



ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

*Department of Agricultural
and Food Sciences*



*The 75th EAAP Annual Meeting
Session 86. Tailored housing and management
strategies from incubation to slaughter house, for
poultry*

Classification, Evaluation, and Control of Myopathies in the Broiler Chicken

Massimiliano Petracci, Martina Bordini, Marco
Zampiga, Federico Sirri & Francesca Soglia

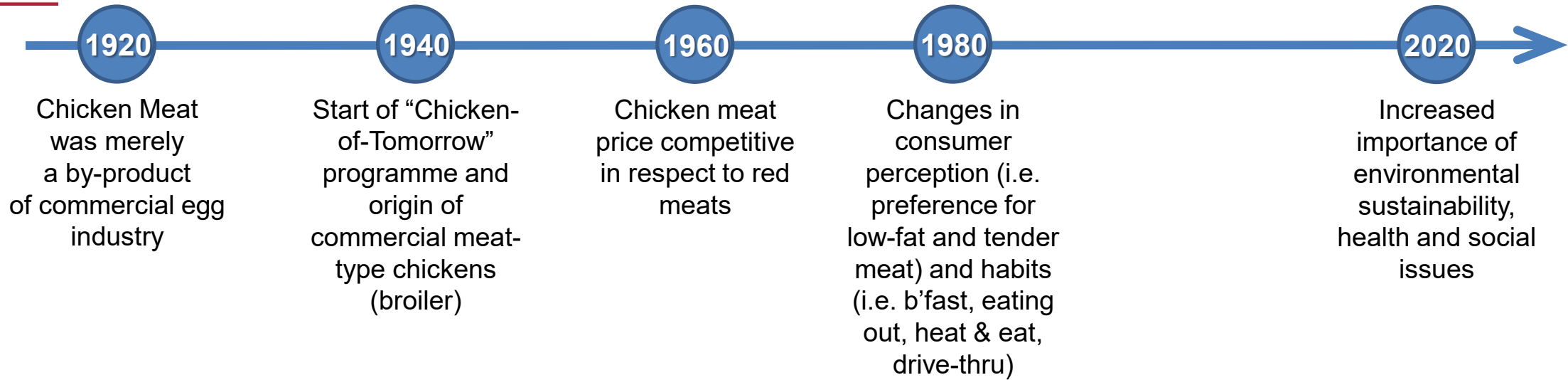
September 4th, 2024

OUTLINE

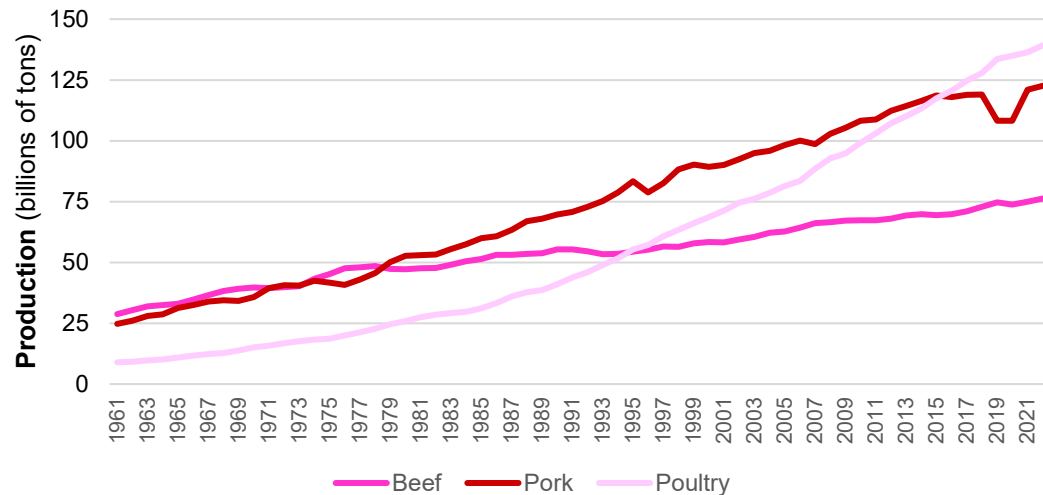
- **Occurrence of Broiler Growth-related Abnormalities and Classification Criteria**
- Possible Causative Mechanisms Underlying Growth-related Abnormalities
- Strategies to Mitigate the Incidence of Growth-related Abnormalities in Broilers
- Conclusions



Development of the Modern Broiler Industry

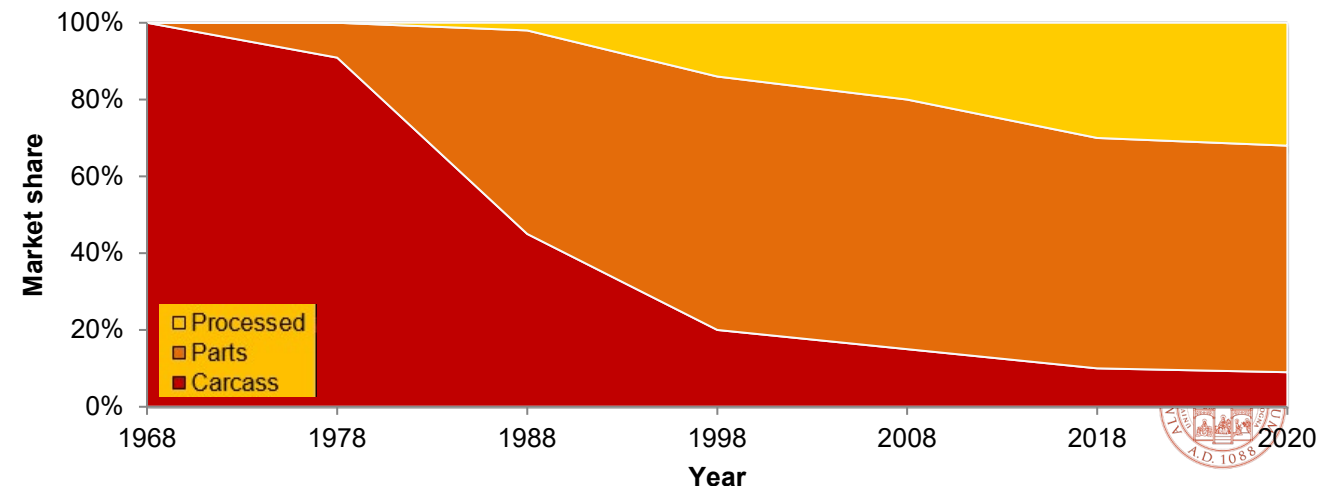


Evolution of Meat Production



Data source: Faostat

Evolution of Chicken Meat Marketing



Data source: National Chicken Council

Improvement of Broiler Performances

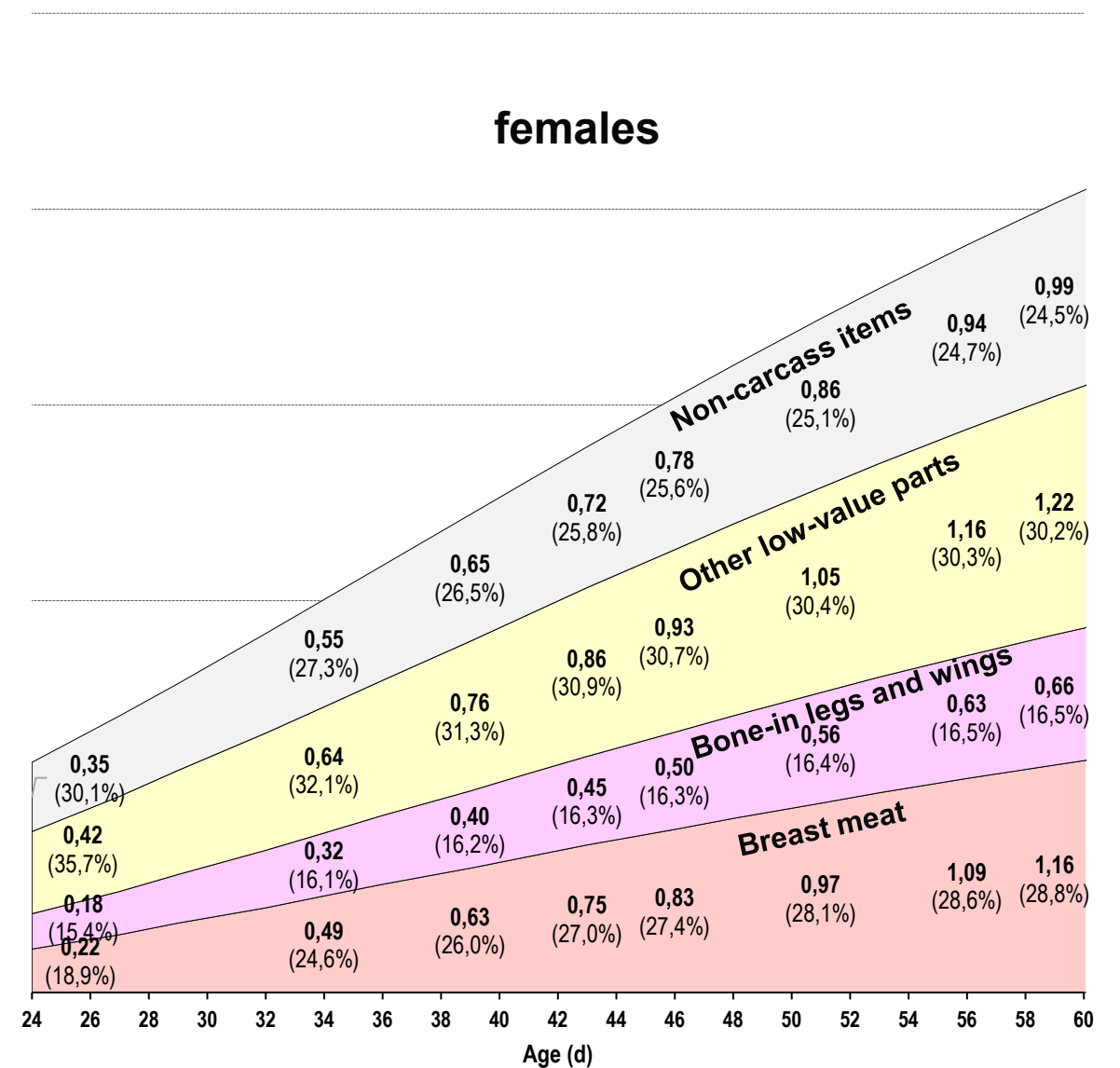
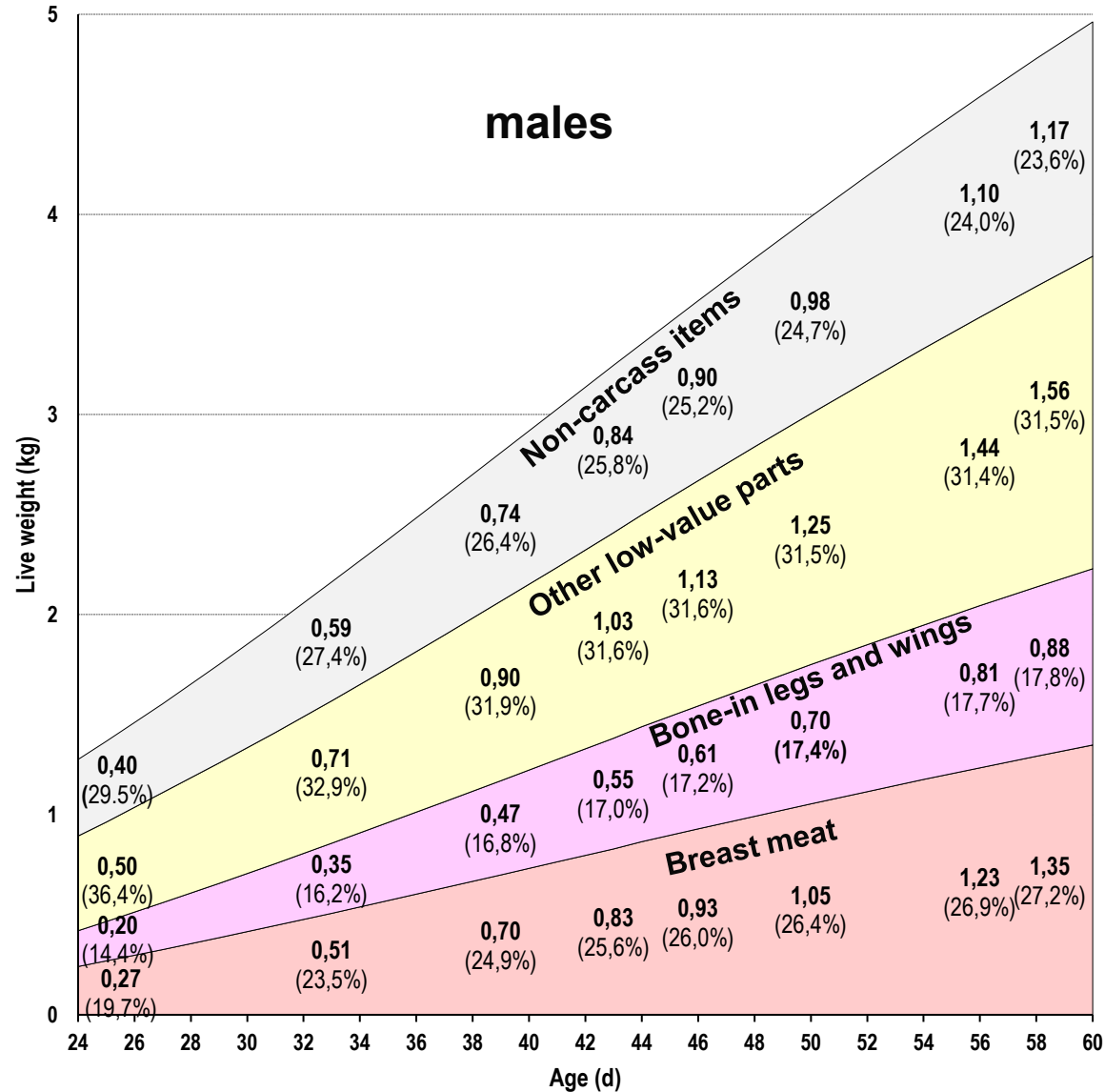
Year	Hybrid	BW (kg)	Age (d)	Growth rate (g/d)	FCR (g/g)	Carcass yield (%)	Breast meat (g)	Breast yield (%)
1957 ¹	ACRBC	1,715	84	20	3.57	65.2	207	12.1
2007 ²	Ross 308	2,768	41	66	1.68	72.5	536	19.4
2014 ²	Ross 308	2,811	40	69	1.63	73.1	627	22.3
2022 ²	Ross 308	2,774	38	72	1.44	73.3	696	25.1

