

# Potential of bioactive components in wheat grain fractions – results from human studies.

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**HEALTHGRAIN Final Conference**

**Enhancing health benefits of cereal foods -  
results, perspectives and challenges.**

**Scandic Star Hotel, Lund, Sweden.**

**06/05/10**





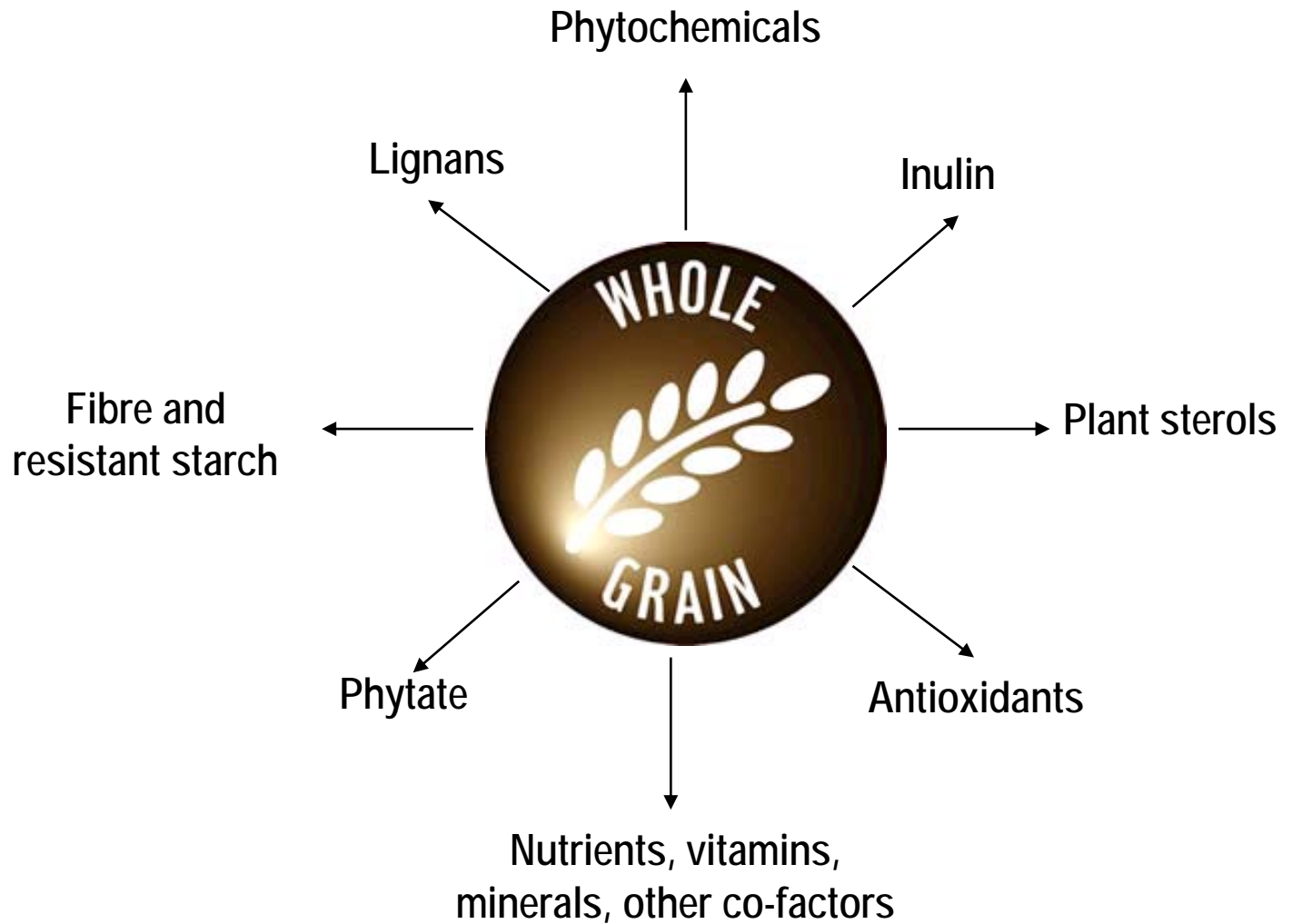
# Epidemiological evidence

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- **Wholegrains can help protect against:**
  - × **Heart disease**
  - × **Cancers**
  - × **Diabetes**
  - × **Stroke**
  - × **Inflammation**



# Potential bioactive components and mechanisms



# Mechanisms of interest

- **Antioxidant potential**

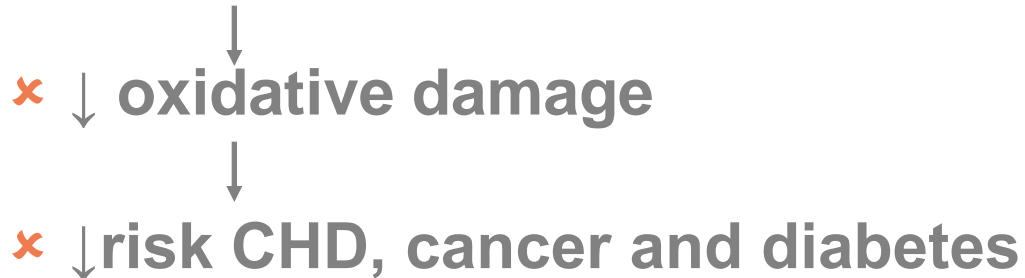
↓  
× ↓ **oxidative damage**

↓  
× ↓ **risk CHD, cancer and diabetes**

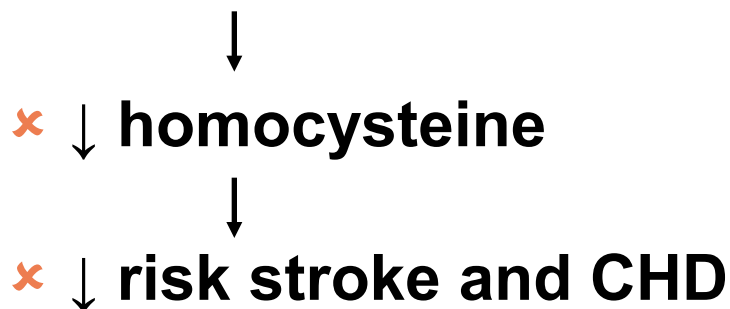


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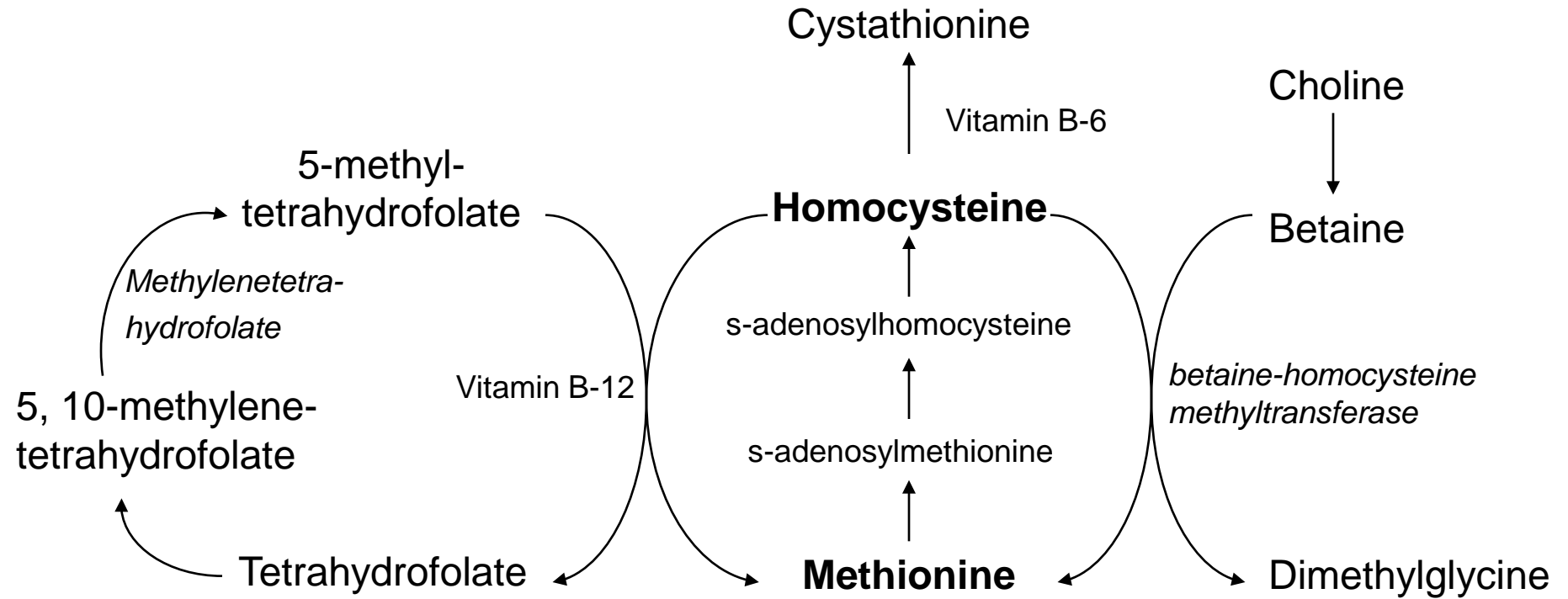


