Consequences of breeding broilers for rapid growth and high breast meat yield, and their genetic mitigation

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40 years of research with colleagues and graduate students

Special contribution:

Joseph (Nader) Deeb (1990's)

Shelly Druyan (2000's)

Yair Hadad (2010's)

<u>Outlines</u>:

- Genetic elevation in <u>growth rate</u> and in <u>feed consumption</u>
- Excessive fat deposition (detailed)
- Leg problems (brief)
- Ascites (detailed)
- Breast muscles myopathies (brief)
- *Susceptibility to heat (if time permits…; brief or detailed)*

Early history of breeding chickens for meat production

- Since domestication, chickens were reared mainly for egg production. Meat was a secondary product, due to availability of other sources of meat.

- During 1940's, chicken meat became more popular in North America and Europe. Mechanized processing and cold-chain shipping and marketing were developed.

- With the increasing demand for chicken meat in North America and Europe, efficient meat production became (around1950's) an important breeding objective.

- Rapid growth is essential for efficient meat production, due to efficient utilization of
  1. feed
  2. facilities
  3. labor

- Slow-growth: lower efficiency, higher production costs, higher prices of products

70 years of life experience…

My parents reared egg-type chickens under simple management in 1940's, and in battery cages from the 1950's.

The male brothers of these layers were not good for meat production.

In late 1950's, my parents started to raise meat-type chickens (broilers).

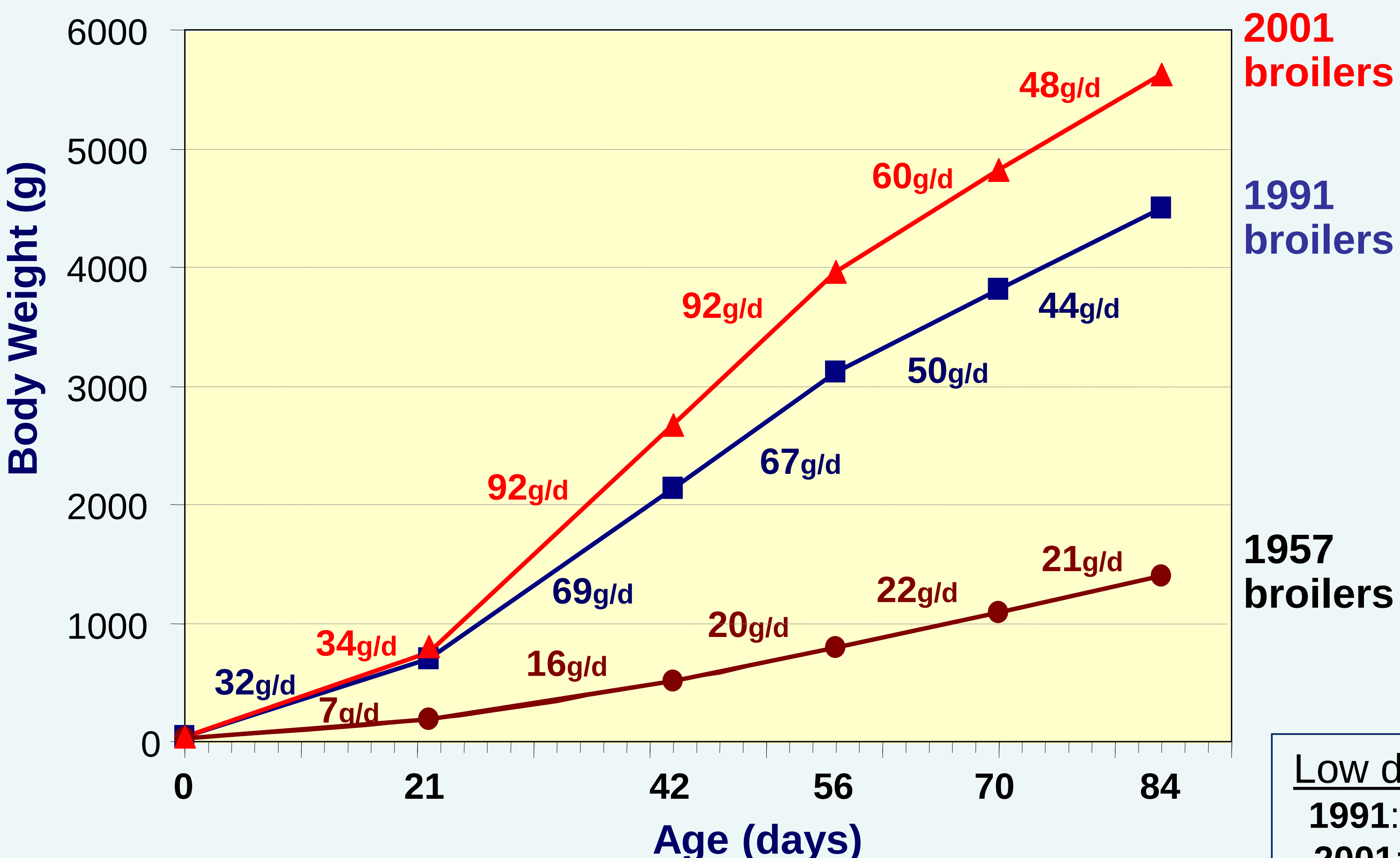
Growth rate of these broilers was higher than layers, but much lower than today's broilers, and they did not suffer from physiological and a-biotic stresses.

Rishpon, ISRAEL (1950)

Genetic improvement in growth rate since 1950's (#1)

Growth curves of 1957, 1991, & 2001 broilers

Havenstein conducted two similar trials, in 1991 and 2001, with the 1957 broilers and contemporary commercial broilers, at the same facility and management in NCSU.



Low density
1991: 7/m^2;
2001: 5/m^2

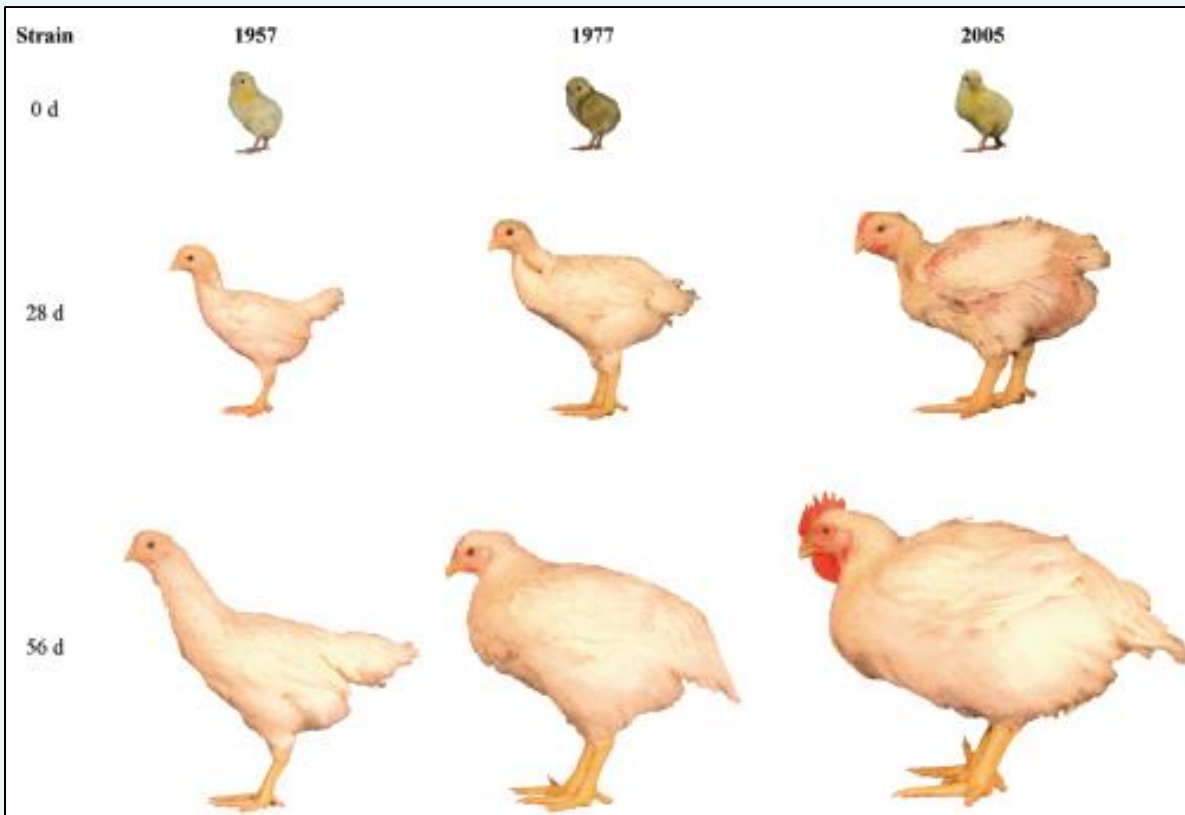
(Based on Havenstein *et al*., 1994 and 2003)

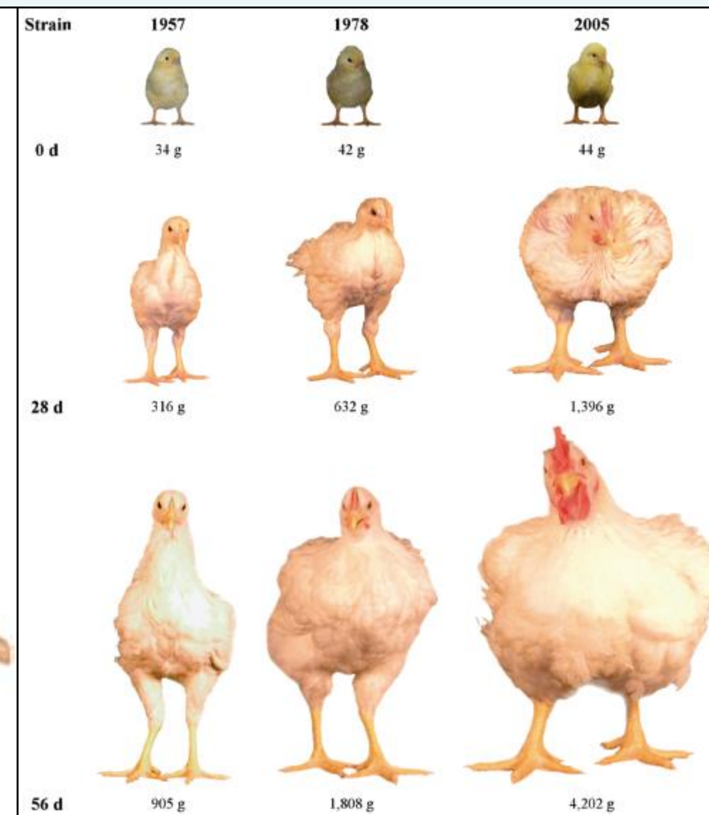
Genetic improvement in growth rate since 1950’s (#2)

Zuidhof et. al. (2014) conducted trial in Alberta (Canada)with three broiler strains: two research strains kept in the university with no selection from **1957** and **1977**, were compared with commercial Ross 308 broilers (in **2005**, the year of the trial)

The three strains were reared together with standard feed but <u>low stocking density.</u>

Typical broiler from each strain was photographed at hatch, at 28 and AT 56 days.

