CA18105

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Risk-based meat inspection and integrated meat safety assurance

RIBMINS WG2/WG3 Training school: Farm and abattoir interventions in a risk-based meat safety assurance system

Dragan Antic | 29-Jun-22 | virtual, UK

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Risk-based meat inspection and integrated meat safety assurance

Physical abattoir interventions

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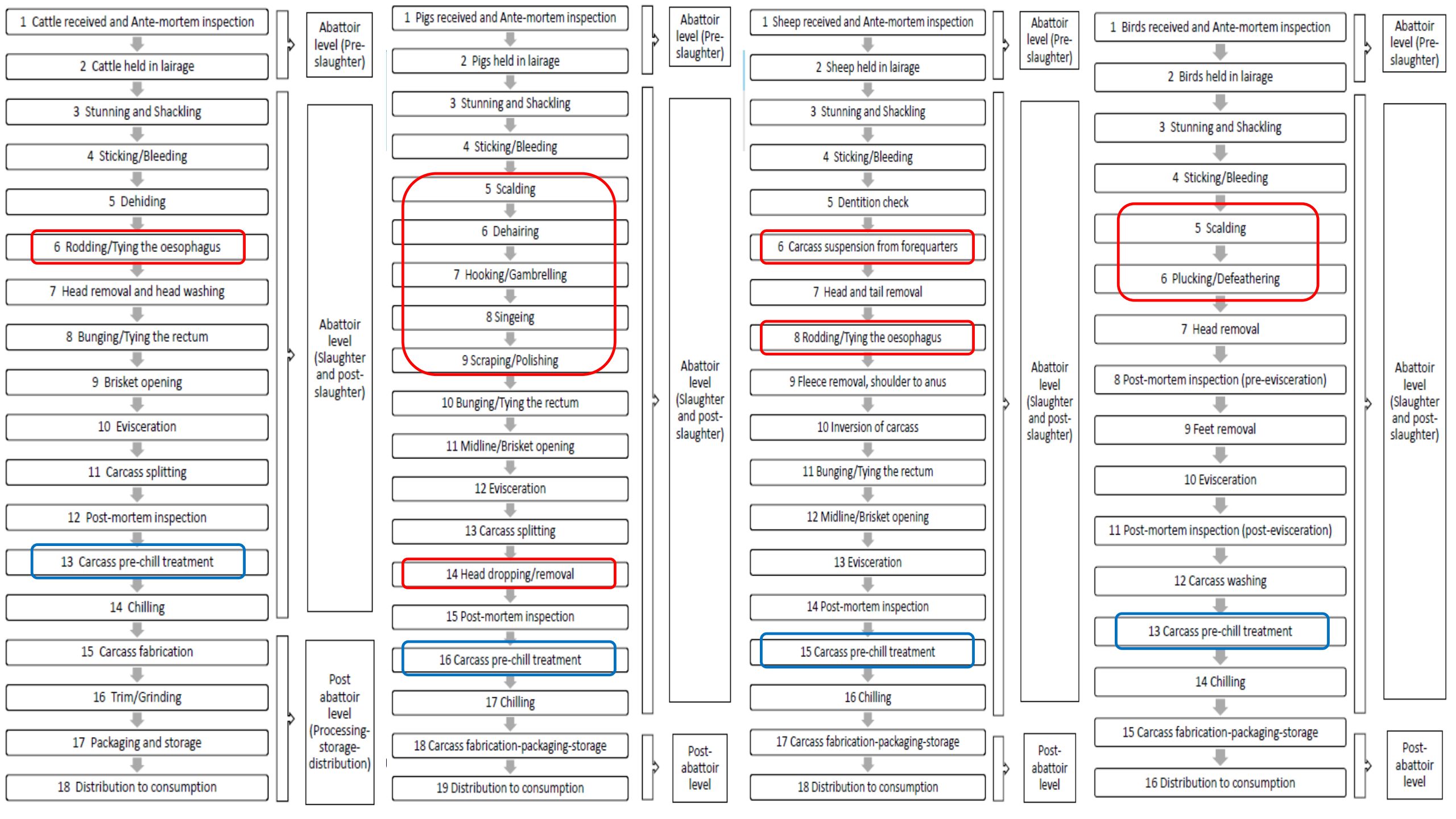
Interventions

