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Processing and meat quality 1

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Introduction

This series of articles will address some of the practical issues of processing poultry and how to prevent carcass downgrading and meat quality problems.

Chicken is a versatile and healthy meat and the industry has been very successful at adapting to meet the changing demands of consumers for variety, versatility, convenience, quality and value.

Poultry products can be divided into three broad categories; whole bird, fresh portions, and further processed products (for example value added and convenience foods).

Products in these categories have different tolerances in terms of carcass finish, downgrading, and meat quality.

Carcass downgrading can be caused by a multitude of factors including disease, contamination and physical trauma or damage.

The severity ranges from major problems leading to whole bird condemnation to minor trimming of wing tips or skin.

This series of articles will deal only with problems caused by the physical interactions between the bird and its environment and the handling of the carcass and meat.

The incidence of downgrades will vary between companies; the key is for individual processing plants to understand what happens in their own plant.

Monitoring downgrades will enable a processor to quickly identify and deal with any deviation from the 'normal' situation.

Meat quality here refers to the attributes of the meat such as drip loss, cook loss, texture, tenderness, flavour, juiciness, and appearance.

Problems with cook and drip loss can result in a loss of yield and having to re-pack precooked products.

Poor texture, juiciness, tenderness and flavour will affect consumer satisfaction and whether they purchase a product again.

Variability in appearance, such as colour, strongly influences consumer selection at point of purchase.

In addition, fat content can affect the shelf-life of a product and can cause problems complying with labelling of products. The perceived importance of meat quality will depend on the requirements of specific products.

Meat quality is influenced by complex interactions of a whole range of factors including genetics, management, nutrition, environmental conditions, preslaughter stress, and postmortem handling of the meat.

Many of the factors that affect the carcass quality and meat quality also have implications for bird welfare, highlighting the importance of monitoring welfare and optimising conditions at all stages from farm through to processing.

For more details on these topics subsequent articles in this series will cover:

- Understanding and measuring meat quality.
- On the farm – factors influencing carcass and meat quality.
- Transport and the slaughter plant – key considerations.
- Stunning birds at the processing plant – methods and potential problems.
- Post-mortem handling of carcasses and meat.
- Shelf-life.
- Key points in preventing downgrade and meat quality problems. u

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Measuring meat quality

Poultry products have expanded rapidly into further processed and convenience foods. Meat quality characteristics such as drip loss, cook loss, texture, flavour and appearance influence processing ability and properties of these products, which affect consumer satisfaction. Meat quality is affected by management, environmental conditions, pre-slaughter stress, and post-mortem handling of the meat. Many of these factors will be discussed in subsequent articles.

First it is important to understand post-mortem muscle metabolism and its effect on meat quality. After slaughter, glycogen is converted to energy via glycolysis, with an accumulation of lactic acid causing a drop in muscle pH.

The rate and extent of drop in pH, combined with muscle temperature, affect meat quality. These are determined by glycogen content at slaughter and the rate of glycolysis.

Stress stimulates glycogen breakdown and influences post-mortem muscle metabolism. Short, acute stress increases muscle temperature and accelerates metabolism, causing a rapid drop to low pH, implicated in the development of pale meat with poor water retention. Conversely, prolonged stress depletes muscle glycogen so pH remains high, leading to darker meat, with poor shelf-life.

The simplest measurements to take on-line as an indication of meat quality are pH and colour. Initial pH (to allow an indication of the rate of drop) should be measured immediately after slaughter, as soon as there is access to the birds and before final pH is reached. The timing of measurement of initial pH must be consistent but this is less critical for final pH, provided that pH has reached an end-point. Final pH and colour (for example lightness/reflectance - L*, green/redness - a*, blue/ yellowness - b*) are often measured at deboning.

Colour and pH give a quick indication of variation in meat quality and can be used to investigate the effects of management, processing and seasonal factors. Colour measurements may also be used to grade meat on-line. However, first it is necessary to establish the quality criteria required for a product by establishing the relationship between pH, colour and quality aspects of the meat (for example drip loss, toughness and texture). With this information meat could then be sorted for specific products.

