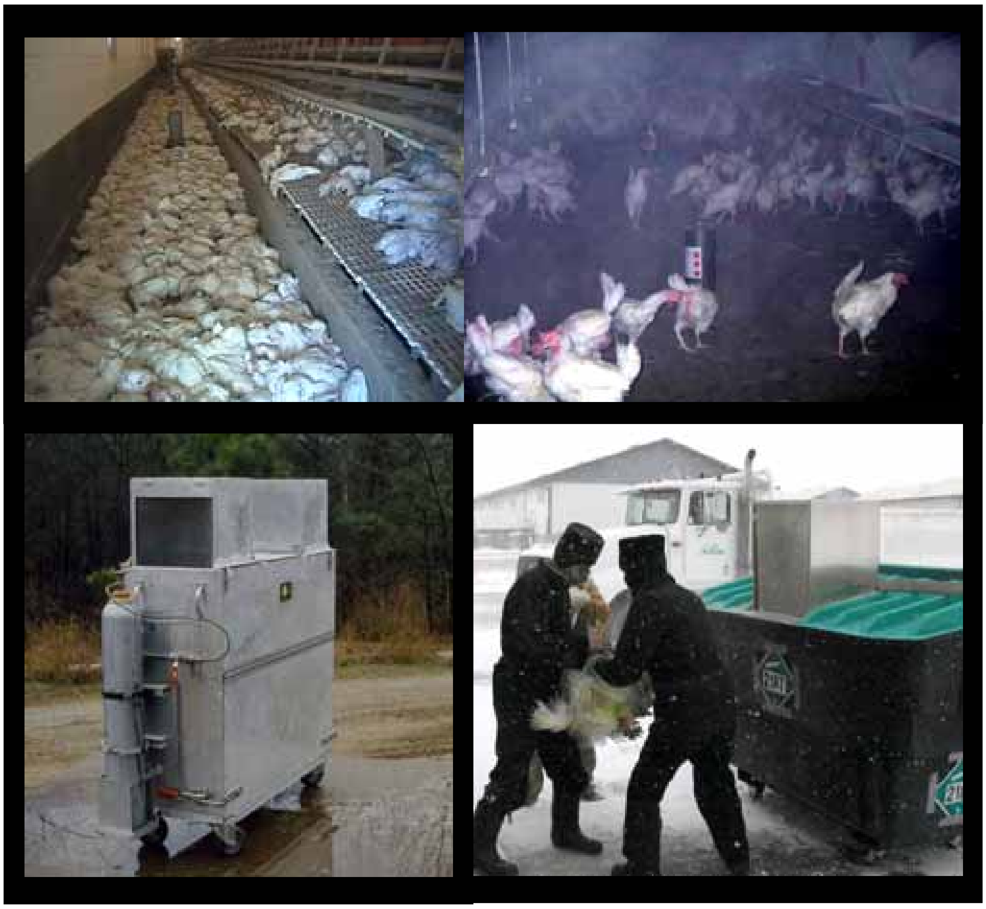
Welfare during handling and killing of spent hens

Djurvälfärd vid bedövning och avlivning av värphöns

Sophie Atkinson, Bo Algers



Sveriges Lantbruksuniversitet **Skara 2006** **Rapport 9**
Institutionen för husdjurens miljö och hälsa
Avdelningen för husdjurshygien

Swedish University of Agricultural Sciences ***Report 9***
Department of Animal Environment and Health
Section of Animal Hygiene

ISSN 1652-2885

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INTRODUCTION

Every year there are approximately 5.8 million spent hens removed in Sweden from at least 500 different farms (SJV, 2006; Svenska Ägg, 2006). Approximately 256 farms depopulate over 5000 hens at any one time. Flock sizes generally range between 10, 000 to 30,000 hens. The largest farm has approximately 300,000 laying hens and depopulates over 90,000 hens at any one time. There are four methods for the depopulation of hens:

- Killing hens on farm by releasing carbon dioxide (CO_2) at high concentrations in to layer sheds
- Killing hens on farm by releasing Cyanide (HCN) at high concentrations in to layer sheds
- Killing on farm by way of a portable electrical water-bath stun/neck cut kill apparatus
- Sending hens by road transport to slaughter at a commercial abattoir that uses an electrical water-bath stun/neck cut kill system

The killing method egg producers use is largely influenced by farm location. There is now only one abattoir in Sweden that processes spent hens. This abattoir is not within reasonable transport distances to some farms causing high transport costs and excessive transport duration for the hens. These farms therefore practice on-farm killing. In the 1980´s cyanide gas was used for on farm killing, but since year 2001, CO_2 gassings have mostly been used. Killing of spent hens with CO_2 or HCN is actually not permitted under Swedish law (SJVFS 2001-75, chapter 6, part 1). However, farmers can apply to the Swedish animal welfare authority for an exemption from this regulation. The farmer must apply for a permit for every flock they wish to kill. In 2005, approximately 19 farms (11 from Gotland) were given permission to depopulate their layer shed using CO_2 gas. The number of hens ranged from the smallest flock size of 1100 to the largest of 88,000 hens. The total number of hens gassed with CO_2 was 364, 600 hens, 34% which came from Gotland and 66% from the mainland, mostly around the Kalmar area (Swedish Animal Welfare Agency, 2006).

Many producers with hens in loose house systems prefer to practice on farm killing due to welfare concerns with the catching, caging and transportation necessary when sending hens to slaughter. The carcasses of hens killed on farm by gassing must be sent to a specialised animal rendering plant for burning at cost to the farmer. In northern Sweden, there are 14 egg producers (the smallest with 3000 hens, the largest with 44,000 hens). These farmers practice on farm killing of hens with a small electrical water-bath stunning apparatus that is transportable and shared between them. The hens are then sent to the rendering plant. At least 140,000 hens are killed this way (Norrlansägg, 2006).

There is one small company that offers on farm hen killing services for the purposes of processing the hens to pet food. The company travels to the farm with a portable electrical water-bath stunning apparatus, similar to the one used in northern Sweden, and hens are killed, debled and defeathered on the farm. The farmer does not have to pay for the disposal of the carcasses, as the carcasses are used by the company for pet food production providing some subsidy for the service. This company provided on farm killing and carcass removal services to approximately 20 farms in 2005 (Stefans and Nillans Foder, 2006).

Nearly 80% or 3.1 million hens were sent to abattoir slaughter in the year 2005 (Svenskt Fågelkött AB, 2006). These hens are transported to the abattoir by the company's own trucks. Transport distances vary from local to as far away as 714kms to the north, and 370kms to the south. Approximately 370 farms send hens to this abattoir. The farmer must pay for the transport and slaughter of these hens which are sent as fresh and frozen carcasses to Germany for soup and buljong production.

Another aspect on the depopulation of birds is the need for depopulation to stop the spread of contagious disease such as e.g. Avian influenza. In an outbreak in the Netherlands 2003 more than 30 million birds were killed within a few weeks in order to stop the spread of the disease. During this outbreak CO_2 stunning and killing was used instead of HCN mainly due to the risks of using HCN for human health during operating procedures, but also because enough HCN was not available on the market (Ooms, pers. comm. 2006). If a disease outbreak of such a kind should occur in Sweden a stamping out strategy needs to be applied where the welfare concerns are met in accordance with the "OIE GUIDELINES FOR THE KILLING OFANIMALS FOR DISEASE CONTROL PURPOSES".

Swedish on farm killing methods have been little studied from a welfare perspective. Therefore this study aimed to get a better understanding of hen welfare by observing different killing methods, and investigating the possibilities of making changes to improve hen welfare.

BACKGROUND

Live transport and slaughter by water bath stun/kill system

Live transport requires hens to be caught and loaded into cages, and placed into the transport vehicle. Most hens in Sweden (3.6 million) or almost 60% are kept in some type of loose house systems such as the RED-L design. The handling process involved with catching, transport, unloading and slaughter is time consuming and stressful to hens. Generally restrictive husbandry systems (such as caged hens), leads to weaker bones and an increased likelihood of bone breakages during handling and transport (Knolwles et al., 1993). Free range systems allow hens to move freely promoting wing movements and therefore stronger bones (Newman and Leeson, 1998). Approximately 40% of hens are kept in cages, most (2.2 million) in enriched caged systems (Swedish Animal Welfare Agency, 2006). In one survey it was found that 31% of birds from cages had freshly broken bones compared with 14% of birds from free- range systems (Gregory et al., 1990). Therefore a combination of the housing system and the catching process must be considered when looking at the overall picture for assessing the welfare of depopulation methods for spent layer hens.

Electrical water bath stunning

The purpose of electrical stunning in poultry is to induce insensibility in order to perform humane neck cutting and avoid recovery of consciousness and wing flapping during debleeding and the minimum current per bird should be 120mA according to EU and Swedish regulations (91/628; 93/119). The process of water-bath stunning involves shackling live and conscious birds on to a conveyer belt that transports the birds to a water-bath. After the shackling process, a proportion of birds are lowered into a water-bath where upon the head is immersed and a voltage applied to complete a circuit through the hens. Hens in this type of circuit represent a series of resistors connected in parallel. The amount of current that flows through each individual bird is dependent upon the voltage applied and the electrical impedances of the birds in the bath. The effectiveness of an electrical water-bath stunning system is dependent upon not only the electrical variables used (i.e. current, voltage, waveform, frequency and duration), but also the biological factors that affect bird impedance (i.e. size, weight, sex, composition and feather cover) (Bilgili, 1999). Wetting the shackles prior to immersion in the water-bath can reduce electrical resistance between shackle and legs (Uijttenboogaart, 1999).

EFSA (2004) reported welfare concerns in birds killed with the electrical water bath system, in that during handling and shackling some birds struggle and wing flap, which leads to dislocations and fractures. By recording nociceptors (or nerve endings) in the skin of the lower leg area, it was demonstrated by Gentle and Tilston (2000), that the forces exerted by shackling excited the majority of nociceptors (nerves) in the skin, indicating that shackling birds is painful to them, which can cause wing flapping and struggle behaviour.

Killing using carbon dioxide gas

A good death for animals is one that occurs without pain or distress (Gerritzen, 2004). Gas stunning on a commercial scale for stunning and killing of poultry has largely been developed as an alternative to the more widely used electrical water bath stunning methods as many studies conclude that the level of pain and distress caused to birds is lower (Raj et al., 1998; Lambooij et al., 1999; Gerritzen et al., 2000). However, the avian respiratory system is highly adapted for efficient gaseous exchange, making them extremely sensitive to inhaled gases, especially high concentrations of CO_2 (CAS workshop, 2005). There are many different and changing recommendations available on what are the best gas mixes and concentrations to use to reduce aversion during killing of birds. Most studies have also been conducted for the purposes of commercial scale slaughter of broilers in a modified atmosphere chamber system and not for on-farm in house gassings. Carbon dioxide is a colourless, virtually odourless, non-flammable, non-explosive gas that presents minimal hazards to operators handling the gas. Though when inhaled in high concentrations (over 50%) it has an irritant effect and produces a choking sensation and respiratory distress in all mammals (EFSA, 2004). A behavioral sign of respiratory distress in hens is indicated by gasping and head shaking and occurs when concentration levels reach 30% (Raj, et al, 1992, pers.comm Raj, 2006). Although gas killing within the housing system avoids catching, transport and shackling of hens, the suitability of a particular gas depends on whether an animal experiences distress between the time it begins to inhale the gas and the time it loses consciousness and dies. There is no research on large shed gassing that indicates the aversion time, or what time limit would be acceptable. Typical in shed gassing require the shed to be sealed up, and compressed and vaporised gas slowly pumped into the shed at high pressure.This method was applied in the Netherlands during the influenza outbreak in 2003 although it was considered to lead to impaired animal welfare but it was not investigated to what extent (Ooms, pers. comm., 2006).

