Relating beef production at farm level to human health aspects, and the state of art of meat substitution products

HOCQUETTE Jean-François, GRUFFAT Dominique, DURAND Denys
INRA, VetAgro Sup, UMRH, F-63122 Saint-Genès Champanelle

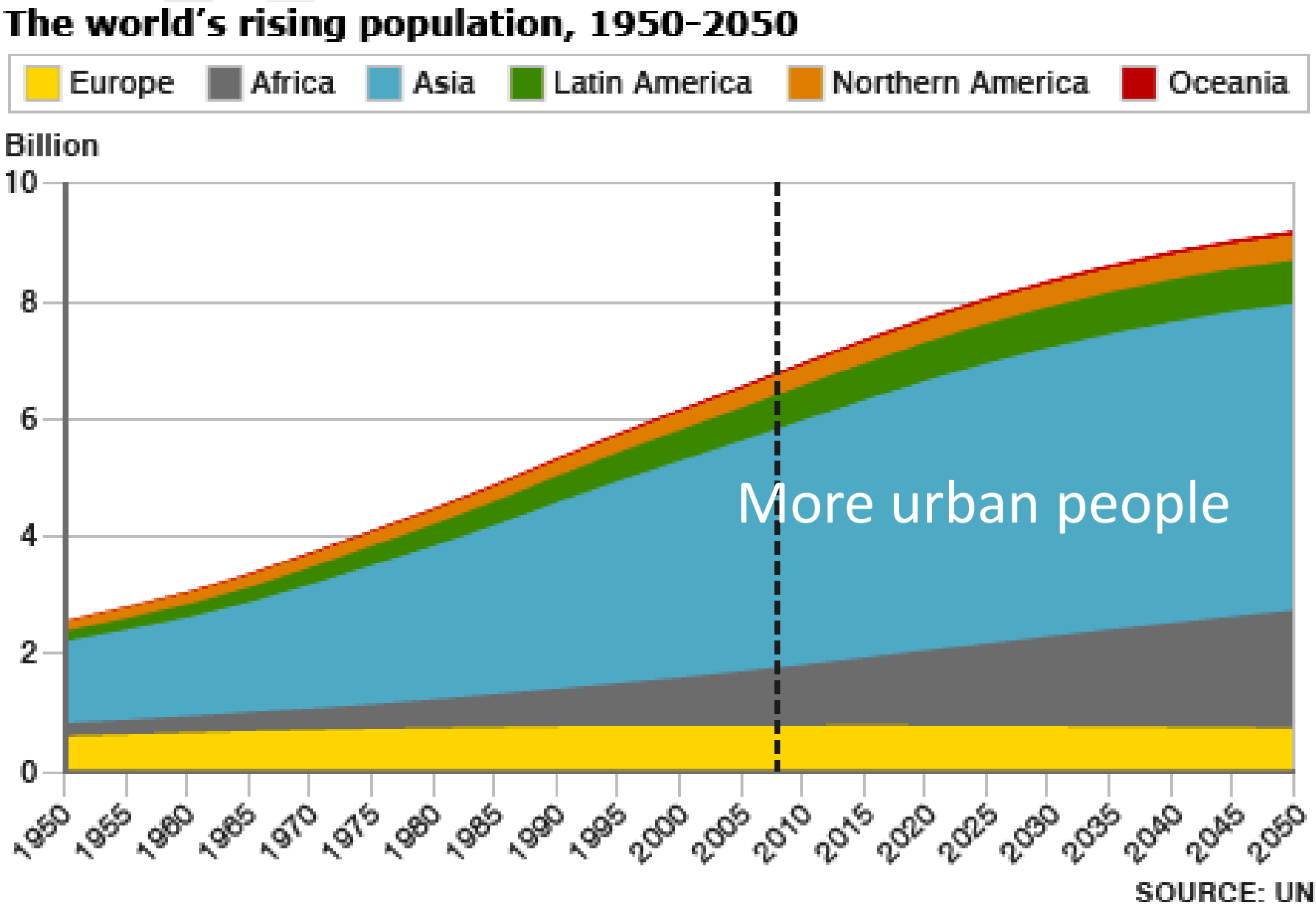
1. Meat substitutes for a better health
2. Is beef really bad for health?

The problem to solve

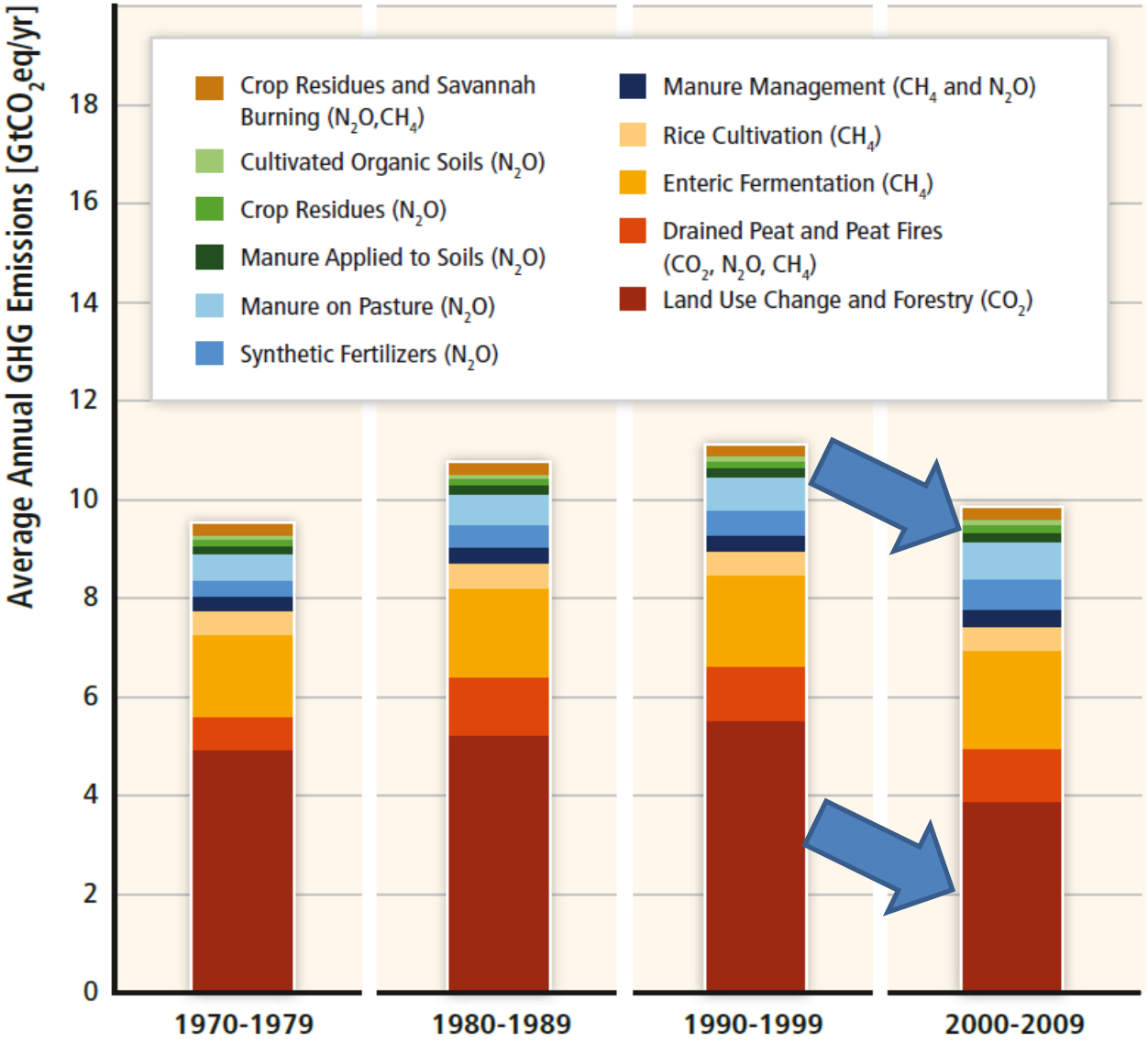
Nowadays, the livestock and meat sectors are facing new and important challenges:

- their environmental impact and role in global climate change;
- balancing the need for increased production of animal products (to satisfy the increasing human population)
- coupled with a lower footprint,
- and addressing societal needs in terms of animal welfare and product quality for the consumer

Scollan et al., Animal Production Science, 2011, 51, 1–5.


The world's rising population, 1950-2050
Europe
Africa
Asia
Latin America
Northern America
Oceania
Billion
10
8
6
4
2
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
More urban people
SOURCE: UN

Some improvements in conventional meat production in terms of GHG emission

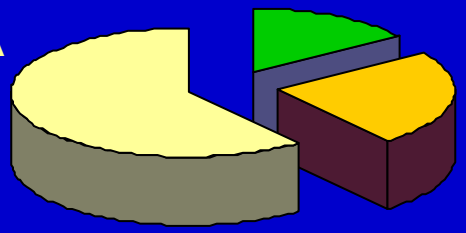


Smith P., M. Bustamante, H. Ahammad, H. Clark, H. Dong, E. A. Elsiddig, H. Haberl, R. Harper, J. House, M. Jafari, O. Masera, C. Mbow, N. H. Ravindranath, C. W. Rice, C. Robledo Abad, A. Romanovskaya, F. Sperling, and F. Tubiello, 2014: Agriculture, Forestry and Other Land Use (AFOLU). In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Composition in Fatty Acids (FA) of ruminant products

