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UNUSUAL ASPECTS OF THE FAT CONTENT OF MEALWORM LARVAE AS A NOVEL FOOD

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ABSTRACT

The work focuses on some aspects of content and properties of the fat in mealworm as a novel food. The total fat content of this species is a markedly variable nutritional value that is significantly dependent on the breeding conditions. In this work, the fat content of a mealworm from various Czech suppliers ranged from 202 $g.kg^{-1}$ to 282 $g.kg^{-1}$ dry matter, determined using the Soxhlet extraction method. The total average value from all suppliers was 235.8 ±40.8 $g.kg^{-1}$. This is a range that can be expected by the customer when buying mealworm larvae from a random Czech supplier. Furthermore, the work graphically compares the values of the total fat content with other comparable commodities of animal origin, e.g. chicken or fish. Finally, the aim was to obtain initial information about the comparison of the sensory properties of the mealworm fat with other fats of animal origin using a simple electronic nose. There was a difference between the fat obtained from insect larvae and the conventional unprocessed fats. This work brings a wider view of fat as a taste carrier in a new food - a mealworm.

Keywords: mealworm; fat; breeder; electronic nose

INTRODUCTION

The inclusion of edible insect as novel foods in human nutrition is affected by several factors such as nutritional value, consumer gastronomic requirements, as well as economic and ecological aspects **(Cerritos, 2011; Chae et al., 2012; Fontaneto et al., 2011; Mariod, Abdel-wahab and Ain, 2011; Premalatha et al., 2011)**. The attitude of consumers towards entomophagy varies in different parts of the world. In developing countries, the edible insect is a common basic food with an interesting nutritional value, such as protein and fat content. On the contrary, in the developed world, especially in Europe and North America, it is predominantly an enjoy-ment food **(De Foliart, 1992; Ramos-Elorduy et al., 2011)**. By changes of European legislation, edible insect became a novel food that is being increasingly promoted on European markets **(EFSA 2015; EFSA, 2018)**. The reason is the growing consumer interest in repeated eating of edible insect, not only because of its interesting nutritional value but also for its specific sensory properties **(Adámek et al., 2018)**.

Insect is consumed mostly culinary processed (baked, blended into rice, soups, pasta, or salads) **(van Huis, 2015)**. Fat as a carrier of taste is generally rich in edible insect. However, its quantity varies considerably among species. Its value for mealworm (*Tenebrio mollitor*) is most often in the range of 150 to 300 $g.kg^{-1}$. Not only the amount of fat but also the fatty acid profile is dependent on various aspects (diet, developmental stage, breeding temperature). In terms of purchasing insect in native state, however, many aspects are unknown for the consumer. Information on total fat content is important to consumers because of the use of edible insect material as part of food products and meals. The fat content can determine the final product properties. In the case of including insect in the food basket of the Czech consumer, it is important to compare it with commonly consumed foods of animal origin. For the consumer, not only the nutritional value but also the organoleptic properties play an important role. The primary assessment of a consumed food is its visual appearance and aroma, on the basis of which the consumer chooses to consume. A firmly defined state of a food with a certain flavor can be recorded using the electronic nose to distinguish this firmly defined state of the food (commodity) from other states. This can be used, for example, to determine the authenticity and safety of foods, the maturity of a particular raw material, and so on.

Scientific hypothesis

A) Average values of the total fat content of the mealworm as a novel food by individual breeders do not differ by more than ±10% from the total average fat content of all selected suppliers. B) The total fat content of the mealworm as a novel food is comparable to other commodities of animal origin from common livestock. C) The results of comparison of the fat sensory evaluation of mealworm as novel food with other fats of animal origin using a simple electronic nose will be different.

Aim

The aim of this work was to evaluate some aspects gained and analyzed during the monitoring of nutritional values of mealworm, especially for fat. The work observes and compares the total fat content of mealworm from different breeders including the determination of its average value and the standard deviation and its comparison with other fats of animal origin commonly used. Furthermore, the aim was to obtain initial information on the comparison of the sensory properties of the fat of the mealworm with other fats of animal origin using a simple electronic nose.

