Benefits of wheat processing on the bioavailability of phenolic acids and potential health effects

Nuria Mateo Anson, Maastricht University

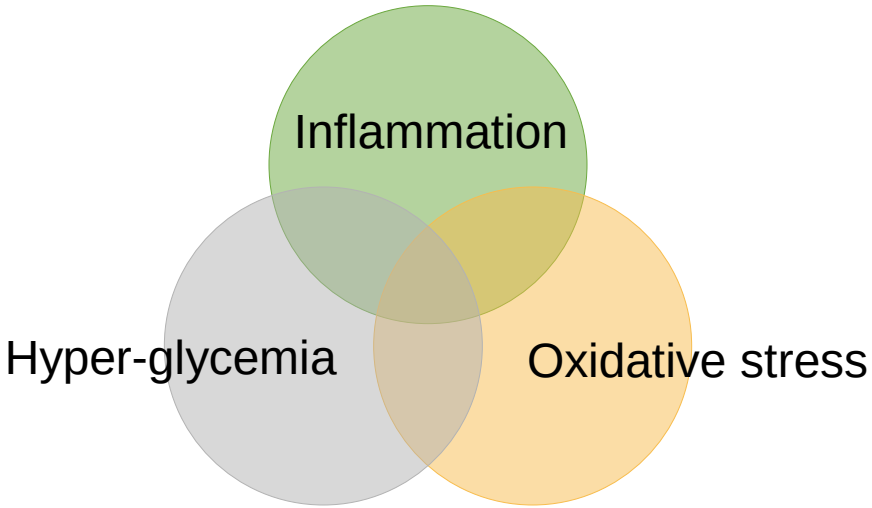
HEALTH·GRAIN

Universiteit Maastricht

HEALTH·GRAIN

INTRODUCTION (1)

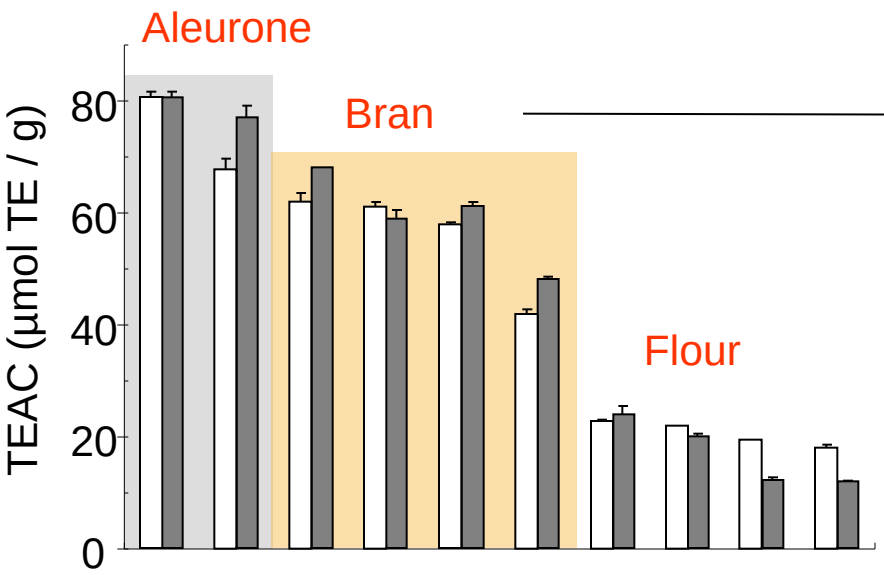
- **Whole-grain → Type-2 diabetes, cardiovascular diseases, metabolic syndrome**

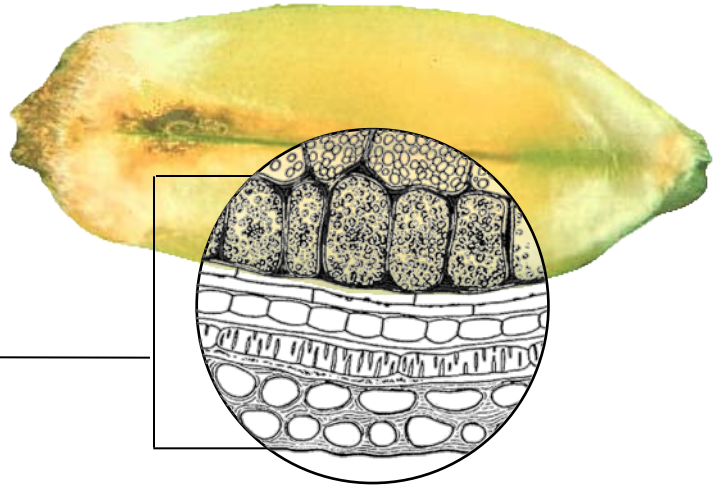


- **Bioactive compounds - phenolic acids**

INTRODUCTION (2)

