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## Metabolic balance of [3H]-BADGE in rodents: a spotlight on the complex in vivo fate of the diglycidyl ether analogue of bisphenol A

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## Introduction

**Bisphenol A diglycidyl ether = BADGE** (2,2-Bis[4-(glycidyloxy)phenyl]propane, CAS N°1675-54-3, MW 340.4)

- Used in the manufacture of **epoxy resins** and **polycarbonates** for **food packaging**
- Synthesized by a condensation reaction between **epichlorohydrin** and **Bisphenol A**
- Protective coatings**: car and marine industry, food packaging, adhesives, dental sealants, etc.<sup>[1, 2]</sup>
- Reported **human daily intake**: approximately **0.16 µg/kg b.w./day**<sup>[2, 3]</sup>

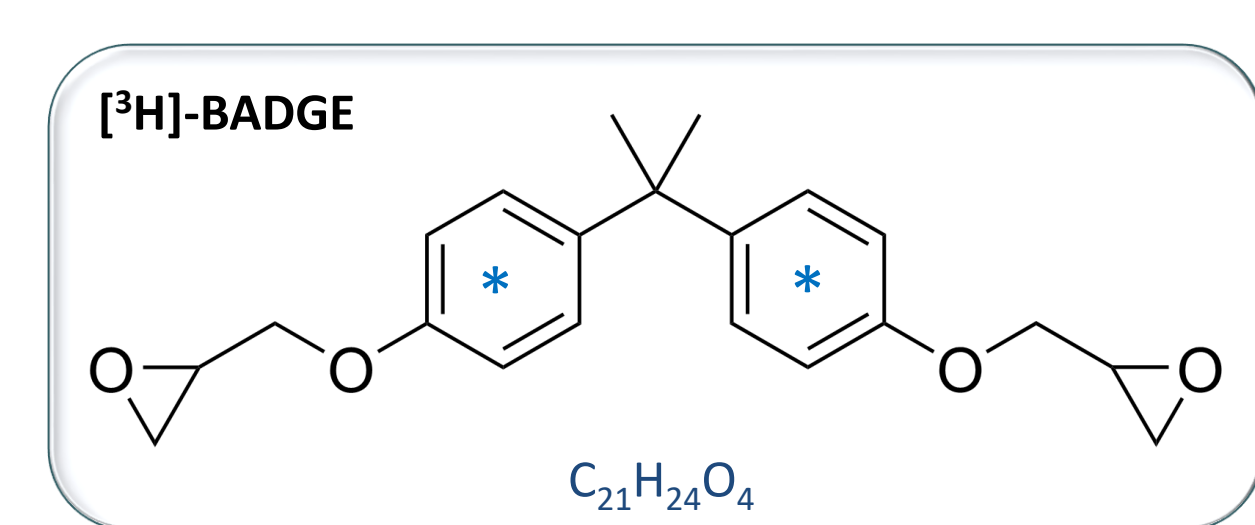


- Tolerable Daily Intake, BADGE + hydrolysis products = 0.15 mg/kg b.w.<sup>[4]</sup>
- Migration** of BADGE + hydrolysis products does not exceed: 9 mg/kg in food, 1 mg/kg for chlorinated derivatives<sup>[4]</sup>
- Possible **endocrine disruptor** (PPARγ antagonist)<sup>[5, 6]</sup>

**Objectives:** Investigate the **fate of BADGE** in male and female Wistar rats  
**Explore BADGE metabolic balance and identify the different metabolic pathways** involved in its **biotransformation** for **toxicological purposes**  
**Identify candidate biomarker metabolites**, with the perspective of further human biomonitoring studies

## Methodology

### Chemicals:



[<sup>3</sup>H]-BADGE (radiochemical purity > 97 %, specific activity 10.9 GBq/mmol) was synthesized in-house from radio-labelled [<sup>3</sup>H]-Bisphenol A (Moravek). Unlabeled BADGE was purchased from Sigma Aldrich.

### Animal experiment:

3 male and 3 female 8-week Wistar rats were forced an adjusted single [<sup>3</sup>H]-BADGE dose of **50 µg/kg b.w.** (1.6 MBq/kg b.w.) dissolved in corn oil. After **24h** spent in individual stainless steel metabolic cages, with water and food supplied *ad libitum*, rats were weighed and euthanized.