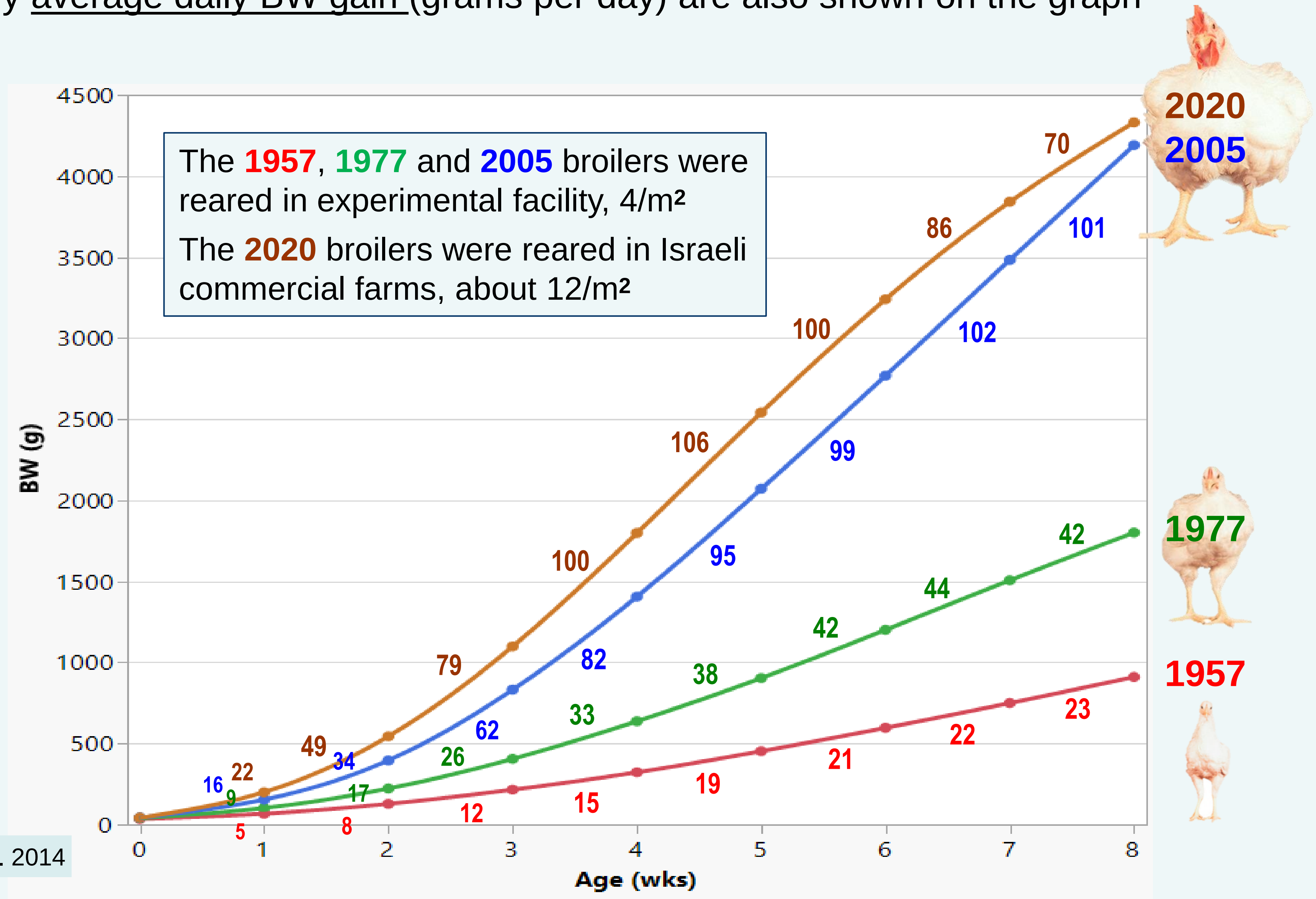




Genetic improvement in growth since 1950's

Growth curves of two strains kept without selection from 1957 and from 1977, and Ross 308 broilers in 2005 and in 2020 (weekly means of body weight, BW)

Weekly average daily BW gain (grams per day) are also shown on the graph

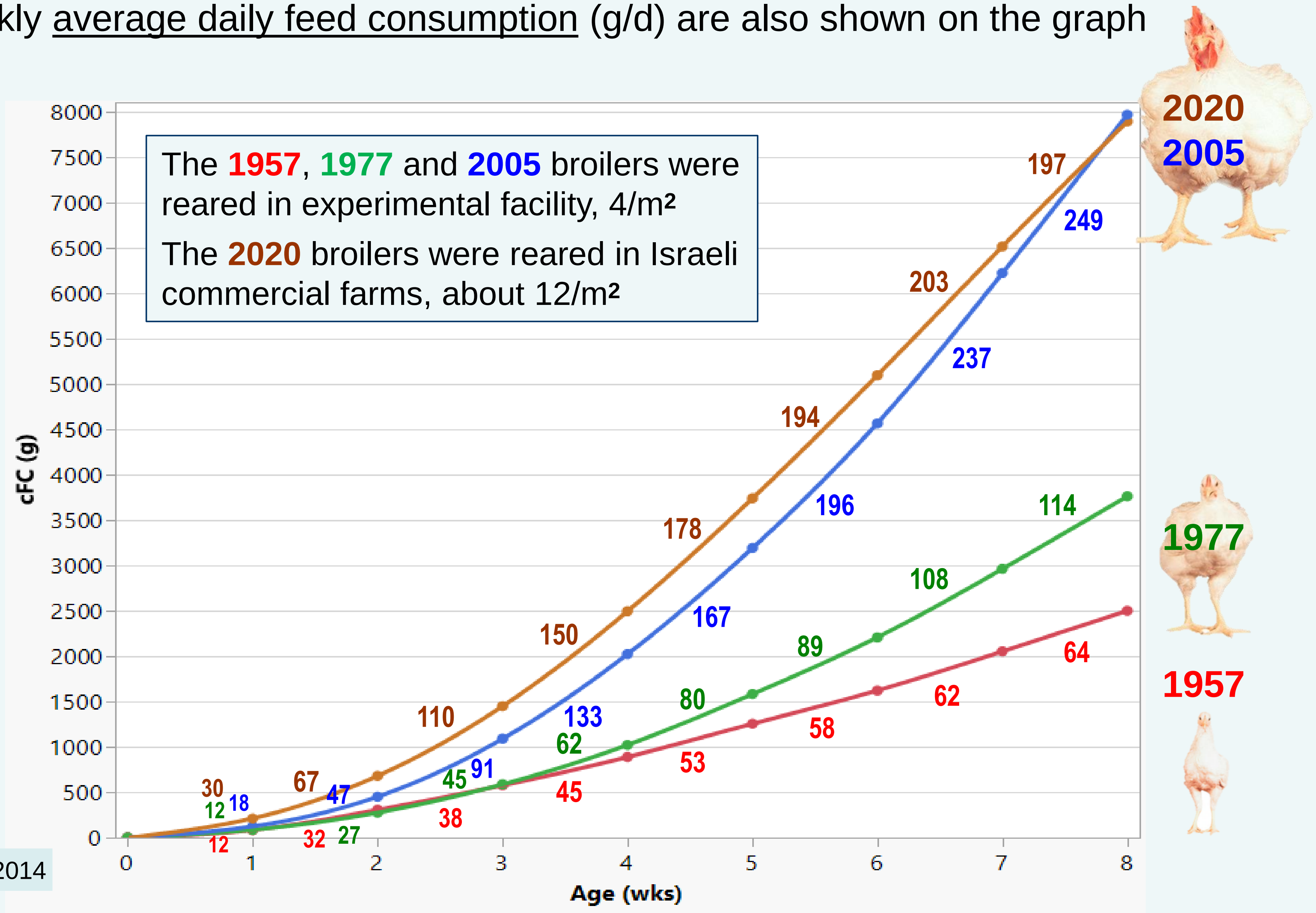


Zuidhof et.al. 2014

Genetic elevation in feed consumption since 1950's

Weekly means of cumulative feed consumption of strains kept without selection from 1957 and from 1977, and Ross 308 broilers in 2005 and in 2020.

Weekly average daily feed consumption (g/d) are also shown on the graph



Zuidhof et.al. 2014

Consequences of elevated feed consumption

- Higher growth rate is driven by higher rate of feed consumption, therefore the **selection for rapid growth actually elevate the rate of feed consumption**

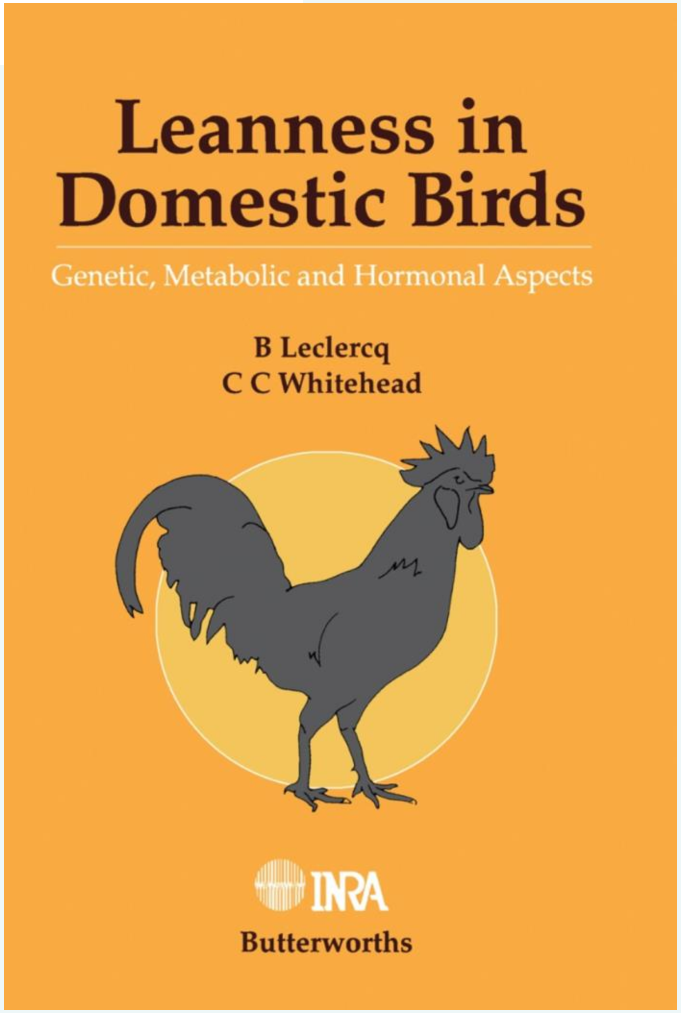
- With higher intake of dietary energy, excessive fat deposition became a problem for the broiler industry, due to negative attitude of consumers towards carcass fat

- Due to the apparent genetic association between growth and excessive fatness, the primary breeding companies suggested nutritional and processing practices to mitigate the excessive fatness in commercial broiler flocks

- Much research was done during the 1970’s-1980’s on biological and practical aspects of fat deposition in domestic birds, mainly broilers

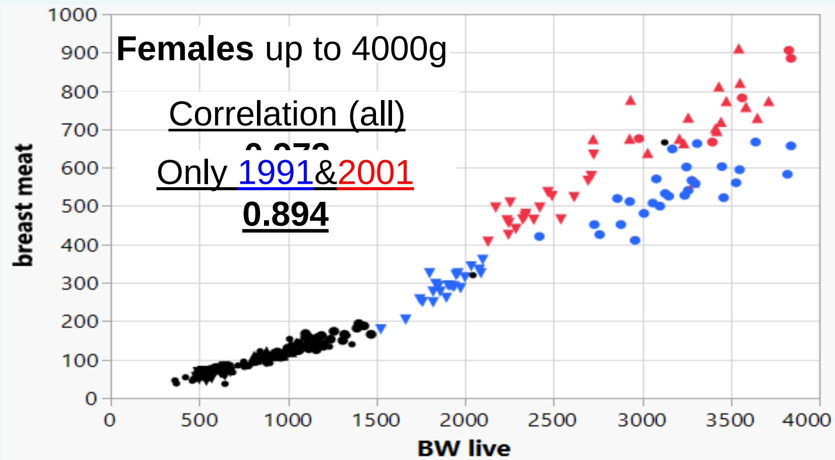
Leanness in domestic birds : genetic, metabolic, and hormonal aspects / [edited by] B. Leclercq and C. C. Whitehead.
p. cm.
Proceedings of a symposium held in Tours, France, from 4th to 6th August 1987.