- **BRAN**
  - ↑ Antioxidant capacity





  - ↑ Ferulic acid

- ↓ **Bioaccessibility = intestinal release**

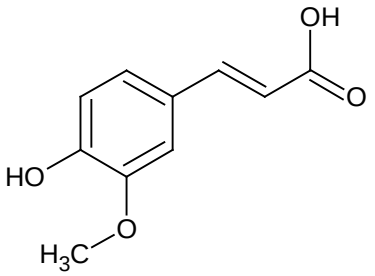
HEALTHGRAIN

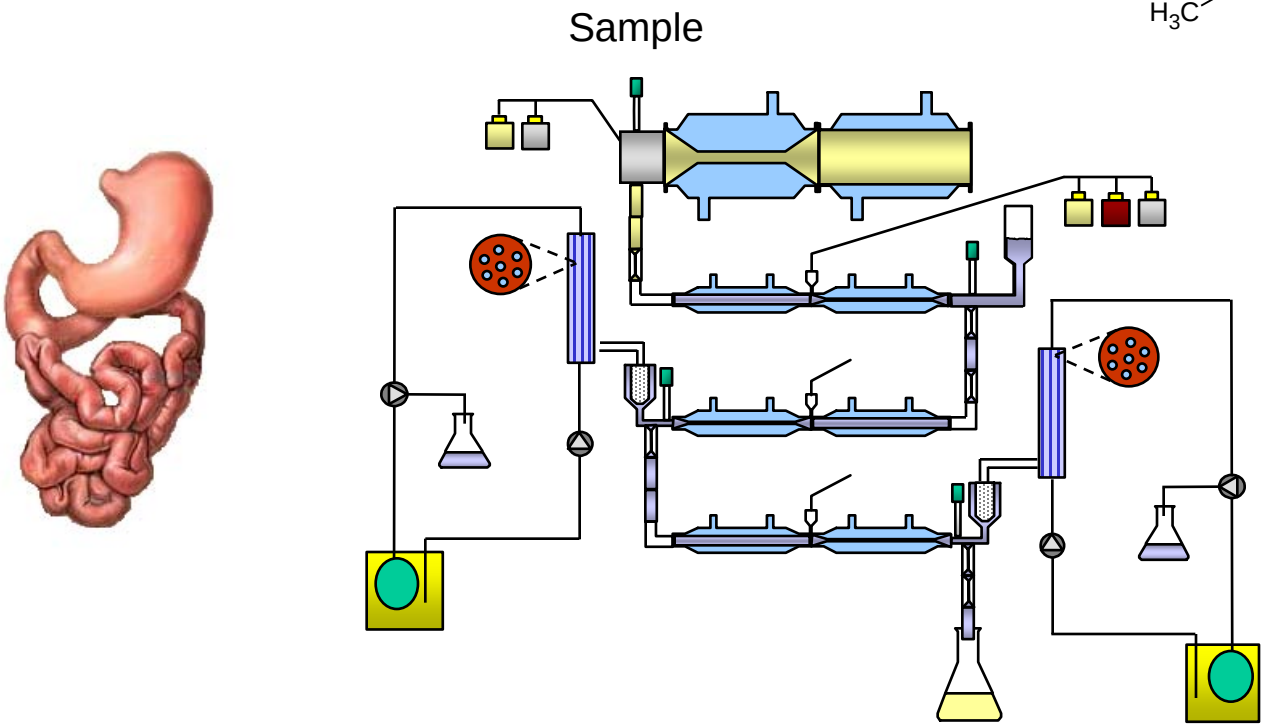
AIM

- **In vitro**
  - Effects of processing on the bioaccessibility
- **In vivo**
  - Effect of processing on the bioavailability, antioxidant capacity and inflammatory response

In vitro

- TIM-1 SYSTEM → Bioaccessibility of Ferulic acid

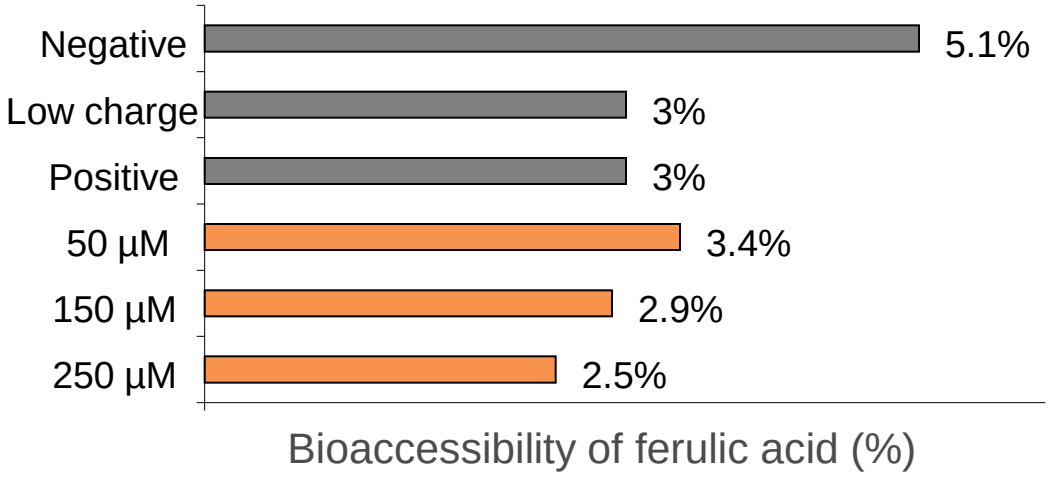




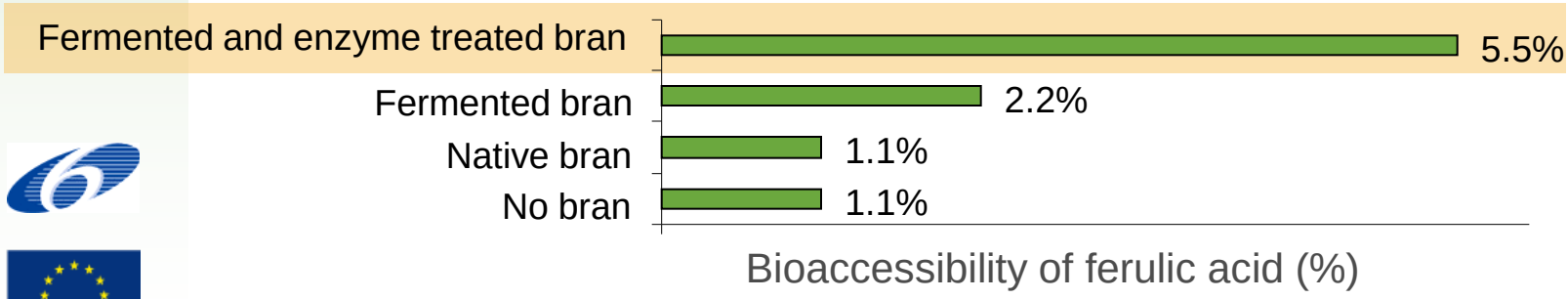
HEALTH·GRAIN

In vitro

- Dry processing techniques: electrostatic separation, grinding



- Wet processing techniques: enzyme technology and fermentation

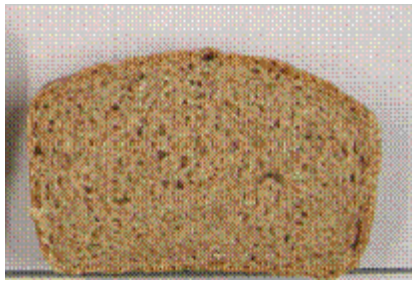


HEALTHGRAIN

In vivo

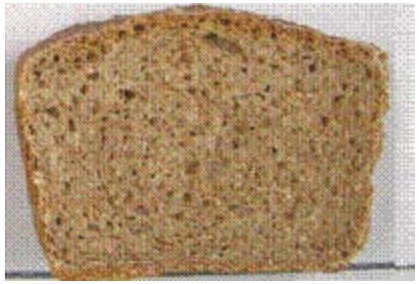
- BREADS
  - **CONTROL BRAN BREAD**

    Wholegrain + bran (9%)



  - **BIOPROCESSED BRAN BREAD**

    Wholegrain + bioprocessed bran (9%)

