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REVIEW ARTICLE

Effects of Post-Slaughter Carcass Handling on Meat Quality

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ABSTRACT

The quality of meat from the processing plant or as found on the market will have an influence on its processing properties and eating qualities. The processing properties and eating qualities will also influence consumers' acceptability and profits to be realized by producers, processors and retailers. A number of factors including the genetics of the animal, production practices, age of the animal at slaughter and how live animals are handle prior to and during slaughter contribute significantly to meat quality. Apart from these, post-slaughter practices also influence meat quality to an appreciable extent. In recent times, various processing conditions and addition of ingredients/additives have been manipulated to improve upon the quality of processed meat products. This mini-review discusses the effects of post-slaughter practices on meat quality.

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INTRODUCTION

Post-slaughter animal handling involves all the activities and processes animals are subjected to after sticking. After sticking, carcass (the body of animal killed for food) is obtained (Warriss, 2000; Adzitey, 2011). Therefore it is the carcass that undergoes various handling processes post-slaughter and the way this is done would have adverse effect on meat quality. Adzitey (2011) reported that poor carcass quality will definitely reflect in poorer meat quality. Post-slaughter animal handling begins at the abattoir (just after killing), and continues to processers of meat (processing meat into various meat products), to the market (selling of meats) and finally to consumers (cooking and eating). Post-slaughter carcass handling processes can be categorized into carcass condemnation, cutting of meats into various parts, application of processes such as electrical stimulation at the slaughter plant, storage conditions, processing of meats into products and cooking conditions.

Warriss (2000) defined meat quality on the basis of its conformational and functional qualities. He referred to the functional qualities as the desirable attributes in a product whilst the conformance qualities take into consideration producing products that exactly meets consumer's specifications. In addition, properties such as appearance and technological characteristics, ethical quality, palatability, wholesomeness, yield and gross composition are the components of meat quality. Various meat quality defects including pale soft exudative, dark firm dry meat, bloodspalsh, bruising, skin blemish, cyanosis, two-toning, protein degradation, spoilage of meat, broken bones/fractures and death/loss of animals due to various causes bedevils the meat industry (Calkins *et al.,* 1980; Ayaz, 2000; Parveen *et al.,* 2003; Khan *et al.,* 2004; Forrest, 2010a, Adzitey and Nurul, 2011; Węglarz, 2011). Adulteration of inferior and perhaps poor quality meat with superior ones during processing is a common practice globally and thus meat quality specification is essential for quality control measures in the meat industry (Singh and Neelam, 2011). This mini-review discusses some of the major processes carcasses are subjected to and their effects on meat quality. It also highlights on the general effects of poor post-slaughter handling on meat quality without much emphasis on species specific.

Carcass condemnation: Carcasses unfit for human consumption are condemned and do not enter the market. Condemnation may be partial or total depending on the extent to which the meat has been affected. Conditions such as dark firm dry meat, blood splash, bruises or diseased parts are trimmed off reducing meat yield. In extreme cases where carcasses are fully diseased or spoiled due to poor storing temperature conditions, the

carcasses are totally condemned. The effect of carcass condemnation is that, there is total or partial loss of yield and meat quality.

In the United Kingdom, Meat Hygiene Service figures in 2005 indicated that 3.5 whole pig carcasses in every 1000 slaughtered are condemned as a result of pyemia, generalized, abscessation, edema, emaciation, fever, septicemia and toxemia (White, 2006). In a Spanish abattoir a total of 513 pig carcasses out of 6017 (8.5%) were rejected and condemned during meat inspection due to abscesses, cachexia, catarrhal bronchopneumonia, vertebral osteomyelitis, arthritis, pleuritis, peritonitis and pleuropneumonia (Martinez *et al*., 2007). Poultry carcass condemnation due to contamination by visceral content during evisceration was 22.5 and 33.61% for two different poultry slaughter plants in Brazil (Santana *et al.,* 2008). Of the 1,162,410 processed cattle, from 2001-2007 in Canada, a total of 6875 carcasses were rejected for reasons of which septicemia and/or toxemia were typically the leading cause for condemnation (Alton *et al.,* 2010). Roeber (2010) also reported that a dairy industry lost nearly $12 million due to cattle and/or carcass condemnations.

Cutting of carcasses into parts: For easy handling, transportation and processing of animals, their carcasses are divided into portions after slaughter. Nonetheless, dressed carcasses can also be stored whole or cut into primer parts to facilitate storage and further processing. During cutting, particles or pieces of meats may fall off and do not enter the food chain. The result of this is probably insignificant meat loss and reduction in meat quality. However, in large processing plants with high through puts, this should weigh several kilograms of meats. There appear to be unpublished data on the amount of meat lost during cutting of carcasses into various parts. Although report is available on meat lost due to trimmings. For instance, White (2006) reported that meat trimmings can account for an average loss of 2 kg in every 1000 kg pig slaughtered (0.2%). Besides meat loss, meat trimming would be time consuming, increases the work load of meat inspectors and interrupts the normal operation of abattoirs. Furthermore, meat parts are exposed to spoilage microorganisms such as *Pseudomonas* spp., *Acinetobactor* spp., *Enterobacter* spp, and *Brochothrix thermospacta* during cutting, which may be present on cutting knives, chopping tables and other equipments. These microorganisms cause spoilage thereby reducing meat shelf life and it quality.