¹Havenstein et al. 2003 Poult Sci 82:1509

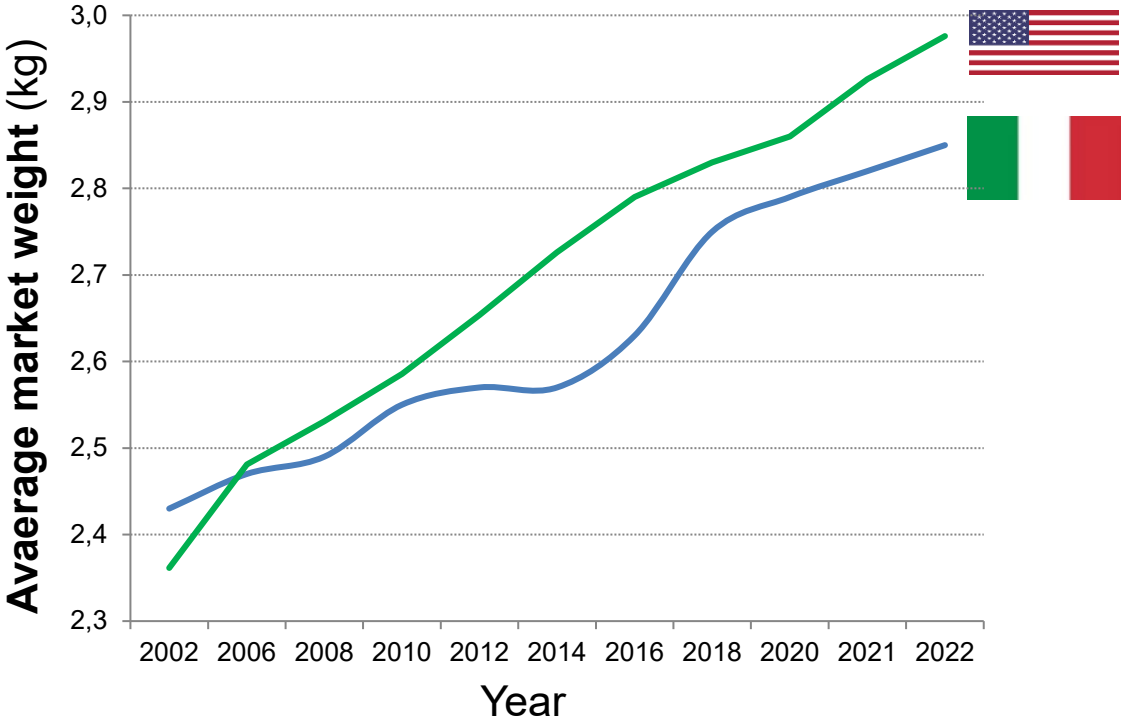
²Ross 308 Broiler Performance Objectives



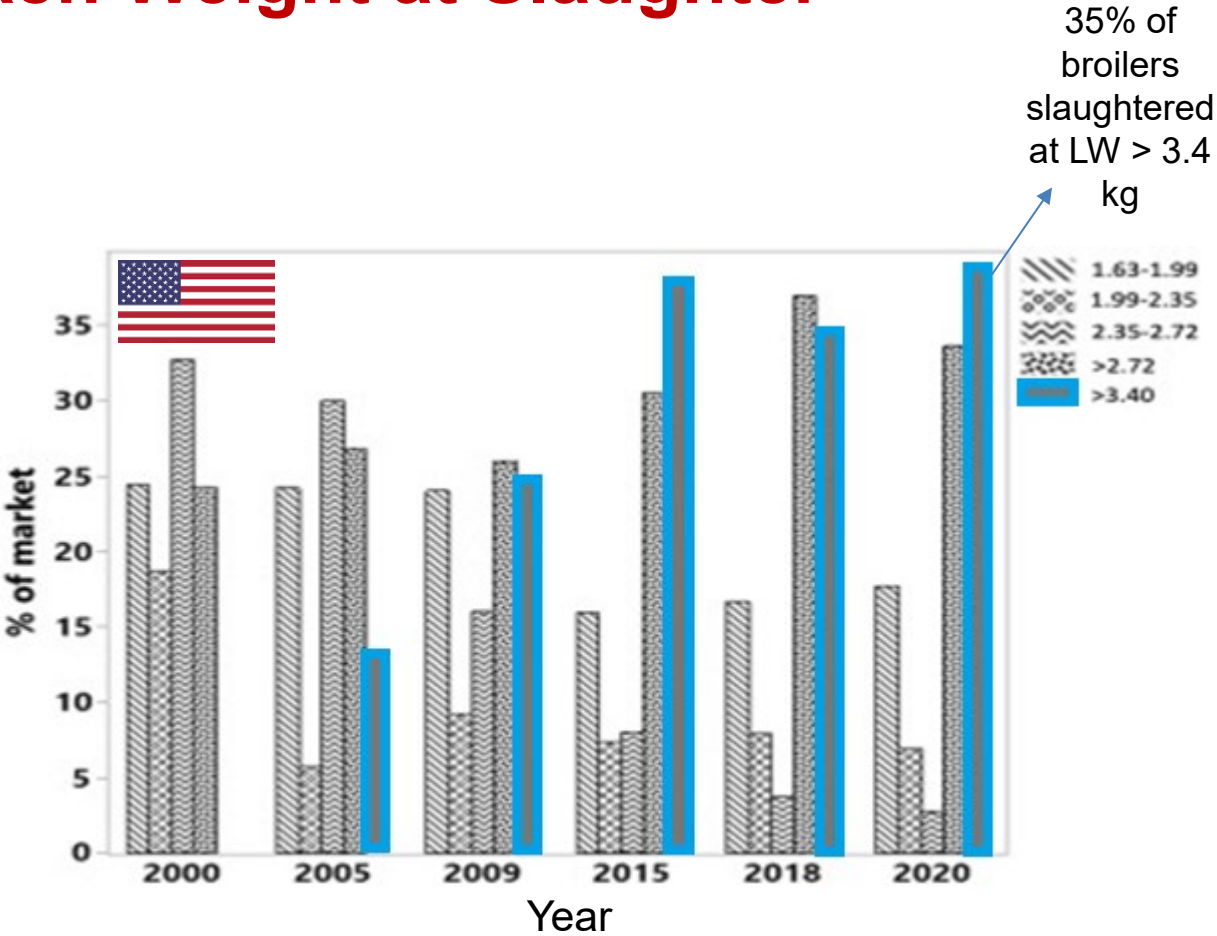
Increased (breast) Meat Yield through Increased Slaughter Age



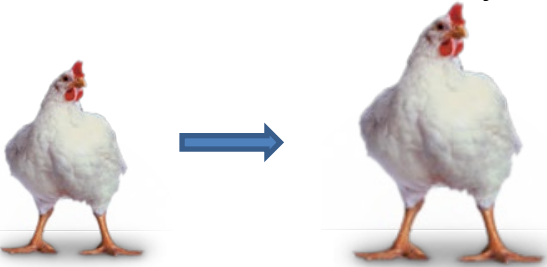
Increase of Live Chicken Weight at Slaughter



Data source: Agri-ISTAT and National Chicken Council



Maharjan et al. (2021) Animal 15:100284



Main Breast Muscle Abnormalities in Broilers



1985 Deep Pectoral Myopathy

Deep Pectoral Myopathy: A Penalty of Successful Selection for Muscle Growth

WALTER G. SILLER

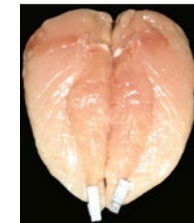
*Agricultural and Food Research Council, Poultry Research Centre,
Roslin, Midlothian EH24 9PS, Scotland*



1998 Pale-Soft-Exudative-like

**BIOPHYSICAL BASIS OF PALE, SOFT, EXUDATIVE (PSE)
PORK AND POULTRY MUSCLE: A REVIEW**

M.B. SOLOMON¹, R.L.J.M. VAN LAACK² and J.S. EASTRIDGE¹



2009 White Striping

104 Occurrence of white striping in chicken breast fillets in relation to broiler size. L. J. Bauermeister^{*1}, A. U. Morey¹, E. T. Moran¹, M. Singh¹, C. M. Owens², and S. R. McKee¹, ¹*Auburn University, Auburn, AL*, ²*University of Arkansas, Fayetteville*.



2012 Wooden Breast

Myodegeneration With Fibrosis and Regeneration in the Pectoralis Major Muscle of Broilers

H.-K. Sihvo¹, K. Immonen¹, and E. Puolanne¹



2015 Spaghetti Meat

**Worthwhile Operational
Guidelines & Suggestions**



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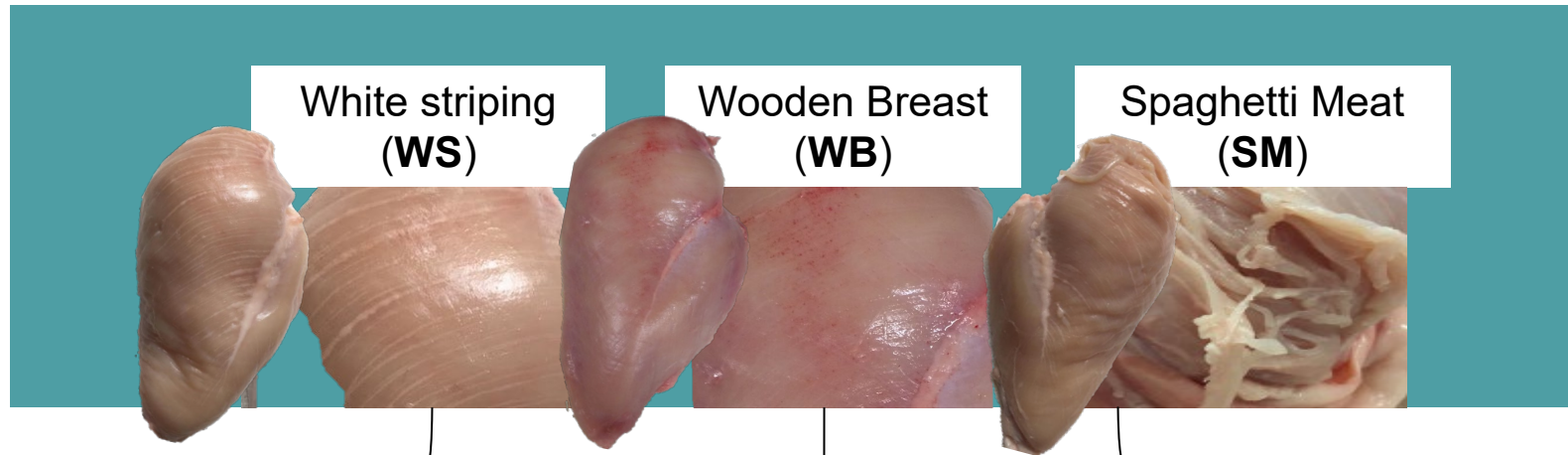


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BROILER CHICKEN MYOPATHIES IV. STRINGY/MUSHY BREAST

Growth-related Breast Abnormalities in Broilers

– Macroscopic features –



White striations of variable thickness (up to few mm) running **parallel** to the **fiber direction** on the surface of the broiler breast fillet

Region of **tough muscle fibers** within breast fillet. It can be accompanied by **out-bulging** and **pale areas** of hardened of the muscle which sometimes can be associated with the presence of **haemorrhages** and **exudate of viscous materials**

Splitting of the **muscle fibre bundles** that tend to detach one from the others, mainly in the anterior part of the fillet

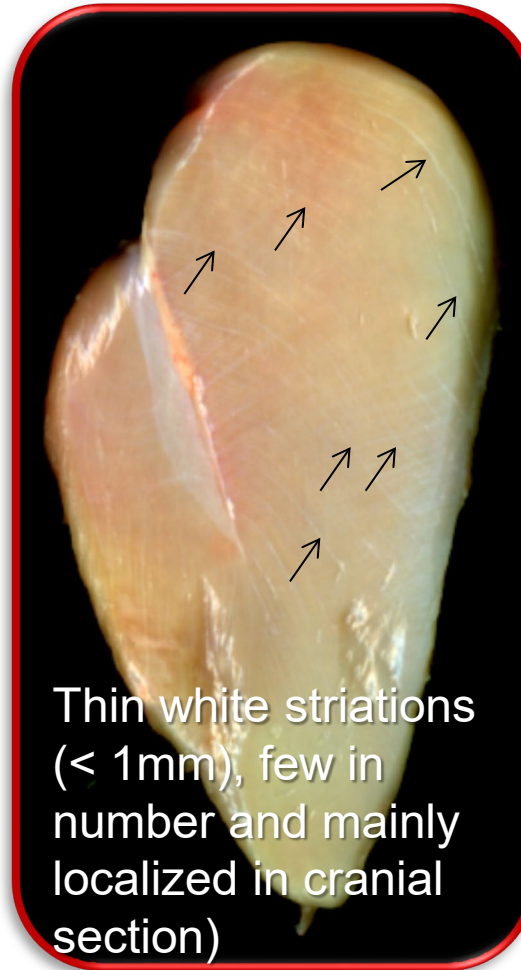


Classification Criteria for WS (3-point scale)

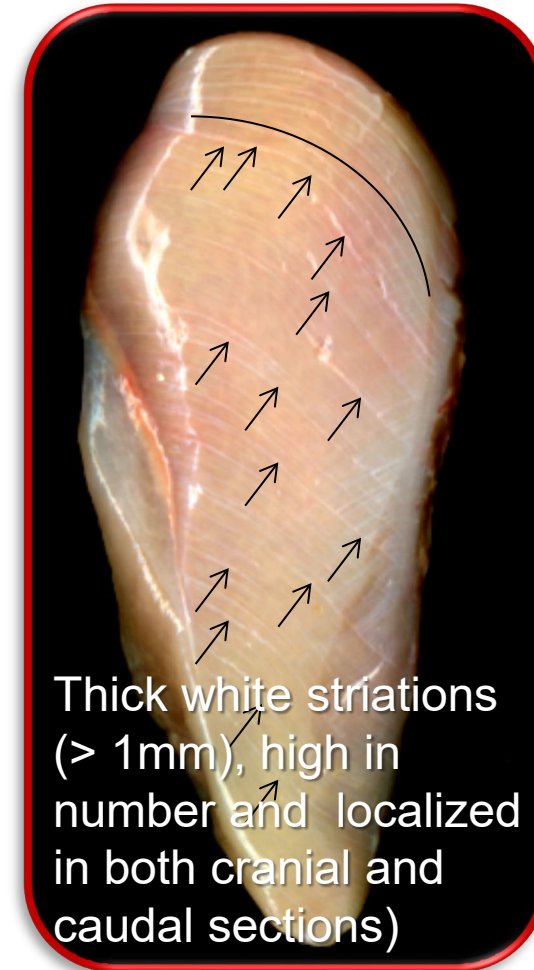
**Normal
(NORM)**



**Moderate WS
(MOD)**



**Severe WS
(SEV)**



Classification Criteria for WS (4-point scale)

Normal – No
distinct white
lines

Severe – Large white lines
(1 - 2 mm thick) very
visible on the fillet surface



Moderate – Small white
lines, generally < 1 mm
thick, but apparently
visible on the fillet
surface

Extreme – Thick white
bands (> 2 mm thickness)
covering almost entire
surface of fillet



Classification Criteria for WB (3-point scale)