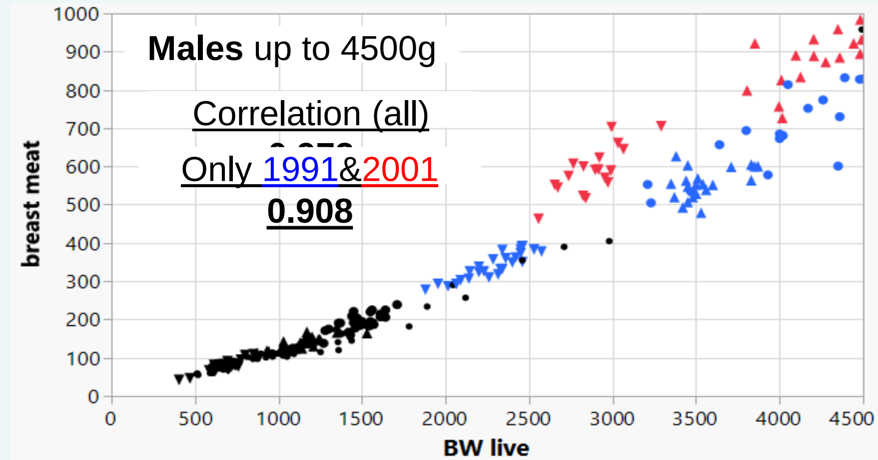
I Genetic basis for leanness and selection experiments

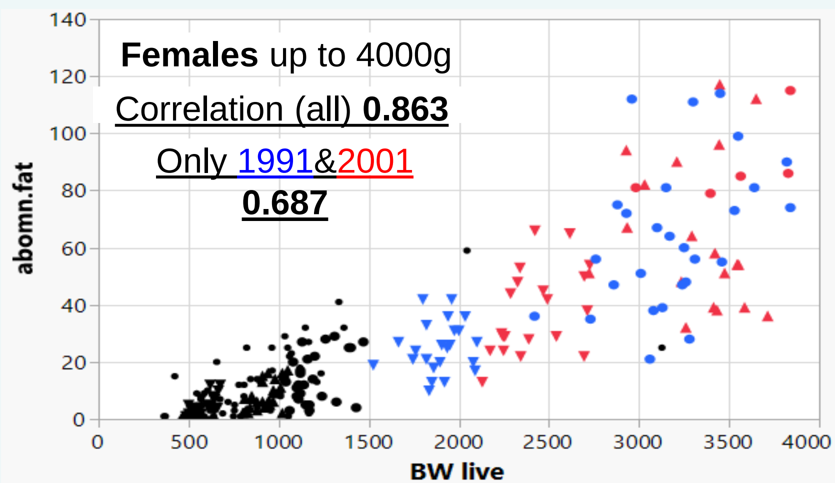


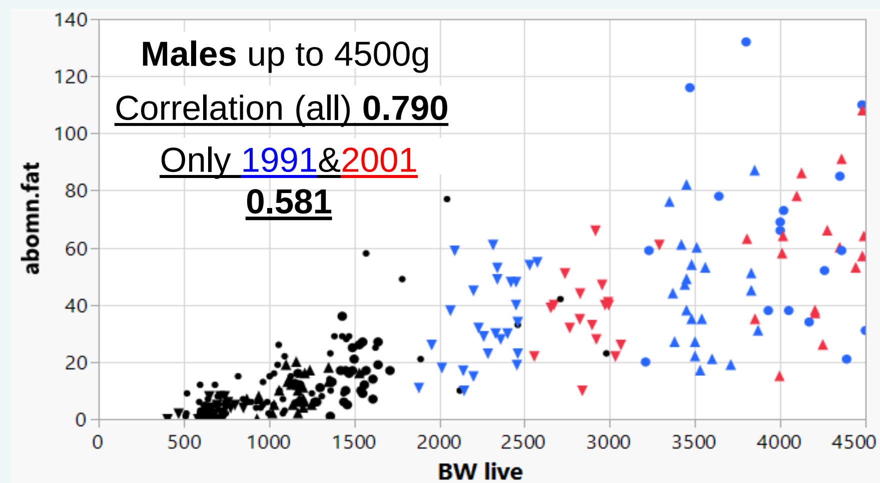
Breast yield and abdominal fat data from **Havenstein** trials are used to show why selection for higher BW could be combined with selection against excessive fatness

Broilers from each genotype (**1957**, **1991**, **2001**) were slaughtered at 6 (▼), 8 (●) and 10 (▲) wks.
The weights of breast meat and adnominal fat of each bird are plotted versus its live BW.









Positive correlation of fat and BW supposedly hinder combined selection for high BW and low fat, but the association is not symmetrical, allowing to select **lean heavy genotypes**, once identified

Breeding to improve the efficiency of feed utilization

Feed accounts for 60-70% of total production costs chicken meat;
It has been highly desired to improve the feed conversion ratio (**FCR**)

Total feed consumption (**FC**), from hatch to marketing, consists of two components:

Feed consumed for body **maintenance** + Feed consumed for **growth**

$$FCR = \frac{\text{Total feed consumption}}{\text{Body weight gain}} \quad ➧ \quad FCR = \frac{\text{FC maintenance} + \textbf{FC growth}}{\text{Body weight gain}}$$

Maintenance FCR improves as the broilers grow faster (another slide…)

Growth FCR improves as the broilers deposit less fat and more muscles

Water content is ~80% in muscles and only ~20% in fat tissues,

1 gr feed deposited in muscles, add **5** gr body weight (1 gr 'dry matter' + 4 gr water)

1 gr feed deposited in fat tissue, add **1¼** gr body weight (1 gr 'dry matter' + ¼ gr water)

Deposition of nutrients in muscles is 4-times more effective than in fat tissues

Excessive fatness has been successfully mitigated by the commercial selection for better feed efficiency and for higher breast meat yield

Selection for higher beast meat yield

The increasing demand for breast meat led to a very successful selection for higher breast meat yield, rising from ~10% of BW to ~25% in recent years.

Broilers of 1957

6 weeks **8 weeks** **10 weeks** **12 weeks**

Broilers of 2001

The change in breast shape solved the problem of breast blisters
With lower breast yield in slow-growing broilers, blisters are back…

Genetic improvement in breast meat yield since 1950's

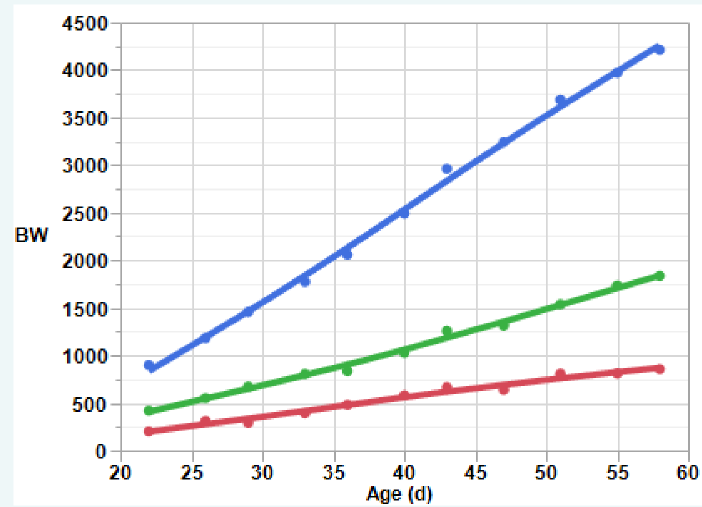
(Zuidhof et.al. 2014)

Pectoralis muscles yield (% of BW) of broilers with the genetics of **1957**, **1977**, and **2005**, measured on 8 birds per strain every 3-4 days

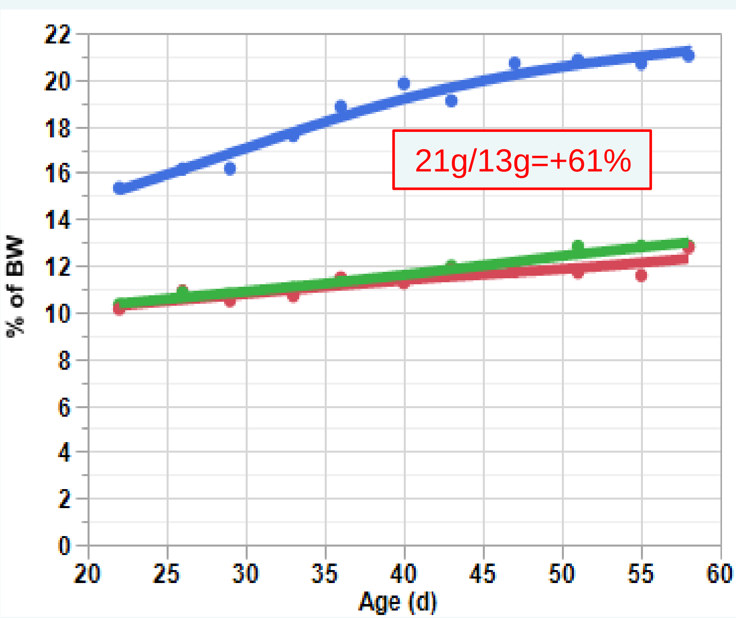
The broilers of 1977 grew faster than the those of 1957, yet breast meat yield did not change during these years. The 2005 broilers exhibit the significant genetic response: <u>direct selection for higher breast yield started in the 1980's</u>.