Storage conditions: The rate at which carcasses are chilled after slaughter has influence on meat quality. Speeding up the rate of chilling will help reduce microbial growth on the carcass surface because the generation time for microorganisms increases at lower temperatures. Fast chilling also reduces evaporative weight loss, reduce the manifestation of pale soft exudative meat, improve lean color and water holding capacity, all of which would have had negative effect on meat quality (Warriss, 2000; Adzitey and Nurul, 2011). Furthermore, the rate at which temperature drops after slaughter has influence on the enzyme activity, because enzyme activities are temperature dependent. Therefore different cooling rates affects pH fall through lactic acid production, the disappearance of adenosine triphosphate (ATP) and creatine phosphate, and hasten up the occurrence of rigor mortis (Warriss, 2000). Chilling can also result in weight loss. Stanisz *et al*. (2009) reported a weight loss of 4.51, 3.95, 3.05, and 2.35, for white improved, 1/4 boer and 3/4 white improve, 1/2 boer and 1/2 white improve, and 3/4 boer and 1/4 white improve kids, respectively slaughtered after 24 h of chilling at 2-4°C.

When muscles are cooled below 10°C before the onset of rigor, cold shortening occur which makes the meat tough upon cooking, and slow freezing may produce cold shortening before freezing whilst rapid freezing may results in thaw rigor (Warriss, 2000). Thaw rigor meat losses large amount of drip or water during thawing and are tough upon cooking. A condition known as heat ring characterized by darker band muscle forming can occur in beef carcasses subjected to relatively fast chilling (Warriss, 2000). Meat from such carcasses (heat ring and thaw rigor) will have poor appearance.

Various preservation techniques are available, and aimed at improving meat quality by increasing shelf life for a longer time as fresh meat is an idea medium for the growth of both spoilage and pathogenic organisms (Adzitey *et al.,* 2010; Adzitey *et al.,* 2011). For example drying and salting are old preservation methods that reduces the water activity of meat, reducing the available water needed to support the growth of microorganisms. Salting also gives meat a characteristic salty taste which is preferred by some consumers although others are septic about it due to the health implications of consuming salt. A preservative technique- freeze drying, ensures that water is sublimated from meat (water passes directly from ice to vapor) without damaging the meat structure while enabling the meat to be stored for a longer period has been described (Warriss, 2000). Curing and smoking are also preservative techniques that give meat a characteristic taste and flavor liked by some consumers. Nonetheless, depending on the extent to which smoking or curing is done the appearance of the meat can be affected either negatively or positively.

In most developing Africa countries and traditional meat shops in developed world meats are normally displayed unpackaged. Packaging primal or retail cuts have been achieved by controlling the gas atmosphere (oxygen, carbon dioxide and nitrogen gases) surrounding the meat to produce favorable effects most especially on meat shelf life and appearance. Warriss (2000) reported that packaging has three main functions that is protecting meat from contamination and inhibiting microbial growth, reducing or eliminating evaporative weight loss and surface drying, and enhancing the color of the product. Warriss (2000) explained further that *Pseudomonas* (most common spoilage microorganism) can grow below 5°C under aerobic condition but adding high concentration of carbon dioxide in the pack restricts their growth and promote the growth of lactic acid bacteria which are far less likely to cause spoilage. Consumers also associate meat color to its freshness. Bright red meat (oxygenated meat), is thought to be fresh while purple (myoglobin) and grey brown (metmyoglobin) is perceived to be old meat. Packaging meat in plastics which allow different gases permeability or plastics filled with the required gases can

affect oxidation or oxygenation of meat and thus change the color of the meat surface.

Processing procedures and conditions: Certain processes and processing procedures have effect on meat quality. These include carcass decontamination, electrical stimulation, hot processing, mechanically recovered meat, ageing, injecting non-meat ingredients, tumbling, comminution, and addition of antioxidants.

Decontamination procedures using water sprays (portable water or hot water with temperature below 75°C operated under high pressure), physical (use of ultraviolet light, ionizing radiation and ultrasound) and chemical (use of chlorine, hydrogen peroxide, trisodium phosphate and organic acids) methods have been employed to reduce initial microbial load on carcasses and to prolong shelf life of meats (Warriss, 2000).

Electrical stimulation stimulates the contraction of muscles, lowers pH of meat and speeds up the offset of rigor mortis, reduces the risk of cold shortening and improves tenderization of meats (Zocchi and Sams, 1999); and these processes (rate of rigor development, occurrence of rigor mortis, and the rate of change in pH) is temperature dependent. However, defects such as broken bones, hemorrhages, reduced bleeding can occur during electrical stimulation (Wilkens *et al.,* 1999) which has adverse effects on meat quality. Hanging carcasses by hooking the hind legs puts many muscles into tension and stretches the sarcomere lengths which may produce meats that are more tender (Warriss, 2000).