Carbon dioxide is heavier than air therefore it accumulates in the lower areas of the shed. The CO_2 kills the hens by causing respiratory and metabolic acidosis, which reduces the pH of cerebrospinal fluid, depressing the central nervous system leading to death by hypoxia. As the introduction of gas is gradual, many birds are exposed to low CO_2 concentrations for a period. In order to cause unconsciousness in birds, the CO_2 levels need to be at least 30% concentration in air for at least 1 minute. In order to kill the birds the levels then need to be increased to 50% for at least 1 minute (pers.comm,Raj, 2006) and according to Gerritzen et al. (2004), for in shed gassings the concentrations should be at least 50% for 30 minutes. EFSA (2005) report that the delay between first gas contact and unconsciousness varies greatly between sheds, and are not known although there is mention of anecdotal reports of birds starting to die 35 minutes after the gassing.

Killing using gas mixtures

Experiments have shown that aversion reactions in birds during gas killing can be reduced by mixing in inert gasses such as Argon (Ar) or Nitrogen (N) with the CO_2. Inert gases have no taste or odour, and do not cause birds distress at any concentrations. Argon is presently cheaper and more available than Nitrogen, and is therefore more commonly used in modified atmosphere stunning systems. Trials showed that when Ar with less than 2% oxygen was presented in a feeding chamber, hens entered spontaneously and were killed by it (Raj and Tserveni-Gousi, 2000). The mix of Ar at concentrations of at least 60% with $CO_{2,}$ has been shown to cause a non aversive hypoxia in poultry (Raj, 1996) and it is concluded by the European Food Safety Authority, that it is better to kill birds with this mixture than high CO_2 concentrations (EFSA, 2004).

As far as bird welfare is concerned, a minimum of 90% Ar in air is the best mixture for killing hens. However, a mixture of 30% CO_2 and 60% Ar in air is better than using a high concentration of CO_2 in air, and is therefore the second choice. If for economic reasons only CO_2 can be used, it is recommended that there is a two stage system that involves firstly stunning of birds with a low concentration of CO_2 (<30%) and then killing them with a high concentration (>80%) (Raj and Tserveni-Gousi, 2000). Studies completed by Gerritzen et al (2004) suggest that broilers can be anaesthetised by gradually increasing levels of CO_2 to 17%.

Killing using cyanide gas

Cyanide (HCN) is a colourless, volatile, and extremely poisonous chemical compound with vapours that have a bitter odour. HCN kills hens by causing paralysis of the respiratory centre, and some hens exhibit convulsions (wing flapping) prior to death. According to the EFSA (2005) HCN is a quick an effective killing agent although it has been reported to cause violent convulsions before the onset of unconsciousness. According to the American veterinary association and an EU report on euthanasia of animals, HCN poses an extreme danger to personnel and the manner of death to animals is not acceptable (AVMA, 1993; EFSA 2004; SJV, 2003). However, there is little literature available on welfare assessments of hens being killed by HCN. According to Coenen in Barton Gade et al. (2000), the gas euthanasia process is acceptable as long as there are minimal signs of agitation, discomfort and distress during the gassing period. Symptoms that should be closely looked at that could indicate agitation levels include amount of heavy gasping and long lasting muscle contractions.

Other killing methods

There are other methods of on farm killing hens used in other countries. However, many of these methods have greater welfare concerns for hens compared to the methods mentioned in this report. Some methods include the use of pesticide fumigation of sheds, using chemicals such as Parathion, Diazion and Malathion. The application of oral substances for culling poultry during the eradication of a contagious disease by stamping out procedures was reviewed during the Influenza outbreak in the Netherlands. The conclusion was that it is an uncertain / uncontrollable route which results in impaired animal welfare. Therefore the advice was not to apply the oral route for culling poultry during stamping out (Ooms, pers. comm.., 2006).

Carbon Monoxide (CO) is another method that has only been assessed for piglets. As it is odourless it may not cause distress and loss of consciousness occurs without pain and with minimal discomfort. Carbon monoxide is a rapid and effective method of euthanasia as it combines with the hemoglobin in the red blood cells in preference to oxygen, causing hypoxia. Only a pure, commercially compressed source of CO should be used. Vehicle exhaust is not an acceptable source of CO for euthanasia because it is hot and contains contaminants. High levels of CO are deadly to humans, and only well-trained personnel should therefore use carbon monoxide and then only under properly controlled circumstances. The gas should be delivered into tightly sealed containers and the area around the containers monitored for leakage. Depending on how many birds are being euthanized, a circulation system may be necessary to ensure that the gas does not become stratified (OIE, 2003).

PROJECT OBJECTIVES

The project objectives were to study different depopulation methods used on egg layer farms to measure:

1) Bird welfare during handling, stunning and killing
2) Bio security
3) Feasibility/Cost analysis

METHOD

This project investigated the following killing methods:

- 3 studies of on farm CO_2 gassing of buildings where hens were housed
- 2 studies of on farm HCN gassings of buildings where hens were housed
- A study of hens transported and slaughtered at the hen processing facility in Sweden
- A study of the portable electrical water bath stun/kill apparatus
- A study of container gassings using CO_2 and Argon/ CO_2 mixes

Layer shed gassings

The general operational procedures for the on farm CO_2 and HCN gassings were observed and documented, and where possible, the killing process filmed. Several small surveillance cameras were installed in the sheds on both the highest and lowest levels that hens could be. These cameras recorded in black and white (no sound) directly onto VHS videos. A digital camera was also used on each farm, recording in colour and with sound. Recordings were made continuously from several minutes before, during and a couple of hours after the gassing process. For filming of the CO_2 gassing process, cameras could only be placed at the opposite end of the shed to the gas inlet pipe to avoid damage to the cameras from the incoming high pressure gas. The films recordings were analysed synchronously with the start of the gas flow and the times when hens showed specific behaviours.
Behaviour observations recorded were:

- neck stretching
- head shaking
- gasping
- body movements
- wing flapping
- loss of posture
- cessation of all movements

From these behavioural observations, estimations were made on the onset of loss of consciousness and time of probable death. In this research project, hens were judged to be in a likely state of unconsciousness during gassing if they had lost posture, no longer showed eye reflexes, no longer showed gasping reflexes and showed minimal body movements. This was considered to be the most important time to consider when assessing the welfare of hens during gas killing. The duration of symptoms such as convulsions, wing flapping, seizures, and vocalisations, after the hen had become recumbent, were considered to occur during an unconscious state.

Head shaking is a behaviour indicating irritation of the nasal mucosa, and is defined as quick side to side or flicking of the head movements. Gasping is defined as breathing with open beak, which can open and close quickly indicating shallow breathing or opening for a longer period. Gasping and neck stretching are indicators for breathlessness. Loss of posture is defined as the bird unable to maintain a sitting position. According to Gerritzen, 2004, loss of posture and neck tension is a behavioural indicator of loss of consciousness. However, for the purposes of this study, if a bird has lost posture, but showed eye blinking and gasping, it was considered still conscious.

A number of birds in each film for each type of killing method were selected, and the specific behavioural symptoms recorded and timed using a stop clock. A comparison was made of hen behaviour for average reaction time, time to likely unconsciousness, and probable time of death for the different gas killing methods observed.

Temperature probes were placed at various points inside the sheds to record temperature changes during CO_2 gassing. On one of the farms several birds were collected and sent for post mortem analysis to determine the cause of death.

Electrical water bath stunning

Electrical currents that do not lead to an immediate stun may be experienced as painful even if the brain was included in the current path (von Wenzlawowicz and von Holleben, 2001). Insufficiently stunned chickens will leave the water-bath stunner vocalising and wildly flapping their wings in a futile attempt to fly away (Ali et al. 1995). Signs that were looked for when assessing stun quality of hens included:
Prestun:

- Were heads properly immersed?
- Any wing flapping, vocalisations?
- Any premature electric shocks?

After stunning

- Any breathing?
- Any birds with corneal reflex?
- Any birds reacting to painful stimuli?

(based on Shütt and Abraham 1996)

RESULTS

Carbon dioxide gas killing of hens in shed

Table 1 outlines the shed volume, number of hens killed, amount of gas used, and duration of gas infusion for each of the studied CO_2 shed killings. It also shows the recommended amount of CO_2 usage based on the calculation for concentrations to be at least 80% during the killing process. AGA Gas Company state in their guidelines for CO_2 gassing, that the concentrations should be at least 80% in the shed, yet the formula they use in actual calculations are written for a 60% CO_2 gas concentration (Appendix 1). On farm 1 and 2, the amount of gas used equates to CO_2 concentration of 67 and 66% respectively, and on the 3rd farm, where the shed volume was highest, the concentration was 92%.

Table 1: *Summary of CO_2 gassing details for each farm / shed studied*

	Farm 1		**Farm2**	**Farm 3**
	Shed 1	Shed 2	Shed 1	Shed 1
No. Hens killed	9,900	9,900	19,000	31,000
Shed volume m^3	3750	3750	5034	8467
Amount CO_2 used (kg) (% concentration)	4515.3 (67%)	4495 (67%)	6020 (66%)	14038 (92%)
Recommended CO_2 (kg) (% concentration)	5400 (80%)	5400 (80%)	7248 (80%)	12192 (80%)
Time of gassing (mins)	10	10	13	26

**note: to get amount of CO_2 (kg) for 80% concentration in shed the formula used is: shed volume x 1.8 x 0.8*

The gassing procedures were basically the same for every farm visited. Each shed to be gassed was sealed. All windows and doors were covered in wood panels, and smaller areas blocked with insulation material. All ventilation openings were closed, fans shut down, and the lights and electricity in the sheds shut off. A truck from AGA Gas Company would connect a flexible 5 meter hose from the truck containing CO_2 gas in vapour form to a permanently installed metal inlet pipe fixed to the hen shed (figure 1). The pipe diameter was 25mm (figure 2), and the CO_2 gas was pumped through the pipe at high pressure (at least 15 bar) which always created a high noise level. The pipe was positioned 72cm on one farm, and 1 meter on another, from the inside ground level of the shed. Most sheds had the pipe located at the short end of the shed, with one farm having it located on the long side. In the smallest shed the pressure used to spray the gas into the shed was 22 bar (pumped in for 10 minutes) compared to 35 bar for the largest shed (pumped in for 26 minutes).

Figure 1: *Method for pumping CO_2 gas into shed at high pressure from a truck*

Figure 2*: Flexible hose with a 25 mm diameter pipe fixture that goes through shed wall transporting CO_2 gas into the shed*

Temperature change

A radical temperature drop inside the shed was found to occur during the gassing procedures by the digital temperature probes. Figure 3 shows the temperature drop on one farm from plus 21°C to minus 40.4°C (a difference of 61 degrees), at a rate of approximately 3 degrees per minute. This probe was located close to the incoming gas. In the mid part of the shed the temperature dropped to minus 32°C and the far section to minus15°C. One hour after the gassing, the temperature rose to plus13°C. It was also found that hen carcasses closest to the inlet pipe, were actually frozen, even after 2 hours, while those further away, were cold. Six hens from this shed were randomly collected from an area of approximately 20 meters around the gas inlet pipe and sent for post mortem analysis. The results indicated that the probable cause of death was from freezing (appendix 2). The film footage collected in this study taken close to the inlet pipe shows instant misting from incoming gas, the misting being frozen air particles. Therefore, many hens located closest to the gas inlet pipe probably die of freezing. The footage taken from the back of the shed however shows less misting and hens can be seen gasping and neck stretching before loosing posture, indicating death by hypoxia (suffocation).