Separate measurements of the two *Pectoralis* muscles show that *P. major* increased more than *P. minor*

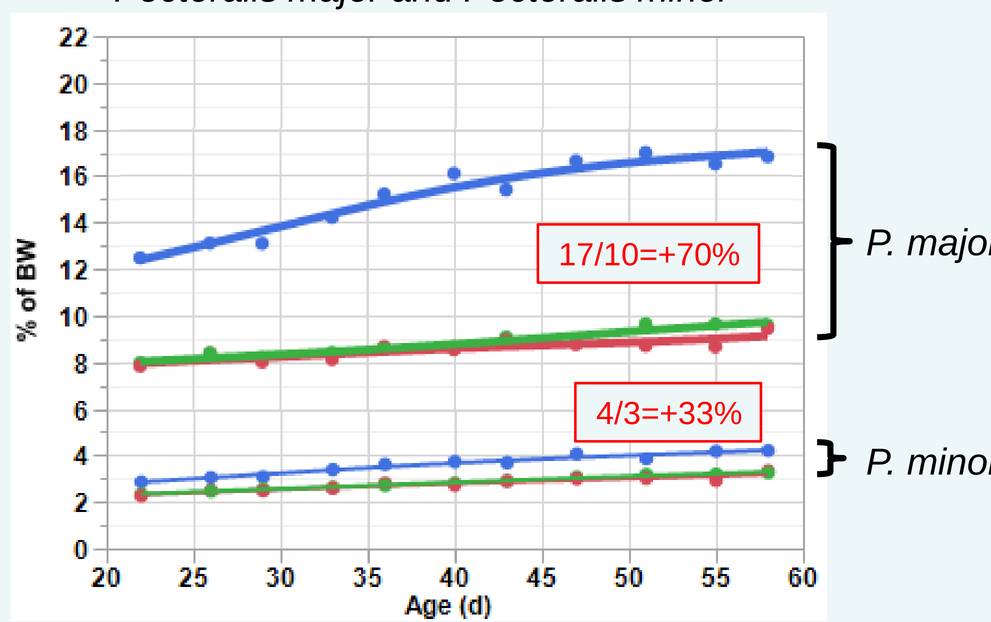
Body weight (BW) of sampled birds



Breast meat (*P. major* + *P. minor*)



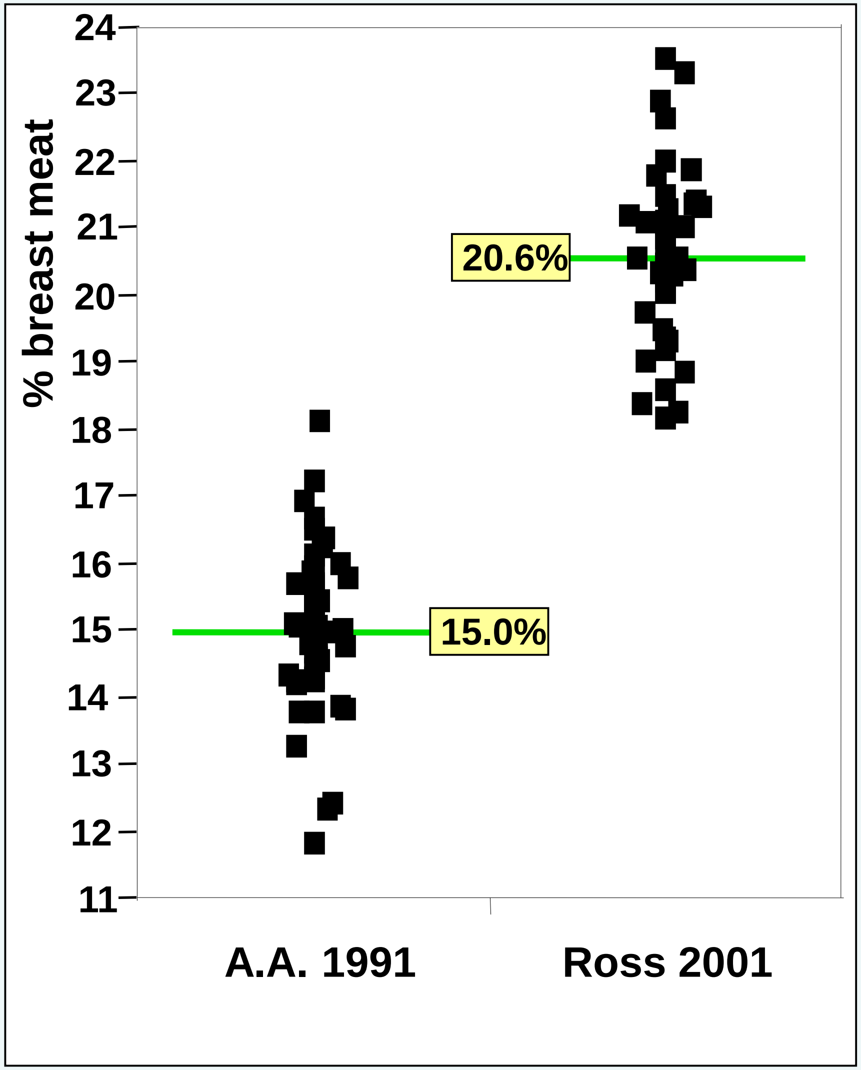
Pectoralis major and Pectoralis minor



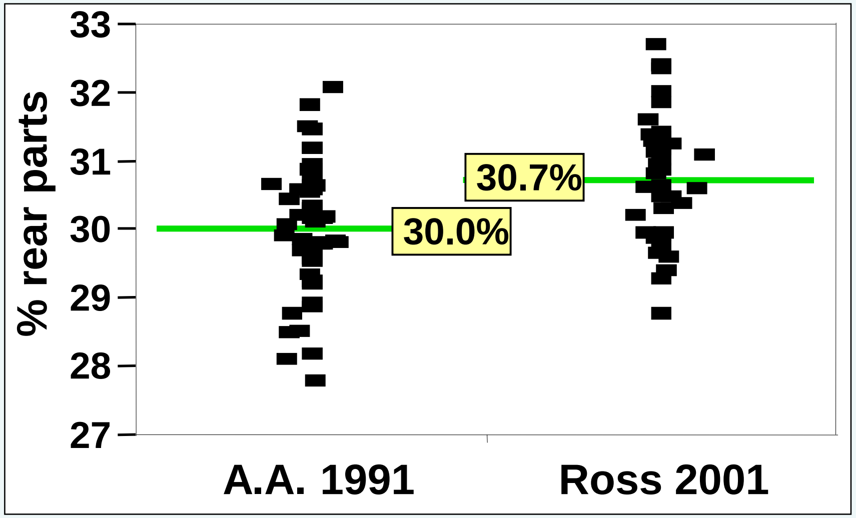
Meat yield of 1991 vs. 2001 broilers at 42 days

High variation in %Breast *(more than %Rear)* resulted in genetic response to selection

% Breast meat



% Rear parts (legs and thighs)



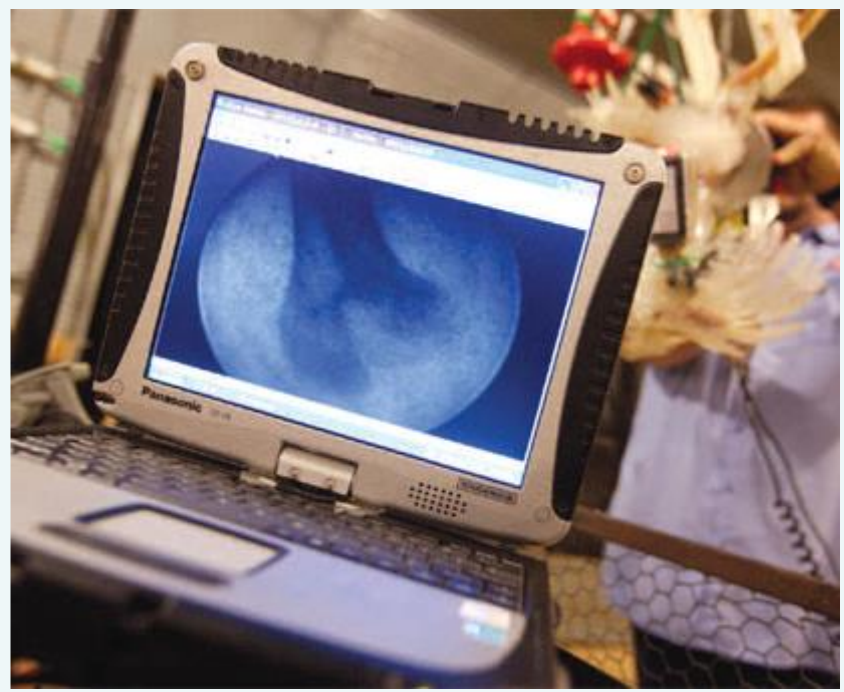
(Havenstein *et al*., 2003)

Breeding against leg problems

Leg problems emerged in 1980’s and increased as broilers grew faster to higher BW

Tibia Dyschondroplasia (TD) was identified as the main cause for these problems. This heritable ‘defect’ affects the legs only in heavy broilers, but not related genetically to BW, allowing breeding against TD without compromising rapid growth and high BW

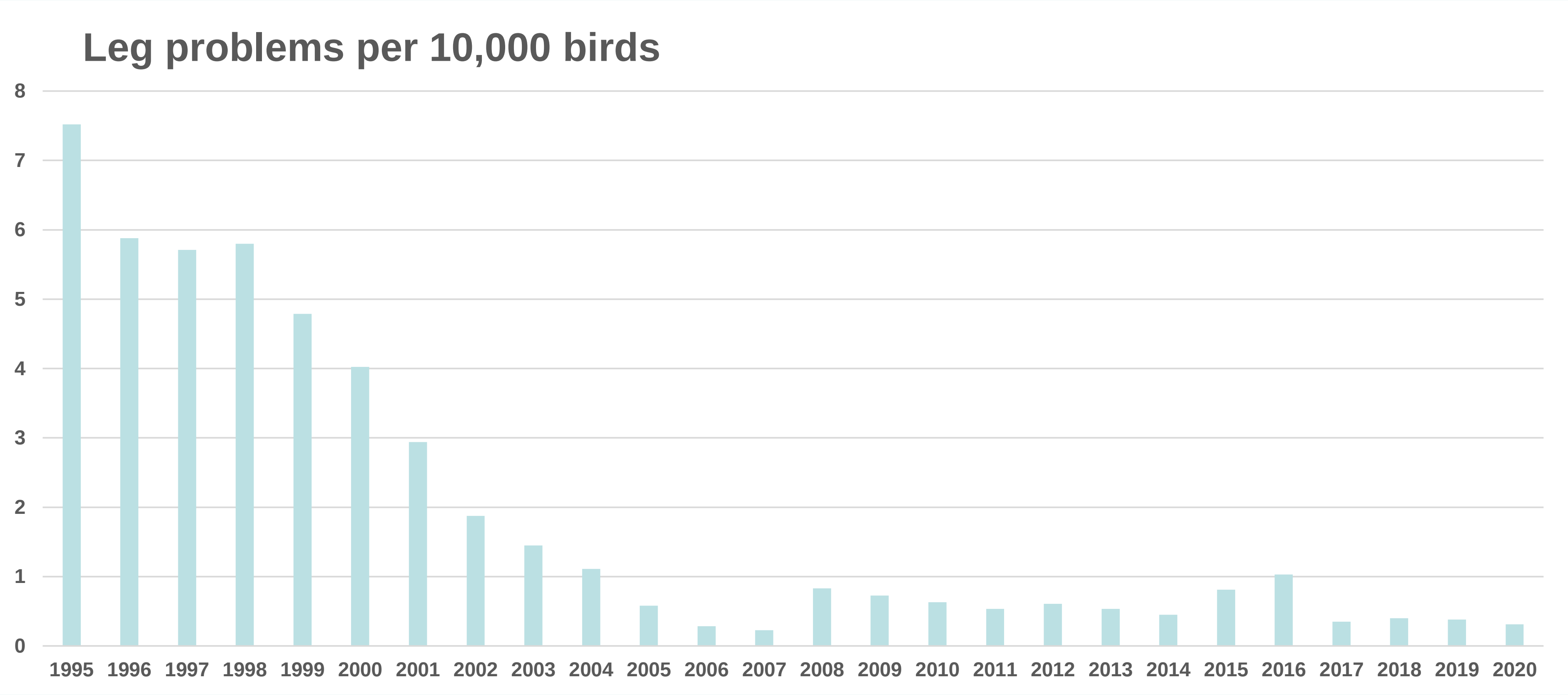
Portable X-ray machine (Lixiscope) facilitated effective large-scale selection, by identifying the broilers prone to develop **TD** and culling them out.