Recommended nutritional supply

MUFA
60% total FA



PUFA
15% total FA

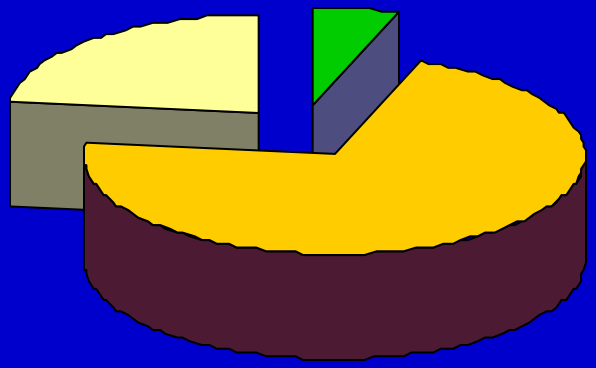
SFA
25% total FA

Too much SFA, not enough PUFA, variable content in *trans-FA*

MILK

MUFA
20-25% tot. FA

PUFA
5% tot. FA

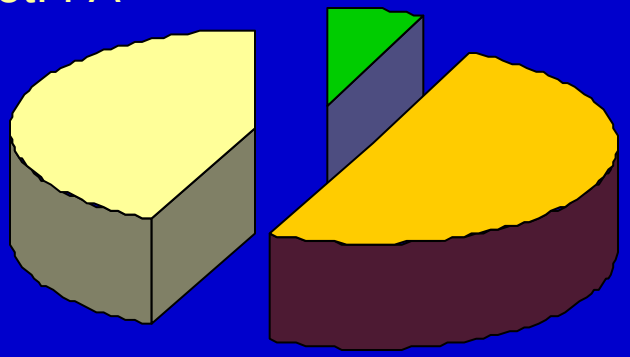


SFA
65-68% tot. FA

MEAT

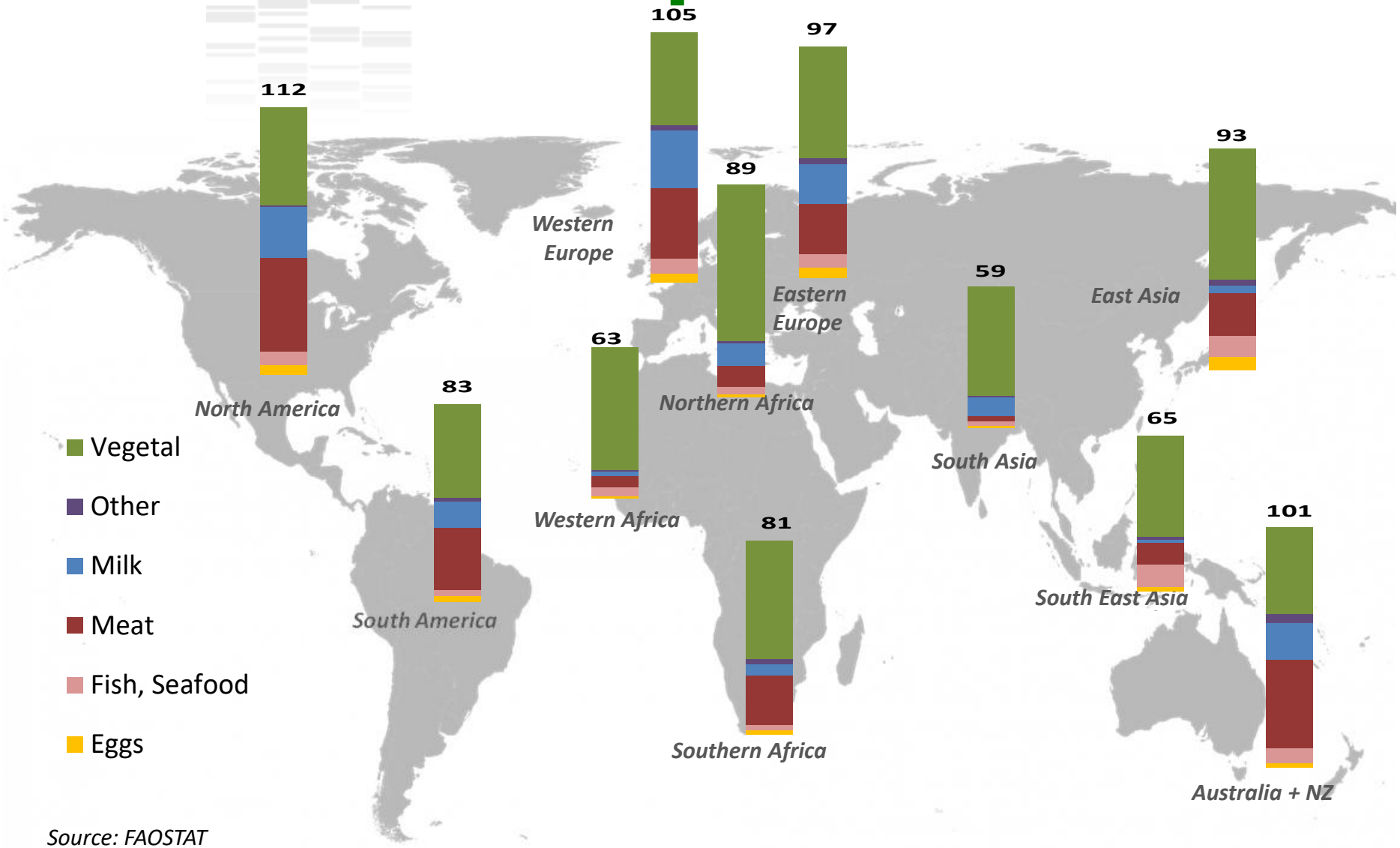
MUFA
40-45 % tot. FA

PUFA
6% tot. FA



SFA
50% tot FA

Protein consumption in the World



Source: FAOSTAT

In some countries, much less animal proteins are consumed

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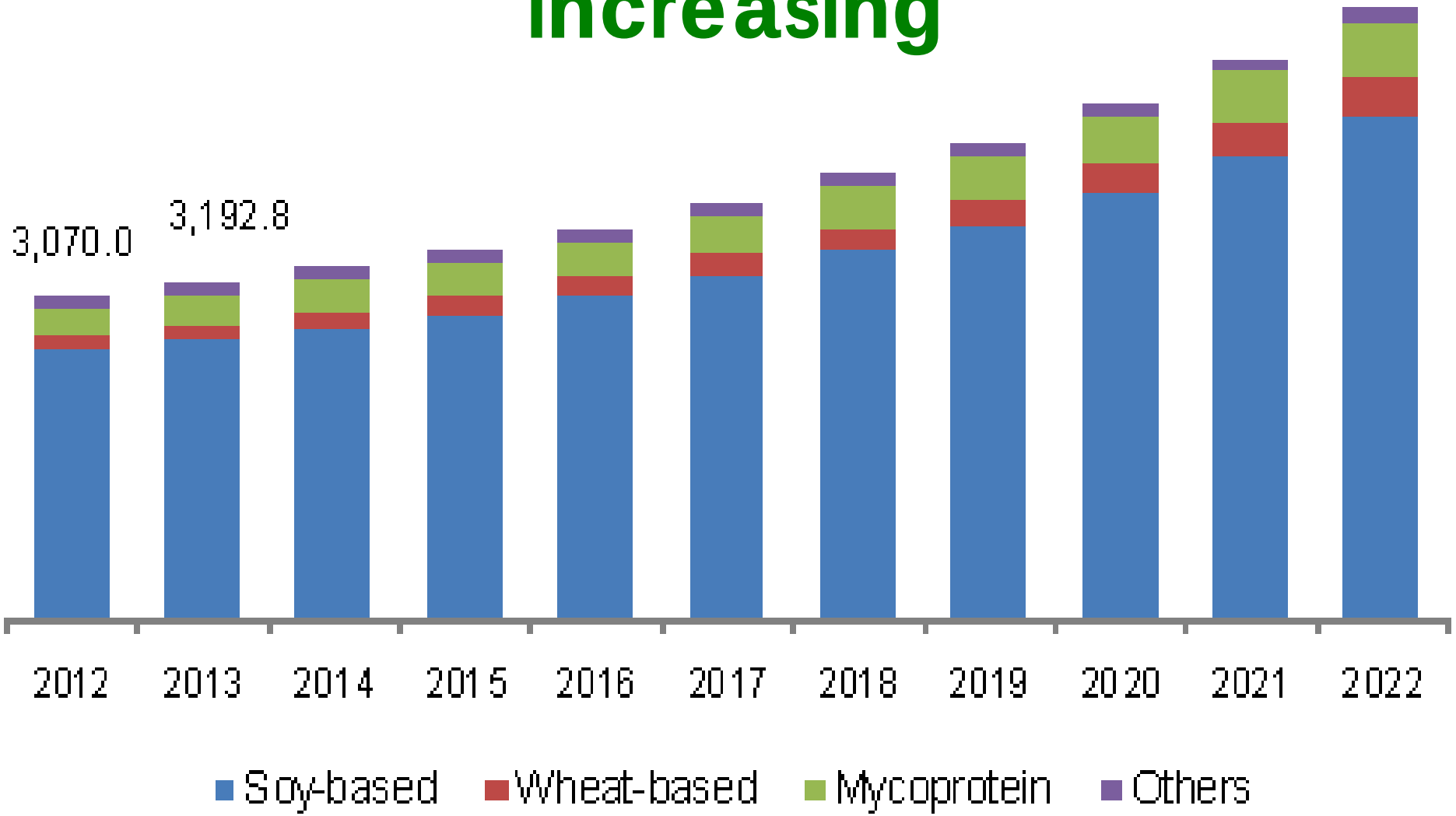
The meat substitutes market is increasing



http://www.grandviewresearch.com/industry-analysis/meat-substitutes-market

Eating proteins from plants

DID YOU KNOW?

100 calories of steak

=

8.0 grams of protein

7.4 grams of fat

100 calories of broccoli

=

11.1 grams of protein

0.4 grams of fat

+

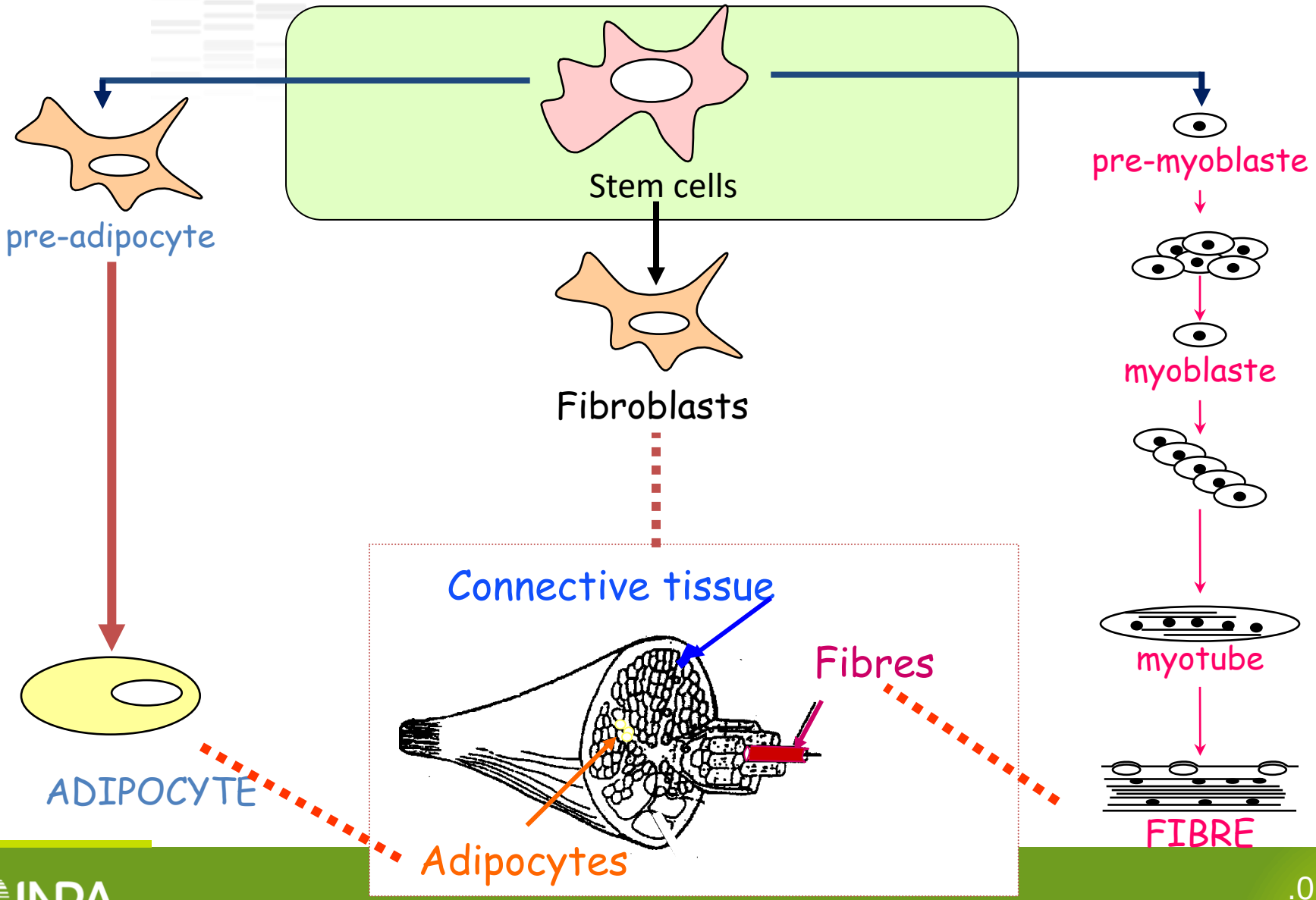
phytochemicals, vitamins and essential nutrients that prevent disease and promote health

Source: Eat to Live, Dr. Joel Furhman

https://mamasuorganic.wordpress.com/2014/05/21/animal-vs-plant-protein-how-do-they-stack-up/

Eating proteins from mushrooms ?