MATERIAL AND METHODOLOGY

Material

Mealworm (*Terebrio mollitor*) larvae in the last and the penultimate developmental stages (full length of the body just before the pupae) were used. The larvae were taken from the breed, left to starve for 48 hours, killed with boiling water (100 °C) and immediately dried at 105 °C. The samples prepared this way were homogenized and stored in a refrigerator at 4 – 7 °C until analysis.

The larvae were purchased from three companies in the Czech Republic. In addition, the data of the author described in **(Adámková et al., 2016; Adámková et al., 2017)** were used for comparison. Furthermore, the average values and standard deviations from available literature were compared with a focus on breeding and sales in the Czech Republic.

Methods

Determination of fat content using Soxhlet extraction method

Determination of fat content was carried out by Soxhlet extraction method **(Soxhlet, 1879)** using Gerhardt Soxtherm machine (C. Gerhardt, Germany). 5 g of dried and homogenized samples (with an accuracy of 0.0001 g) were placed in the extraction cartridge and extracted with 150 ml petroleum ether (program: 70 °C for 120 minutes). The extracted sample was then dried at 103 °C and repeatedly weighed to a constant weight.

E-nose

Fat samples were further analyzed using the simple electronic nose described in **Adámek et al. (2018)**. Samples were analyzed at 20 °C – 23 °C.

Statisic analysis

The data were analyzed using Excel 2013 (Microsoft, USA). Results were expressed by average ± standard deviation. For the calculation of the general average fat values for mealworm and their comparison, also the values from the available literature complemented by the optimal conditions of breeding focused on the breeding area in the Czech Republic were used together with the measured values.

In case of measurement by E-nose, data was evaluated using Excel 2013 (Microsoft, USA) and Gnuplot 5.0: an interactive plotting program **(Williams et al., 2016)**.

RESULTS AND DISCUSSION

Comparison of the total fat content in samples from each supplier

To determine the overall value of the total fat content of the mealworm larvae and its comparison, the total fat content in samples from three suppliers (2 direct breeders + 1 supplier with unknown breeder) was determined in the first step. The basic results determined by the Soxhlet method are shown in Table 1.

From the results shown in Table 1. average values and standard deviations for individual suppliers were calculated and these values were compared with other literary sources focusing on the area of the Czech Republic, as shown in Table 2.

Table 2 shows that even under optimal breeding conditions, the total dry fat content of mealworm larvae (*Tenebrio molitor*) samples may differ statistically, even if the breeders are from one geographical area. By random purchase, the consumer gained insect with a total fat content ranging from 170 $mg.g^{-1}$ to 360 $mg.g^{-1}$ of fat in dry matter. The mean value calculated from the experimental values and available literature sources for Europe for the optimal breeding conditions stated is 243 ±57 $mg.g^{-1}$.

Table 1 Basic results of total fat content determination in samples from three breeders.

Supplier / Number of sample	Weight (g)	Cartridge (g)	Cartridge with fat (g)	Fat (g)	Fat (%)
1/1	5.0730	125.7388	126.8781	1.1393	22.5
1/2	4.9918	127.5941	128.5756	0.9815	19.7
1/3	4.9943	126.6273	127.7322	1.1049	22.1
1/4	5.0119	127.1224	128.0918	0.9694	19.3
1/5	5.0684	125.5152	126.4834	0.9682	19.1
1/6	5.0132	127.1985	128.1483	0.9498	18.9
2/1	5.1480	140.6099	142.0639	1.4540	28.2
2/2	5.0160	144.0048	145.4104	1.4056	28.0
2/3	5.1116	143.0519	144.5135	1.4616	28.6
2/4	4.7388	143.3339	144.6375	1.3036	27.5
2/5	5.0217	141.0421	142.4845	1.4424	28.7
2/6	4.9480	140.4960	141.8926	1.3966	28.2
3/1	5.0095	140.4526	141.4555	1.0029	20.0
3/2	4.9979	140.0654	141.1921	1.1267	22.5
3/3	5.0967	143.0847	144.1158	1.0311	20.2

Table 2 Comparison of total fat content from analyzed samples from three suppliers with other literary sources focusing on the area of the Czech Republic.