**Normal
(NORM)**



**Moderate WB
(MOD)**



Moderate hardened areas especially located in the caudal part

**Severe WB
(SEV)**



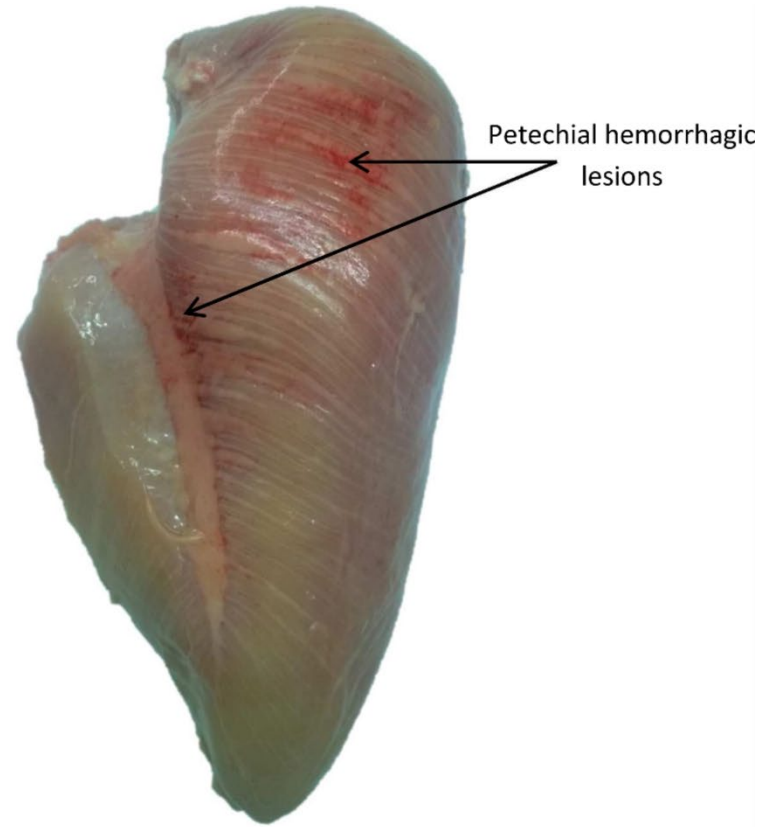
Severe hardened areas from cranial region to caudal, pale colour, and possible presence of haemorrhages and exudate of viscous materials

Classification Criteria for WB (4-point scale)

0 = fillets that were flexible throughout (normal)



Score 0



Score 2

0 = fillets that were flexible throughout (normal)

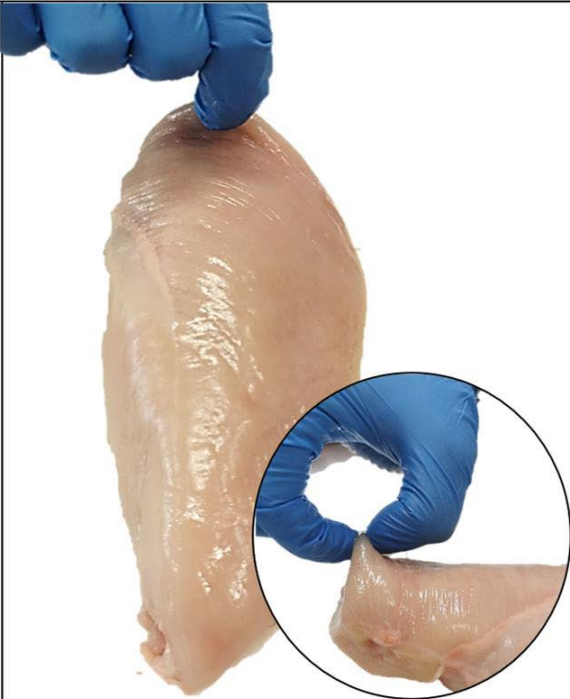
1 = fillets that were hard mainly in the cranial region but flexible otherwise (mild)

2 = fillets that were hard throughout but flexible in mid to caudal region (moderate)

3 = fillets that were extremely hard and rigid throughout from cranial region to caudal tip (severe)



Classification Criteria for SM (3-point scale)

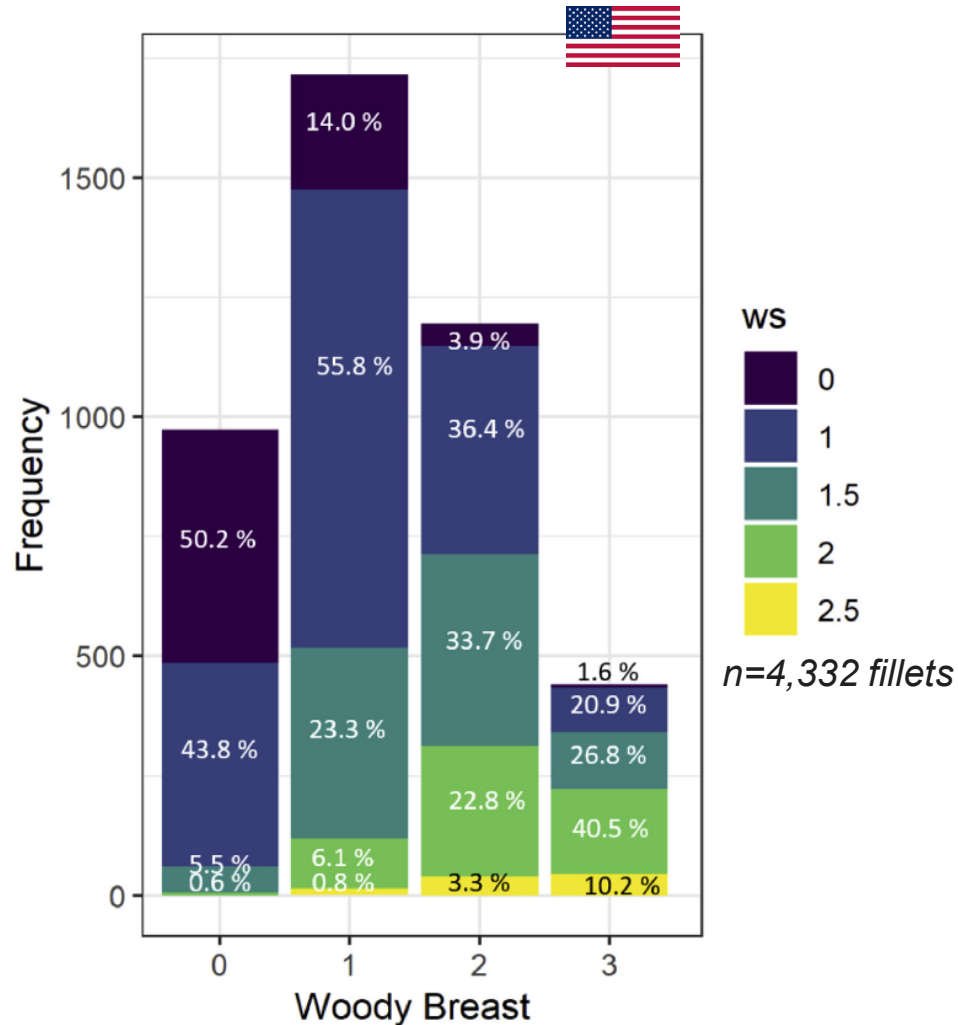
		
SCORE 0 Normal	SCORE 1 Moderate	SCORE 2 Severe
<i>P. major</i> muscle shows normal consistency and does not display any sign of muscular lesion	<i>P. major</i> muscle does not show any evident superficial laceration but exhibits soft and stringy texture, perceivable by pinching the muscle on its cranial surface	<i>P. major</i> muscle shows extensive superficial lacerations on its cranial and/or caudal surface. Muscle fibers bundles separate from each others, resembling spaghetti pasta



Growth-related Breast Abnormalities in Broilers

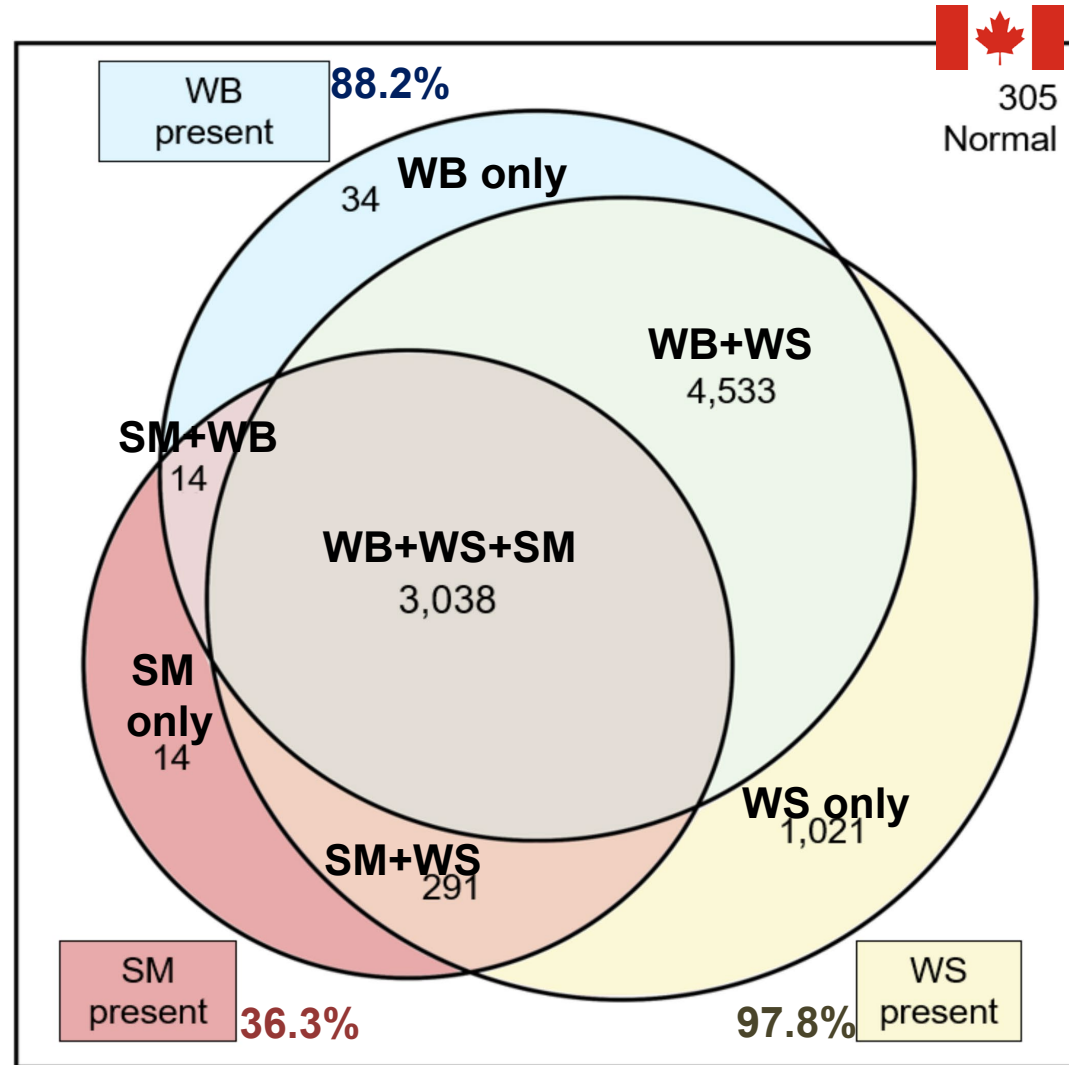
– Reciprocal association –

Woody Breast & White Stripping (WS)



Aguirre et al. (2020) Poult Sci 96:3723

White Stripping (WS), Woody Breast & Spaghetti Meat (SM)



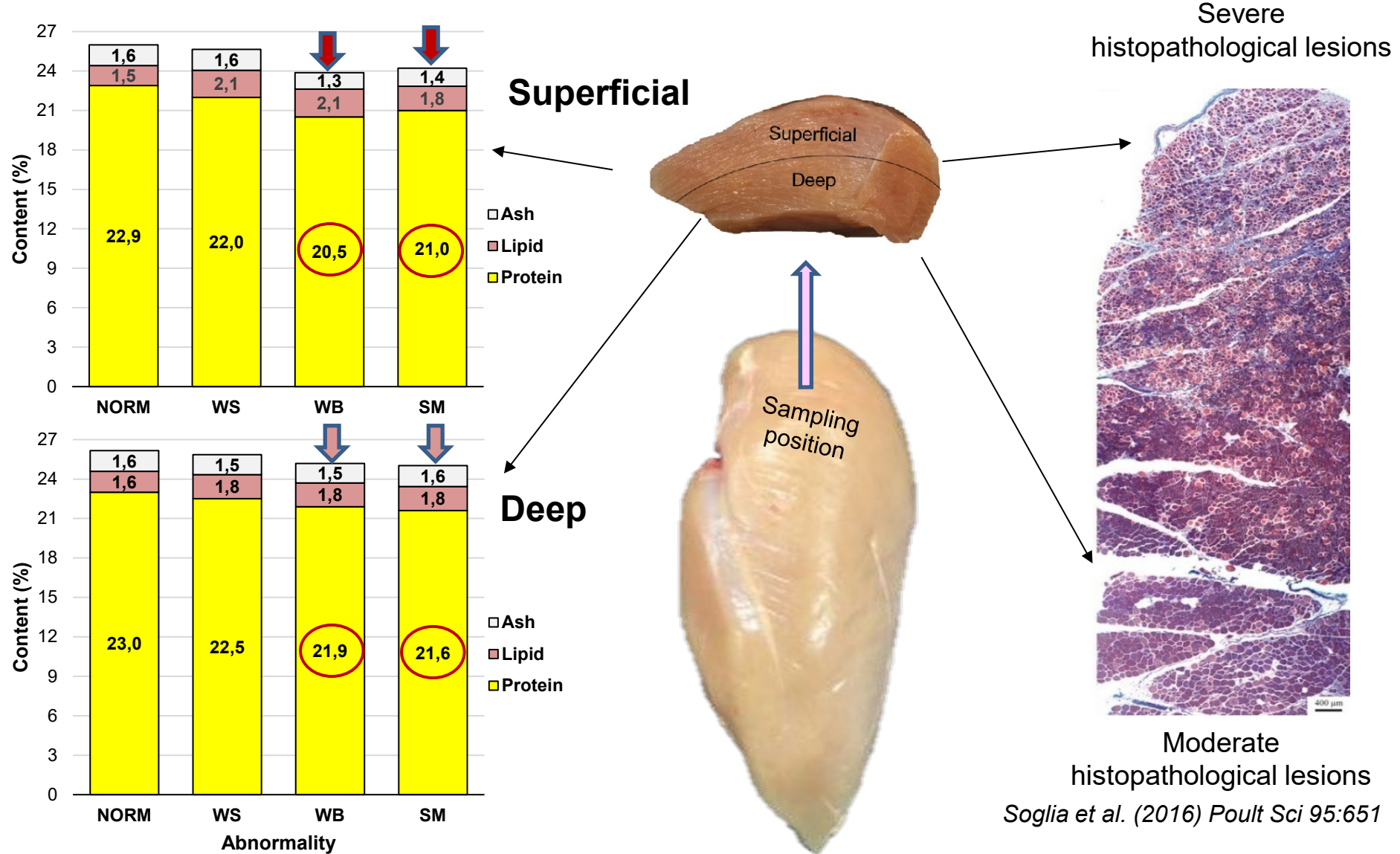
Che et al. (2022) PLoS ONE, e0267019



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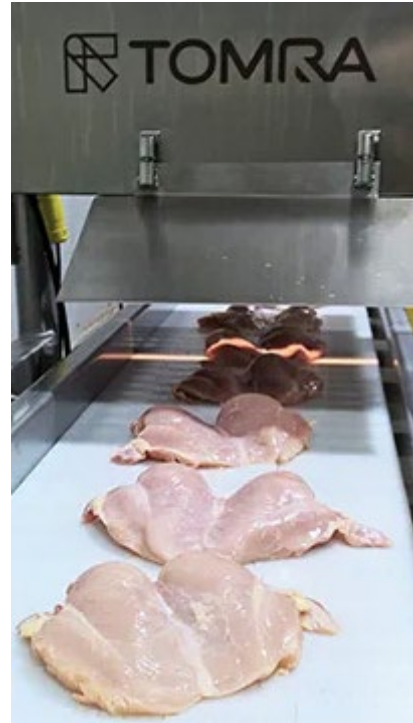
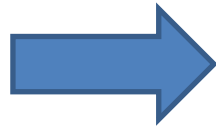
Consequences of Growth-related Abnormalities