Hot processing or boning (the removal or cutting of carcasses into parts or meat while it is still hot about 37-39 °C) can increase yield, promote more uniform color and better water holding capacity but reduces tenderness, promote abnormal shape of joints and difficulty in handling such meats (Warriss, 2000; Fletcher, 2002). Li *et al.* (2009) compared three boning methods and reported that cold-boning at 36 h post-mortem had the advantages of giving muscles a better color, the lowest cooking loss and cooked shearing value, and the highest sensory tenderness, juiciness, flavor and overall liking. Botha *et al.* (2006) compared hot deboning of ostrich meat to that of cold deboning and found that hot deboned muscles were initially tougher, had no significant effect on shear force and tenderness, but cause significantly more purge (3.4±2.33 % versus 2.1±2.06 %). Muscles microbial load were within acceptable limits for Aerobic Plate Counts (APC < 10^4 cfu/g) and *E. coli* (*E. coli* < 10^1 cfu/g) (Botha *et al.,* 2006). Mechanically recovered meat (MRM) ensures that meat wastage is reduced by making use of meats attached to bones after the normal boning of carcasses.

In aging or conditioning carcasses or meats are held in refrigerated temperatures for extended periods of time (between 2 to 4 weeks) after slaughter and initial chill; this helps to improve tenderness and flavor (Thielke *et al.,* 2005; Forrest, 2010b). Li *et al.* (2009) found aging hitherto 8 days to be enough to obtain an acceptable sensory attributes. Comminution is the grinding, mincing, chopping or flaking of meats into particulate sizes. Comminution improves the texture of low value meats and increases it economic values, although such meats are prone to spoilage and loss of some vitamins (Warriss, 2000; Adzitey *et al.,* 2011). Tumbling of meat has the ability to increase meat weight, by loosening protein strands in meats as the meats knocks against each other in a tumbler and absorbing water. This may also improve meat tenderness and juiciness when cooked.

Marination (using salt, vinegar or wine) and injection (using calcium chloride solution) tenderizes meat and improves its juiciness by breaking muscle structure due to the actions of collagenases, cathepsins and proteolytic calpain, making the myofibrils swell to hold more water (McFarlane and Unruh, 1996). In beef, injection of calcium chloride solutions may produce unfavorable effects on taste, flavor, turn meat surfaces brown in no time due to faster oxidation of heme pigments and reduce the shelf life of the meat if higher concentrations are used (Warriss, 2000). Nonetheless, this problem can be overcome by the combined effect of calcium chloride and ascorbic acid (Wheeler *et al*., 1996). Antioxidants such as Vitamin C (ascorbic acid), Vitamin E (α-tocopherol), propyl gallate, butylated hydroxyanisole and butylated hydroxytoluene are used in meats to reduce the effects oxidation during storage. Oxidation of meat is detrimental to meat color (formation of brown metmyoglobin), flavor (by lipid oxidation leading to rancidity) and reduces shelf life (Warriss, 2000).

Cooking procedures: The essence of cooking is to improve on the sensory characteristics (by maillard reaction and fat oxidation) to make meat more palatable and edible. Cooking to an adequate temperature destroys both spoilage and pathogenic microorganisms to make meat safer for consumption and to increase the shelf life. Due to these advantages barely do people eat raw or fresh meat. Cooking can improve the quality of meat by making it tender. Warriss (2000) showed that cooking meat from old animals or meats with more connective tissue at low temperature breaks down the connective tissue and improves its tenderness. Cooking temperatures also affect meat appearance. This is supported by Warriss (2000) who reported that beef cooked to 60°C is quite red inside, at 70°C it's pink brown and at 80°C it's brown due to the enhancement of degradation and the products of maillard browning reactions.

Nonetheless cooking to a certain degree normally beyond or below recommended temperatures can destroy (under cooked, overcooked or burned) meats making it inedible or unpalatable and consequently loss of meat quality. For instance, Wood *et al.* (1995) showed that as temperature increases, juiciness and cooking loss (%) decreases while pork flavor increases. McCance and Widdowson (1997) found that cooking by grilling reduced water and fats contents from 66.7 to 59.3% and 13.5 to 12.1%, respectively and thus increasing the relative energy content from 821 to 912 kJ $100g^{-1}$ and concentrating the protein content from 18.9 to 27.3%; which has positive implication on consumer health. Sheard *et al.* (1998) also reported a percentage reduction of fat in minced ground beef content to be 62%. Cooking especially (grilling, roasting, smoking) melts fats and some volatiles fatty acids from the meat can be lost by evaporation; also some lipids can be lost in the cooking container or energy source.

Conclusions: Post-slaughter practices contribute significantly to the quality of meat produced. This will in turn affect profits, processing/functional properties, eating qualities and the acceptance of the meat in question by consumers. All post-slaughter practices have been geared towards producing meat of better qualities, although some of these practices come with it negative effect on meat quality and human health. The practices in place have targeted and cover the carcass itself, cutting them into parts, the storage, processing and cooking conditions.

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