### Metabolic Balance and Tissue Distribution:

Urine, feces, blood, liver, genital tract, glands, adipose tissue, muscle, digestive tract (and its content), brain, kidney, spleen, lung, heart, bladder, pancreas, skin and the remaining carcass were **collected for radioactivity quantification**. Extractions were performed on feces and digestive contents. Radioactivity was measured in liquid samples using a **Packard scintillation analyzer** (a)

Tri-Carb 2910TR, with Ultima Gold as the scintillation cocktail (Perkin Elmer). Feces were dried and ground before **solubilization** in **Soluene** (Perkin Elmer). Radioactivity in homogenized tissues, organs, blood, and carcasses was determined by complete **combustion** using an **Oxidizer 307** (b, Perkin Elmer), followed by quantification on a scintillation analyzer. At least 3 replicates were analyzed for each sample.

### Metabolic profiling and identification:

**High-performance-liquid-chromatography coupled to on-line radioactivity detection (Radio-HPLC)**. Excreted metabolites were separated on an Ultimate 3000 (c, ThermoScientific) HPLC system, with a Zorbax SB-C18 column (5 µm ; 4.6 x 250 mm, Agilent) coupled to a Flo-One A610TR detector (d, Perkin Elmer), using 2 mL/min Flow-Scint II (Perkin Elmer) as the scintillation cocktail.

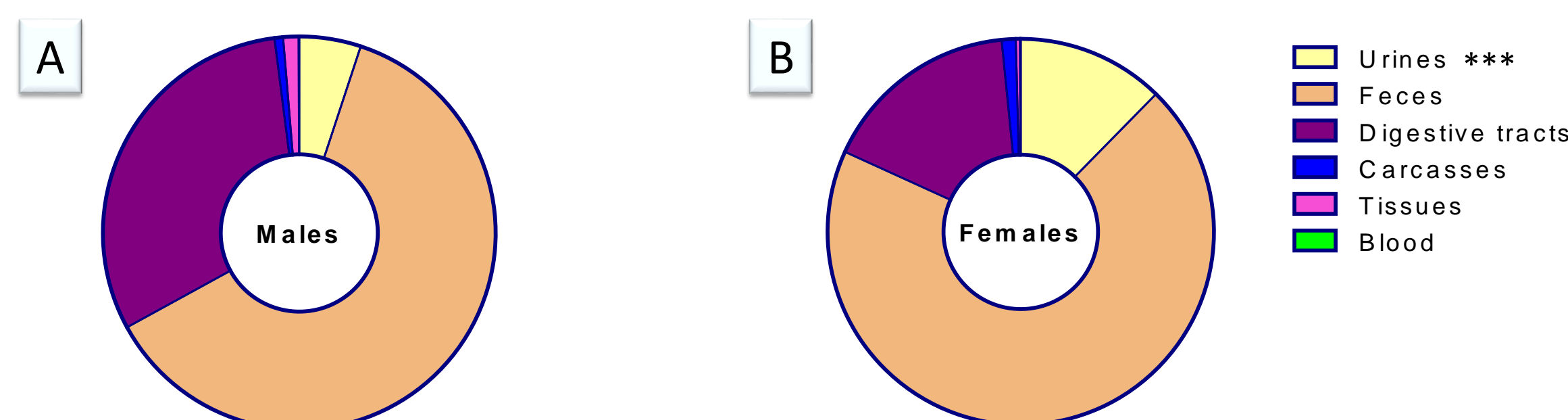
### Analytical conditions:

Flow rate	1 mL/min	Column temperature	25 °C	Analysis time	55 min
<b>Phases</b>	A: Ammonium acetate buffer 20 mM pH 3,5 / Acetonitrile (95:5 v/v) B: Ammonium acetate buffer 20 mM pH 3,5 / Acetonitrile (10:90 v/v)				
<b>Gradient</b>	0-4 min: 100 % A, 4-6 min: 100-75 % A, 6-16 min: 75 % A, 16-18 min: 75-70 % A, 18-25 min: 70 % A, 25-27 min: 70-30 % A, 27-38 min: 30 % A, 38-40 min: 30-0 % A, 40-50 min: 0 % A, 50-51 min: 0-100 % A, 51-55 min: 100 % A				