Principles of cell culture to produce a muscle



The first artificial steak was tasted

A special issue of Journal of Integrative Agriculture in 2015

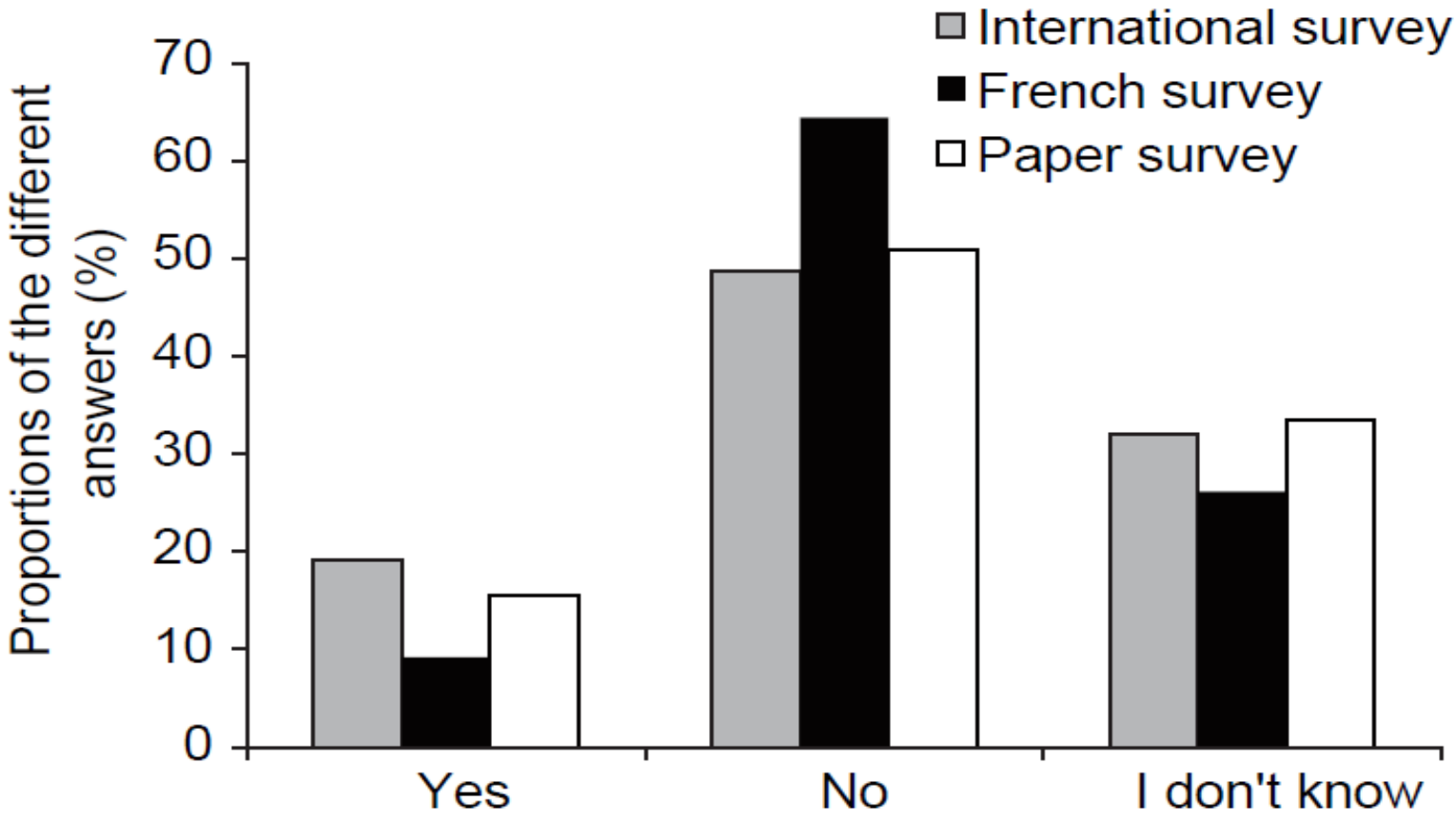
"Important issues remain to be solved, including technical, social and ethical problems. Consumer acceptance and confidence might be a major issue".

Artificial meat's strength and weakness

- The environmental impact of artificial meat is difficult to evaluate due to the absence of references on production units.
- However, it may have a moderate interest in reducing greenhouse gas emissions and pollution by nitrates,
- a limited interest for decreasing fossil fuel use or
- a very limited interest concerning water use,
- but it would make more land available.
- It may result in the presence of organic molecule residues in water.
- Furthermore, artificial meat is thought not to be healthy for consumers due to artificial hormones and growth factors, fungicides, and antibiotics required for cell culture.

Consumers' acceptance ?

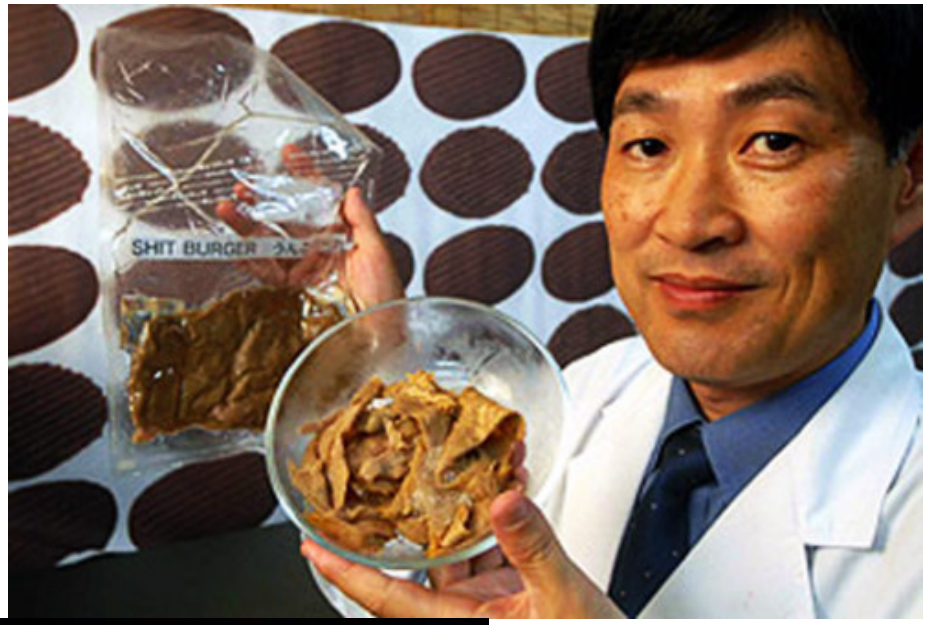
According to your perception, will *in vitro* meat be well accepted by consumers? Will consumers buy it?



Hocquette et al., Journal of Integrative Agriculture 2015, 14(2): 273–284

“cacaburger” : the protein of the future?

Japanese scientist Mitsuyuki Ikeda has developed a “burger” made from soya, steak sauce essence, and **protein extracted from human feces present in sewage sludge** of Tokyo.



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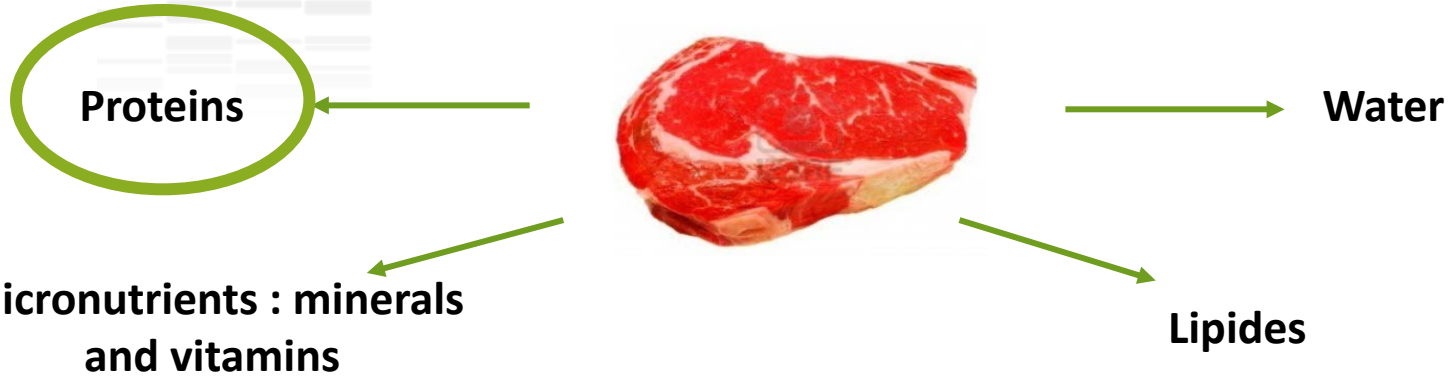
Nutritional quality of beef



- 100 g of beef provide :
  - 30 to 50% of proteins Recommended Dietary Allowances (RDA)
  - 48 à 75% of 9 essential amino acids

- High DIAAS Index (Digestibility Indispensable Amino Acid Score), higher than the one for vegetable products (Rémond *et al.*, 2014)

➢ Beef is a preferred source of proteins for human body

Nutritional quality of beef

	Quantity	RDA	
Fe	3 mg / 100 g	20 to 30%	More absorbable than in plants
Zn	3 to 7 mg / 100 g	20 to 30%	Very good availability
Se	10 µg / 100 g	20 to 30%	Very rich
Vitamin B12	2.2 µg / 100 g	50 to 100%	Only in animal products

➢ **Beef is an important, and sometimes exclusive, source of micronutrients**

The nutritional value of meat

Nutrient per 100g	Beef	Lamb	Pork	Calf liver
Vitamin A				Rich source
Vitamin B_1			Rich source	Rich source
Vitamin B_2	Source		Source	Rich source
Vitamin B_3	Rich source	Rich source	Rich source	Rich source
Vitamin B_6	Rich source	Source	Rich source	Rich source
Vitamin B_{12}	Rich source	Rich source	Rich source	Rich source
Iron	Source			
Zinc	Rich source	Rich source	Source	Rich source
Selenium			Source	Rich source
Potassium	Source	Source	Source	Source
Phosphorus	Source	Source	Source	Rich source

≥ 15% of the RDA per 100g = *Source;* ≥ 30% of the RDA per 100g = *Rich source*

Nutritional quality of beef

Proteins

Water

Lipides

Micronutrients : minerals and vitamins

The same amount of lipids is obtained with

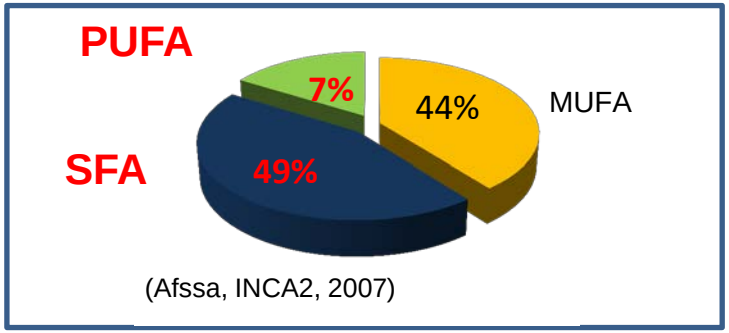
Beef steak	Farmed salmon	Egg
100 g	53 g	58 g

- **Poor in lipids**: 1 to 10 %

(Basarab *et al.,* 2007; Cuvelier *et al.,* 2005)

- **Poor in cholesterol**: < 0,8 %

(Geay *et al,* 2002)