The use of portable X-ray machine to identify the individuals prone to develop **TD** and cull them out, is a routine on-going practice in all broiler breeding programs. *(picture and text from Aviagen's website)*

Aviagen utilizes an X-ray unit called a Lixiscope, which offers the opportunity to safely detect and identify Tibial Dyschondroplasia (TD). The introduction of the Lixiscope has enabled Aviagen to identify TD accurately and select against its presence and improve overall leg health in the breeding program. Aviagen was the first to implement use of the Lixiscope and in combination with individual bird walking assessment, it has significantly improved leg strength in all our products worldwide.

Leg problems condemnation in Canadian slaughterhouses



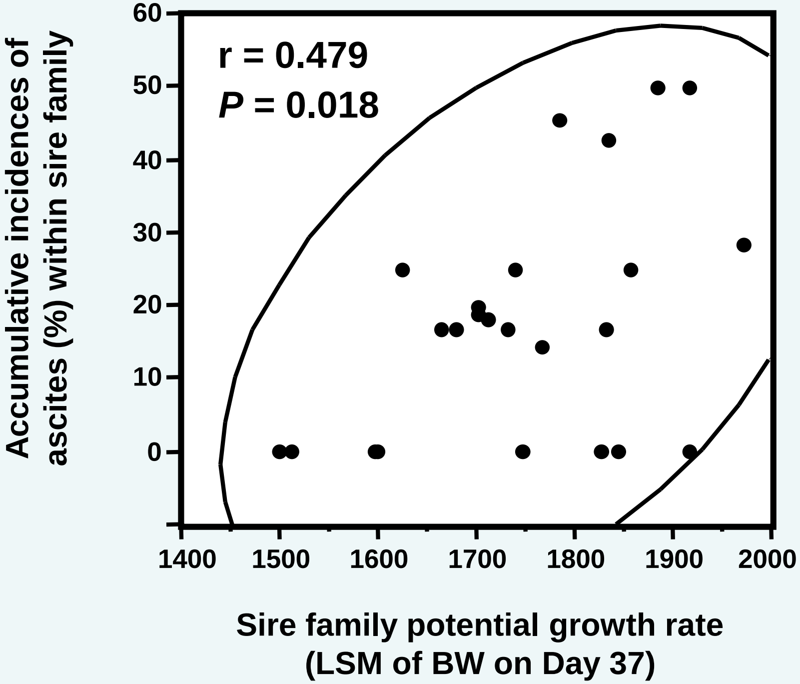
<u>Ascites syndrome</u>

Broilers with this syndrome accumulate ascitic fluid, stop growing and eventually die

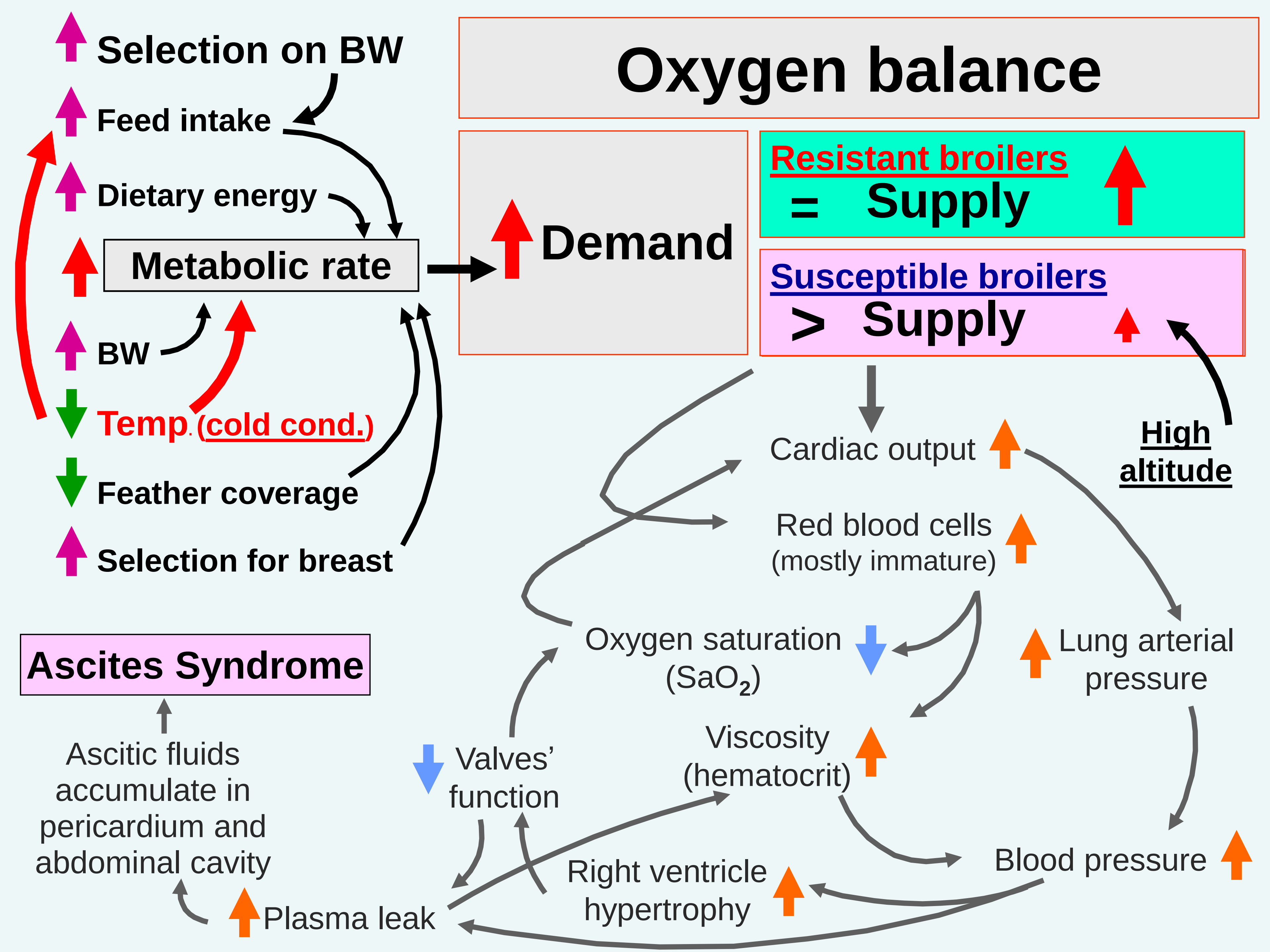
Ascites syndrome develops in broilers suffering from <u>insufficient supply of oxygen</u>

High growth rate ⇨ high feed intake ⇨ high metabolic rate ⇨ <u>high oxygen demand</u>

Broilers with higher growth rate need more oxygen, hence more prone to develop ascites



The genetic association between growth rate and ascites was evident from its increasing incidence, from the 1980’s onwards, and also from controlled studies



Oxygen balance
Selection on BW
Feed intake
Dietary energy
Metabolic rate
BW
Temp. (cold cond.)
Feather coverage
Selection for breast
Demand
Resistant broilers
= Supply
Susceptible broilers
> Supply
High altitude
Cardiac output
Red blood cells
(mostly immature)
Oxygen saturation
(SaO_2)
Lung arterial pressure
Viscosity
(hematocrit)
Valves' function
Blood pressure
Right ventricle hypertrophy
Plasma leak
Ascites Syndrome
Ascitic fluids accumulate in pericardium and abdominal cavity

Management practices to mitigate ascites

Due to the apparent genetic association between growth and ascites, the breeders suggested management practices to reduce ascites in commercial broiler flocks

Insufficient supply of oxygen happens when demand is increasing or supply is reduced

1. Oxygen demand increases under:

1a. low ambient temperatures

1b. high metabolic rate (due to ad-lib consumption of high density feed)

2. Oxygen supply is lower at high altitudes, due to lower levels of oxygen in the air

Suggested management practices:

1. Lowering oxygen requirement of broilers under cold conditions:

1a. Extra heating allows normal growth; but this increase energy costs

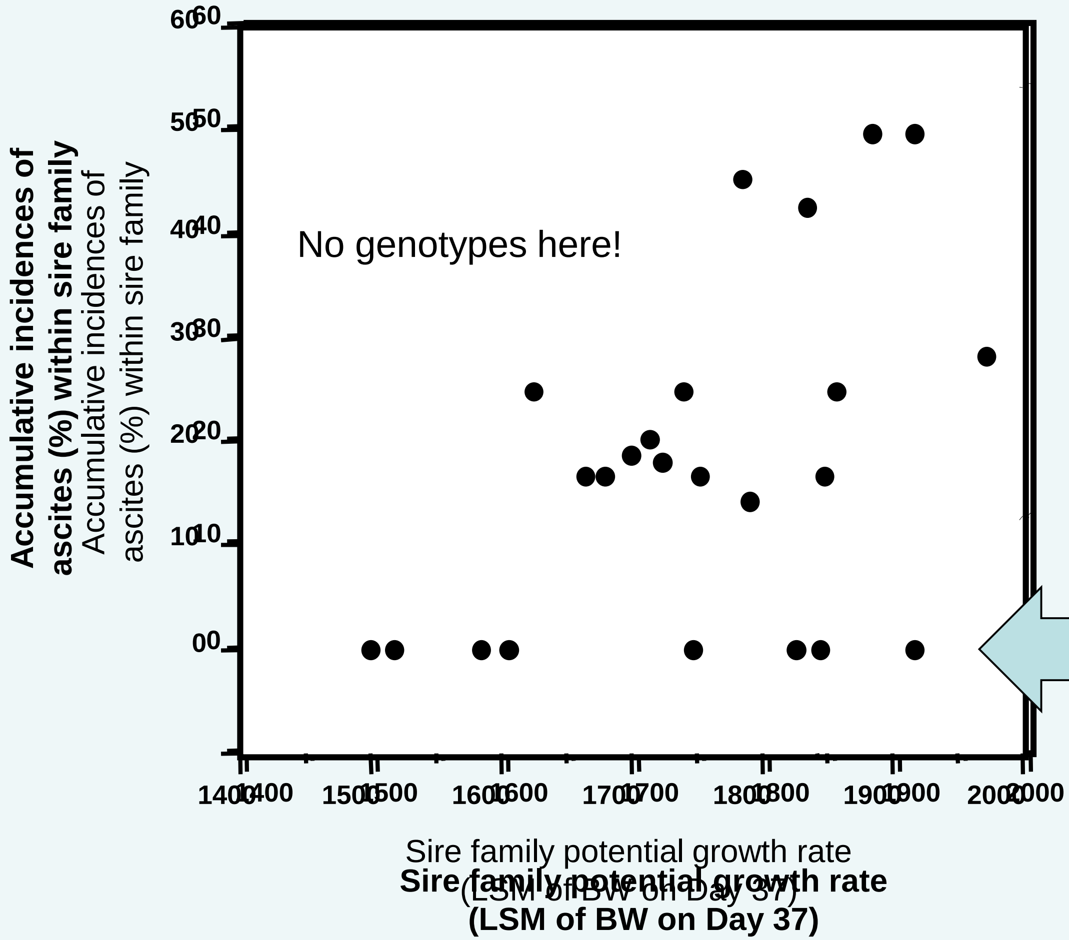
1b. Restricting intake of dietary energy; but this increase feed costs because growing below the genetic potential negatively affect FCR

2. Avoiding broiler production at high altitudes is not feasible in mountainous regions

These practices are not needed if broilers are bred to always meet oxygen demand

<u>Genetic association</u> between <u>growth rate</u> and <u>incidence of ascites</u> was evident from controlled studies

But this association in not symmetrical…



Is it useful to select the genotypes with high growth rate and low ascites incidence?