- **Physiological methyl donor micronutrients**



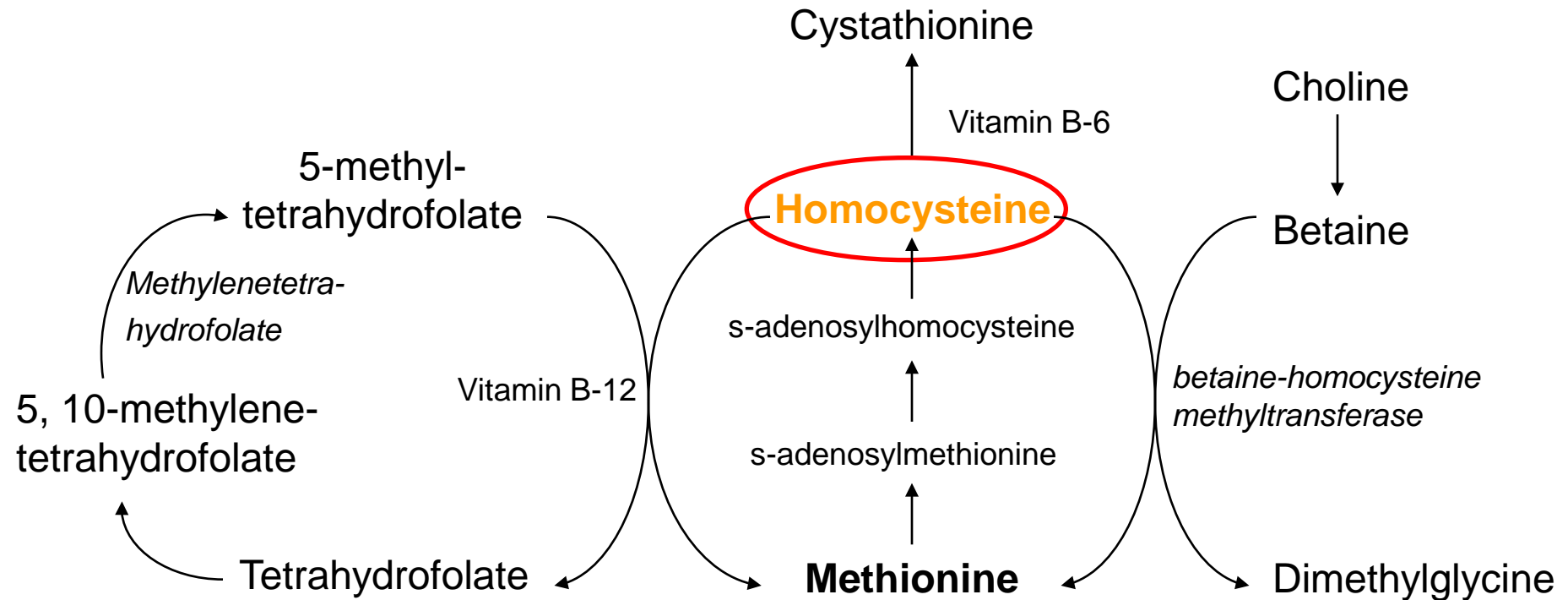


# Homocysteine cycle



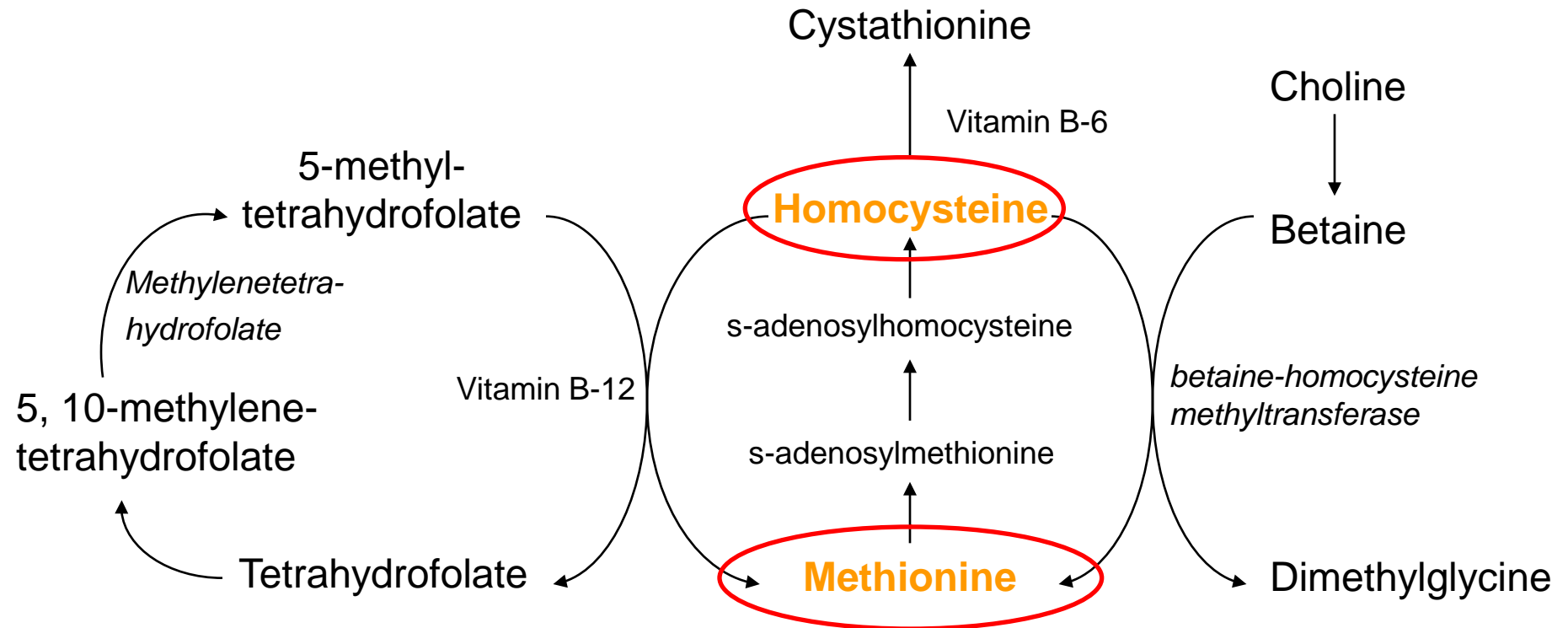


# Homocysteine cycle



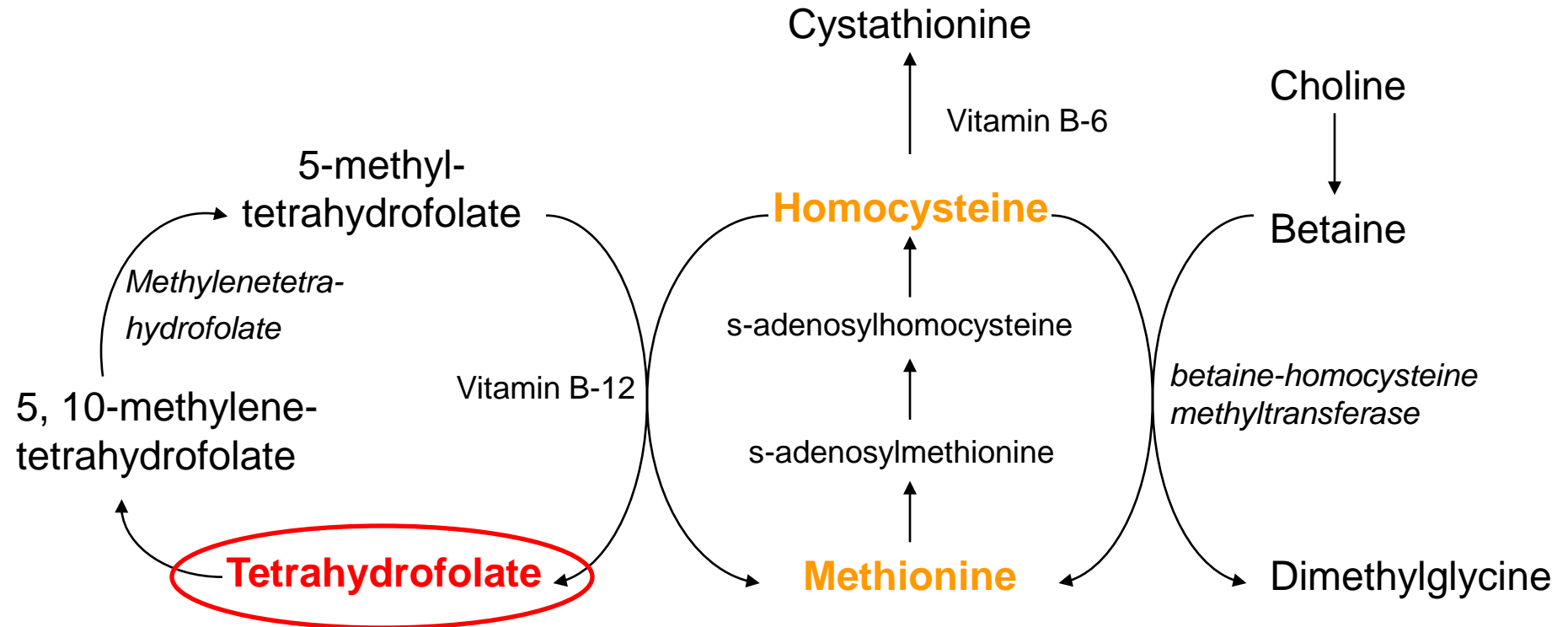


# Homocysteine cycle





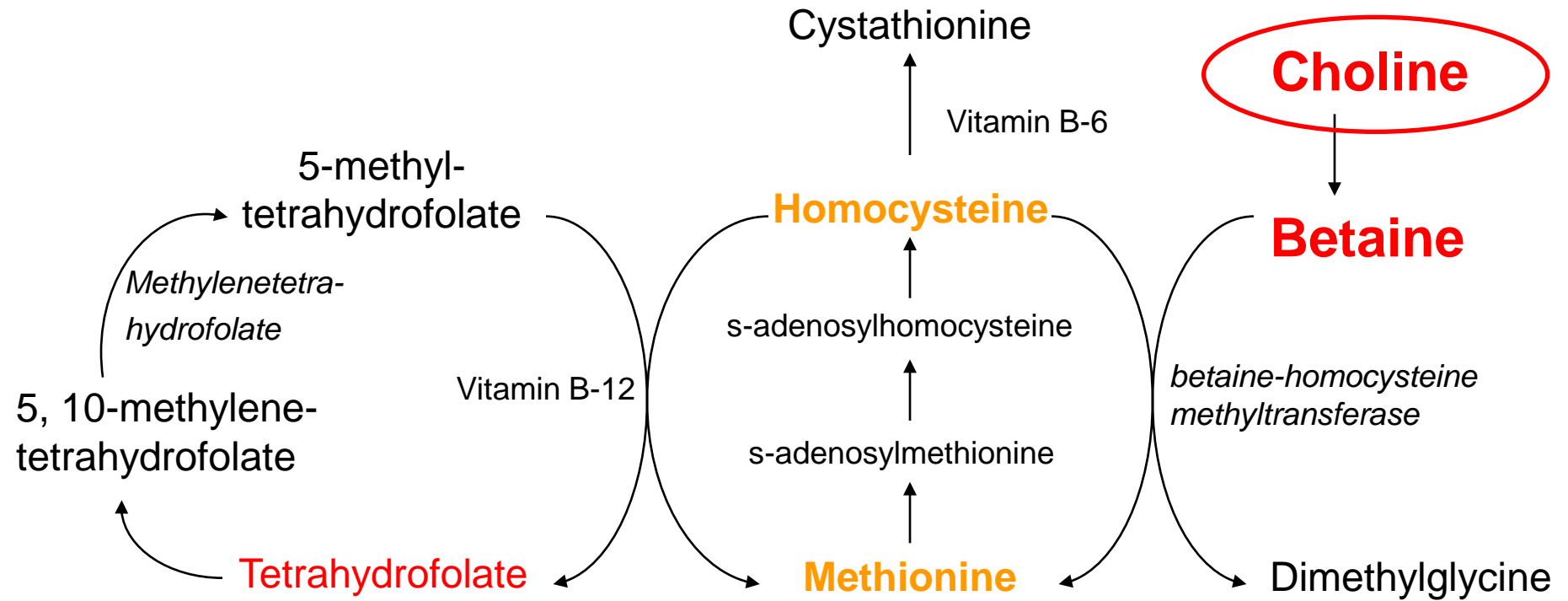
# Homocysteine cycle







# Homocysteine cycle





# Components of interest

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- **Antioxidants**
  - ✗ **Tocols**
  - ✗ **Phenolics**
- **Physiological methyl donor micronutrients**
  - ✗ **Choline**
  - ✗ **Betaine**
  - ✗ **Folate**