For advice on measuring meat quality please contact Dr Joanne Gatcliffe. u

Measurements of colour, using a Minolta chromameter, and pH, using a meat probe, as indicators of meat quality.

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Key influences on the farm

Transferring birds from the farm to the processing plant is the time when birds are at the greatest risk from physical damage and stress; leading to downgrading or meat quality problems. In order to avoid these, good welfare and a consistency in how the birds are treated should be planned and achieved.

On the farm and loading:

Environmental conditions

The farm manager should aim to provide optimal, consistent conditions (air quality, temperature and humidity) and avoid long, chronic stress or short acute stress (for example heat stress), both of which can influence meat quality.

Stocking density

High stocking density can reduce performance and uniformity of the flock. In addition, competition between the birds increases the risk of physical damage (scratching, bruising, wing fractures etc) and stress.

Nutrition

Good nutrition promotes healthy, balanced growth with good skeletal and muscular development. Uniform, healthy birds are better able to cope with any additional stressors. Also, fat in the diet has a direct effect on the meat, product quality and shelf-life. Nutritional supplements (for example vitamin E) can help protect against muscle damage and oxidation of the meat. Shelf-life will be covered in a later article.

Feed withdrawal (FW)

Removal of feed on the farm reduces faecal contamination in the processing plant. The FW programme implemented needs to be consistent between flocks and it is important to keep good records for each house on a farm. The calculation of FW time should include transport and holding time at the processing plant. For broilers a FW of 4-8 hours is sufficient and for turkeys 8-10 hours. Water should always be available to the birds. Prolonged FW (>12h) increases gut fragility (higher risk of contamination) and in extreme cases energy reserves are depleted, which could have a detrimental effect on meat quality. Intermittent feeding, caused by removal and return of feed between loads, can be very stressful for the birds, especially if depopulation of a house occurs over a long time. This type of stress can slow down digestive transit and increase the risk of faecal contamination and in extreme cases may affect meat quality.

Depopulation

It is important to minimise stress during catching and loading. Exposure to loud noises, bright lights, large changes in temperature etc, are major stressors and can cause panic leading to physical damage. Any equipment used should be in good repair and personnel must be trained in appropriate bird handling and identifying birds that are not fit for transport.

Transport crates

Transport crates need to be in good repair and designed to avoid damage to the birds during loading and in transit. It is important that stocking density is optimal for the welfare of the birds; encouraging the birds to sit during transport with support from other birds without overcrowding.

It can not be over emphasised that good welfare is vital to produce good quality products.

The next article in this series will cover transport and the slaughter plant. u

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Key transport considerations

Transportation to the slaughter plant presents a range of potential stressors. It is in the interests of the company/processor to manage and control these stresses to ensure birds arrive in good condition.

Transport:

- **Loading.** The birds' ability to cope with stress is affected by health, physical condition and handling. If birds are badly handled during catching and loading they will be less able to deal with the additional stress of transport.
- **Crate density.** Bird weight and environmental conditions influence the optimal number of birds per crate. There should be enough birds to prevent excessive movement during transport (can cause physical damage), whilst avoiding overcrowding as this reduces the birds' ability to thermoregulate.
- **Environmental temperatures and ventilation.** Birds are susceptible to heat and cold stress and the conditions experienced can vary due to location on the truck. Poor air circulation can lead to 'hot-spots' in some locations, whilst birds located on the outer edges can suffer hypothermia due to wetting and air velocity. Trucks with forced ventilation (operates when the truck is moving) may experience problems with heat stress during traffic hold-ups or delays at the slaughter plant. Climate controlled vehicles offer the best solution, providing good conditions and reducing variation.
- **Transport time.** The length of the journey can have a major impact on condition of the birds at slaughter. Birds experience vibration, noise, motion and thermal stresses during transport and the longer the transport time the greater the impact is likely to be on the birds' physical condition at slaughter.

