Chilling Rate Effects on Pork Loin Tenderness

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Background

- NPB tenderness prediction RFP/Project
- Chilling method project
- Mitigation

5. National Pork Board RFP/Project

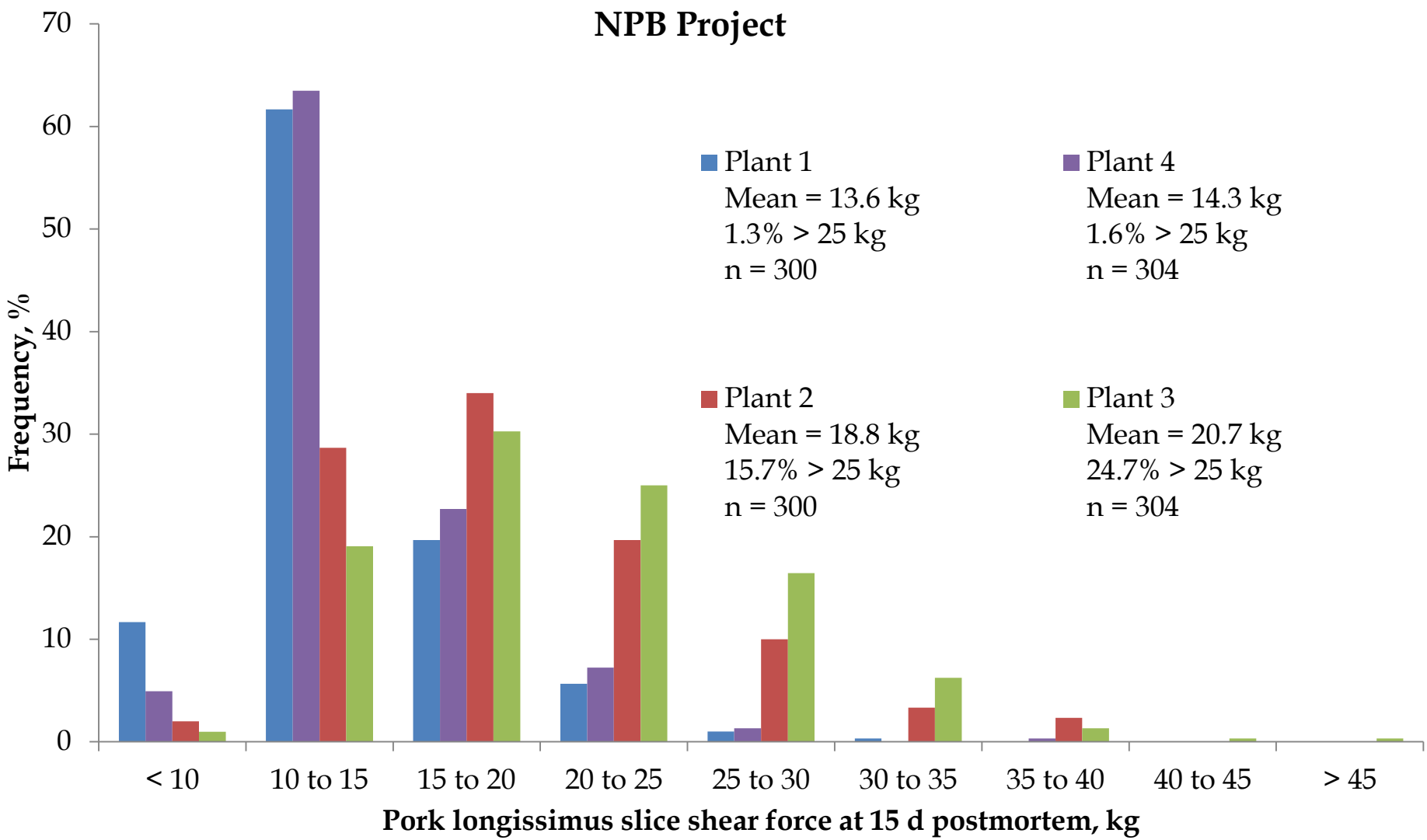
F.

iv. A total of 1,208 loins were sampled.

a. Plant 1 -- 300 loins were sampled on Nov 17, 2009
b. Plant 2 -- 300 loins were sampled on Nov 19, 2009
c. Plant 3 -- 304 loins were sampled on Jan 12, 2010
d. Plant 4 -- 304 loins were sampled on Jan 14, 2010

It is only one day in each plant!

Plant differences in slice shear force



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3 blizzards and extreme cold

Results

1) What is the source of the plant differences and what can we do about it?

Is it chilling rate?

1) Could we by-pass blast chill with some carcasses to document the effect?
   A. Not easy to do
   B. Is that the same as spray chill?
2) Plant comparison
   A. Are the plant differences repeatable?
   B. Document temperature differences

6. Chilling method project

- For each of two replicates, hogs were sourced from a single barn of a commercial finishing operation that fed hogs from a single terminal crossbred line.
- The same genetic line was used in each replicate but hogs were sourced from a different finishing facility for each replicate.
- Hogs were sorted and loaded on trucks following conventional procedures for those finishing facilities.

