Dietary Fat Modification in Beef:

Implications for Nutrition and Health

Tasks 4-6

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Dietary Fat and Health

Imbalance

+

High intakes

cardiovascular risk

Obesity

Type 2 diabetes

Cancer

In the WHO/European Region

over 50%
of people are
overweight or **obese**

over 20%
of people are
obese

17.5 million people

die per year from

CARDIOVASCULAR DISEASE including

HEART ATTACKS

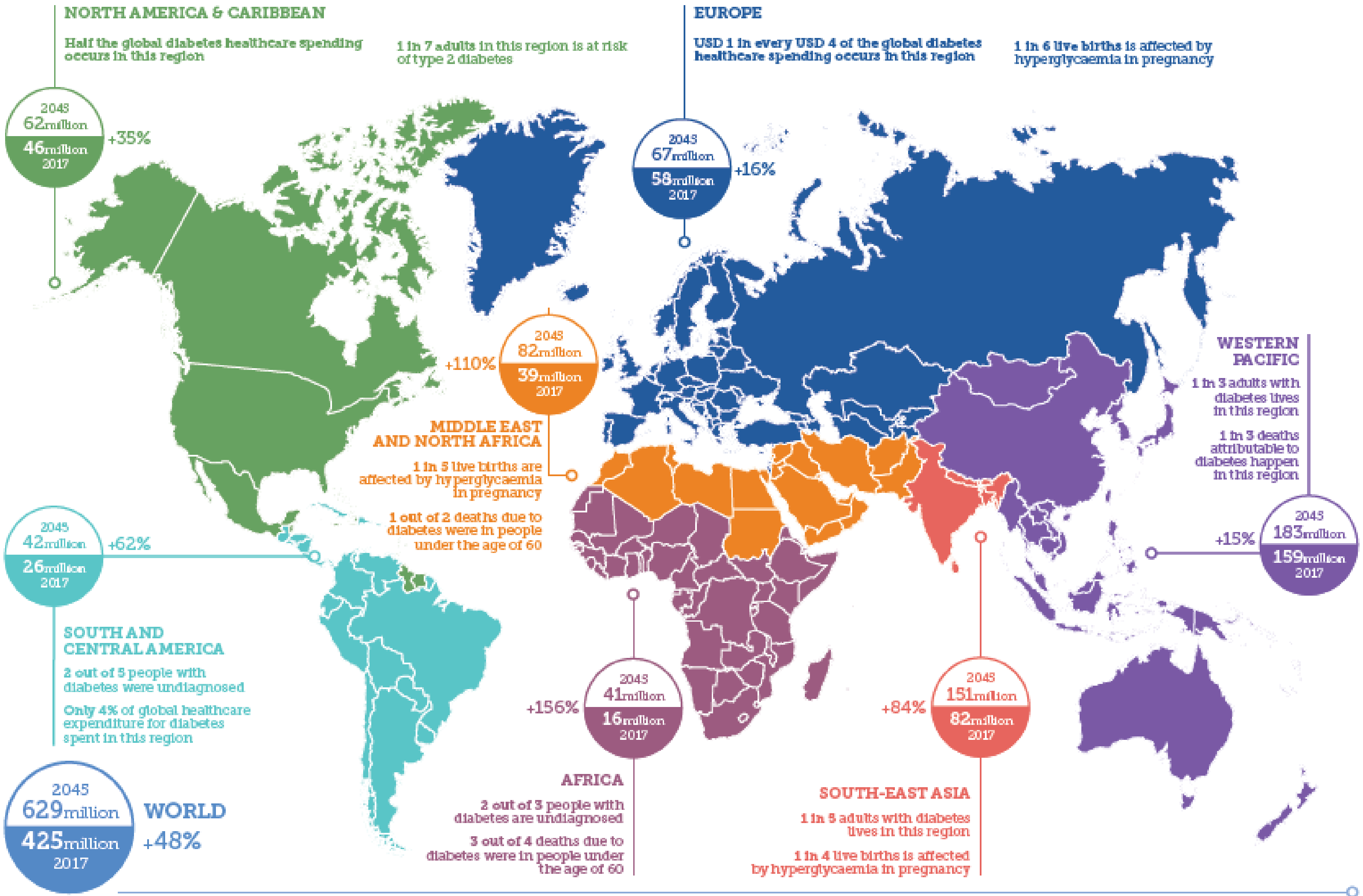
and **STROKES**

the world's biggest killer

World Health Organization

www.who.int/global_hearts

Global prevalence of Diabetes



Almost half of the 4 million people who die from diabetes are under the age of 60

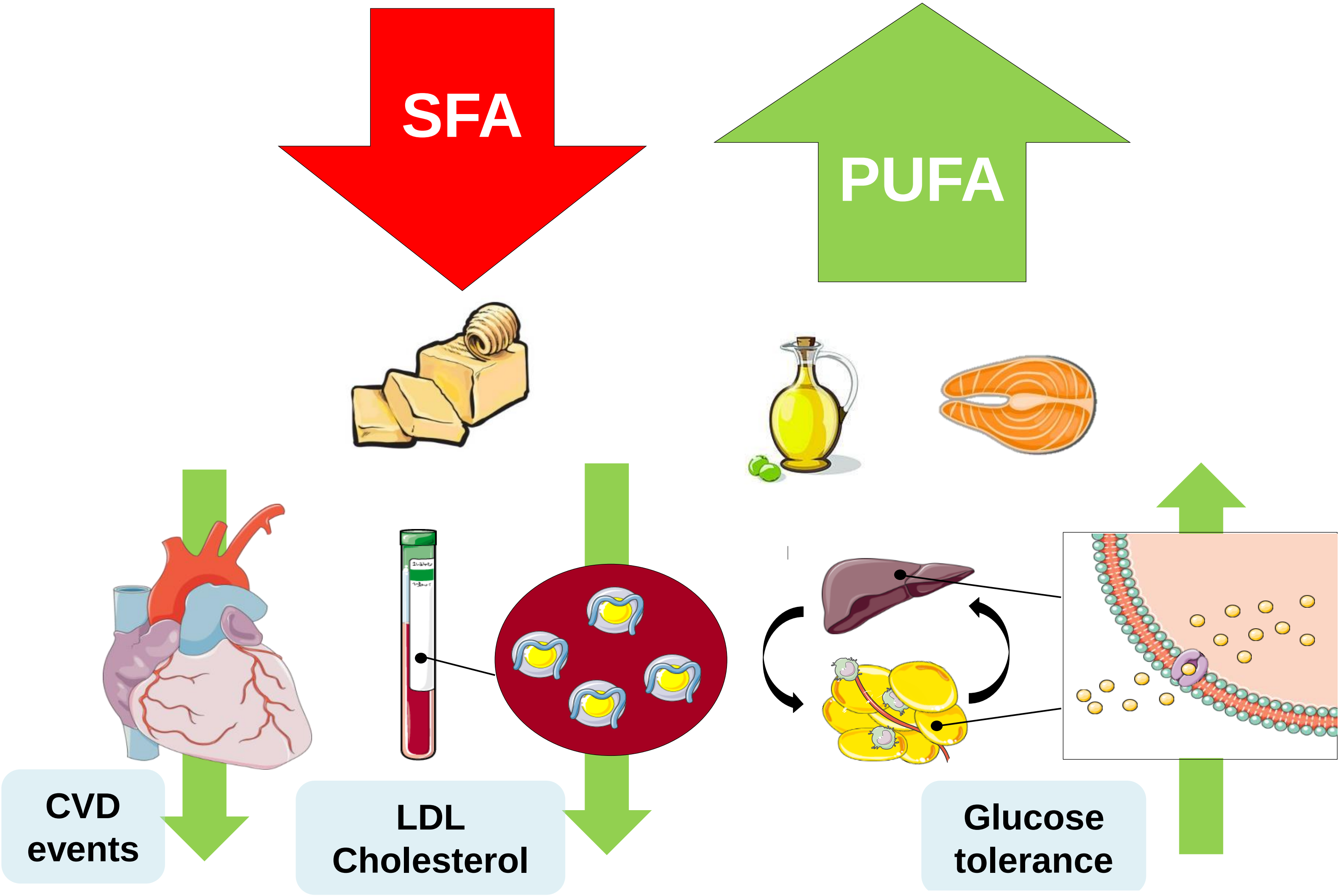
4 out of 5 people with diabetes live in low- and middle-income countries

Among high income countries, 79% of global healthcare expenditure on diabetes was spent, but only 36% of deaths below 60 years occured

International Diabetes Federation

Public health strategies required!