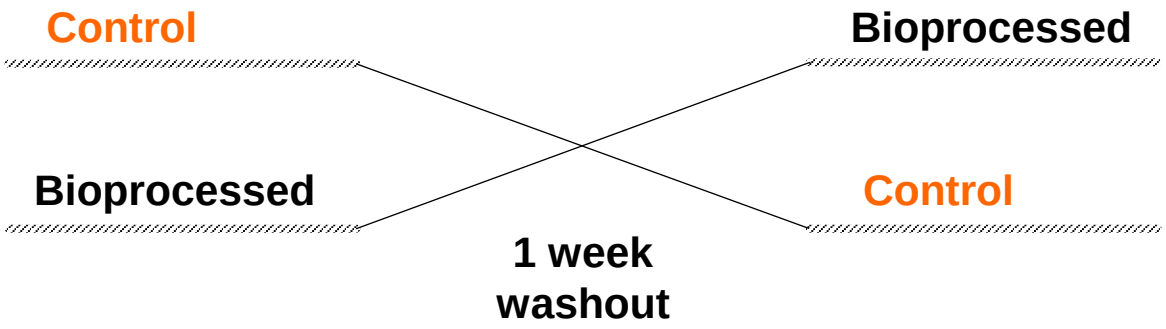


Bioprocesssing of bran: yeast fermentation and enzymatic treatment (20 h 20 °C)

HEALTH·GRAIN

In vivo

- STUDY DESIGN (1)
  - Cross-over design randomized



  - N = 8 male healthy volunteers BMI < 30
  - 3 Days before intervention low phenolic diet

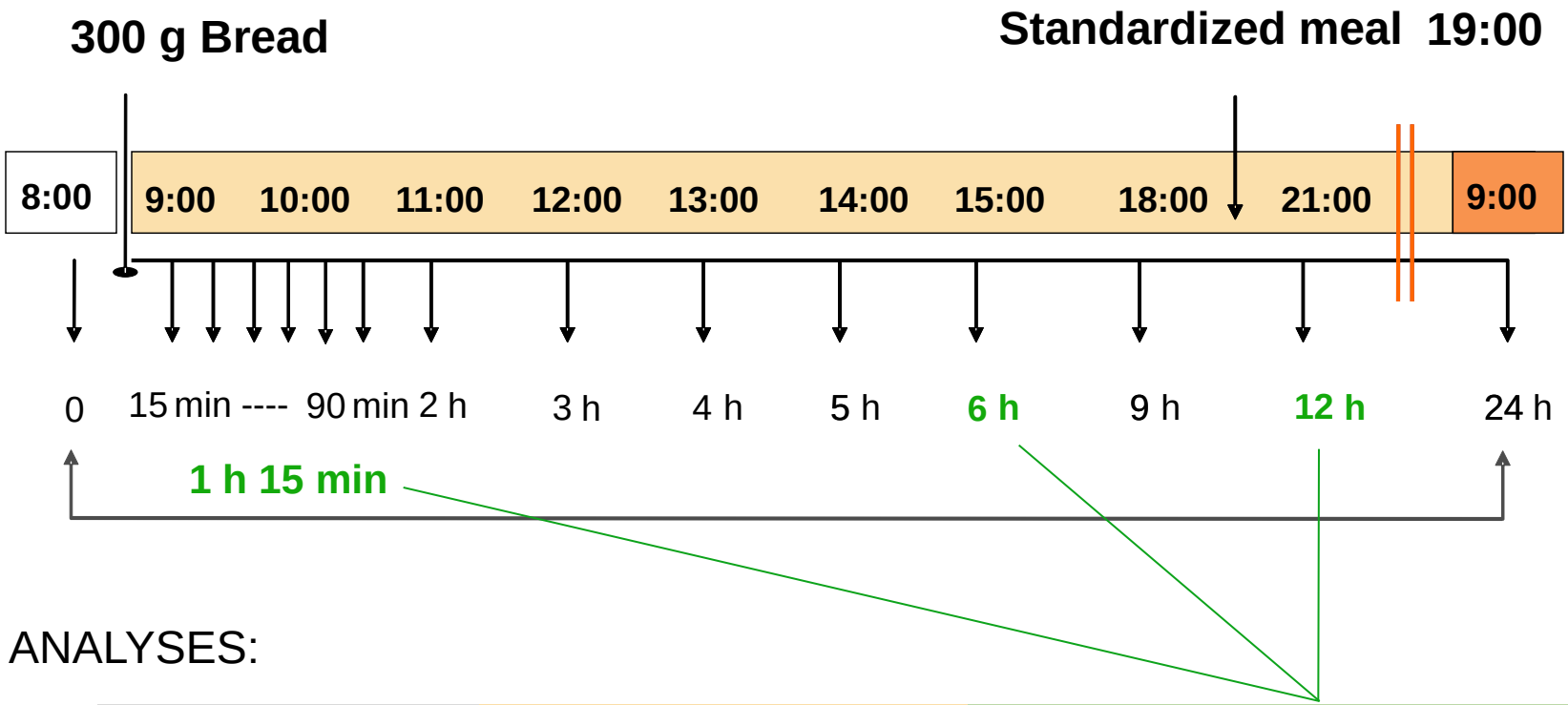
HEALTH·GRAIN

In vivo

- STUDY DESIGN (2)

Intervention day

Next day



ANALYSES:

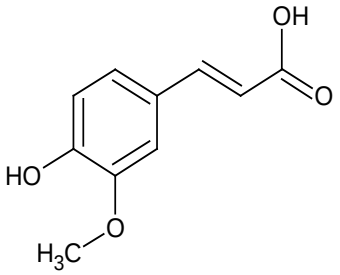
Phenolic acids	Antioxidant Capacity	*Ex vivo* LPS-Inflammation