## Preliminary results

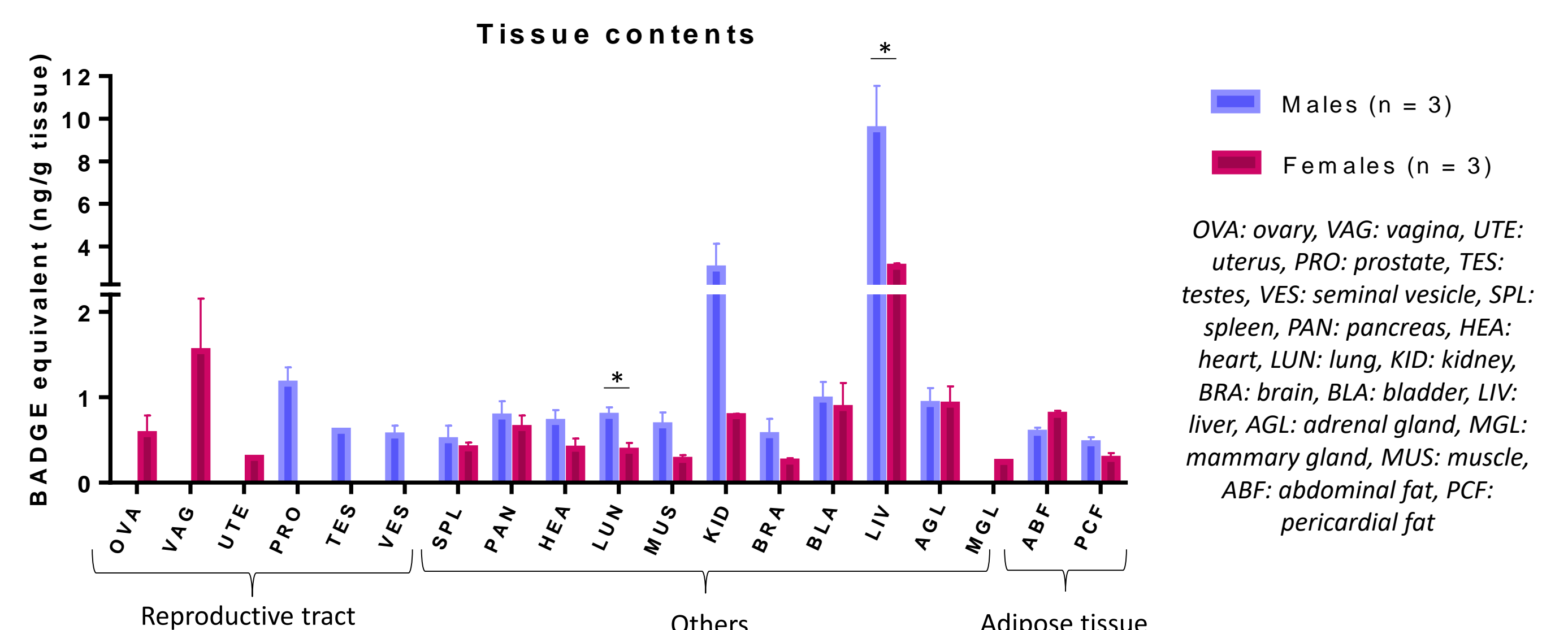
### Metabolic balance of [<sup>3</sup>H]-BADGE following a single oral dose administered to male and female Wistar rats

For each animal, radioactivity remaining in the feeding material was quantified to calculate the nominal [<sup>3</sup>H]-BADGE dose administered: **46.8 ± 2.2 µg/kg b.w.** (1.5 ± 0.07 MBq/kg b.w.).