WHO/SACN Draft Report: Saturated Fats & Health



Reformulation is a potential strategy to achieve this

Task 4
Dietary assessment / enhancement strategies for PUFA, CLA & micronutrients in the Irish diet

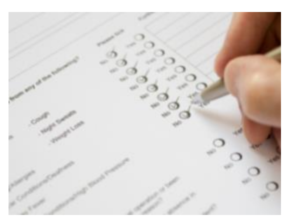
Task 4.1
Investigate patterns of beef intakes and the relationship with cardio-metabolic health

Task 4.2
The impact of altering the composition of the target fatty acids in grass fed beef for Irish adults

National Adult Nutrition Survey (NANS)

National Adult Nutrition Survey

N=1500



Beef Intakes in the NANS

Beef Consumption	Non Consumer (n=306)		Low Consumer (n=248)		Medium Consumer (n=249)		High Consumer (n=248)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	P value*
Beef consumption (g/d) Ψ	0.0[a]	0.0	20.0[b]	7.6	44.4[c]	7.9	90.9[d]	33.7	**<0.001**
Gender (% M/F) §	41/59		39/61		53/47		68/32		**<0.001**
Mean age (years) Ψ	46.9[a]	17.8	43.9[ab]	17.1	43.9[ab]	17.0	41.8[b]	16.7	**0.006**
Social class (%) §									
Professional	53.4		49.8		44.5		42.0		0.126
Non-manual	16.8		15.4		19.5		20.8		
Skilled manual	11.3		15.4		15.7		14.3		
Unskilled	18.5		19.5		20.3		22.9		
Currently smoking (%) §	17.8		19.4		22.1		20.2		0.450
Supplements (%) §	35.1		27.5		32.4		31.5		0.219
Physical activity (hrs/wk) Ψ	88.8	71.5	92.3	80.0	102.7	161.1	104.6	81.4	0.252

Ψ One-way ANOVA (Bonferroni), § Pearson chi-squared, * significant difference $P<0.05$, (a,b,c,d) inter-group differences

Nutrient Intakes Across Beef Consumers

	Non Consumer (n=306)		Low Consumer (n=248)		Medium Consumer (n=249)		High consumer (n=248)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	P value
Macronutrients (%TE)									
Carbohydrate	44.7[a]	6.5	43.1[b]	6.3	42.3[b]	7.0	40.4[c]	6.9	**<0.001**
Sugars	18.0[a]	5.9	17.3[ab]	5.6	16.9[ab]	6.1	15.8[b]	5.3	**0.005**
Protein	16.3[a]	3.4	15.7[a]	3.3	16.3[a]	3.0	17.5[b]	3.7	**<0.001**
Total fat	33.6[a]	6.0	34.4[ab]	6.1	34.6[ab]	6.3	34.5[b]	6.6	**0.027**
Saturated fat	12.9[a]	3.5	13.5[ab]	3.3	13.8[b]	3.5	13.7[b]	3.4	**0.001**
Monounsaturated fat	12.1[a]	2.7	12.5[ab]	2.6	12.6[ab]	2.7	12.7[b]	2.7	**0.017**
Polyunsaturated fat	6.3	2.3	6.1	1.9	6.0	2.3	5.8	2.6	0.432
Alpha linolenic acid	0.6	0.7	0.6	0.3	0.6	0.4	0.6	0.2	0.720
Eicosapentanoic acid	0.3	2.3	0.5	4.4	0.2	1.6	0.2	1.6	0.444
Docosahexanoic acid	0.3	2.3	0.5	4.3	0.2	1.6	0.2	1.5	0.409
g/10MJ									
Dietary fibre	24.9[a]	8.5	22.7[b]	7.5	21.9[b]	7.4	20.5[b]	6.5	**<0.001**

General Linear Model, Age & Gender adjusted (bonferoni),* significant difference P <0.05, (a,b,c,d) inter-group differences

Nutrient Intakes Across Beef Consumers

	Non Consumer (n= 306)		Low Consumer (n=248)		Medium Consumer (n=249)		High Consumer (n=248)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	P Value*
Vitamins (mg/10MJ)									
Vitamin B6	5.6	13.1	4.4	7.4	4.0	5.0	4.7	7.7	0.238
Vitamin C	163.8	261.1	144.9	380.3	136.0	283.2	145.5	204.4	0.717
Vitamin E	20.0	48.8	16.5	32.1	14.4	30.7	14.8	19.8	0.492
Vitamins (µg/10MJ)									
Vitamin A	1428.4	1003.7	1248.5	816.1	1401.3	1247.1	1308.1	1294.1	0.224
Folate	452.0	276.4	431.2	411.3	437.8	399.1	415.3	181.8	0.916
Vitamin B12	10.9	71.5	6.2	9.1	7.9	25.8	7.9	8.9	0.562
Vitamin D	6.6[a]	10.5	4.9[ab]	5.4	4.8[b]	5.6	5.6[ab]	6.6	0.043
Minerals (mg/10MJ)									
Iron	16.2	16.2	16.5	19.5	18.0	22.4	19.5	27.6	0.056
Calcium	1225.1[a]	490.8	1127.2[ab]	454.1	1071.7[b]	365.0	1056.2[b]	402.7	**0.003**
Zinc	11.5[a]	9.8	11.2[a]	9.1	11.9[a]	3.9	14.5[b]	7.3	**<0.001**
Copper	1.6	2.5	1.4	2.0	1.4	1.1	1.3	1.1	0.369
Pottasium	3741.9[a]	1664.8	3534.5[b]	845.2	3552.3[ab]	703.9	3547.8[b]	672.7	0.065
Magnesium	364.3[a]	111.0	343.3[ab]	120.2	334.5[b]	79.2	332.1[ab]	78.8	**0.014**
Phosphorus	1679.2[a]	336.3	1585.6[b]	312.0	1598.4[ab]	298.0	1616.7[ab]	284.5	**0.009**
Sodium	2926.0	662.3	2971.6	645.0	2917.2	635.2	2866.9	611.6	0.294

General Linear Model, Age & Gender adjusted (bonferoni),* significant difference P <0.05, (a,b,c,d) inter-group differences

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Dietary Patterns

Pattern 1 (n 131)

- Wholemeal Bread
- Fish
- Vegetables
- Fruit
- Yoghurts

Pattern 2 (n 70)

- Chips
- Processed Potatoes
- Rice & Pasta
- Fruit juices & Smoothies
- Cheeses

Pattern 3 (n 405)

- Alcoholic Beverages
- RTEB Cereals
- Savouries
- Confectionery

Pattern 4 (n 180)

- White bread
- Processed red meat
- Butters
- Whole milk
- Potatoes

RTEB – Ready to Eat Breakfast

Metabolic Health

	Pattern 1		Pattern 2		Pattern 3		Pattern 4		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	P-value*
Glucose (mmol/l)	5.19	0.88	5.09	0.73	5.20	0.81	4.58	1.31	1.000
Insulin (µIU/ml)	9.52	10.97	10.30	9.48	12.10	13.73	15.82	25.79	1.000
Triglyceride (mmol/l)	1.11	0.59	1.09	0.65	1.32	0.83	1.41	0.82	1.000
Total Cholesterol (mmol/l)	5.01	0.92	4.72	0.90	4.94	1.06	4.97	0.99	1.000
HDL - Cholesterol (mmol/l)	1.70	0.48	1.66	0.39	1.55	0.40	1.54	0.41	1.000
LDL - Cholesterol (mmol/l)	2.78	0.78	2.57	0.77	2.80	0.88	2.80	0.93	1.000
Adiponectin (ug/ml)	7.08	4.51	6.59	3.01	5.89	2.93	5.81	2.68	1.000
Leptin (ng/ml)	5.29	6.03	6.14	5.85	5.29	6.85	5.10	6.85	1.000
Homocysteine (mmol/l)	11.5	3.92	11.9	2.88	12.00	3.35	13.49	5.01	0.672
TNFα (pg/ml)	6.66	3.05	6.17	1.62	6.72	1.96	7.52	2.88	1.000

a,b,c Mean values with unlike superscript letters are significantly different between groups (P < 0·05).
** Differences in fatty acids and markers of metabolic health across dietary patterns were assessed using a one-way ANOVA.† Differences in fatty acids and markers of metabolic health across dietary patterns were assessed using general linear model adjusted for age, sex, energy (kJ (kcal)), social class, smoking status, supplement usage and fasting status. Bonferroni correction was applied by multiplying the P values by the number of traits in the table. P values that exceeded 1·0 have been marked down to 1·000.*

(a,b,c,d) inter-group differences

Task 4.1 - In Summary

Individuals with the highest beef intakes presented lower carbohydrate intakes and higher intakes of protein and fat, with greater zinc intakes

No association was observed between high consumption of processed red meat and biomarkers of cardio-metabolic health

*Lenighan et al BJN 2017

Task 4.2: The impact of altering the composition of target fatty acids in grass-fed beef for Irish adults and their relationship with health

Grass-fed
(GRASS)

Grass/concentrate-fed (GRN)

Concentrate-fed
(CONC)

Teagasc
Agriculture and Food Development Authority

NANS beef codes updated for fatty acid composition (*n*=42 FA)

Impact on dietary intakes

efsa
European Food Safety Authority

Adherence to dietary recommendations

Impact on Dietary Intakes

High (n=157g/d)							
	GRASS		GRN		CONC		
	Mean	SD	Mean	SD	Mean	SD	P*
%TE							
Total Fat	35.0	6.8	35.1	6.7	35.7	6.8	1.000
SFA	13.7	3.5	14.0	3.5	14.1	3.5	1.000
MUFA	13.3	2.9	13.3	2.9	13.8	3.0	0.236
PUFA	5.9	2.3	5.6	2.1	5.6	2.1	1.000
ALA	0.6	0.3	0.6	0.3	0.5	0.3	1.000
EPA	0.2	1.5	0.2	1.5	0.2	1.5	1.000
DHA	0.2	1.5	0.2	1.5	0.2	1.5	1.000
Trans-fat	0.3[a]	0.2	0.2[b]	0.1	0.2[c]	0.1	<0.001

[a,b,c] Indicates significant differences between dietary interventions (P<0.05) * One-way ANOVA for comparison of means between beef interventions. Bonferroni correction was applied by multiplying the P value by the number of traits in the table. P values that exceeded 1.0 have been marked down to 1.000.