- Large reduction in meat protein content -



Development of On-line Grading Systems to Detect Wooden Breasts

Increased need of manual sorting to discard affected breast fillets



Main variation in the NIR spectra are attributed to differences in protein and water contents

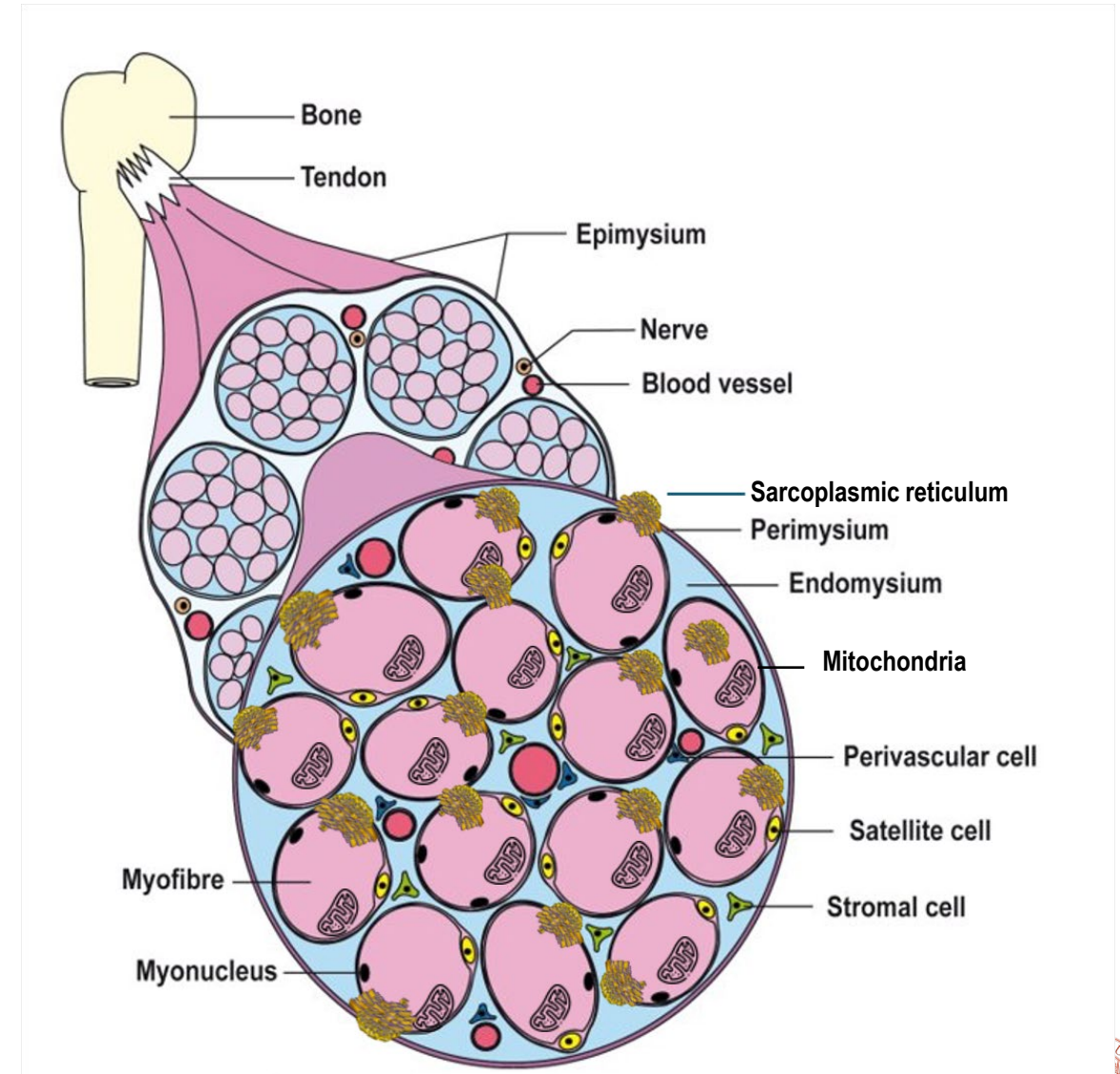
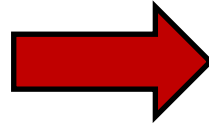
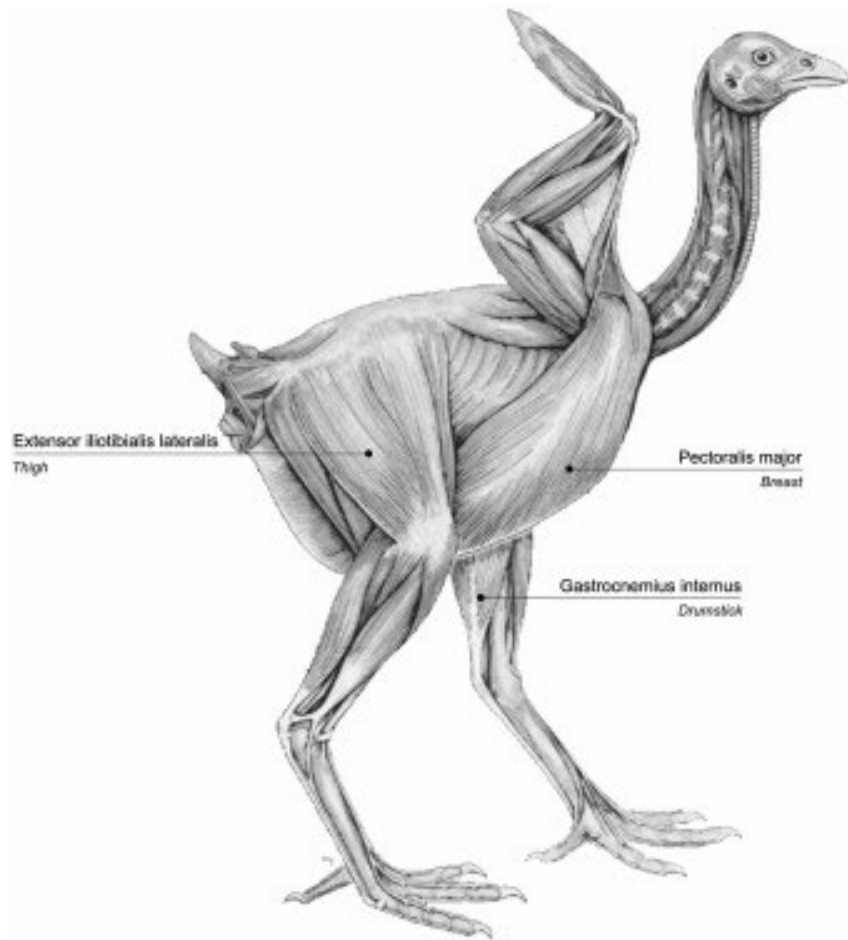


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Avian Muscle Architecture



Source: Baldi et al. (2021), *Poult Sci.* 100:1299

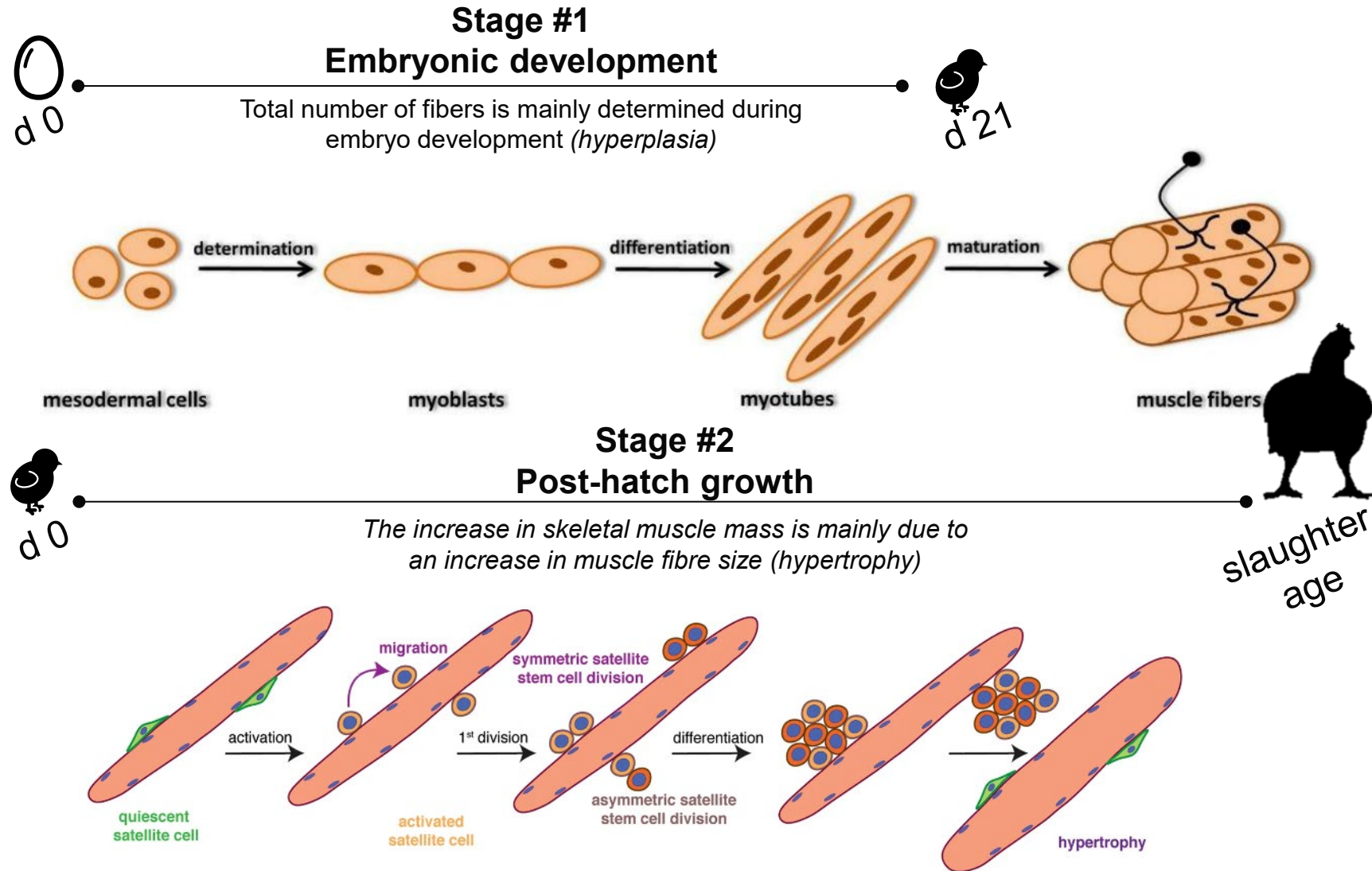
Source: Trenz et al. (2011), doi: 10.1007/978-1-61779-322-6_10



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Avian Muscle Development and Growth

– Embryonic and post-hatch stages –

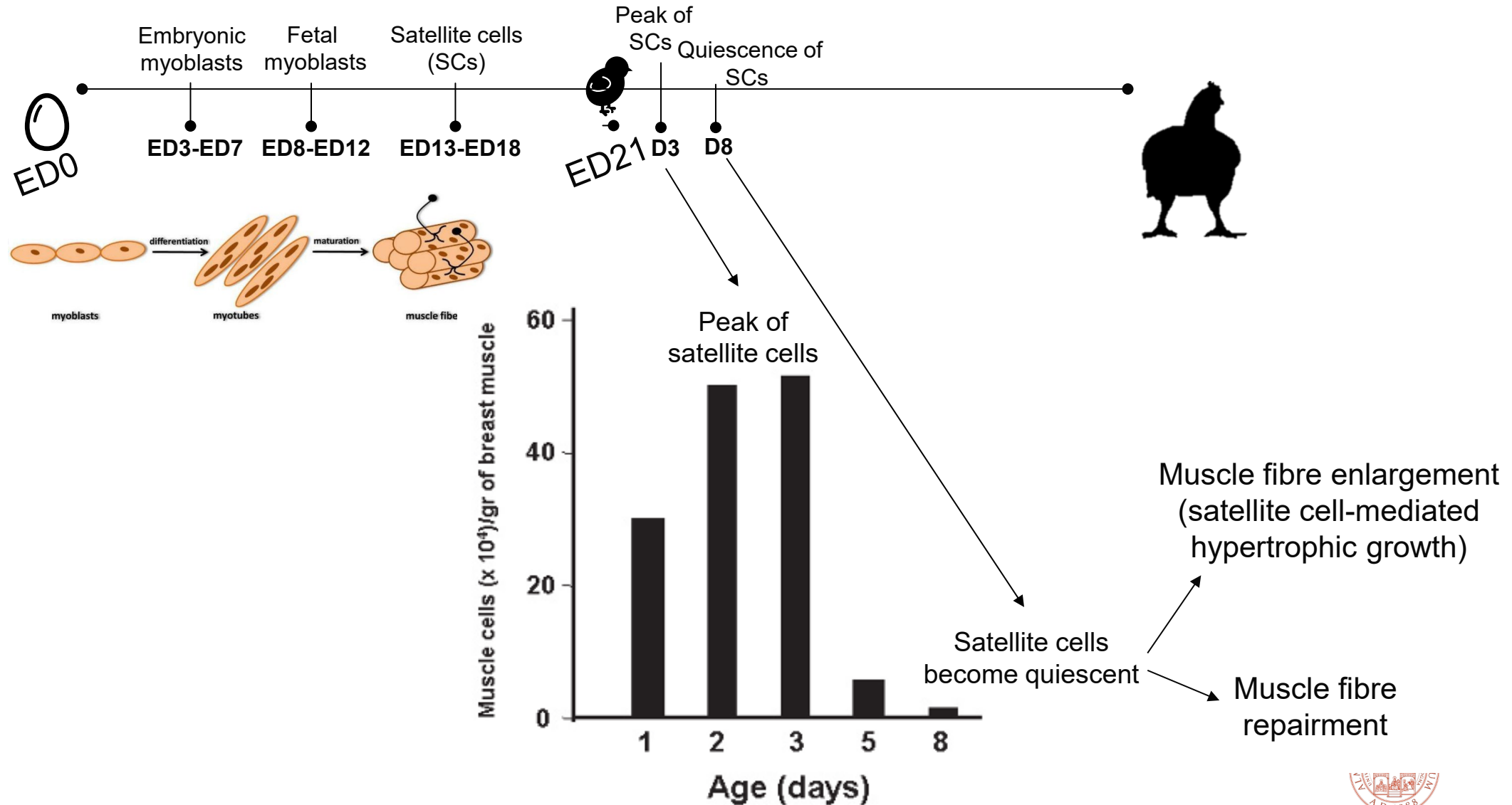


Satellite cells are not only responsible for muscle repair and regeneration, but also for hypertrophic growth: they fuse to radially and longitudinally growing muscle fibers and contribute new muscle cell nuclei (myonuclei)



