Understanding the development of intramuscular fat in cattle – a mini review

Jean-François HOCQUETTE [1] & David PETHICK [2]

[1] INRAE, Université Clermont Auvergne, VetAgro Sup, UMR1213 Herbivore, Theix, 63122 Saint-Genès Champanelle, France, Murdoch

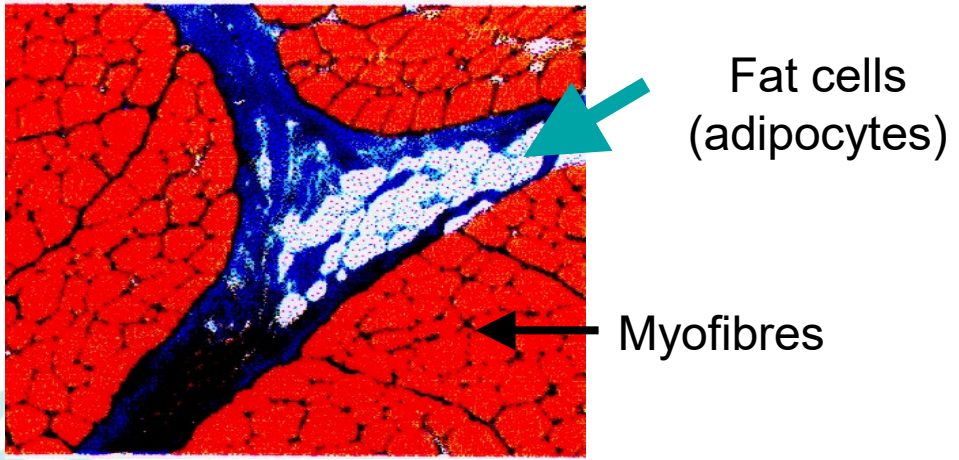
[2] University, Murdoch, 6150 WA, Australia

Outline

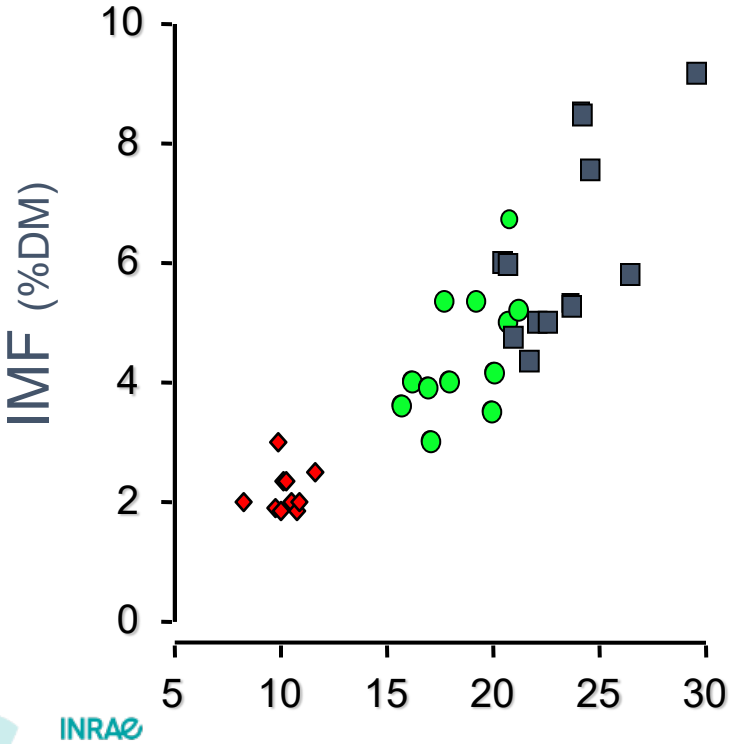
1. Definition of marbling and relevance for consumers
2. Biological determinism of marbling
3. On farm strategies to increase marbling
4. How to better value marbling and IMF

IMF and marbling: definitions

- IMF is the **amount of fat** within muscles → it is determined using a **biochemical assay in a lab (→ the reference method)**
- Marbling refers to the **appearance of white flecks or streaks of IMF** between the bundles of muscle fibres. It indicates the amount, the size, the distribution and the fineness of fat inclusions in muscles.