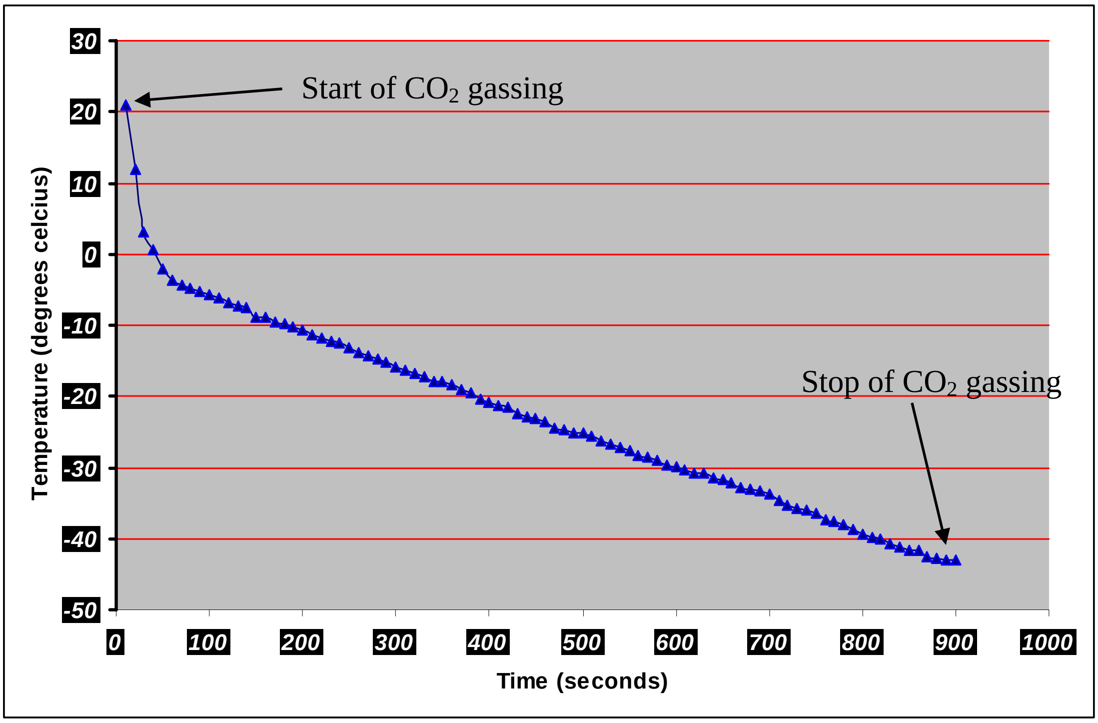


Figure 3: *Temperature decrease in shed 2 during CO_2 gassing*

Distribution of dead hens after gassing

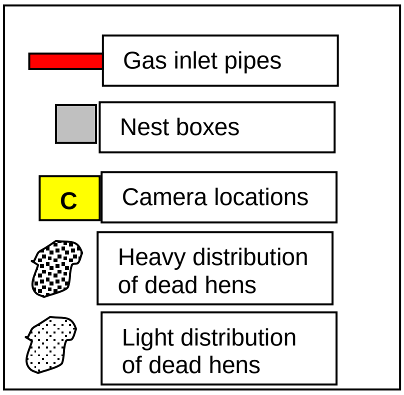
In all deliberate CO_2 gassings, no hens were found alive when the sheds were opened for clearing 2 hours after the gassing. In each shed the distribution of dead hens was different, depending on the location of the gas inlet pipe. Figure 4 shows the typical pattern of dead hens found after CO_2 gassing, with fewer hens at the pipe entrance, and a heavy build up of hens at the end of the shed away from the gas inlet pipe.

***Figure 4**: Typical distribution of dead hens after gassing in area closest to the gas inlet pipe and farthest away to gas inlet pipe*

Film footage shows hens rapidly running/flying away from the incoming gas, and dust flying. It seems that the force of the incoming gas from the pipe blows the hens and floor litter away from it. On one farm the gas inlet pipe was located mid way on the long side of the shed, pointing in towards the nest boxes (figure 5). An inspection of the shed two hours after the gassing found many wing patterns stamped into the dust along the nest boxes. Some birds were still actually frozen and pinned in this position, indicating they had been blasted by the force of the gas against the nest boxes. This physical trauma probably killed them instantly. In the other sheds the gas inlet pipes were located on the short side of the shed, pointing into the lane ways. Although hens were cold, none were found still actually frozen, and no hens were pinned against nest boxes. The distribution of dead hens still showed a pattern of light distribution around the gas inlet pipe, although on one farm it was less extreme (figure 6). This was because the farmer had closed off the middle lane opposite the gas inlet pipe to keep birds in the 2 outer lanes for the purposes of making emptying of the shed easier after the gassing. The farmer had also cleaned out the floor litter the previous day. The pattern of dead hens and floor litter was found to be more even than seen in other sheds. The farmer had inadvertently improved bird welfare during the killing process by locking the birds out of close vicinity to the incoming gas. Cleaning out the floor litter would have also meant less dust flying around the shed during the gassing, probably reducing stress to the birds.

In the third farm study, three sheds were located next to one another, each containing 31,000 hens. Only one shed was supposed to be gassed with CO_2. However, after the gassing it was found that CO_2 had leaked into the shed next door through a hole approximately 20 cm diameter where a conveyer belt for feed went through the wall at ceiling height where it had accidentally not been sealed off. This gas leakage caused the death of approximately 16,000 (50%) of the 31,000 hens in this shed that were supposed to be left alive. These dead hens were found only on the floor level in a light and even distribution (figure 7) with more dead hens on the outer lanes than in the centre lane. No hens were seen dead on the upper tiers. The birds found living, were all sitting on the upper levels in what looked to be a healthy and unstressed condition.

Legend for figures 5 to 7



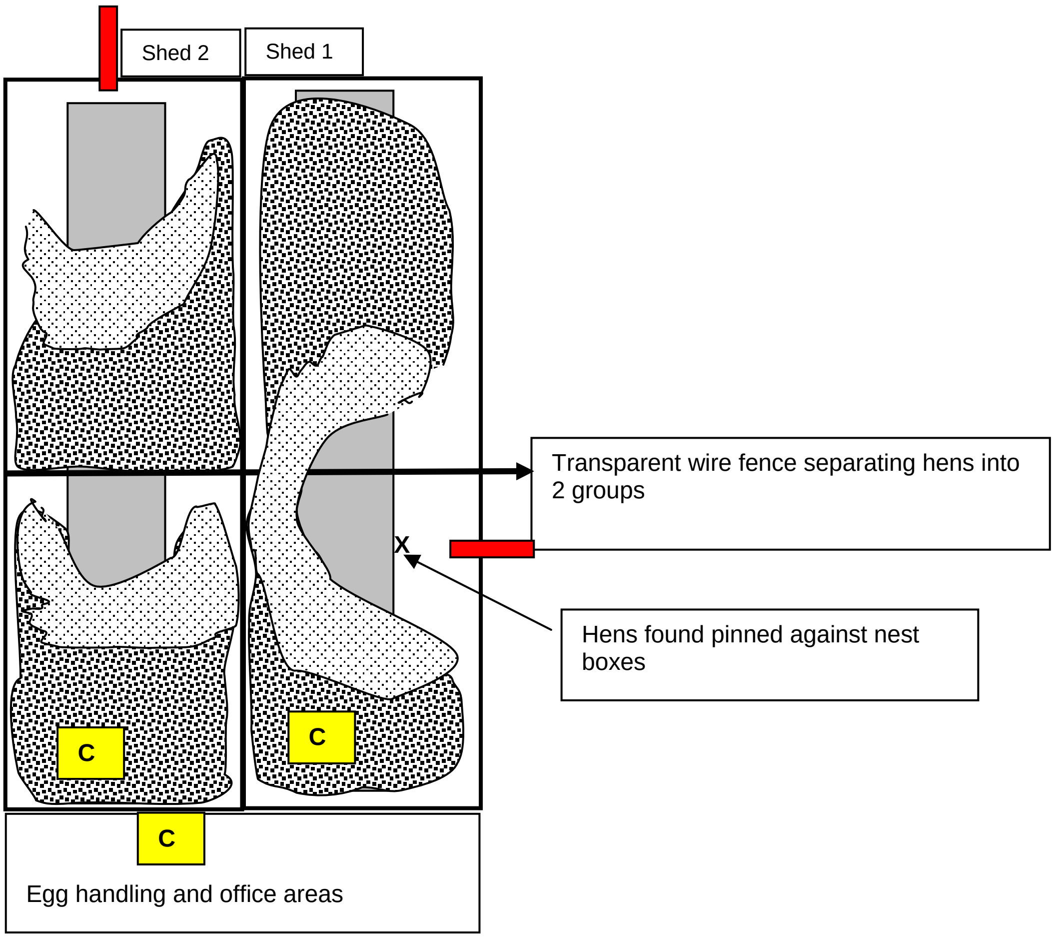


***Figure 5**: Farm study 1. Hens found frozen and pinned against nest boxes in shed 1, due to location of gas inlet pipe*

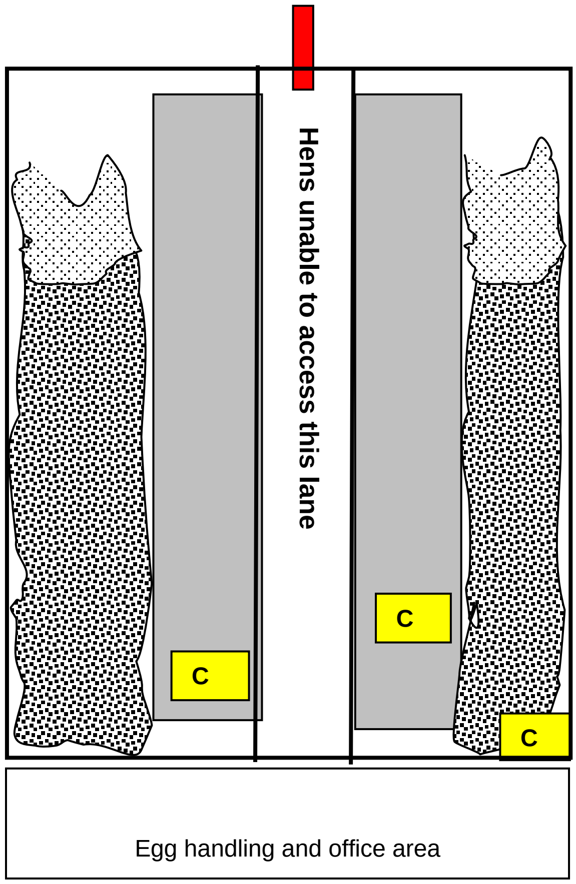


Figure 6*: Farm study 2, shows a more even distribution of dead hens due to closure of lane opposite gas inlet pipe.*

