VOLATILE PROFILE OF SEVEN UNHEATED EDIBLE INSECTS

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I. INTRODUCTION

In recent years, there has been a growing interest in edible insects, not only as an alternative protein source but also for their potential technological advantages [1]. Taking into account the existing aversion towards insect consumption in Western countries [2], and given the importance of food flavour, it is imperative to understand their flavour potential, in order to develop products that avoid consumer rejection and facilitate its introduction as a regular product in the diet. Then, this study allows a better understanding of the volatile profile of 7 unheated edible insect species.

II. MATERIALS AND METHODS

Insects were provided by a commercial supplier, including, on the one hand, *Tenebrio molitor* (TM), *Zophobas morio* (ZM), *Galleria mellonella* (GM) and *Alphitobius diaperinus* (ALD) in their larvae form, and on the other hand *Acheta domesticus* (ACD), *Locusta migratoria* (LM), and *Blaptica dubia* (BD) in their adult stage. After 24h of starvation, they were slaughtered by freezing at -20 °C, lyophilised, ground and weighed (1 g) into 20 ml headspace amber glass vials. Five vials per insect were stored at -20 °C until Headspace solid-phase microextraction coupled to gas chromatography–mass spectrometry (HS-SPME-GC/MS) analysis. Extraction conditions were optimised to minimise lipid oxidation and Maillard reactions. Headspace vials were incubated for 10 min at 45 °C, extracted using a Divinylbenzene/Carboxen/Polydimethylsiloxane (DVB/CAR/PDMS) fibre for 50 min at 45 °C and separated in a gas chromatograph equipped with an MS detector using an HP-Innowax column. Identification was carried out by comparing mass spectra with libraries (match factor >85%) and by calculating the retention index relative to a series of standard alkanes (C5-C16) and comparing it with the literature. The effects were examined through one-way ANOVA by IBM SPSS 23.0 statistical software, followed by, when applicable, a Tukey's posthoc test ($P>0.05$) to identify statistical differences among insects.

III. RESULTS AND DISCUSSION

A total of 67 compounds were identified and classified into ten chemical families (Table 1). The predominant family in ALD, BD, GM, TM and ZM were carboxylic acids, mainly due to the high peak area of acetic acid. However, in ACD, ketones were the major family, while the largest peak areas in LM relate to hydrocarbons, whose aroma contribution is low, but it is also to be noted that a large peak area was associated with trichloromethane, which brings sweet smells to this insect [3]. Aldehydes and ketones greatly influenced the aroma of ACD, notably due to the presence of 3,5-octadien-2-one with a fatty and herbal odour and 2,3-pentanedione with a buttery odour [4,5]. In contrast, the highest number of unpleasant odour compounds was observed in ZM, including octanoic acid and phenol, as well as trimethylamine and indole. The latter, characterised by a low detection threshold, is responsible for strong faecal and fishy odours and was also present in BD and GM [4,5]. A rancid and faecal smell could also be found in BD due to the large occurrence of butanoic acid and 4-methylphenol [4,5]. On the other hand, GM showed the lowest total peak area, in which γ-butyrolactone represented the highest peak area, a compound that was also rather dominant in ALD and contributes to a creamy and oily scent [5].

Table 1. Mean peak area values and standard error of the main chemical families of volatile compounds in unheated insects expressed as AU x 10^4/g DM (n=5)