Supplier	Breeding conditions	M [mg/g]	SD [mg/g]	
Supplier no. 1	optimal	202.7	15.9	
Supplier no. 2	optimal	282.2	4.3	
Supplier no. 3	optimal	209.3	14.0	
Mean (three suppliers)		**235.8**		
Supplier (reference)	**Breeding conditions**	**M**	**SD**	**Reference**
Carassius, Prague, Czech Republic	optimal	167.0	1.1	**(Baštová, 2017)**
Radek Frýželka, Brno, Czech Republic	optimal	170.0	1.0	**(Adámková et al., 2016)**
Radek Frýželka, Brno, Czech Republic	optimal	361.0	53.0	**(Bednářová, 2013)**
Fabryka Owadów, Warsaw, Poland	optimal	247.0	15.0	**(Zielińska et al., 2015)**
Alicante, Spain	optimal	301.0	7.0	**(Barroso et al., 2014)**
Krmiva Hostivice, Hostivice, Czech Republic	optimal	245.6	31.0	**(Adámková et al., 2017)**
Krmiva Hostivice, Hostivice, Czech Republic	optimal	251.7	27.3	**(Adámková et al., 2017)**
Krmiva Hostivice, Hostivice, Czech Republic	special	146.7	10.2	**(Adámková et al., 2017)**
Krmiva Hostivice, Hostivice, Czech Republic	special	245.6	31.0	**(Adámková et al., 2017)**
Krmiva Hostivice, Hostivice, Czech Republic	special	233.2	36.2	**(Adámková et al., 2017)**
Kreca, Ermelo,The Netherlands	special	250.0	single analysis	**(van Broekhoven et al., 2015)**
Kreca, Ermelo,The Netherlands	special	263.0	single analysis	**(van Broekhoven et al., 2015)**
Kreca, Ermelo,The Netherlands	special	276.0	single analysis	**(van Broekhoven et al., 2015)**
Kreca, Ermelo,The Netherlands	special	189.0	single analysis	**(van Broekhoven et al., 2015)**
Mean (optimal breeding conditions)	**optimal**	**243.0**		

From a standard deviation of 23.4% of the average total fat content, it can be estimated that the consumer is not able to estimate the amount of fat in a particular insect sample with sufficient accuracy. The real extreme values can occur in breeds where welfare is not respected by the breeder and especially the seller **(Adámková et al., 2017)**.

The analyzed data show the total fat content of mealworm is not affected by the area of breeding. The content of the fat will be influenced by the breeding temperature, seasons, stress and nutrition in managed breeds **Broekhoven et al. (2015); Nowak et al. (2016)**. Here, too, it is confirmed that nutrition is one of the important factors influencing the quantity and variability of fat as it is for other commodities of animal origin (patent). The fat content of mealworm can be compared with the fat content of the parts of the body of common livestock (Figure 1) **(Pipek, 1995; Steinhauser, 1995)**. Due to the size of the insect, from the whole body of the insect, whereas in common livestock it is possible to extract the fat from individual parts thereof. In addition, it is necessary to consider that fat consumption from ordinary livestock can take place after a short heat treatment or even in the raw state, insect fat can be used for food purposes only after chemical extraction. This increases the cost of this raw material. On the other hand, in the longterm storage process there are no significant biochemical and microbiological changes and no specific storage conditions **(Adámek et al., 2018)**.

When comparing the total fat content in the dry matter of the mealworm with the total fat content of the conventional meat, the analyzed values for the mealworm are in a wide range from 16% to 36%. This can be compared with both lean chickens (14%) and, for example, salmon (37.6%). This range includes, for example, beef sirloin, mackerel or turkey meat.