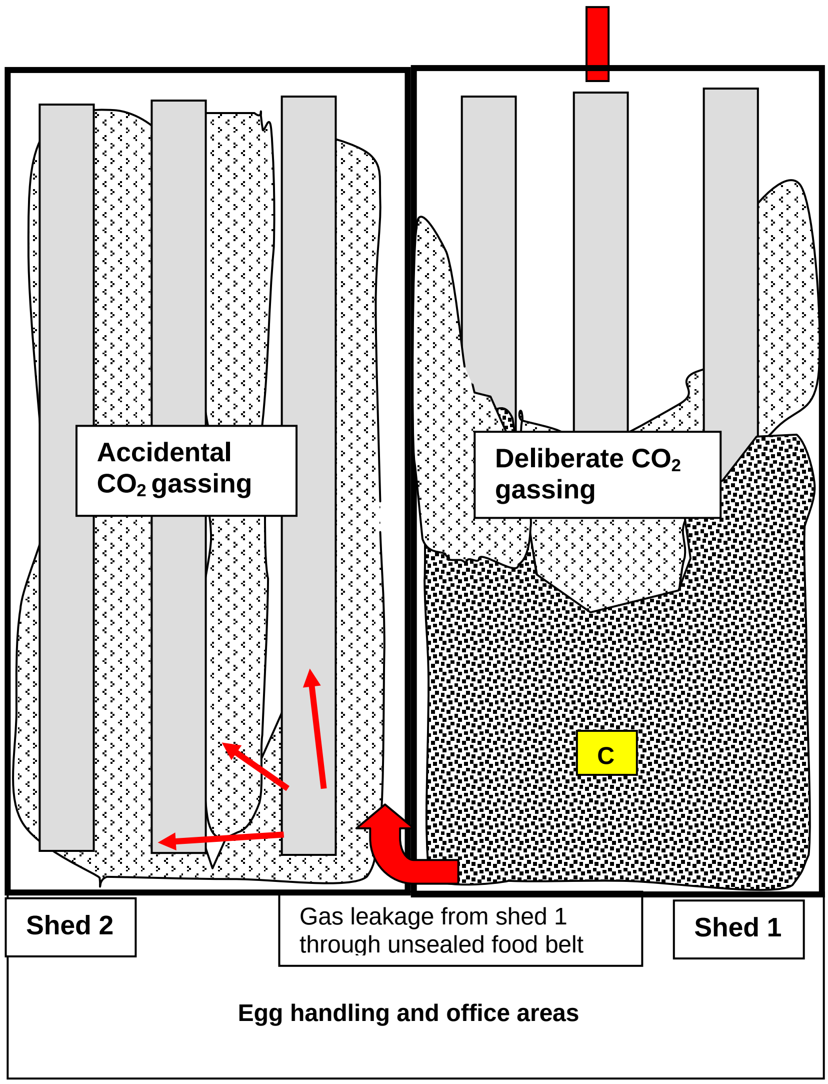


Figure 7: *Farm study 3 showing distribution pattern of dead hens after deliberate CO_2 gassing (shed 1) and accidental gassing (shed 2).*

Behavioural observations

Film footage shows that hens displayed similar behavioural reactions to the gassing and generally in the same sequence on all nest levels, including the ground level. The start and duration of the reactions however, varied from farm to farm (table 2). The best film footage collected was from cameras installed on upper levels.

Table 2: *Time Sequence (minutes: seconds) of symptoms displayed by hens filmed during CO_2 gassings on 3 different farms, filmed on upper, lower and mid shed levels (gassing starts at 00:00)*

Symptom displayed	**Farm 1 (top level)**	**Farm 2 (top level)**	**Farm 2 (ground level)**	**Farm 3 (mid level)**
Beak opens & closes	01:33	01:05	01:05	02:08
Head shaking	01:40	01:21	01:30	02:08
Gasping begins	01:42	01:26	01:26	02:22
Long gasping sessions	01:53	01:49	01:41	02:38
Start to loose balance	02:56	02:08	02:46	02:40
Head drooping	04:00	02:08		
Fall over (loss of posture)	05:12	02:27	02:46	02:45
Estimated time of loss of consciousness	05:39	03:40	After 04:55 *whiteout	After 03:56 *whiteout
Last movement seen (estimated time of death)	11:37	08:55	After 5:05 *whiteout	After 04:30 *whiteout

Hens immediately start to move away from the incoming gas in a nervous manner. This behaviour occurred much quicker and was more obvious in hens located on the ground level compared to the upper levels, and hens on the ground level quickly crowded together (figure 8). It took between 1 and 2 minutes (depending on the shed size) before hens displayed symptoms indicating that they could detect the CO_2 gas. These symptoms started with opening and closing of the beak, followed by frequent head shaking, and then gasping in short sessions becoming longer (figure 9) and more strained with the neck stretching out (figure 10). After this stage hens would start to loose balance occurring between 2 to 3 minutes from the start of the gassing. Some hens remained upright with the head drooping down (figure 11), eventually slowly rolling forward on to the breast or side. Some hens periodically fell over then regained posture. Once laying some hens went into bouts of wing flapping, lasting for only a few seconds. After hens had lost posture; body twitches, slight wing movements, gasping and respirations continued, gradually decreasing until movements stopped altogether at which point death probably occurred. Some hens were clearly still conscious after loosing posture.

Figure 8: *Hens quickly crowd down the shed end at ground level, moving away from the incoming gas*

Figure 9: *Gasping starts in short intervals which become more strenuous as the gas concentrations increase (photos from upper level in shed gassing)*

Figure 10: *Neck stretching is a typical symptom seen during in shed gassing with CO_2*

Figure 11: *Hens gradually droop their head and loose muscle tension in the neck as they start to loose consciousness*

The longest period a hen showed symptoms of gas aversion while in a probable conscious state (indicated by blinking of the eye and rhythmic drawn out gasping sessions) was approximately 5 minutes and 40 seconds. The longest period a hen showed movements (shallow respirations and body twitching) before becoming still was 11 minutes and 37 seconds. A group of 5 hens were observed closely in the film footage and the durations of the symptoms they displayed before estimated time of loss of consciousness was timed. The average time to loss of consciousness was 3 minutes and 45 seconds.

Hens filmed at ground level could only be observed up to the first few minutes as misting occurred on the cameras. However, the footage did show that even though hens filmed in the largest barn (farm 3) took 1 minute longer to react to the gas compared to farm 2, they lost balance and posture 6 seconds faster. Heavy misting in the film footage also occurred 1 minute faster. This probably happened because there was a much higher gas flow rate used in farm 3 due to the larger shed volume. In this shed, there was also a more extreme clearance of dead hens and dust found around the gas inlet pipe compared to other farms (figure 12).

Figure 12: *Lane way opposite gas inlet pipe on farm study 3 (largest shed gassed), showing almost complete clearance of hens due to the high velocity of the gas blowing hens to the other end of the shed.*

The sound of the hens was recorded during the 13 minute gas process on farm study 2. After about 2 minutes into the gassing, hens start a high pitched vocalization, which increased in pitch over time. Although hens are seen in the film lying, these high pitched vocalizations are heard continually for 5 minutes, after which they reduce. A few hens can be heard vocalizing for as long as 12 minutes even after the gassing has stopped. It is not understood to what level if any, these vocalizations indicate consciousness, as hens often vocalize just prior to death (pers.comm. Raj, 2006).

Cyanide gas killing of hens in shed

On 2 occasions on the same farm, the procedure of cyanide gassing was studied and filmed. The gassing was conducted by 2 people from a professional chemical handling company (EQUS) from southern Sweden. The cyanide was transported and delivered to the farm in a specially sealed box which contained pressurised sealed cans of cyanide. The cyanide cans were placed in each of the 4 lanes in the hen shed. In each study, a total of 15 cans were used, each containing 1.5 kg of 60% absorbed cyanide in cellulose form. This was calculated at a total of 22.5 kg cyanide. A total of 31,000 hens were killed in the first study, and 16,000 in the second study. The cans were evenly distributed throughout the shed by the personnel wearing chemical protection suits and oxygen breathing equipment. They walked through the shed, opening the cans as they went, while spreading special filters around each can, throwing them on each tier level, every few meters and on the ground. The purpose of the filters was to draw the gas out of the can to the filter, causing the cyanide to mix with air, providing a poisonous gas which the hens inhaled (figure 13).

Figure 13: *Cans containing cyanide positioned in laneways of hen shed, ready to be opened for killing hens*

Approximately 1 hour after the gassing, the building was entered. The hens were found laying dead in a fairly even distribution on all tier levels. No hens were found alive in the first study, but in the second study about 5 hens remained alive in a depressed state. According to the farm owner, this was the first time in 15 years (and 20 in shed gassings with HCN), that any hens were found alive. The living hens however, were found only in the vicinity of the pen constructed for filming purposes in this project. There could have been 2 reasons for the survival of the hens. One reason given by the chemical company supplying the cyanide was that this particular batch of HCN had been stored over a longer period than usual before being used (due to a delay in permission from the animal welfare agency to use the gas). The gas may have been stored at a too low temperature (below 20°C) lowering its maximal effect. The second reason could have been because the cage construction prevented the HCN filters from reaching hens behind the back section of the cage, possibly exposing these hens to an inadequate HCN dose. If the cage was not there, the filters would have been placed in a closer vicinity to the birds. No veterinarians were present at the time when the shed was opened for clearing and the birds were found alive.

<u>Behavioural observations</u>

Hens appeared to be affected by the cyanide gas only if they came within about 5 meters of a filter. Upon contact with the gas, the first reaction in most hens was to loose posture, with further symptoms occurring while in a recumbent state. Within 15 seconds of the filters being thrown on the roof of the cage constructed for film purposes, hens could be seen reacting to the gas. Some hens could be seen showing strong reactions to the cyanide, while others standing close by appeared totally unaffected by it. Some hens started to sway for a few seconds before rolling over. Most hens started to wing flap 10 to 20 seconds after loosing posture for about 10 to 15 seconds. Wing flapping occurred for up to 25 seconds in many hens. After the bout of wing flapping, most hens showed no more movements (35 to 50 seconds from first symptoms seen). The longest time a hen showed symptoms until loss of posture, was 1 minute and 8 seconds, and it sat in a depressed state until rolling slowly over. The fastest a hen was seen affected by the gas was 1 second and it showed no other symptoms other than falling over. The longest period a hen showed movements from the first reaction behaviour to cessation of all movements seen (i.e. probable time of death), was 1 minute and 30 seconds. In an observation of approximately 100 hens, it took less than 1 minute for all hens to stop all movements, with most lying still after 40 seconds. A group of 25 hens were observed closely in the film footage and the durations of the symptoms they displayed were timed until estimated time of loss of consciousness. The average time to loss of consciousness was 20 seconds.

Table 3 summarises the general behavioural symptoms seen. The sound of the hens can also be heard in one of the films, and once hens start to fall over many cry out in a strange high pitched clucking sound.