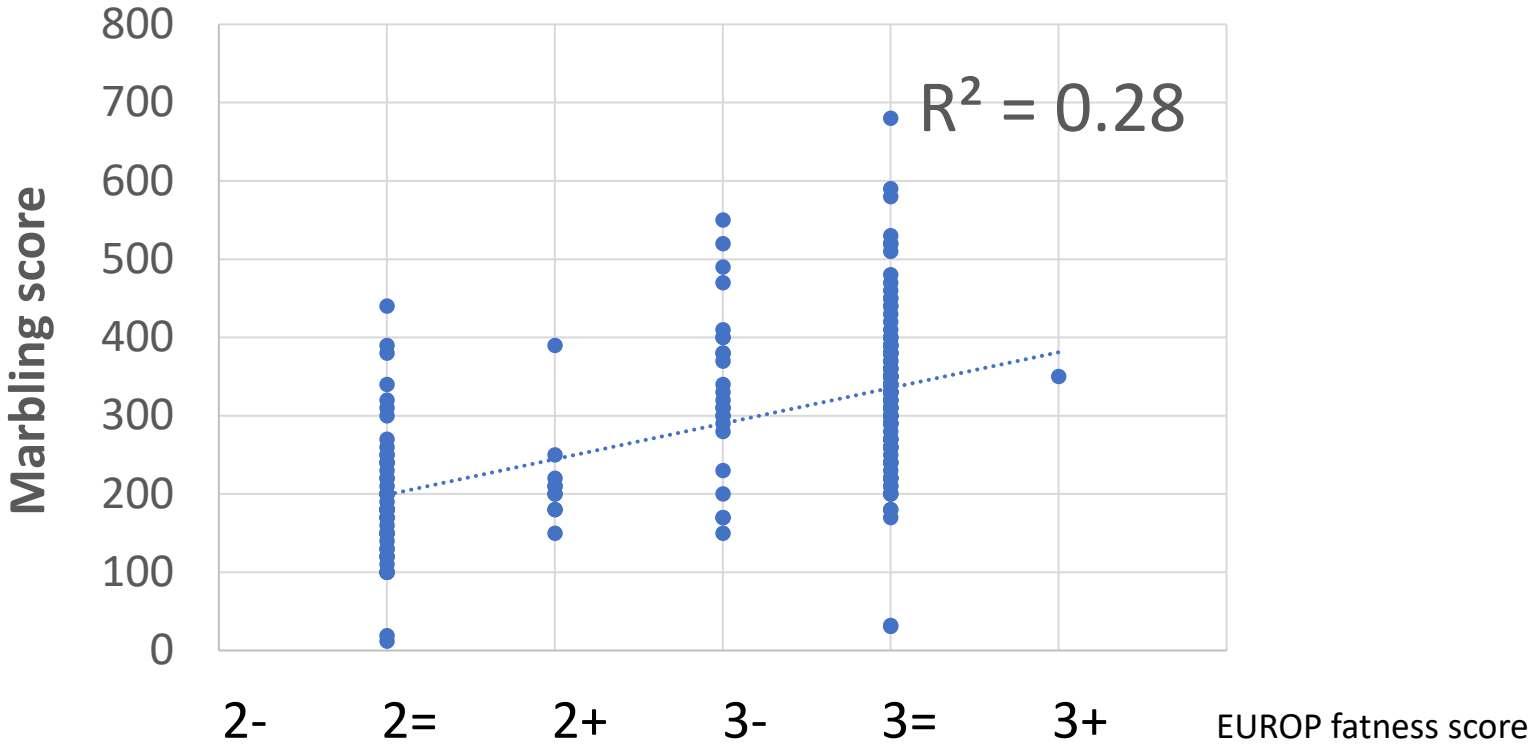


Total carcass fat versus IMF across breeds



Cuvelier et al., 2005

Carcass fatness is poorly related to marbling within breed



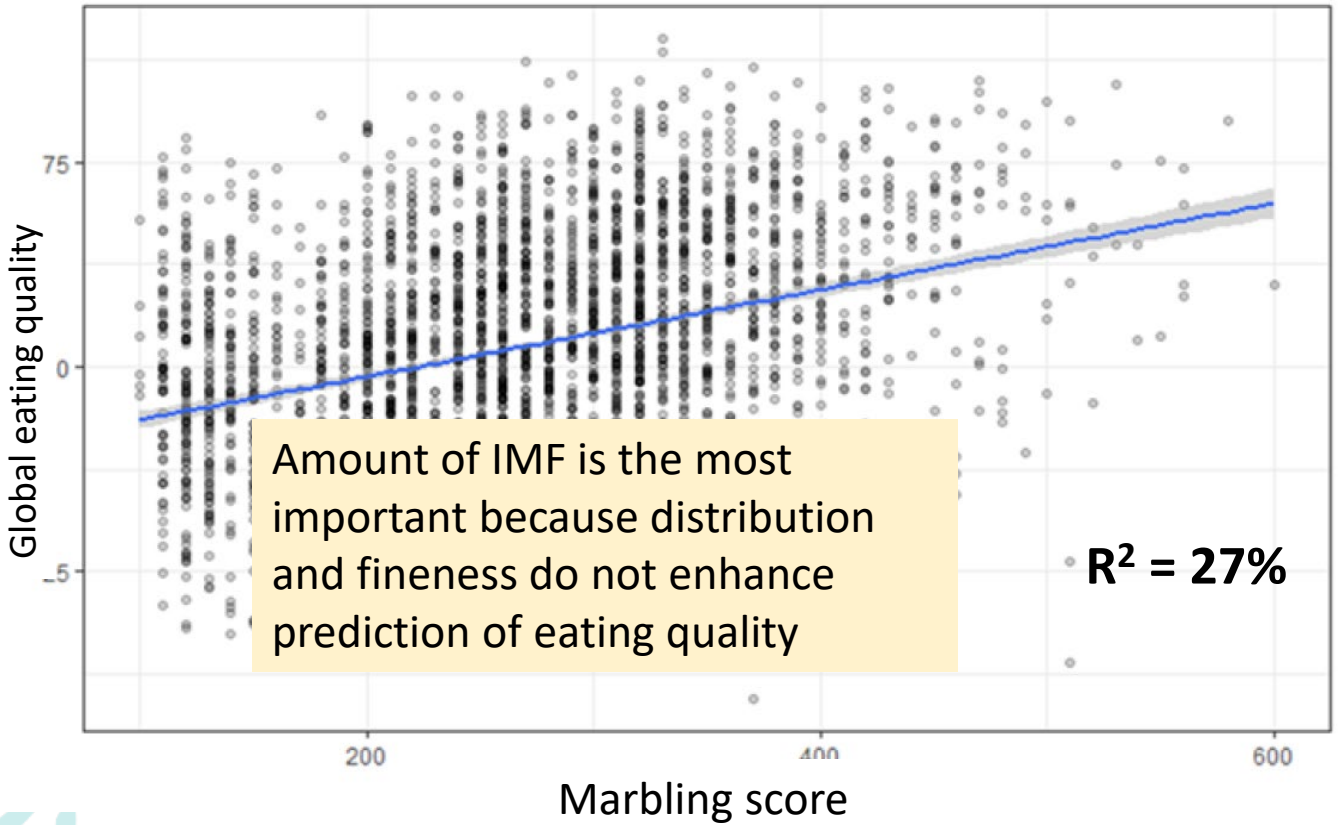
Liu et al., 2021 with 208 carcasses mainly from the Limousin breed