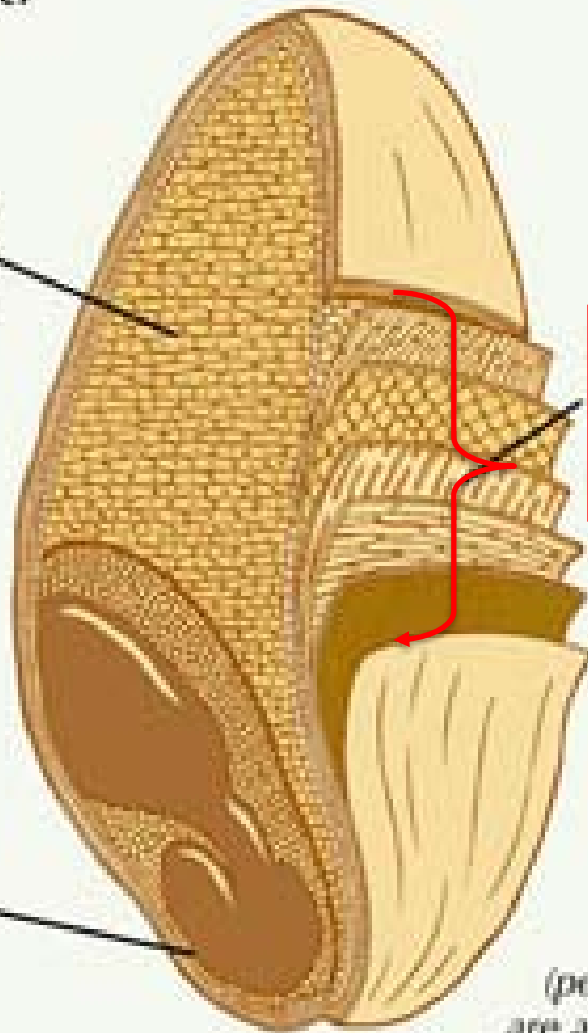


## Wheat Kernel

*Endosperm  
makes up  
83% of the  
kernel*

*Bran  
makes up  
14% of the  
kernel*

*Germ  
makes up  
3% of the  
kernel*



*(percentages  
are approximate)*





## Wheat Kernel

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*(percentages  
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# Wheat fraction analysis

	Bran	Aleurone
<b><i>Antioxidants</i></b>		
Phenolics (mg/100g)	352	515
Ferulic acid (mg/100g)	257	426
Tocols (mg/100g)	11	18
Antioxidant activity ( $\mu\text{mol FRAP} / 100\text{g}$ )	1067	1375
<b><i>Methyl donors</i></b>		
Choline (mg/100g)	61	92
Betaine (mg/100g)	488	926
Folate ( $\mu\text{g}/100\text{g}$ )	100	153

Phenolic, tocols, betaine and choline analysis: Rothamsted Research; Tocol and folate analysis: University of Helsinki, Antioxidant activity: University of Ulster





# Post-meal availability studies

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**To establish the availability of ferulic acid, tocopherols, folate, choline and betaine from aleurone in 2 studies:**

- **Study 1:** Minimally processed aleurone
  - ✗ Provide maximum achievable doses of minimally processed aleurone to assess effects
- **Study 2:** Aleurone incorporated into a bread product
  - ✗ Incorporate similar dose of aleurone into a palatable baked product to assess effects of processing



# Study 1

## 1. Aleurone



## 2. Control



# Study 2

## 1. Aleurone-rich bread roll



## 2. Control bread roll





# Outcome measures

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- **Antioxidant related:**

- ✗ Tocopherols:  $\alpha$ -tocopherol,  $\gamma$ -tocopherol
- ✗ Total ferulic acid

- **Methyl donor related:**

- ✗ Folate
- ✗ Choline
- ✗ Betaine



# Results

		Study 1 - Minimally processed	Study 2 - Processed bread rolls
<b><i>Antioxidant related</i></b>			
<b>Tocopherols</b>	Plasma	NC	NT
<b>Ferulic acid</b>	Plasma	Sig*** ↑	Sig*** ↑
	Urine	Sig*** ↑	Sig*** ↑



NC, no change; Sig, significant; ↑, increase; NS, not significant; NT, Not tested; \*\*\*, P<0.001

# Results

		Study 1 - Minimally processed	Study 2 - Processed bread rolls
<b><i>Antioxidant related</i></b>			
<b>Tocopherols</b>	Plasma	NC	NT
<b>Ferulic acid</b>	Plasma	Sig*** ↑	Sig*** ↑
	Urine	Sig*** ↑	Sig*** ↑
<b><i>Methyl donor related</i></b>			
<b>Folate</b>	Plasma	NS ↑	NS ↑
<b>Choline</b>	Plasma	NS ↑	NS ↑
<b>Betaine</b>	Plasma	Sig*** ↑	Sig*** ↑



NC, no change; Sig, significant; ↑, increase; NS, not significant; NT, Not tested; \*\*\*, P<0.001



# Conclusions

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- The aleurone meals substantially increased:
  - ✗ plasma and urinary ferulic acid
  - ✗ plasma betaine
- No significant changes in plasma folate, choline or tocopherols
- Processing had little effect on the uptake of components
- **Results suggest that aleurone contains available betaine and ferulic acid, with the potential to exert beneficial physiological impacts.**

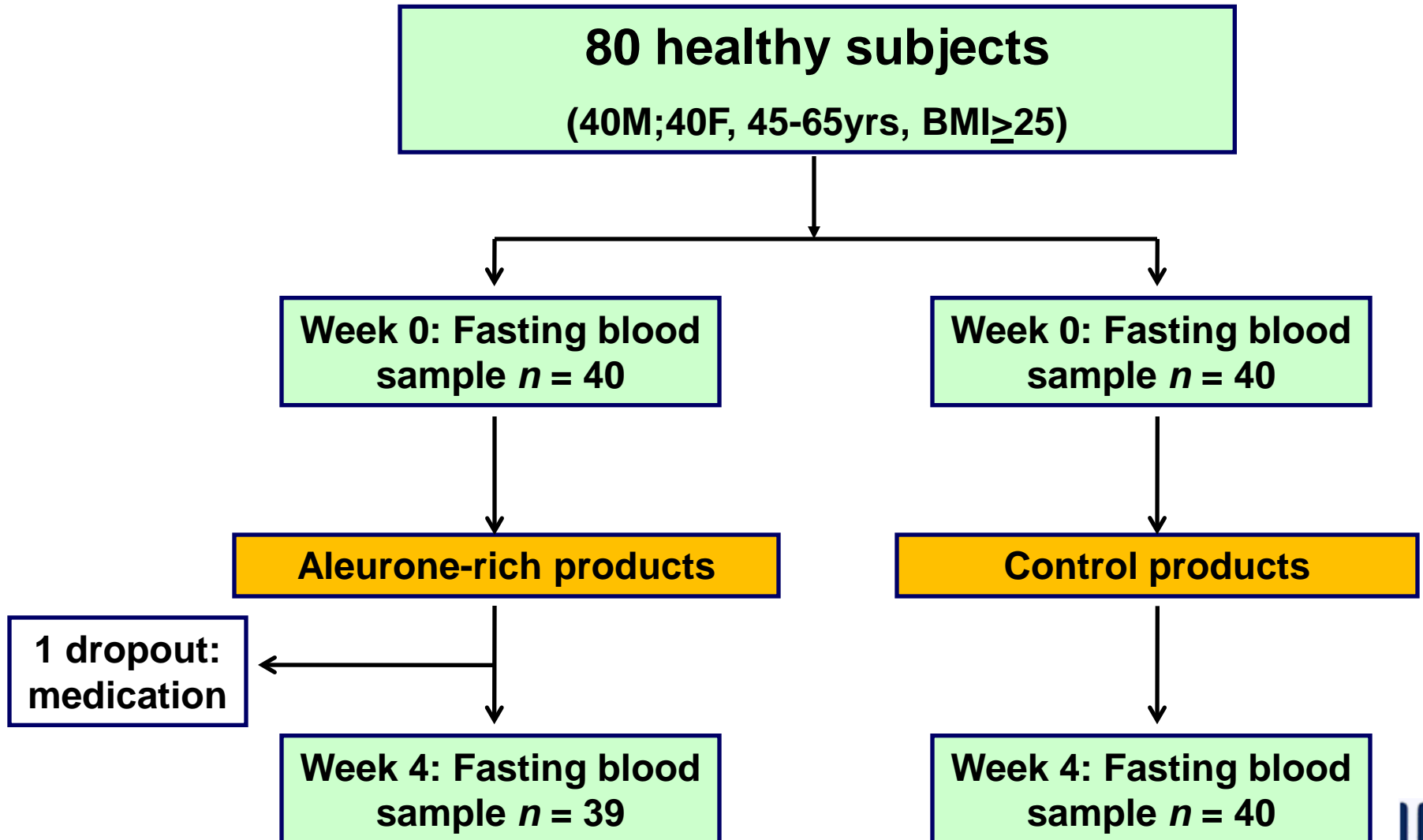


# Longer-term intervention

- Hypothesis:
  - ✗ That the long-term consumption of aleurone-rich cereal products impacts favourably on risk factors for heart disease and metabolic syndrome in apparently healthy, 'at risk' men and women



# Study design



# Intervention products

## 1. Aleurone-rich cereal products

### 2 bread rolls

- ✗ Produced by Barilla
- ✗ 67g portions
- ✗ Each roll contains **9g** aleurone



### 1 RTE cereal

- ✗ Produced by Bühler
- ✗ 40g portions
- ✗ Each portion contains **9g** aleurone

Total consumption of aleurone / day = **27g**

## 2. Control cereal products

### 2 bread rolls

- ✗ Produced by Barilla
- ✗ 67g portions
- ✗ Contains **no** aleurone



### 1 RTE cereal

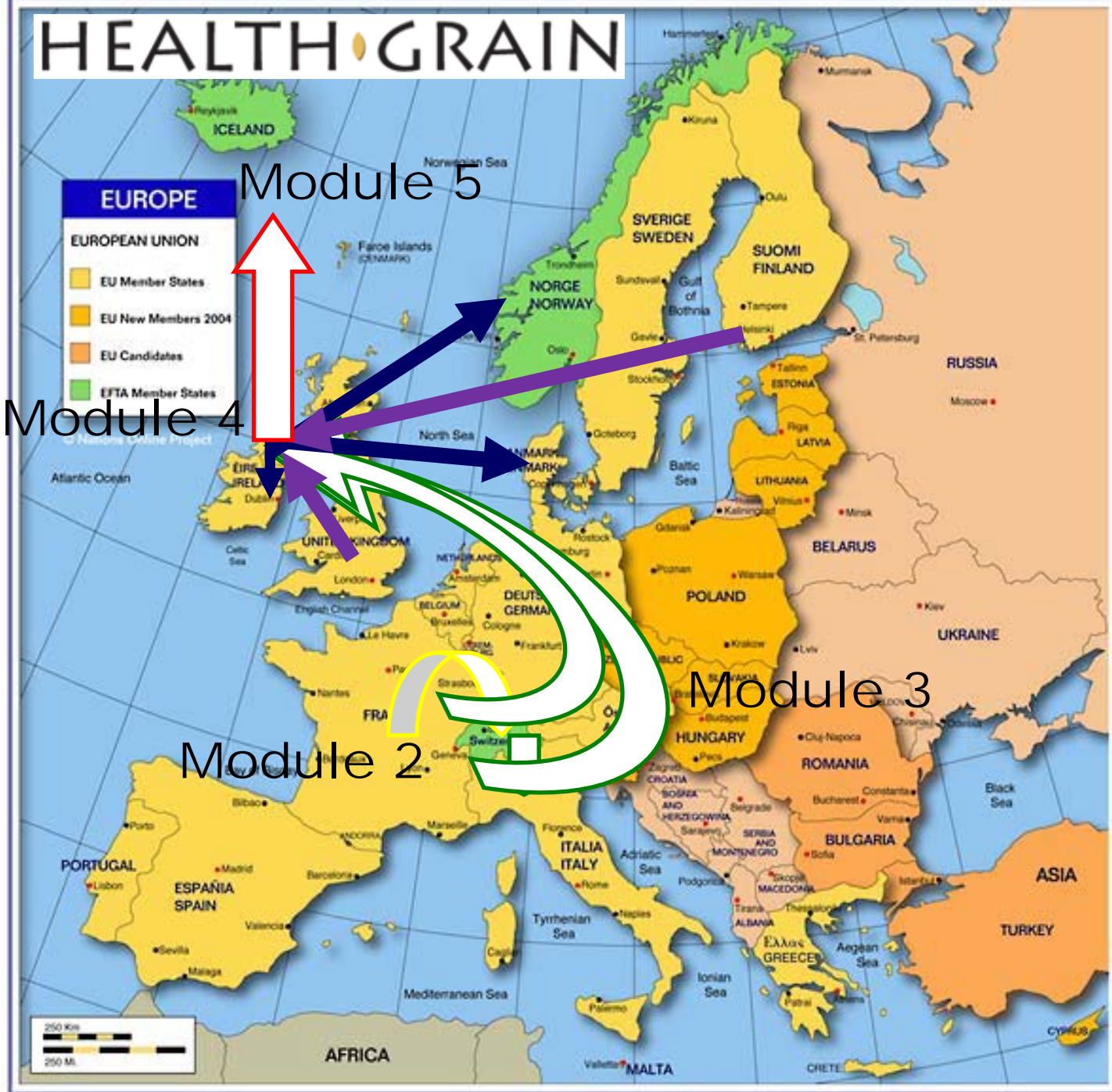
- ✗ Produced by Bühler
- ✗ 39g portions
- ✗ Contains **no** aleurone

