Brittle Bones:
Osteoporosis and the Battery Cage

A report for Compassion in World Farming

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1.1 The welfare of battery hens

There are around 30 million laying hens in the UK, in an egg industry which has been characterised in the last 60 years by a trend to increasing specialisation, larger units and steadily increasing egg output per hen (FAWC, 1997). Laying hens today produce about twice as many eggs as they did fifty years ago. About 86% of UK egg production comes from cages hens housed in the battery cage system.

The battery cage system represents an approach to egg production in which the producers' dominant concern is to maximise the yield from the hens, even at the expense of their health and welfare. The battery cage continues to be highly controversial, with the weight of scientific opinion supporting the feeling among the general public that hens "suffer in battery cages" (Appleby, 1991). Since the mid-1980s the proportion of battery eggs produced has even declined slightly as consumers have opted for non-cage alternatives and the market for free-range eggs, in particular, has grown strongly.

Table 1. Growth of battery cage system and productivity per hen between 1936 and 1996 (data from FAWC, 1997).

Year	% of eggs produced in battery cage system	average number of eggs per hen per year
1936	-	149
1946	-	121
1956	15	170
1966	67	202
1976	94	245
1986	93	279
1996	86	310

Compassion in World Farming's recent report *Beyond the Battery - a Welfare Charter for Laying Hens* (Lymbery, 1997) set out the health and welfare problems associated with battery cages which have been emphasised by a number of official bodies, including the UK House of Commons Agriculture Committee (1981), the European Parliament (1987) and the EC Scientific Veterinary Committee (1992 and 1996). The battery cage system creates a highly barren and restrictive environment which prevents a caged hen from stretching her wings fully, performing natural behaviours such as foraging, dust-bathing and nesting, or exercising.

This report aims to highlight one particular aspect of the effect of the battery cage on the health and welfare of hens. This is the problem of pathological bone weakness, or cage-layer osteoporosis (CLO), also known as Cage

Layer Fatigue, which probably affects millions of hens in the UK laying flock each year. The extent of the problem is shown by the fact that a recent commercial scale study of caged hens found that 35% of all mortalities during the laying cycle were attributable to bone fragility. This was diagnosed on the basis of the carcass having at least one fracture of the ribs, sternum, humerus, radius, femur or tibia (McCoy et al., 1996).

Osteoporosis is the loss of mineralised bone volume, resulting in fragile, brittle bones which are easily broken. It can result in death from paralysis or starvation if the hen cannot reach food and water, at a time when the hen shows no other disease and is producing normal eggs. A laying hen's bones and the shells of the eggs she produces both require minerals, in particular calcium. Egg-shells may be produced at the expense the hen's bone mineral. While all high-producing laying hens may need to utilise their body's calcium reserves to form egg-shells, only hens kept in the battery cage system suffer from caged layer osteoporosis (Abdul-Aziz, 1998).

1.2 A problem for the industry

The industry and poultry scientists recognise CLO as a significant welfare problem. However, the condition also has a commercial aspect, and is quite extensively studied for this reason. It is generally accepted that large numbers of live 'spent hens' and their carcasses have bones broken in the process of depopulating the cages at the end of the laying cycle, transport, slaughter and processing (Knowles, 1994). During this time the birds' bodies are likely to be handled quite roughly. By the end of the processing, many of the bones in a hen's carcass may have disintegrated, leaving splinters of bone in the meat products which may make these hens unacceptable to processors. A 1989 UK study has found that up to 98% of spent hen carcasses had broken bones by the end of processing, with an average of 6 breaks per carcass (Gregory and Wilkins, 1989).

Although the problem of CLO has been quite extensively researched by the industry in terms of causes and possible cures, unfortunately this has often been done within the assumption that the battery cage is a necessary part of the egg industry. As one report put it, "It is more economical to keep hens in cages; therefore, the problem cannot be corrected by maintaining hens in floor pens" (Arafa and Harms, 1987). This cannot be seen as an acceptable approach to the problem of osteoporosis in caged laying hens.

1.3 The need for change

This problem of CLO is not controversial either in terms of the facts of the disease or its probable major causes. However, in terms of the suffering it undoubtedly causes to hens and the urgent need to find a solution, it has not yet received the attention it deserves in official reports such as that of the government advisory body the Farm Animal Welfare Council in 1997, or from the industry. This report aims to draw together the evidence on the existence and causes of laying hen osteoporosis and argues that bone weakness is very likely to be an inevitable result of the battery cage system itself.

The well-documented evidence against the battery cage system in terms of welfare is so compelling that CIWF believes that urgent action is needed to phase out this system on a Europe-wide basis. Indeed, the public and veterinary concerns about the welfare of caged hens are reflected in the fact that the European Commission recently published proposals for amendment of the Battery Hens Directive (88/166/EEC). Disappointingly, these proposals do not at the moment call for a phase-out of the cage system itself. Instead, they include small increases in floor area per hen, increased minimum cage height and the provision of perches. Minor modifications of this sort cannot solve the problem of bone weakness in battery hens. As this report shows, the problem is inherent in the system of confining hens in small cages.