Marbling, an indicator of beef eating quality

- At the time of purchase, consumers prefer lean meat
- When eating blindly, consumers prefer fatter beef because intramuscular fat positively affects flavour liking, juiciness and tenderness (Harper *et al.,* 2003 ; Choi *et al.,* 2019)

Normand et al., 2017

Relationship of marbling with eating quality



Study with 3057 carcasses
Stewart et al., 2020

R^2 = 32% with IMF

Marbling and beef eating quality

CUB045[1]	MQ4 score = 0.024***marbling+50.32 (R^2 = 0.37)
STA045[2]	MQ4 score = 0.028***marbling+43.08 (R^2 = 0.45)
STP045[3]	MQ4 score = 0.032***marbling+39.95 (R^2 = 0.50)
OYS036[4]	MQ4 score = 0.012***marbling+60.43 (R^2 = 0.19)
BLD096[5]	MQ4 score = 0.011***marbling+44.36 (R^2 = 0.07)
RMP131[6]	MQ4 score = 0.006***marbling+43.62 (R^2 = 0.02)
KUN066[7]	MQ4 score = 0.011***marbling+37.25 (R^2 = 0.08)
OUT005[8]	MQ4 score = 0.009***marbling+34.67 (R^2 = 0.05)
EYE075[9]	MQ4 score = 0.006***marbling+34.63 (R^2 = 0.02)
CHK074[10]	MQ4 score = 0.020***marbling+48.61 (R^2 = 0.30)

Liu et al., 2021

[1]CUB045, M. longissimus thoracis; [2]STA045, M. longissimus thoracis et lumborum, anterior striploin piece; [3]STP045, M. longissimus thoracis et lumborum, posterior striploin piece; [4]OYS036, M. infraspinatus; [5]BLD096, M. triceps brachii caput longum; [6]RMP131, M. gluteus medius; [7]KNU066, M. rectus femoris; [8]OUT005, M. biceps femoris; [9]EYE075, M. semitendinosus; and [10]CHK074, M. semispinalis capitis.

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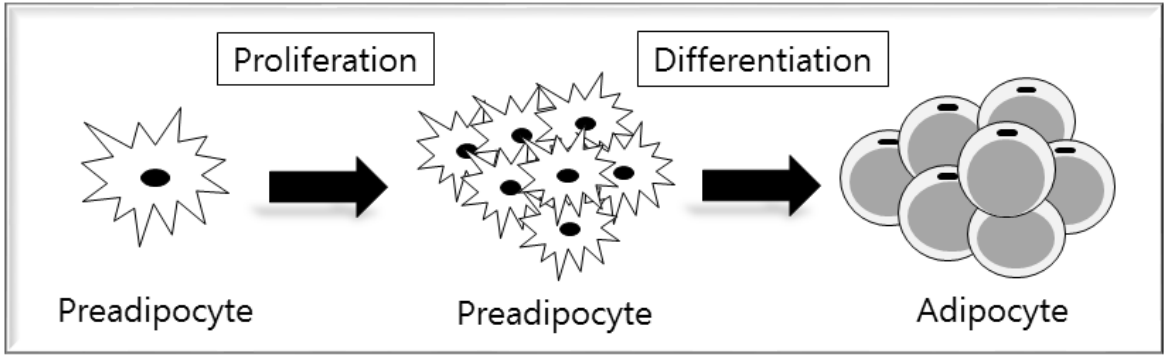
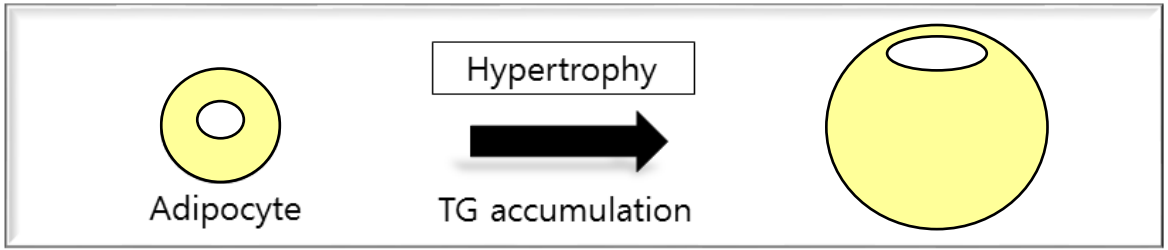
Deposition of fat tissues