HEALTH·GRAIN

In vivo

Phenolic acids

BIOAVAILABILITY FERULIC ACID

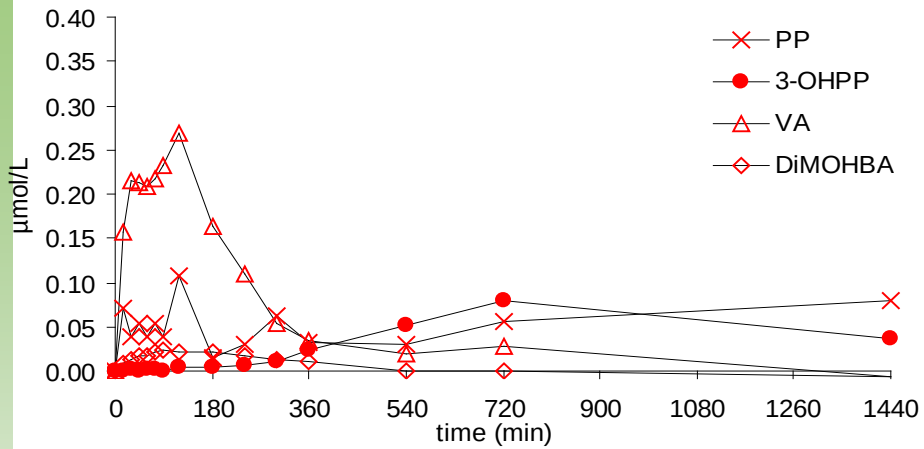


t_{max} 90 -105 min

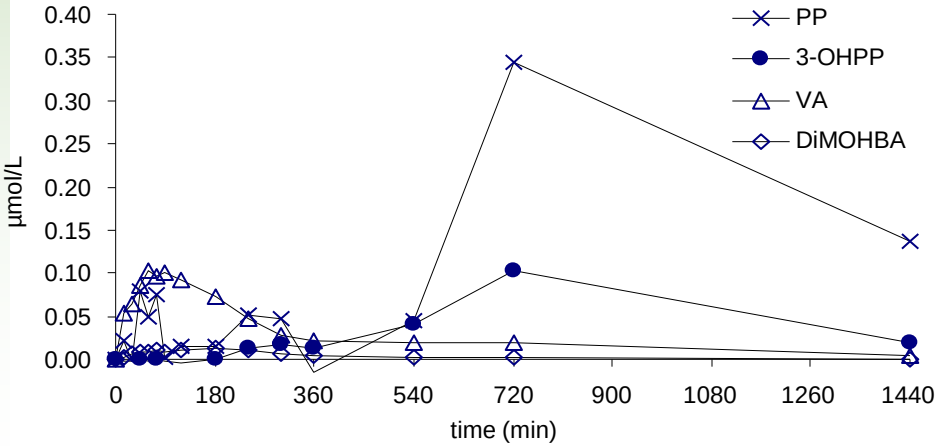
In vivo

Phenolic acids

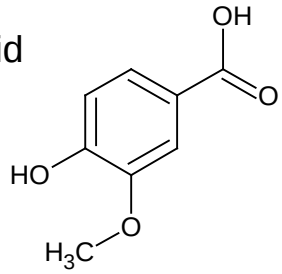
BIOPROCESSED BREAD



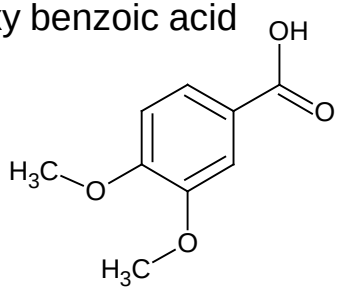
CONTROL BREAD



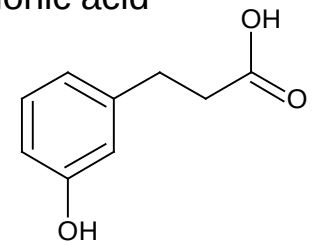
↑ Vanillic acid



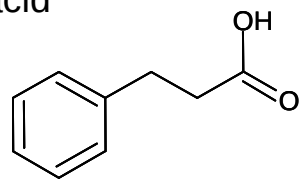
↑ 3,4-Dimethoxy benzoic acid



3-OH phenylpropionic acid



Phenylpropionic acid



In vivo

Phenolic acids

PHARMACOKINETICS

	Ferulic acid		Vanillic acid		Dimethoxybenzoic acid	
	Control	Bioprocessed	Control	Bioprocessed	Control	Bioprocessed
AUC $_{0\text{-}t}$ (µmol*min/L)	**242** (107)	**643** (228) *	**39** (18)	**70** (35) *	**5.4** (5.3)	**9.9** (5.9) *
Cmax (µmol/L)	0.88 (0.15)	2.7 (0.63) *	0.10 (0.00)	0.25 (0.18) *	0.014 (0.00)	0.026 (0.02) *
t_{max} (min)	90 (38)	105 (56)	105 (45)	120 (41)	150 (90)	120 (30)

* $P < 0.05$

↑↑↑ Ferulic acid

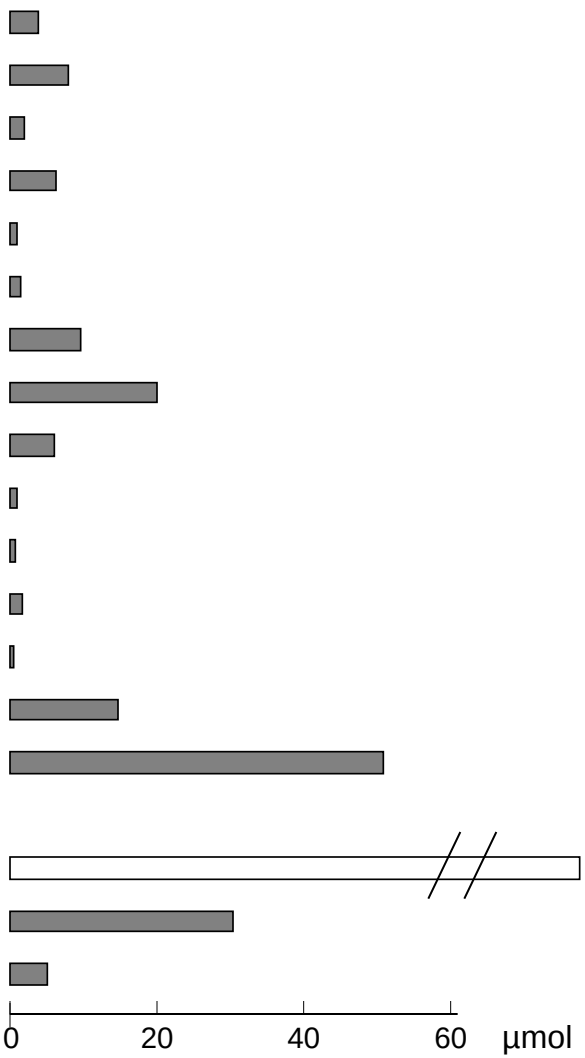
$$\text{Relative bioavailability} = \frac{AUC_{Bioprocessed}}{AUC_{Control}} = \mathbf{2.6}$$