- Actions taken during slaughter and processing to reduce microbial contamination of carcasses
  - Three modes of action: microbial **removal**, **immobilisation (prevention of contamination)** and **killing (elimination)**
- Interventions:
  - **GHP-based Standard Processing Procedures (SPPs)** - pre-requisites:
    - at the pre-slaughter stage (e.g. lairage holding time, feed withdrawal, logistic slaughter, animal cleanliness scoring, animals clipping/washing); and
    - during slaughter and carcass dressing (e.g. bunging/rectum sealing, rodding/oesophagus sealing, cattle hide removal methods, scalding, singeing, pig head removal, knife trimming, carcass water washing, chilling)
  - **Hazard-based** – established efficacy on cattle/sheep skins and carcass meat surface:
    - hot water washing, steam pasteurisation, organic acid washes, other chemical washes
- Priority microbiological hazards for control in: **beef**: *Salmonella* and STEC; **pigs**: *Salmonella* and *Yersinia*; **sheep**: STEC; and **poultry**: *Salmonella*, *Campylobacter* and ESBL/AmpC *E. coli*
- Indicator microorganisms for process hygiene assessment: aerobic colony count (ACC), *Enterobacteriaceae* count (EBC), generic *E. coli* count (ECC)


1 Cattle received and Ante-mortem inspection
2 Cattle held in lairage
3 Stunning and Shackling
4 Sticking/Bleeding
5 Dehiding
6 Rodding/Tying the oesophagus
7 Head removal and head washing
8 Bunging/Tying the rectum
9 Brisket opening
10 Evisceration
11 Carcass splitting
12 Post-mortem inspection
13 Carcass pre-chill treatment
14 Chilling
15 Carcass fabrication
16 Trim/Grinding
17 Packaging and storage
18 Distribution to consumption
Abattoir level (Pre-slaughter)
Abattoir level (Slaughter and post-slaughter)
Post abattoir level (Processing-storage-distribution)
1 Pigs received and Ante-mortem inspection
2 Pigs held in lairage
3 Stunning and Shackling
4 Sticking/Bleeding
5 Scalding
6 Dehairing
7 Hooking/Gambrelling
8 Singeing
9 Scraping/Polishing
10 Bunging/Tying the rectum
11 Midline/Brisket opening
12 Evisceration
13 Carcass splitting
14 Head dropping/removal
15 Post-mortem inspection
16 Carcass pre-chill treatment
17 Chilling
18 Carcass fabrication-packaging-storage
19 Distribution to consumption
Abattoir level (Pre-slaughter)
Abattoir level (Slaughter and post-slaughter)
Post-abattoir level
1 Sheep received and Ante-mortem inspection
2 Sheep held in lairage
3 Stunning and Shackling
4 Sticking/Bleeding
5 Dentition check
6 Carcass suspension from forequarters
7 Head and tail removal
8 Rodding/Tying the oesophagus
9 Fleece removal, shoulder to anus
10 Inversion of carcass
11 Bunging/Tying the rectum
12 Midline/Brisket opening
13 Evisceration
14 Post-mortem inspection
15 Carcass pre-chill treatment
16 Chilling
17 Carcass fabrication-packaging-storage
18 Distribution to consumption
Abattoir level (Pre-slaughter)
Abattoir level (Slaughter and post-slaughter)
Post-abattoir level
1 Birds received and Ante-mortem inspection
2 Birds held in lairage
3 Stunning and Shackling
4 Sticking/Bleeding
5 Scalding
6 Plucking/Defeathering
7 Head removal
8 Post-mortem inspection (pre-evisceration)
9 Feet removal
10 Evisceration
11 Post-mortem inspection (post-evisceration)
12 Carcass washing
13 Carcass pre-chill treatment
14 Chilling
15 Carcass fabrication-packaging-storage
16 Distribution to consumption
Abattoir level (Pre-slaughter)
Abattoir level (Slaughter and post-slaughter)
Post-abattoir level

Presentation in process flow order for all species: beef, pig, sheep, broiler chicken interventions

I. Pre-slaughter (lairage) GHPs and SPPs
II. Animal coat interventions (post-exsanguination)
III. GHP-based SPPs for carcasses on the slaughterline
IV. Hazard-based physical interventions for carcasses (pre- and post-evisceration, pre-chilling)
V. Chilling
VI. Multiple interventions

I. Pre-slaughter (lairage) GHPs and SPPs

- **Lairage**: holding facilities (pens, yards and other holding areas) used for accommodating animals in order to give them necessary attention (such as water, feed, rest) before they are moved on or used for specific purposes, including slaughter
- **GHP-based SPPs**: A range of different practices that are pre-requisites to hazard-based interventions, are qualitative in nature and based on empirical knowledge and experience and may have a pathogen-reduction effect