Step 1: Hyperplasia: increase in adipocyte numbers



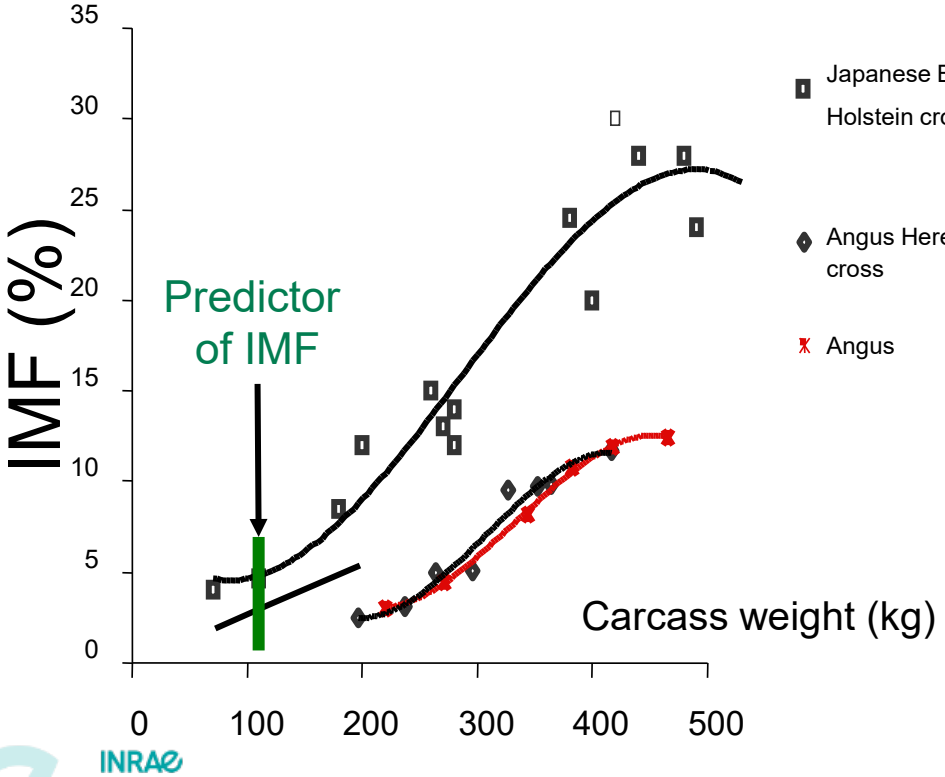
A-FABP (Adipocyte Fatty Acid Binding Protein) is a marker of adipocyte number (Jurie et al., 2017).

Step 2: Hypertrophy: increase in adipocyte size due to triacylglycerol (TG) accumulation



Park et al., 2018

The ‘starting’ value of marbling is crucial



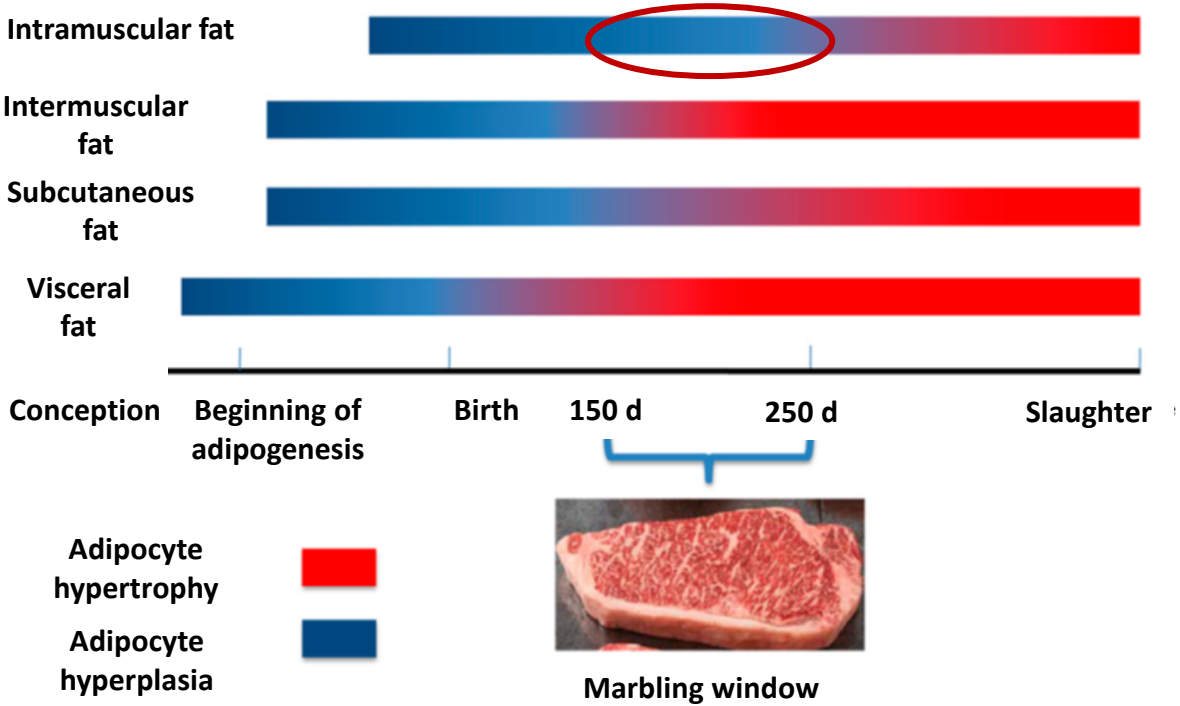
START 2 vs 4 %

END 12 vs 27%

Factor of 2 is huge at the end (Δ13% vs 2%)