Impact on Dietary Intakes

	High (n=157g/d)						
	GRASS		GRN		CONC		
	Mean	SD	Mean	SD	Mean	SD	P*
%TE							
C14:0	0.19[a]	0.15	0.23[b]	0.14	0.24[b]	0.14	<0.001
C15:0	0.03	0.02	0.03	0.02	0.03	0.02	1.000
C16:0 (PA)	1.37[a]	0.90	1.62[b]	0.94	1.73[b]	0.97	<0.001
C18:0	0.40	0.37	0.38	0.37	0.38	0.36	1.000
C16:1	0.19	0.20	0.20	0.22	0.23	0.24	0.642
C18:1 (OA)	1.73	1.47	1.41	1.15	1.61	1.36	0.116
C18:1t11 (TVA)	0.11[a]	0.11	0.07[b]	0.07	0.04[c]	0.03	<0.001
C18:2 (LA)	1.10[a]	1.13	1.27[a]	1.05	1.51[b]	1.26	<0.001
C18:2c9t11 (CLA)	0.06[a]	0.04	0.04[b]	0.03	0.03[c]	0.02	<0.001
C18:3 (ALA)	0.60	0.33	0.56	0.30	0.55	0.30	0.804
C20:4 (AA)	0.01[a]	0.01	0.01[a]	0.01	0.01[b]	0.01	<0.001
C20:5 (EPA)	0.17	1.53	0.17	1.53	0.17	1.53	1.000
C22:5 (DPA)	0.01[a]	0.01	0.00[b]	0.00	0.00[c]	0.00	<0.001
C22:6 (DHA)	0.18	1.50	0.18	1.50	0.18	1.50	1.000
LA:ALA	2.17[a]	2.68	2.64[a]	2.51	3.25[b]	3.15	<0.001
Total n-6:total n-3	1.85[a]	2.33	2.28[a]	2.20	2.83[b]	2.79	<0.001

GRASS, grass-fed; GRN, grass and concentrate fed; CONC, concentrate-fed; total n-6: LA+AA; total n-3: ALA+EPA+DPA+DHA. [a,b,c] Indicates significant differences between dietary interventions (P<0.05) * One-way ANOVA for comparison of means between beef interventions. Bonferroni correction was applied by multiplying the P value by the number of traits in the table. P values that exceeded 1.0 have been marked down to 1.000.

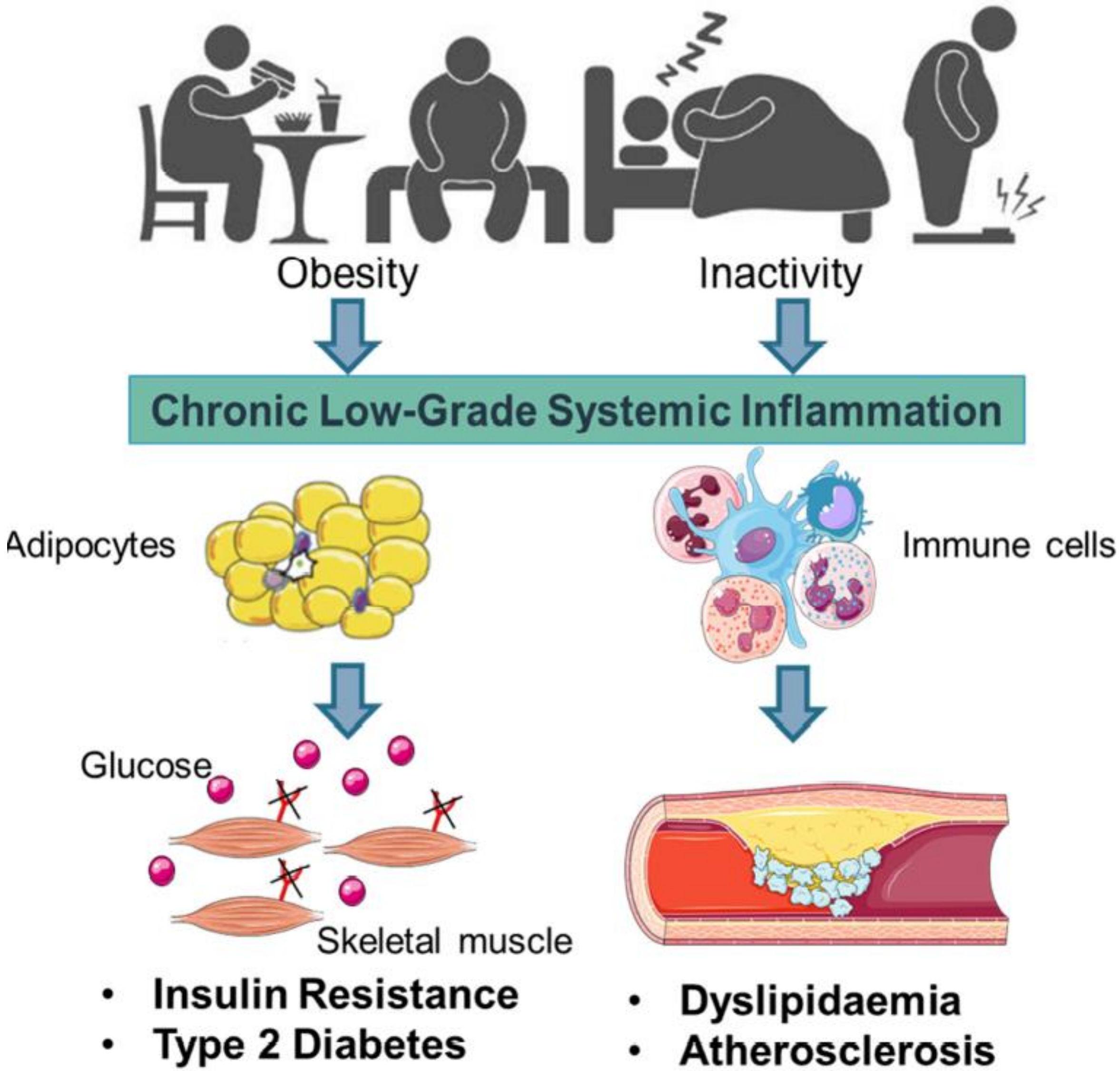
Task 4.2 - In Summary

Consumption of grass-fed beef has the potential to change the composition of dietary fatty acids and to improve population adherence to dietary recommendations

Suggests that habitual consumption of grass-fed beef is a potential public health strategy to improve dietary fat quality.

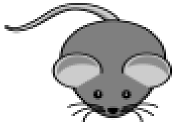
Task 5

Grass-based production to enhance the effects of beef on metabolic health on metabolic health and reduce cardiovascular risk factors

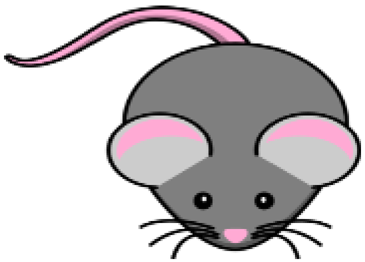

Obesity
Inactivity
Chronic Low-Grade Systemic Inflammation
Adipocytes
Immune cells
Glucose
Skeletal muscle
• Insulin Resistance
• Type 2 Diabetes
• Dyslipidaemia
• Atherosclerosis

Task 5.1:Grass fed CLA/n-3 PUFA enriched beef & high-fat diet induced obesity, insulin resistance and T2D risk

APOE.3L



CETP

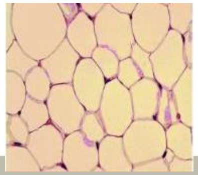


APOE3L.CETP

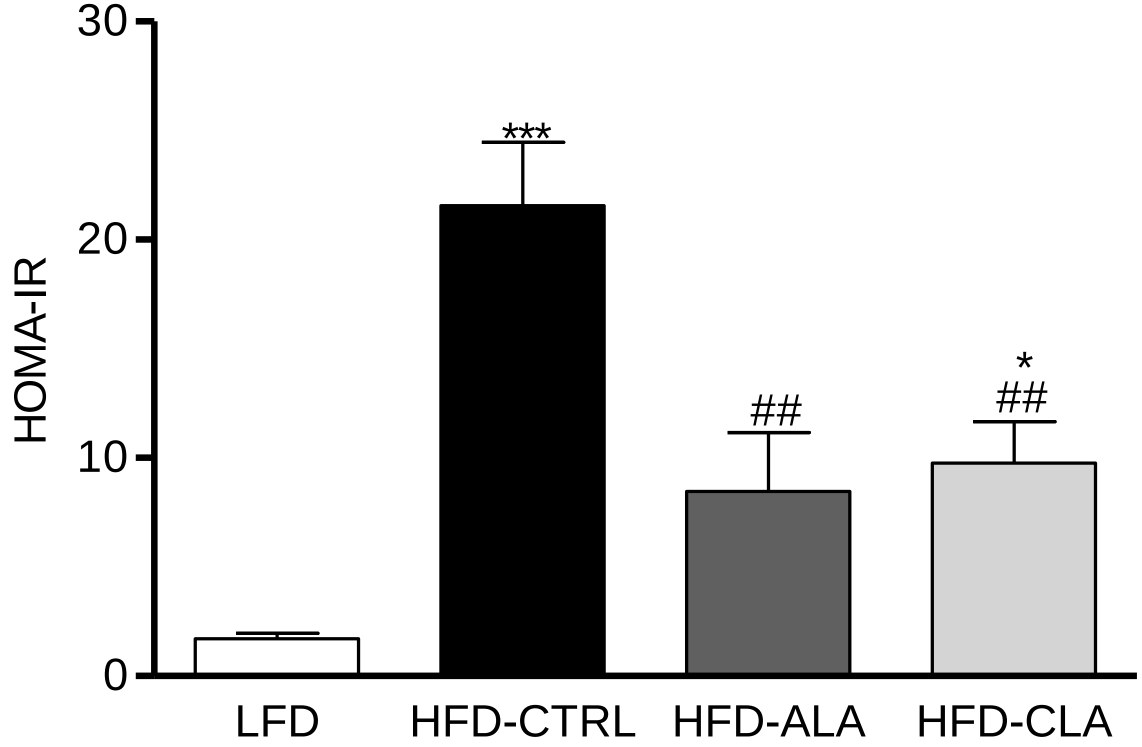
LFD	**HFD-CTRL**	**HFD-ALA**	**HFD-CLA**
(10%)	(42% SFA, 3% MUFA)	(42% SFA, 1.5%MUFA, 1.5% ALA)	(42% SFA, 1.5%MUFA, 1.5% CLA)