Table 3: *General behaviour of approximately 10 hens during HCN gassing filmed with different cameras*

Time (minutes: seconds)	**Observed behaviour**
00:00	HCN can opened
00:15	Filters thrown out on roof of pen
00:35-38	First hen showing symptoms staggers then falls
00:35-48	Most hens have lost posture
48	Wing flapping bouts start
00:53	First high pitched vocalisations can be heard
01:20	Many wing flaps stop
01:08	Longest time it took for a hen to loose posture from 1st behavioural indication of HCN exposure
01:30	Longest time a hen displayed movements from 1st behavioural indication of HCN exposure to cessation of all movements
03:50	All hens are silent, no more vocalisations
10:00	All persons out of shed and HCN process complete

Transport to slaughter and electrical water bath killing

The only operating hen processing plant in Sweden was visited, and the unloading, shackling, stunning and neck cutting of hens observed. Hens are generally collected from the farm by one or more of the 3 trucks that the slaughter plant own. If the farm is not locally situated, the hens are normally collected the day before slaughter. The truck then parks at the slaughter plant the night before. Each truck is equipped with mechanical fan ventilation which can be connected to an electricity supply so that the ventilation system can be continued during the night. There are temperature sensors inside the truck that display the inside temperature conditions, and the fan system is adjusted according to the temperature.

Ventilation openings are installed at the bottom part of the truck, allowing the fan system to blow incoming air from the roof, circulating it down through the hens, expelling it through the openings situated on the lower sides of the truck (figure 14). According to the abattoir the temperature generally lies between 15 and 20º C. There were no means for measuring the humidity conditions inside the vehicles. The abattoirs latest figure on transport mortality for the last 6 months was 0.14%.

Figure 14: *Ventilation outlets positioned in the lower area of the poultry transport vehicle*

Each transport vehicle can take 10,000 hens. The largest farm sends up to 30,000 hens to slaughter at any one time, depopulating different sheds up to 4 times per year. Hens are caught manually and loaded into transport cages. Each cage of the size 85cm long X 50cm wide and 32cm high holds 10 to 12 normal sized hens. It takes approximately 3 hours to unload one transport vehicle. Loaded cages are wheeled out of the trucks (figure 15), and placed on to a conveyer belt, where the hens are transferred to the shackle line. Three staff members unload the cages, taking hens out one by one and hanging them by both feet on to a moving shackle line (figure 16). The hens are transferred while conscious upside down for 12 to 25 seconds for a distance of 2 to 3 meters to the electrical water bath stunner. The shackle conveys the hens through the 2 meter long bath, where the head and neck up to the breast area, is lowered into the water for stunning. Eight hens at a time are passing through the water bath. The shackle line continues and hens go through a neck cutting device approximately 2 meters (20 – 25 seconds by shackle line) from the water bath exit (figure 17). A monitor displayed the electrical values of the water bath stunner fluctuating between 109 to 115 mA during the observation period. Salt was added periodically to the stun bath water to improve conductivity. The shackles were dry before taking the hens through the stunner device.

__Figure 15:__ Unloading hen cages from the truck

__Figure 16__: Shackled hen

__Figure 17:__ Hens coming out of water bath stunner and approaching the neck cutting device

Behavioural observations

During unloading, hens were not heard vocalising excessively. However hens had been in the transport truck for some time, and were probably adjusted to the surroundings. Few hens showed wing flapping or shackle climbing while on the shackle line. However most of the hens started struggling behaviour (wing flapping, shackle climbing and vocalising) as they made contact with the water bath stunner, before they entered the actual water bath. The surface around the water bath stunner was also covered in water from the stun bath. It appeared that they may have received pre stun shocks at this time. This behaviour lasted for a few seconds before the hen was stunned.

No hens were seen vocalising, wing flapping, or with corneal, body or pain reflexes upon exit of the water bath stunner up to neck cutting. It seemed that the hens were properly immersed in the water during the stunning process. Hens came out of the water bath wet from the breast downwards.

Portable electrical water-bath stunner

In northern Sweden egg farms have no access to abattoirs that process spent hens. Therefore these farms (north of Söderhamn) practice on farm killing with the use of a portable electrical water-bath stunning apparatus that is shared between them. Thirteen to fourteen farms are known to use this apparatus. The farm sizes range between 3000 and 44, 000 hens, the average being 10 -15,000hens. So far 140,000 hens are booked to be killed with this machine in 2006. The apparatus transports on a 6 x 2.4 meter trailer, and can stun 800 - 900 hens per hour. The process involves catching the hens, taking them to the water-bath stunner where they are then shackled by both legs on to a conveyer that lowers them into a 1-meter long water-bath. Four to five hens can go through the water-bath system at the one time. Electrocution is by way of normal 160-volt (50 Hz) electricity, aiming for 120mA current per hen. Debleeding is done mechanically on both sides of the neck. The blood and hen carcasses are collected in a container, which is transported for rendering/destruction at Konvex (Norrlansägg, 2003). It takes approximately 1 full day for a farmer to depopulate approximately 10,000 hens using this method. Observations made from watching a video film of the system in progress while depopulating a farm, showed that the hens were calm during the time on the shackle and all the way to the water bath. Hens were not seen struggling when they made contact with the water bath stunner, as was seen during abattoir slaughter.

In mid Sweden, south of Stockholm, a company offers on farm killing of hens using a similar design of a portable water bath stun apparatus as that mentioned above. Hens are killed, debled and defeathered on the farm, and the carcasses taken for processing to pet food. The farmer does not have to pay for the disposal of the carcasses at Konvex, as the carcasses are sold by the company for pet food which subsidizes the service. This company could give no information on number of hens they have slaughtered in total or in the last year, but they apparently provided on farm killing and carcass removal services to approximately 20 farms in 2005. Their services are becoming in high demand, due to the cheaper option for farmers compared to sending the hens to slaughter or on farm gassing services. However they are only able to process approximately 5000 hens per day, with a kill rate of 1000 to 1500 hens per hour. Therefore their services are more suited to smaller layer farms. The operation of this system could not be observed as the company was not using the machine during the time of this project.

Container gassings

Hens can be killed on farm by placing them in containers filled with CO_2 gas. This method has been used occasionally in Sweden, but not in containers that were specifically designed for this purpose. The ability to control the gas input into the container during loading is important for hen welfare, as adequate CO_2 concentrations cannot be maintained unless gas is periodically added during loading of hens. Also each time hens are placed into the container oxygen can enter reducing CO_2 concentrations leading to birds being resuscitated.

The process of placing birds in specially designed gas filled containers to stun them is known as “Controlled Atmosphere Stunning” (CAS). If birds are killed by the gas the system is know as “Modified Atmosphere Killing” (MAK). In the USA and Canada, on farm killing using MAK is widely used. In UK developments have been made using containers specifically designed to achieve MAK on farm using a mixture of 80% Argon and 40% CO_2 (figures 18 and 19) (pers. comm, Thompson; DEFRA, UK, 2006). Both CAS and MAK systems are beneficial to hen welfare in that hens die more quickly than when CO_2 gas is pumped into the entire shed. The period of aversion to the gas is minimised, due to the ability to control the gas concentrations in the containers during the killing period.
Some basic requirements for effective container gas killing of hens include:

- Containers should allow the required gas concentration to be maintained and accurately measured
- The equipment should allow hens to be observed during the gas process
- Hens should be introduced into the container after it has been filled with the required CO_2 concentration, and held in this atmosphere until death is confirmed
- Personnel should ensure that there is sufficient time allowed for each batch of hens to die before introducing others into the container
- Containers should not be overcrowded and measures in place to avoid animals suffocating by climbing on top of each other

Figure 18: MAK container developed in UK using Argon and CO_2 gas mixes (photos courtesy Peter Featherstone, DEFRA, UK)

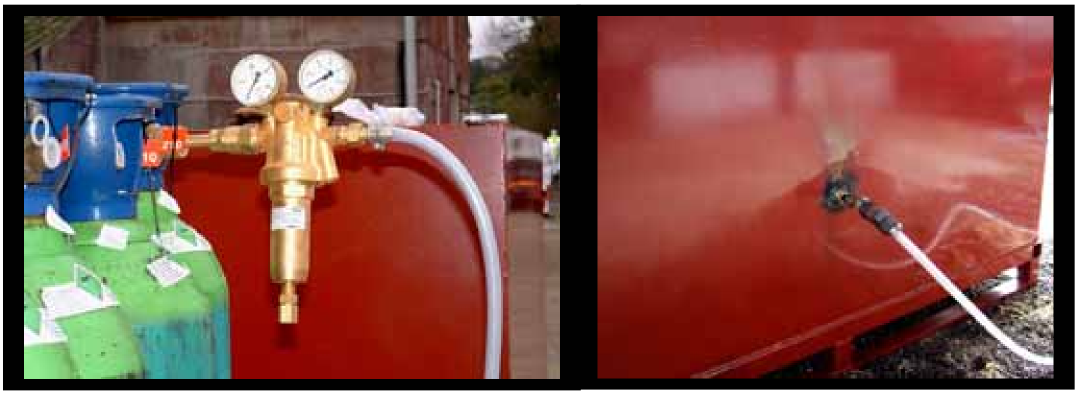


Figure 19: *MAK container developed in UK using Argon and CO_2 gas mixes (photos courtesy Peter Featherstone, DEFRA, UK)*

USA MAK system

In America, Dr Bruce Webster from the Department of Poultry Science at the University of Georgia in the USA developed a MAK container for on farm killing which is now commercially available to farmers. It is designed so that it can be wheeled into the actual layer shed and rolled down the narrow lanes of the battery style sheds that exist in the USA. Hens can be taken directly out of the cages and placed into the carts (Figure 20). The killing rate of each cart is approximately 1000 birds per hour. The CO_2 is supplied by small exchangeable bottles that attach to the cart (figure 21) which can kill about 1500 birds per bottle. Each cart holds about 200 birds at a time, and when full an unloading door allows a quick exit of the dead hens (figure 22). The system is designed so that CO_2 can be periodically added, ensuring that there is always a suitably high concentration of gas inside the container to kill hens. Hens can also been seen during the gas process on 2 sides if the cart, and assessments can be made on the consciousness levels of the hens.

A welfare assessment was made using the MAK carts by Webster et al. (1998), and unconsciousness was considered to occur in the MAK carts when hens became recumbent (had lost posture), and the neck no longer supported the head. Convulsions (in the form of a series of rapid wing beats) that came after loss of posture were not considered to indicate welfare problems. The gas concentrations in the cart fluctuate between 30 and 60% during the process, but all hens should be unconscious within 1 minute and dead within 2 minutes (pers comm; Webster, 2006; Gasper, 2006). Some farms have many MAK carts available. It has been reported that on one farm a crew of 8 people using 8 MAK carts managed to kill 30,000 hens in one day.

The in shed MAK carts are commercially available through a company called FPM, Inc. in Nebraska, USA. This company sell MAK units for $USA1089, and are willing to sell units to Sweden (Gasper, FPM inc. 2006).