- Animals handling in lairage and holding time
- Logistic slaughter
- Animal cleanliness scoring
- Animal clipping
- Animal washing

I. Pre-slaughter (lairage) GHPs and SPPs: **animals handling in lairage and holding time**

- The time animals are held in lairage before slaughter and other handling practices
- Increased opportunity for cross-contamination between animals and animals and surfaces, due to prolonged lairage time and/or increased stress
- **Cattle**: 47% of *E. coli* O157 and 65% of *Salmonella* **hide** strains attributable solely to the lairage environment; 67% of *E. coli* O157 and 30% of *Salmonella* **carcass** strains, attributed solely to the lairage environment (Arthur et al 2008)
- Eight times greater risk of having *E. coli* O157-positive cattle hides at slaughter if lots of cattle held in *E. coli* O157-positive lairage pens (Dewell et al. (2008))
- **Pigs**: Avoiding lairage reported a protective treatment effect on *Salmonella* prevalence, reduction from 21% to 5% (measured in caecal prevalence of slaughter pigs) (FAO, 2016)

I. Pre-slaughter (lairage) GHPs and SPPs: **logistic slaughter**

- Strategic risk categorisation and scheduling of slaughter of animals from herds categorized as 'low risk' for given pathogen **prior to** animals from herds categorized as 'higher risk', to minimise the potential for cross-contamination.
- Used for pigs and poultry, based on the analysis of FCI and ante-mortem inspection.

- **Pigs**: Inconsistent efficacy reported on *Salmonella* in carcasses and the effects depend on lairage design and efficiency of cleaning abattoir surfaces and equipment
- **Poultry**: slaughtering negative flocks before positive flocks had negligible effect on their contamination with both *Campylobacter* (Pless, 2012) and *Salmonella* (Zutter, 2005)
- Slaughterhouse environment more important source of broiler carcass contamination.

I. Pre-slaughter (lairage) GHPs and SPPs: **animal cleanliness scoring**

- **Definition**: scoring and categorisation of hide/fleece cleanliness before cattle/sheep slaughter according to the established objective system, and actions taken in case animals are too dirty to be processed hygienically
- **Mechanism of action**: informing further actions to be taken to prevent contamination from hide/fleece to dressed carcass
- **Used in**: UK, Ireland, Norway, Sweden, Finland, France, Belgium, Germany
- **Expected efficacy**: ~1 $\log_{10}$ of general indicators and ~0.7 $\log_{10}$ faecal indicators reduction in carcass bacterial load, when clean **cattle/lambs** were processed vs. dirty

I. Pre-slaughter (lairage) GHPs and SPPs: **cattle / sheep clipping / shearing**

- **Definition:** Clipping or shaving hair from hide surface to physically remove dirt and contamination from hides.
- Procedures in place for use pre-slaughter to deal with excessively soiled animals should not compromise animal welfare
- **Mechanism of action:** Physical removal of dirt and microorganisms.
- **Used in:** Most countries
- **Expected efficacy:** Negligible, less than 0.5 $\log_{10}$ of general indicators, very often increase bacterial recoverability and transfer onto resulting carcasses

I. Pre-slaughter (lairage) GHPs and SPPs: **cattle / sheep water washing**

- **Definition:** ambient or cold-temperature wash to physically remove dirt and contamination from hides.
- **Mechanism of action:** Physical removal of dirt and microorganisms.
- **Used in:** Australia, New Zealand, South America (rarely used in Europe)
- **Expected efficacy:** Negligible, less than 0.5 $\log_{10}$ of general indicators, very often increase bacterial recoverability and transfer onto resulting carcasses.
  - "… to clean live lambs (thorough washing) … even if satisfying visually they effect only a trivial reduction in contamination of the hide, and have so little effect on the general contamination of the carcass that they are a waste of time bacteriologically" (Roberts, 1980)

II. Animal coat interventions (post-exsanguination)

- Cattle hide and sheep fleece treatments after animal stunning and bleeding, before dehiding
- “Proactive” interventions dealing with sources of contamination

- Cattle hide online clipping
- Microbial immobilisation treatments (‘shellac hide coating’)
- Thermal interventions (scalding bob-veal hide-on carcasses)