<u>Genetic aspects of susceptibility to ascites syndrome</u>

<u>Hypothesis No. 1:</u> The tendency of broilers to develop ascites is **heritable;**

<u>Genetically resistant broilers never develop ascites</u>, also under inducing conditions.

After 4 generation of divergent selection on incidence of **<u>ascites mortality</u>** per family, the incidence of ascites was <u>95% in the susceptible line</u> and <u>5% in the resistant line</u> when broilers from both experimental lines were reared together under cold conditions.

<u>Hypothesis No. 2:</u> Rapid growth is **<u>not</u>** the primary cause of ascites syndrome, hence selection for ascites resistance is not expected to reduce growth rate and BW.

This was proved in replicated trials with several populations of commercial broilers.

Final body weights of broilers remaining healthy under ascites-inducing conditions were similar to the body weights suggested by the breeding company for that age.

These results were obtained under experimental stress *(next slide),* and in trial that allowed maximal growth rate of broilers at 2400m above sea level *(Ecuador, 2009)*

Genetic differences in susceptibility to <u>Ascites</u>

Broilers were reared (in 2002) under extreme ascites-inducing conditions, and many died from ascites.

At the age of 38 days, all surviving broilers were inspected for ascites

Broilers with ascites (mean BW=1.5 kg)

<u>In the same flock</u>:

Healthy broilers (mean BW=2.5 kg)

These broilers were healthy in spite of their rapid growth to a high BW

They were <u>genetically resistant</u>!

Identifying resistant vs. susceptible individuals in breeding programs should allow to genetically reduce the incidence of ascites in broiler flocks.

Breeding against the tendency to develop ascites

We suggest that **ascites** develops due to heritable sub-clinical cardiopulmonary defect, expressed in broilers challenged externally (cold, low O_2) or internally (high metabolism)

Individuals with genetic tendency to develop ascites should be identified and bred out

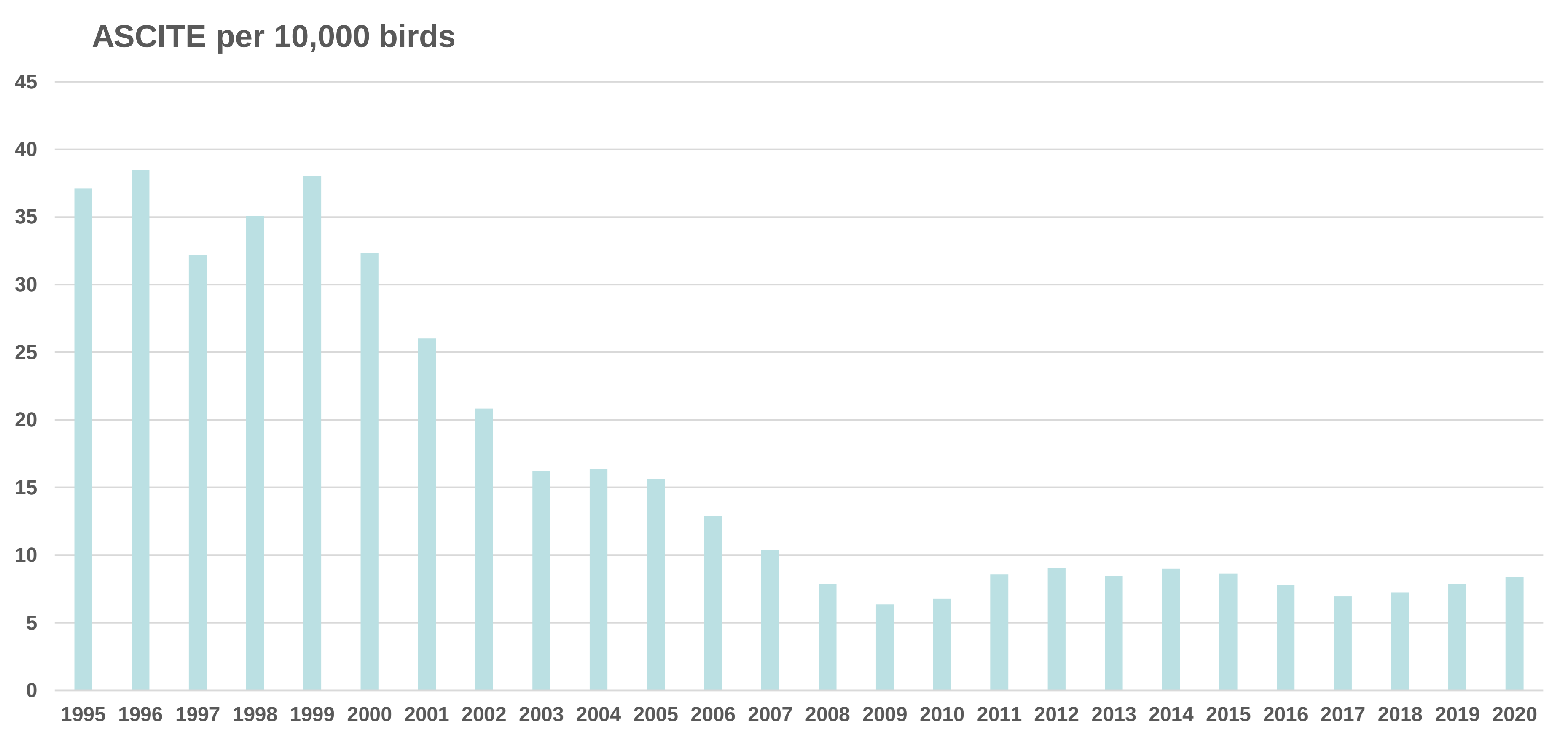
We predicted that in ascites-free stocks, **all** broilers will fully express their genetic potential for rapid growth and high BW, even under ascites-inducing conditions

This statement, written 15 years ago, proved true: ascites is now very rare!

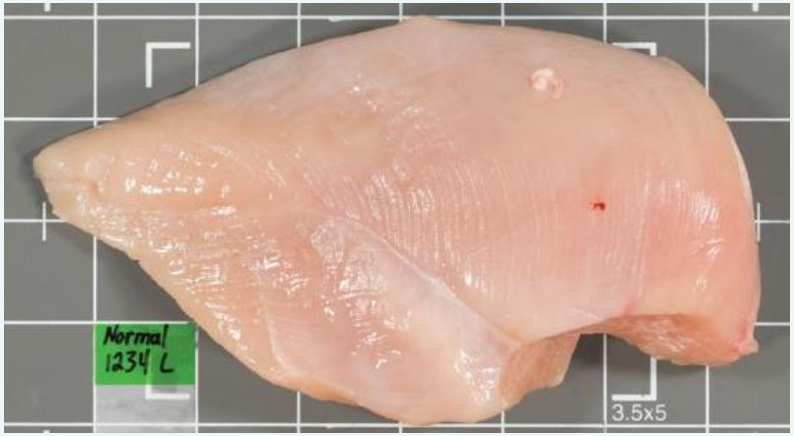
Successful breeding was achieved by identifying the susceptible individuals: those with low levels of **oxygen saturation** in the blood (poor cardiopulmonary function)

Veterinary Oximeter (pictured), detects the bird's heart beat (345 b/m here) from the wing, and then accurately measures oxygen saturation (96% here).

Ascites condemnation in Canadian slaughterhouses



New problem: breast muscle myopathies



Normal breast

In recent years, breast muscle myopathies are showing up, mainly in flocks of ‘high-yield’ broilers, when reared under conditions allowing very rapid growth

White Stripping

Wooden Breast

Spaghetti Meat

If the tendency to develop myopathies is **heritable**, and susceptible individuals can be **identified** and are **not inferior** in growth and yield, **myopathies are expected to be mitigated by breeding**

The breast muscles of 42-d males were scored for White Striping (WS) and for Wooden Breast (WB) by 3 categories: **0**=normal, **1**=moderate, **2**=severe

ANOVA between the 3 categories was used to test the association between the myopathies and the main performance traits: live body weight and breast yield

The broilers with normal breasts had significantly lower body weight and breast yield, suggesting against combined selection for higher weights and against myopathies

Oneway Analysis of Live weight By White Striping

Oneway Anova

Analysis of Variance

Source	DF	F Ratio	Prob > F
White Striping	2	4.5063	0.0139*
Error	81		
C. Total	83		

Means and Std Deviations

Level	Number	Mean
0	47	3170.4
1	32	3283.6
2	5	3465.0

Means Comparisons

Comparisons for each pair using Student's t

Connecting Letters Report

Level			Mean
2	A		3465.0
1	A		3283.6
0		B	3170.4

Oneway Analysis of Live weight By Wooden Breast

Oneway Anova

Analysis of Variance

Source	DF	F Ratio	Prob > F
Wooden Breast	2	7.2278	0.0013*
Error	81		
C. Total	83		

Means and Std Deviations

Level	Number	Mean
0	61	3170.8
1	15	3390.0
2	8	3392.5

Means Comparisons

Comparisons for each pair using Student's t

Connecting Letters Report

Level			Mean
2	A		3392.5
1	A		3390.0
0		B	3170.8

Oneway Analysis of Breast weight By White Striping

Oneway Anova

Analysis of Variance

Source	DF	F Ratio	Prob > F
White Striping	2	16.4799	<.0001*
Error	81		
C. Total	83		

Means and Std Deviations

Level	Number	Mean
0	47	575.1
1	32	649.6
2	5	729.4

Means Comparisons

Comparisons for each pair using Student's t

Connecting Letters Report

Level				Mean
2	A			729.4
1		B		649.6
0			C	575.1

Oneway Analysis of Breast weight By Wooden Breast

Oneway Anova

Analysis of Variance

Source	DF	F Ratio	Prob > F
Wooden Breast	2	27.2553	<.0001*
Error	81		
C. Total	83		