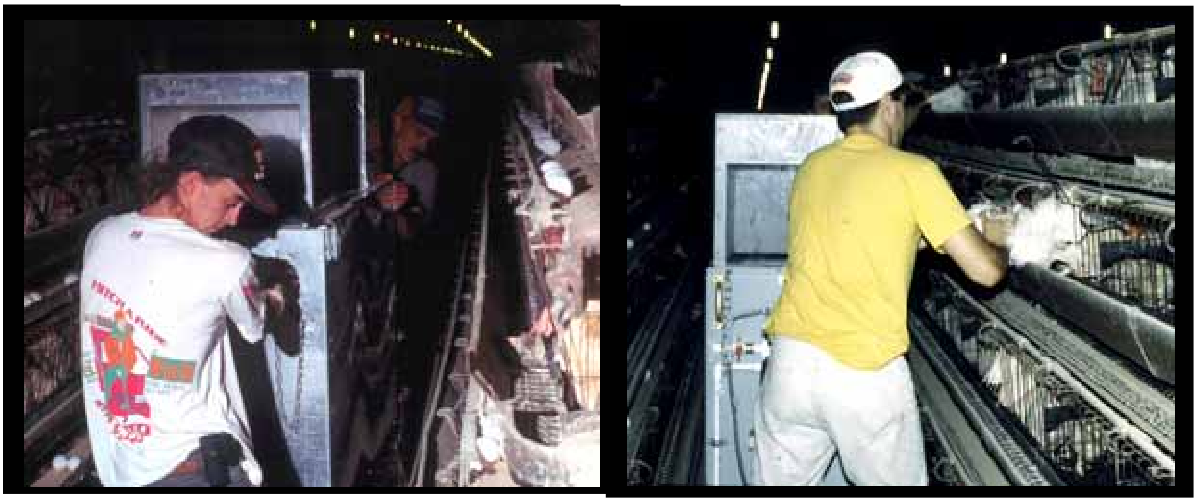


Figure 20: *MAK carts being rolled into battery layer shed during depopulation (photos courtesy Dr Bruce Webster)*

Figure 21: *MAK cart with CO2 gas cylinder attached (photos courtesy Dr Bruce Webster)*

***Figure 22**: Emptying of a MAK cart*
(photos courtesy Dr Bruce Webster)

Canadian MAK system

In Canada, there are many more farms with loose house systems than in the USA. This has prompted the development of a MAK system that is much larger than that used in the states. This system has been developed in consultation with Dr John Church, Leader of the Welfare Unit, Alberta Agriculture Food and Development department, as a follow up of the MAK unit developed by the University of Georgia. At the moment the present system uses CO_2 gas only. However, there are funding possibilities to develop the same type of container gassing using Ar and CO_2 (pers. comm. Church, 2006).

The MAK container consists of a large plastic bin approximately 180cmx120cmx120cm with a hinged lid. A hole is cut in the lid and covered by an aluminum hood with a hinged front flap. Birds are dropped into the bin by pushing open the flap (figure 23).The bin has a PVC pipe mounted in each corner, with each pipe having small holes drilled along the length of it. The gas (CO_2) is supplied from a liquid Dewar. To obtain a high enough rate of gas, the CO_2 is taken from the Dewar as a liquid and run through a vaporizer to produce the gas needed to fill the bin. The vaporizer is a modified hot water tank, filled with a water/antifreeze mixture and heated by propane. The CO_2 runs through coils of copper tubing installed inside the tank. A regulator on the outlet of the vaporiser allows control of the gas rate used. The bin is designed so that it can be lifted for dumping into a truck or onto a pile (figure 24). The bin is emptied by means of hydraulic cylinders, which rotate the bin around its pivot point and allow the dead birds to fall out.

Each bin can kill approximately 435 birds. It takes approximately 6 minutes to load a bin with hens. It takes about 10 minutes to fill, gas and empty hens from the containers. Killing efficiency is about 3,000 birds per hour. Trials have been conducted on commercial layer farms where 2 bins and 20 people depopulated 30,000 hens in a day.

It takes between 7 and 15 seconds for birds to be rendered unconscious after being loaded into the bin and death occurs within 30 to 60 seconds. This MAK cart fits on one trailer, making it easy to transport. A fully equipped MAK container (including CO_2 gas supply and all relevant components) is approximately CAN$4440.

Figure 23: *Loading of a MAK container developed for on farm killing of hens in Canada (photos courtesy Dr John Curch)*

Figure 24: *The MAK container can be lifted by a front end loader for emptying (photos courtesy Dr John Church)*

BIO SECURITY

All methods of killing hens in Sweden require some type of transport or equipment to be introduced on and off the farm from an outside source. The methods of on farm killing using gas and the portable electrical water bath stunning used by farmers in northern Sweden, necessitate the need for carcasses to be removed by the rendering company Konvex. The farmers are normally supplied with containers before depopulation, and after the killing, Konvex vehicles collect the containers filled with the carcasses. From a bio security point of view, gas euthanasia provides a low risk killing alternative as there is no debleeding required minimising the fluid leakage from carcasses. The electrical water bath stunner however, requires hens to have the neck severed in order to kill them. The bleeding makes this alternative a greater bio security risk due to the greater fluid leakage on farm. The company that processes hens for pet food also has to defeather the hens on the farm. As this company travels from farm to farm, this killing method poses a greater bio security risk than gas killing.

Hens transported live to slaughter pose a minimal risk, as any fluid leakage should be contained in the abattoir. However, the fact that the trucks are carrying live birds, and that the trucks move from farm to farm during collection, adds a bio security risk for spreading diseases between farms.

FEASIBILITY/COST ANALYSIS

The costs involved with both carbon dioxide and cyanide gas processes depends on the number of hens to be killed, shed volume and the farm distance from the gas company head quarters. The actual cost of CO_2 is 3.21 kr per kilo gas if more than 1000kg gas is used, and 4.04 kr/kg if less than 1000kg is used. There is also a cost of 630 kr for every hour the driver is working on the farm (pumping in the gas).

After gas killing or killing of hens with the portable electrical water bath stunner (as used by farmers in northern Sweden), the carcasses must be sent to Konvex. In gas killing, there are no labour costs involved with catching hens but there are labour costs involved with the emptying of sheds after killing to place hens in containers to be transported to Konvex. In all killing methods, the costs to the farmer increases the further they are from the company that is involved with either the killing process or with the carcass collection. The cost to send hens to Konvex for destruction is approximately 2.50kr per hen. There are other fees involved with Konvex some of which include container delivery fees (56kr per 10 kms) and container hire at 1100kr / container. One farmer stated that the total cost of sending hens to Konvex was 4.50kr per hen (includes emptying of shed, container hire, and container transport costs to Konvex). However on farm gassing is a feasible method for killing hens. This is because hens can be killed, and sheds cleared within a working day. This is convenient to the farmer, and highly advantages in the case of disease outbreak, where sheds need to be cleared and hens disposed of quickly. Processing costs for hens sent to slaughter are about 2.25 kr per hen. However this does not include the costs to the farmer for catching live hens and loading them into cages for the transport process. Catching of live hens takes longer and has higher labour costs than clearing sheds of dead hens.

The costs involved with processing of hens for pet food, include an overall hiring fee of 2000kr, with travel costs increasing with distances over 200kms from the company location. The processing costs are 1 kr per hen. The farmer has other costs involved with using this system such as the costs and time involved with catching and transferring the hens to the water bath stun/slaughter area.

One of the farmers wrote up a cost analysis for the killing of hens with Cyanide, $CO_{2,}$ and live transport to slaughter. The direct costs of killing 31,000 hens with cyanide were 20,352kr and for carbon dioxide 24,100kr (excluding Konvex rendering costs). If the farmer sent the hens to slaughter, the total cost would have been approximately 161,800kr. If labour expenses for shed clearing are included, the total costs for the depopulation methods for 31,000 hens are:
HCN gas process + unloading of shed + sending carcasses to Konvex = 159,502kr
CO_2 gas process + unloading of shed + sending of carcasses to Konvex = 163, 250 kr
Catching of hens from shed and live transport to slaughter = 161, 800kr

For this farm, the cheapest depopulation alternative was HCN gas killing of hens, but only marginally so (all methods cost around 5,2 kr per hen). From a welfare perspective the transport to slaughter option would probably have been the worst. According to the farmer, it would take 11 hours for 28 people to catch and load all 31,000 hens into transport trucks. Three trucks would be required, and the transport time would have been approximately 5 to 6 hours.

On farms that kill hens using CO_2, hens are in no way utilised and must be sent as high risk biological material for rendering at Konvex. Farmers find this process expensive. It is possible to process hen carcass material for the production of Bio Gas. This is already being done in Denmark by a company called DAKA. Recently there have been developments in Sweden for this, which would help to reduce costs for the farmer, while utilising the hens in a purposeful and hygienic way.

DISCUSSION

Gas killing of hens in shed

During in shed gassing of hens, film results show that hens displayed a series of specific and consistent behavioural symptoms before dying. During CO_2 gassing these symptoms included head shaking, neck stretching, gasping, head drooping, loss of balance, and body movements. Wing flapping occurred in some birds, though not all and some birds vocalised throughout the dying process. During HCN gassing, some hens immediately lost posture upon gas exposure and showed no other behavioural symptoms. Others would start to stagger, and after loosing posture go into seizure positions where the wings were spread out and the body stiffened or the legs stretched out. Bouts of extreme wing flapping seizures could periodically follow until death. Hens can wing flap, twitch, run, fly and even vocalise while in an unconscious state. This makes it problematic to detect at which point hens really do loose sensitivity to pain. However the general view for commercial operations of CAS stunning systems for poultry is that the for welfare reasons, induction of unconsciousness with gas mixtures should be non-aversive and not distressing to birds (EFSA 2004), with minimal behavioural signs of agitation shown during the gassing period (Coenen in Barton Gade et al. 2000).

Film footage indicates that it can take some two minutes for CO_2 gas to reach birds on the upper levels in the shed while birds on the lower levels and closer to the gas inlet pipe, became affected much more quickly. One hen displayed conscious aversion behaviour to the CO_2 gas in the form of gasping and neck stretching while blinking for almost 6 minutes before it lost posture and blinking ceased. When CO_2 concentrations reach 30%, hens will start to display behaviour signs of gasping and head shaking (pers. comm.Raj, 2006). Therefore in this film, when these behaviours were seen, we could determine that the CO_2 gas concentrations had reached around that level. As CO_2 levels reach sub lethal concentrations, which occur above 45%, hens will start wing flapping. Therefore, it was probable that the faster the wing flapping sessions occurred in hens the faster the CO_2 concentrations had reached high and lethal concentrations in the film footage seen. The gasping and neck stretching behaviours seen in so many hens for periods of many minutes are a cause for concern. Especially as the average length of time of all birds seen displaying this behaviour while clearly conscious was over 3 minutes. One hen showed shallow respirations and body twitching for 11 minutes and 37 seconds. It is difficult to determine at what point that hen lost consciousness. However, a good indication of loss of consciousness under CO_2 gassing is eye closure and loss of neck muscle tension according to Raj (2006). Assessing whether the period of aversion is acceptable from an animal welfare perspective is problematic. Findings of definitions in scientific literature of what constitutes acceptable or not acceptable aversion behaviours in birds and for how long are limited. There are no defined scores for gauging suffering. For example, it has generally been thought that bouts of wing flapping that occur after birds have lost posture are probably occurring as reflexes, and not in conscious birds. However, some recent research found EEG levels (indicating some level of consciousness) during wing flapping bouts in birds gassed with high CO_2 levels (McKeegan; CAS workshop meeting, 2006). It is therefore not possible to be completely confident that birds do not feel pain or distress during wing flapping bouts.

In order for CO_2 to be transported, it must be pressurised to keep it in its liquid state. It also boils at -80oC, and is therefore extremely cold when changed from liquid to gas form. The rapid expansion of CO_2 going from its liquid state to the gas state when being sprayed into the layer sheds can cause the piping to freeze. Therefore the pipe diameter needs to be at least 25 cm diameter and the gas sprayed in at high pressure to reduce this freezing effect. However, this causes the gas to come into the shed at an extremely high flow rates. This has 4 detrimental effects on hen welfare:

1) The high flow rate of the gas radically blows hens and floor litter in the vicinity of the pipe, causing possible death to hens through trauma.
2) The CO_2 gas sinks to the ground level as it is heavier and colder than air, causing uneven killing of hens, with hens on upper tiers dying more slowly than those on the lower levels.
3) The high flow rate creates very high noise level, causing stress to hens during gas procedures and hens tend to collect down one end of the shed possibly smothering one another
4) Hens in the vicinity of the gas inlet pipe can freeze to death.