Reviewed by Pethick et al., 2007

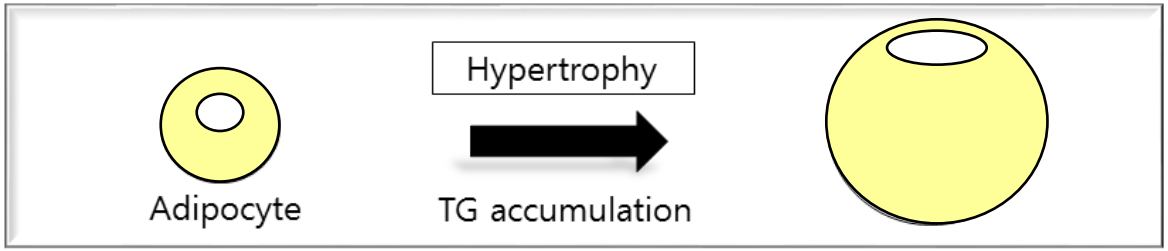
Hyperplasia during the foetal life and the « marbling window »

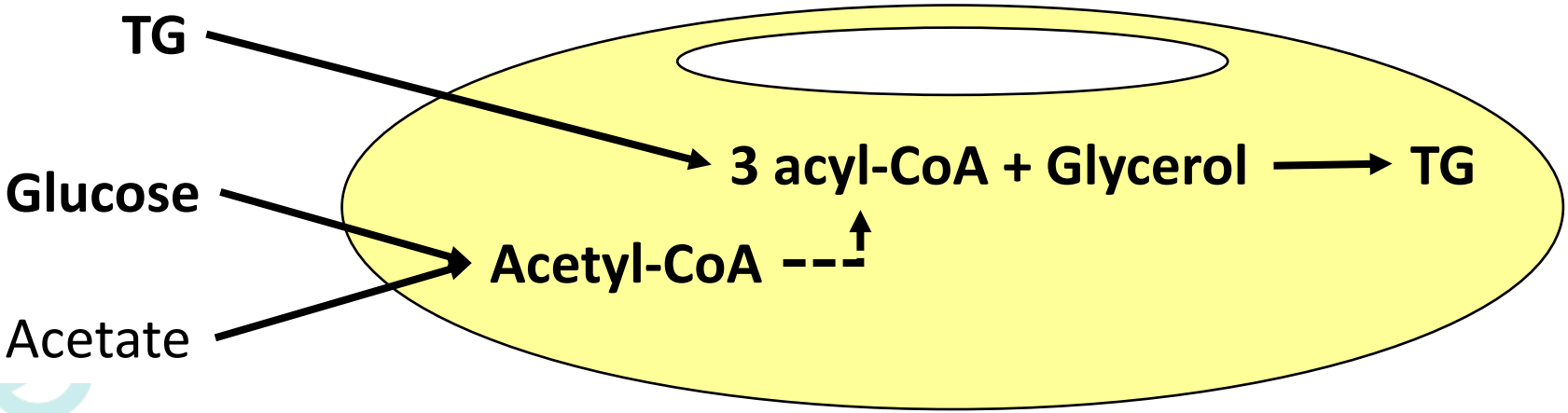


Du et al., 2013

Hypertrophy: increase in adipocyte size due to TG accumulation

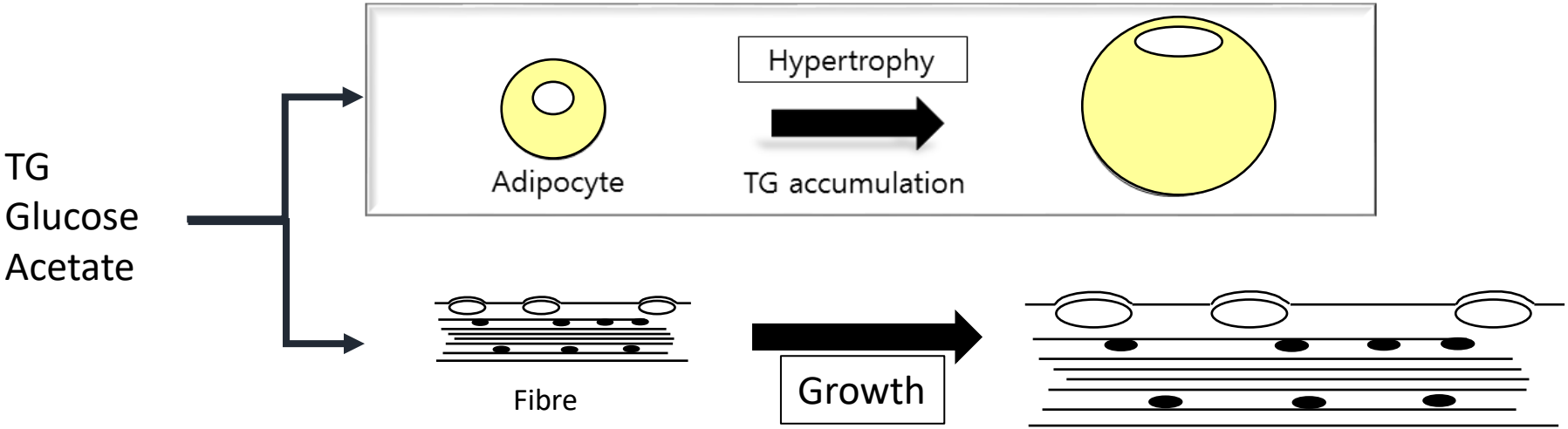
Step 2: Hypertrophy: increase in adipocyte size due to triacylglycerol (TG) accumulation