Avian Muscle Development and Growth

– Embryonic and post-hatch stages: satellite cell proliferation –

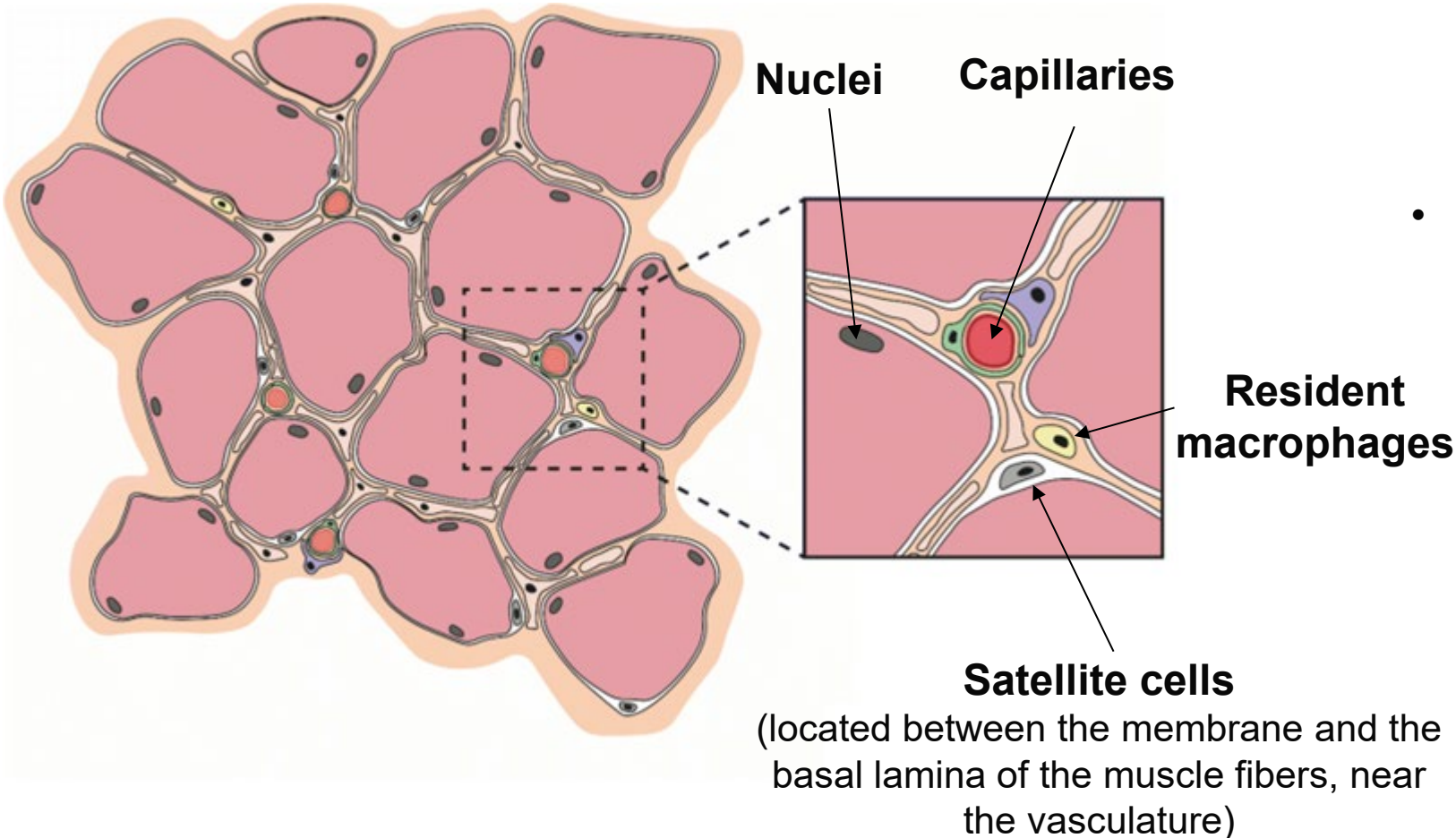


Avian Muscle Development and Growth

– Importance of extracellular environment (niche) for satellite cells –

Interstitial spaces

(between fibres and fibre bundles)



- Space between fibre bundles (perimysium) and individual muscle fibres (endomysium) is necessary for liveability of the muscle
- Satellite cells require appropriate niche environment and vascularization for muscle fibre enlargement and regeneration



Growth-related Breast Abnormalities in Broilers

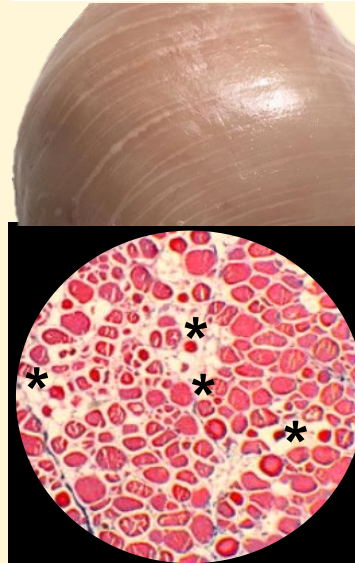
– Microscopic features –

Common histological features

- Loss of normal muscle **architecture**
- **Abnormal fibres** exhibiting **rounded profile**, **nuclear internalization**, **degeneration**, necrosis up to lysis and concurrent **regenerative processes** (small-caliber regenerative fibers intermingled to abnormal ones having large caliber)
- **Compromised** perimysial and endomysial **connective tissue**, fat and inflammatory cells infiltration

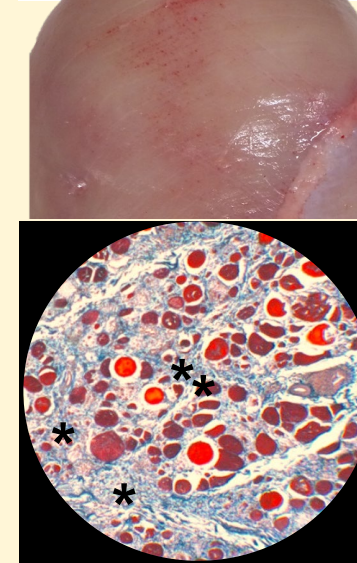
Peculiar features

White striping
(WS)



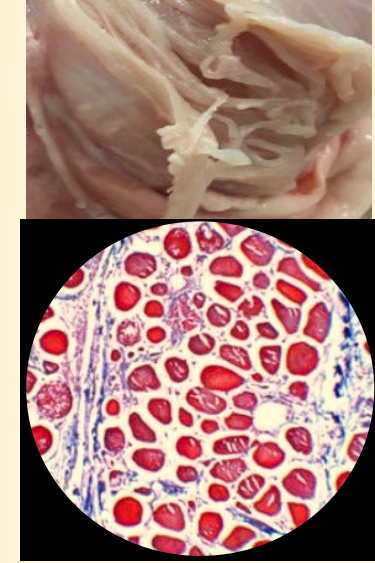
Abnormal deposition of **adipose tissue** at perimysial level (lipidosis)

Wooden Breast
(WB)



Proliferation and thickening of the **perimysial network** (fibrosis)

Spaghetti Meat
(SM)

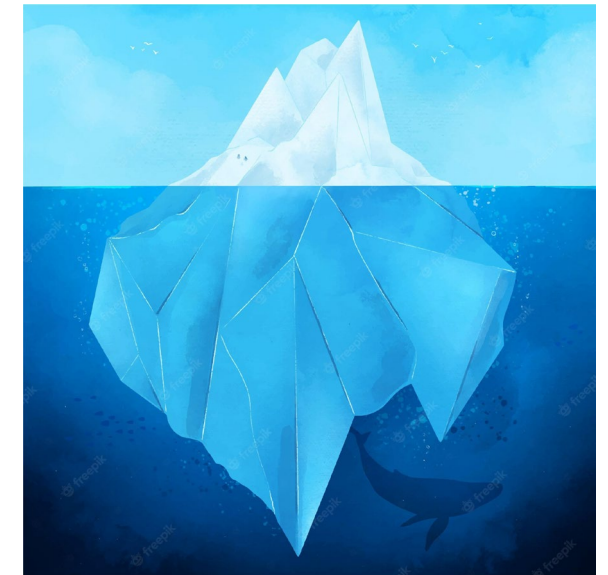
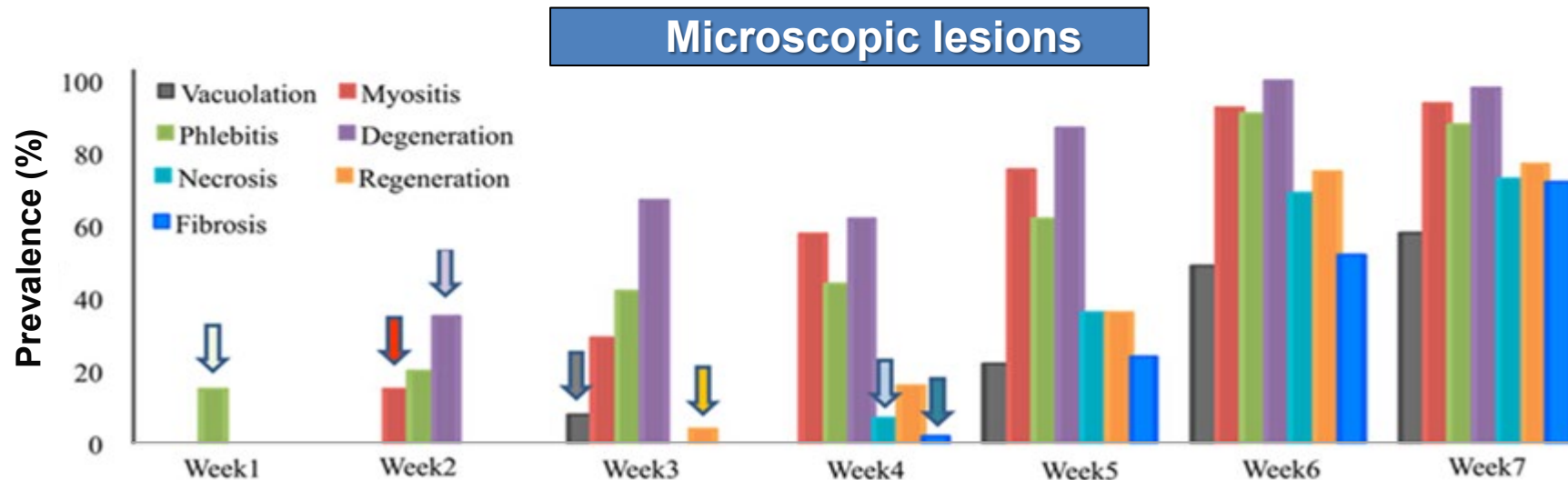
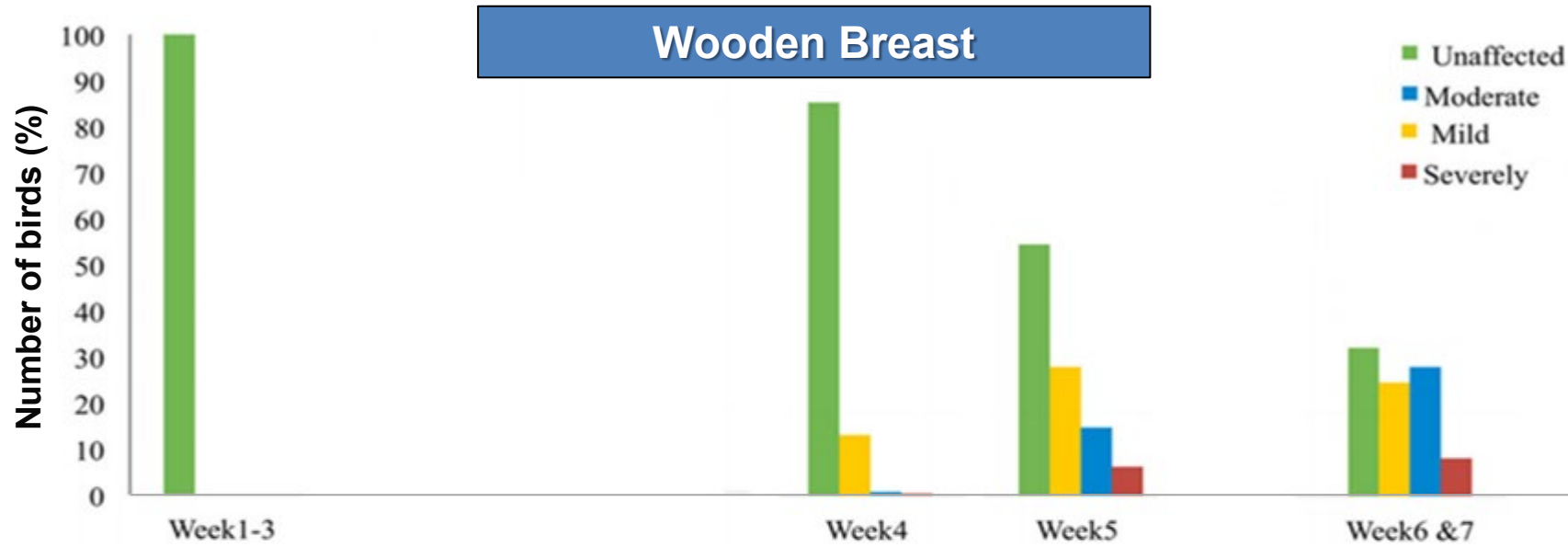