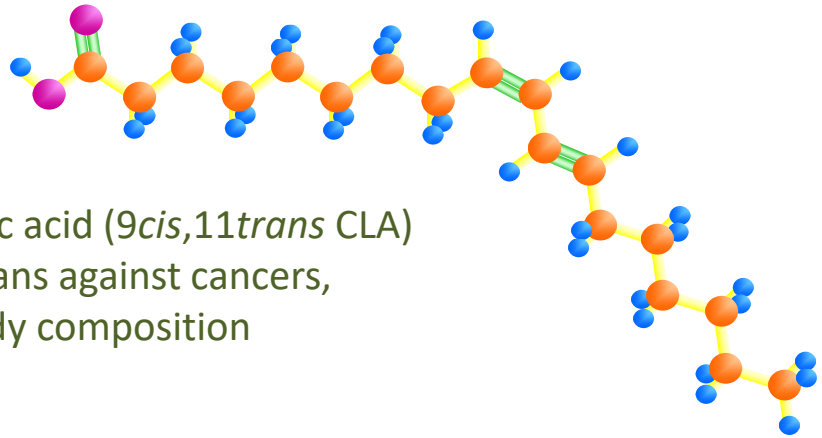


(Afssa, INCA2, 2007)

- **FA composition of beef must be improved but…**

…Beef contains interesting FA

9*cis*,11*trans*-CLA



- **Conjugated Linoleic Acids (CLA)**
  - primarily synthesized by ruminants
  - 24 identified isomers whose majority is rumenic acid (9*cis*,11*trans* CLA)
  - Many potentially beneficial properties for humans against cancers, cardiovascular disease, diabetes, immunity, body composition
- ***Trans* MUFA**
  - The major isomer is 11*trans* 18:1 (Vaccenic acid) ⇨ Many potentially beneficial properties for humans
  - But some diets can increase the content of another isomer (9*trans* 18:1) ⇨ harmful to human health
- **n-6/n-3**
  - Good balance between PUFA n-6 and PUFA n-3 ⇨ n-6/n-3 < 5
- **PUFA LC n-3**
  - Significant amounts of EPA (20:5 n-3) and DPA (22:5 n-3) ⇨ Many beneficial properties for human
  - Low amount of DHA (22:6 n-3) ⇨ Many beneficial properties for humans

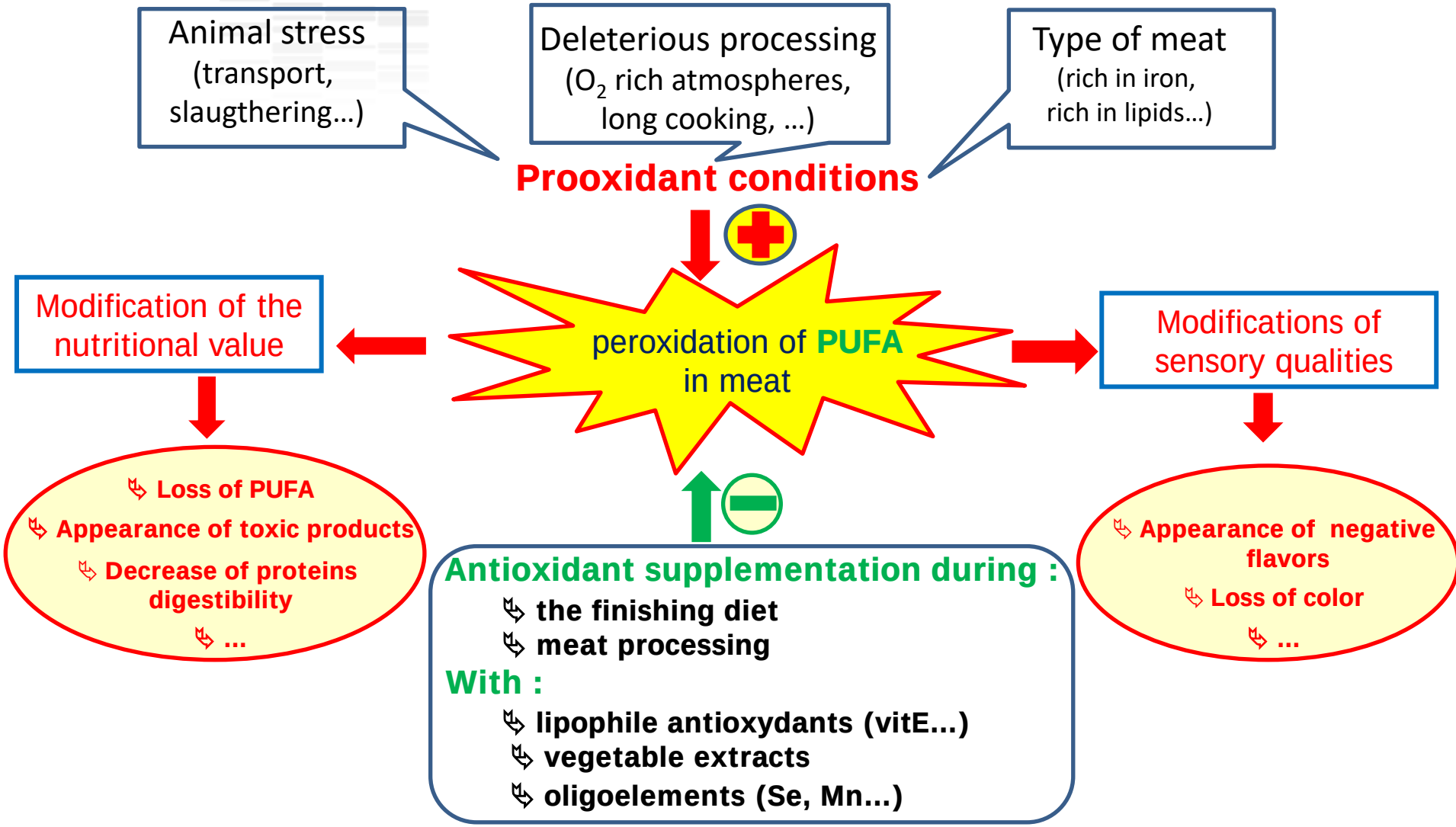
Animal feed: a mean to modulate beef FA

	Concentrate	Concentrate + linseed	Pasture
Total lipids (g/100 g)	3.8	1.7	2.9
	% of total FA		
SFA	48.5	39.0	38.4
Trans MUFA	1.9	6.5	3.2
CLA	0.3	0.4	0.7
PUFA n-3	1.0	4.4	2.9
PUFA n-6	4.3	9.8	5.0
LC PUFA n-3	0.5	1.5	1.1
n-6/n-3	5.1	2.7	1.7

(Bauchart *et al.*, 2009, Garcia *et al.*, 2008)

- **Linseed supplementation or pasture improve nutritional quality of beef (n-6/n-3 < 5)**
- **But be careful to increased *trans* MUFA (beneficial or harmful isomers?)**

Why and how limit peroxidation of PUFA in meat?



Lipid peroxidation in steaks after 9-month-frozen storage : effect of antioxidant diet supplementation

		MDA concentration (µg/g tissue)		
Muscle	**Ageing methods**	Control	Control + Vitamin E (155 IU/kg DM)	Control + Vitamin E + Plant extracts (rich in polyphenols)
Longissimus thoracis	carcass	0,265 ^{a}	0,236 ^{ab}	0,130 ^{b}
	vacuum	0,176 ^{a}	0,136 ^{a}	0,124 ^{a}
Semi-tendinosus	carcass	0,210 ^{a}	0,162 ^{ab}	0,136 ^{b}
	vacuum	0,174 ^{a}	0,127 ^{a}	0,105 ^{a}

(Gobert et al., 2011)

- carcass ageing is the most deleterious conditions for lipid peroxidation
- animal diet supplementation with vitamin E combined with plant extracts rich in PP exert an effective antioxidant action preserving frozen meats towards peroxidation

Lipid peroxidation during processing : effect of antioxidant diet supplementation

Experimental design

Animals

Twenty five 4-5 year old
Normand cull cows

Feeding conditions

	Basal diet	Lipid supplement	Antioxidant supplement
Diet L	Straw (30) Concentrate (70)	Extruded linseeds	
Diet LE	Straw (30) Concentrate (70)	Extruded linseeds	V it E
Diet LEP	Straw (30) Concentrate (70)	Extruded linseeds	V it E + PERP
		40 g oil/kg diet DM	155 UI/kg diet DM + 7 g/kg diet DM

100 d. finishing period

SLAUGHTER (D_0)

Meat processings

***Semitendinosus* (ST) muscle**

Ageing

12d in entire carcass

ST steaks

Packaging

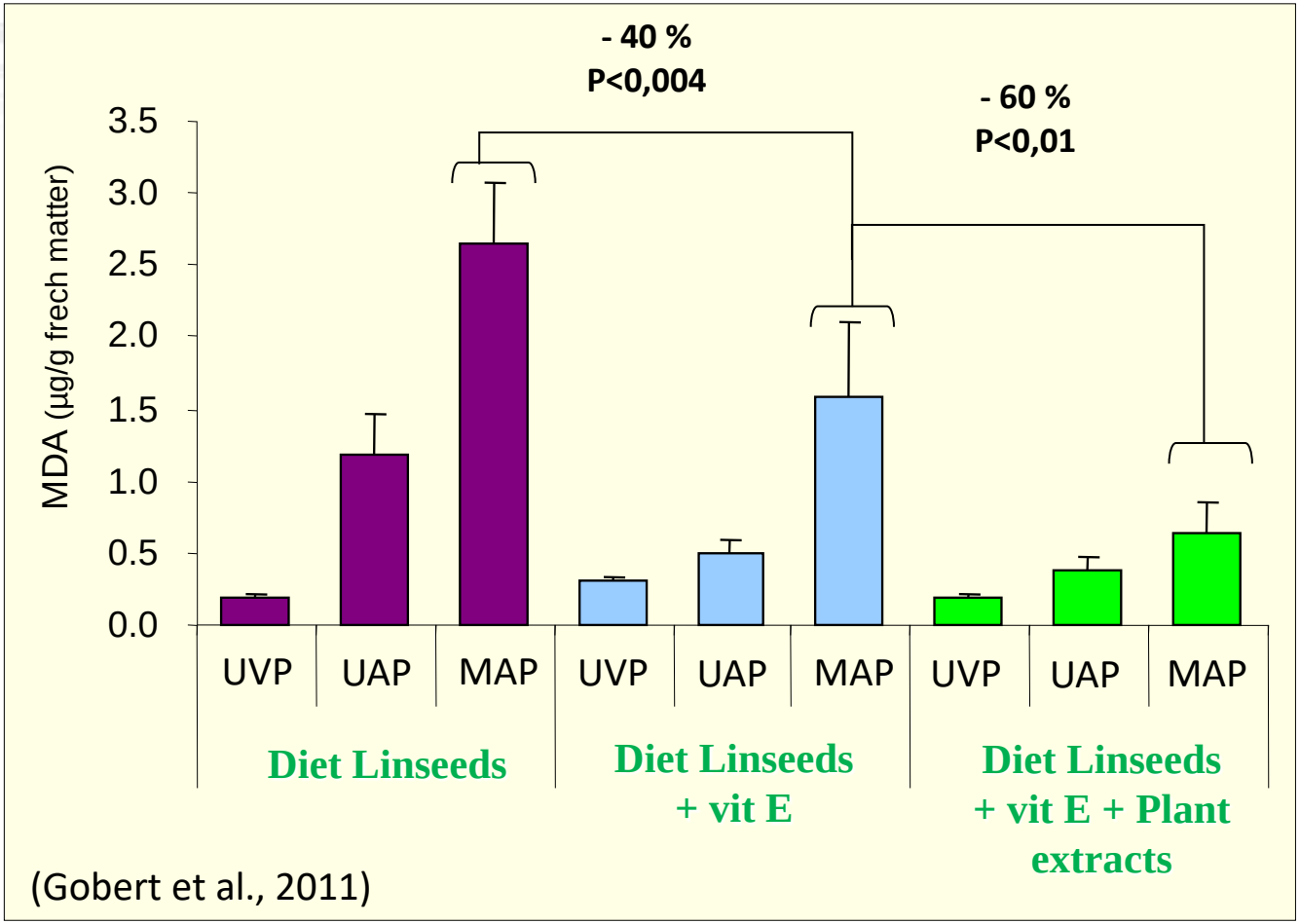
- 4d. under air → **(UAP)**
- 14d. Under vacuum → **(UVP)**
- 7d. under modified atmosphere → **(MAP)**