HEALTH·GRAIN

In vivo

Phenolic acids

URINE 24H (µmol)	CONTROL	BIOPROCESSED
3,4-Dihydroxybenzoic acid	3.9 (0.90)	3.3 (0.63)
3,4-Dihydroxyphenylacetic acid	8.1 (4.7)	6.9 (3.5)
3,4-Dihydroxyphenylpropionic acid	1.9 (1.1)	2.4 (4.8)
3,4-Dihydroxytoluene	6.2 (8.4)	6.0 (7.9)
3,4-Dimethoxybenzoic acid	1.1 (0.85)	2.1 (1.9)[a]
3-Coumaric acid	1.5 (2.5)	1.1 (0.65)[b]
3-Hydroxybenzoic acid	9.7 (5.6)	9.5 (6.4)
3-Hydroxyphenylacetic acid	20 (14)	14 (9.6)
3-Hydroxyphenylpropionic acid	6.1 (4.1)	5.6 (3.5)
Phenylpropionic acid	0.90 (1.2)	0.5 (0.70)
4-Coumaric acid	0.70 (0.40)	0.55 (0.30)[b]
4-Hydroxybenzoic acid	1.6 (3.2)	0.95 (0.48)[b]
4-Hydroxyphenylpropionic acid	0.60 (0.53)	0.30 (0.30)[b]
Benzoic acid	15 (9.3)	9.3 (7.5)
Ferulic acid	51 (9.7)	110 (46)[a]
Gallic acid	0.20 (0.08)	0.20 (0.10)
Hippuric acid	1550 (1510)	1100 (833)
Vanillic acid	30 (7.8)	49 (34)[a]
Sinapic acid	5.1 (3.7)	12 (3.2)[a]



HEALTHGRAIN

In vivo

Phenolic acids

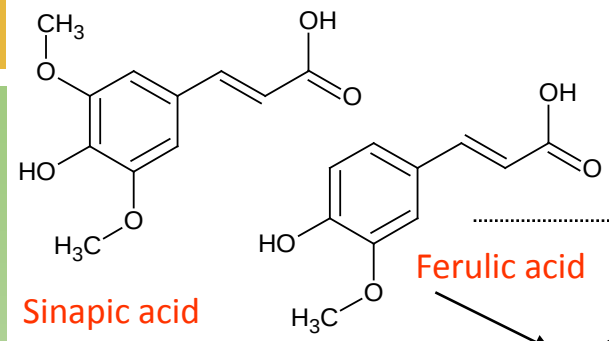
Urine 24 H excretion related to Intake

24-h Urine	Control Bran Bread	Bioprocessed Bran Bread
Ferulic acid	4 %	10 %
Sinapic acid	7%	15%
p-Coumaric acid	2%	2%
Vanillic acid	104%	160%