Chilling method project

- On each day (Mar 02 and Mar 30), three trucks were loaded with each of those trucks delivering the hogs to a different plant.
- Transportation distance was controlled such that the time and distance in transit was approximately equal for each plant.
- Hogs were unloaded and allowed to rest overnight for 12 hours before harvest.

Chilling method project

The three different commercial facilities differed in regards to two factors that may contribute to variation in meat quality and in particular tenderness.

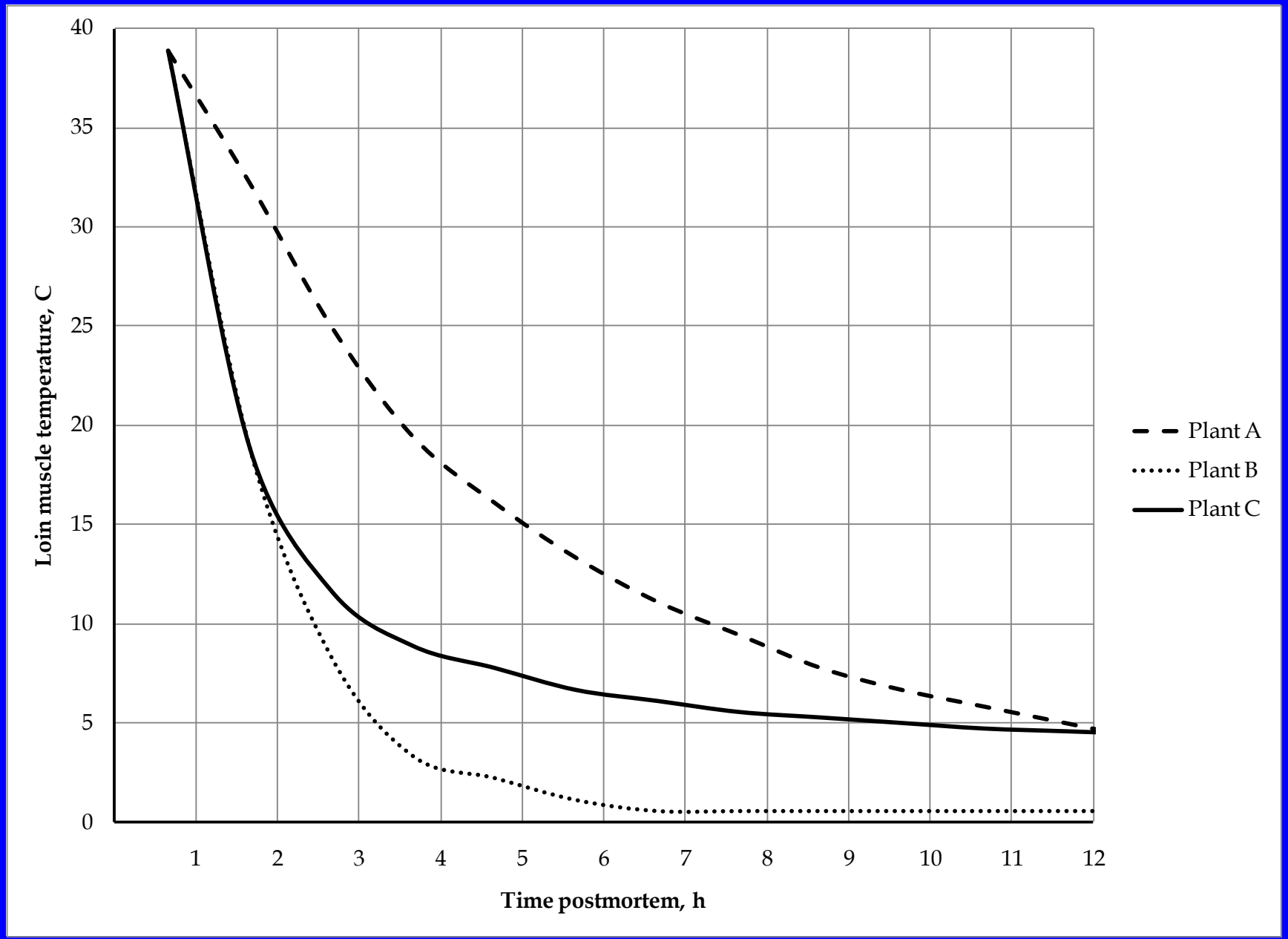
1) Plant A utilized CO_2 stunning and conventional chilling
2) Plant B utilized CO_2 stunning and blast chilling
3) Plant C utilized electrical stunning and blast chilling

The CO_2 stunning systems used at Plants A and B were the same.

It is important to note that the blast chilling systems used in plants B and C differ and resulted in different loin muscle temperature decline curves, particularly after 2 h postmortem.

Therefore, comparison of stunning method differences between plants B and C are somewhat confounded.

Chilling method project



Chilling method project

- From each truckload, 100 carcasses (approximately 50 barrows and 50 gilts) were identified for inclusion in the study that were > 190 lbs (lightweight carcasses whose loins normally would not be boned were excluded).