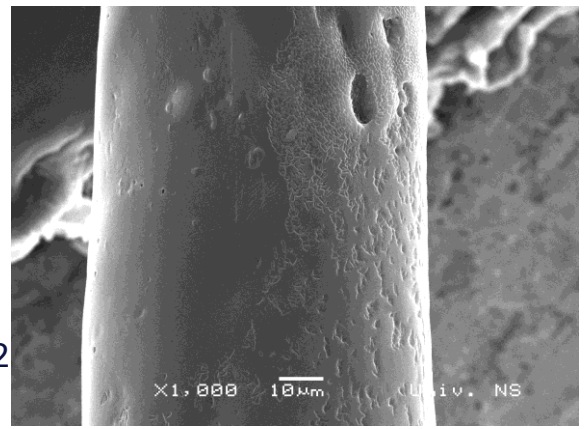
II. Animal coat interventions (post-exsanguination): **cattle hide online clipping**

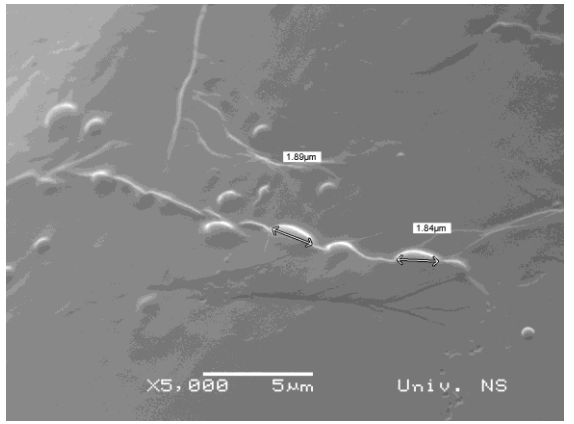
- **Definition:** Clipping or shaving hair from hide surface to physically remove dirt and contamination from hides.
- **Mechanism of action:** Physical removal of dirt and microorganisms.
- **Used in:** Ireland, UK, France
- **Expected efficacy:** Negligible, less than 0.5 $\log_{10}$ of general indicators, very often increase bacterial recoverability and transfer onto resulting carcasses; cross-contamination on the slaughterline

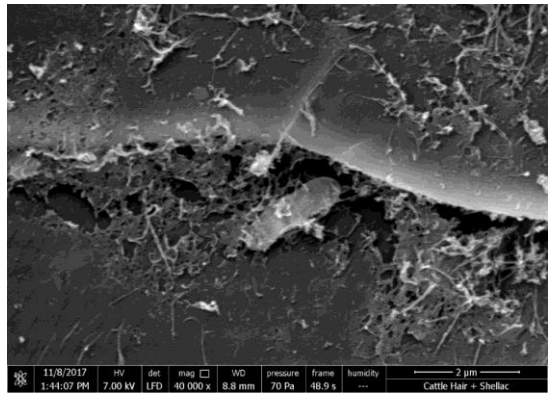
VacClip® system

II. Animal coat interventions (post-exsanguination): **shellac hide coating**

- **Definition:** spray treatment of cattle hides with natural resin shellac, to form a protective coating as a barrier to microorganisms, resulting in the reduction in their transfer to beef carcasses
- **Mechanism of action:** microbial immobilisation, coating on the hide's hair so to prevent microorganisms detachment
- **Used in:** experimental development
- **Expected efficacy:** ~1-1.5 $\log_{10}$ of general and faecal indicators reduction in transfer from hide to carcass during dehiding







II. Animal coat interventions (post-exsanguination): **scalding bob-veal hide-on carcasses**

- **Definition:** heat treatment, hot water washing to destroy microbial cells, usually at >60^{o}C, 4-6 minutes
- **Mechanism of action:** thermal inactivation, destroying non–spore-forming microorganisms.
- **Used in:** USA, experimental
- **Expected efficacy:** 2-4 $\log_{10}$ of *E. coli* in challenge trials, likely over estimated

III. GHP-based SPPs for carcasses

- Cattle hide removal methods
- Inverted dressing of sheep carcasses
- Scalding
- Singeing
- Oesophagus sealing (“rodding”)
- Bung bagging (“bunging”) / rectum sealing
- Separation of pig head
- Knife trimming
- Steam vacuuming
- Final carcass water washing