Slaughter Plant:

- **Holding area/lairage.** It is good practice to have a short period of rest and recovery when the birds arrive, provided conditions are conducive to recovery. Lairage should be designed to minimise noise, light, and temperature extremes, be well ventilated and provide protection from the elements (wind, rain, sun). In hot climates water misting systems can be useful to cool the birds. However, care should be taken to avoid high humidity, as this can be lethal to the birds by reducing the effectiveness of heat loss through panting and evaporation. Birds recover quickly from stress under the right conditions. A prolonged holding time may increase stress and fatigue, particularly in adverse conditions.
- **Unloading and shackling**. Live handling is a period of extreme stress for the birds. Careful handling, dimmed lights or blue lighting, and low noise levels will help to keep the birds calm. Systems for controlled atmosphere stunning (CAS) reduce stress by removing the need to hang live birds on the shackles.

Getting the birds to the slaughter line is a crucial step with many potential stressors. Every factor needs to be considered and carefully managed to ensure the birds arrive in optimal condition. The next article in this series will review systems for stunning and killing the birds and the potential impact on carcase and meat quality. u

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Stunning birds at processing

Pre-slaughter stun/kill has improved the welfare of poultry. This article will discuss electrical water-bath and gas stun/kill systems. Stunning by any method must kill the bird or stun until death through blood loss. The most common gas systems stun/kill birds in transport containers. Exposing to gas until dead is preferable due to the short recovery time. There are three commonly used gas mixtures:

- Inert gas/mixture (for example argon, nitrogen) in air with maximum 2% oxygen by volume (anoxia).
- Inert gas/mixture plus carbon dioxide (<30%) and oxygen (<2%).
- Two-stage: 40% CO_2 + 30% O_2 + 30% N_2 followed by 80% CO_2 in air.

Advantages of gas stun/kill:

- Not hanging live birds – improved welfare.
- Delay in neck cutting is not a welfare problem.
- Improved carcase and meat quality.
- No affect on blood loss provided neck-cut is within three minutes of exposure.
- Anoxia accelerates rigor development and maturation of meat, enabling earlier deboning.

Electrical stun/kill systems commonly use constant-voltage, multi-bird water-baths. Current must be sufficient to induce immediate loss of consciousness. It is not possible to control actual current to each bird due to individual variation in resistance, hence the effectiveness of the stun varies.

Inadequate stun can affect neck-cut accuracy, especially with automated systems, with implications for welfare, bleed-out, and carcase quality.

Conductivity can be improved by wetting the shackle; adding salt (0.1%) to the water-bath; submerging birds to the base of their wings; and ensuring constant connection between the earth and shackle lines. Water-bath length and line speed determine how long the birds receive the current and depth and duration of stun. The 'live' electrode must extend the entire length of the water-bath to apply current for the full time the birds are submerged.

Pre-stun shocks entering the water-bath are a welfare issue and affect carcase quality.

Control by:

- No overflow of water at the entry.
- Electrically isolating the entry ramp.
- Minimising flapping.

Flapping increases the risk of haemorrhages, wing breaks, dislocations, and red wing tips and can result in an inadequate stun.

Reduce by:

- Careful handling.
- Low light intensity, blue or UV lights in the 'live' area.
- Avoid loud noises; jolts, dips, or sharp turns in the shackle line.
- Breast comforters.
- Correct shackle size.
- Time to settle on the shackle before stunning.

Low frequency currents (50/60 Hz) provide the most effective stun/kill but are associated with greater incidence of downgrades (broken bones, bruised wing joints, red wing tips etc).

Higher frequencies reduce downgrades but also the depth and duration of stun, making it harder to achieve an adequate stun. The influence of current, waveform, frequency and duration on the effectiveness of stun is complex and requires expert advice to ensure correct bird welfare. All individuals involved in the slaughter of poultry must ensure they comply with all legislation and regulations. u

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Post-mortem handling of meat

Events post-mortem are as important for carcase and meat quality as live bird handling and killing.