Metabolite of ferulic acid

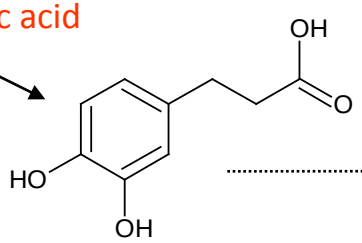
COLONIC METABOLISM

HEPATIC METABOLISM

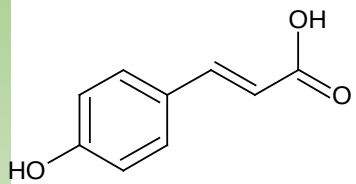


Sinapic acid

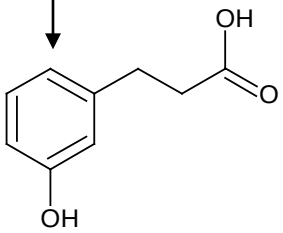
Ferulic acid



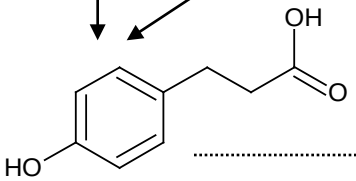
3,4-Dihydroxyphenylpropionic acid



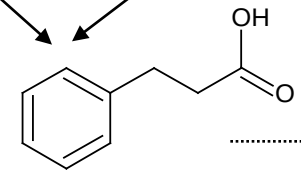
ρ-Coumaric acid



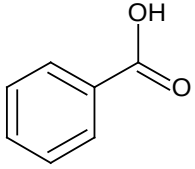
3-Hydroxyphenylpropionic acid



4-Hydroxyphenylpropionic acid

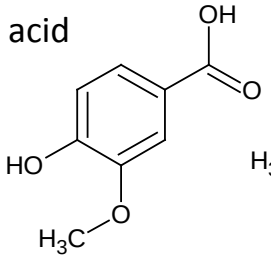


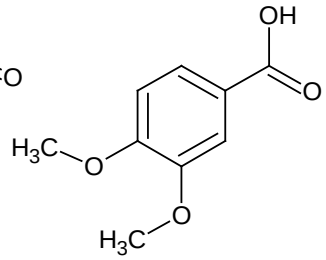
Phenylpropionic acid



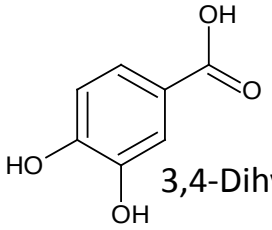
Benzoic acid

Vanillic acid

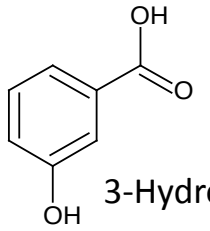




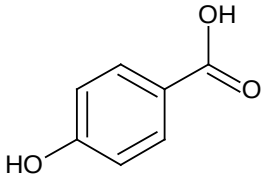
3,4-Dimethoxybenzoic acid