•All meals balanced for macronutrients, fibre & energy





# HEALTH GRAIN



EUROPE	
EUROPEAN UNION	
	EU Member States
	EU New Members 2004
	EU Candidates
	EFTA Member States

Module 5

Module 4

Module 1

Module 2

Module 3

Module 4



# Antioxidant components provided by intervention products / day

	<b>Aleurone group</b> (2 bread roll + 1 RTE cereal)	<b>Control group</b> (2 bread roll + 1 RTE cereal)
<b>Total tocols (mg)</b>	<b>9.4</b>	<b>5.8</b>
<b><math>\alpha</math>-tocopherol (mg)</b>	<b>1.6</b>	<b>1.3</b>
<b><math>\beta</math>-tocopherol (mg)</b>	<b>0.4</b>	<b>0.3</b>
<b>Selenium (<math>\mu</math>g)</b>	<b>45</b>	<b>36</b>
<b>Copper (mg)</b>	<b>0.6</b>	<b>0.3</b>
<b>Zinc (mg)</b>	<b>3.5</b>	<b>1.3</b>
<b>Total phenolics (mg)</b>	<b>145</b>	<b>10</b>
<b>Ferulic acid (mg)</b>	<b>114</b>	<b>7</b>



# Methyl donor micronutrients provided by intervention products / day

	<b>Aleurone group</b> (2 bread roll + 1 RTE cereal)	<b>Control group</b> (2 bread roll + 1 RTE cereal)
<b>Choline (mg)</b>	<b>78</b>	<b>36</b>
<b>Betaine (mg)</b>	<b>508</b>	<b>216</b>
<b>Folate (<math>\mu\text{g}</math>)</b>	<b>103</b>	<b>63</b>
<b>Riboflavin (<math>\mu\text{g}</math>)</b>	<b>88</b>	<b>40</b>
<b>Vitamin B6 (<math>\mu\text{g}</math>)</b>	<b>331</b>	<b>0</b>





# Outcome measures: food intake and body composition

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- **Food intake: pre- and during intervention**
- **Body composition**
  - × Weight
  - × Waist-hip ratio



# Plasma outcome measures

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# Outcome measures: antioxidant related

- **Antioxidant micronutrients and phytochemicals:**
  - ✗ Selenium, zinc & copper
  - ✗ Tocopherols –  $\alpha$ -tocopherol and  $\gamma$ -tocopherol
  - ✗ Ferulic acid
- **Antioxidant status:**
  - ✗ Antioxidant activity (FRAP)
  - ✗ Superoxide dismutase (SOD)
  - ✗ Neopterin
  - ✗ Methionine sulfoxide (MetSO)
- **Inflammation status:**
  - ✗ C-reactive protein (CRP)
  - ✗ Monocyte chemoattractant protein (MCP)
  - ✗ Interleukin(IL)- $1\beta$ , IL-6, IL-10, tumor necrosis factor (TNF)- $\alpha$





# Outcome measures: methyl donor related

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- **Methyl donor micronutrients:**
  - ✗ Choline
  - ✗ Betaine
  - ✗ Folate
  - ✗ Riboflavin
  - ✗ Pyridoxal 5'-phosphate (PLP)
- **Methyl donor related parameters:**
  - ✗ Dimethylglycine (DMG)
  - ✗ Homocysteine
  - ✗ Methionine





# Outcome measures: Glycaemia and lipid related

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- **Glycaemia related:**
  - ✗ Insulin
  - ✗ Glucose
- **Lipid profile:**
  - ✗ Total cholesterol
  - ✗ HDL- and LDL-cholesterol
  - ✗ Triglycerides
- **Short-chain fatty acids:**
  - ✗ Total
  - ✗ Butyric, acetic, propionic, isobutyric, caprioc



# Results

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# Baseline characteristics and compliance

	<b>Aleurone (n 39)</b>	<b>Control (n 40)</b>	<b><i>P-value</i></b>
<b>Age (years)</b>	<b>51.5 <math>\pm</math>4.8 (46-62)</b>	<b>51.7 <math>\pm</math>4.8 (45-65)</b>	<b>1.00</b>
<b>Gender (M:F)</b>	<b>20:19</b>	<b>20:20</b>	<b>-</b>
<b>BMI (kg/m<sup>2</sup>)</b>	<b>28.7 <math>\pm</math>3.6 (24.8-40.3)</b>	<b>29.1 <math>\pm</math>3.2 (25.1-37.8)</b>	<b>0.68</b>
<b>Compliance (%)</b>	<b>95.9 <math>\pm</math>7.4 (67.9-100)</b>	<b>96.3 <math>\pm</math>6.8 (70.2-100)</b>	<b>0.17</b>

\*Mean  $\pm$ SD (range)



# Reported food intakes

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
Energy (Kcal)	2036	2044	2122	2074	0.51
Fat (g)	80	79	85	76	0.13
Carbohydrate (g)	243	240	249	246	0.92
Protein (g)	83	91	87	92	0.82
Fibre (g)	14	27	15	29	0.12



# Body composition

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
<b>Weight (Kg)</b>	<b>84.9</b>	<b>84.7</b>	<b>84.0</b>	<b>83.9</b>	<b>0.94</b>
<b>Waist : hip ratio</b>	<b>0.92</b>	<b>0.93</b>	<b>0.91</b>	<b>0.92</b>	<b>0.99</b>



# Antioxidant related plasma measures

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# Antioxidant micronutrients and phytochemicals

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
<b>Selenium (µg/L)</b>	<b>76.8</b> (± 1.9)	<b>79.0</b> (± 1.7)	<b>82.5</b> (± 1.4)	<b>83.4</b> (± 1.5)	<b>0.70</b>
<b>Zinc (µg/L)</b>	<b>763</b> (± 17)	<b>783</b> (± 16)	<b>801</b> (± 15)	<b>796</b> (± 17)	<b>0.26</b>
<b>Copper (µg/L)</b>	<b>942</b> (± 29)	<b>964</b> (± 31)	<b>956</b> (± 24)	<b>979</b> (± 26)	<b>0.89</b>
<b>α-tocopherol (µmol/L)</b>	<b>29.1</b> (± 1.6)	<b>28.9</b> (± 1.6)	<b>29.3</b> (± 1.3)	<b>29.4</b> (± 1.2)	<b>0.64</b>
<b>γ-tocopherol (µmol/L)</b>	<b>0.19</b> (± 0.14)	<b>0.17</b> (± 0.14)	<b>0.20</b> (± 0.11)	<b>0.19</b> (± 0.11)	<b>0.06</b>
<b>Ferulic acid (nmol/L)</b>	<b>98.0</b> (± 4.3)	<b>97.2</b> (± 3.0)	<b>101.4</b> (± 6.0)	<b>106.3</b> (± 7.4)	<b>0.52</b>



Mean (± SE); Base, baseline; Post, post-intervention; <sup>a</sup> Comparison of post-intervention data between groups

# Antioxidant status

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
Antioxidant activity ( $\mu\text{mol FRAP/L}$ )	1149 ( $\pm 40$ )	1121 ( $\pm 36$ )	1180 ( $\pm 37$ )	1174 ( $\pm 36$ )	0.27
SOD (U/gHb)	1506 ( $\pm 47$ )	1499 ( $\pm 42$ )	1465 ( $\pm 35$ )	1450 ( $\pm 32$ )	0.68
Neopterin (nmol/L)	11.3 ( $\pm 0.7$ )	10.9 ( $\pm 0.8$ )	10.4 ( $\pm 0.5$ )	9.9 ( $\pm 0.3$ )	0.95
MetSo ( $\mu\text{mol/L}$ )	1.01 ( $\pm 0.05$ )	1.16 ( $\pm 0.05$ )	1.04 ( $\pm 0.05$ )	1.12 ( $\pm 0.06$ )	0.48

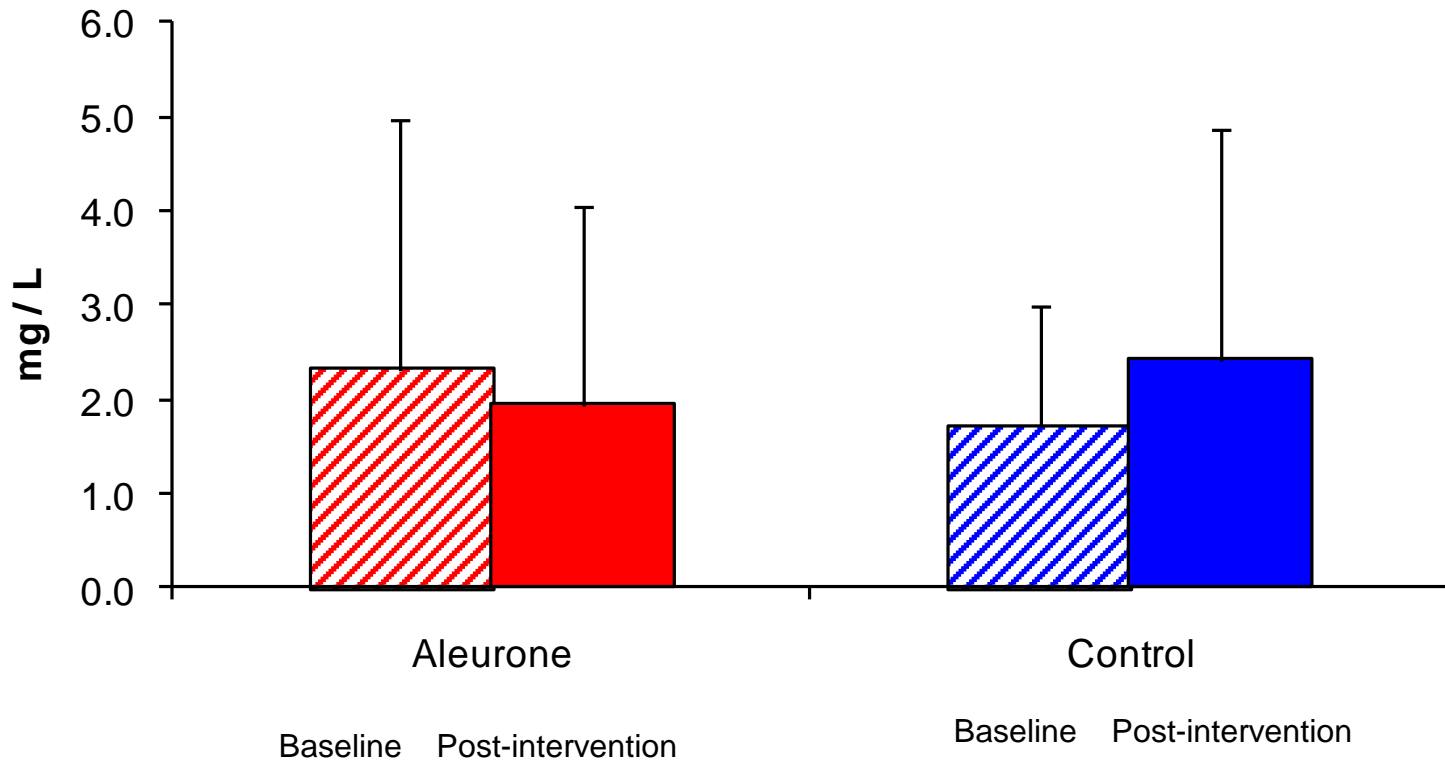


# Inflammation markers

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
CRP (mg/L)	<b>2.32</b> (± 0.42)	<b>1.94</b> (± 0.34)	<b>1.74</b> (± 0.20)	<b>2.42</b> (± 0.39)	<b>0.03</b>