III. GHP-based SPPs for carcasses: **cattle hide removal methods**

- **Definition:** improved hygiene during cattle hide removal; downward automated hide removal
- **Mechanism of action:** prevention of microbial transfer onto resulting beef carcasses
- **Used in:** Most countries
- **Expected efficacy:** variable and influenced by various other factors, in some studies up to 1 $\log_{10}$ reduction of transfer of indicators from hide to carcass when 'more hygienic dehiding' was used
  - downward hide removal vs. upward hide removal - no improvement in microbial status of beef carcasses in one study (Kennedy et al., 2014)

III. GHP-based SPPs for carcasses: **inverted dressing of sheep carcasses**

- **Definition:** process where carcasses are inverted and hanged for their fore limbs to ensure more hygienic pelt removal. After pelt removal, carcasses are inverted and hanged again for hind limbs to perform evisceration in this position.
- **Mechanism of action:** prevention of microbial transfer from fleece onto resulting sheep/lamb carcasses
- **Used in:** Most countries
- **Expected efficacy:** ~1-1.5 $\log_{10}$ of general and faecal indicators reduction in transfer from fleece to carcass during inverted vs. conventional dressing

III. GHP-based SPPs for carcasses: **scalding**

- **Definition:** the point where the pig/poultry carcasses are sprayed with hot water or steam or immersed into hot water (53°C to 58°C chicken, 62°C to 65°C pigs) to soften the hair/feathers facilitating their removal in the subsequent step.
- **Mechanism of action:** thermal inactivation, destroying non–spore-forming microorganisms
- **Used in:** Most countries
- **Expected efficacy:**
  - **pigs:** ~2.5 $\log_{10}$ reduction of general indicators, 20-fold prevalence reduction of faecal indicators and *Salmonella*;
  - **chickens:** ~1.5 $\log_{10}$ reduction of *Campylobacter*, ~1 $\log_{10}$ reduction of *E. coli*

III. GHP-based SPPs for carcasses: **singeing**

- **Definition:** the point in the process where pig carcass surface is burned for a few seconds (>1,000°C) in order to improve the hair removal and reduce or eliminate the pathogens of skin surface.
- **Mechanism of action:** thermal inactivation, destroying non–spore-forming microorganisms
- **Used in:** Most countries
- **Expected efficacy:**
  - **pigs:** ~2 $\log_{10}$ reduction of general indicators, 4-fold prevalence reduction of faecal indicators and *Salmonella*

III. GHP-based SPPs for carcasses: **oesophagus sealing ("rodding")**

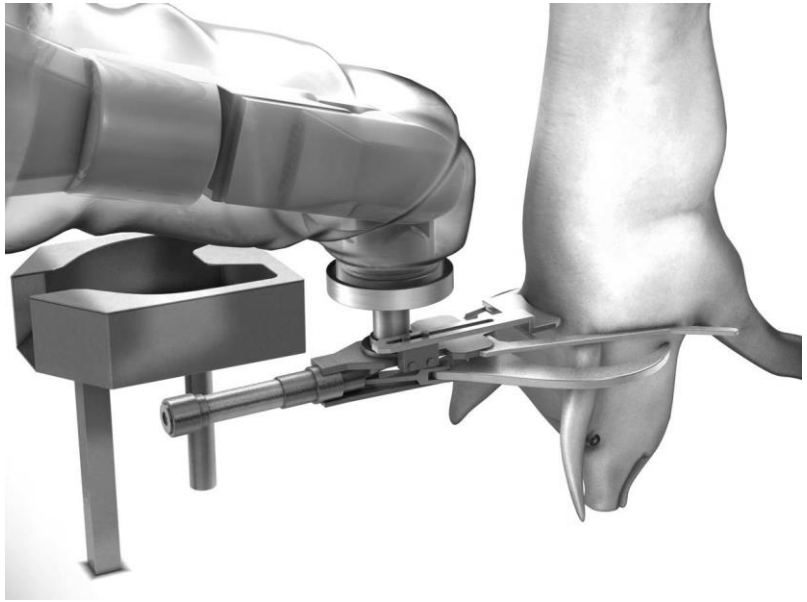
- **Definition:** sealing off the oesophagus in ruminants using a rubber band or clip to prevent leakage of ruminal contents
- **Mechanism of action:** prevention of microbial transfer from rumen onto resulting carcasses
- **Used in:** Most countries
- **Expected efficacy:** not known