	ACD	ALD	BD	GM	LM	TM	ZM	p-value
Linear hydrocarbons	38.60±0.96^{a}	49.1±4.2^{a}	238±18^{b}	7.65±0.55^{a}	293±26^{b}	36.2±2.6^{a}	49.0±2.1^{a}	<0.001
Branched hydrocarbons	n.d.^{a}	n.d.^{a}	39.2±3.1^{b}	17.7±2.6^{a}	79±10^{c}	12.02±0.92^{a}	6.54±0.73^{a}	<0.001
Cyclic hydrocarbons	3.05±0.20^{b}	n.d.^{a}	n.d.^{a}	n.d.^{a}	n.d.^{a}	3.76±0.26^{c}	n.d.^{a}	<0.001
Total hydrocarbons	41.7±1.1^{a}	49.1±4.2^{a}	277±20^{b}	25.4±2.3^{a}	372±36^{c}	52.0±3.7^{a}	55.6±2.5^{a}	<0.001
Saturated linear aldehydes	787±137^{b}	7.6±2.1^{a}	10.42±0.92^{a}	6.6±1.4^{a}	11.9±1.8^{a}	10.4±1.3^{a}	90±17^{a}	<0.001
Unsaturated linear aldehydes	247±17^{b}	n.d.^{a}	n.d.^{a}	n.d.^{a}	0.57±0.07^{a}	n.d.^{a}	3.60±0.44^{a}	<0.001
Branched aldehydes	8.34±0.35^{a}	7.04±0.69^{a}	3.34±0.30^{a}	n.d.^{a}	n.d.^{a}	49.6±4.9^{b}	4.70±0.11^{a}	<0.001
Total aldehydes	1043±72^{b}	14.7±1.3^{a}	13.76±0.47^{a}	6.57±0.64^{a}	12.43±0.83^{a}	60.0±5.1^{a}	98.3±8.1^{a}	<0.001
Carboxylic acids	126±18^{a}	843±39^{b}	2882±151^{d}	95±9.9^{a}	97.9±7.3^{a}	1801±107^{c}	2741±189^{d}	<0.001
Ketones	1590±175^{b}	91±13^{a}	40.2±5.2^{a}	5.98±0.35^{a}	20.63±0.98^{a}	111±20^{a}	26.5±1.8^{a}	<0.001
Alcohols	66.1±4.3^{a}	144±20^{a}	85.0±5.9^{a}	54±16^{a}	19.3±1.7^{a}	295±55^{b}	471±42^{c}	<0.001
Phenolic compounds	n.d.^{a}	2.01±0.28^{a}	66.7±4.9^{b}	n.d.^{a}	2.86±0.43^{a}	2.22±0.31^{a}	108.1±7.6^{c}	<0.001
Esters	n.d.^{a}	15.6±1.5^{c}	20.3±1.4^{c}	1.98±0.09^{ab}	27.8±2.1^{d}	7.38±0.64^{b}	27.9±2.3^{d}	<0.001
Furans	52.7±3.2^{b}	1.23±0.12^{a}	2.91±0.29^{a}	n.d.^{a}	n.d.^{a}	1.42±0.10^{a}	1.45±0.11^{a}	<0.001
S-Compounds	25.6±4.3^{b}	9.16±0.80^{a}	1.57±0.07^{a}	1.75±0.14^{a}	3.87±0.42^{a}	19.6±1.1^{b}	3.52±0.19^{a}	<0.001
Others	93.6±7.9^{a}	285±20^{c}	254±19^{bc}	123.3±9.4^{a}	143±12^{ab}	498±58^{d}	656±23^{e}	<0.001
TOTAL COMPOUNDS	**3040±248^{cd}**	**1456±91^{b}**	**3645±194de**	**315±24^{a}**	**700±57^{ab}**	**2849±197^{c}**	**4189±257^{e}**	**<0.001**

$^{a-d}$ Mean values in the same row (corresponding to the same volatile compound) not followed by a common letter differ significantly ($p < 0.05$). DM: dry matter; n.d.: not detected; ACD: *A. domesticus*; ALD: *A. diaperinus*; BD: *B. dubia*; GM: *G. mellonella*; LM: *L. migratoria;* TM: *T. molitor*; ZM: *Z. morio*.

IV. CONCLUSION

In short, the profile of volatile compounds was very diverse, even among insects of the same family, with GM showing the lowest abundance of volatiles and ZM being the one with the most negative odour characteristics. But, despite the chemical analysis of the volatile compounds, sensory analysis is necessary to obtain insight into the actual aroma perception by humans.

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