# Change in plasma C-reactive protein (CRP)



Groups significantly different post-intervention ( $P=0.035$ )\*



# Inflammation markers

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
CRP (mg/L)	<b>2.32</b> (± 0.42)	<b>1.94</b> (± 0.34)	<b>1.74</b> (± 0.20)	<b>2.42</b> (± 0.39)	<b>0.03</b>



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	Base	Post	Base	Post	
CRP (mg/L)	<b>2.32</b> (± 0.42)	<b>1.94</b> (± 0.34)	<b>1.74</b> (± 0.20)	<b>2.42</b> (± 0.39)	<b>0.03</b>
MCP (µg/L)	<b>763</b> (± 17)	<b>783</b> (± 16)	<b>801</b> (± 15)	<b>796</b> (± 17)	<b>0.55</b>
IL-1β (µg/L)	<b>942</b> (± 29)	<b>964</b> (± 31)	<b>956</b> (± 24)	<b>979</b> (± 26)	<b>0.12</b>
IL-6 (µmol/L)	<b>29.1</b> (± 1.6)	<b>28.9</b> (± 1.6)	<b>29.3</b> (± 1.3)	<b>29.4</b> (± 1.2)	<b>0.16</b>
IL-10 (µmol/L)	<b>0.19</b> (± 0.14)	<b>0.17</b> (± 0.14)	<b>0.20</b> (± 0.11)	<b>0.19</b> (± 0.11)	<b>0.16</b>
TNF-α (nmol/L)	<b>98.0</b> (± 4.3)	<b>97.2</b> (± 3.0)	<b>101.4</b> (± 6.0)	<b>106.3</b> (± 7.4)	<b>0.30</b>



Mean (± SE); Base, baseline; Post, post-intervention; <sup>a</sup> Comparison of post-intervention data between groups

# Methyl donor related plasma measures

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# Methyl donor related micronutrients

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
<b>Choline (μmol/L)</b>	<b>8.95</b> (± 0.3)	<b>9.11</b> (± 0.3)	<b>8.63</b> (± 0.3)	<b>8.73</b> (± 0.3)	<b>0.53</b>

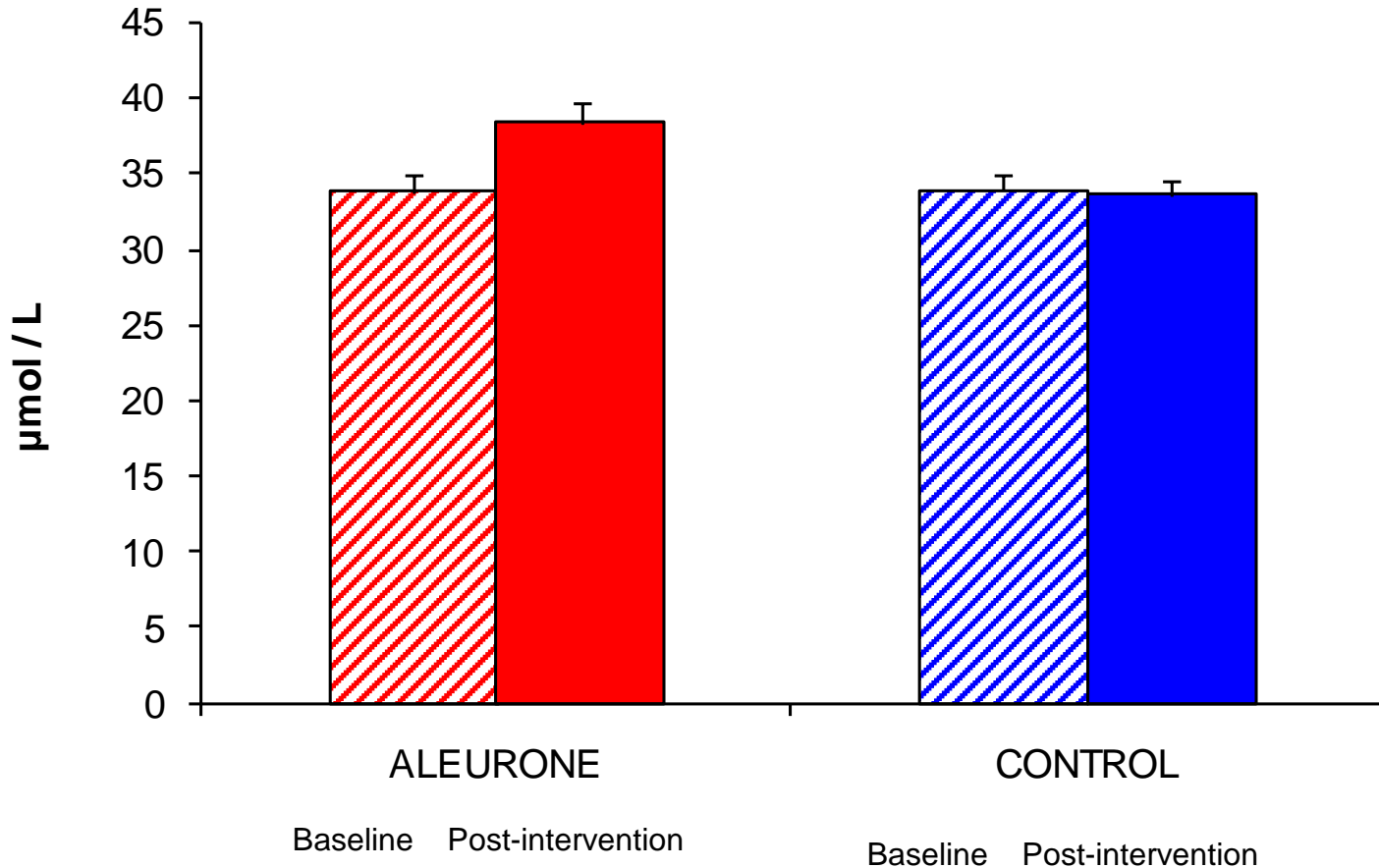


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	Base	Post	Base	Post	
<b>Choline (μmol/L)</b>	<b>8.95</b> (± 0.3)	<b>9.11</b> (± 0.3)	<b>8.63</b> (± 0.3)	<b>8.73</b> (± 0.3)	<b>0.53</b>
<b>Betaine (μmol/L)</b>	<b>33.7</b> (± 1.3)	<b>38.4</b> (± 1.4)	<b>34.1</b> (± 1.0)	<b>33.6</b> (± 1.0)	<b>&lt;0.01</b>



# Change in plasma betaine



Groups significantly different post-intervention ( $P < 0.001$ )\*\*\*



# Methyl donor related micronutrients

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
<b>Choline (μmol/L)</b>	<b>8.95</b> (± 0.3)	<b>9.11</b> (± 0.3)	<b>8.63</b> (± 0.3)	<b>8.73</b> (± 0.3)	<b>0.53</b>
<b>Betaine (μmol/L)</b>	<b>33.7</b> (± 1.3)	<b>38.4</b> (± 1.4)	<b>34.1</b> (± 1.0)	<b>33.6</b> (± 1.0)	<b>&lt;0.01</b>



# Methyl donor related micronutrients

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
<b>Choline (µmol/L)</b>	<b>8.95</b> (± 0.3)	<b>9.11</b> (± 0.3)	<b>8.63</b> (± 0.3)	<b>8.73</b> (± 0.3)	<b>0.53</b>
<b>Betaine (µmol/L)</b>	<b>33.7</b> (± 1.3)	<b>38.4</b> (± 1.4)	<b>34.1</b> (± 1.0)	<b>33.6</b> (± 1.0)	<b>&lt;0.01</b>
<b>Folate (nmol/L)</b>	<b>13.1</b> (± 1.1)	<b>11.5</b> (± 0.8)	<b>13.9</b> (± 1.2)	<b>13.4</b> (± 1.4)	<b>0.69</b>
<b>Riboflavin (nmol/L)</b>	<b>20.7</b> (± 6.6)	<b>18.9</b> (± 5.7)	<b>17.7</b> (± 2.8)	<b>16.8</b> (± 2.2)	<b>0.64</b>
<b>Pyridoxal 5'-phosphate (nmol/L)</b>	<b>64.1</b> (± 5.1)	<b>65.1</b> (± 4.7)	<b>64.3</b> (± 4.2)	<b>63.7</b> (± 5.3)	<b>0.20</b>

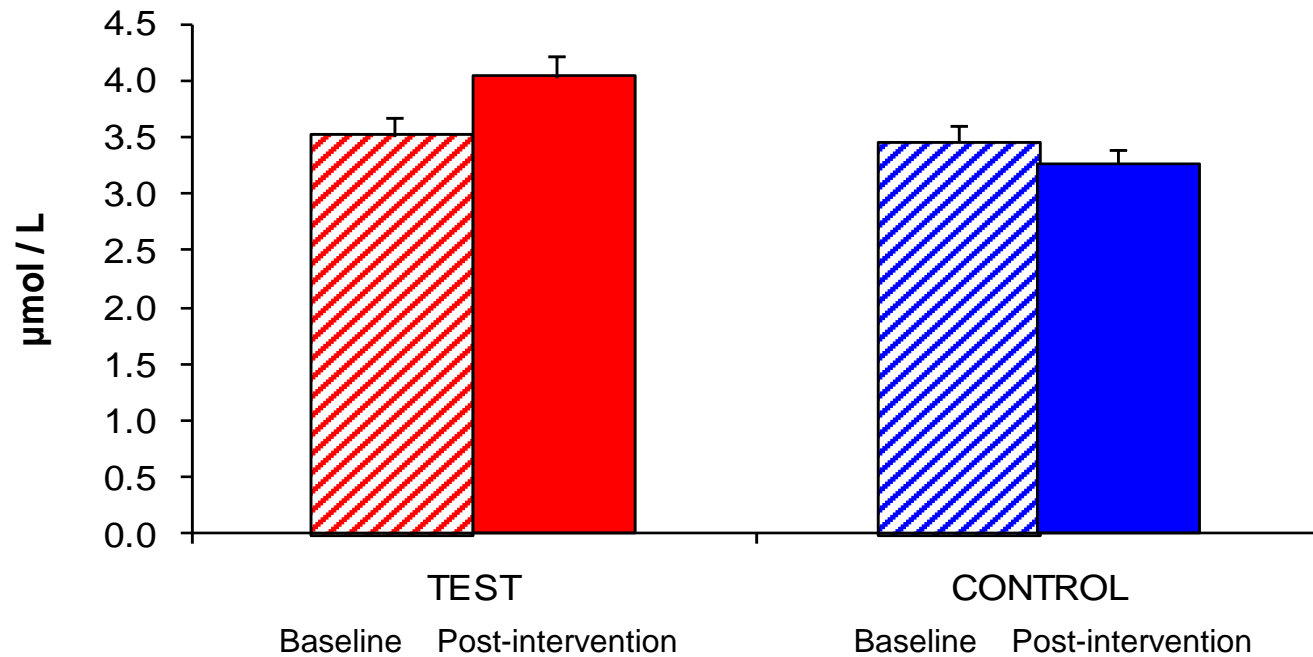


# Methyl donor related measures

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
<b>Dimethylglycine (<math>\mu\text{mol/L}</math>)</b>	<b>3.51</b> ( $\pm 0.2$ )	<b>4.04</b> ( $\pm 0.2$ )	<b>3.45</b> ( $\pm 0.1$ )	<b>3.28</b> ( $\pm 0.1$ )	<b>&lt;0.01</b>