Lipid peroxidation during processing: effect of antioxidant diet supplementation

UAP: Under vaccum packaging

UAP: Under air packaging

MAP: modified atmosphere packaging



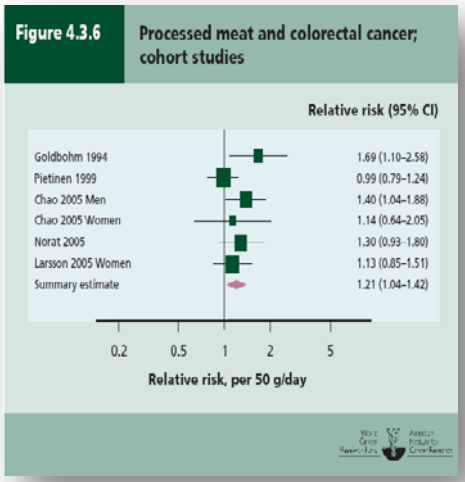
(Gobert et al., 2011)

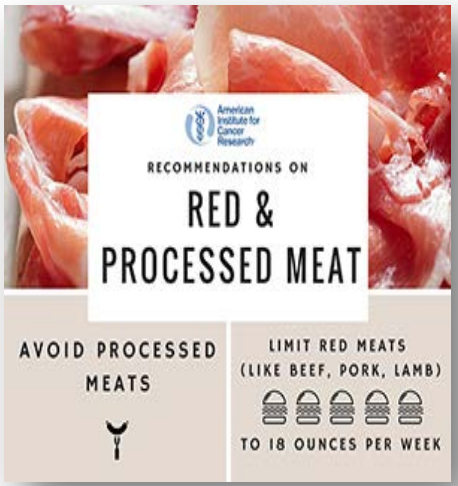
- **higher lipoperoxidation in meats under air or modified atmosphere packaging**
- **The association of vit E and plant extract rich in polyphenols protected all packaging conditions even in meats enriched in n-3 PUFA against lipoperoxidation**

Carcinogenicity of consumption of red and processed meat

Cohort studies & meta-analysis

World Cancer Research Fund International





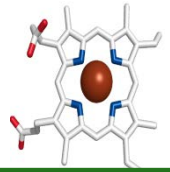
IARC Conclusions

American Institute for Cancer Research supports the International Agency for Research on Cancer World Health Organization's classification of processed meat as "carcinogenic to humans."

Lancet Oncol 2015

Processed meat:
Group 1 (Carcinogenic)

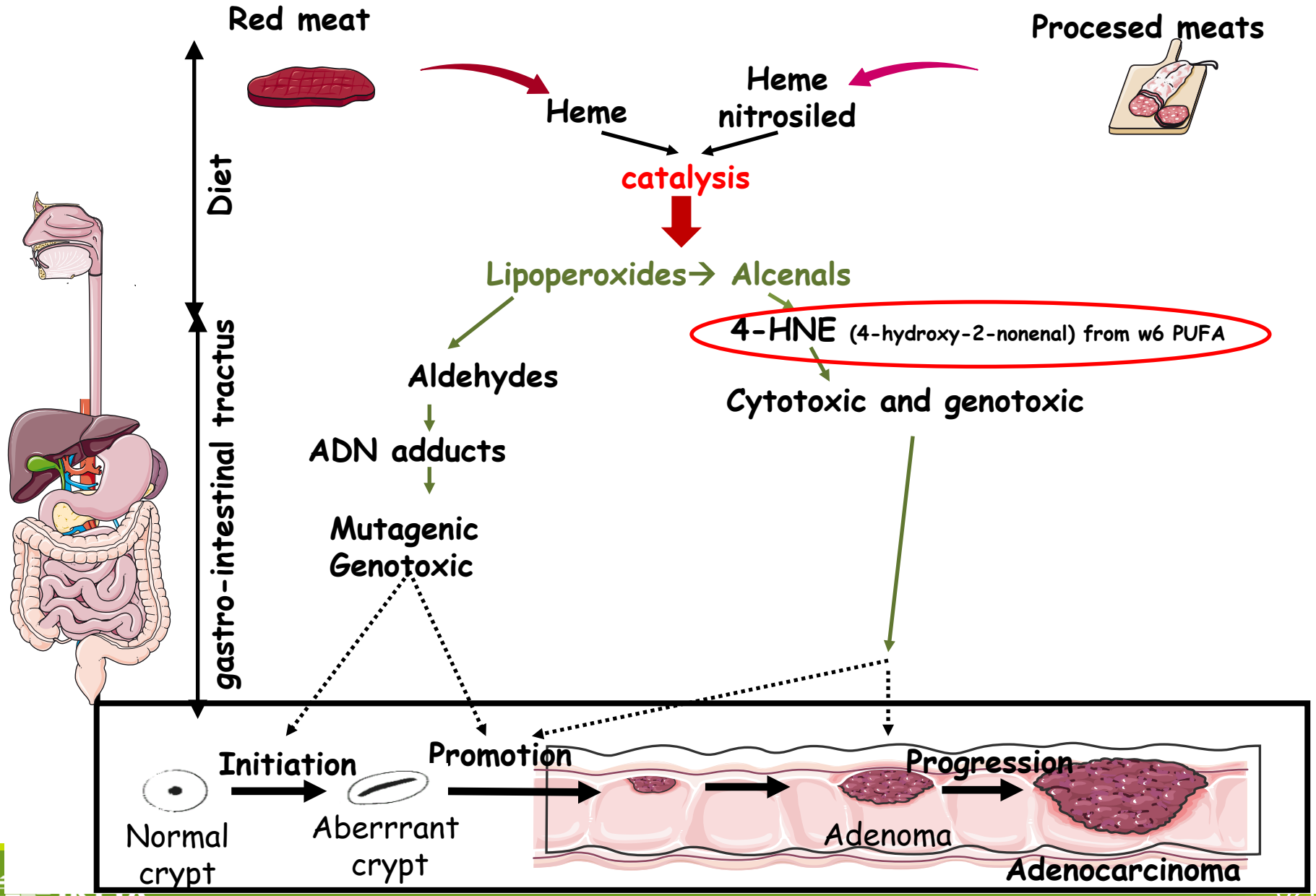
Red meat:
Group 2A (Probably Carcinogenic to Human)



Among multiple meat components, **heme iron** has been shown to play a pivotal role in the promotion of colorectal carcinogenesis.

(Bastide *et al.* 2015, Cancer Research, Bastide *et al*. 2016, Cancer Epidemiol Biomarkers Prev)

Central role of heme in carcinogenesis



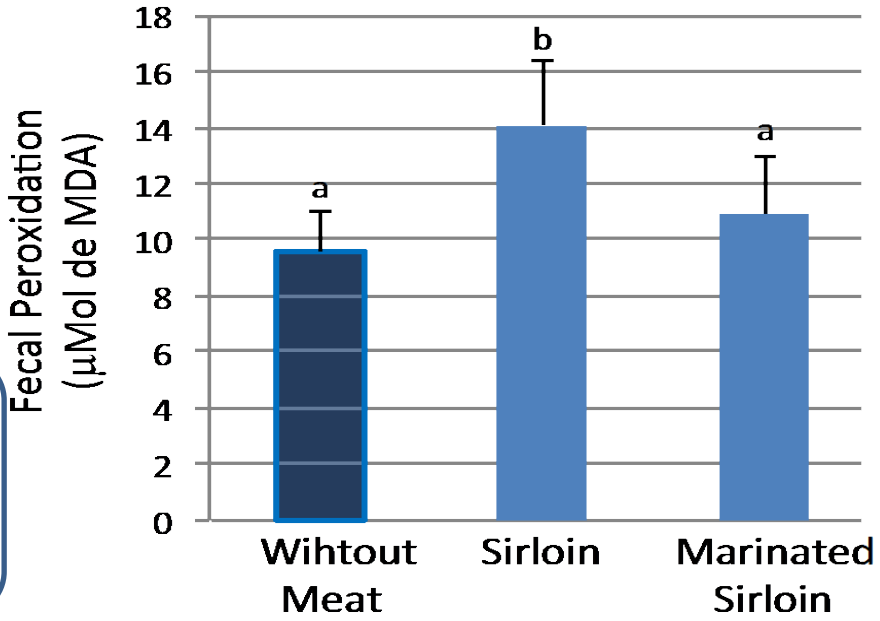
How to limit (prevent) this risk ?

First strategy

Formulation of meat products which **limit** the formation of peroxides, N-nitroso compounds or cytotoxic compounds in intestine :

↳ addition of antioxidant during processing

*Experimentation: animal model which received a control diet or a diet with **marinated** meat or not*



Another strategy :

Animal dietary strategy during finishing period with vitamins, trace elements and vegetable extracts rich in polyphenols are developed on live animals to prevent peroxidation processes

- **the grap-olive marinade limits the effect of red meat consumption on peroxidation in the colonic lumen**
- **numerous studies show that animal diet supplementation with vitamin E combined with plant extract rich in PP increases antioxidant capacity of meat**

MARTIN OCB, NAUD N, TACHE S, LEVEQUE M, BOUTET E, THEODOROU V, PIERRE FHF, CORPET DE. Beef meat promotes colorectal carcinogenesis in Min mice and in carcinogene-induced rats. Effect of antioxidant marinade and of cooking. 2014 AICR Annual Research Conference on Food, Nutrition, Physical Activity and Cancer. 29-31 October, Washington DC (USA).

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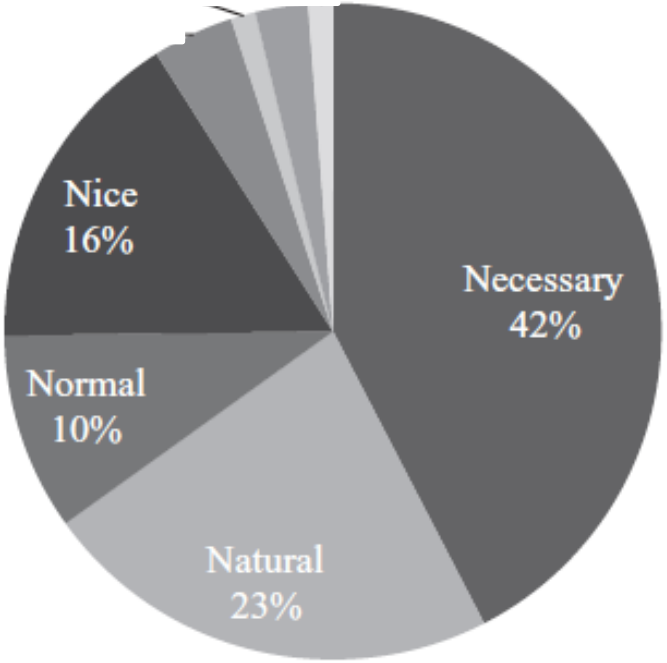
Conclusions

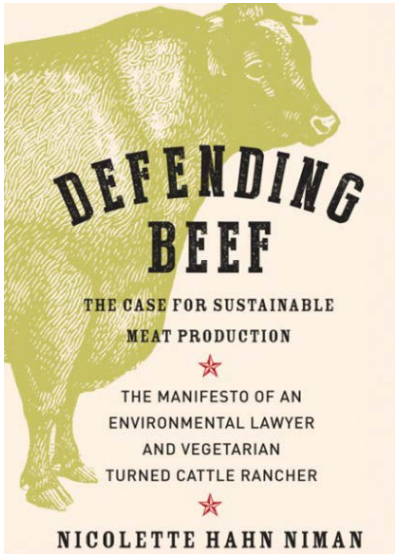
Points of view in favour of meat

We eat meat because it is necessary, natural, normal and nice (4Ns)