From the health point of view, not only the total fat content but also the fatty acid profile, especially linoleic acid and linolenic acid, is important. EFSA Recommendation on fat and other lipophilic substances ingestion from 2010 **(EFSA, 2010)** no longer state recommendation for the n-6: n-3 ratio but, indicate that linoleic acid intake should not fall below 4% and linolenic acid below 0.5% of total energy intake. In the case of mealworm meal consumption and required energy intake of 10,000 $kJ.day^{-1}$, linolenic acid in the amount of 205 g and 708 g of linolenic are needed. Considering the linolenic acid intake, the quantity contained in the dry matter is insufficient and must be supplemented from other sources. On the contrary, the amount of linoleic acid is sufficient, and the dry matter can serve as the source of this acid **(Adámková, 2017)**. Although mealworm is included among livestock since 2015 **(EFSA, 2015)**, it must be considered a specific species with special biological properties. For this reason, insect has to be bred under the defined breeding conditions to achieve the desired properties.

In the next part, the flavor of raw pork and beef fat was measured with a simple electronic nose and compared with fat obtained by the extraction from mealworm larvae. The results in Figure 2 show the difference between insect fat and pork and beef fat.

The most significant difference was recorded by the MQ-8 type sensor, which responds in particular to Hydrogen (H_2), next to alcohol, LPG and cooking fumes. Therefore, the difference between fats can be caused by the treatment of fat from insect during extraction or different fat composition.

In today's food industry, modern techniques such as electronic nose, eye or tongue are used to capture sensory properties. The disadvantage of these techniques is that they cannot replace the human sensory organ in full. The advantage is good repeatability even in longterm measurements (human can be tired) and in some cases a better sensitivity, resolution or range wider than a human can possess (e.g. electronic eye). An electronic nose used to record flavors from commodities of animal origin is described, for example, by **Gopal (2015)**, who in his study used the Peres' electronic nose to assess the freshness and durability of the meat. The electronic nose plays another important role in detecting food counterfeiting and assessing its authenticity **(Peris and Escuder-Gilabert, 2016)**. In the case of edible insect as a novel food that is being introduced to the market, however, this technology has been used only minimally. The introduction of this technology is one of the arguments for persuading the Czech (European) consumer that food from edible insect is safe and has properties similar to other commodities of animal origin. It is necessary to bear in mind that the insect fat is extracted.