Means and Std Deviations

Level	Number	Mean
0	61	579.4
1	15	697.2
2	8	708.1

Means Comparisons

Comparisons for each pair using Student's t

Connecting Letters Report

Level			Mean
2	A		708.1
1	A		697.2
0		B	579.4

Oneway Analysis of Breast % By White Striping

Oneway Anova

Analysis of Variance

Source	DF	F Ratio	Prob > F
White Striping	2	16.1604	<.0001*
Error	81		
C. Total	83		

Means and Std Deviations

Level	Number	Mean
0	47	18.1
1	32	19.8
2	5	21.1

Means Comparisons

Comparisons for each pair using Student's t

Connecting Letters Report

Level			Mean
2	A		21.1
1	A		19.8
0		B	18.1

Oneway Analysis of Breast % By Wooden Breast

Oneway Anova

Analysis of Variance

Source	DF	F Ratio	Prob > F
Wooden Breast	2	24.1457	<.0001*
Error	81		
C. Total	83		

Means and Std Deviations

Level	Number	Mean
0	61	18.3
1	15	20.6
2	8	20.9

Means Comparisons

Comparisons for each pair using Student's t

Connecting Letters Report

Level			Mean
2	A		20.9
1	A		20.6
0		B	18.3

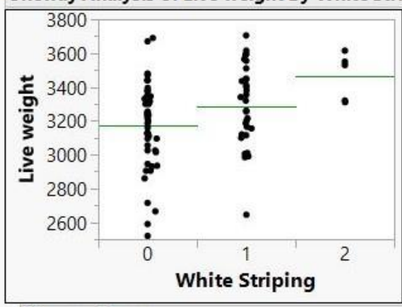
The breast muscles of 42-d males were scored for White Striping (WS) and for Wooden Breast (WB) by 3 categories: **0**=normal, **1**=moderate, **2**=severe

ANOVA between the 3 categories was used to test the association between the myopathies and the main performance traits: live body weight and breast yield

The broilers with normal breasts had significantly lower body weight and breast yield, suggesting against combined selection for higher weights and against myopathies

For breeding, the distributions of individuals is important (more than means)

Oneway Analysis of Live weight By White Striping



Oneway Anova

Analysis of Variance

Source	DF	F Ratio	Prob > F
White Striping	2	4.5063	0.0139*
Error	81		
C. Total	83		

Means and Std Deviations

Level	Number	Mean	Std Dev
0	47	3170.4	253.7
1	32	3283.6	238.7
2	5	3465.0	140.5

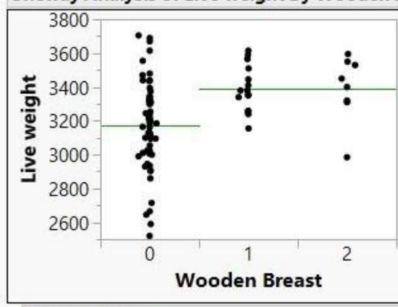
Means Comparisons

Comparisons for each pair using Student's t

Connecting Letters Report

Level			Mean
2	A		3465.0
1	A		3283.6
0		B	3170.4

Oneway Analysis of Live weight By Wooden Breast



Oneway Anova

Analysis of Variance

Source	DF	F Ratio	Prob > F
Wooden Breast	2	7.2278	0.0013*
Error	81		
C. Total	83		

Means and Std Deviations

Level	Number	Mean	Std Dev
0	61	3170.8	258.5
1	15	3390.0	135.6
2	8	3392.5	195.0

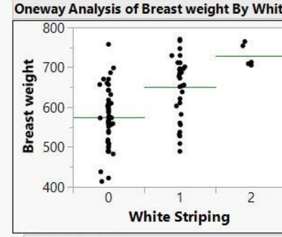
Means Comparisons

Comparisons for each pair using Student's t

Connecting Letters Report

Level			Mean
2	A		3392.5
1	A		3390.0
0		B	3170.8

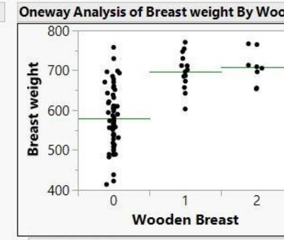
Oneway Analysis of Breast weight By White Striping



Oneway Anova

Analysis of Variance

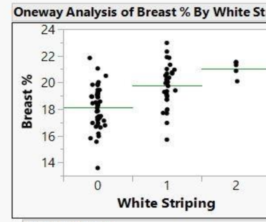
Oneway Analysis of Breast weight By Wooden Breast



Oneway Anova

Analysis of Variance

Oneway Analysis of Breast % By White Striping



Oneway Anova

Analysis of Variance

Source	DF	F Ratio	Prob > F
White Striping	2	16.1604	<.0001*
Error	81		
C. Total	83		

Means and Std Deviations

Level	Number	Mean	Std Dev
0	47	18.1	1.5
1	32	19.8	1.6
2	5	21.1	0.6

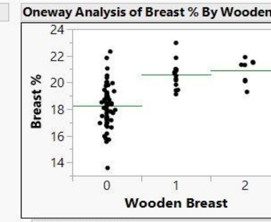
Means Comparisons

Comparisons for each pair using Student's t

Connecting Letters Report

Level			Mean
2	A		21.1
1	A		19.8
0		B	18.1

Oneway Analysis of Breast % By Wooden Breast



Oneway Anova

Analysis of Variance

Source	DF	F Ratio	Prob > F
Wooden Breast	2	24.1457	<.0001*
Error	81		
C. Total	83		

Means and Std Deviations

Level	Number	Mean	Std Dev
0	61	18.3	1.6
1	15	20.6	1.0
2	8	20.9	0.9

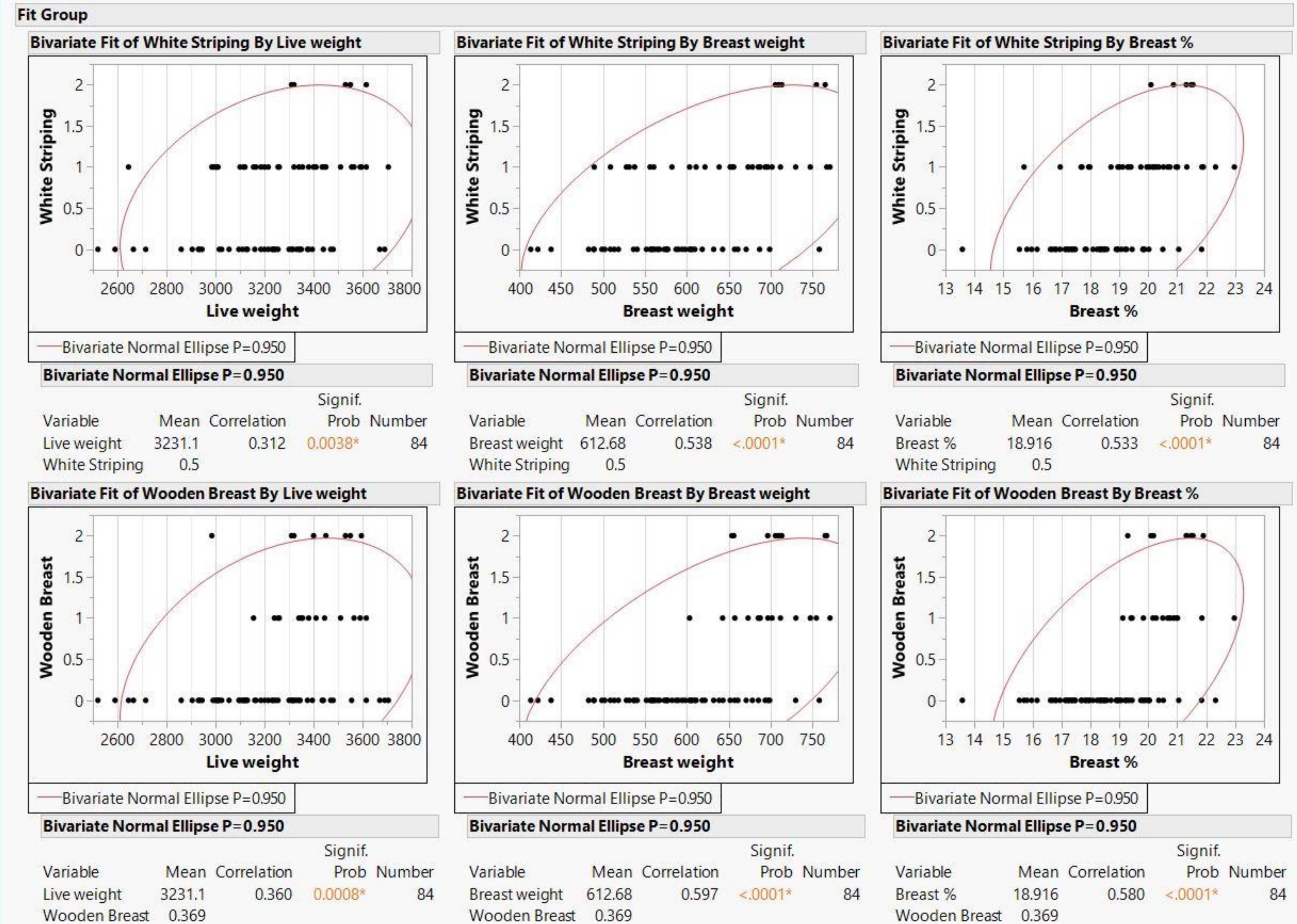
Means Comparisons

Comparisons for each pair using Student's t

Connecting Letters Report

Level			Mean
2	A		20.9
1	A		20.6
0		B	18.3

The three levels of myopathy are assumed to represent continuous variation (as % body fat and % oxygen saturation). Accordingly, they are plotted and correlated with body weight and breast yield, to asses the feasibility of breeding for improved performance combined with lower incidence and severity of breast muscle myopathies



Bivariate Normal Ellipse P=0.950

Variable	Mean	Correlation	Signif. Prob	Number
Live weight	3231.1	0.312	0.0038*	84
White Striping	0.5			

Bivariate Normal Ellipse P=0.950

Variable	Mean	Correlation	Signif. Prob	Number
Breast weight	612.68	0.538	<.0001*	84
White Striping	0.5			

Bivariate Normal Ellipse P=0.950

Variable	Mean	Correlation	Signif. Prob	Number
Breast %	18.916	0.533	<.0001*	84
White Striping	0.5			

Bivariate Normal Ellipse P=0.950

Variable	Mean	Correlation	Signif. Prob	Number
Live weight	3231.1	0.360	0.0008*	84
Wooden Breast	0.369			

Bivariate Normal Ellipse P=0.950

Variable	Mean	Correlation	Signif. Prob	Number
Breast weight	612.68	0.597	<.0001*	84
Wooden Breast	0.369			

Bivariate Normal Ellipse P=0.950

Variable	Mean	Correlation	Signif. Prob	Number
Breast %	18.916	0.580	<.0001*	84
Wooden Breast	0.369			

Spaghetti meat (SM) is the most important breast muscle myopathy

Commonly, it is also scored by 3 categories: **0** = normal, **1** = moderate, **2** = severe

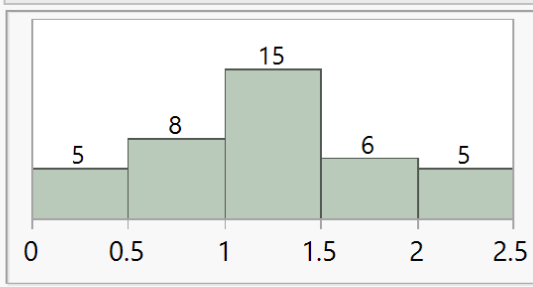
The SM level appears to be continuous hence not accurately described by 3 classes

More accurate measuring will help breeding against the tendency to develop SM

Scale with 5 categories is suggested, with 0.5 and 1.5 for intermediate levels

Distributions Sex=Fem.

