Symposium: Recent Advances in Poultry Slaughter Technology

Slaughter Technology

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ABSTRACT Slaughter technology has changed dramatically over the past 30 yr. Methods of handling the live animal immediately prior to slaughter, methods of stunning, killing, early postmortem handling, and carcass treatment have all seen technological advancement. The primary factors driving changes in these technical aspects of poultry slaughter have been to increase efficiency of commercial operations and the improvement of carcass and meat quality. Paralleling these developments, changes in social and legal expectations regarding animal well-being have also had an impact on these technical developments. The purpose of this symposium is to review the developments of these changing technologies and how they are being implemented in commercial operations. Special emphasis is on the technologies of electrical stunning, gas stunning, and electrical stimulation and their effects on carcass and meat quality.

(*Key words*: slaughter, electrical stunning, gas stunning, electrical stimulation)

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INTRODUCTION

Slaughter refers specifically to the killing of animals for food. Traditional slaughter practices have dealt primarily with factors that insure both wholesomeness and quality of the meat. In this context, wholesomeness refers to both the physiological and psychological aspects of the food, including safety, aesthetic, and religious issues. Quality, on the other hand, refers primarily to the more subjective and economic value-based issues such as shelf life, product desirability, and market value.

Traditional slaughter practices in North America and Europe are based heavily upon the old testament laws as still practiced in the Jewish and Moslem religions. Under religious or ritual slaughter, animals must be killed under strict guidelines, many of which are based on solid health and sanitary principles. For example, animals acceptable for food must be killed and not be allowed to die due to natural causes, disease, or accident. Until fairly recently, commercial slaughter practices were based on these traditional methods and were not subject to intensive animal welfare issues. However, over the past several decades, animal welfare issues have surfaced which have had a pronounced influence on several commercial practices.

Commercial livestock slaughter in North America and the European Union is now regulated to insure both product safety and humane treatment of the animal. Where conflicts arise with traditional religious-based ritual slaughter, exceptions are usually made. However, one of the major problems in equipment development and technical application are the differences in animal welfare standards, not only between regulatory units such as in the U.S., Canada, and the European Union, but between ethnic, national, and religious groups. There is by no means an universal animal welfare ethic. Laws regarding the treatment of animals prior to slaughter, and requirements for stunning and killing vary. Up to now, these laws and requirements have led to differences primarily in stunning equipment but will no doubt also affect developments in catching, hauling, holding, and handling prior to stunning.

The time duration between unloading the live animal at the slaughter facility and shackling until entry of the freshly slaughtered animal into the scalders, where it is generally agreed the birds must be dead, ranges from 2.5 to 5 min. It is during this very short time period that the slaughter procedures of unloading, immobilization (shackling), stunning, killing (neck cutting), bleeding, and electrical stimulation (ES) are performed. It is for this reason that these technologies are included in the topical area of slaughter technology. It should also be noted that during this time period, other than for the obvious ante-mortem or "living" condition of the prestun birds and the obvious post-mortem or "dead" condition of the birds entering the scalder, there is a

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Abbreviation Key: AC = alternating current; ATP = adenosine triphosphate; DC = direct current; ES = electrical stimulation; MTPS = Minimum Time Process System.

time period in which the status of the bird may best be described as being perimortem. It is during this period, between initial stunning of the live bird and sufficient exsanguination of the bird to result in irreversible failure of the circulatory, respiratory, and central nervous systems, that numerous events occur that affect ultimate meat quality.

STUNNING

Stunning was originally performed as a method of animal immobilization to allow easier and safer manipulation of the animal (especially for human handling of large animals) for efficient cutting of the blood vessels in the neck. In poultry, for which immobilization during slaughter was not as critical to manual killing, stunning was necessary for the subsequent development of efficient automated killing machines. In recent years, stunning has been viewed primarily from an animal welfare perspective as a means to minimize the pain and suffering associated with slaughter. From an animal welfare perspective, stunning should produce a rapid onset of stress-free insensibility of sufficient duration to allow the animal to remain unconscious until dead, either from the results of the stun itself or due to subsequent killing operations such as neck cutting during slaughter.

Stunning prior to slaughter can be accomplished using chemical, mechanical, or electrical means. Chemical means include gas stunning with carbon dioxide, argon, nitrogen, or other agent that ultimately results in unconsciousness and possibly death via anoxia. Mechanical means include the archaic method of "brain sticking" (piercing the brain) or concussion, as used in large animal slaughter. Because of the logistical and welfare difficulties of positioning the bird for mechanical methods under automated line conditions, there are at present no commercial systems in use. Electrical stunning is by far the most widely used method of preslaughter stunning in poultry.

Electrical Stunning

Electrical stunning was found to be an effective means to render the bird unconscious such that it could be mechanically aligned for automated neck cutting. Electrical stunning was also found to reduce struggle and convulsions during slaughter and to subsequently reduce carcass damage associated with these convulsions. However, electrical stunning has also been shown to cause other carcass and meat defects.