Appetite 91 (2015) 114–128

More and more people are defending meat (or beef)

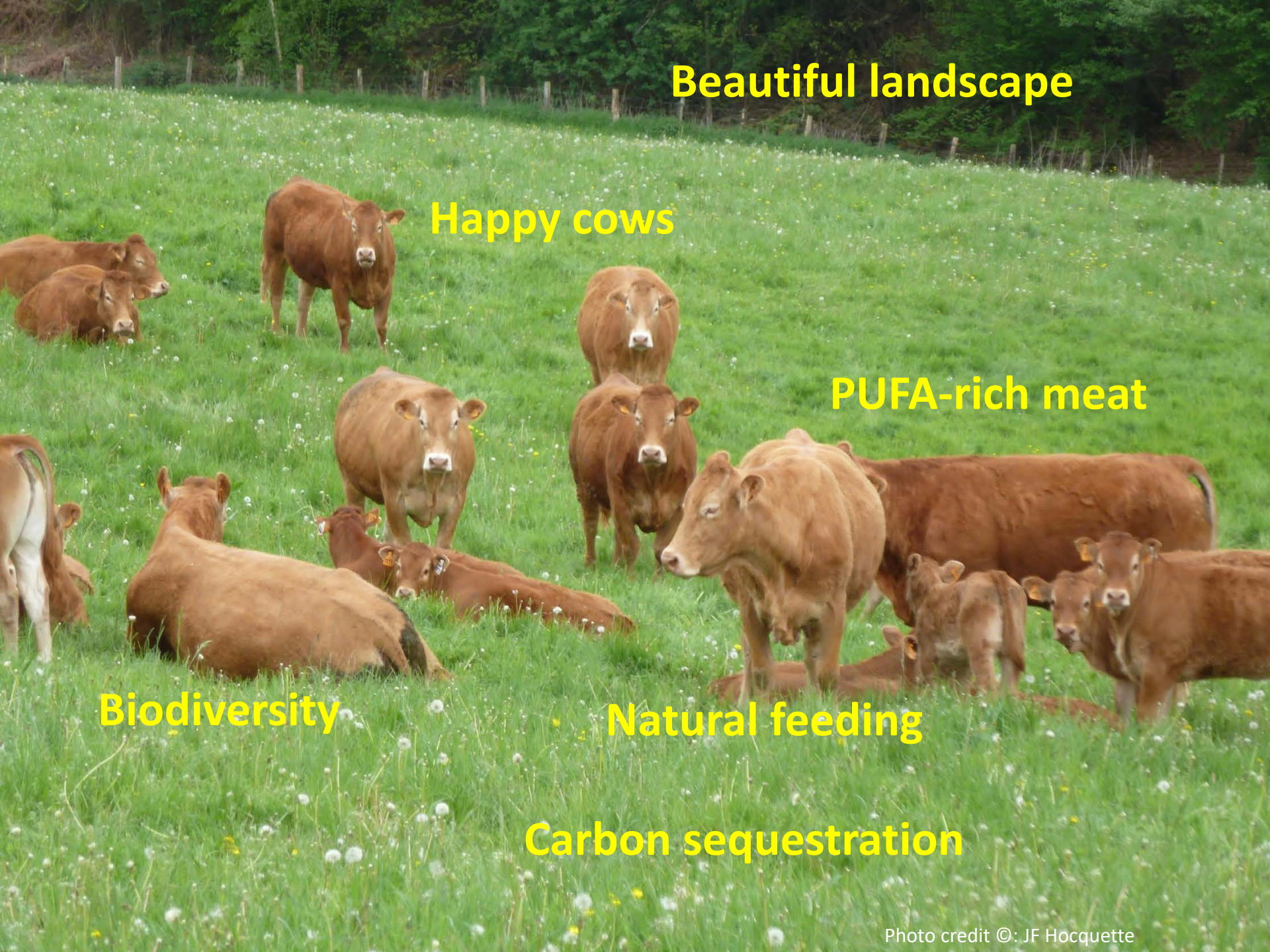


http://www.wsj.com/articles/actually-raising-beef-is-good-for-the-planet-1419030738

ESSAY

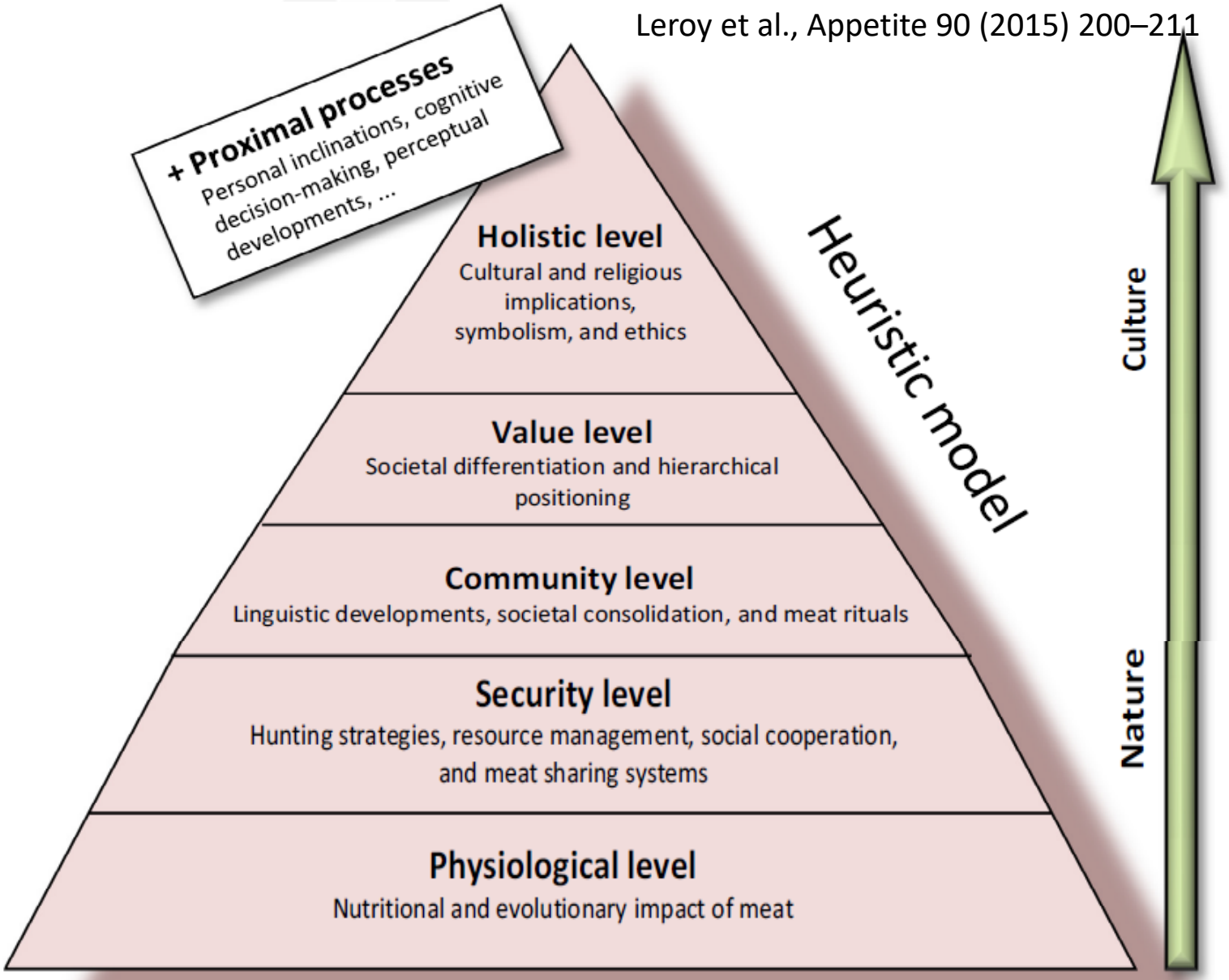
Actually, Raising Beef Is Good for the Planet

Despite environmentalists' worries, cattle don't guzzle water or cause hunger—and can help fight climate change

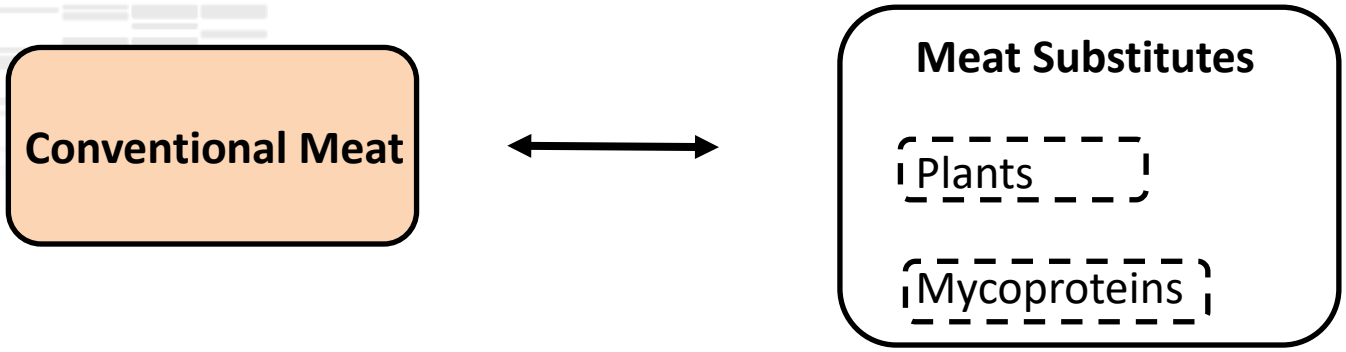

Beautiful landscape
Happy cows
PUFA-rich meat
Biodiversity
Natural feeding
Carbon sequestration
Photo credit ©: JF Hocquette