12 Week Feeding Study

Week 0	**Week 2**	**Week 4**	**Week 6**	**Week 8**	**Week 10**	**Week 11**	**Week 12**
					Glucose Tolerance Test	Insulin Tolerance Test	Adipose Tissue Inflammation



Fat modification improves insulin sensitivity

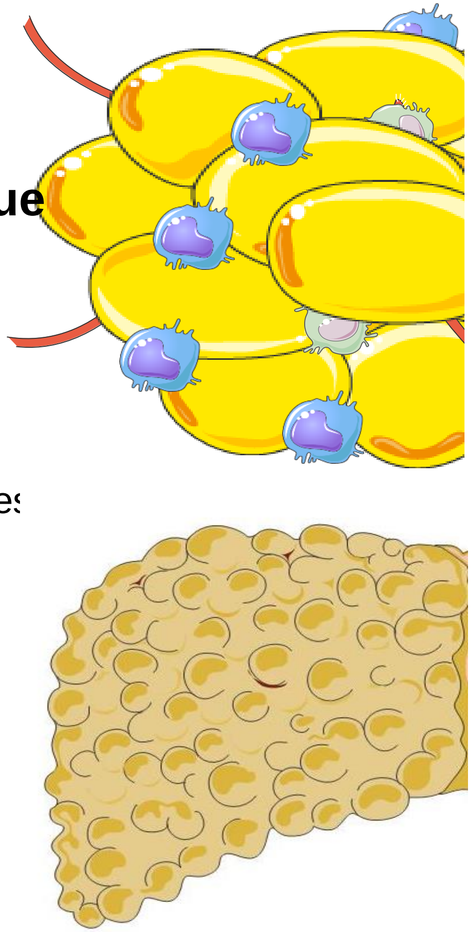


A one-way ANOVA with Bonferroni correction was applied to test for differences between dietary interventions. *p<0.05, ***P<0.001 w.r.t. LFD; ##p<0.01 w.r.t. HFD-CTRL

In Summary

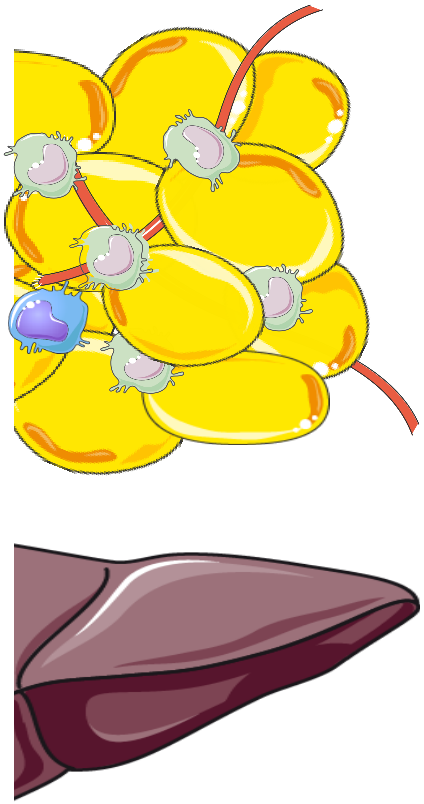
Adipose Tissue

Liver



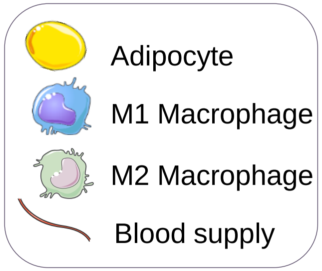
- ↑ Insulin resistance
- ↑ M1 macrophages
- ↑ Crown-like structures
- ↑ Proinflammatory cytokine secretion

SFA Diet



- ↑ Insulin sensitivity
- ↑ PPAR expression
- ↑ M2 macrophages
- ↓ Proinflammatory cytokine secretion

SFA diet with PUFA replacement



Lenighan *et al.* (In press)

Task 5.2: Grass fed CLA/n-3 PUFA enriched beef & atherosclerosis in a humanized mouse model

LFD
(10%)

HFD-CTRL
(42% SFA, 3% MUFA)

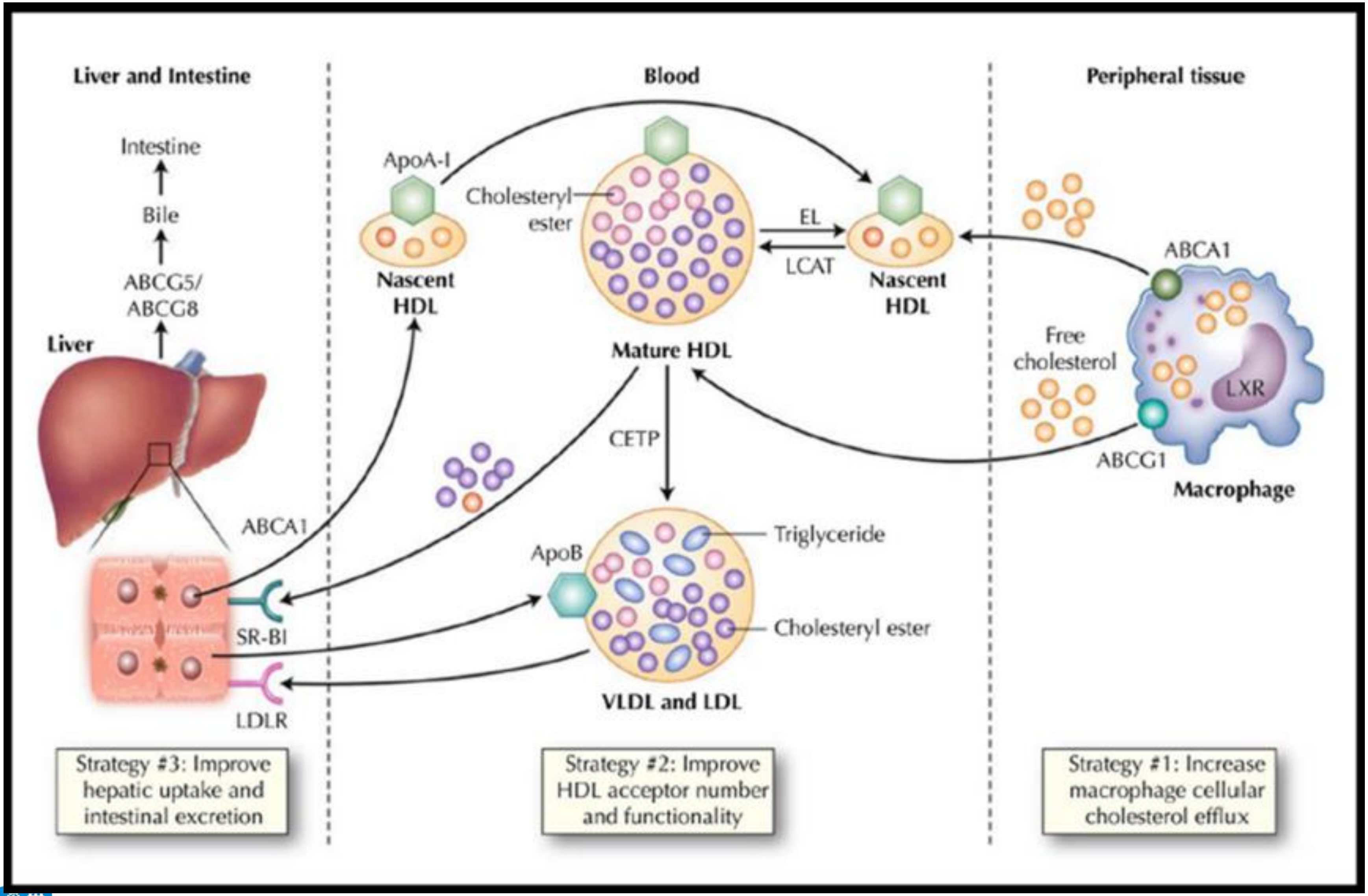
HFD-ALA
(42% SFA, 1.5%MUFA, 1.5% ALA)