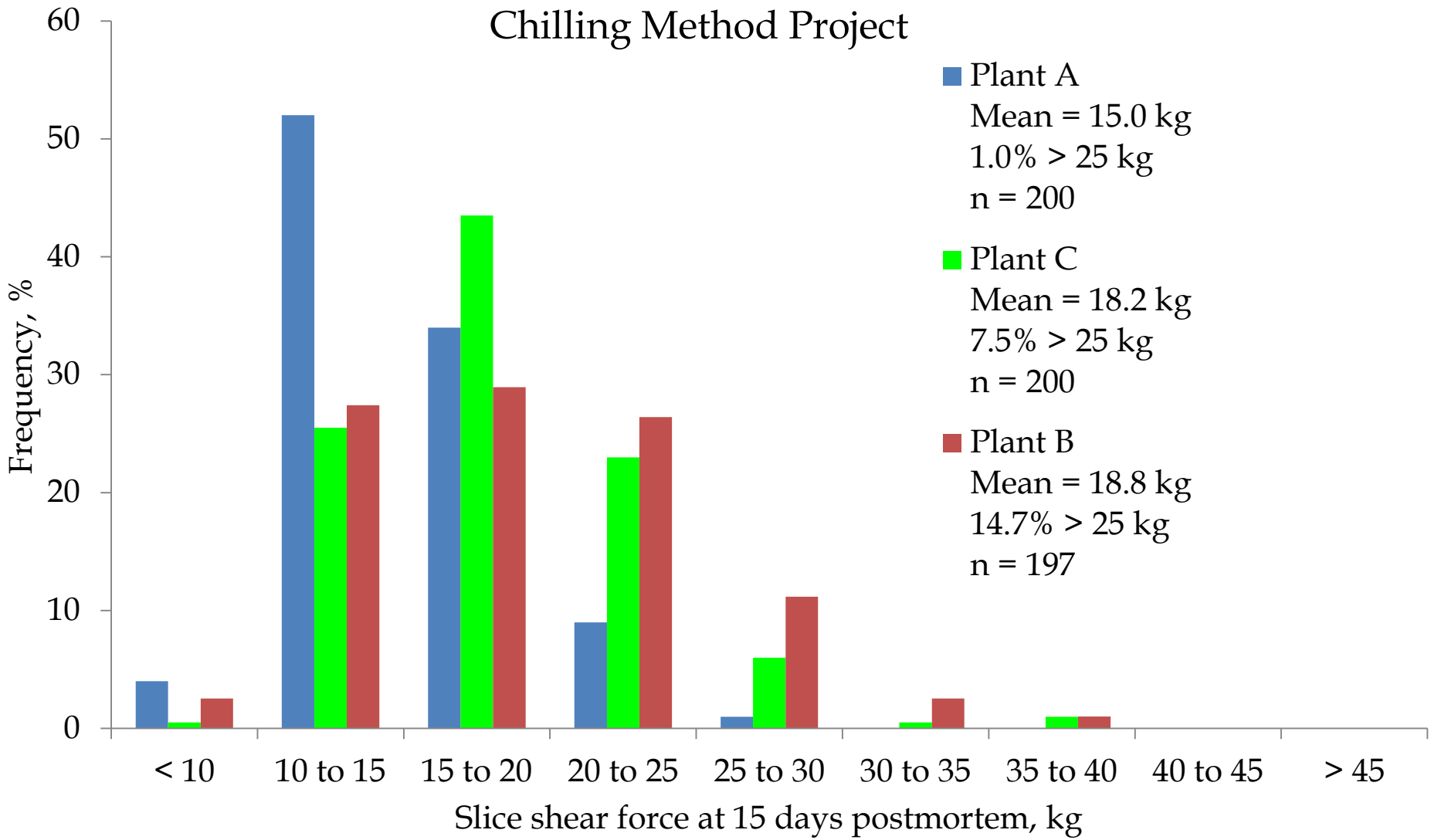
Chilling method project

- The boneless loin was obtained from the left side of each carcass.
- VISNIR was conducted on-line
- Boneless loins were vacuum-packaged, boxed, and transported (-2.8ºC) to the U.S. Meat Animal Research Center.
- All loins arrived at USMARC within 6 to 12 hours of boning and were immediately refrigerated (1.5ºC), unboxed, and placed on solid shelf carts with a single layer of vacuum-packaged boneless loins on each shelf.
- Vacuum-packaged boneless loins were weighed for subsequent determination of purge loss.
- All loins were aged dorsal side (fat side) up.

Chilling method project

- At 14 days postmortem, loins were unpackaged allowed to drip for 5 minutes and weighed for determination of purge loss.
- Two chops were obtained from the 11th rib region of each loin.
- The following day (i.e., 15 days postmortem), fresh loin chops were cooked and slice shear force was determined.
- The average slice shear force was determined for each pair of chops and that value was used for subsequent analysis.