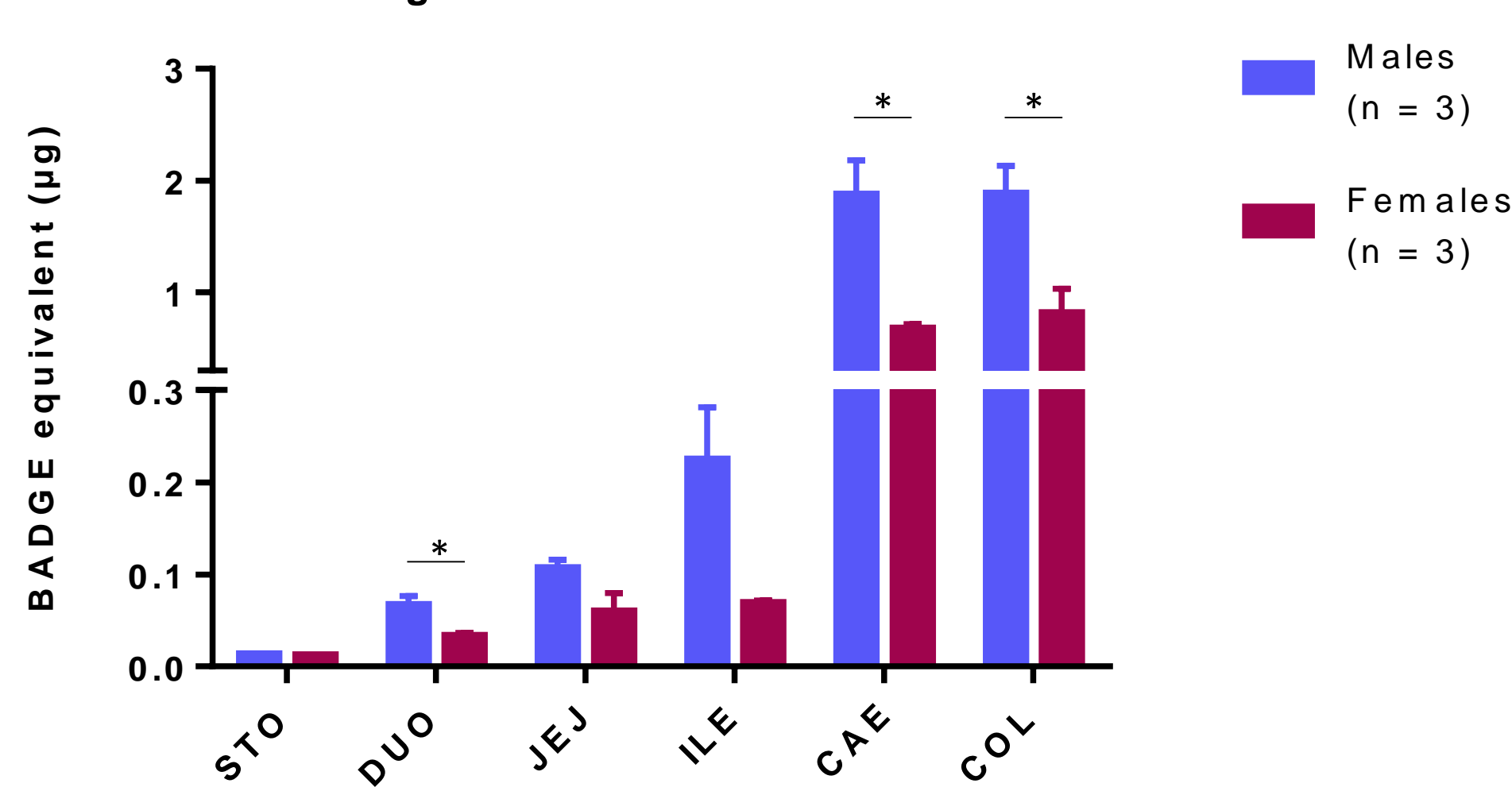
**Fig. 1:** 24h metabolic balance in male (A) and female (B) Wistar rats. Results (mean, n = 3 for each group) are expressed as % of the administered radioactivity (t-test, \*\*\* p-value ≤ 0.001, Graphpad®)

- 92.1 ± 9.4 %** of the administered radioactivity recovered at 24h following BADGE administration (n = 6).
- Feces was the main route of excretion** (55.1 ± 16.8 % in males, 66.2 ± 6.7 % in females), and the **digestive tract** accounted for 27.5 ± 6.7 % of the administered radioactivity in males and 15.8 ± 4.1 % in females, respectively.
- Significant sex-related differences were observed for **urine**: 4.5 ± 0.9 % recovered in males, 11.8 ± 0.9 % in females.