HFD-CLA
(42% SFA, 1.5%MUFA, 1.5% CLA)

12 Week Feeding Study

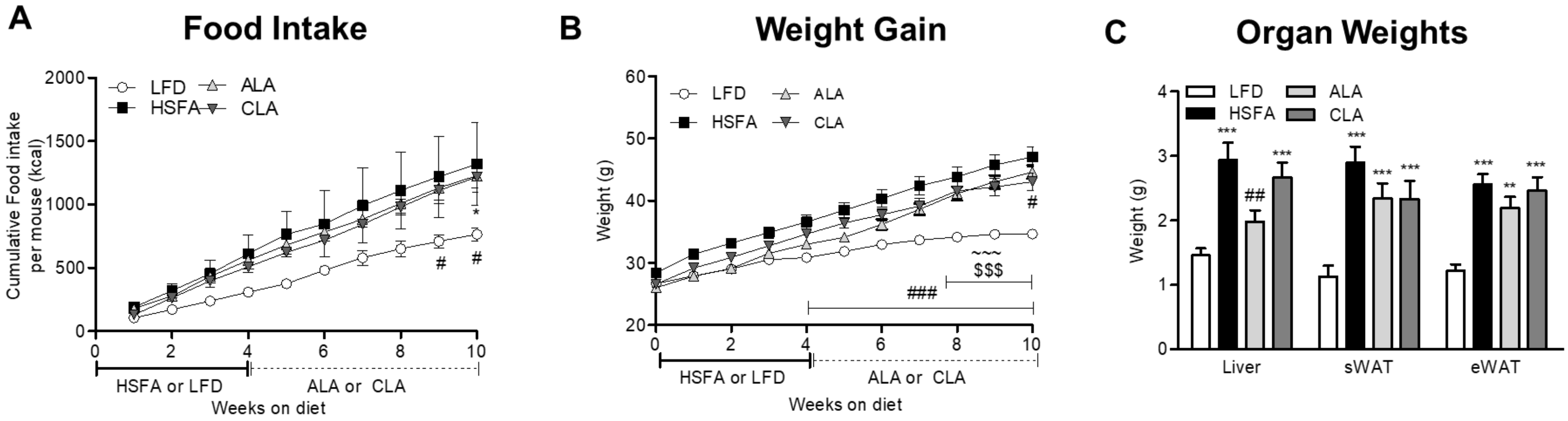
Week 0 | **Week 2** | **Week 4** | **Week 6** | **Week 8** | **Week 10** | **Week 11** | **Week 12**
Reverse Cholesterol Transport

Reverse Cholesterol Transport



Khera and Radar, Curr Atheroscler Rep. 2010 January ; 12(1): 73–81.

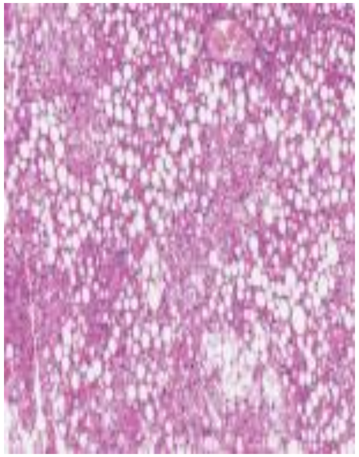
ApoE3L.CETP mice fed a HSFA diet supplemented with ALA have reduced liver weight compared to mice fed a HSFA diet



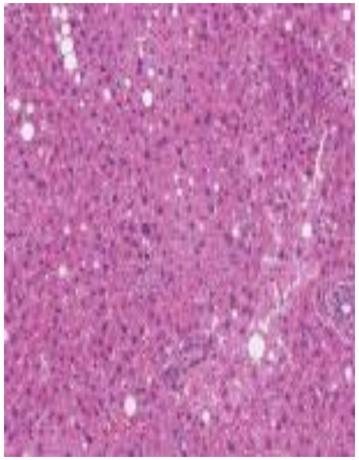
(A) Cumulative food intake per mouse (kcal) ($^{\#}p<0.05$ w.r.t. HSFA **(B)** Weight gain per mouse (g) ($^{\#}p<0.05$, $^{\#\#\#}p<0.001$ w.r.t. HSFA; ~~~p<0.001 w.r.t . ALA; $^{\$\$\$}p<0.001$ w.r.t CLA) **(C)** Organ weights (g) (***p<0.001 w.r.t. LFD; $^{\#\#\#}p<0.001$ w.r.t HSFA (n=8-12)

Impact on liver metabolism

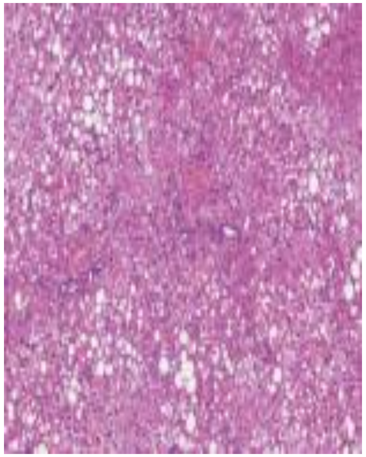
LFD



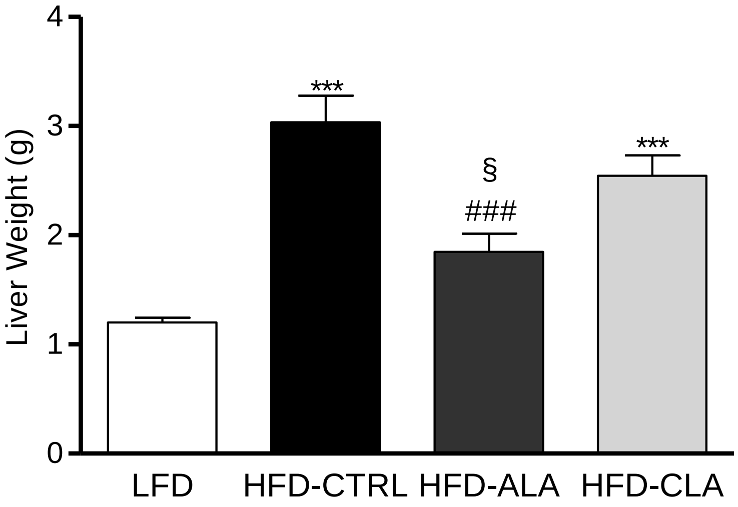
HFD-CTRL



HFD-ALA



HFD-CLA



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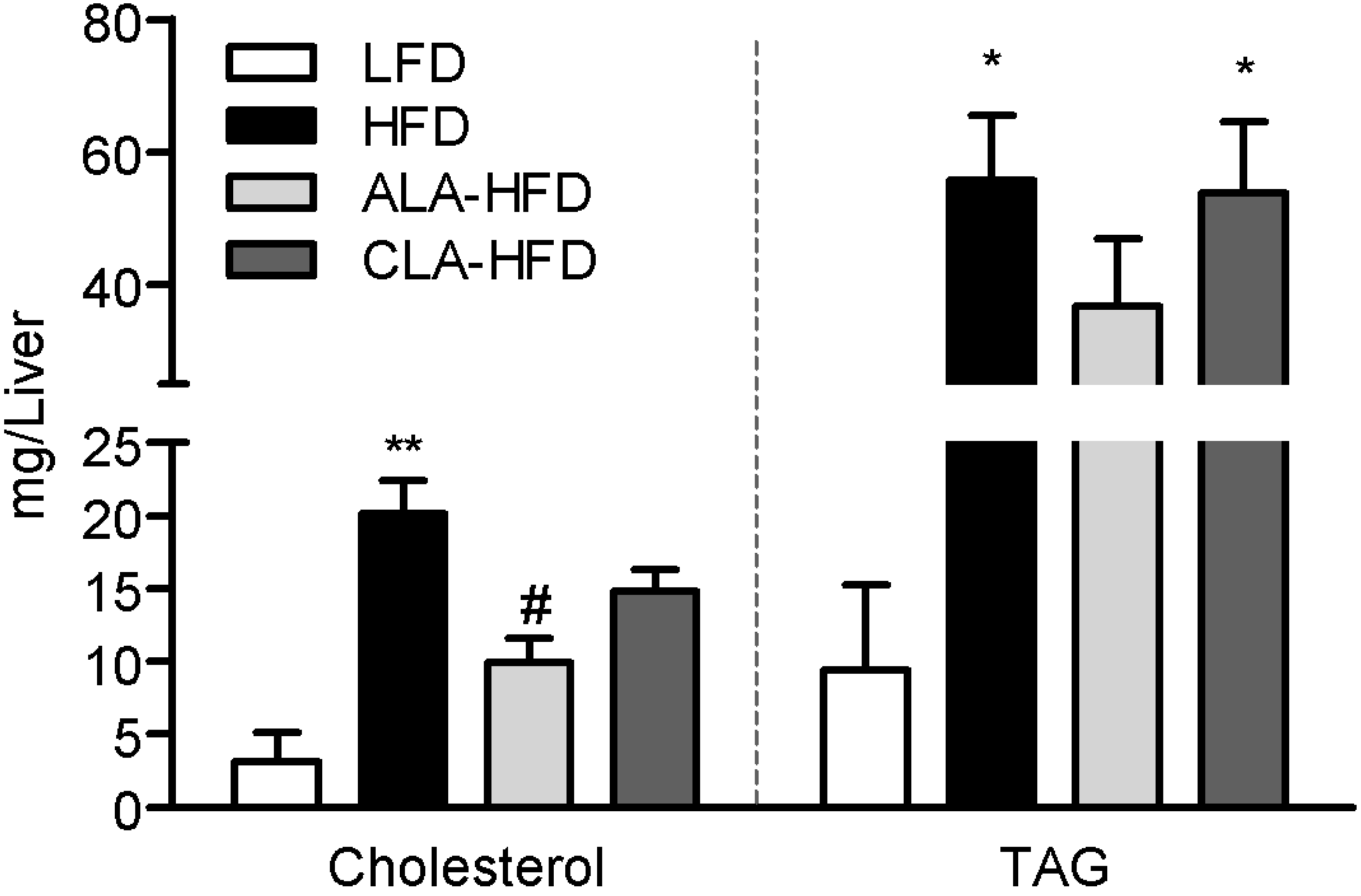
A one-way ANOVA with Bonferroni correction was applied to test for differences between dietary interventions.
*p<0.05, **p<0.01, ***p<0.001 w.r.t. LFD; #p<0.05, ##p<0.01, ###p<0.001 w.r.t. HFD-CTRL, $p<0.05 w.r.t. HFD-CLA