Meat traditions: the co-evolutions of humans and meats

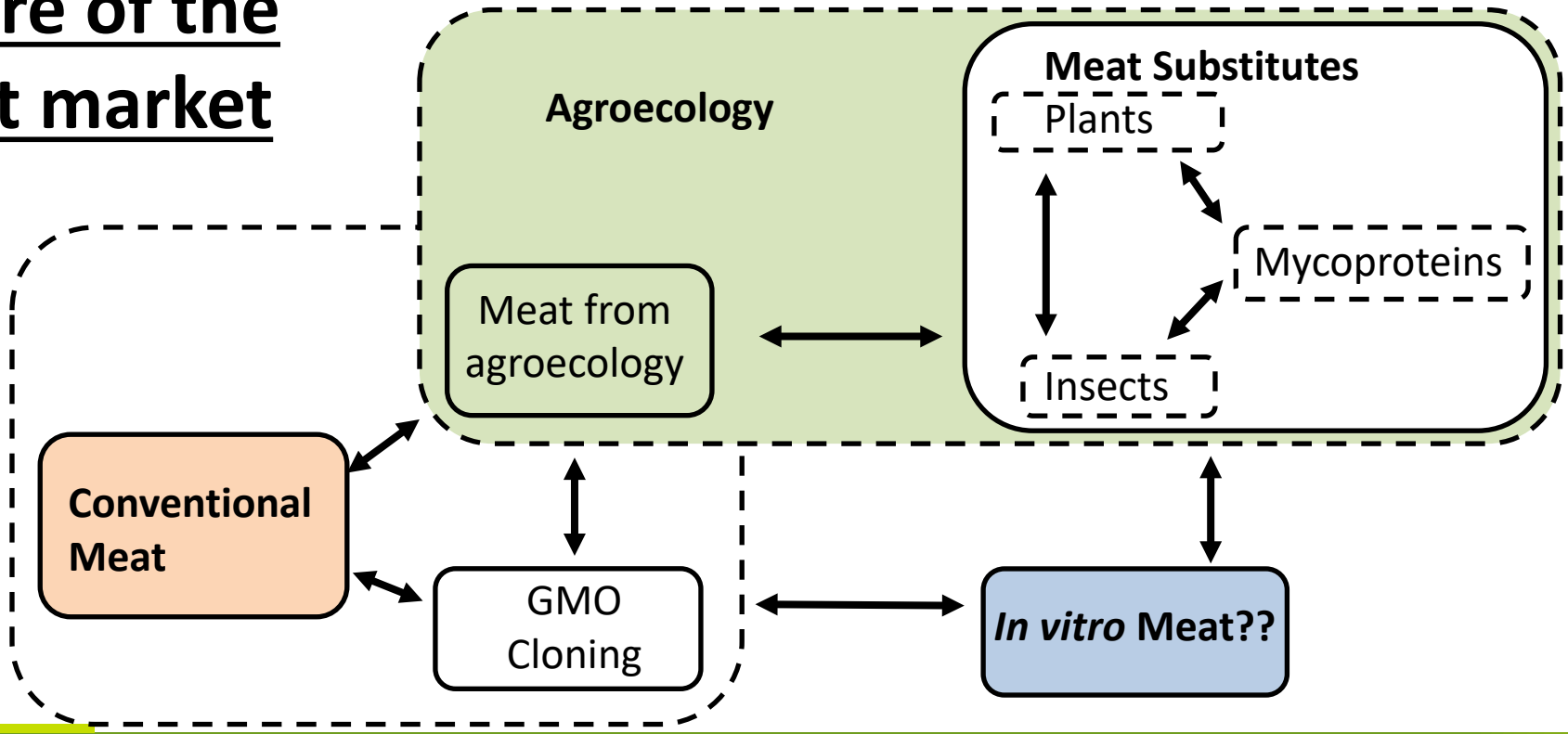
Leroy et al., Appetite 90 (2015) 200–211



The meat market today



Future of the meat market



Bonny et al., 2015. Journal of Integrative Agriculture 2015, 14(2): 273–284

Conclusions

The success of meat substitutes are partly due to the new social drivers of meat consumption (the necessity to improve human health, animal welfare and environmental protection).

The urbanisation of human beings further and further away from rural culture has brought about a decrease in knowledge and acceptance of conventional meat production, making people also less able to express a critical and informed view about artificial meat.

Meat has a high health value.

Beef is a preferred source of proteins for human body
Beef is an important, and sometimes exclusive, source of micronutrients
Beef contains good and bad fatty acids
Linseed supplementation or pasture improve nutritional quality of beef
Attention should be taken to prevent peroxidation of fatty acids and hence the carcinogenicity of meat

Meat does bring with it positive health, social and historical values.

The future market of meat is likely to be more complex.

Final thoughts of Prof De Smet

- *"Meat is a delicious, high quality nutrient dense-food, but the importance of meat in the diet should not be overestimated*
- *The content of some micronutrients in meat can be increased mainly by feeding strategies, but the impact of these approaches is at best modest*
- *High consumption of red and/or processed meat is associated with a small increase in risk for colorectal cancer*
- *There are mitigation options for the adverse effects of high red and processed meat consumption*
- *Meat consumed in moderate amount fits very well into balanced diets"*

De Smet et al., 2016. ICoMST August 2016.

Enhancing the nutrient profile of meat by primary production strategies

"Pro:

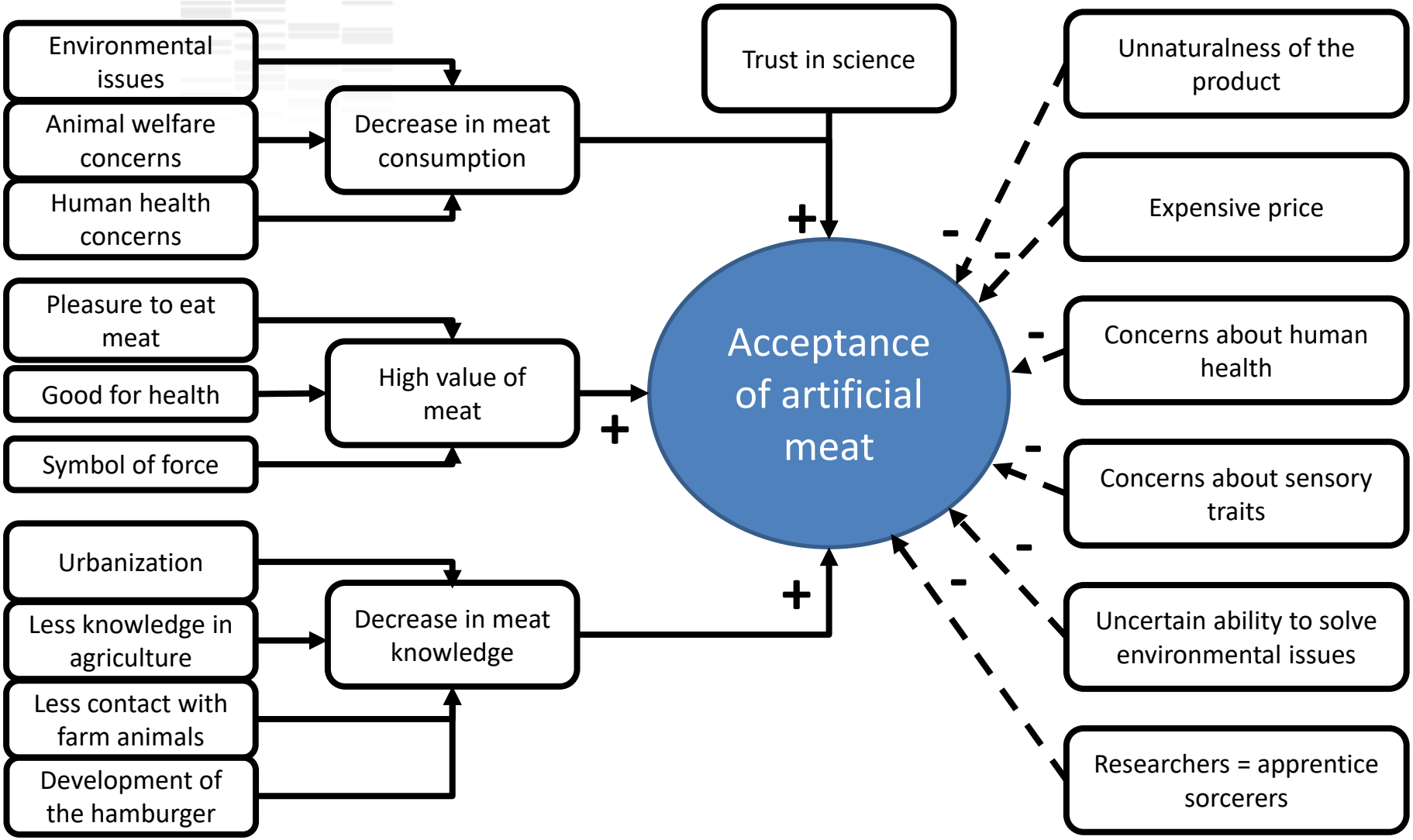
- *Natural*
- *No shift in eating pattern required*
- *Population-wide impact*
- *Good bioavailability*
- *No risk for overdosing*
- *Potential added value for meat producers"*

"Contra:

- *Less versatile compared to processing*
- *Variable out outcomes, hard to make nutrition claims*
- *Milk and eggs more responsive than meat*
- *Possible sensory defects*
- *Allocation of added value questionable"*

De Smet et al., 2016. ICoMST August 2016.

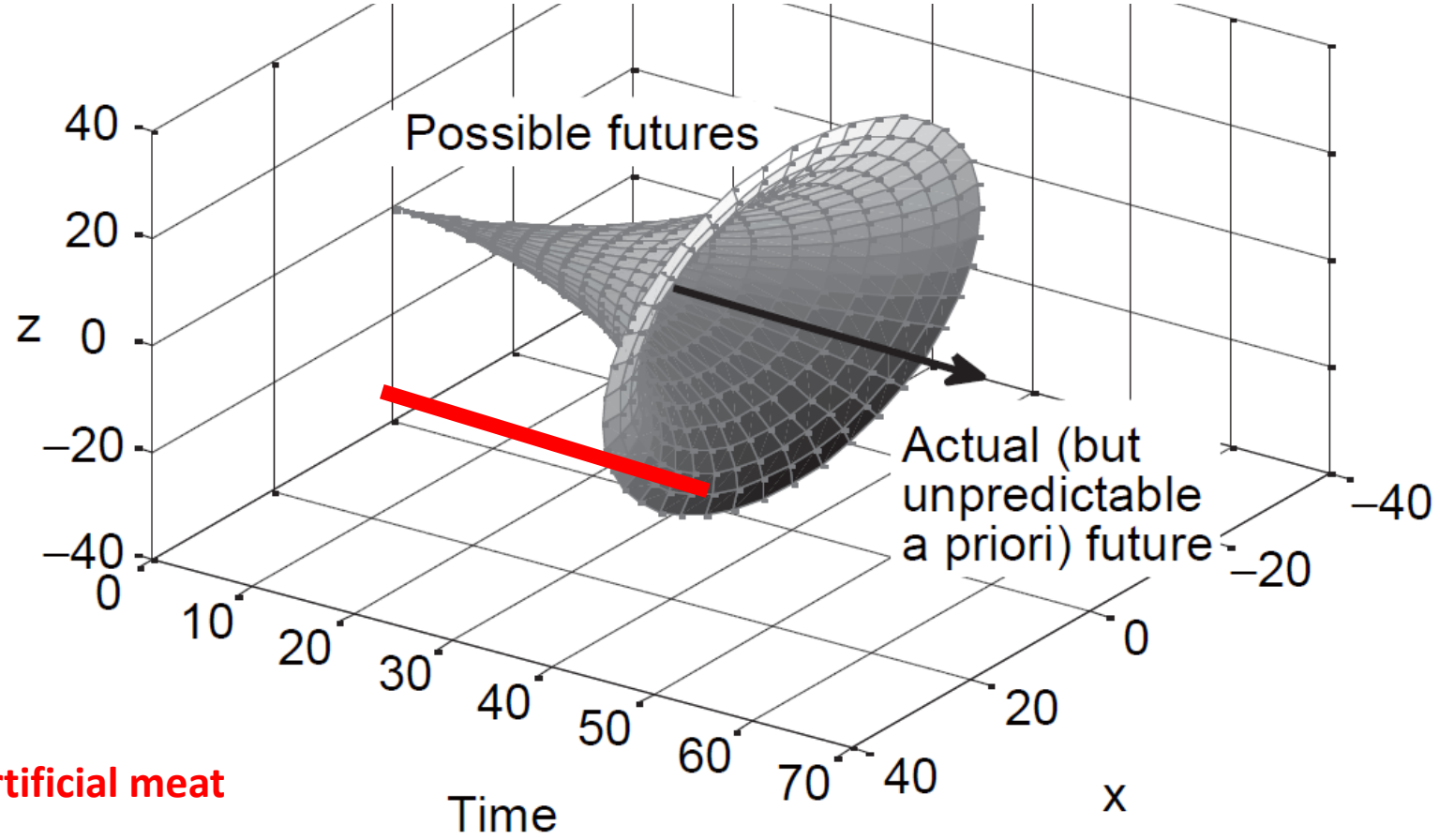
Driving forces in favour or against artificial meat



Maybe one day?