An effective neck-cut and sufficient bleed-out time (typically 90s) will reduce carcase defects and meat discolouration due to blood retention.

The most effective neck-cut, to achieve a good bleed-out and rapid death by exsanguination, is to sever both carotid arteries and jugular veins in the neck. Blood loss of less than 2% bodyweight has been implicated in engorged veins and darkening of breast meat.

Hot water scalding assists feather removal, with temperature and dwell time affecting ease of plucking and carcase appearance. The ideal scald will depend on carcase size and final product requirements. For example, a soft scald (typically 50-5°C, 2.5-3.0 mins) leaves the cuticle intact making it the preferred method for air-chilled, whole, fresh, dry carcases, whereas a medium to hard scald (58-60°C, 1.5-2.0 mins) improves plucking but removes the cuticle, resulting in unsightly barking of the skin (browning) if air-chilled. This method would be unacceptable for fresh, dry carcases but is suitable for water-chilled, fresh wet or frozen (packed), whole birds or meat. Problems with scalding, such as line stoppages, incorrect temperature, and ineffective mixing of the water (temperature gradients) can cause barking and surface discolouration of the breast meat (white cooked appearance 1-2mm deep).

Plucking machinery has improved the efficiency of the process and reduced labour required, however, the severity of plucking can have implications for carcase quality.

Uniformity of the birds and the correct settings for the size of bird will reduce the incidence of skin tears, bone breakages, ruptured veins (blood stains under skin) and improve feather removal.

Several chilling systems are available. The most common are water-immersion, water-spray (often referred to as evaporative air chilling), and air-chill. The aim is to remove heat from the carcases quickly and efficiently (typically to a max. 4°C after 1.5-2.0 hours for a 1.5-2kg carcase).

Rapid chilling alleviates potential meat quality problems such as pale, exudative meat. This can result from a combination of high muscle temperature and low pH (denatured muscle proteins leading to increased drip loss and pale meat) so by chilling the carcases rapidly the risk is minimised.

When carcases are used for cutting then hot-boning is ideal from an economic/efficiency perspective, as the birds can be processed in-line, reducing time, labour and storage requirements. However, hot-boning can result in unacceptably tough meat so normal practice is to take carcases off-line and age for at least 6-8 hours.

Many commercial plants now utilise techniques that accelerate the rigor process, reducing the maturation time and improving tenderness.

For example, electro-stimulation pulses electricity through the carcases to advance the rigor process and is reported to achieve maturation in-line in three hours (or the equivalent of four hours maturation off-line).

Other techniques include control atmosphere stunning and maturation chilling (two-phase air-chill designed to promote enzyme activity to break down proteins). u

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Shelf-life of poultry meat

Shelf-life covers the risk to human health (pathogenic micro-organisms) and acceptability (spoilage). Micro-organisms causing foodborne illnesses (salmonella, campylobacter) may be present prior to slaughter and cross-contamination of carcases may occur. Steps to reduce bacterial load and inhibit microbial growth can improve product safety and shelf-life. Many chemical and physical treatments can be effective (chlorine; organic acids; hydrogen peroxide; TSP; carcase rinses; hot dips; steam; irradiation; electron accelerators; electromagnetic waves; modified atmosphere packaging (MAP)). Application of these techniques is dependant on local legislation and consumer acceptance.

Spoilage relates to unpleasant odours, rancidity, deterioration of colour, and surface slime. Spoilage is due to micro-organisms and chemical changes in the meat, influenced by environmental factors (temperature, humidity, oxygen, light). Spoilage bacteria are not present at slaughter; they are derived from the environment and can multiply at low temperatures on fresh meat. Chemical spoilage due to oxidation of lipids (fat) causes changes in flavour and odour and is responsible for the development of rancidity.