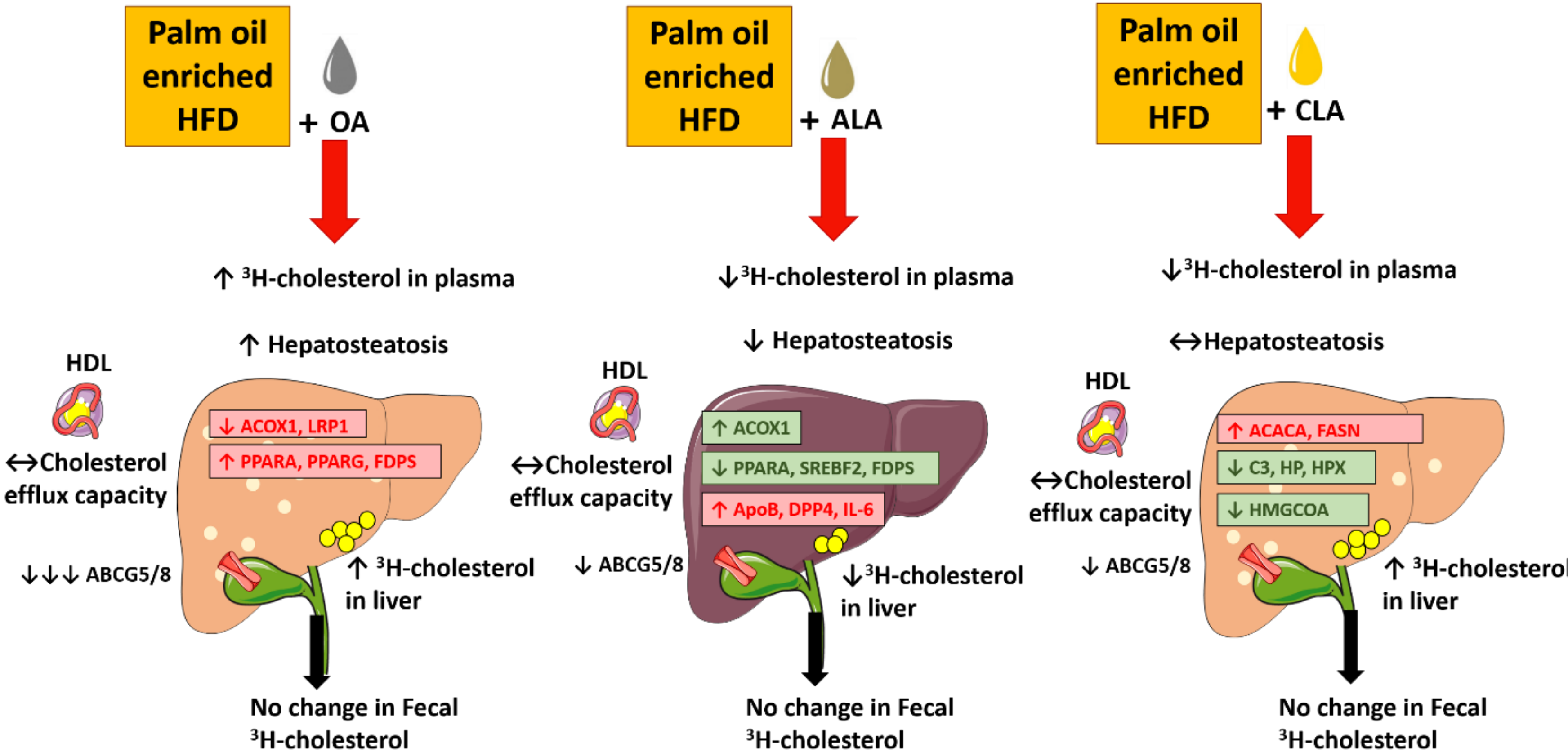
Partial replacement with ALA improves lipid metabolism



UCD DUBLIN
UCD Institute of Food & Health

*p<0.05, **p<0.01, ***p<0.001 w.r.t. LFD; ##p<0.01 w.r.t HFD (n=8-12)

In Summary

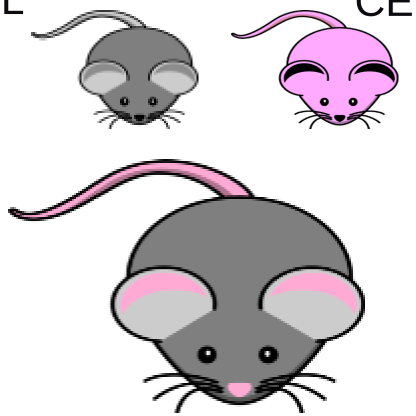


Palm oil enriched HFD
+ OA
↑ ³H-cholesterol in plasma
↑ Hepatosteatosis
HDL
↔Cholesterol efflux capacity
↓ ACOX1, LRP1
↑ PPARA, PPARG, FDPS
↓↓↓ ABCG5/8
↑ ³H-cholesterol in liver
No change in Fecal ³H-cholesterol
Palm oil enriched HFD
+ ALA
↓³H-cholesterol in plasma
↓ Hepatosteatosis
HDL
↔Cholesterol efflux capacity
↑ ACOX1
↓ PPARA, SREBF2, FDPS
↑ ApoB, DPP4, IL-6
↓ ABCG5/8
↓³H-cholesterol in liver
No change in Fecal ³H-cholesterol
Palm oil enriched HFD
+ CLA
↓³H-cholesterol in plasma
↔Hepatosteatosis
HDL
↔Cholesterol efflux capacity
↑ ACACA, FASN
↓ C3, HP, HPX
↓ HMGCOA
↓ ABCG5/8
↑ ³H-cholesterol in liver
No change in Fecal ³H-cholesterol

Task 5.3: Synergistic effects of ALA & CLA in meat with meat protein on cardio-metabolic health parameters

APOE.3L

CETP



APOE3L.CETP

30% fat

Grass

Grain

Casein

12 Week Feeding Study

Week 0 | **Week 2** | **Week 4** | **Week 6** | **Week 8** | **Week 10** | **Week 11** | **Week 12**