**Fig. 3:** Residual levels of radioactivity in tissues of male and female Wistar rats. Results (mean ± SEM) are expressed in ng of BADGE equivalent/g tissue (ppb) (t-test, \* p-value ≤ 0.05, Graphpad®)

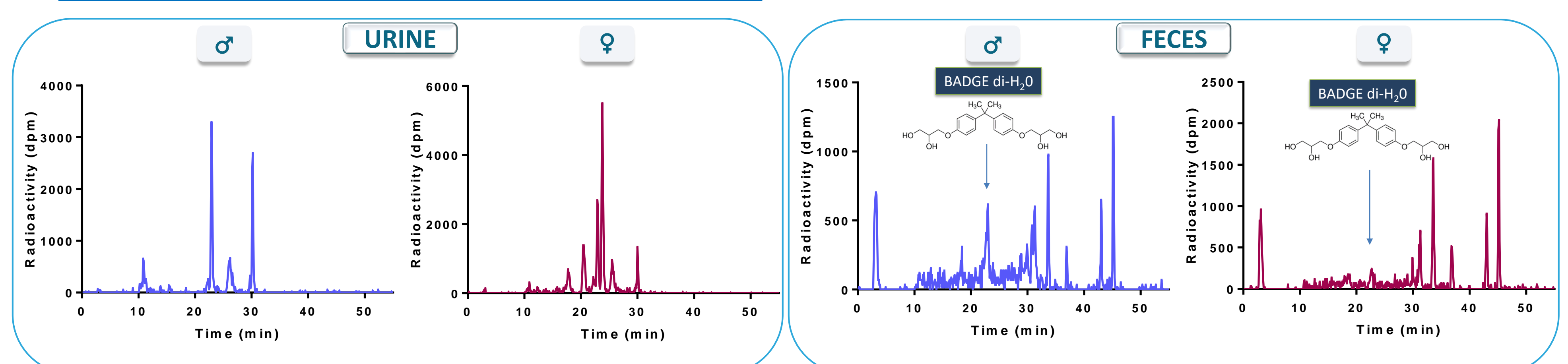
### Digestive tract contents



**Fig. 2:** 24h metabolic balance: residual radioactivity in digestive tract contents of male and female Wistar rats. Results (mean ± SEM) are expressed in µg of BADGE equivalent (t-test, \* p-value ≤ 0.05, Graphpad®)

STO: stomach, DUO: duodenum, JEJ: jejunum, ILE: ileon, CAE: caecum, COL: colon

### Radiochromatographic profiling of urine and feces



**Fig. 4:** Typical Radio-HPLC profiles for urine and feces collected over 24h

- Sex-related differences** were highlighted for **urine and fecal metabolite profiles**
- Complex radiochromatographic profiles underline the **chemical reactivity of BADGE**

## Conclusions

In this **first *in vivo* 24h-study** of [<sup>3</sup>H]-BADGE carried out in male and female Wistar rats, radioactivity was found to be **excreted** mainly in **feces**, with residues found in all tissues, including reproductive organs. **Sex-related differences** were highlighted for **urine, liver, lung** as well as **duodenum, caecum and colon contents**. Qualitative differences are also suggested by first Radio-HPLC analyzes carried out for urine and feces. BADGE elimination over 24h (urine + feces) appears to be faster in female rats compared to males (77.9 ± 6.2 % in females vs. 59.6 ± 16.2 % in males). Preliminary HPLC Radio-profiling analyzes strongly suggest a **complex metabolism** of this molecule. **Further HPLC-MS/MS investigations** are being carried out, with the aim to identify unknown **BADGE metabolites**.

## References

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 [3] Wang L. *et al.*, 2015, Environ Sci Technol. 49(5):3150-7.  
 [4] European Commission regulation N°1895/2005 on the restriction of use of certain epoxy derivatives in materials and articles intended to come into contact with food, 2005

[5] Wright HM. *et al.*, 2000, J Biol Chem. 275(3):1873-7.  
 [6] Satoh K. *et al.*, 2004, Food Chem Toxicol. 42(6):983-93.

All the experimental procedure was carried out in accordance with the accepted standards of animal care and validated by the local ethical committee for animal experimentation N°086 (project number: APAFIS#1308-201706161630824 v3) and by the French Ministry of Higher Education, Research and Innovation (agreement: C3155513)