Plant differences in slice shear force



Plant X Rep interaction on SSF

Plant	**Rep I**	**Rep II**
Plant A; CO_2 stunning and conventional chilling	14.3^{d}	15.7^{c}
Plant B; CO_2 stunning and blast chilling	17.6^{b}	20.1^{a}
Plant C; Electrical stunning and blast chilling	18.4^{b}	18.0^{b}
Pooled SEM = 0.46		

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Loin temperatures identical among Reps

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Loin temperatures colder for Rep II

Plant differences in WHC

Plant	Purge loss (%)	Cooking loss (%)
Plant A; CO_2 stunning and conventional chilling	0.48^{c}	16.7^{b}
Plant B; CO_2 stunning and blast chilling	0.64^{b}	16.4^{b}
Plant C; Electrical stunning and blast chilling	0.78^{a}	17.6^{a}
SEM	0.03	0.13

Plant differences in lean color @ 14 d postmortem

Plant	**L***	**a***	**b***
Plant A; CO_2 stunning and conventional chilling	51.0	-1.3	20.6
Plant B; CO_2 stunning and blast chilling	51.4	-1.2	20.1
Plant C; Electrical stunning and blast chilling	53.4	-1.1	19.8

Plant differences in pH @ 14 d postmortem

Plant	**Ultimate pH**
Plant A; CO_2 stunning and conventional chilling	5.74[a]
Plant B; CO_2 stunning and blast chilling	5.72[a]
Plant C; Electrical stunning and blast chilling	5.65[b]

7. Mitigation

- Biochemical mechanism of tenderness
- Is it causing cold shortening?
- Is it reducing postmortem proteolysis?

Biochemical mechanism

- Apparently not cold shortening
- Sarcomere length did not differ among plants
  - Plant A = 1.74 μm; n = 100
  - Plant B = 1.73 μm; n = 97
  - Plant C = 1.72 μm; n = 100
- Sarcomere length does account for a significant proportion of the within plant variation in SSF (r = -0.65, -0.57, -0.62, respectively)
- VISNIR accounts for a significant proportion of the variation in sarcomere length

Biochemical mechanism

- Apparently not affecting postmortem proteolysis
- Western blotting of desmin
  - Plant A = 83.6% of desmin degraded; n = 100
  - Plant B = 82.6% of desmin degraded; n = 97
  - Plant C = 76.5% of desmin degraded; n = 100
- Very small plant differences and most samples in all plants are highly degraded.
- Variation in postmortem proteolysis does account for a significant proportion of the within plant variation in SSF (r = -0.39, -0.42, -0.37, respectively)