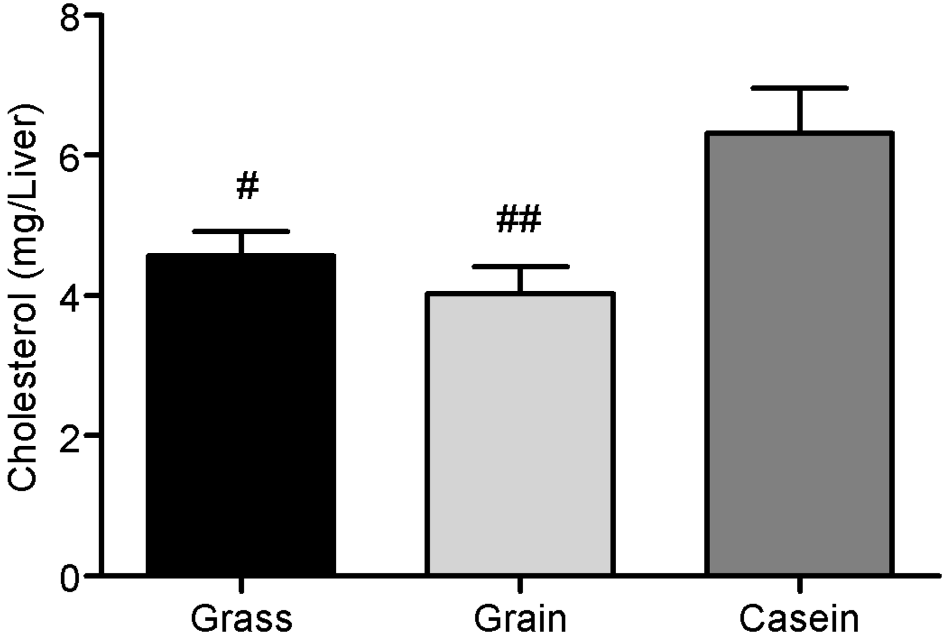
Week 10: Glucose Tolerance Test

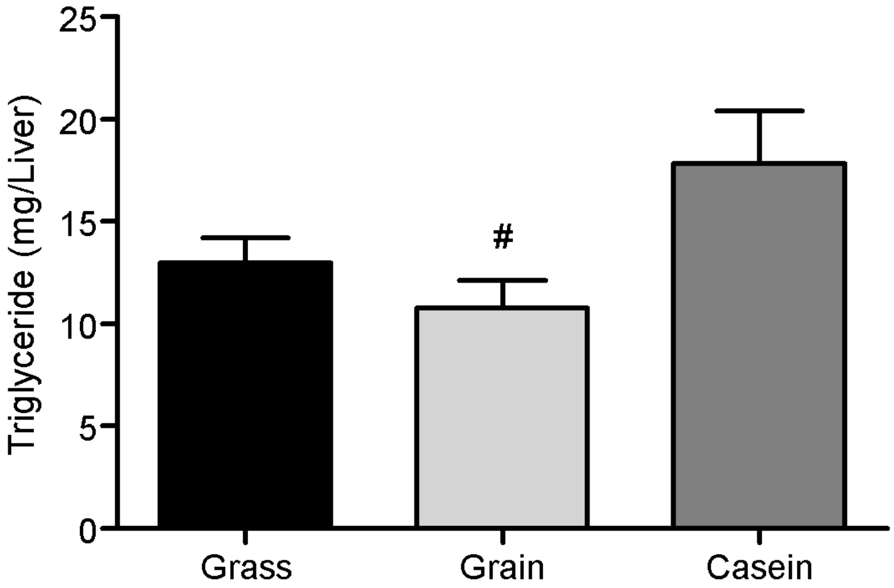
Week 11: Insulin Tolerance Test

Week 12: Reverse Cholesterol Transport

Adipose Tissue Inflammation

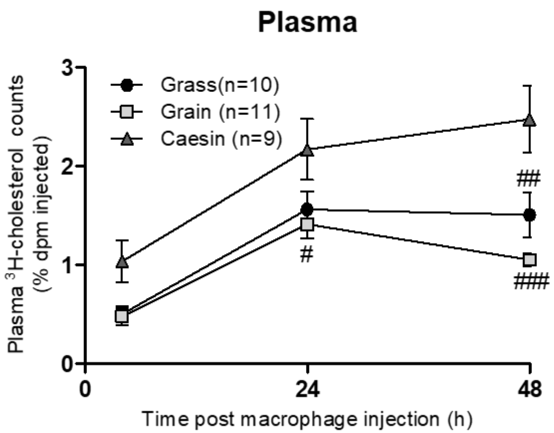
Grain-based feeding improved liver lipid metabolism

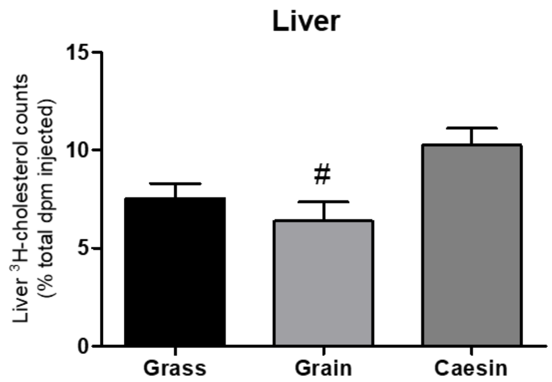


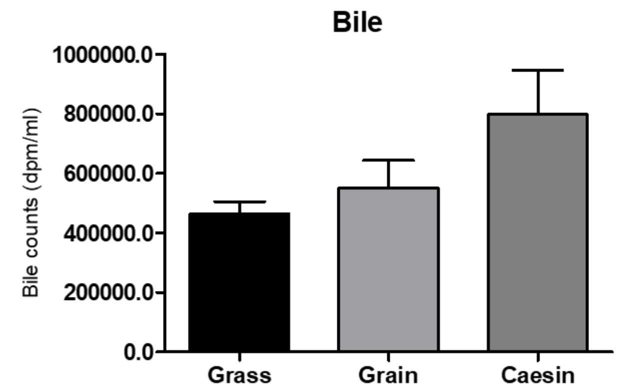


#p<0.05, ##p<0.01, ###p<0.001 w.r.t. Casein

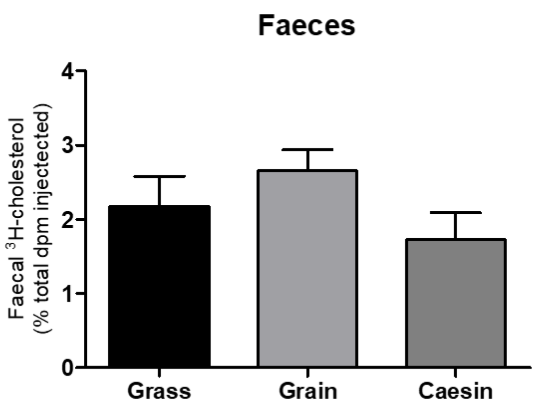
Grain / Grain-based feeding and Reverse Cholesterol Metabolism

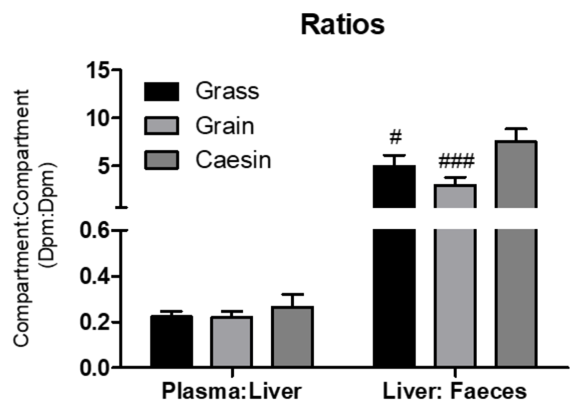






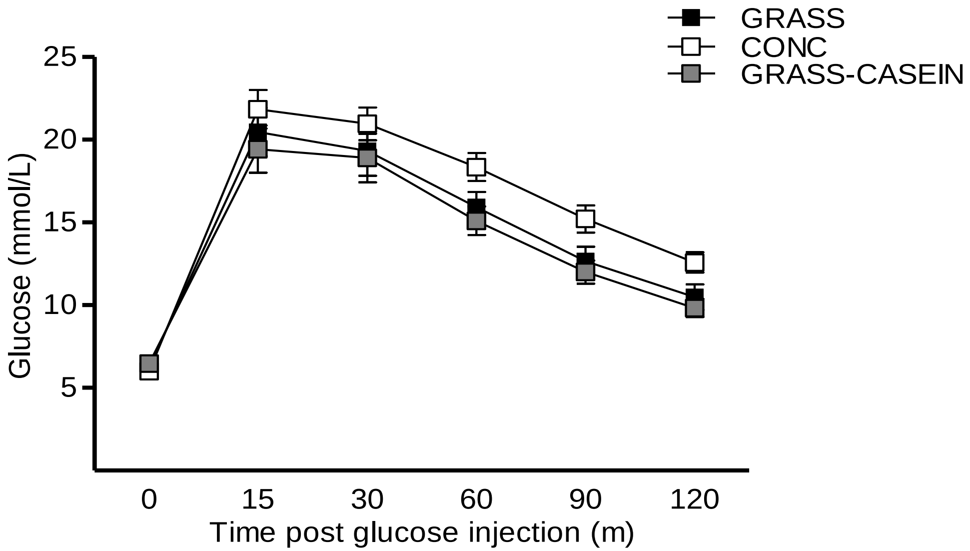
$^{\#}p<0.05$, $^{\#\#}p<0.01$, $^{\#\#\#}p<0.001$ w.r.t. Diet C