1.4 The welfare potential of non-cage systems

CIWF believes that the UK government and the European Union need to take a positive approach to maximising the welfare of hens by insisting on husbandry systems which have the highest 'welfare potential'. This requirement must exclude the battery cage, which has been described by the EU Scientific Veterinary Committee as having "inherent severe disadvantages for the welfare of hens" (SVC, 1992, 1996).

The essential difference between the battery cage and non-cage alternatives as husbandry systems for laying hens should be seen in terms of the concept of welfare potential. Welfare problems which undoubtedly exist in many current non-cage systems can be addressed by improved design and management. However, the adverse welfare features of the battery cage are inherent in the system.

Leading UK poultry expert Mike Appleby concluded a review of the scientific literature by stating: "Hens suffer more in battery cages than in well-run, alternative systems" (Appleby, 1991).

Hen housing systems

The battery cage system. Rows of metal and wire cages are arranged up to 8 tiers high. Each cage measures 50 cm x 50 cm in area and up to 5 hens are kept in each one, giving a legal minimum space per hen of 450 cm^2. The minimum cage height is 40 cm over 65% of the cage and 35 cm over the rest. The cage floor is sloping wire mesh and each shed can contain between 10,000 and 90,000 hens.

Non-cage systems (Appleby et al., 1992; FAWC, 1997).

Perchery (also called barn or aviary) systems. Hens are kept in loose flocks in sheds with raised perches or platforms. Littered flooring is usually provided. 15 cm of perch is to be provided for each bird and the maximum stocking density is 25 hens per square metre of floor space.
Deep litter systems. Hens are kept on the floor in sheds and perches are not usually provided. Part of the floor is littered and part contains a droppings pit covered with wire. The maximum stocking density is 7 hens per square metre of floor space, which is 1425 cm^2 per hen.
Free-range system. Hens are kept in perchery or deep litter type houses but have access to the outdoors during the day. They can also be accommodated in small groups in small moveable houses. The maximum EU allowed stocking density is 1 hen per 10 square metres of outdoor range, which must be "mainly covered by vegetation".

2. What is Caged Layer Osteoporosis?

2.1 Egg-laying and the hen's bone structure

Laying hens become sexually mature and therefore capable of laying eggs at about 16-18 weeks. Before this time, they may be reared either in cages or in floor pens. In cage systems, the pullets (immature hens) are then transferred to cages where they remain for the whole of their laying life. The hens lay almost continuously from typically 20 weeks to 72 weeks of age and a high-producing modern laying hen can lay 310 eggs per year. The whole process of producing an egg takes a hen at least 24 hours. The shell is deposited onto the egg in the uterus, where epithelial cells secrete calcium salts which bond to the egg membrane. Calcium carbonate is the major constituent of egg shells. By 72 weeks of age (known as 'end of lay') the egg production of the unit as a whole has fallen to about 70% of its theoretical maximum. The whole unit is then 'depopulated' and the 'spent hens' transported to the slaughterhouse (Rose, 1997).

The skeleton of a hen consists of structural bone (cortical and trabecular bone) which provides mechanical strength and supports the muscles, and a type of medullary (inner) bone special to birds, which has little mechanical function but acts as a reserve of calcium needed to form egg shells. The hen's medullary bone is formed just before the onset of sexual maturity and the start of egg laying and this coincides with a marked reduction in the volume of trabecular bone (the internal supporting framework of structural bone) (McCoy et al., 1996; Abdul-Aziz, 1998). 98% of body calcium and 80% of body phosphorus is present in the hen's skeleton, in the form of the mineral calcium hydroxyphosphate, which gives bones their strength and also acts as a mineral reserve. Calcium and phosphorus are each necessary for the absorption and utilisation of both of them from the diet and vitamin D_3 is also necessary as it controls the absorption of calcium through the production of calcium binding protein (Fowler, 1990). These nutrients should be provided in adequate quantity in the hen's diet.

It is quite normal for high-producing hens to use the calcium reserves in their bones to produce egg shells. Egg-shell formation is most intense in the period of darkness when the hen does not eat. She therefore has to use calcium from the medullary bone, by a process of resorption. When this process leads to disease, it is because the medullary bone has become depleted of calcium and the hen starts to break down the structural bone to use the calcium for the formation of egg shell and to replenish the minerals in the medullary bone. The result is a serious decrease in the amount of structural bone and the hen's skeleton becomes thin and brittle (Abdul-Aziz, 1998).