# Change in plasma dimethylglycine (DMG)



Groups significantly different post-intervention ( $P < 0.001$ )\*\*\*



# Methyl donor related measures

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
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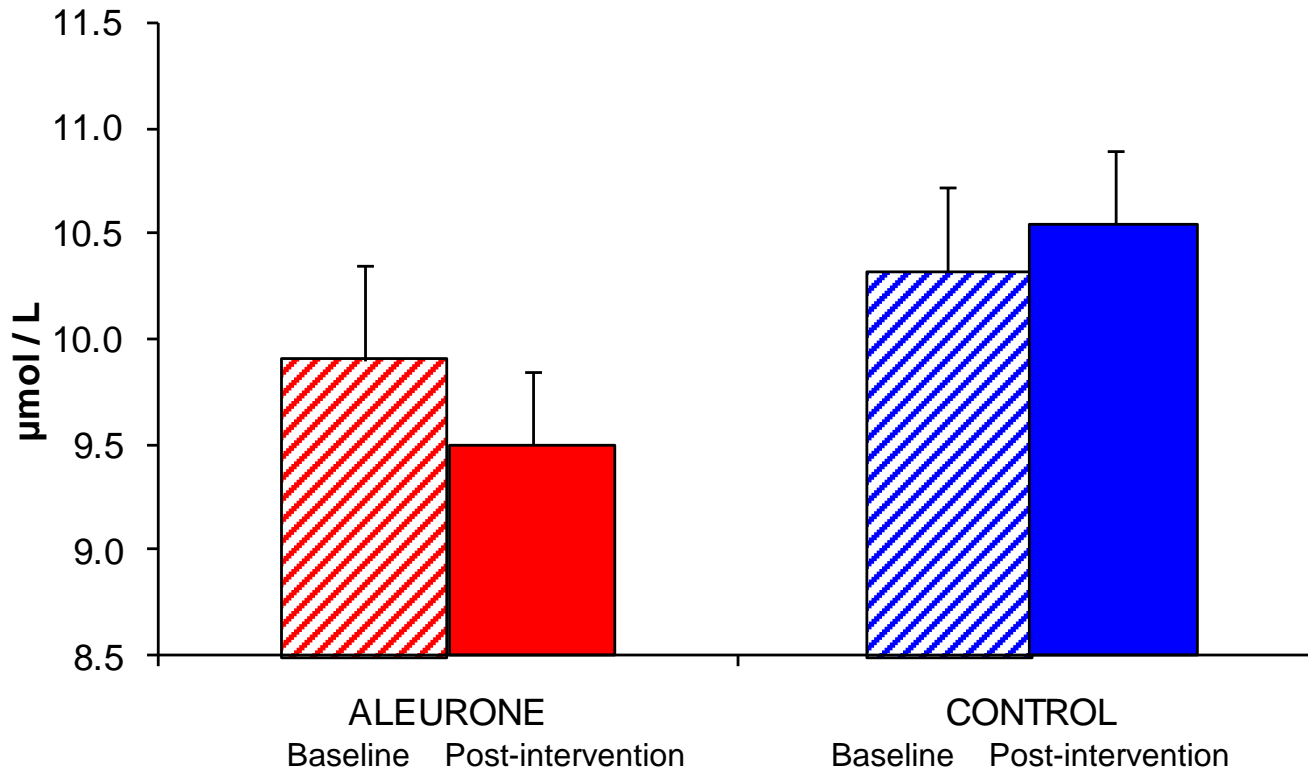


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	Base	Post	Base	Post	
<b>Dimethylglycine (<math>\mu\text{mol/L}</math>)</b>	<b>3.51</b> ( $\pm 0.2$ )	<b>4.04</b> ( $\pm 0.2$ )	<b>3.45</b> ( $\pm 0.1$ )	<b>3.28</b> ( $\pm 0.1$ )	<b>&lt;0.01</b>
<b>Homocysteine (<math>\mu\text{mol/L}</math>)</b>	<b>9.90</b> ( $\pm 0.5$ )	<b>9.5</b> ( $\pm 0.3$ )	<b>10.3</b> ( $\pm 0.4$ )	<b>10.5</b> ( $\pm 0.3$ )	<b>0.01</b>
<b>Methionine (<math>\mu\text{mol/L}</math>)</b>	<b>28.8</b> ( $\pm 0.8$ )	<b>29.5</b> ( $\pm 0.7$ )	<b>29.1</b> ( $\pm 0.7$ )	<b>28.3</b> ( $\pm 0.6$ )	<b>0.03</b>