III. GHP-based SPPs for carcasses: **bung bagging ("bunging") / rectum sealing**

- **Definition:** closing off the rectum by cutting around the anus, placing a bag over the rectum and securing it in place with an elastic band or similar during evisceration, to minimise the spread of contamination on a carcass.
- **Mechanism of action:** prevention of faecal leakage and microbial transfer from rectum onto resulting carcasses
- **Used in:** Most countries
- **Expected efficacy:**
  - **pigs:** 1.5-fold prevalence reduction of *Yersinia enterocolitica* (Nesbakken, 1994; Laukkenen 2010)
  - **beef**: 8-fold prevalence reduction of *Salmonella,* 3-fold prevalence reduction of STEC (Stopforth, 2006)

III. GHP-based SPPs for carcasses: **separation of pig head**

- **Definition:** the procedure where highly contaminated pig head (oral cavity, tonsils and tongue) is left undisturbed, removed from the carcass before carcass splitting, and processed on separate line.
- **Mechanism of action:** prevention of microbial transfer onto other parts of carcass or splitting equipment to avoid further cross-contamination
- **Used in:** unknown
- **Expected efficacy:**
  - **pigs:** limited, up to 0.5 $\log_{10}$ reduction of indicators, no difference in *Salmonella* and *Yersinia* prevalence in one study (Biasino, 2018)



III. GHP-based SPPs for carcasses: **knife trimming**

- **Definition:** removal of visible contamination from carcasses using knife
- **Mechanism of action:** physical removal of visible contamination and microorganisms
- **Used in:** Most countries
- **Expected efficacy:**
  - **beef:** ~1-2 $\log_{10}$ reduction of general indicators on visibly contaminated sites; highly variable and depend on the skill and diligence of the operator

III. GHP-based SPPs for carcasses: **steam vacuuming**

- **Definition:** spot application of steam and/or hot water (usually >82°C) to loosen contamination and kill bacteria, followed by a vacuuming
- **Mechanism of action:** thermal inactivation, destroying non–spore-forming microorganisms, combined with physical removal of microorganisms
- **Used in:** Most countries
- **Expected efficacy:**
  - **Beef/sheep:** ~1-1.5 $\log_{10}$ reduction of general and faecal indicators on visibly contaminated sites; highly variable and depend on the skill and diligence of the operator

III. GHP-based SPPs for carcasses: **final carcass water washing**

- **Definition:** ambient or cold-temperature wash to physically remove contamination from carcass surface. Warm water washes (usually <60°C) have a similar effect in removing bacteria (depending on the pressure used), and when applied for a short time do not have a microbicidal effect
- **Mechanism of action:** physical removal of microorganisms
- **Used in:** Most countries, but not recommended for beef/sheep carcasses
- **Expected efficacy:**
  - **Beef/sheep/pigs:** usually no effect, often increase in general and faecal indicators and prevalence of *E. coli*;
  - **Chicken**: high pressure (6 bar) inside-outside wash can reduce indicators and *Campylobacter* by ~0.5-1 $\log_{10}$

IV. Hazard-based carcass physical interventions

- **Hazard-based interventions:** developed from scientific research to specifically control certain hazards and are able to provide demonstrable and quantifiable reduction in bacterial load
- Washes, rinses and sprays aimed at microbial removal and/or killing, applied pre- and/or post- evisceration (pre-chilling)
- Physical interventions using water (cold, warm, hot, steam) accepted by the legislation and do not specifically need regulatory approval

IV. Hazard-based carcass physical interventions

- **Thermal interventions**: refers to various heat treatment washes to destroy microbial cells
- **Non-thermal interventions**: refers to non-chemical and non-thermal interventions that aim to reduce microbial contamination while preserving product quality and nutrients that can be affected by thermal treatments (electron beam irradiation, gamma irradiation, ultraviolet (UV) light, ultrasound, high hydrostatic pressure, pulsed light and cold atmospheric plasma).

- Hot water washing
- Steam pasteurisation
- Ultrasound/ultrasonication

IV. Hazard-based carcass physical interventions: **hot water washing**

- **Definition:** washing carcasses with water at temperatures >74°C, up to 85°C (pre-evisceration, or post-splitting)
- **Mechanism of action:** thermal inactivation, destroying non–spore-forming microorganisms. Ribosome damage/denaturation, multiple cellular injury involving proteins and enzymes.
- **Used in:** USA, Canada, Denmark (*Salmonella* reduction treatment)
- **Expected efficacy:**
  - **beef:** ~1.5-2 $\log_{10}$ of indicators, 10-fold prevalence reduction of *Salmonella*
  - **pigs:** ~1.5 $\log_{10}$ of indicators,