The colour of meat is determined by the concentration and chemical state of myoglobin (Oxymyoglobin – red, Myoglobin – purple/red, Metmyoglobin – brown discolouration). Over time meat discolours permanently due to the accumulation of metmyoglobin. Discolouration can be a problem in dark poultry meat (thigh) when small pieces in a pack turn brown, reducing the perceived shelf-life. The products of lipid oxidation (free radicals) trigger oxidation of oxy- and myoglobin to metmyoglobin.

The rate of discolouration is highly variable and influenced by many factors. Common causes of reduced shelf-life:

- Temperature abuse in the supply chain. Chilling quickly and storing at low temperatures inhibits growth of pathogenic micro-organisms and delays lipid oxidation and meat discolouration. Storing close to 0°C compared to 3 or 4°C gives additional benefits.
- Low antioxidant content in diet/meat. Antioxidant supplementation (vitamin E) in the diet can be highly beneficial for shelf-life.
- High fat content of diet/ meat. Fat in the diet is related to fat content in the meat. High fat content promotes lipid oxidation.
- High proportion of unsaturated fat in diet/meat. Unsaturated fats are more susceptible to oxidation. The fatty acid composition of lipid in poultry is directly affected by dietary fatty acids and is a major determinant of flavour and shelf-life.
- Packaging faults – poor quality materials, faulty seals, incorrect gas mixture, meat contacting film. Excluding oxygen by vacuum packing or MAP in CO_2 increases shelf-life by reducing oxidation. MAP with 60-70% O_2 and 30-40% CO_2 can have a beneficial effect on shelf-life and appearance as high O_2 promotes oxygenation of myoglobin to oxymyoglobin, which gives a more appealing colour and is more stable against oxidation to metmyoglobin.
- The rate and extent of oxidation can also be influenced by pre-slaughter stress and post-mortem events (early pH and temperature profile). u

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Prevent carcase downgrades

This series of eight articles has addressed many of the practical issues concerned with producing and processing poultry, in terms of minimising economic loss due to downgrading and producing good quality products.

The causes of quality issues are multi-factorial and can occur at any stage of production – on the farm; catching and loading; transport; stunning and killing; and during post-mortem handling of the meat.

The key to identifying and solving problems lies in a good understanding of the processes the bird goes through from farm to processing and a knowledge of the 'normal' level for downgrades and meat quality.

Large variations exist between companies due to differences in production systems; breeds; slaughter age and weight; processing methods; inspection criteria; and how data is recorded.

It is important to monitor the situation at the processing plant in order to quickly identify problems and associated economic loss and to go on to investigate causes.

To achieve this it is helpful to consider the following steps:

- Define the downgrade/ quality criteria.
- Measure and record the incidence at the processing plant.
- Estimate the economic loss to the processing plant.
- Determine importance for the welfare of the birds.

Based on this information, make a decision regarding legal requirements and the economic benefits of reducing the incidence of damage.

Previous articles in this series dealt with some of the areas commonly associated with carcase downgrading and meat quality problems:

- Live bird: the farm environment; stocking density; nutrition; feed withdrawal; catching and loading; transport; unloading and shackling; stunning and killing.
- Processing: bleed-out; scalding; plucking; chilling; deboning; packaging and storage.

Prevention is always the best option to minimise losses and maximise profits. Good bird welfare is directly related to good product quality.

Continuous assessment and monitoring of all the areas covered above, particularly where there is close interaction between the bird and operational staff, should help to prevent quality and welfare issues arising.

As an industry we have an ethical and legal obligation to maintain the highest standards of bird welfare in all areas of production, from the genetics of the birds, to the rearing, handling and processing.

It is the responsibility of the breeding companies to ensure that fitness traits pertinent to the welfare of the birds (for example leg strength, walking ability, conformation and fitness) are included in a balanced selection programme.

The industry as a whole must be transparent in all areas of production to nurture consumer confidence.

Each company has a responsibility to ensure that all stock persons, catching teams, and slaughter plant personnel (involved in live bird handling) are fully trained, well equipped and aware of the importance of welfare regulations and company codes of practice relating to management and handling of live birds. u