Path dependency

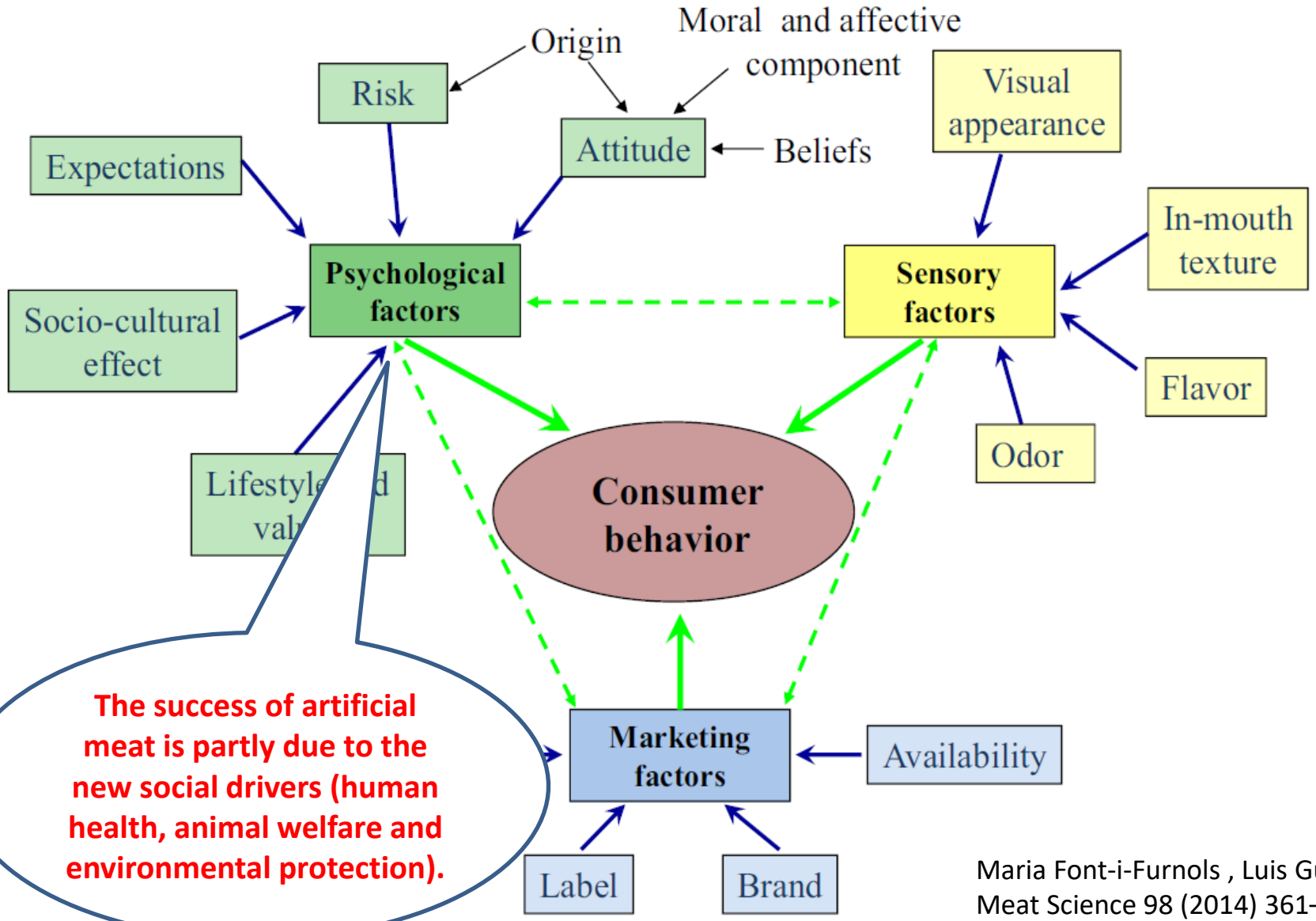
Cultured meat will almost certainly be accompanied by unintended and unanticipated consequences



The choice in 2050, or later on?

Post, 2012

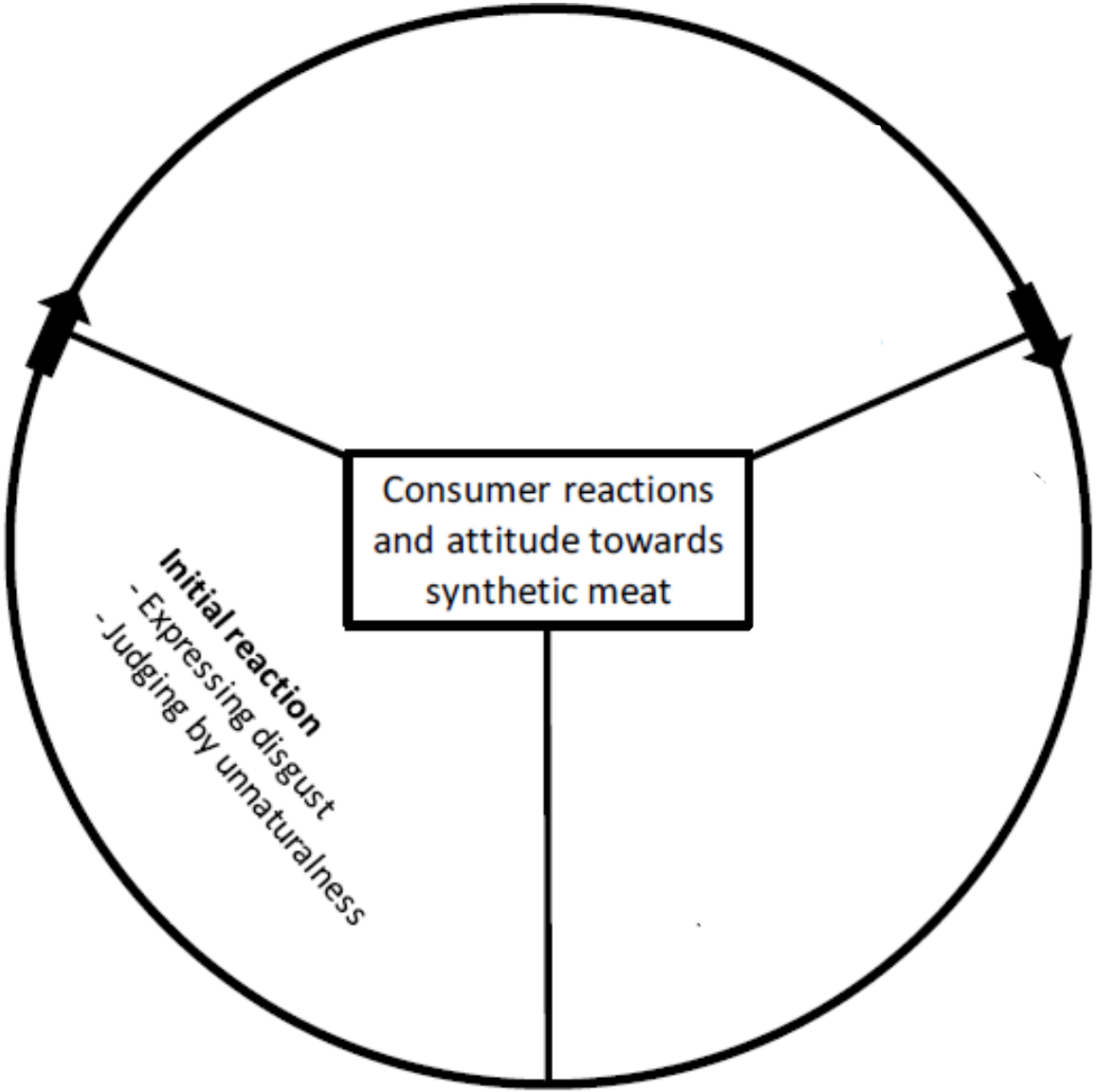
Consumer preference, behavior and perception about meat



Maria Font-i-Furnols , Luis Guerrero, Meat Science 98 (2014) 361–371

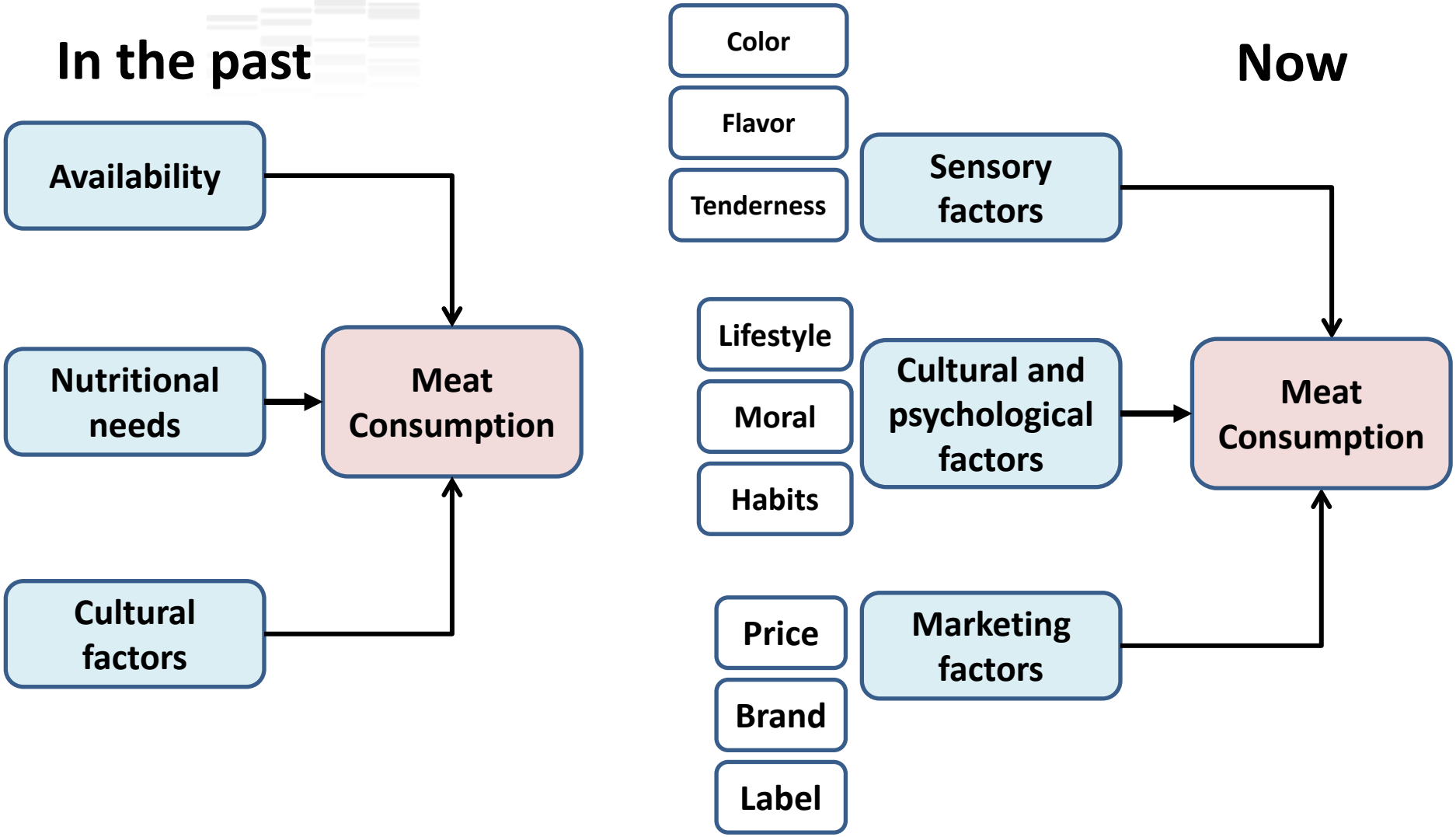
Consumers' reactions and attitude formation

Most of the consumers hesitate when asked the question whether they would be willing to try cultured meat in the future (Verbeke et al., J Integr Agric 2015, 14(2): 285–294)



Verbeke et al., 2015. Meat Science

Drivers of meat consumption



Meat: a social issue?

Meat: a social issue?

Do not be afraid to say
« I love meat »