In the late 1970s and early 1980s, reports in Europe began to indicate that there were problems with electrical stunning of poultry. Electrical stunning of broilers was shown to be unreliable in that approximately one third of the birds emerged from the stunner dead, whereas another third were unstunned (Heath, 1984). Research conducted primarily in Germany and the UK resulted in European recommendations that broilers be stunned with a minimum of 120 mA to both instantaneously render the animal unconscious and to effect heart failure such that the animal can not recover consciousness. Therefore, electrical stunning systems in Europe are generally "high current" systems designed to irreversibly stun (i.e., "stun-to-death") the bird to insure animal welfare. Although such high current systems have also been related to increased incidences of carcass quality defects, the recommendation for a minimum stunning current was based solely on achieving optimum welfare and not on avoiding carcass defects (van Hoof, 1992).

In the U.S., poultry are specifically not included in the legislation covering the humane slaughter of livestock and as such stunning conditions are not mandated. As expected, differences exist in the methods of stunning between the U.S. and Europe. Although not specifically required, a survey of poultry slaughtering plants in the U.S. show that more than 97% of all poultry are subjected to electrical stunning (Heath *et al*., 1994). In this survey, 92% of the broilers were electrically stunned and the majority of the remaining 8% were subject to religious slaughter. Of the 329 poultry slaughter plants surveyed in 1991, 279 (85%) used electrical stunning, 216 (66%) used low voltage, high frequency (10 to 25 volts, 500 Hz), and the remaining 63 plants (19%) reported variations in stunning conditions ranging from 7.5 to 600 V, no specified waveform [alternating (AC) or direct current (DC)], and currents ranging from 0.3 to 10 mA. The authors concluded that although there were variations in methods of stunning and slaughter, the majority of plants were in voluntary compliance with the humane slaughter provisions, and the birds were stunned sufficiently to remain unconscious through exsanguination.

It is clear that there is no universally accepted electrical stunning system. Technical stunning matters such as current type (AC or DC), optimum amperage, constant amperage, voltage, and frequency have all been examined in an attempt to optimize bird stunning. Bilgili (1992) reviewed some of the basic concepts of electrical stunning and its effects on carcass quality.

Gas Stunning

Problems related to traditional slaughter practices, the application of high current electrical stunning for animal welfare considerations, and changing carcass quality issues have all resulted in the search for alternative slaughter technologies. The increased demand for cut-up poultry, deboned meat, and further processed products has resulted in a change in quality assessments such that meat defects, such as broken bones and deep muscle hemorrhages, are more critical. Because it is well documented that high current stunning results in a higher incidence of broken bones and muscle hemorrhaging (Gregory and Wilkins, 1989; Walther, 1991) and high current stunning is necessary for animal welfare issues in

Europe, alternatives to electrical stunning such as gas stunning have been examined.

Gas stunning, primarily with carbon dioxide, has been successfully used in pork slaughter for many years and has been investigated for possible use in poultry since the 1950s (Drewniak *et al*., 1955; Kotula *et al*., 1957). Although investigated and commercially evaluated, except for a limited number of exceptions, gas stunning has yet to be widely accepted as an economically and commercially viable alternative to traditional electrical stunning and slaughter.

In recent years, however, a new concept in gas application developed which has resulted in renewed interest in gas stunning. In a series of research papers from the U.K., Mohan Raj and associates have shown that gas killing birds in their transport cages had both animal welfare and carcass quality benefits over high current electrical stun-to-kill systems (Mohan Raj *et al*., 1990a,b). Authors from the same lab using a combination of carbon dioxide and argon gases showed that gas stunning could result in improved meat quality of early deboned carcasses (Mohan Raj and Gregory, 1991; Mohan Raj *et al*., 1991).

In the past 5 yr, extensive research evaluating different gas mixtures and their effects on carcass and meat quality have been conducted. The major difference in this research, as opposed to earlier work, has been the concept of gassing the birds prior to unloading (thus greatly reducing the damage associated with unloading live birds) and possible meat quality advantages. Currently, prototype gas stunning systems are in various developmental stages at several locations as well as commercial systems currently being used in Brazil, Europe, and the U.S.

ELECTRICAL STIMULATION

Electrical stimulation is a process in which an electrical current is applied to an animal carcass shortly after slaughter to stimulate muscular contraction and post-mortem metabolic activity. Post-mortem stimulation has been shown to both accelerate rigor mortis and to result in micro-structural changes that lead to a more tender meat.

Electrical stimulation has been used in the red meat industry since the 1970s primarily to accelerate rigor mortis and reduce adverse toughening associated with cold shortening and hot deboning. Electrical stimulation has been tested in poultry as far back as 1960 by deFremery and Pool, who reported that ES increased the rate of adenosine triphosphate (ATP) depletion and pH decline in breast muscle, but that acceleration of rigor onset resulted in less tender meat.