2.2 How osteoporosis affects battery hens

As long ago as the 1970s it was known that caged hens have significantly weaker bones that hens kept in non-cage systems (Rowland and Harms, 1972; Meyer and Sunde, 1974). The strength of the bones of caged hens declines steadily through their laying life, whereas the bones of hens kept on the floor weaken less or not at all (Table 2.).

Table 2. Changes in the strength of hens' bones between 20 and 64 weeks of age. Data from (a) Rowland and Harms, 1972 ; (b) Harms and Arafa, 1986; Arafa and Harms, 1987.

% change in tibia breaking strength with age of hen		
Age between	20 to 32 weeks	32 to 64 weeks
cage (a)	-1	
cage (b)	-38	
cage (c)		-17
floor (a)	+23	
floor (b)	-17	
floor (c)		+30

By the end of their laying life, a 1994 British study found that in caged birds the strength and radiographic density of the humerus (upper wing bone) was lower by 40-50%, the bone volume by 30% (neck region) and 15% (leg region), the tibia (leg bone) strength by 25% and the tibia radiographic density by 15%, compared to hens in non-cage systems (Fleming et al., 1994).

However, some hens are so severely affected during their laying life that they collapse and die in their cages. The results of osteoporosis have been described graphically in the 1990 textbook, *Poultry Diseases*:

> "Clinically, 'caged layer fatigue' is seen in caged hens which are producing well, in fair bodily condition, and which suddenly become recumbent (sometimes paralysed) with legs extended. The cortices of their brittle bones are thin; ribs and sternum are frequently deformed; skeletal fractures are common, sometimes thoracic, with spinal compression and resulting paralysis." (Duff, 1990).

A 1993 report in *Poultry Adviser* tells us:

> "After long period of egg production, caged layers have difficulty standing and their body is held in a vertical position. They may lose control of their legs and lie on their sides, indicative of a type of paralysis. Usually there is no loss of egg production, shell quality or interior egg quality. Some of the bones may be fractured, some will break when the bird is handled….The birds appear healthy but they die due to starvation later on if left in cages in the recumbent position. The bones appear to be osteopetrotic [diseased] and so brittle that the ribs give way causing the heart to be punctured." (Bhat, 1993).

Most of the affected birds will recover if taken out of cages in the early stages of the disease and placed on the ground or floor and given access to food and water (Bhat, 1993; Abdul-Aziz, 1998).

More often the weakness of the hen's bones is not apparent until she is pulled from the cage and transported to the slaughterhouse, where the condition becomes a commercial problem. The large number of broken and shattered bones in caged hen carcasses can even mean that in some cases processors refuse to buy spent hens (Wilson and Harner, 1988; Bhat, 1993). A recent study in Sweden found that broken wings were nearly 3 times as common in the carcasses of caged hens compared to aviary hens and the humerus (upper wing bone) of the caged hens was only half as strong as for the aviary hens (Abrahamsson and Tauson, 1995).

The results of two such studies are given in Table 3, showing that hens raised on the floor or in an aviary have a reduced incidence of broken bones of up to 70 percent compared to caged hens.

The commercial problem is described by Bhat:

> "It is a known fact that the breaking strength of bones from layers held in cages is less than those kept on a litter floor…Furthermore, the brittleness of the bones of caged birds at the end of their laying year may be so great as to make the spent hens unacceptable for poultry processing. Their bones disintegrate causing fine splinters in the meat… This phenomenon reduces the market value of the spent hens often to the point that the birds cannot be sold." (Bhat, 1993).

If the condition is unnoticed or untreated, the hen often dies a slow death at the back of the cage. Abdul-Aziz noted recently that, “Birds which live for several days after going down may dehydrate or emaciate, and are out of production. Although affected birds initially are alert and can continue to eat, they generally die from dehydration and starvation since they may not be able to reach a water or food source” (Abdul-Aziz, 1998).

Table 3. Reduction in incidence of broken bones during depopulation and processing for hens in floor or aviary system compared to hens in battery cage. Data from (a) Arafa and Harms, 1987; (b) Abrahamsson and Tauson, 1995 (average over 2 aviaries).

	reduction in incidence of broken bones	
hen housing system	broken wings	other recorded breaks
(a) floor [1]	55% reduction	41% reduction
(b) aviary [2]	64% reduction	67% reduction

[1] data at 64 weeks of age
[2] data at 80 weeks of age

The scientific evidence therefore leaves no doubt that the disease of osteoporosis is the direct result of keeping laying hens in the battery cage system and that it causes suffering to hens during their laying life and, as we shall see, when they are caught and transported for slaughter. Fleming and coworkers, writing in the journal *British Poultry Science* in 1994, concluded that:

> “The high incidence of fractures in live birds, which can occur both during the egg production period and in the course of depopulation and subsequent transport and handling, represents a severe welfare problem.” (Fleming et al., 1994).