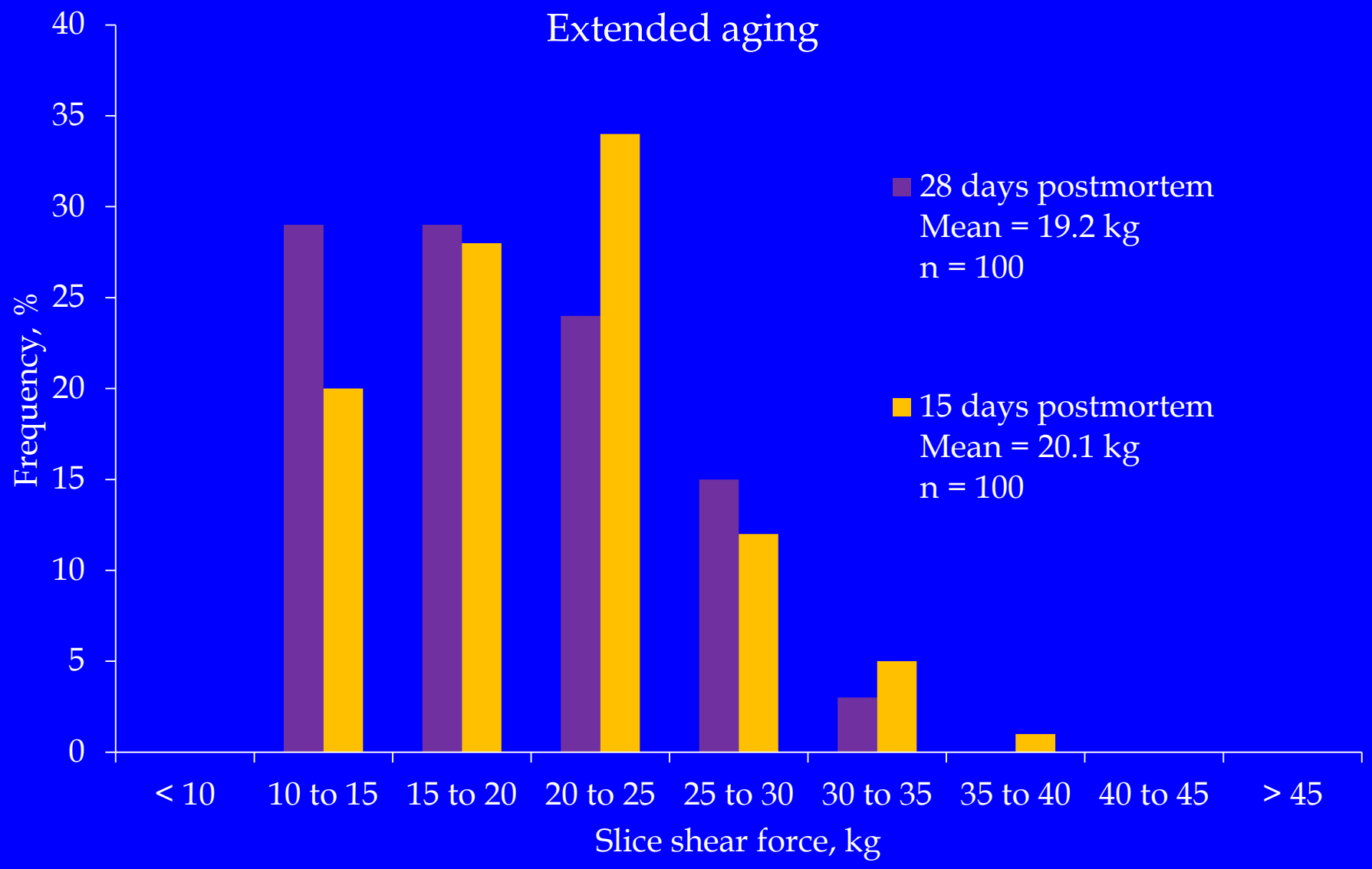
Biochemical mechanism

- Not sarcomere length
- Not postmortem proteolysis
- But, subsample testing of SSF outliers with Myofibril Fragmentation Index suggests less degradation in tough samples from blast chill plants.
- So, what is going on?
- We don’t know.

Mitigation

- Extended aging?
  - 15 days
  - International

Extended aging – Plant B Rep 2



Mitigation

- Electrical stimulation?
- We conducted two in-house study to test this
  - We do not have blast chill
  - We do not have CO_2 stunning
- In both experiments, hogs were electrically-stunned, skinned, eviscerated, split, and sides were hung on separate trolleys.
- Alternating sides were electrically-stimulated (a single 10 s pulse of 120 v, 10 hz) at 34 min post-exsanguination.

Mitigation

- Experiment A. Pilot study (6 hogs) to assess impact of blast chilling and ES on postmortem proteolysis.
- Boneless loins were removed from the carcass at 35 min postmortem and subdivided.
- At 40 min postmortem, loin sections were placed in water or ice-water baths to mimic conventional and blast chill temperature declines.
- Temperature decline data was very similar to the data that we had for Plants A and B in the chilling method project.

Postmortem proteolysis

- Postmortem proteolysis data indicated no effect of chilling regime or ES.
- This made us question whether or not we add actually impacted tenderness.
- So we measured slice shear force @ 13 days postmortem.

SSF

- Rapid chill had much higher SSF than slow chill and ES appeared to help SSF of rapid chill

Plant	Control	ES
Rapid chill	21.5	16.8
Slow chill	11.2	13.0

- But, this was excised (6 inch long) sections of boneless that was free to shorten

pH at 3:40 min postmortem

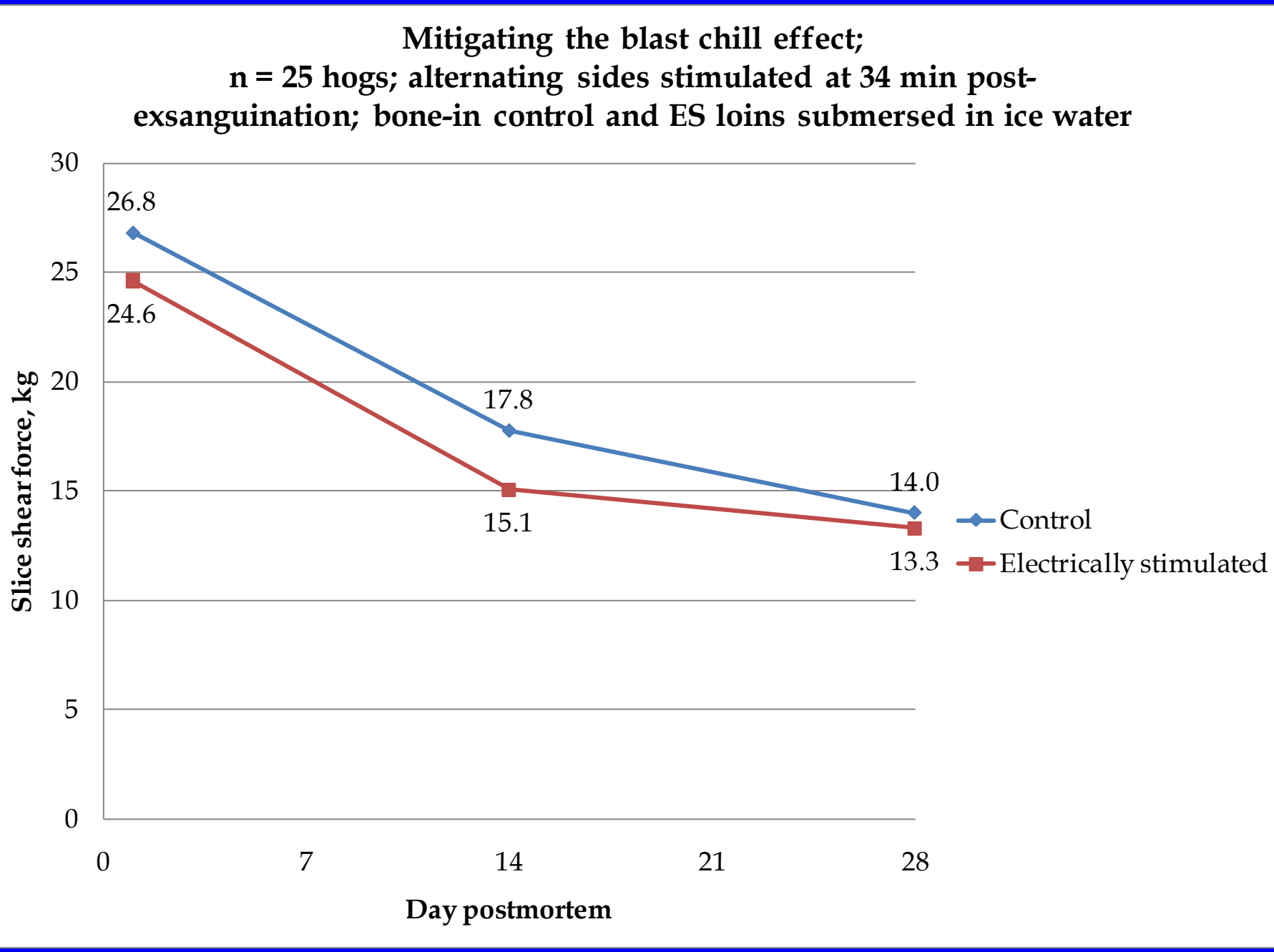
Plant	Control	ES
Rapid chill	6.19	6.09
Slow chill	5.98	5.86