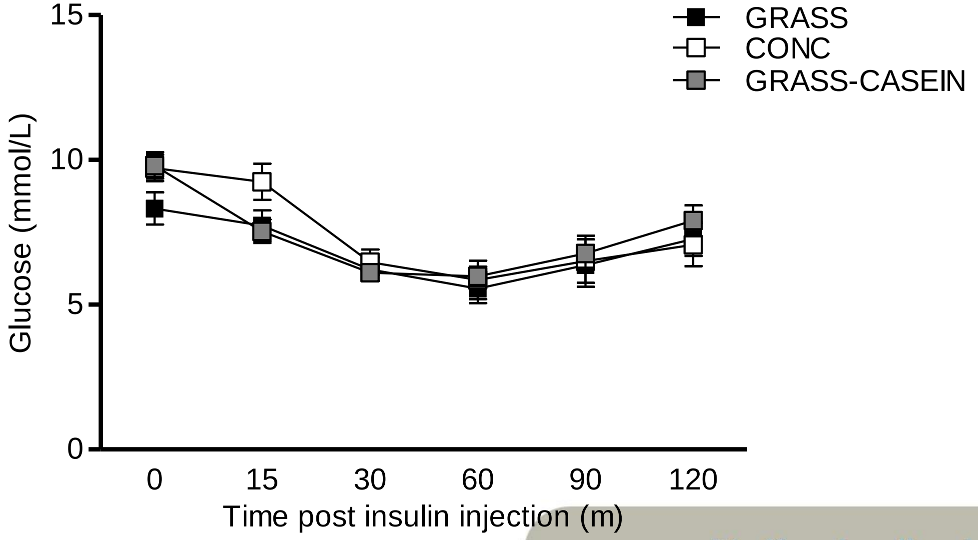




$^{\#}p<0.05$, $^{\#\#}p<0.01$, $^{\#\#\#}p<0.001$ w.r.t. Caesin

Glucose tolerance and insulin sensitivity





In Summary

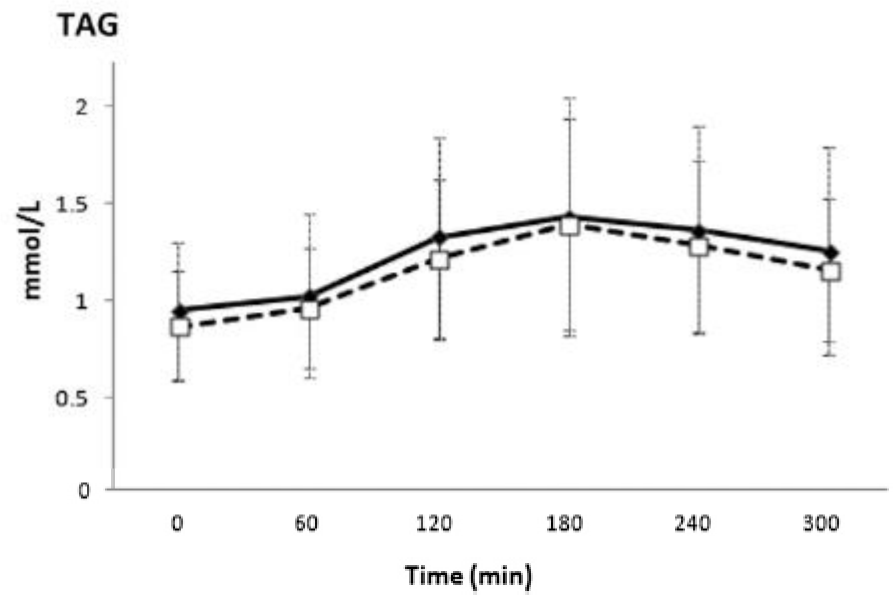
Grass-fed dietary fat modification within the beef matrix:
No impact on glucose tolerance & adipose inflammation – T2D.

No differential effect on RCT & atherosclerosis.

Task 6

Cardio-metabolic health effects of grass-based beef in man – insights from acute test meal challenges

Rationale and Methodology



Males (n=12)
(BMI>25kg/m^2)

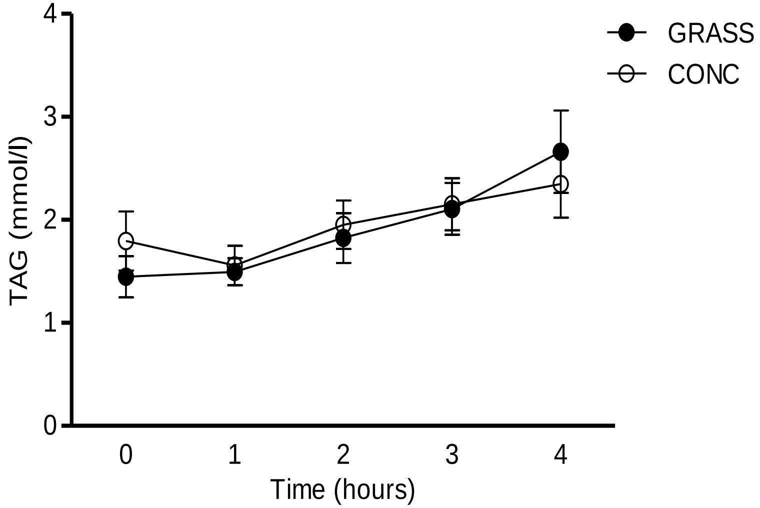
Grass-fed/
Concentrate-fed
40g/challenge

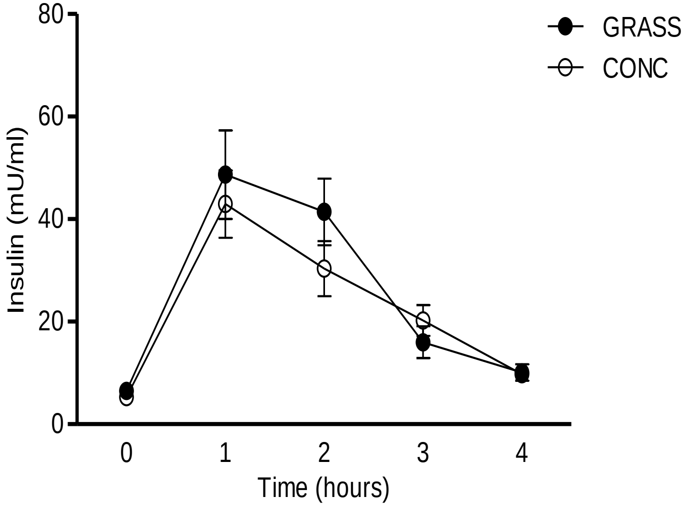
0-4 hours

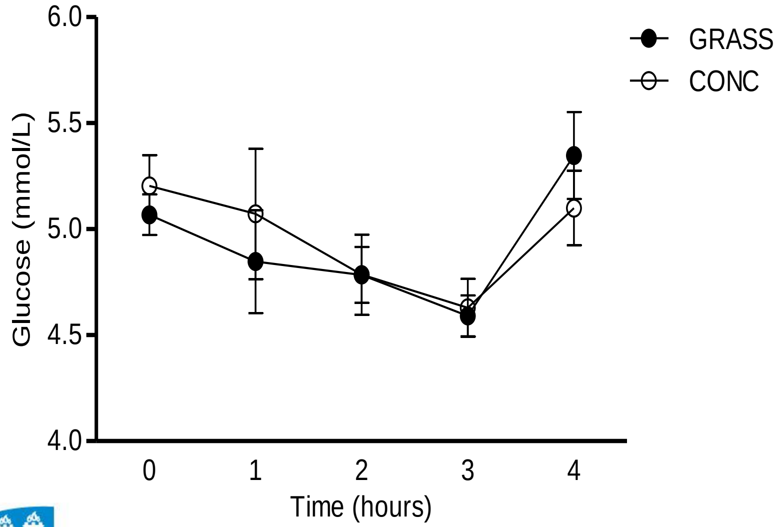
Plasma FA
TAG
Markers of Health

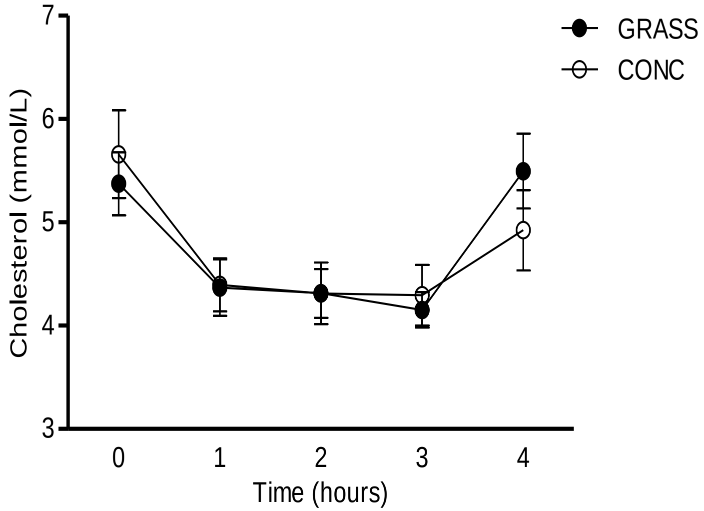
Ryan (2013) *Am J Clin Nutr* **97:**261-7

Markers of metabolic health









Plasma Fatty Acid Composition

	CONC (n=12)				GRASS (n=12)					
	T0		T4		T0		T4			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	P*	P†
% Total Fatty Acids										
SFA										
C14:0	6.59	2.38	6.1	2.08	6.03	2.38	6.27	3.96	0.599	0.901
C16:0	36.16	6.02	37.14	2.49	33.92	3.6	34.83	4.78	0.291	0.210
C18:0	23.3	8.46	25.25	6.07	20.75	12.65	21.68	9.11	0.563	0.353
MUFA										
C16:1	3.23	1.31	3.28	1.09	3.93	1.02	3.05	1.26	0.257	0.998
C18:1	17.08	6.26	14.73	3.24	18.32	5.54	15.95	4.29	0.617	0.307
PUFA										
C18:2	0.1	0.04	0.1	0.02	0.11	0.03	0.11	0.04	0.354	0.216
C18:3	0.03	0.02	0.03	0.02	0.03	0.02	0.04	0.03	0.346	0.446
C20:4	5.59	4.21	3.98	1.56	4.06	1.63	6.41	3.53	0.349	0.781

*Paired samples t-test was applied to test for differences between groups at baseline (TO)
†Paired samples t-test was applied to test for differences after 4 hours (T4).

Overall Conclusion

Grass-fed beef consumption has the potential to improve dietary fat intakes without affecting habitual dietary intakes.

Further research is required, using randomized controlled trials to determine the impact of habitual grass-fed beef consumption on metabolic health.

Future perspectives

- Medium/long term RCT required to define impact of habitual grass-fed beef consumption on metabolic health

- Can fatty acid composition be improved further using additional ruminant feeding practices?

- Define dose of PUFA required to provide optimal benefit?