Hypertrophy: increase in adipocyte size due to TG accumulation

Step 2: Hypertrophy: increase in adipocyte size due to triacylglycerol (TG) accumulation



Competition between muscular fibers and adipocytes to use nutrients

Comparison with other fat depots

- Evidence is fat depots all develop more or less at the same rate (IMF development is even early maturing in prime lambs)

- Intramuscular (marbling) = IMF% = $100 \times \frac{\text{Wt muscle fat}}{\text{Wt muscle fat + muscle}}$

- But, IMF% is controlled by both muscle and fat growth.
- Therefore, IMF% is late maturing

- Consequently, in young animals and highly muscled breeds, muscle and fat growth together and % fat stays the same.

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1. Definition of marbling and relevance for consumers

2. Biological determinism of marbling

3. On farm strategies to increase marbling
   (genetic, sex, age, nutritional and management factors)

4. How to better value IMF

Feeding during the «marbling window»

Experimental design:

- **American** context
- **Early weaning (105-115** days)
- Followed by energy supplementation
- Feeding: **cereals, soya, distillers grains**
- Breeds: **Angus** and **Hereford x Angus**
- Animal type: young bulls, steers and heifers

Schoonmaker et al., 2002; Scheffler et al., 2014; Smith et al., 2015; Nayananjalie et al., 2015; Koch et al., 2018

Effects:

- Marbling: **+++** (between 59 and 127)
- Fat thickness: **=** (on the 12th rib)

Impact of the diet during finishing on lipogenesis

Forages

Concentrate

Feeding

Volatile fatty acids

Acetate

Propionate

RUMEN

glucose

Subcutaneous lipogenesis and others

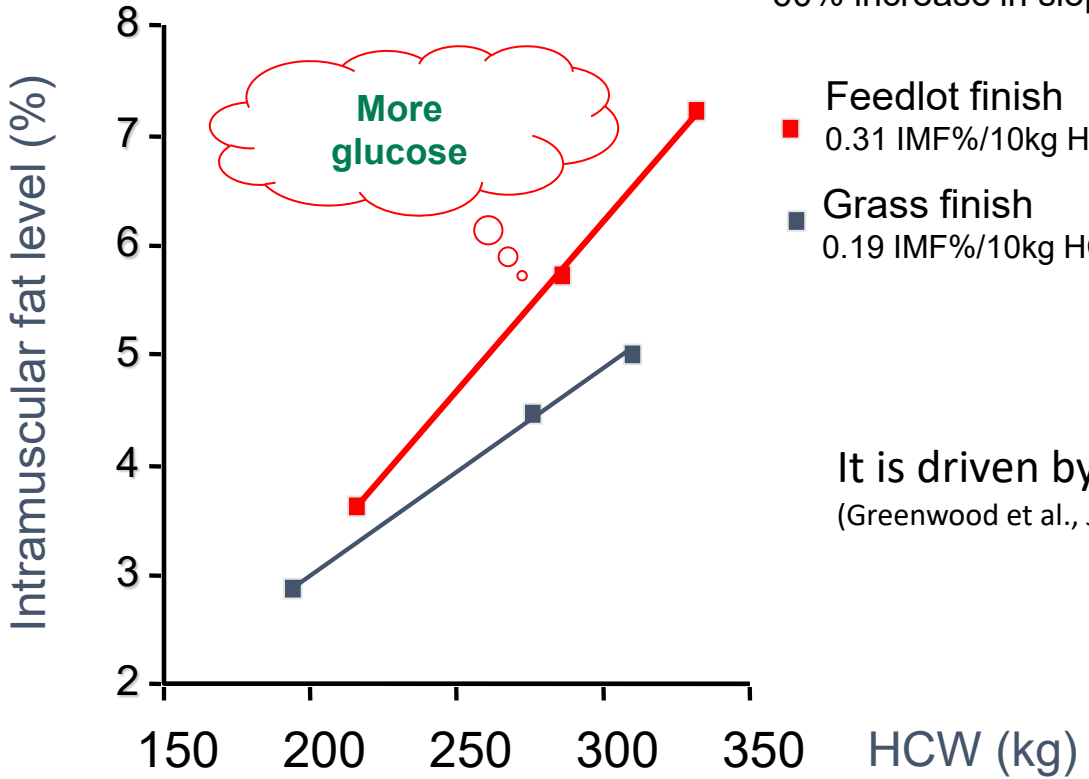
Intramuscular fat lipogenesis

Lipogenesis

INRAE

Adapted from Lake et al., 2009

Grass *vs* grain finishing in beef cattle



60% increase in slope

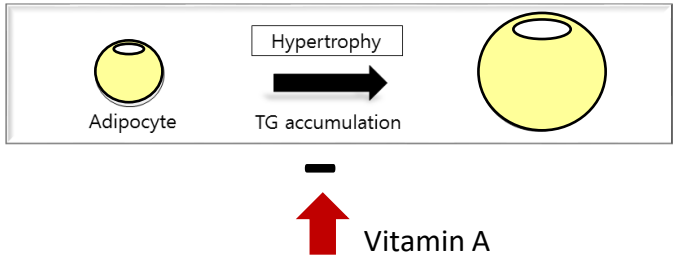
Feedlot finish
0.31 IMF%/10kg HCW

Grass finish
0.19 IMF%/10kg HCW

It is driven by energy intake only
(Greenwood et al., J. Anim. Sci. 2015.93:4132–4143)