Mitigation

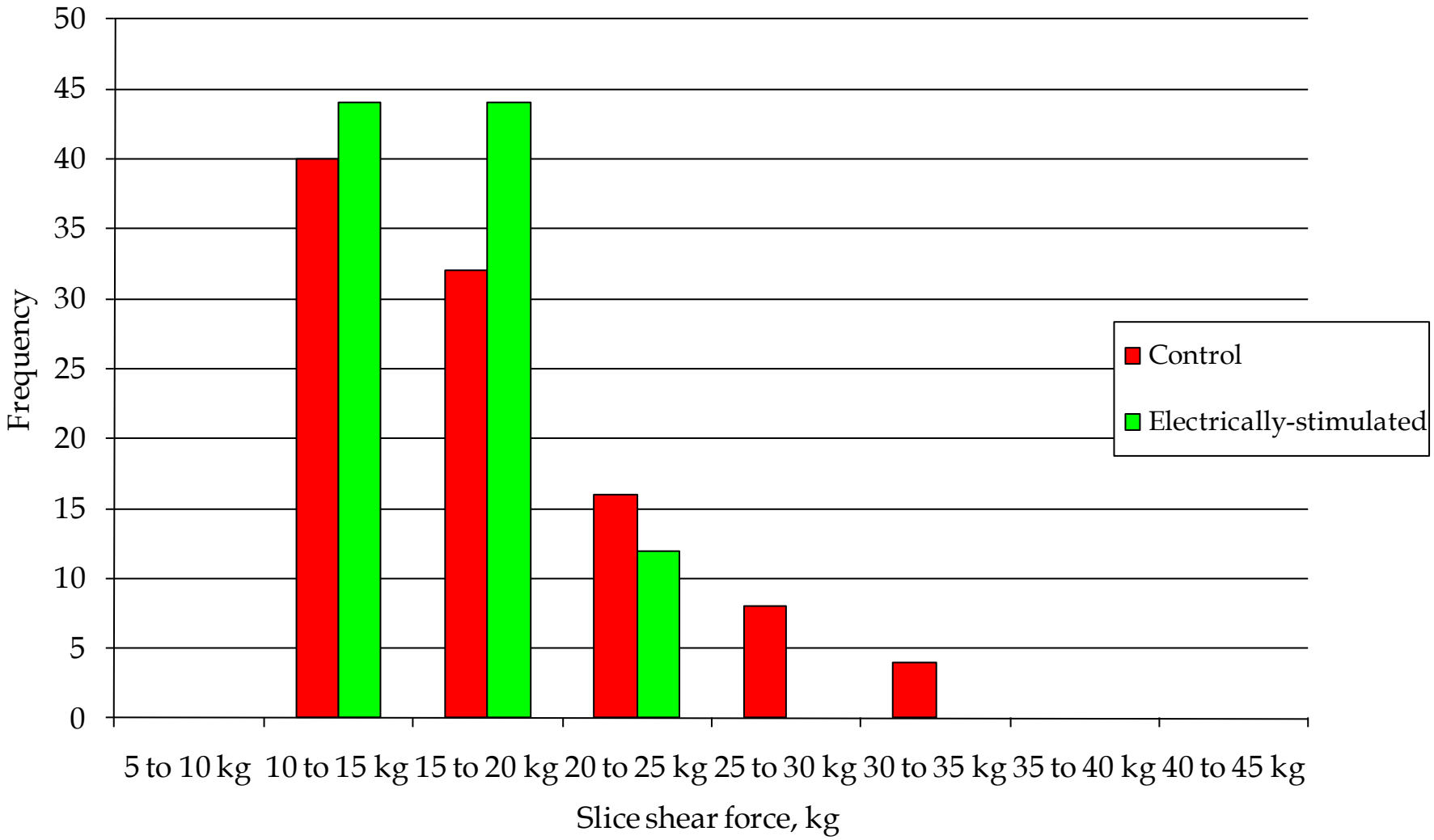
- Experiment B. 25 hogs.
- For this experiment we attempted to rapidly chill all loins.
- Bone-in loins were removed from the control and ES carcass sides and submersed in ice water.
- The temperature decline data indicates that we were not successful at achieving as rapid a temperature decline as blast chilling

Mitigation

- At 22 h postmortem, a 9-inch long boneless loin section was obtained posterior to the 10th rib.
- Two chops were removed from the anterior end of the boneless loin section for measurement of SSF at 1 d postmortem and the remainder of the boneless loin section was weighed, vacuum packaged, and aged.
- At 13 d postmortem, loin sections were unpackaged and reweighed for determination of purge loss.
- Chops were obtained for measurement of SSF at 14 d postmortem.
- Again, loin sections were repackaged and aged until 27 d postmortem when chops were obtained for measurement of SSF at 28 d postmortem.