  3-fold prevalence reduction

  of *Salmonella*

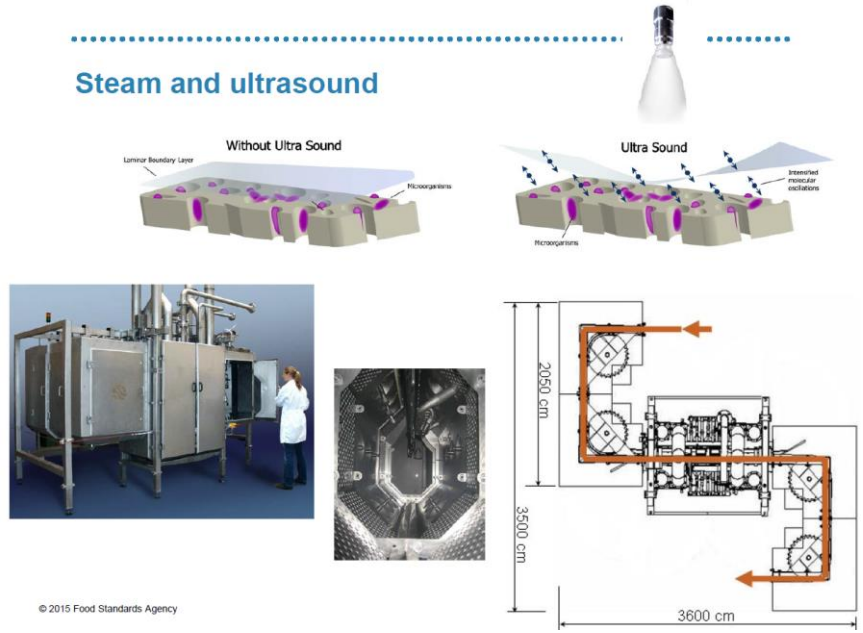
IV. Hazard-based carcass physical interventions: **steam pasteurisation**

- **Definition:** steam (usually >82°C, up to 105°C) applied to a whole carcass in a closed cabinet. Method involves:
  - i) removal of water from carcass side surfaces, which remains after post-evisceration washing, using air blowers or vacuum;
  - ii) surface "pasteurisation" with pressurised steam (6.5–10 s); and
  - iii) a cold-water spray to cool down carcass surfaces before they are moved to chillers
- **Mechanism of action:** thermal inactivation, destroying non–spore-forming microorganisms. Ribosome damage/denaturation, multiple cellular injury involving proteins and enzymes.
- **Used in:** various countries
- **Expected efficacy:**
  - **beef:** ~1.5 $\log_{10}$ of indicators,

    7-fold prevalence reduction of *E. coli*

IV. Hazard-based carcass physical interventions: **ultrasound/ultrasonication**

- **Definition:** sound waves with frequencies higher than 20 kHz, used in liquid media (usually combined with hot water 70°C to 75°C) create microbubbles, which expand and then implode on contact with the chicken skin ('acoustic cavitation'). This creates localised heat and high-pressure water jets.
- **Mechanism of action:** thinning of cell membranes, disrupts bacteria biofilm and damages the cell membrane, causing cytoplasmic leakage; the implosion removes bacteria from the chicken skin and into a hot water.
- **Used in:** UK, USA
- **Expected efficacy:**
  - chicken: ~1 $\log_{10}$ of *Campylobacter* and *E. coli*



V. Chilling: **dry chilling and spray chilling**

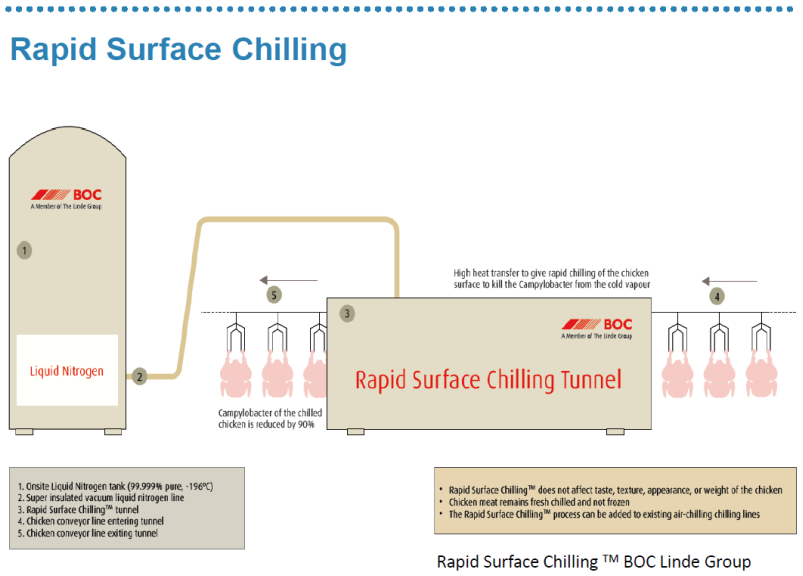
- Reducing the carcass temperature to prevent microbial growth, immediately after slaughter and dressing process; Carcass surface desiccation effect most important
- Regulatory mandated temperatures:
  - <7°C red meat, <4°C white meat, <3°C offal