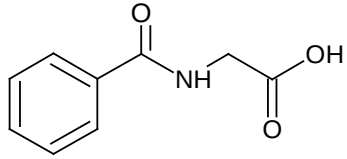
3,4-Dihydroxybenzoic acid



3-Hydroxybenzoic acid



4-Hydroxybenzoic acid



Hippuric acid

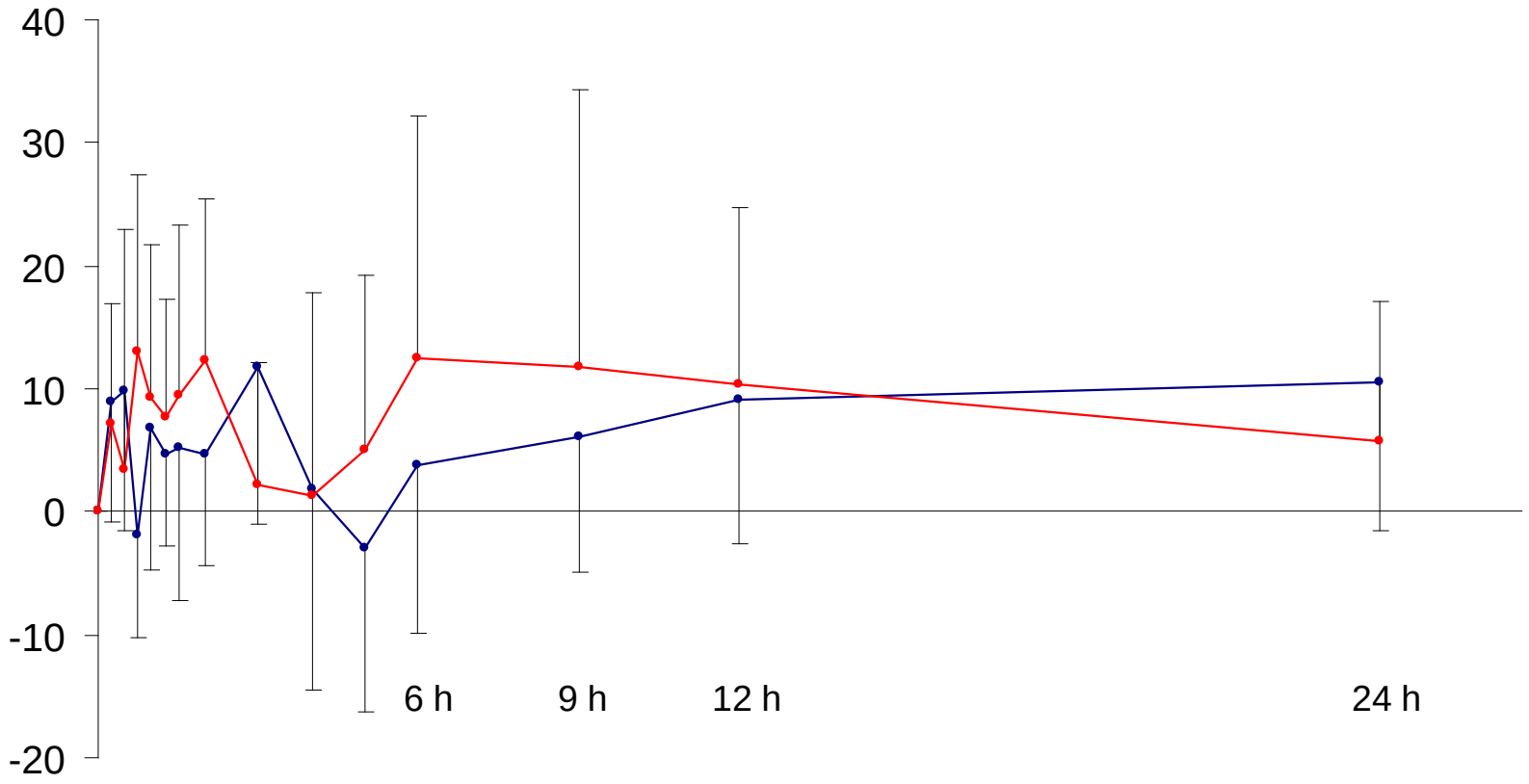
HEALTH·GRAIN

In vivo

Antioxidant Capacity

Total Antioxidant Capacity

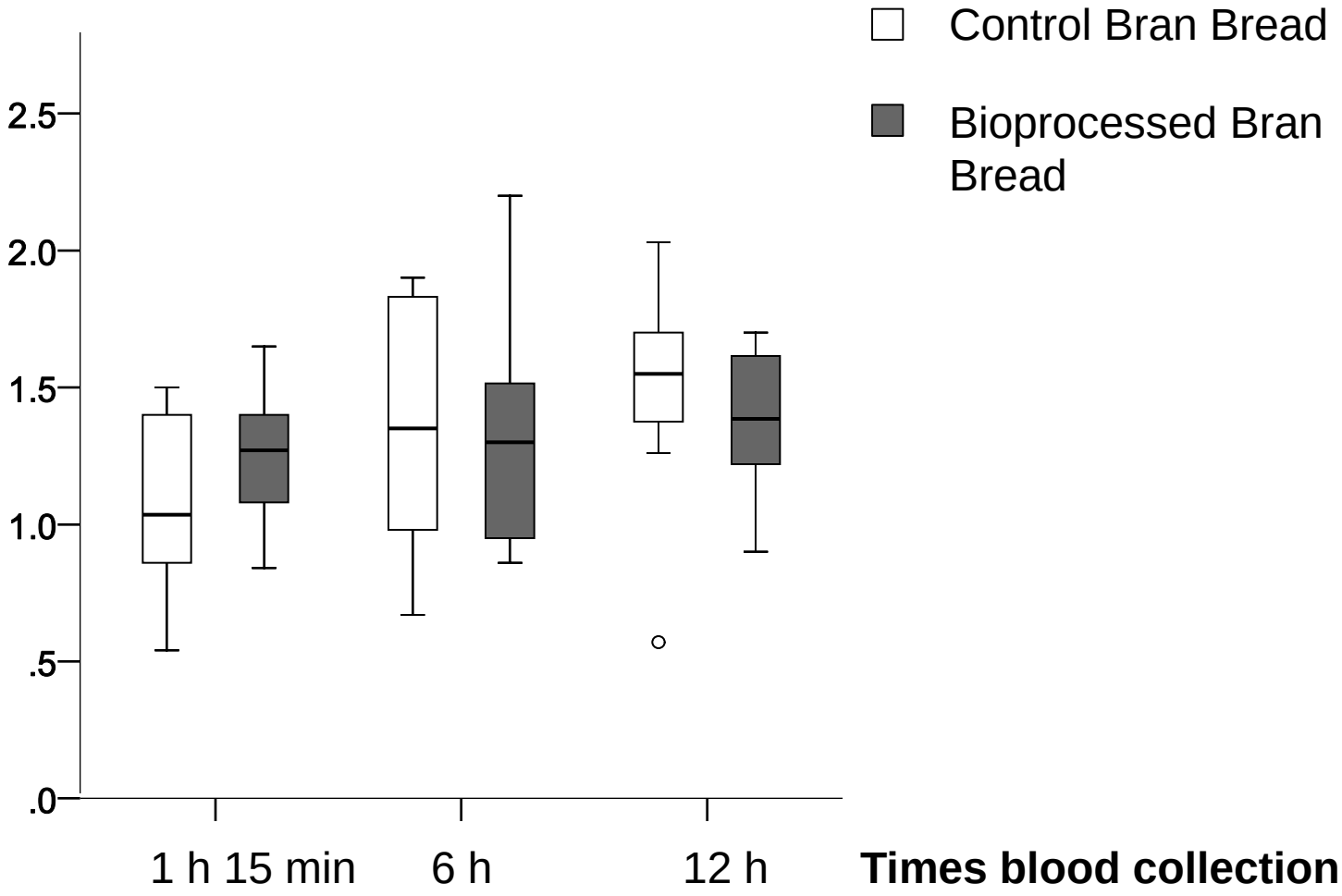
µmol TE / L



In vivo

Ex vivo LPS-Inflammation

IL-10 related to t 0 h

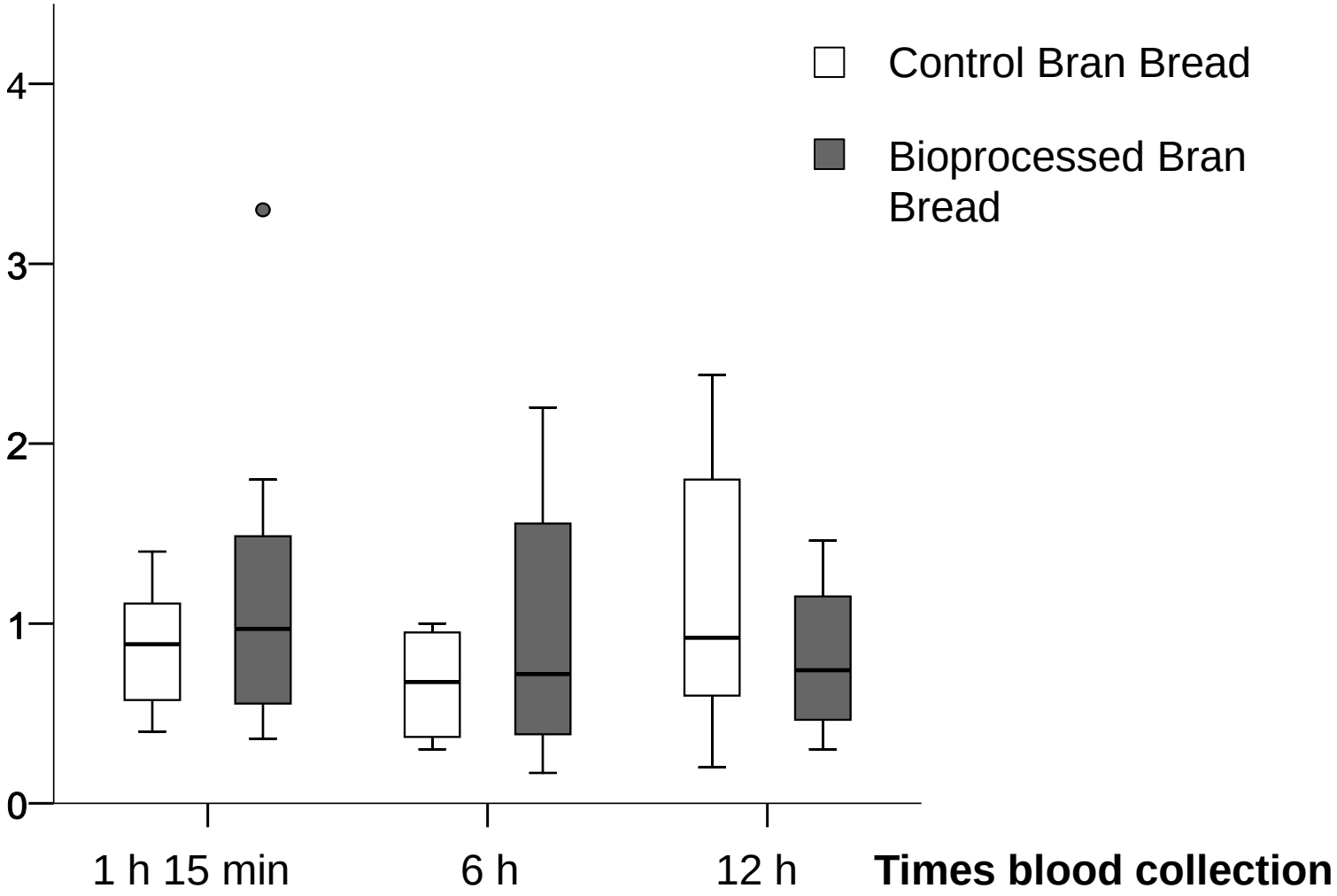


HEALTH·GRAIN

In vivo

Ex vivo LPS-Inflammation

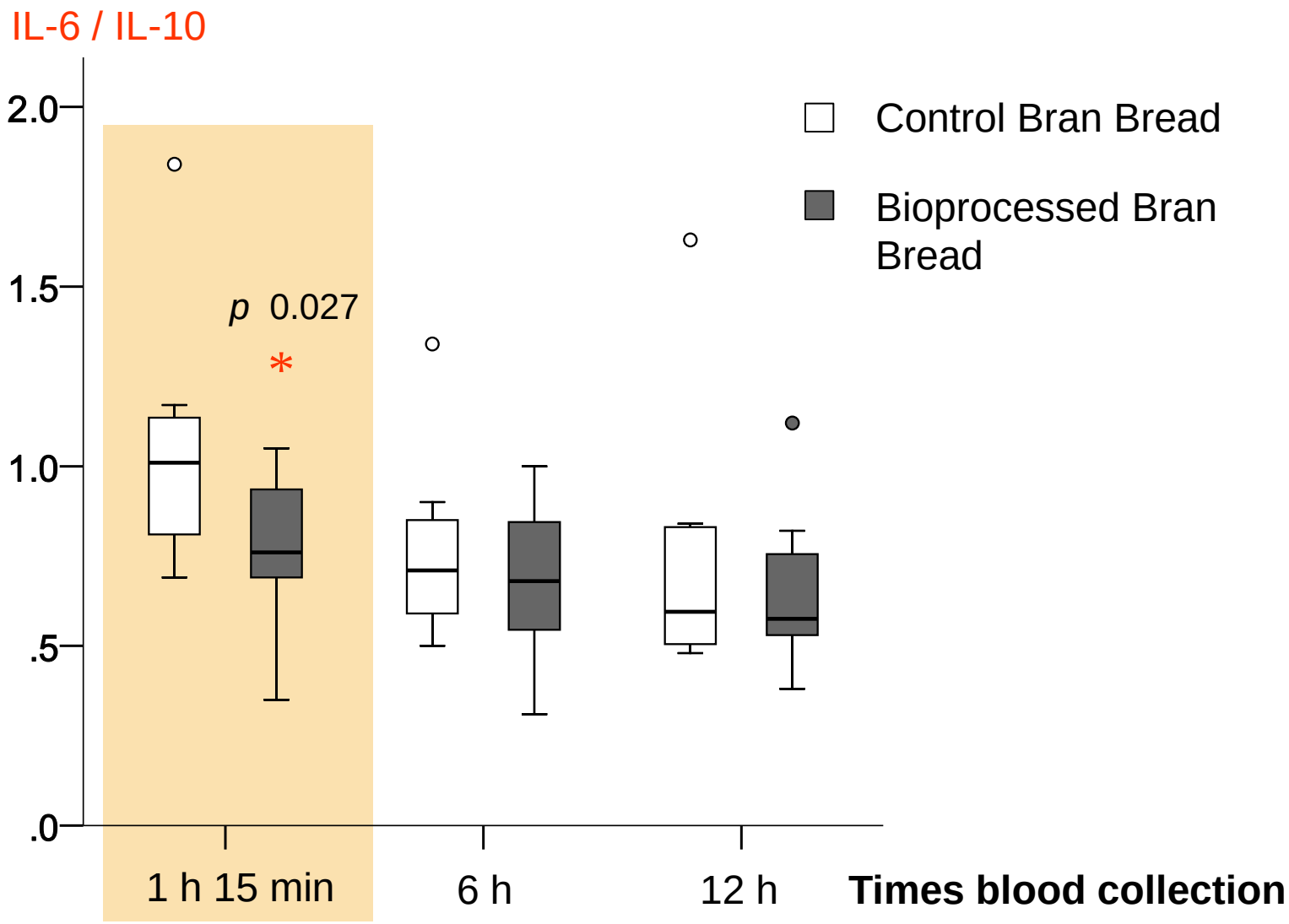
TNF-α / IL-10



HEALTH·GRAIN

In vivo

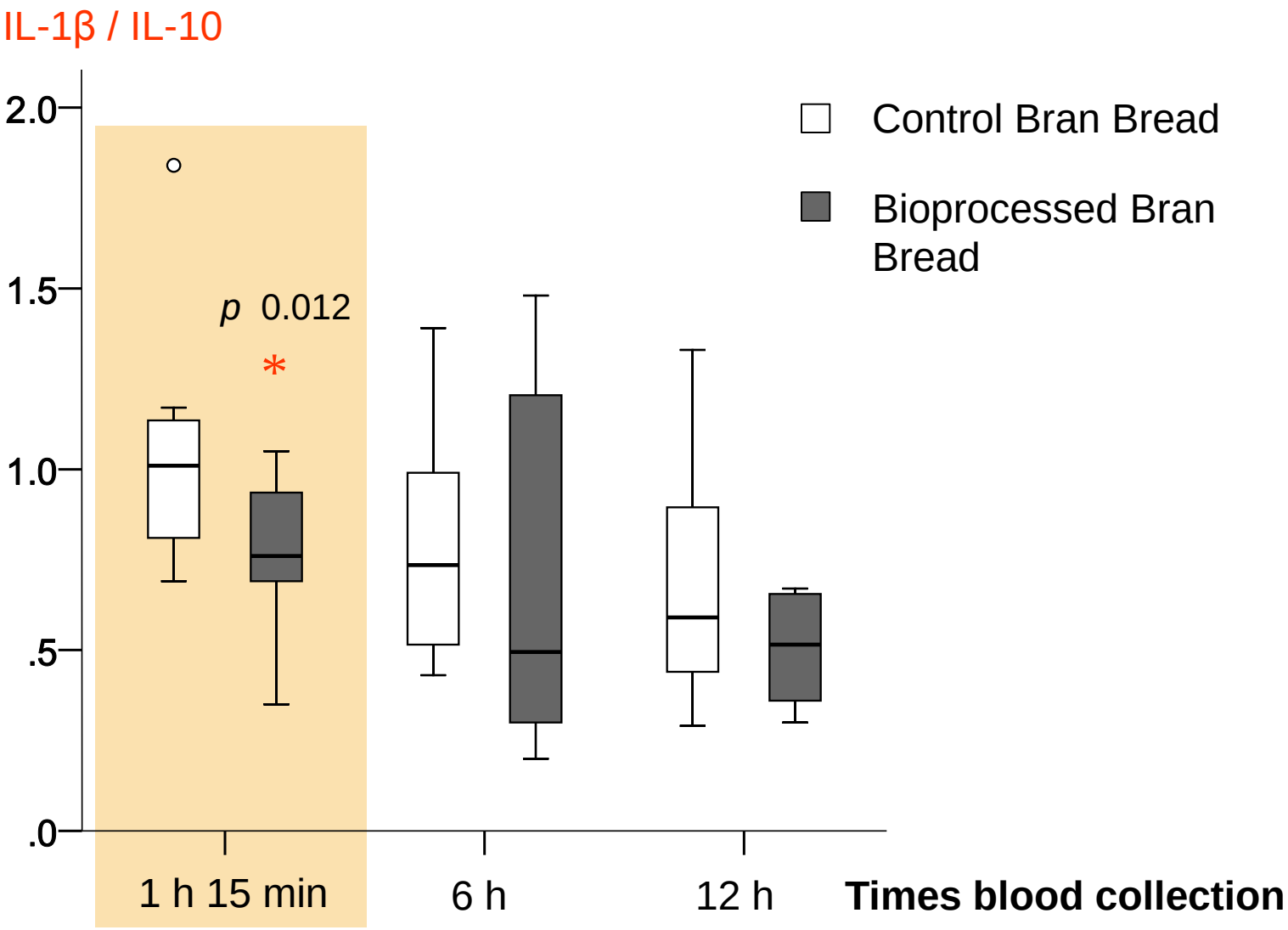
Ex vivo LPS-Inflammation



HEALTH·GRAIN

In vivo

Ex vivo LPS-Inflammation



HEALTHGRAIN

CONCLUSIONS

- **Bioprocessing → ↑Bioavailability of Ferulic acid**
  - Also other compounds / metabolites:
    - Sinapic acid
    - Vanillic acid
    - Dimethoxybenzoic acid

- **Increase in the bioavailability of phenolic acids**
  → **Antioxidant capacity**
    - Radical scavenging

- **Increase in the bioavailability of phenolic acids**
  → **Anti-inflammatory effect**
    - Pro-inflammatory cytokines / Anti-inflammatory cytokines

HEALTH·GRAIN

Acknowledgements

- ***VTT Research Centre of Finland***
  - Anna-Marja Aura
  - Airi Hyrkäs
  - Istmo Mattila
  - Emilia Selinheimo
- ***INRA***
  - *Youna Hemery*
  - *Xavier Rouau*
- ***TNO, Quality of Life, Zeist***
  - Robert Havenaar
  - Wouter Vaes
  - Lisette Bok
- ***Maastricht University***
  - Guido Haenen
  - Aalt Bast
  - Marie-Jose Dritty-Reijnders
  - Jiska Balk
  - Erik Coolen
  - *All the volunteers*