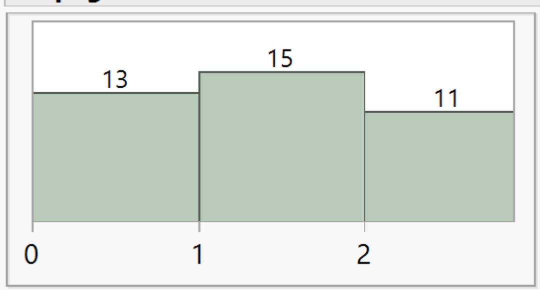
Spaghetti 5



Summary Statistics

Mean	0.974359
Std Dev	0.5954733
Std Err Mean	0.095352
N	39
Variance	0.3545884
CV	61.11436

Spaghetti 3

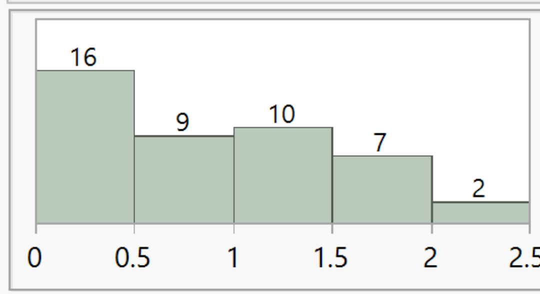


Summary Statistics

Mean	0.9487179
Std Dev	0.7930195
Std Err Mean	0.1269847
N	39
Variance	0.6288799
CV	83.58854

Distributions Sex=Male

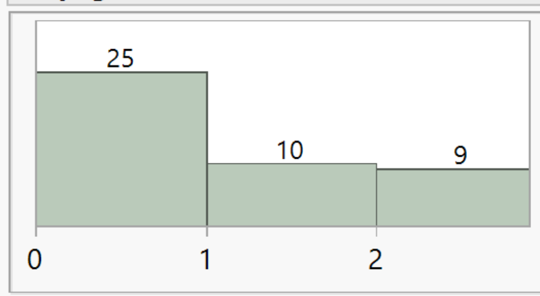
Spaghetti 5



Summary Statistics

Mean	0.6590909
Std Dev	0.6266627
Std Err Mean	0.094473
N	44
Variance	0.3927061
CV	95.079857

Spaghetti 3



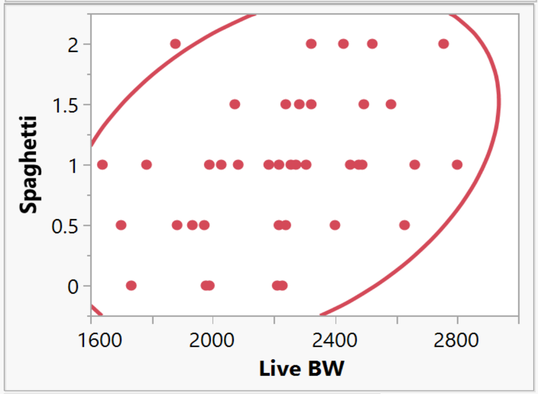
Summary Statistics

Mean	0.6363636
Std Dev	0.8095623
Std Err Mean	0.1220461
N	44
Variance	0.6553911
CV	127.21693

Measurements of individual broilers facilitate consideration of selection against spaghetti, combined with continuous breeding for high body weight and breast meat yield

Fit Group Sex=Fem.

Bivariate Fit of Spaghetti By Live BW Sex=Fem.

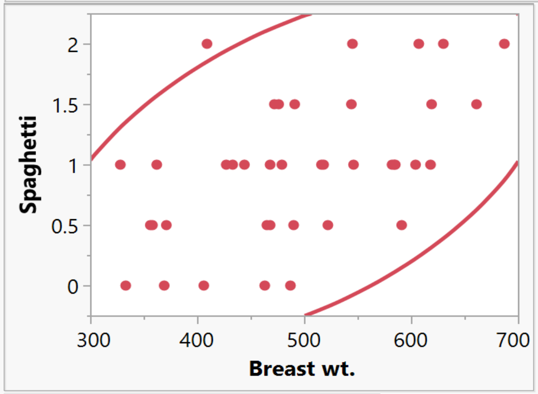


Bivariate Normal Ellipse P=0.950

Bivariate Normal Ellipse P=0.950

Variable	Mean	Correlation	Signif. Prob	Number
Live BW	2221.43	0.378	0.0176*	39
Spaghetti	0.974359			

Bivariate Fit of Spaghetti By Breast wt. Sex=Fem.

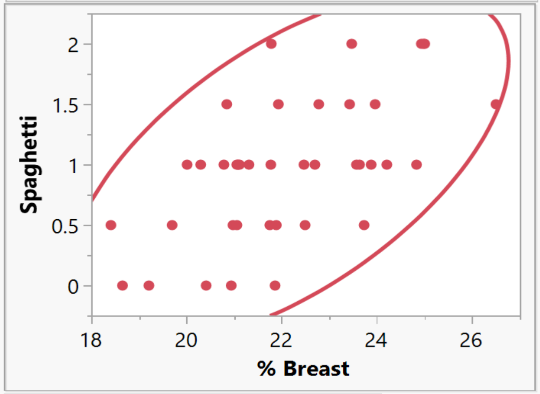


Bivariate Normal Ellipse P=0.950

Bivariate Normal Ellipse P=0.950

Variable	Mean	Correlation	Signif. Prob	Number
Breast wt.	495.2308	0.522	0.0007*	39
Spaghetti	0.974359			

Bivariate Fit of Spaghetti By % Breast Sex=Fem.



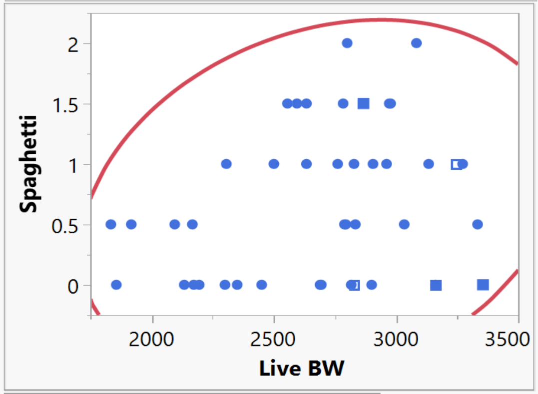
Bivariate Normal Ellipse P=0.950

Bivariate Normal Ellipse P=0.950

Variable	Mean	Correlation	Signif. Prob	Number
% Breast	22.1408	0.607	<.0001*	39
Spaghetti	0.974359			

Fit Group Sex=Male

Bivariate Fit of Spaghetti By Live BW Sex=Male

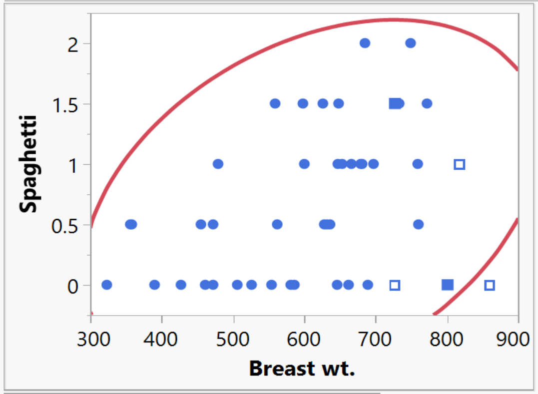


Bivariate Normal Ellipse P=0.950

Bivariate Normal Ellipse P=0.950

Variable	Mean	Correlation	Signif. Prob	Number
Live BW	2692.534	0.249	0.1034	44
Spaghetti	0.659091			

Bivariate Fit of Spaghetti By Breast wt. Sex=Male

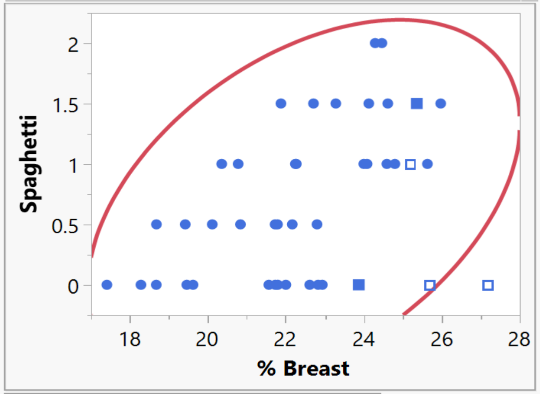


Bivariate Normal Ellipse P=0.950

Bivariate Normal Ellipse P=0.950

Variable	Mean	Correlation	Signif. Prob	Number
Breast wt.	610.0682	0.362	0.0157*	44
Spaghetti	0.659091			

Bivariate Fit of Spaghetti By % Breast Sex=Male



Bivariate Normal Ellipse P=0.950

Bivariate Normal Ellipse P=0.950

Variable	Mean	Correlation	Signif. Prob	Number
% Breast	22.46497	0.443	0.0026*	44
Spaghetti	0.659091			

Summary: growth-related problems, and their genetic mitigation

High growth rate (GR) and high body weight (BW)

High GR and BW ⇨ leg problems (TD etc.) -- but **not** in all broilers!

Incidence of leg problems has been mitigated by breeding (with proper measurements)

High BW ⇦ High GR ⇦ High metabolic rate ⇦ High feed intake

High feed intake ⇨ excessive fatness -- but **not** in all broilers!

Excessive fatness has been mitigated by breeding (for feed efficiency and meat yield)

High BW ⇦ High GR ⇦ High metabolic rate ⇦ High feed intake

High metabolic rate ⇨ ascites under insufficient oxygen -- but **not** in all broilers!

Incidence of ascites has been mitigated by breeding (with proper measurements)

Rapid breast muscles growth ⇦ High breast meat yield ⇦ High BW & High GR

Rapid breast muscles growth(?) ⇨ muscles myopathies -- but **not** in all broilers!

Muscle myopathies hopefully will be mitigated by breeding (with proper measurements)

Heat susceptibility ⇨ *depress growth, FCR and meat yield – in **all** fast-growing broilers*

<u>Hot conditions (heat stress)</u> negatively affect **<u>fast-growing</u>** <u>broilers</u>:

1. Depress actual growth
2. Reduce meat yield and quality
3. Decrease feed efficiency mitigated

The heat effects are not due to ‘biological defect’, but due to the basic need to maintain normal body temperature, hence **<u>all broilers</u>** <u>suffer from heat</u>.

This problem is effectively mitigated by ventilation and cooling, but with higher costs (facilities, equipment, energy), compare to genetic mitigation

Another full-length lecture (…) is needed to cover my 20 years of research on genetic mitigation of the susceptibility of broilers to heat

One aspect of my work on genetics of heat tolerance, is presented in my final slide…


Thank you