Rarefaction of the endomysial and perimysial **connective tissue**

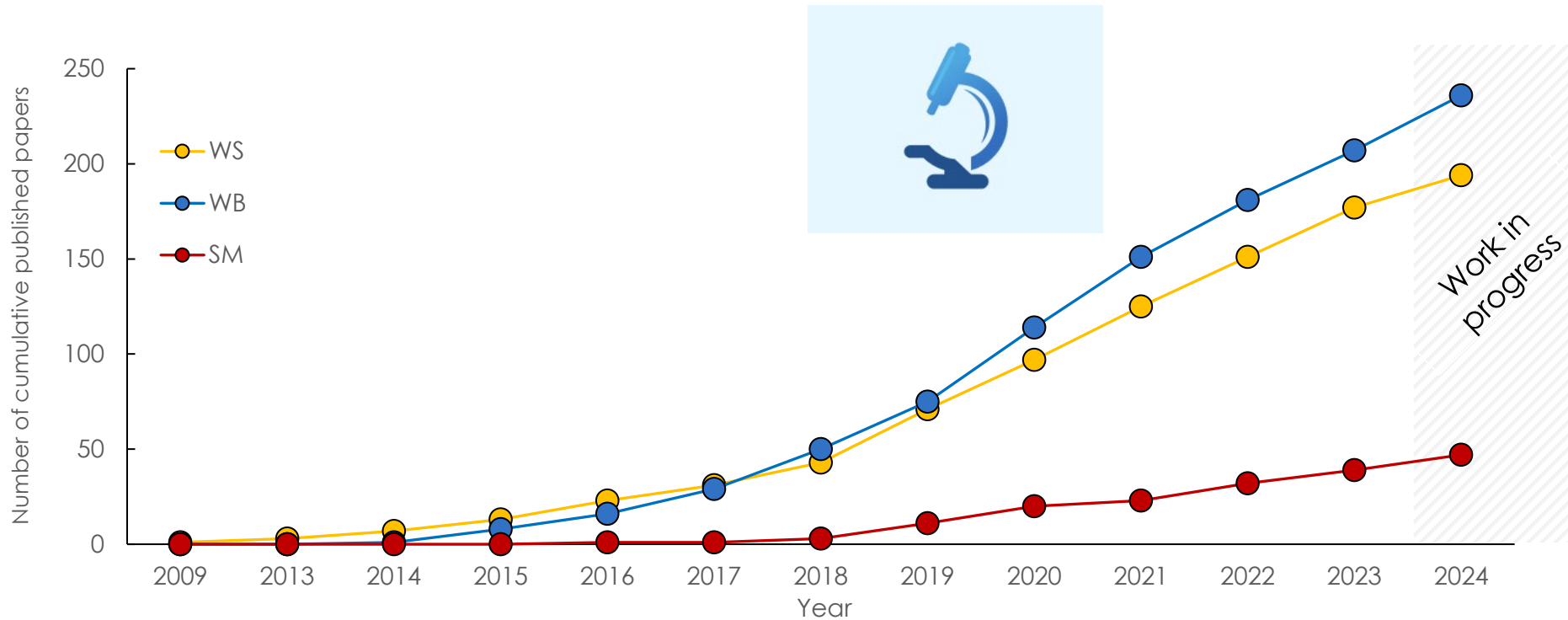
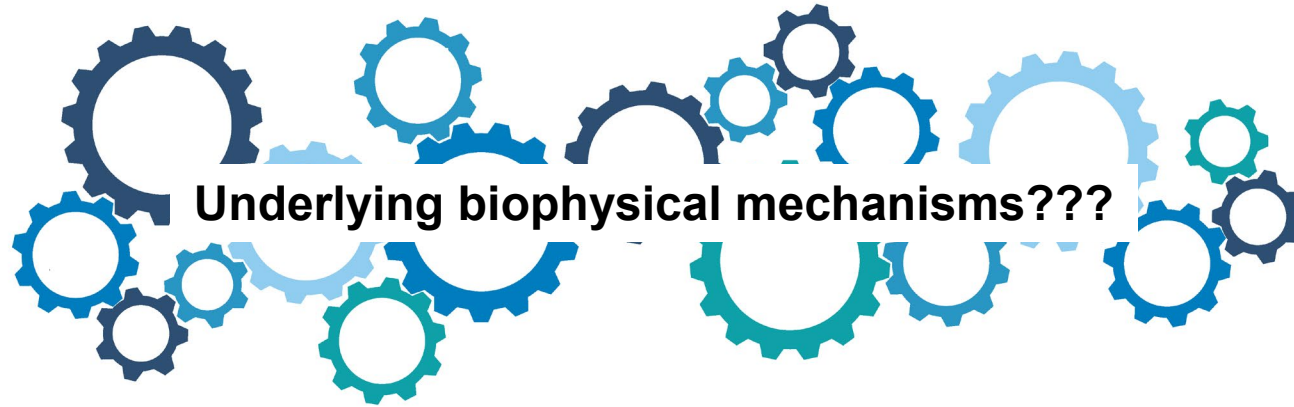


Growth-related Breast Abnormalities in Broilers

– Progression of macroscopic and microscopic lesions –



Growth-related Breast Abnormalities in Broilers



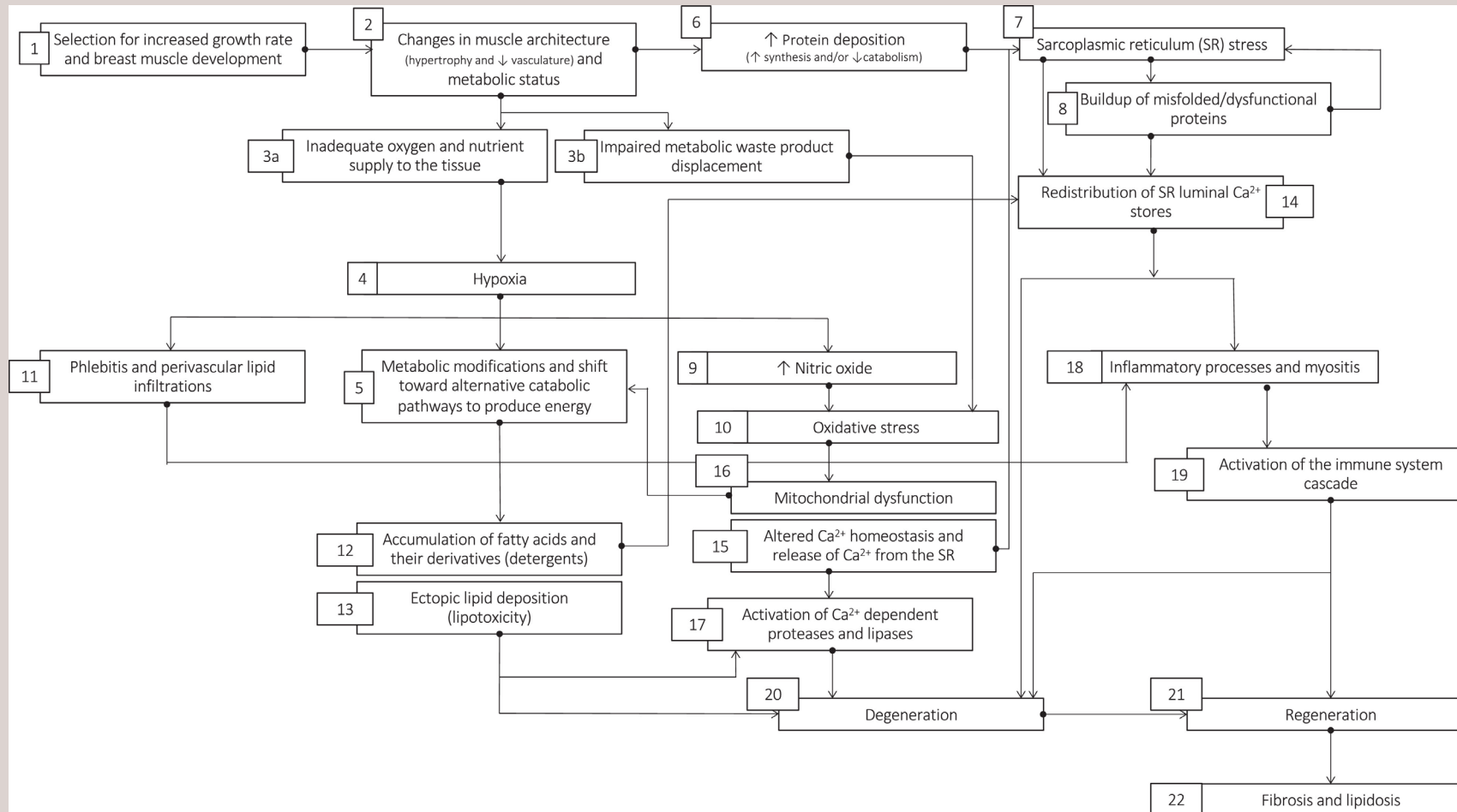
Source: Scopus (accessed on August 31st, 2024)



Biophysical Mechanisms

– Overall picture –

Schematic representation of the possible time series of events, molecular pathways and biological processes involved in the onset and triggering the occurrence of the White Striping, Wooden Breast, and Spaghetti Meat Abnormalities affecting broilers'

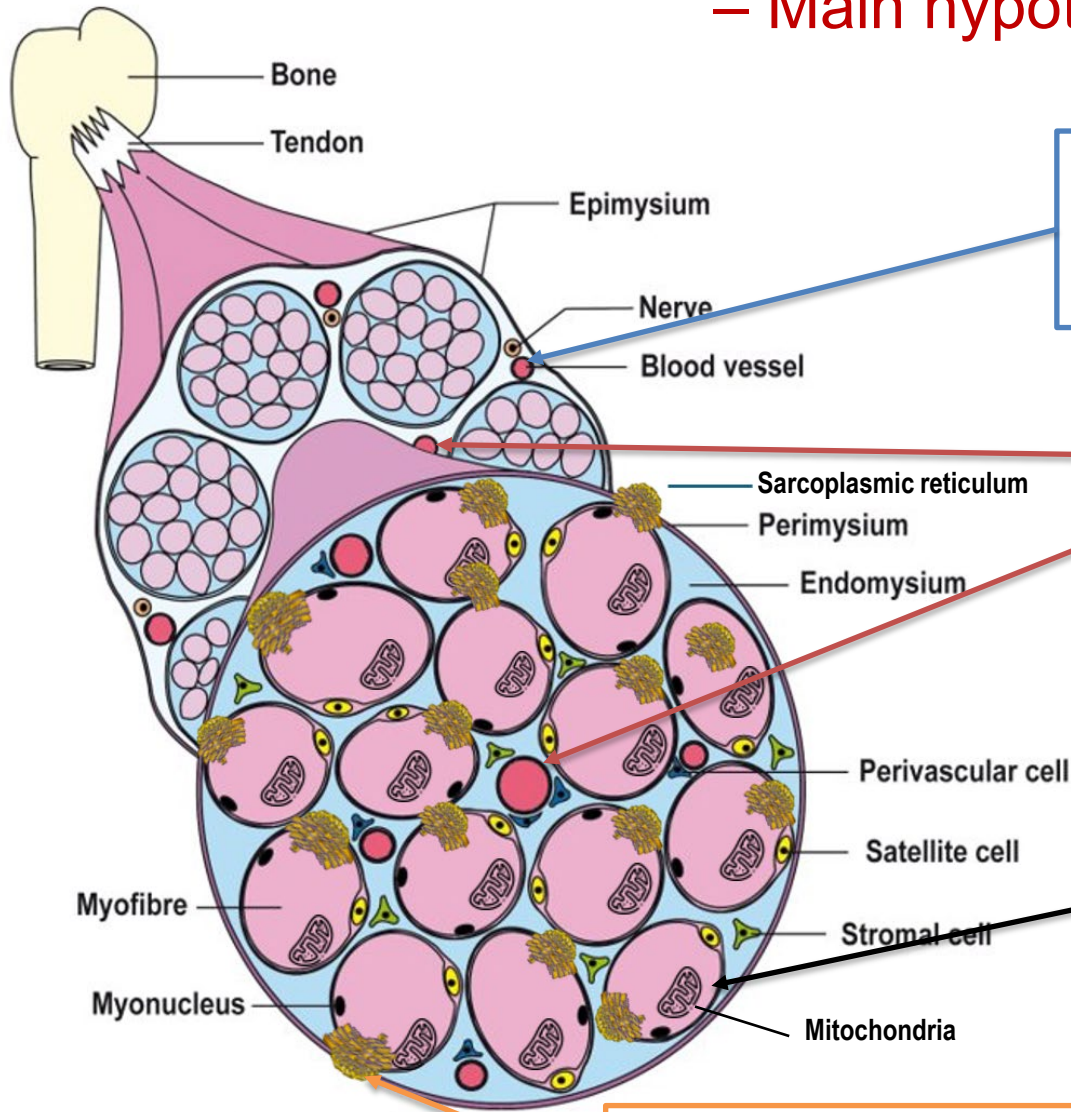


WORK IN PROGRESS



Biophysical Mechanisms

– Main hypotheses (WS & WB) –



Vascular shortcomings leading to the development of **hypoxic conditions** within muscle

Lacking in connective tissue spacing between fiber bundles and individual fibers promotes fiber degeneration and causes **suppression of satellite cell-mediated myofiber regeneration**

Mitochondrial disfunctions and **altered energy** (lipid and glucose) **metabolism** which involve dysfunction of endothelial cells

Endoplasmic reticulum stress induced by **accumulation of misfolded and dysfunctional proteins**