A comprehensive review of electrical stimulation in poultry was published by Li *et al*. (1993). This review clearly showed that ES parameters of voltage, current, waveform, frequency, duty cycle, method of application, and time of application during processing varied greatly between researchers. As would be expected, the results also varied considerably. The authors concluded that the limited data on poultry were inconclusive.

In 1988, a trade journal article featured the results of research and a patent from the Campbell Institute for Research and Technology on a "Minimum Time Process System" (MTPS), which could result in the deboning of tender meat in 24 min postmortem (Amey, 1988). The MTPS system used a combination of ES and high temperature conditioning to accelerate rigor. This process received considerable attention in both the industry and research communities and since then the amount of research on the application of ES has increased.

In a two-part series, Sams (1994, 1995) reported on the combined results of numerous research findings from his lab as well as prototype systems on the commercial application of ES. In these articles, summarizing their research findings, it was reported that ES applied on the kill line could result in an acceleration of rigor sufficient to allow deboning of tender breast fillets immediately following chilling. These two articles, along with the accompanying research papers, have greatly stimulated interest in commercial ES. At present, there are a number of ES systems being commercially tested in the U.S. as well as in Brazil (Bowers, 1996).

DISCUSSION AND SUMMARY

Electrical stunning, gas stunning, and ES are three processes that have been shown to have a profound effect on carcass quality, early rigor development, and meat quality. Stunning, regardless of method, should result in a relatively stress-free induction of unconsciousness of sufficient duration that the bird does not regain consciousness prior to exsanguination and death. Because the processes of stunning, neck cutting, and bleeding are performed in rapid succession, it does not matter when the bird actually dies. This assumption is supported by the results of the high current stun-to-death systems as well as the recent gas stunning results in which either cardiac arrest or respiratory failure occur prior to neck cutting and bleeding without negative effects on ultimate blood loss, or carcass quality. Thus, from a technical standpoint, stunning, neck cutting, and bleeding should be considered a continuous slaughter process and not as distinct steps. In this context, gas stunning and gas killing, or high current stunning and killing are indistinguishable in the slaughter process.

Interpretations of research results comparing the relative merits of each system can be confounded by numerous differences in methods of application and comparison bases. For example, many of the observations made in Europe that numerous birds were either being under-stunned or over-stunned led to recommendations to stun at high currents to insure animal welfare.

However, in the U.S., similar situations were not observed and most electrical stunning is performed at relatively low voltages. It is difficult to make direct comparisons between the two systems because the methods of stunning application (equipment) and method of slaughter (neck cutting) vary.

Electrical stunning has been shown by numerous researchers to temporarily delay rigor development. Recent research results have shown that this rigor delay is affected by electrical stunning parameters. Papinaho and Fletcher (1995) reported that stunning currents between 0 and 200 mA affected the rate of early rigor development but had no effect on final meat quality. In a companion study, it was shown that stunning delays rigor mortis primarily due to an inhibition of peri-mortem struggle (Papinaho *et al*., 1995). In a direct comparison between a high current stunning system as recommended in Europe and a commercial low voltage stunner commonly used in the U.S, it was shown that high current stunning resulted in delayed rigor development but no difference in ultimate meat pH, color, or shear (Craig and Fletcher, 1997).

In an effort to avoid the negative quality implications of high current stunning, gas stunning was investigated. Comparing gas stunning with carbon dioxide and argon to traditional high current stunning and slaughter appeared to show dramatic improvements in carcass quality (less damage), faster rigor, and improved meat quality. However, subsequent research has clearly shown that these benefits were primarily a function of the high current stunning and not necessarily direct effects of the gas stunning. In a study comparing gas stunning/killing to both high current stunning and low voltage stunning, there were no differences in rigor acceleration or meat quality between low voltage stunning and gas stunning (Poole and Fletcher, 1997).

It is interesting that electricity applied to the live animal (stunning) results in a delayed rigor development whereas electricity applied seconds later to the dead or dying animal (stimulation) accelerates rigor development. This would indicate that the effectiveness of ES may be influenced by stunning method. The results of current research show that there is indeed a significant interaction between ES and stunning at either high current or low voltage. Birds subjected to ES showed a more pronounced rigor acceleration effect on the high current stunned birds than on those stunned with low voltage (Craig *et al*., 1999). These results would indicate the ES effectiveness may be dependent on the rigor state of the bird as influenced by the method of stunning. Thus, birds stunned at higher current levels may benefit more from ES than birds stunned at low voltage. This fact may help to explain some of the variability in previous research results on ES.

At present there is interest in accelerated processing (the ability to debone tender breast meat immediately upon exiting the chiller) and in slaughter effects on meat quality. The increased interest in meat quality is being driven by the expansion of deboned and further-processed meat being more susceptible to slaughter related defects (for example, stunner-related hemorrhages). These two factors have tremendous potential financial implications on processing and as such they will continue to receive considerable developmental interest. In addition, concerns regarding animal welfare and regulatory policy will continue to shape the environment into which these developing technologies must be adapted.

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