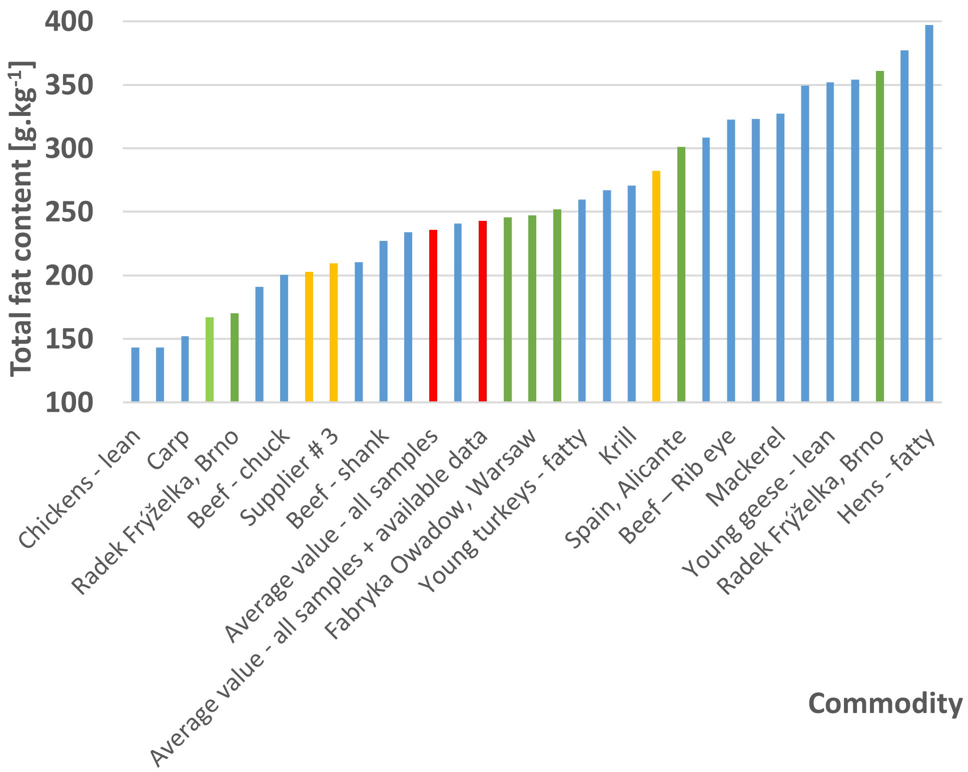

Figure 1 Comparison of total fat content in mealworms and conventional meat **(Pipek, 1995; Steinhauser, 1995)**.

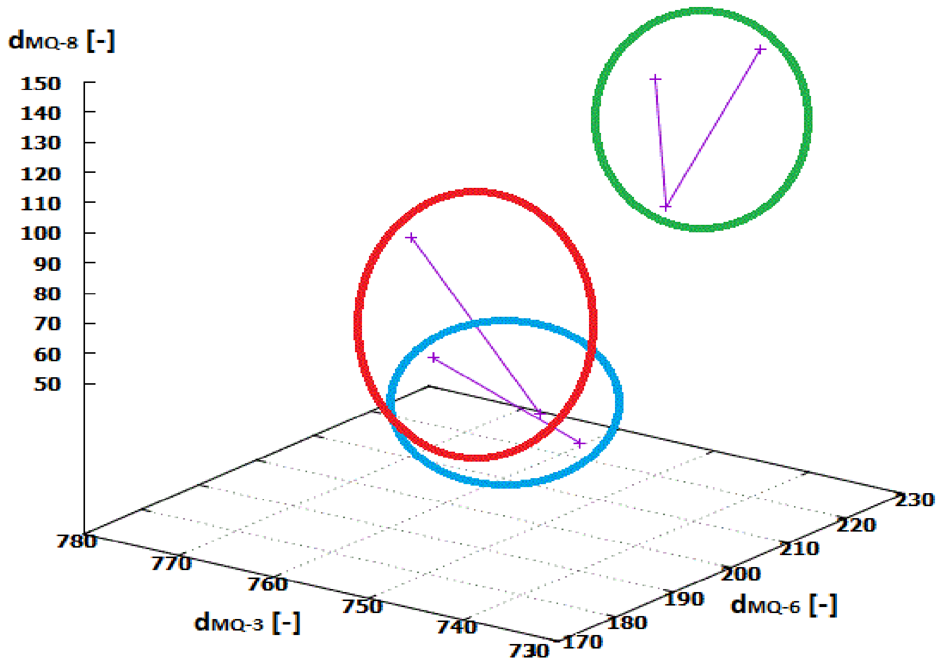

Figure 2 Comparison using a simple electronic nose of pork (blue) and beef (red) crude fat with fat obtained by extraction from mealworm (green).

CONCLUSION

The total fat content of the mealworm is a significantly variable nutritional value, which is highly dependent on the breeding conditions.

In this work, the fat content of the mealworm from various Czech suppliers ranged from 202 $g.kg^{-1}$ to 282$g.kg^{-1}$ dry matter. The overall mean value of all suppliers 235.8 ±40.8 $g.kg^{-1}$ does not confirm the hypothesis that the fat content of the dry matter will not differ by more than 10% of the average fat value. The result demonstrated the wide range of fat content even though the supplier has stated the optimal breeding conditions for the species. If a consumer needs to obtain insect with a specific fat content, the solution to this problem can be to communicate directly with the breeder and ensure adequate breeding conditions to achieve the required nutritional value. Considering the wide range of fat content in mealworm samples it is possible to compare the fat content with, for example, lean chickens (14%) and salmon (37.6%). This range includes, for example, beef sirloin, mackerel or turkey meat. On the other hand, measurement using an electronic nose demonstrated the differences between insect fat and unprocessed (raw) pork and beef fat. The article brings some new information on some aspects of edible insect as a source of fat.

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