Post mortem results from hens collected on one farm within 20 meters of the gas inlet pipe, did in fact show that the hens had died as a result of freezing. This is no surprise considering that temperatures inside the shed were recorded as decreasing from plus 21^{o}C to minus 40.4^{o}C with sub zero temperatures recorded within the first 60 seconds. A few hens were also found still frozen hard 2 hours after the gassing commenced. These hens were found directly opposite the gas inlet pipe. Hens that die from the freezing probably die much faster than those that die of suffocation from the CO_2.

Film footage collected in the vicinity of the gas pipe showed instant misting (the misting being frozen air particles from the CO_2 gas), while footage taken from the back of the shed showed gradual misting, indicating that the gassing is not uniform, with hens on the upper levels taking longer to die than those on lower levels. One solution would be to use fans in the shed during the gassing process to help to distribute the CO_2 gas more quickly and evenly throughout the shed, achieving a faster killing rate.

Most science indicates that inductions of CO_2 at concentrations above 30%, causes distress to poultry. For this reason, Argon CO_2 gas mixes appear to be the best option on the grounds of welfare (EFSA, 2005). Alternatives to spaying high concentrations of CO_2 gas into layer sheds has yet to be developed in Sweden and other countries and the feasibility of conducting such gassing is not yet known, but is probably a challenging issue. The use of gas mixes in containers has been trialled and tested in other countries with positive results for hen welfare. A short term solution for achieving faster killing rates of hens using CO_2 would be the investment into these already developed specialised containers for killing hens. These containers are available in USA, Canada and UK. Hens are dropped into an atmosphere already containing a high concentration of $CO_{2,}$ the immediate exposure resulting in a quick death. Trails in both USA and Canada indicate that birds die within 60 seconds of entering the gas chamber. Although the system requires catching of hens, they are minimally handled as the containers can either be located at the shed entrance, or in the case of the American system, it can be wheeled into the hen shed.

The slow leakage of CO_2 through the small hole in the ceiling in one of the shed gassing probably caused the concentrations of CO_2 to rise very gradually on the floor level of that shed, as the gas would have sunk directly to the ground due to its heaviness. This would explain why the hens on the upper tier levels were not affected by the gas. According to a meeting in UK with leading scientists on the controlled atmosphere killing of poultry, research has suggested that when CO_2 is exposed to birds at a concentration no more than 40%, stunning can be achieved without causing aversion to the birds (CAS workshop meeting, 2005). In Italy, a system has been developed where birds are slowly anesthetised and killed by progressively increasing CO_2 levels over 6 minutes, with very little aversion by the birds reportedly shown if the concentrations are gradually raised (Zanotti, 2005). It is therefore possible that the hens in the second shed were killed in a similar manner as that reported by Zanotti, inadvertently causing slow CO_2 induction, and therefore anaesthetic effects before death.

Cyanide versus carbon dioxide in shed gassing

Although the first cyanide gassing worked very well, with all birds in the shed being quickly killed, the second HCN gassing showed that some hens can survive the procedure if it is not properly conducted. In this case it was either due to the cage preventing the filter from reaching the hens close enough, or it was due to the gas being stored too cold, reducing its effectiveness. However, only 5 birds of 16,000 survived or if you consider both HCN gassings 0.01% survived, and the kill success rate was 99.9% effective.

CO_2 gassing procedures took from 10 minutes for the smallest shed of 9000 birds to 26 minutes for the largest shed of 31,000 birds. The time for the cyanide procedure to take place from start to finish was 10 minutes for 31,000 birds. Table 4 shows a general summary of the different processes of CO_2 and cyanide gassing, including the duration of behavioural symptoms seen in the film footage. The longest a hen showed aversion behaviour to HCN gas before loss of consciousness was 1 minute and 8 seconds, while for CO_2. it was 5 minutes 39 seconds. Some hens clearly lost consciousness within 1 second of HCN exposure, yet the least amount of time a hen showed aversion to CO_2 gassing in the films, was 2 minutes 27 seconds. Film footage and a personal eye witness account during the HCN gassing process, showed that hens were quickly unconscious when exposed to the HCN gas, and the aversion behaviour was very short lived compared to hens seen in this study killed by CO_2. However, bouts of excessive wing flapping (convulsions) were much more strenuous in hens gassed with HCN compared to CO_2.

Table 4: *Duration in minutes: seconds of certain activities and hen behaviour seen in films during gassing with either CO_2 or HCN*

	CO_2	HCN
Duration of gassing process (mins)	10:00 to 26:00	10:00
Time when first hen in films is seen to loose posture (mins)	02:27	00:01
Longest time a hen shows aversion behaviour before likely loss of consciousness (mins)	05:39	01:08
Longest time it takes for a hen to die from gas process (mins)	11:37	01:30

Transport and slaughter by electrical water-bath stun/kill

The main concerns with abattoir slaughter are the handling involved with catching, caging and transporting hens that are used to being in a free range type system. The fragility of the hens makes them susceptible to bone breakages, wing dislocations and bruising. Once at the abattoir, the unloading and shackling upside down by the feet further prolongs the stresses imposed on these animals, although the shackling stress is very short lived (less than 25 seconds). The stun by electricity seen in this trial appeared rapid, and there were few aversion reactions seen before, and none seen after the process, although only a small proportion of hens were observed (<1000 birds). The transport stress can be significant in times of extreme temperatures and long transport times. Hens can suffer and die during such periods, and although the mortality rate reported for the last 6 months was approximately 0.14%, 30,000 hens died in 2003 due to heat stress (Svenskt Fågelkött AB) and several other cases of high mortality during transport have been reported. Some of the farms that send hens to slaughter require transport times of up to 10 hours. Hens transported longer distances must be held in the truck at the abattoirs overnight. The period of stress to hens when considering catching, transport, and lairage, can therefore be many hours. The gassing process has the advantages in that it requires no hens to be handled or transported prior to killing, and the handling of dead hens during shed clearing after gassing is far less time consuming than clearing sheds of live hens required to load transport vehicles.

It should be noted here that slaughter of broilers is also done with the use of gas for stunning where CO_2 is applied. In Norway two abattoirs use gas for stunning and killing of which one uses CO_2 and one use various mixtures of Nitrogen, Argon and CO_2 (Mejdell,pers. comm., 2006). These abattoirs have a dispensation from current national legislation and little data is available as yet on the effects on animal welfare.

Comparison of methods

Advantages and disadvantages of the methods are outlined in table 5. On farm gassing using HCN or CO_2 appears to be the most feasible and hygienic method available, and considering that the alternative method for killing hens is transport to slaughter and killing by electrical water bath, the welfare concerns involved with gas killing are acceptable. The fact than hens do not need to be handled, caged or transported to slaughter is a particularly positive welfare aspect of in shed gassing. There are also advantages over the electrical water bath stun system in that:

- Hens are not inverted
- Hens are not shackled
- There are no risks with pre-stun shocks
- Gas killing irreversibly stuns and kills hens so that return to consciousness is not dependent on the efficiency of debleeding

__Table 5:__ Advantages and disadvantages of alternative killing methods for hens

Killing Method	Advantages	Disadvantages/Potential problems
CO_2 gassing into premises where hens live	• Stress is relatively short lived compared to live transport • No catching or live shackling of hens required • Some hens killed quickly • Potential to be developed to improve hen welfare • Affordable • Low risk of disease spread • Research is conducted in other countries in CO_2 bird killing • Widely used and tested in Sweden, so many mistakes with management are known • Hygienic due to no neck cutting • Less time commitment for farmer than other methods • Killing and shed clearing can be completed in a day • Gas is readily available through company suppliers • Safe to use • Safe to transport • Easy for farmer to organise • Efficient killing method	• More gas required than container gassing • More expensive than on farm electrical methods • Some hens show aversion behaviour for over 5 minutes • High noise level due to small pipe diameter causing stress to birds • Many hens freeze or die of trauma although probably only for a very short time (less than a minute) • Uneven method of inserting gas into shed, effecting hens located in different shed areas differently i.e. hens on upper levels getting affected more slowly than on lower levels • More expensive than HCN • Risk of leakages and improper killings • Risk of accidents with high pressure hose • Stressful due to cold gas, noise, flying dust levels and suffocation effects
HCN gassing into premises where hens live	• Cheaper than CO_2 • Fast kill efficiency, faster than CO_2 • Short aversion behaviour seen in hens • Hygienic	• Dangerous to handle • Dangerous to transport • Many welfare authorities do not approve of it (though no proven reason as to why) • Little research done on welfare perspectives and its use in killing birds • Not widely used, therefore the potential for mistakes are not really known
Transport to slaughter & killing with electrical water-bath stunner	• Hens are utilised • Readily available depopulation method for farmers within reasonable distances • Economically viable	• Potentially unreasonable transport durations • Catching and handling of hens required • Long duration of stress imposed on birds • Pain and stress caused to birds during shackling • Risk of not properly stunned birds • Time consuming for farmer
Portable water-bath stunner	• Farmer can have equipment on farm ready to use at any time wanted • Easy for farmer to operate • Cheaper than gas stunning • Suitable for small farms • Economical	• Catching and handling of hens required • Pain and stress caused to birds during shackling • Risk of not properly stunned birds • Risk of disease spread due to neck cutting & fluid leakage • Time consuming for farmer

CO_2/Argon mix gassing into premises where hens live	• Doesn't induce any respiratory distress to hens prior to loss of consciousness • Most humane gas mix available for killing birds • No catching or live shackling of hens required • More hygienic due to no neck cutting • Efficient killing method	• More expensive than CO_2 or electrical methods • Gas mix is not yet available through company suppliers • More gas required than container gassing • Not readily available for farmer
CO_2 gassing of hens in MAK containers	• Fast death • Less use of CO_2 gas required than gassing of entire buildings • hygienic due to no neck cutting • Gas is available through company suppliers • Farmer can have equipment on farm ready to use at any time wanted • Easy to operate • No catching or live shackling of hens required • New developments becoming available in other countries	• The need for special equipment • Catching and handling of hens required to place into containers • CO_2 is aversive to hens • At present more expensive than electrical methods • More difficult to control and check that all hens in container are dead • More time consuming than gassing building premises • More time consuming for farmer than in shed gas killing • No guarantee of immediate loss of consciousness • The risk of suffocation due to overcrowding • Difficulty in verifying death while the animals are in the container
CO_2_ Argon gassing into containers where hens are placed	• Doesn't induce any respiratory distress to hens prior to loss of consciousness • Most humane gas mix available for killing birds • Fast death for hens • No live shackling of hens required • Less use of CO_2 gas required than gassing of entire buildings • More hygienic due to no neck cutting	• Catching and handling of hens required to place into containers • More expensive than using just CO_2

On farm gas killing of hens also allows hens to be killed and sheds cleared within a working day. This is convenient for the farmer, and highly advantageous in the case of disease outbreak where sheds need to be cleared and hens disposed of quickly. Results of this study have shown that the main welfare concerns for hens during on farm CO_2 gassing are the period of aversion some hens go through before loosing unconsciousness. The aversion behaviors seen in hens during CO_2 in shed gassing, involved head shaking, gasping, and neck stretching. Hens could show aversion from 2 to 5 minutes. Hens gassed with cyanide however, showed a much shorter period of aversion from 30 seconds to just over 1 minute. These aversion behaviors included a staggering gait, extreme wing flapping and a few birds sat depressed before loosing posture. Although HCN is a dangerous chemical to handle, in these studies the HCN gassing process was handled carefully and professionally, and the entire process went efficiently. Hens exposed to HCN showed short lived aversion symptoms before dying and most hens were killed quickly. Therefore HCN could be considered as another option for humane killing of hens. However there are obvious concerns due to the dangers of handling such a toxic chemical.