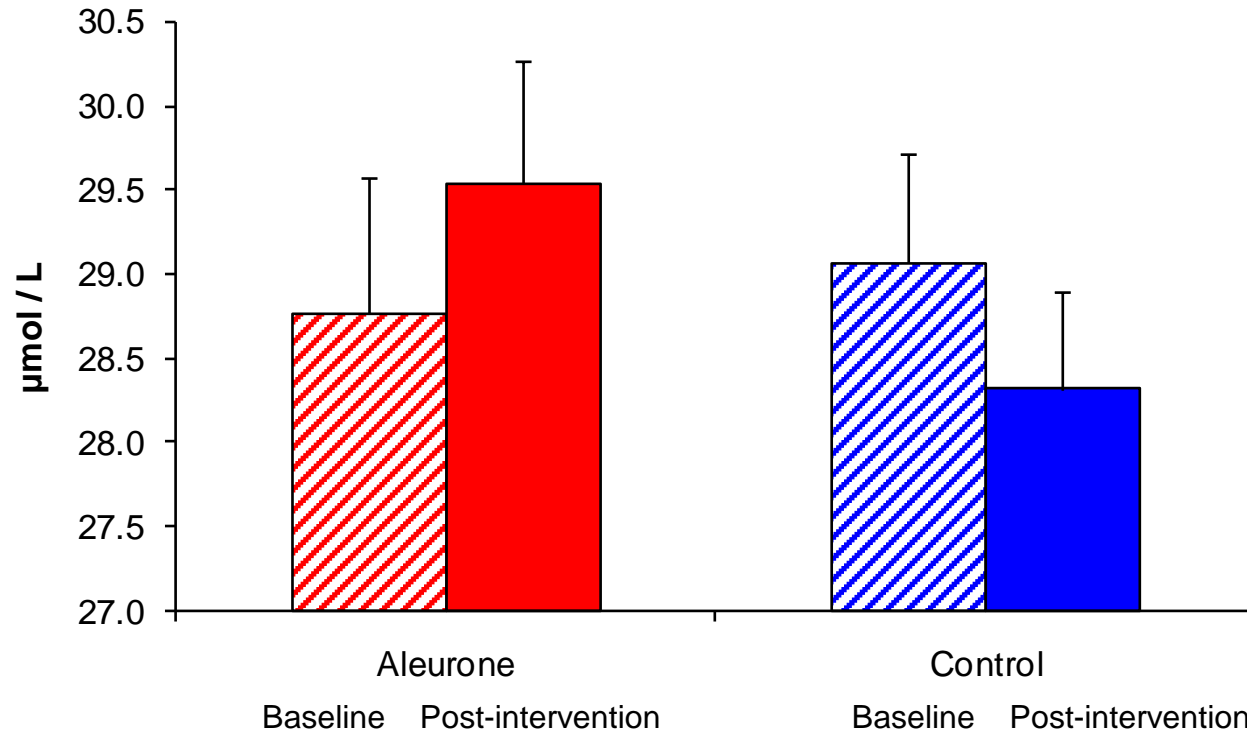
# Change in plasma homocysteine



Groups significantly different post-intervention ( $P=0.01$ )\*



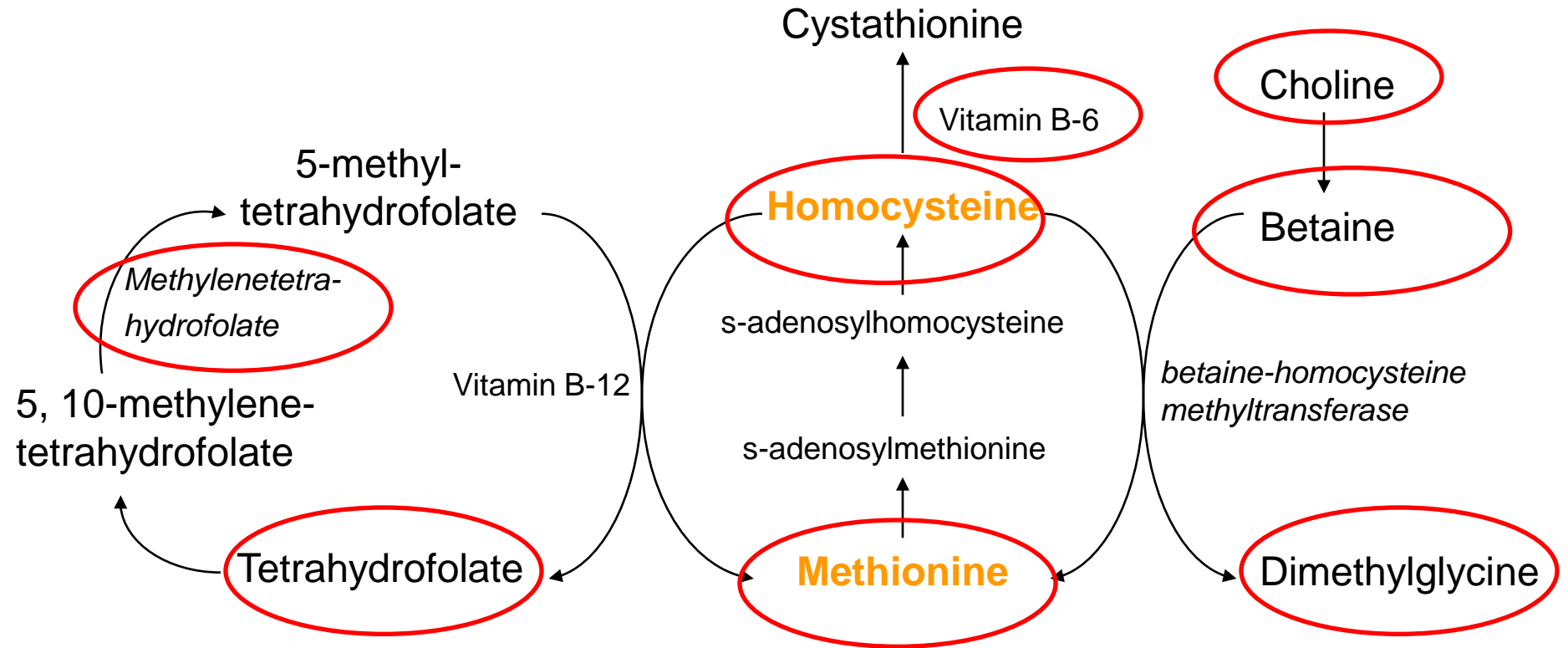
# Change in plasma methionine



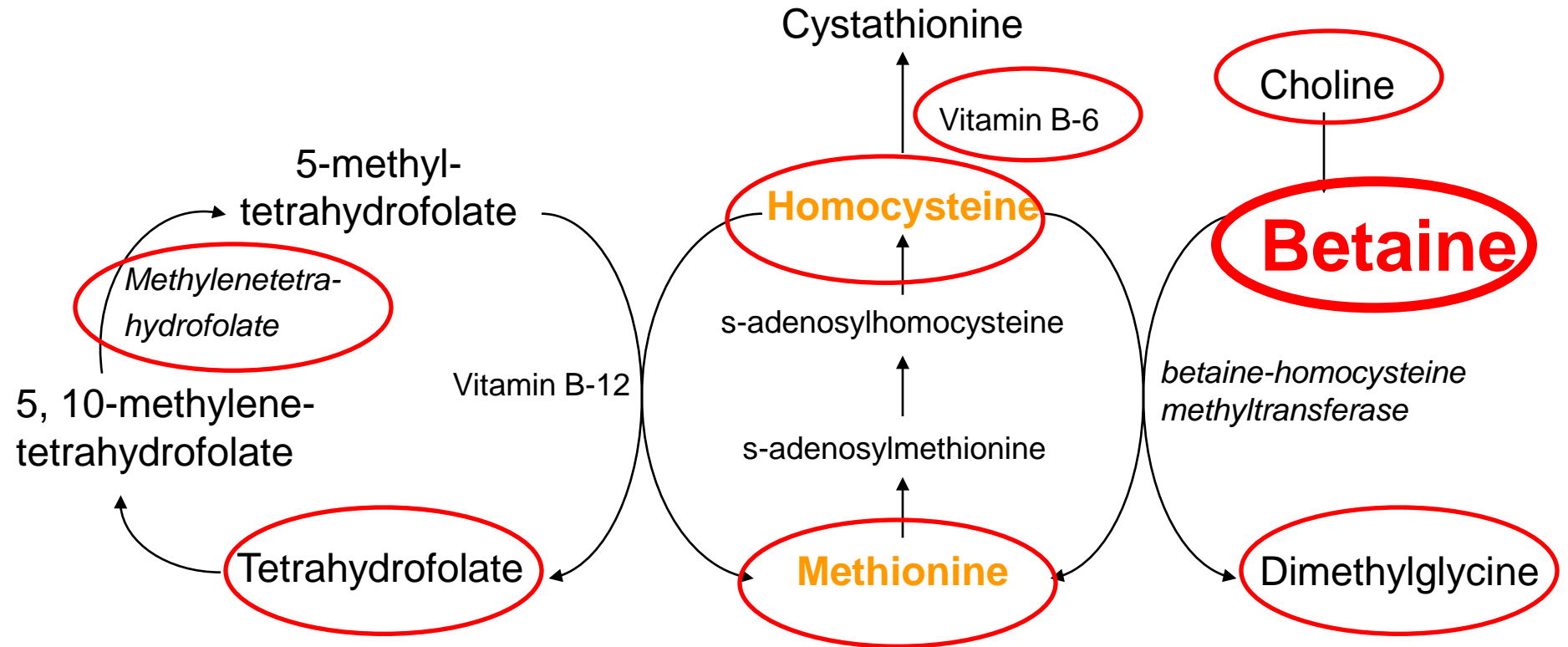
Groups significantly different post-intervention ( $P=0.027$ )\*



# Homocysteine cycle



# Homocysteine cycle



# Glycaemia and lipid related plasma measures

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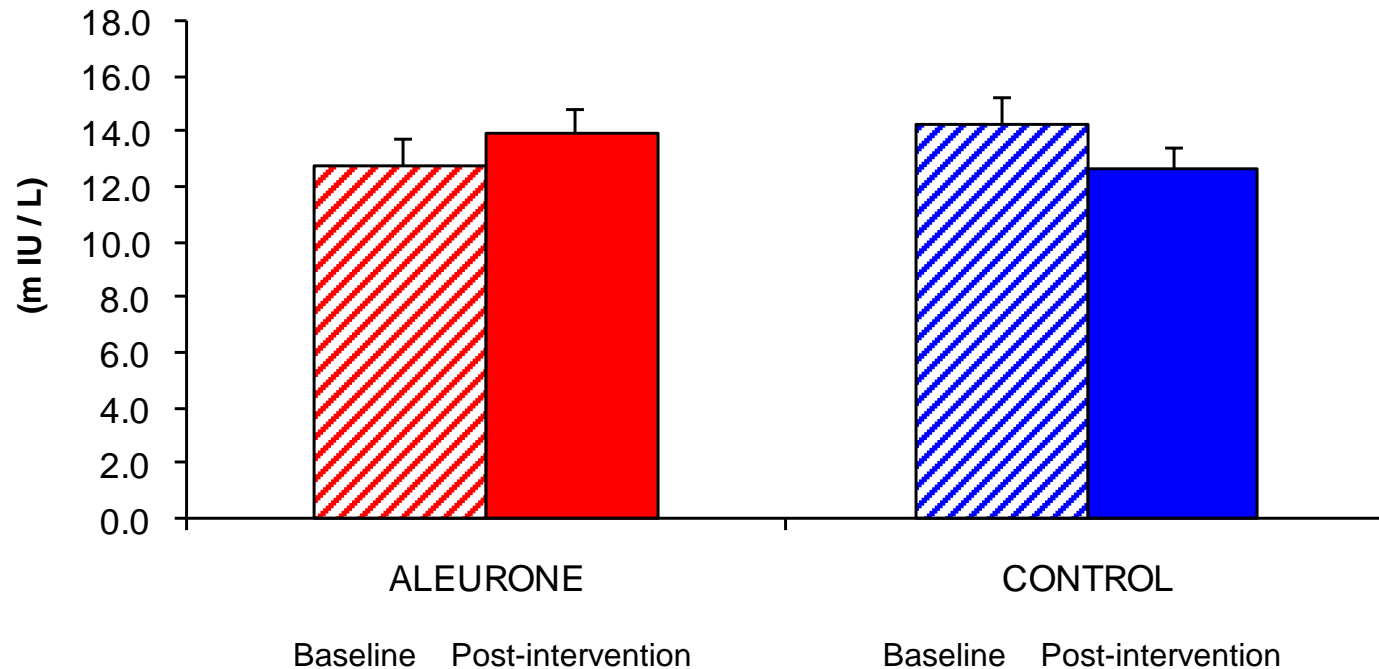
# Glycaemia and lipid related measures

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
<b>Insulin (mIU/L)</b>	<b>12.8</b> (± 0.9)	<b>13.9</b> (± 0.9)	<b>14.3</b> (± 1.0)	<b>12.7</b> (± 0.7)	<b>0.05</b>



Mean (± SE); Base, baseline; Post, post-intervention; <sup>a</sup> Comparison of post-intervention data between groups

# Change in plasma insulin



Groups significantly different post-intervention ( $P=0.049$ )\*



# Glycaemia and lipid related measures

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
<b>Insulin (mIU/L)</b>	<b>12.8</b> (± 0.9)	<b>13.9</b> (± 0.9)	<b>14.3</b> (± 1.0)	<b>12.7</b> (± 0.7)	<b>0.05</b>



Mean (± SE); Base, baseline; Post, post-intervention; <sup>a</sup> Comparison of post-intervention data between groups

# Glycaemia and lipid related measures

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
<b>Insulin (mIU/L)</b>	<b>12.8</b> (± 0.9)	<b>13.9</b> (± 0.9)	<b>14.3</b> (± 1.0)	<b>12.7</b> (± 0.7)	<b>0.05</b>
<b>Glucose (mmol/L)</b>	<b>5.16</b> (± 0.1)	<b>5.08</b> (± 0.1)	<b>5.05</b> (± 0.1)	<b>5.04</b> (± 0.1)	<b>0.59</b>
<b>Total cholesterol (mmol/L)</b>	<b>5.09</b> (± 0.2)	<b>5.04</b> (± 0.2)	<b>5.45</b> (± 0.2)	<b>5.38</b> (± 0.1)	<b>0.57</b>
<b>HDL-cholesterol (mmol/L)</b>	<b>1.45</b> (± 0.0)	<b>1.46</b> (± 0.1)	<b>1.49</b> (± 0.0)	<b>1.46</b> (± 0.0)	<b>0.43</b>



Mean (± SE); Base, baseline; Post, post-intervention; <sup>a</sup> Comparison of post-intervention data between groups

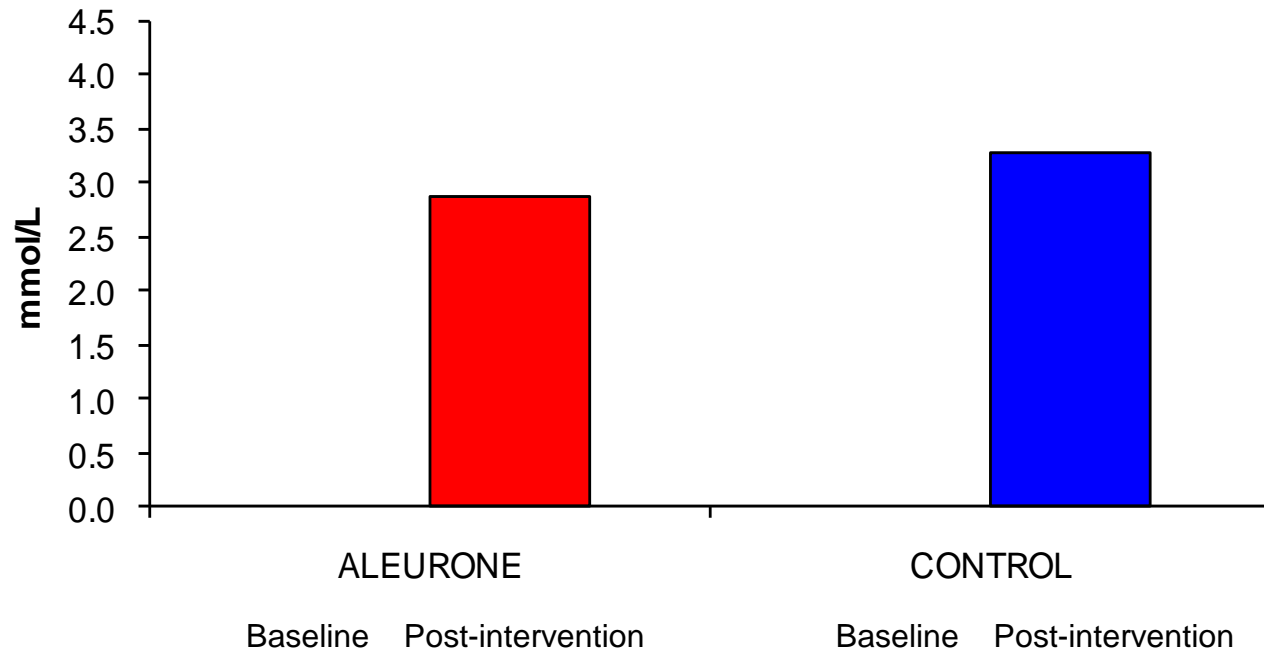
# Glycaemia and lipid related measures

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
<b>Insulin (mIU/L)</b>	<b>12.8</b> (± 0.9)	<b>13.9</b> (± 0.9)	<b>14.3</b> (± 1.0)	<b>12.7</b> (± 0.7)	<b>0.05</b>
<b>Glucose (mmol/L)</b>	<b>5.16</b> (± 0.1)	<b>5.08</b> (± 0.1)	<b>5.05</b> (± 0.1)	<b>5.04</b> (± 0.1)	<b>0.59</b>
<b>Total cholesterol (mmol/L)</b>	<b>5.09</b> (± 0.2)	<b>5.04</b> (± 0.2)	<b>5.45</b> (± 0.2)	<b>5.38</b> (± 0.1)	<b>0.57</b>
<b>HDL-cholesterol (mmol/L)</b>	<b>1.45</b> (± 0.0)	<b>1.46</b> (± 0.1)	<b>1.49</b> (± 0.0)	<b>1.46</b> (± 0.0)	<b>0.43</b>
<b>LDL-cholesterol (mmol/L)</b>	<b>2.94</b> (± 0.1)	<b>2.87</b> (± 0.1)	<b>3.25</b> (± 0.1)	<b>3.28</b> (± 0.1)	<b>0.04</b>