Mitigating the blast chill effect;
n = 25 hogs; alternating sides stimulated at 34 min post-exsanguination; bone-in control and ES loins submersed in ice water
Slice shear force, kg
30
25
20
15
10
5
0
26.8
24.6
17.8
15.1
14.0
13.3
0
7
14
21
28
Day postmortem
Control
Electrically stimulated

Effect of electrical-stimulation on the distribution of pork longissimus slice shear force values at 14 day postmortem – bone-in control and ES loins were submersed in ice-water



Mitigation

- Purge loss was not affected by ES (Control was numerically higher; 1.9 vs 1.6)
- ES did not affect sarcomere length or MFI

Mitigation

- We think that we have done all the good we can do on ES under the limitations of our meat lab conditions (Electrical stunning, skinned carcasses, simulated blast chill).

Mitigation

- Field test ES with current carcass weights

Carcase chilling systems and their impact on meat quality

- Chilling is normally delivered in two stages: a pre-chilling stage consisting of a conveyerised tunnel operating at sub-zero temperatures; and a subsequent conventional-type chilling regime ("equalising chill")
- The reduction in chilling times is the most obvious advantage resulting in improved operational efficiency through increased throughput
- Rapid chilling results in reduced weight losses
- Disadvantages of blast chilling include:
  - High initial capital investment
  - Detrimental effects on pork eating qualities because of cold shortening (unless electrical stimulation is applied, see below)
  - If any major freezing of the lean occurs, there may be a large increase in drip loss from the retail cut
  - Changes in pork colour (rapidly chilled loins can be darker and slightly less colour-saturated)

Measures to improve meat quality in fast chilling systems

Fast chilling systems are designed to reduce the chilling time and the evaporative weight loss but they may have a serious detrimental effect in terms of meat quality, particularly texture. Pork texture, and more specifically, tenderness, is one of the key characteristics determining consumers' overall liking of pork. Therefore, measures should be taken to maintain pork tenderness. At the slaughterhouse level, three main measures have been proven to be effective when improving pork tenderness:

- Electrical stimulation
- Pelvic suspension
- Ageing

Electrical stimulation is suitable where carcases will be rapidly chilled, eg 'blast chilling', but not for conventional chilling systems. Pelvic suspension and ageing can be adopted both where fast chilling systems are used and to enhance tenderness under conventional slow chilling regimes.

Electrical stimulation

The beneficial effect of the electrical stimulation on pork tenderness has been widely demonstrated. Electrical stimulation prevents cold shortening as it accelerates post-mortem metabolism in muscle tissues. Ageing rate is also faster, in particular for the muscles which enter rigor mortis earlier (eg the loin). However, the incidence of Pale Soft Exudative (PSE) meat is likely to increase unless rapid chilling is used because it accelerates the pH decline in muscles.

Pelvic suspension

Pelvic suspension consists of hanging carcases from the aitch bone, rather than from the achilles tendon, after slaughter and prior to the onset of rigor. In addition to pork texture, this measure also improves water-holding capacity of muscles and it reduces drip loss. Furthermore, processing yields (eg brine uptake and retention) can increase in the hindquarter muscles. The major drawbacks of this practice are the increase in chilling space and some health and safety issues in fast pork processing lines.

Ageing

Ageing is the natural process of meat tenderisation post-rigor mortis in which the enzymatic processes in meat break down some of the protein structures holding the meat together and, as a result, tenderness increases *(see Target Pork Quality No4 for further details on this topic)*.

Novel chilling systems

There is a wide range of alternative chilling systems available, including spray, immersion and ice-bank systems. Of particular interest is ultra-rapid chilling in three stages. This blast-chilling method is reported to substantially improve tenderness. Carcases are rapidly chilled to a temperature below 15°C in a blast tunnel, followed by an equilibration stage where temperature is maintained at 10-15°C for 6 hours. Finally, carcases are returned to the blast chilling tunnel for 12 min and placed in an equilibration cold room at 4°C until the next day. This results in reduced drip loss and improved tenderness over traditional blast chilling systems.