Reviewed by Pethick et al., 2007

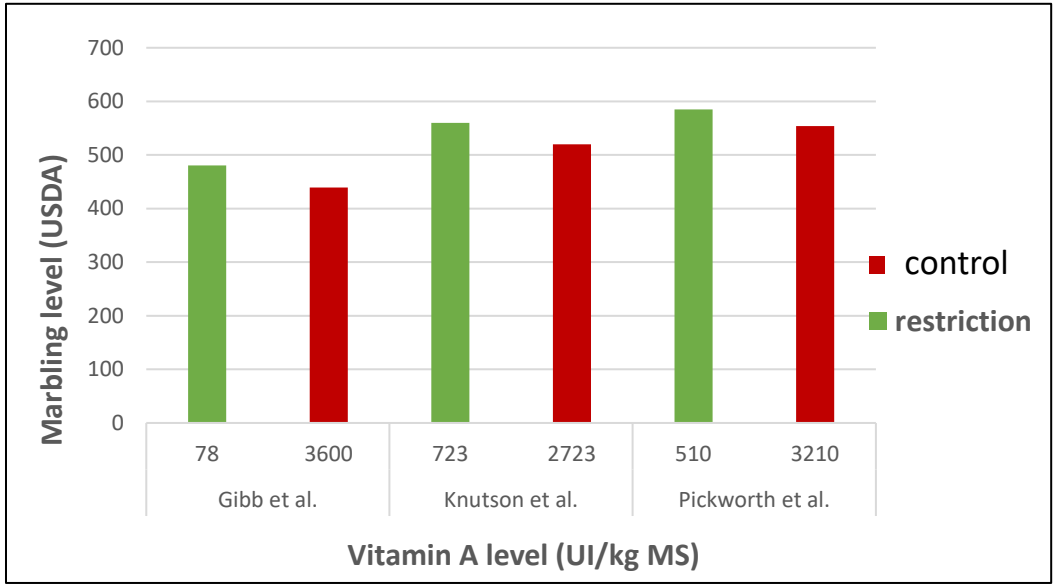
Impact of the vitamin A level on marbling level



Therefore, decrease in Vitamin A increases marbling level.

NB: Vitamin A reduction under recommended levels could have an impact on animal health (cattle can go blind).

Vit. A inhibits TG accumulation during the finishing period



More recent research in beef cattle has shown Vit A injection at birth or there about results in more IMF by promoting preadipocyte formation (Maciel et al (2022) Meat Science 184, 108676, Yu et al (2022) Meat Science 191, 108847). Some debate as to whether other fat depots also increase ?

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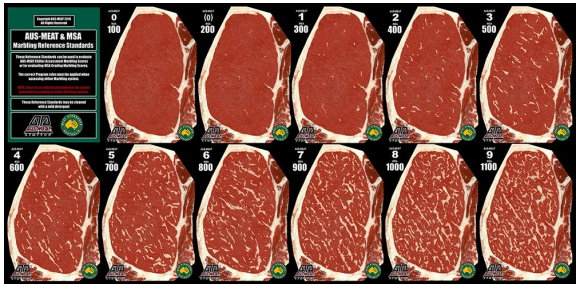
Replacement methods: a grid *vs* a chemical assay

Intramuscular fat level
(reference method in labs)

Replaced by

USDA grid

AUS-MEAT & MSA grids
(Meat Standards Australia)



UNECE

USDA & CANADIAN grids

CANADA	MARBLING SCORE	USA
Canada Prime	Abundant	USDA Prime
	Moderately Abundant	
	Slightly Abundant†	
Canada AAA	Moderate	USDA Choice
	Modest	
	Small†	
Canada AA	Slight†	USDA Select
Canada A	Trace	USDA Standard
	Practically Devoid	

The new French grid

Marbling allows prediction of meat sensory quality to replace IMF

Replacement methods: a device instead of a grid

USDA grid

AUS-MEAT & MSA grids (Meat Standards Australia)

UNECE

USDA & CANADIAN grids

CANADA	MARBLING SCORE	USA
Canada Prime	Abundant	USDA Prime
	Moderately Abundant	
	Slightly Abundant†	
Canada AAA	Moderate	USDA Choice
	Modest	
	Small†	
Canada AA	Slight†	USDA Select
Canada A	Trace	USDA Standard
	Practically Devoid	