Growth-related Breast Abnormalities in Broilers

– Comparison between broilers and turkeys –

Progress in performances

1985  Deep Pectoral Myopathy

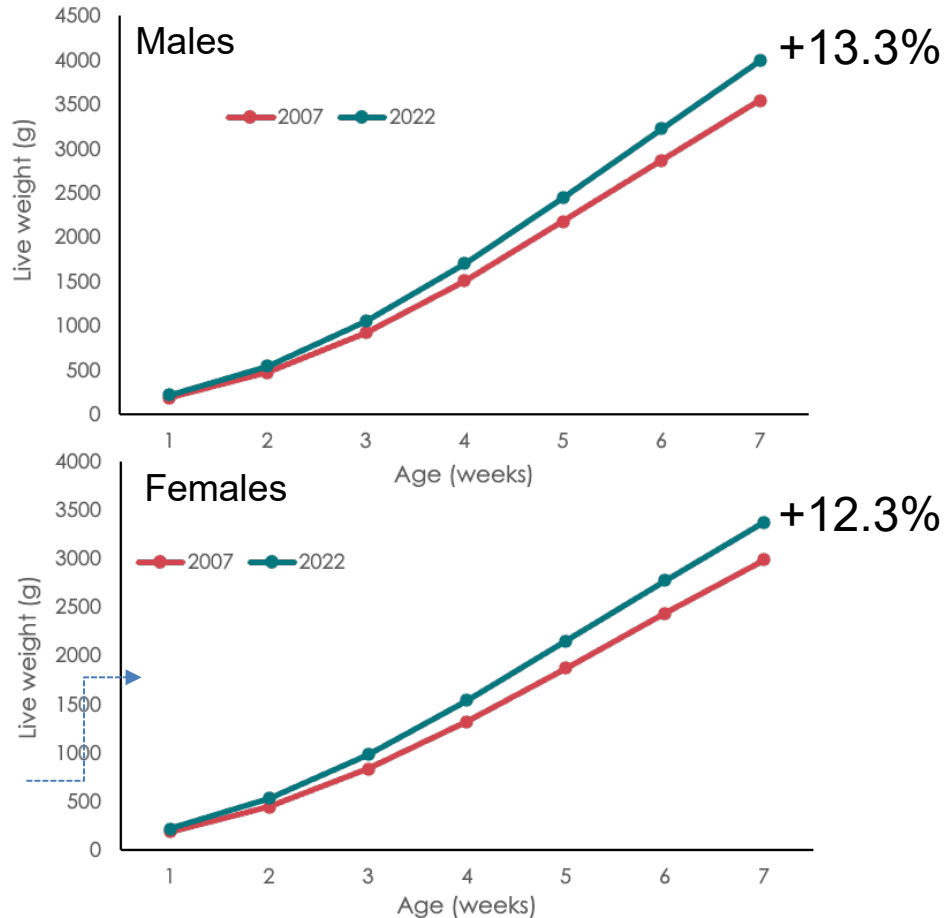
1998  Pale-Soft-Exudative-like

2009  White Striping

2012  Wooden Breast

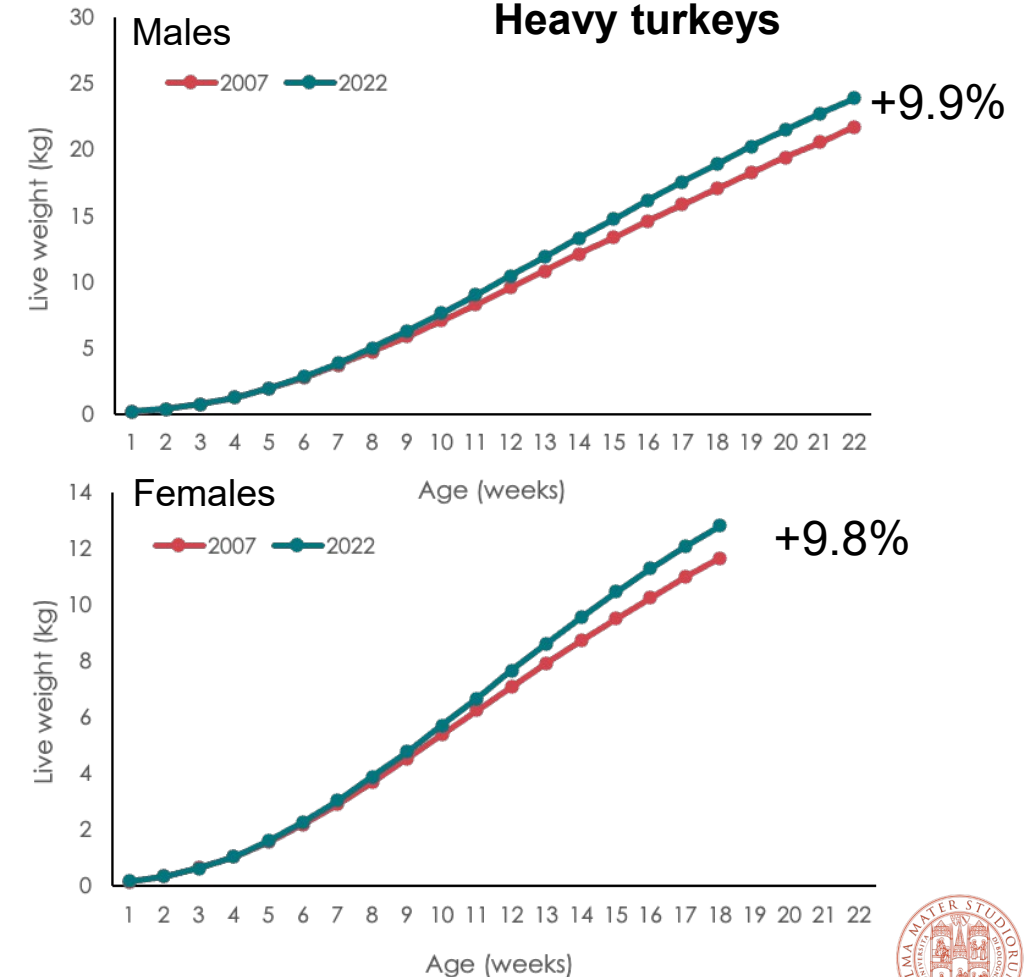
2015  Spaghetti Meat

Broiler chickens



Source: Ross 308 Broiler Performance Objectives

Heavy turkeys



Source: BUT Turkeys Performance Objectives



Growth-related Breast Abnormalities in Poultry

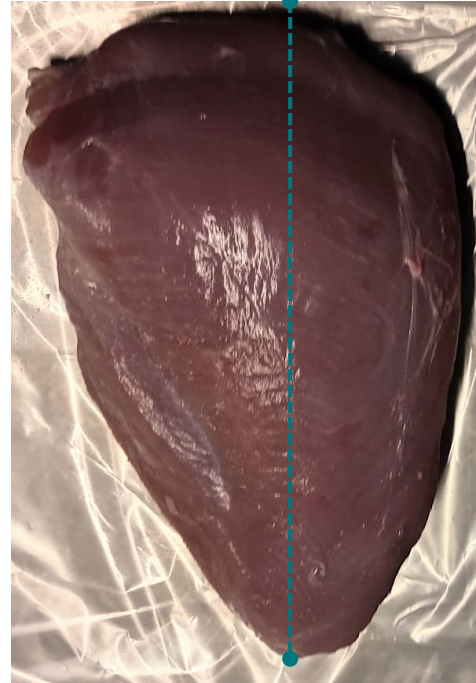
– Why turkeys do not exhibit growth-related abnormalities? –

1985  Deep Pectoral Myopathy

Broiler chickens



Heavy turkeys



Pictures taken by Francesca Soglia

1998  Pale-Soft-Exudative-like

2009  White Striping

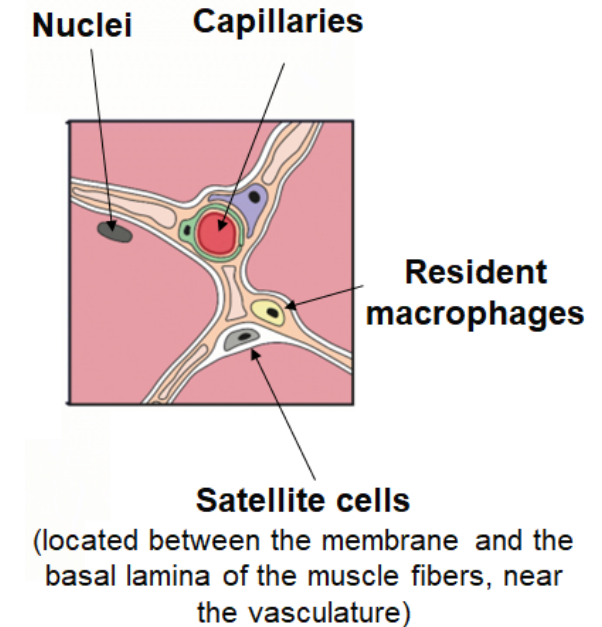
2012  Wooden Breast

2015  Spaghetti Meat



Dissimilarity in breast muscle morphology - the greater the *Pectoralis major* depth, the higher likelihood to find severe myopathic alterations

Griffin et al., 2018 Avian Pathol 47:2



Differences between satellite cells biological activity to regenerate – modern heavy turkeys exhibit increased proliferation and differentiation activities
Velleman (2023) Front Physiol 14:2023.1173988



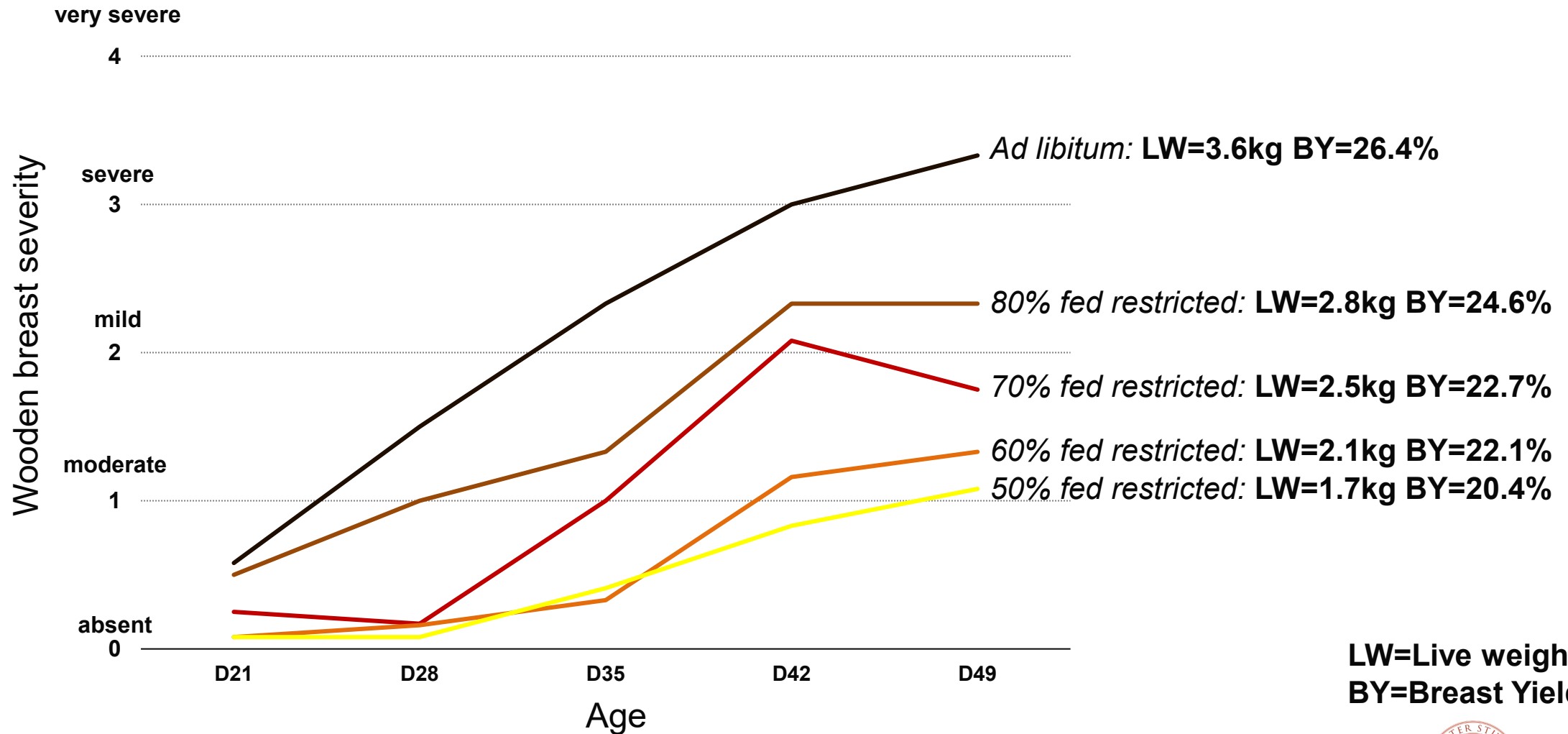
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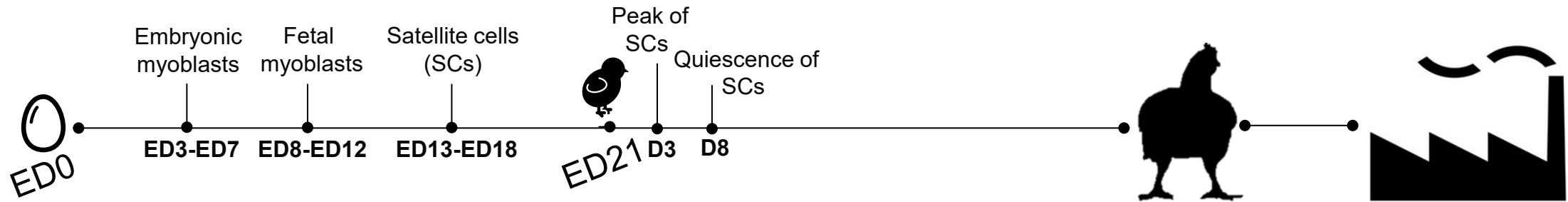


Strategies to Mitigate the Incidence of Breast Abnormalities

– Relationship with growth rate and breast yield –

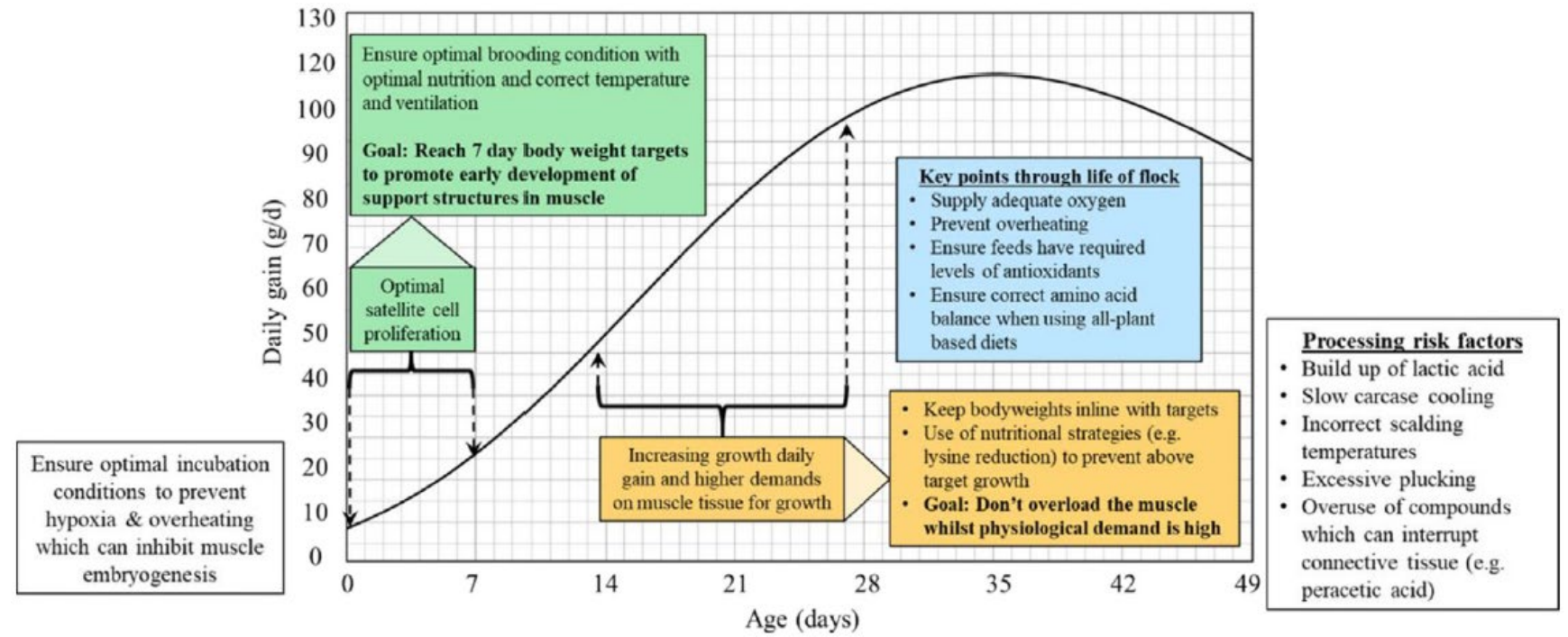


How to mitigate the incidence of abnormalities without reducing (breast) muscle development and growth rate?