For more information and advice contact: BPEX, PO Box 44, Winterhill House, Snowdon Drive, Milton Keynes MK6 1AX
telephone: 01908 844749 • email: kt@bpex.org.uk • website: www.bpex.org.uk

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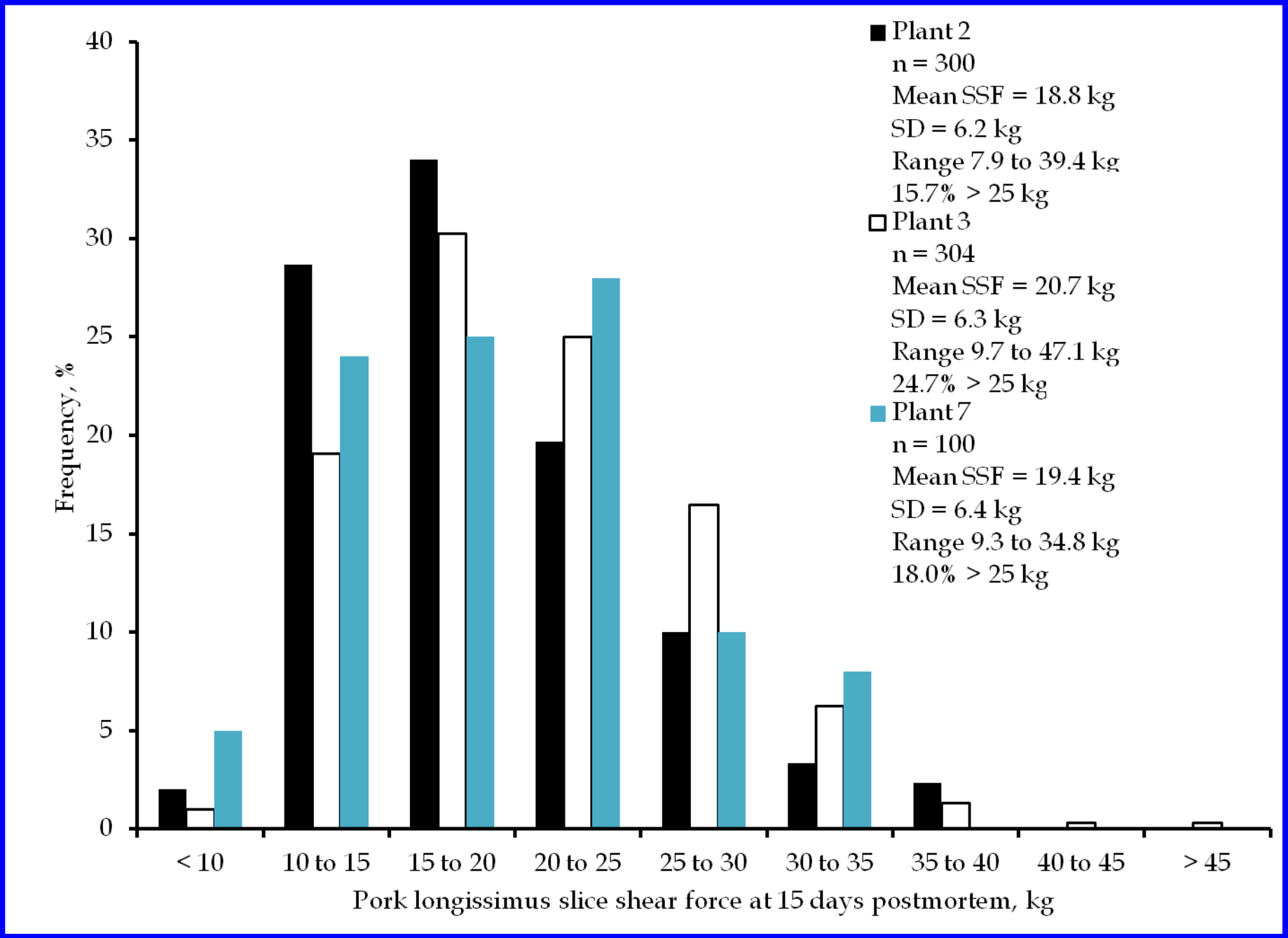
BPEX, PO Bo
telephone: 01

Mitigation

- Marker Assisted Selection
  - We have extracted DNA from all of the loins in the NBP and chilling method project
  - As part of collaboration with MSU and NPB, USMARC scientists have genotyped these loins. Some of these loins have been genotyped with the 60K HD porcine SNP chip and the remainder have been genotyped with a LD porcine SNP chip and 60K genotypes will be imputed.
  - Do some genotypes consistently produce tender meat regardless of chilling method?

Mitigation

- VISNIR sorting
  - Target enhancement


Plant 2
n = 300
Mean SSF = 18.8 kg
SD = 6.2 kg
Range 7.9 to 39.4 kg
15.7% > 25 kg
Plant 3
n = 304
Mean SSF = 20.7 kg
SD = 6.3 kg
Range 9.7 to 47.1 kg
24.7% > 25 kg
Plant 7
n = 100
Mean SSF = 19.4 kg
SD = 6.4 kg
Range 9.3 to 34.8 kg
18.0% > 25 kg
Frequency, %
0
5
10
15
20
25
30
35
40
< 10
10 to 15
15 to 20
20 to 25
25 to 30
30 to 35
35 to 40
40 to 45
> 45
Pork longissimus slice shear force at 15 days postmortem, kg

In-home pork chop evaluation

Slice shear force, kg	n	Average of Like Rating
< 10 kg	306	6.4a
10 to 15 kg	506	5.7b
15 to 20 kg	177	5.2c
20 to 25 kg	77	4.9cd
> 25 kg	44	4.4d