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Replaced by

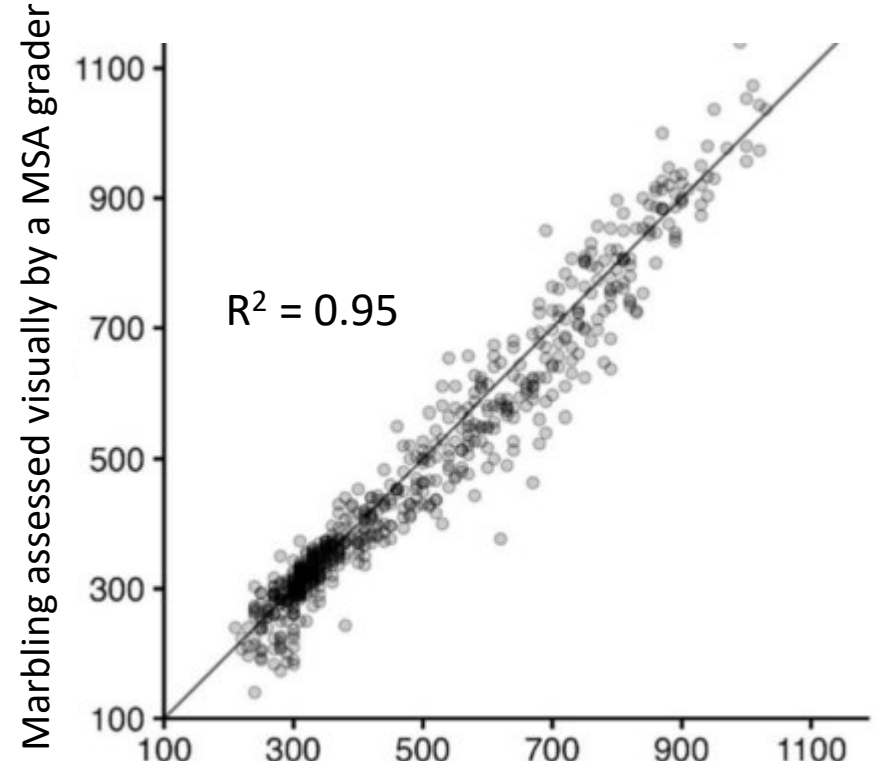
Marbling can be measured using new devices

But training devices on graders can be inaccurate

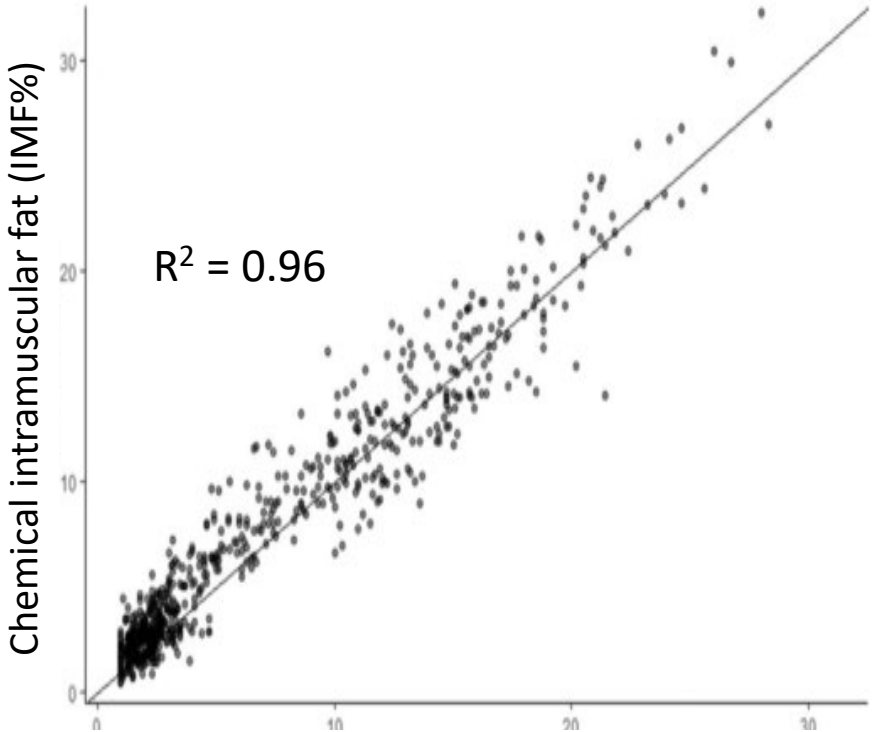
NIR is promising because it is non-invasive and easy to use

Frontmatec Instruments Q-FOM Beef

Prediction using the Q-FOM™ camera



Prediction of marbling using the Q-FOMT^{M} camera



Prediction of IMF% using the Q-FOMT^{M} camera

Stewart et al., 2024. Meat Science, 213, 109500

Summary and conclusions

1. **Intramuscular fat (IMF) and therefore marbling contribute to eating quality**

- However, contribution of IMF and marbling depend on the cut with a minimum required
- Carcass fatness is poorly related to marbling and therefore to eating quality

2. **Two processes are involved in IMF deposition: hyperplasia and hypertrophy**.

- Hyperplasia has a strong genetic determinism and can be influenced by feeding during early life ("marbling window").
- Hypertrophy is associated to growth and long finishing (diet type, vitamin A restriction).

3. **Research is conducted on measurement and value of IMF and marbling.**

- So far, it was easier for the industry to use marbling rather than IMF
- Marbling or IMF can be better measured using portable devices (NIR, image analysis)
- Farmers' incomes should depend on IMF/marbling, or better on eating quality

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Thank you for your attention