by Oonincx (2010). In our opinion, this difference may have been caused by a different methodology, with the measurement of production we employed being performed without the presence of a breeding substrate. This hypothesis is confirmed by the study by Rumpold and Schlüter (2013) who state in

Table 3. Production of carbon dioxide and other greenhouse gases in g CO_2-eq ·kg^{-1} LW in livestock animals

Monitored gas	Production of greenhouse gases in livestock animals per hour Pigs	Poultry	Cattle	Small ruminants
CO_2	0.923	1.182	26.649	1.241
Other gases	0.245	1.862	0.513	0.496

Zervas and Tsiplakou (2011); Phelippe and Nicks (2015); Brouček and Čermák (2015); Henn et al. (2015); Hristov et al. (2015) and Podkowka et al. (2015)

their work that the following microorganisms are found on edible insect farms: *Escherichia coli, Klebsiella aerogenes* and *Staphylococcus* spp. The study by Němcová et al. (2011) states that certain of these species of microorganism may produce a considerable quantity of gases. *Escherichia coli* is capable of producing about 158.673 µg of carbon dioxide an hour at a temperature of 25 °C and as much as 270.76 µg CO_2 an hour at 30 °C depending on the substrate and the quantity of microorganisms present. We performed a comparison of production of the studied greenhouse gases by *Tenebrio molitor* with conventional kinds of livestock animal on the basis of data taken from a number of studies. In their study, Phelippe and Nicks (2015) determined CO_2 production in pigs of a live weight of 70 kg. A value of 0.923 g·kg^{-1} was obtained following conversion of production to kg of live weight an hour. In comparison with carbon dioxide production by *Tenebrio molitor*, this is a value 57.65 times higher. In their study, Zervas and Tsiplakou (2011) state values for the production of other greenhouse gases in pigs. After converting these values to g·kg^{-1} an hour and equivalent carbon dioxide, we obtained a value of 0.245 g CO_2-eq·kg^{-1}·h^{-1} an hour. In comparison with the results we determined for the yellow mealworm, this value is 0.242 g CO_2-eq·kg^{-1} LW·h^{-1} lower. In their research, Henn et al. (2015) state CO_2 production in broiler chickens. The given values were also converted. The resultant production was 1.182 g CO_2-eq·kg^{-1} LW·h^{-1}. This value is 73.83 times higher than that for the yellow mealworm. In their study, Brouček and Čermák (2015) state methane production of 82.636 mg·kg^{-1} an hour and nitrous oxide production of 0.409 mg·kg^{-1} an hour in broilers, which, converted to equivalent carbon dioxide, amounts to 1.862 g CO_2-eq·kg^{-1}·h^{-1}. This value is 3.823 times higher than that for *Tenebrio molitor*. In their work, Hristov et al. (2015) state average CO_2 production in calves. After conversion of these values to g·kg^{-1} LW an hour, production amounts to 26.649 g. In comparison with the species of edible insect we studied, this value is 1664.52 times higher. In their work, Podkowka et al. (2015) state methane and nitrous oxide production for the Czech Republic in kg/head of cattle a year at a live weight of 585 kg. Following conversion of the given values into production in g CO_2-eq·kg^{-1} LW an hour, methane production of 0.4704 g CO_2-eq and nitrous oxide production of 0.0423 g CO_2-eq·kg^{-1} LW·h^{-1} were determined. It is clear from these values that total production is 0.5127 g CO_2-eq·kg^{-1} LW·h^{-1}. When we compare this with production by the yellow mealworm we studied, we find it produces just 0.0257 g CO_2-eq·kg^{-1} LW·h^{-1} less. In small ruminants, production of carbon dioxide amounts to 1.241 g CO_2-eq·kg^{-1} LW (Zervas and Tsiplakou 2011). This value is 1.225 g·kg^{-1} LW higher than that for the species of edible insect we studied. In their work, Zervas and Tsiplakou (2011) also state production of other greenhouse gases in small ruminants. Following conversion of this value into production in g·kg^{-1} an hour and equivalent carbon dioxide, we obtain a value of 0.496 g CO_2-eq·kg^{-1} LW·h^{-1}. The author does not state values of emissions of nitrous oxide produced directly by the animals. By comparison with production in the yellow mealworm, we find that the difference in production is 0.009 g CO_2-eq·kg^{-1} LW·h^{-1}.

These large differences in carbon dioxide production between the yellow mealworm and livestock animals are, according to Quinlan and Gibbs (2006), caused by the physiology of respiration in insects, in particular discontinuous carbon dioxide release from the organism, which serves to reduce water loss from the body of the insect.

Conclusions

It is clear from a comparison between *Tenebrio molitor* and livestock animals in terms of production of greenhouse gases that the most pronounced differences were found in the production of carbon dioxide. The largest difference determined was in comparison with calves and amounted to a value of 26.633 g CO_2-eq·kg^{-1} LW an hour. The differences in the production of other greenhouse gases were not so pronounced. The most interesting difference here was in comparison with pigs, with it being found that *Tenebrio molitor* produces 0.242 g CO_2-eq·kg^{-1} LW·h^{-1} more. (Plate V, Fig. 1, Plate V, Fig. 2).

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