Mean (± SE); Base, baseline; Post, post-intervention; <sup>a</sup> Comparison of post-intervention data between groups

# Change in serum LDL-cholesterol



Groups significantly different post-intervention (**P=0.037**)\*

Mean ( $\pm$  SE); Base, baseline; Post, post-intervention; \* Comparison of post-intervention data between groups



# Glycaemia and lipid related measures (1)

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
<b>Insulin (mIU/L)</b>	<b>12.8</b> (± 0.9)	<b>13.9</b> (± 0.9)	<b>14.3</b> (± 1.0)	<b>12.7</b> (± 0.7)	<b>0.05</b>
<b>Glucose (mmol/L)</b>	<b>5.16</b> (± 0.1)	<b>5.08</b> (± 0.1)	<b>5.05</b> (± 0.1)	<b>5.04</b> (± 0.1)	<b>0.59</b>
<b>Total cholesterol (mmol/L)</b>	<b>5.09</b> (± 0.2)	<b>5.04</b> (± 0.2)	<b>5.45</b> (± 0.2)	<b>5.38</b> (± 0.1)	<b>0.57</b>
<b>HDL-cholesterol (mmol/L)</b>	<b>1.45</b> (± 0.0)	<b>1.46</b> (± 0.1)	<b>1.49</b> (± 0.0)	<b>1.46</b> (± 0.0)	<b>0.43</b>
<b>LDL-cholesterol (mmol/L)</b>	<b>2.94</b> (± 0.1)	<b>2.87</b> (± 0.1)	<b>3.25</b> (± 0.1)	<b>3.28</b> (± 0.1)	<b>0.04</b>



Mean (± SE); Base, baseline; Post, post-intervention; <sup>a</sup> Comparison of post-intervention data between groups

# Glycaemia and lipid related measures (1)

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
<b>Insulin (mIU/L)</b>	<b>12.8</b> (± 0.9)	<b>13.9</b> (± 0.9)	<b>14.3</b> (± 1.0)	<b>12.7</b> (± 0.7)	<b>0.05</b>
<b>Glucose (mmol/L)</b>	<b>5.16</b> (± 0.1)	<b>5.08</b> (± 0.1)	<b>5.05</b> (± 0.1)	<b>5.04</b> (± 0.1)	<b>0.59</b>
<b>Total cholesterol (mmol/L)</b>	<b>5.09</b> (± 0.2)	<b>5.04</b> (± 0.2)	<b>5.45</b> (± 0.2)	<b>5.38</b> (± 0.1)	<b>0.57</b>
<b>HDL-cholesterol (mmol/L)</b>	<b>1.45</b> (± 0.0)	<b>1.46</b> (± 0.1)	<b>1.49</b> (± 0.0)	<b>1.46</b> (± 0.0)	<b>0.43</b>
<b>LDL-cholesterol (mmol/L)</b>	<b>2.94</b> (± 0.1)	<b>2.87</b> (± 0.1)	<b>3.25</b> (± 0.1)	<b>3.28</b> (± 0.1)	<b>0.04</b>
<b>Triglycerides (mmol/L)</b>	<b>1.53</b> (± 0.2)	<b>1.57</b> (± 0.3)	<b>1.58</b> (± 0.1)	<b>1.42</b> (± 0.1)	<b>0.58</b>



Mean (± SE); Base, baseline; Post, post-intervention; <sup>a</sup> Comparison of post-intervention data between groups

# Glycaemia and lipid related measures (2)

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
<b>Total short-chain fatty acids (µmol/L)</b>	<b>96.3</b> (± 2.6)	<b>101.6</b> (± 3.3)	<b>95.2</b> (± 3.1)	<b>100.9</b> (± 3.6)	<b>1.00</b>



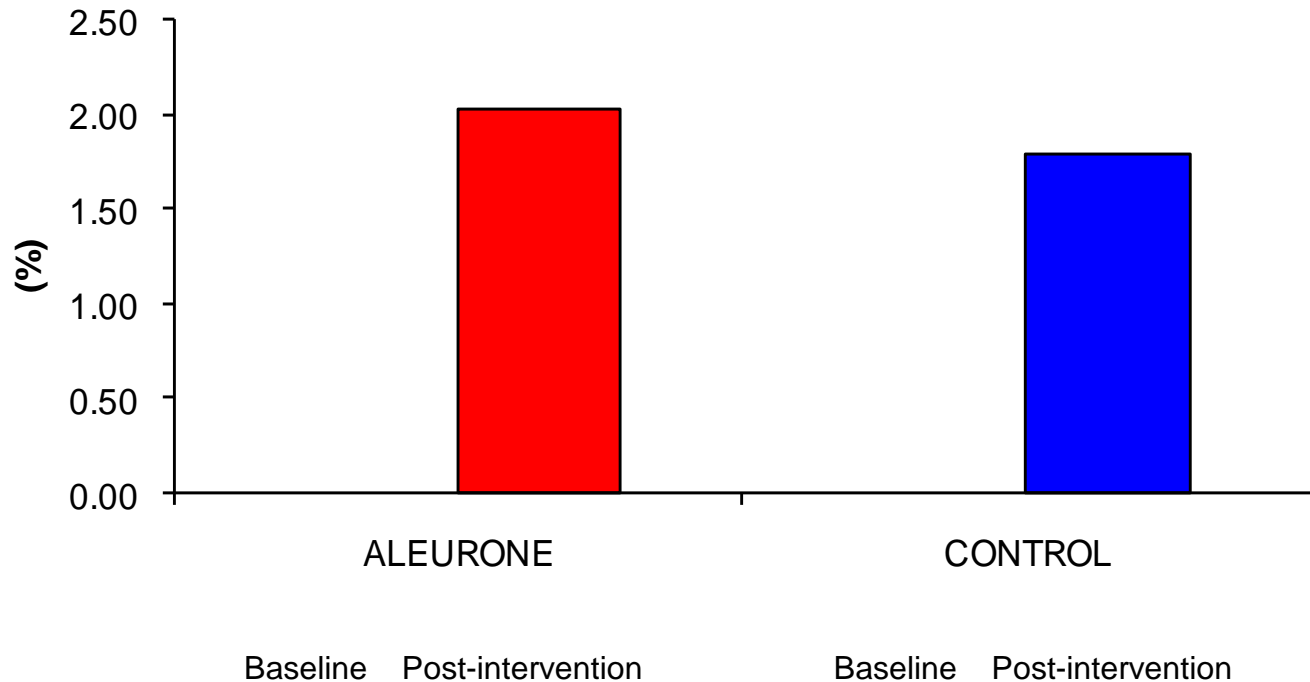
Mean (± SE); Base, baseline; Post, post-intervention; <sup>a</sup> Comparison of post-intervention data between groups

# Glycaemia and lipid related measures (2)

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
<b>Total short-chain fatty acids (μmol/L)</b>	<b>96.3</b> (± 2.6)	<b>101.6</b> (± 3.3)	<b>95.2</b> (± 3.1)	<b>100.9</b> (± 3.6)	<b>1.00</b>
<b>Butyric (%)</b>	<b>1.73</b> (± 0.1)	<b>2.04</b> (± 0.1)	<b>1.98</b> (± 0.1)	<b>1.80</b> (± 0.1)	<b>&lt;0.01</b>



# Change in plasma butyric acid



Groups significantly different post-intervention ( $P=0.037$ )\*



# Glycaemia and lipid related measures (2)

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
<b>Total short-chain fatty acids (μmol/L)</b>	<b>96.3</b> (± 2.6)	<b>101.6</b> (± 3.3)	<b>95.2</b> (± 3.1)	<b>100.9</b> (± 3.6)	<b>1.00</b>
<b>Butyric (%)</b>	<b>1.73</b> (± 0.1)	<b>2.04</b> (± 0.1)	<b>1.98</b> (± 0.1)	<b>1.80</b> (± 0.1)	<b>&lt;0.01</b>



# Glycaemia and lipid related measures (2)

	Aleurone		Control		P-value <sup>a</sup>
	Base	Post	Base	Post	
<b>Total short-chain fatty acids (µmol/L)</b>	<b>96.3</b> (± 2.6)	<b>101.6</b> (± 3.3)	<b>95.2</b> (± 3.1)	<b>100.9</b> (± 3.6)	<b>1.00</b>
<b>Butyric (%)</b>	<b>1.73</b> (± 0.1)	<b>2.04</b> (± 0.1)	<b>1.98</b> (± 0.1)	<b>1.80</b> (± 0.1)	<b>&lt;0.01</b>
<b>Acetic (%)</b>	<b>88.4</b> (± 0.6)	<b>88.6</b> (± 0.4)	<b>87.8</b> (± 0.4)	<b>89.1</b> (± 0.4)	<b>0.10</b>
<b>Propionic (%)</b>	<b>5.54</b> (± 0.4)	<b>5.05</b> (± 0.2)	<b>5.56</b> (± 0.3)	<b>4.83</b> (± 0.2)	<b>0.28</b>
<b>Isobutyric (%)</b>	<b>3.19</b> (± 0.1)	<b>3.12</b> (± 0.2)	<b>3.47</b> (± 0.2)	<b>3.23</b> (± 0.2)	<b>0.71</b>
<b>Caproic (%)</b>	<b>1.17</b> (± 0.1)	<b>1.14</b> (± 0.1)	<b>1.22</b> (± 0.1)	<b>1.06</b> (± 0.0)	<b>0.42</b>



Mean (± SE); Base, baseline; Post, post-intervention; <sup>a</sup> Comparison of post-intervention data between groups



# Conclusion

Results show that the aleurone fraction:

- Contains available betaine and ferulic acid
- If consumed regularly can:
  - ✗ ↓ homocysteine (an independent risk factor for stroke and CHD)
  - ✗ ↓ plasma CRP (a marker of inflammation)
  - ✗ ↓ in plasma LDL-cholesterol (a metabolic risk factor)
  - ✗ ↑ in plasma butyric (short-chain fatty acid with links to health)





# Conclusion

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- **These findings:**
  - ✘ Highlight the potential of aleurone as a food ingredient which may be beneficial for health.
  - ✘ Offers potential mechanisms whereby wholegrains may be beneficial to health.



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    - ✗ Walter von Reding
  - ✗ Barilla G.e R. Fratelli, Italy
    - ✗ Michaela Petronio
    - ✗ Giancarlo Riboldi
  - ✗ Syral, Belgium
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    - ✗ Prof Per Ueland
- **Analysis of food samples**
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    - ✗ Prof Peter Shewry
    - ✗ Dr Jane Ward
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