This study has found there are many potential options available to improve present welfare standards of hens during on farm gas killing. For example to solve the problem of an uneven killing of hens with hens on the upper levels taking longer to die than those on lower levels, a sprinkler system could be investigated, where the CO_2 gas is pumped through a pipe that runs through the upper level of the shed, spraying the gas through small outlet holes. Freezing of the pipe could be prevented by developing some type of mechanism (heated copper wires, a propane fuelled heating tank, anti freeze chemicals etc). Fans turned on during the gassing may help to circulate the CO_2. The aim of the sprinkler design would be to first anasestheise hens through gradual dosing with low CO_2 (30%) before killing them with high CO_2 levels (above 60%). Alternatively, if high concentrations (above 50%) could be more quickly and evenly distributed through the shed than is presently possible, hens would still go through a period of aversion to the gas, but this aversion would last for a much shorter time period.

Other potential developments could include developing whole shed on farm gassings using similar gas mixes used in commercial slaughter. Using at least 60% Ar with 40% CO_2 for example, would cause hens to be anaesthetised before dying. However the feasibility of developing such methods is not known, but is worth consideration. Especially as there have already been developments in England and soon Canada, in killing of hens on farm in specially constructed containers filled with gas mixes of 80% Ar and 20% $CO_{2.}$

The electrical water bath stunning systems seen in this study showed that birds were found to be properly stunned before neck cutting. No birds were seen wing flapping during debleeding.
It is important that further research and studies are conducted in the killing of hens in Sweden so new developments can be made to improve hen welfare. It is also important to collaborate with other countries, as these countries have the same goal to develop systems to improve hen welfare and can offer good research results.

CONCLUSIONS

- This study has shown that there are both positive and negative welfare concerns for hens in all killing methods presently used in Sweden.
- There are many potential options available to improve present welfare standards of hens during on farm gas killing.
- On farm gas killing of spent hens seem to be the method with least negative impact on animal welfare.
- When depopulating farms for disease control purposes, HCN or CO2 gassing into the premises is the method presently at hand causing the least negative impact on animal welfare.
- Further studies should be carried out to study how different gas mixtures and concentration levels affect bird welfare during on farm gassing conditions as well as how such gas should be administered to cause the least adverse effects.

RECOMMENDATIONS

For systems that were studied in detail in this report, the following recommendations are made:

Carbon dioxide gas killing

- Ensure that all parts of shed are properly sealed.
- Increase height of gas inlet pipe to above mid level of building to reduce dust flying and blasting away of birds at ground level, however this would have to be checked to ensure the blasting effect on hens is not worsened.
- Do not locate gas inlet pipe on long side of shed. Better to locate the pipe on the short side, aiming down a lane way and not against nest box walls.
- Close off hen access in lane ways opposite the gas inlet pipe, to reduce blasting of birds in this area.
- Use fans during the gassing to help distribute gas throughout the shed.
- Develop a sprinkler system to distribute gas more evenly throughout shed with some form of vaporiser to prevent freezing.
- Control/reduce pressure of gas spraying in to shed to so that CO_2 concentrations are gradually raised to less than 40%, achieving a less aversive type stun in hens, before they are killed at concentrations above 60%.
- Develop a multi pipe high pressure system to achieve faster rates for achieving appropriate CO_2 concentrations to kill hens more quickly.
- Installation of CO_2 loggers to measure concentrations in different parts of the shed, especially the upper levels.
- Evaluate on farm container gas systems for smaller farms that are available from UK or Canada.
- Customise in shed container gassing to suit the Swedish design of loose house systems for keeping hens.

Cyanide gas killing

- Enclose certain areas of barn to restrict hen access so that they cannot move out of range of the HCN gas, ensuring all hens get a high exposure to high HCN doses.
- Ensure proper storage of HCN gas at room temperature.
- Ensure that only professional chemical companies with experience in killing hens with cyanide are given authorisation to conduct on farm killings.

Transport and slaughter killing

- Use fully climate controlled trucks equipped with humidity loggers and air conditioning possibilities.

General

- As the stunning and killing of poultry is a difficult procedure with obvious implications for the welfare of the birds, animal welfare monitoring schemes should be developed for each method used. Such monitoring should be applied on all on farm killing and on a reasonable sample size in abattoir stunning and killing. These monitoring procedures should be externally audited on a regular basis to ensure that appropriate methods are applied and that good welfare standards are met.

ACKNOWLEDGEMENTS

This report has been funded by the Swedish Animal Welfare Agency (Djurskyddsmyndigheten).

The following are greatly acknowledged for their constructive cooperation in this project:

The farmers who willingly provided access to their facilities

Svenskt Fågelkött AB

Norrlansägg AB

Dr Mohan Raj. Senior Research Fellow. Division of Farm Animal Science. School of Clinical Veterinary Science, University of Bristol, UK

Dr Bruce Webster. Associate Professor and Extension Poultry Specialist
Department of Poultry Science, The University of Georgia, Athens, GA

Dr. John Church. Livestock Welfare Unit, Alberta Agriculture, Food & Rural Development, Canada

Kirk Thompson and Peter Featherstone, Defra Animal Welfare Division, London UK

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APPENDIX 1: Instructions on gas concentration calculations provided by AGA gas company

Förberedelser och instruktioner vid avlivning av höns.

För att avliva höns med koldioxid behövs dispens från jordbruksverket

1. Vid beställning av gas

- Räkna ut en ungefärlig gasvolym. Koncentrationen av koldioxid bör vara ca 80 % i lokalen Mängd gas: lokalens längd (m) * bredd (m)* takhöjd (m)* 1,8 (densitet)* 60 % = antal kilo koldioxid. Avrunda uppåt för marginal. Det går åt mer gas, vid burhöns, då gasen är tung och det är svårare att få upp koncentrationen av gas ända upp i taket
- Beställning första gången: Ring kundservice 040-28 38 78 eller mail: ksmalmo@se.aga.cor och ange namn, telefonnummer, adress, organisationsnummer, då erhåller ni ett kundnummer och kopplas till avtalet. Är leveransen mer än 2 ton gäller 3,21 kr/kg och 630 kr/h för chauffören. Är leveransen under 2 ton gäller 4,04 kr/kg. **Beställning av gas sker p: telefonnummer 0303-699 95**, båten till Gotland går bara en gång i veckan. Vägbeskrivning faxas till faxnr 0303-699 25, transportkontoret Stenungsund.

2. Innan tankbilen kommer

- Se till att ha en fri väg så att AGA-bilen kan komma till
- Förbered om möjligt så att tankbilens slang kan spännas fast någonstans, eller skaffa en rörstump i väggen så att slangen att kopplas på
- Stäng av **all** ventilation, även reservventilationen
- Täta vid ventiler, dörrkarmar och fönsterlister, för att undvika att gasen läcker ut
- Det kan behövas någon öppning uppåt eftersom trycket i lokalen ökar, oftast kan ventilationstrumman fungera som öppning

3. Så här går det till

- Chauffören spänner fast slangen från bilen lämpligast i inredningen eller skruvar fast slangen i stosen
- Koldioxiden tillförs i flytande form under ganska högt tryck (15 bar). Det bildas gas och koldioxidsnö, som sedan förgasas.
- Tiden som behövs för att hönsen/ kycklingarna är döda kan variera beroende på antalet djur per m^2 samt lokalens "täthet" dvs hur mycket koldioxid som läcker ut, men rent erfarenhetsmässigt bör alla vara döda efter ca 5minuter. Vänta ytterligare en halvtimme efter det att chauffören slutat fylla på gas, för att vara säker.
- Öppna därefter alla dörrar samt fönster,dvs vädra ut lokalen **tills ni är säkra på att lokalen är utvädrad.** Vanligtvis cirka en halvtimme.

4. Tänk på att

- Koldioxid är farlig för människor i koncentrationer över 10%. Koldioxid är luktlös och tyngre än luft, vilket gör att den kan samlas nere i gropar. **Läs bifogad varuinformationsblad.**
- **Lyssna** på AGAs Chaufför. Han har bäst kunskap och erfarenhet av denna typ av process.

Giltig fr om 2005-01-01 t om 2005-12-31

APPENDIX 2: Post mortem results on cause of death of hens gassed with carbon dioxide from SVA

Fjäderfäavdelningen

ANKOM
2005 -05- 17

RAPPORT
utfärdad av ackrediterat laboratorium
REPORT issued by an Accredited Laboratory

1 (2)

Kund: 007204
SLU, Inst f husdjurens miljö o hälsa
Avd f husdjurshygien
Bo Algers
Box 234
532 23 SKARA
SVERIGE

Uppdragsnummer: 050429003
Labnr.: OF 348-53/05

Ankomstdatum: 05-04-29
Besvarat den: 05-05-13
Utskriftsdatum: 05-05-13

Fakturamottagare: SLU, Inst f husdjurens miljö o hälsa, Avd f husdjurshygien, SKARA (erhåller skriftligt svar)

Djurägare: [redacted]

Insändare: SLU, Inst f husdjurens miljö o hälsa, Avd f husdjurshygien, SKARA (erhåller skriftligt svar)

Kopiemottagare: [redacted]

INSÄNT MATERIAL

Djurslag: Tamhöns, Värphöns
Provmärkning: Ej angivet
Material: Hel djurkropp
Provtagningsdatum:

UTLÅTANDE

Undersökning av sex avlivade hönor.

Hönorna var i gott hull och hade aktiva könsorgan. Samtliga djur uppvisade en röd missfärgning av kam och slör i varierande omfattning. Hos två hönor var missfärgningen begränsad till kammens toppar.
Hos tre djur sågs blodkoagel på leverns yta. Två av dessa djur uppvisade dessutom blödningar i lungornas parietala delar och i bröstväggen.

Histologisk undersökning visade en uppluckrad/sönderssprängd vävnad i kammarnas och haklapparnas yttre delar.
Lungorna var säte för ett påtagligt ödem och även blödningar.
I luftstruparna sågs inga påtagliga förändringar.

Diagnoser: 1) hudförändringar i kam och slör. 2) Lungödem/lungblödningar

Kommentar: förändringarna i kammarna och slören har med stor sannolikhet uppkommit genom att djure har exponerats för mycket låg temperatur.

Handläggare: Oddvar Fossum

STATENS VETERINÄRMEDICINSKA ANSTALT
Postadress SE-751 89 Uppsala
Tel +46 (0)18 67 40 00, Fax +46 (0)18 30 91 62.
E-post sva@sva.se, Internet www.sva.se
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Hemsida: www.hmh.slu.se

Swedish University of Agricultural Sciences
Faculty of Veterinary Medicine and Animal Science
Department of Animal Environment and Health
P.O.B. 234
SE-532 23 Skara, Sweden
Phone: +46 (0)511 67000
E-mail: hmh@slu.se
Homepage: www.hmh.slu.se