Strategies to Mitigate the Incidence of Breast Abnormalities

Proposed critical stages of broiler lifecycle where management may be critical to reduce breast abnormalities



From Bailey (2023)

Strategies to mitigate the incidence of breast abnormalities

Short-term strategies

- Management
- Nutrition/Feeding
- Environmental conditions
- Meat processing

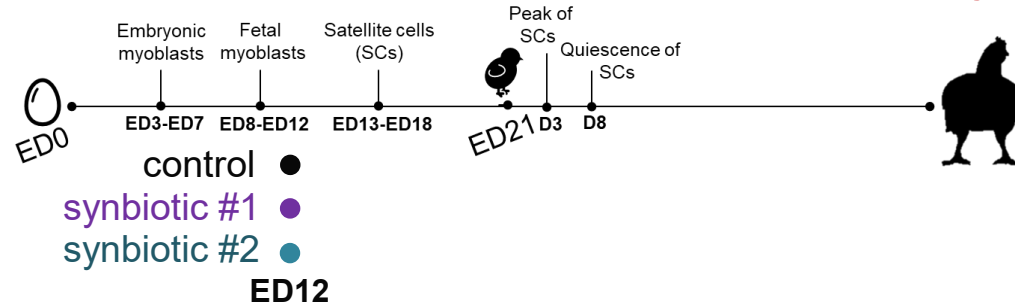
Long-term strategies

- Genetic selection



Strategies during Embryonic Period

– In-ovo injection –



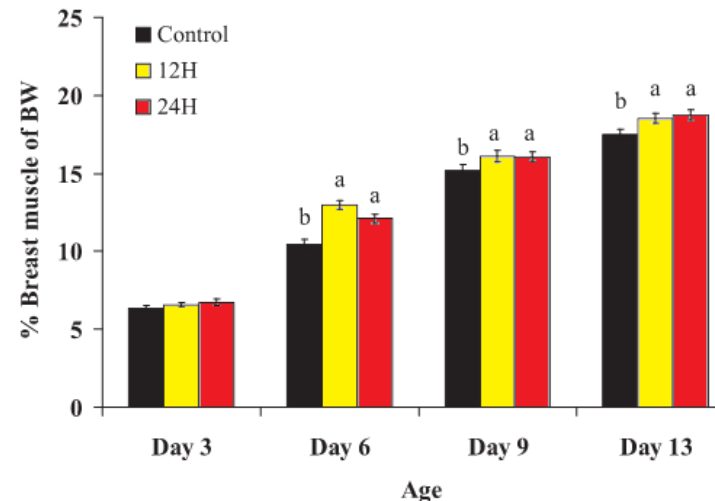
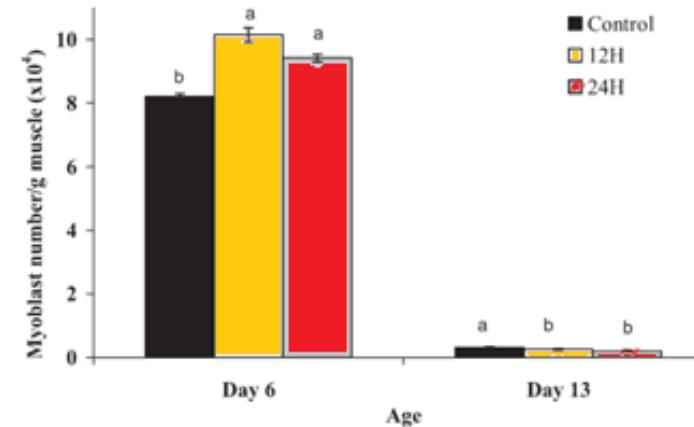
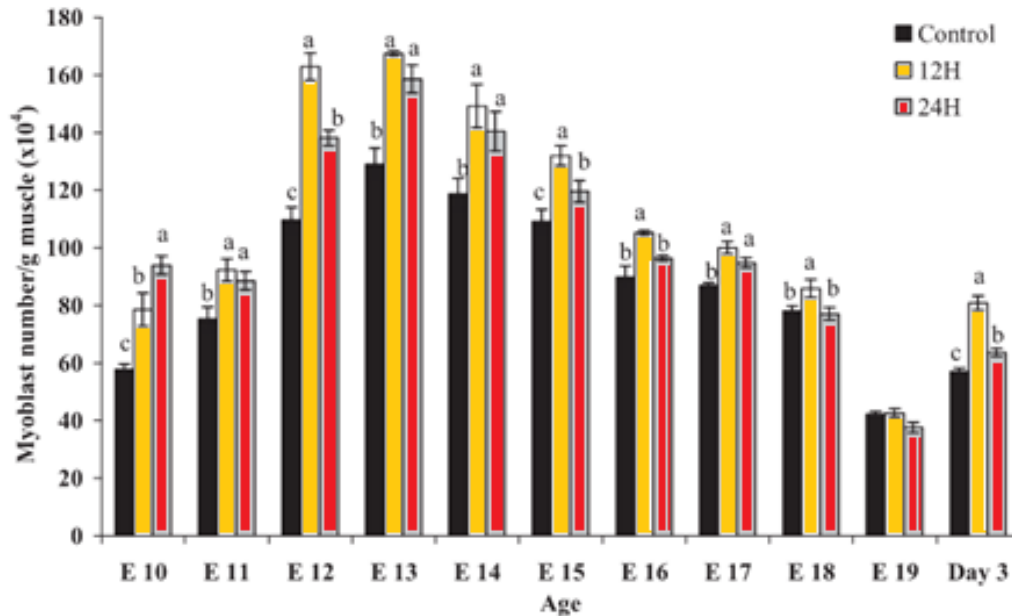
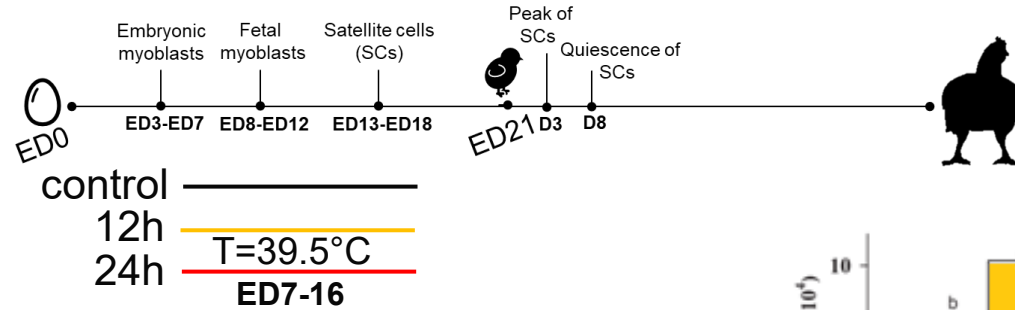
	Control	In-ovo injection with synbiotic #1	In-ovo injection with synbiotic #2
Body weight at 42d (g)	3,033	3,041	2,986
Muscle fiber morphology			
Muscle fibres (n/1.5 mm ²)	300	294	317
Muscle fibre diameter (µm)	48.0	50.5	49,1
N. of capillaries/fibre	1.14b	1.47a	1.34ab
Muscle fibre histology			
Normal fibres (%)	95.5b	97.3a	96.1ab
Fibre necrosis (%)	1.5a	0.6b	1.2ab
Giant fibres (%)	0.07	0.06	0.05
Splitting (%)	2.9a	2.0b	2.7ab

a-b = P<0.05



Strategies during Embryonic Period

- Thermal manipulation during mid-embryogenesis -



Thermal manipulation during mid-embryogenesis:

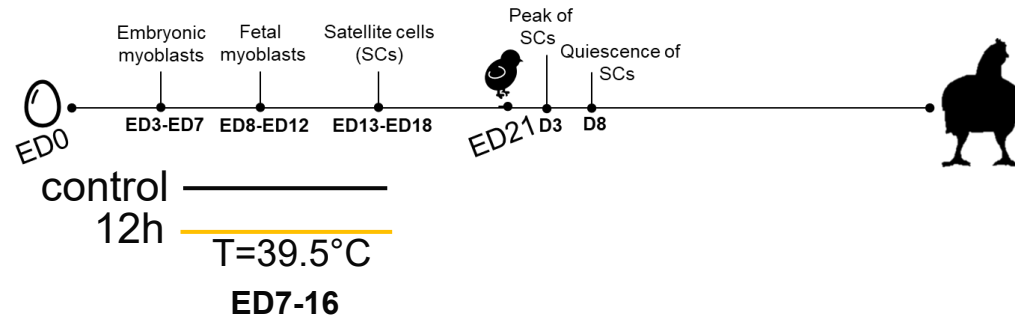
- promotes immediate and continuous myoblast proliferation during periods corresponding to fetal-myoblast and satellite-cell proliferation

- increase myogenic progeny reservoir in the muscle and results in enhanced muscle growth in the embryo with a long-lasting effect on post-hatch chickens



Strategies during Embryonic Period

– Thermal manipulation during mid-embryogenesis –



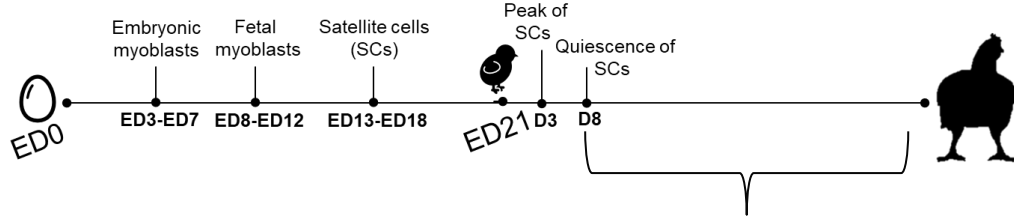
	Performances at 49d			Abnormalities		
	Live wt (g)	Carcass wt (g)	P. Major (%)	WS score	WB score	SM score
Control	3,919	3,190a	28.8	1.96a	1.95a	1.82
Thermally manipulated	3,813	3,071b↓	28.7	1.71b↓	1.70b↓	1.83

a-b = $P < 0.05$



Strategies during Growing Period

– Nutritional and Feeding strategies –



Main nutritional and feeding strategies	Tested strategies	Total publication, %
Reducing dietary amino acids (AA)	Lysine, methionine, glutamine, arginine, valine, leucine, histidine, total sulphur AA, threonine, total amino acids	16
Nutrient allocation (qualitative)	Feeding plans based on diets with different energy and protein contents	9
Nutrient allocation (restriction)	Feeding plans based on different feed restriction levels, and different restriction and refeeding periods	14
Supplementation for controlling oxidation/inflammation	Se, Mg, Zn, Cu, Mn, antioxidants (including vegetal extracts), Vitamin E, alpha lipoic acid, n3 fatty acids (including algae inclusion)	21
Supplementation for improving oxygen homeostasis	Inositol, phytase (one study including a blend with vitamins)	7
Use of antibiotic/gut modulators	Antibiotics and gut modulators (probiotic, vegetal functional compounds, organic acids)	10
Supplementation with guanidine acetic acid	Guanidino acetic acid (plus nucleotides in one paper)	9
Miscellaneous	Fat source, choline chloride, Ca, P, K, vitamins, inorganic (sulphates) and carbo-aminophospho-chelate, methionine (synthetic vs. natural), in-ovo vitamin D, hatching system	14

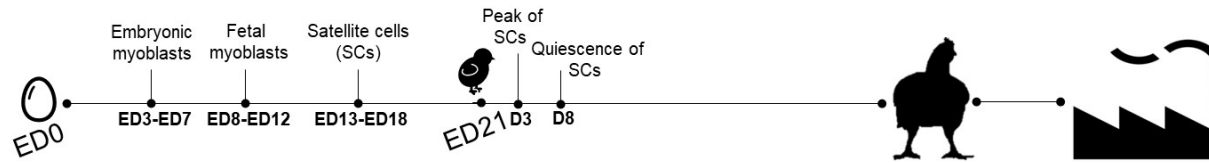
n=65



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Strategies during Slaughtering

– Peculiarity of spaghetti meat –



Spaghetti Meat
(SM)

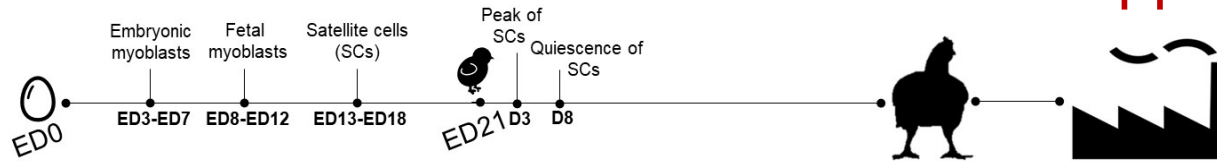


- Incidence level of SM is less strongly associated with weight at slaughter, growth rate and breast yield if compared with white striping and wooden breast
- Strong differences among slaughter plants seem to be associated with:
 - slaughtering operations affecting *post-mortem* muscle acidification and cooling rates (i.e., stunning, electrical stimulation, scalding, chilling)
 - mechanical force applied during slaughtering operations such as defeathering, deboning, etc. which can increase severity of the appearance of this condition



Strategies during slaughtering

– Mechanical force applied during defeathering –



The vigour of defeathering can vary due to number of machines, position and number and speed of the fingers, and their hardness (indicated by different colors).



Processing risk factors

- Build up of lactic acid
- Slow carcase cooling
- Incorrect scalding temperatures
- **Excessive plucking**
- Overuse of compounds which can interrupt connective tissue (e.g. peracetic acid) *Bailey (2023)*

Each defeathering machine has hundreds of rubber 'fingers' mounted on to rows of disks. The rapidly rotating fingers remove the feathers by beating the bodies of the shackled killed broilers.

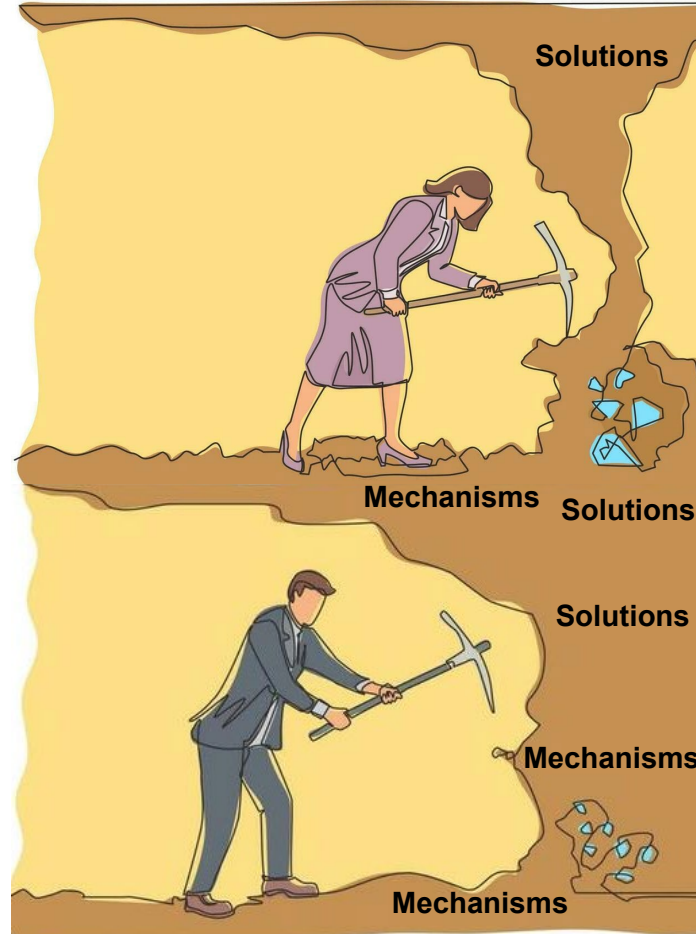
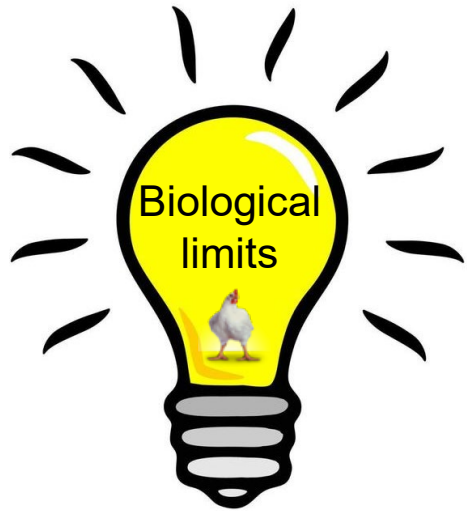


OUTLINE

- Occurrence of Broiler Growth-related Abnormalities and Classification Criteria
- Possible Causative Mechanisms Underlying Growth-related Abnormalities
- Strategies to Mitigate the Incidence of Growth-related Abnormalities in Broilers
- **Conclusions**



Conclusions



- Scientists and industry people are working hard to understand how to fix degenerative processes underlying occurrence of growth-related abnormalities
- Current and soon available knowledge is likely able to allow significant reduction of occurrence of abnormalities (macroscopic traits)
- However, the continuous pressure to improve productive performances like growth-rate and muscle-development is progressively narrowing the space for allow proper and sustainable muscle growth





Thanks for your attention



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