- **Dry chilling:** conventional, limited efficacy on indicators, ~0.5 $\log_{10}$
- **Spray chilling**: Intermittent spraying beef carcass with water during the first several hours of the whole cooling process
  - inconsistent efficacy, usually increases potential for further bacterial growth on carcass surfaces post-chill due to their increased moisture

V. Chilling: **blast chilling and crust freezing**

- **Blast chilling (pigs):** subjecting carcasses to -10 to -25°C for 45 min, followed by chilling at 2°C for required time
- Inconsistent efficacy
- **Crust freezing (poultry):**
  - freezing of the outer surfaces of the carcase only while meat remains unfrozen;
  - cell death due to osmotic stress and/or dehydration
  - subjecting carcasses to -10 to -25°C (or lower)

  for certain time followed by, or during, chilling
  - expected efficacy: ~1 $\log_{10}$ of *Campylobacter*



VI. Multiple interventions

- **Description:** application of interventions based on the 'multiple hurdle approach', where chemical and/or physical interventions are applied in sequence or simultaneously, inflicting concurrent and variable injuries to bacterial cells.
- Sequential application of interventions may involve use of:
  - interventions on cattle hides, followed by skinned carcass knife trimming, steam vacuuming, pre-evisceration washing, washing, thermal decontamination with water or steam, organic acid rinsing, chilling, and chemical spraying before carcass fabrication
- **Used in:** USA, Canada
- **Expected efficacy:**
  - **beef/pigs:** ~2.5-3 $\log_{10}$ of indicators, 3-fold prevalence reduction of *E. coli*, >10-fold prevalence reduction of *Salmonella* (all combined with residual effect during chilling)

VI. Multiple interventions

Pasteurisation and acid treatment system 1: (i) **steam vacuuming** (104 to 110°C, 138 to 345 kPa steam, negative 7 to 12 mm of Hg vacuum),
(ii) **pre-evisceration** carcass washing (29 to 38°C **water** at 193 to 331 kPa, 6 to 8 s),
(iii) **pre-evisceration acetic acid** solution rinsing (1.6 to 2.6% acetic acid solution, 43 to 60°C, 317 to 324 kPa, 2 to 4 s),
(iv) **thermal pasteurising** (71 to 77°C water, 69 to 228 kPa, 10 to 14 s),
(v) **final** carcass **washing** (16 to 32°C water, 483 to 897 kPa, 10 to 14 s), and
(vi) **post-evisceration acetic acid** solution rinsing (1.6 to 2.6% acetic acid solution, 43 to 60°C, 317 to 324 kPa, 2 to 4 s)

Pasteurisation and acid treatment system 2: (i) **pre-evisceration** carcass washing (55°C **water** at 280 psi, 10 s),
(ii) **pre-evisceration** spraying with 2% **lactic acid** (25°C);
(iii) **post-evisceration steam vacuuming** of visible contamination from the rump, brisket and forelegs;
(iv) **post-splitting trimming** visible contamination;
(v) **final** carcass **washing** (40°C, 280 psi, 25 s);
(vi) **steam pasteurisation** (steam at 88-94°C, 12 s); and
(vii) **final** spraying with 2% **lactic acid** (700 psi)

Pasteurisation and acid treatment system 3: (i) **pre-evisceration** carcass washing (55°C **water** at 280 psi, 10 s),
(ii) **pre-evisceration** spraying with 2% **lactic acid** (25°C);
(iii) **post-evisceration steam vacuuming** of visible contamination from the rump, brisket and forelegs;
(iv) **post-splitting trimming** visible contamination;
(v) **final** carcass **washing** (40°C, 280 psi, 12 s);
(vi) **peroxyacetic acid** spray (200 ppm, 280 psi); and
(vii) **steam pasteurisation** (steam at 88-94°C, 12 s)

Thank you for the attention.

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