3. The causes of osteoporosis

We have seen that the most important factor in the development of brittle bones and bone breakage in laying hens is the husbandry system, and primarily the housing. Fleming concluded from his investigation of the incidence of broken bones in hens in 1994:

> “The results of this study show large effects of the type of husbandry system which laying hens are housed on their bone characteristics at the end of the laying period.” (Fleming et al., 1994).

However, osteoporosis is also closely linked to the high productive demands on modern laying hens. While this is true, it is important to emphasise that hens in other systems may lay as many eggs but that the disease only affects caged hens (Knowles and Broom, 1990; Abdul-Aziz, 1998).

It may be possible to achieve some improvement in bone strength through breeding and dietary supplements but it is not clear that these could have a major effect (Gregory, 1988/1989). Research along these lines has not succeeded so far in making any significant progress while keeping hens in standard battery cages.

3.1 The development of bone strength

An important cause of osteoporosis in laying hens seems to be that caging damages the normal process of developing the bone structure of the still-growing pullets. It is well known that the mineralised bones of hens are depleted during their laying lives, so it should be seen as particularly important that they can lay down enough bone during the rearing and growing period (Rowland and Harms, 1972; Whitehead, 1994; Fleming et al., 1994). Unfortunately, the battery cage system takes no account of this biological need.

The structural bones of hens in lay have little or no osteoid (a collagenous material necessary for bone growth) and so they have little ability to form structural bone (Whitehead, 1994). However, modern layers are bred for early sexual maturity and they are not at their maximum adult body weight and development when they start laying. In a 1996 study of a perchery system, hens were only 60% of their mature weight at the start of lay and only reached full weight in mid-lay. For the first 6 weeks of lay, the young hens were still increasing their bone strength (Gregory and Wilkins, 1996).

When pullets are put into cages at the time of sexual maturity, this may inhibit them from developing sufficiently strong bones to withstand the inevitable calcium depletion that happens during their laying lives. There may even be a critical period in a hen’s bone development, from sexual maturity to about one year, when exercise is particularly beneficial and lack of exercise particularly detrimental. In the battery system, hens are immobilised in cages for the whole of this critical time, and this is “likely to exacerbate the osteoporosis observed in these birds” (Fleming et al., 1994).

As long ago as 1972, Rowland and Harms commented from a commercial perspective:

> “Placing pullets in cages prevents the skeletal system from developing sufficient strength to allow a gradual decrease in bone mass during the laying period and still remain strong enough to prevent shattering in the processing plant.” (Rowland and Harms, 1972).

3.2 An egg a day - the demands of high productivity

The output of eggs demanded from a laying hen has approximately doubled over the last half century and now stands at over 300 in the usual laying period of 52 weeks. This means that modern hens have few non-laying days. It is obvious that the high egg production puts great demands both on a hen's reserves of calcium and on her calcium metabolism. But once again we have to remember that only caged hens suffer from osteoporosis. Hens in non-cage systems may lay as much as 97% of the number of eggs laid by caged hens (NFU, 1997) but still have stronger bones.

A 1990 Danish study found that 72 week old hens in a deep litter system laid 92% of the eggs laid by caged hens, but their humerus bones were 76% stronger (Nørgaard-Nielsen, 1990). In a U.S. study of 10 different hen strains, in all but one strain the hens kept on the floor laid a few more eggs than the caged hens, but in spite of their higher egg production the floor hens had on average 20% stronger tibias (leg bones) than the caged hens (Rowand et al., 1972).

The high productivity is, however, likely to contribute to the problem of brittle bones, because the hen has to provide calcium for the egg shells. In normal conditions about 40% of the calcium required for egg shells will come from her medullary bone but continuous egg-laying can also result in depletion of structural bone, as we have seen. Attempts to boost the hen's physiological machinery by feeding extra minerals have come up against the fact that there is a physiological limit to the amount of calcium and phosphorus that she can absorb.

The reality is that even with the best diet the high-producing hen's metabolism may not be able to keep up with the dual demand of egg shell production and bone maintenance. A hen has to move calcium from the blood to the egg at a rate of 115-130 mg per hour, so that she needs a complete turnover of blood calcium over 12 minutes ((Abdul-Aziz, 1998). One study found that calcium uptake from the intestine actually decreases quite rapidly when hens have been in lay about 4 months, but it increases again if they are given a rest from egg production by moult (Al-Batshan et al., 1994). Resting hens by moult after their normal laying cycle of 52 weeks has also been found to increase hens' bone strength quite significantly when they re-start laying, even 8 months after they would normally be considered to be 'spent' (Arafa and Harms, 1987).

The fact that a hen's health can be improved by a rest from laying confirms the opinion of Whitehead (1994) that long periods of laying are detrimental to a hens's bones and suggests strongly that laying hens are being worked beyond their physiological limit. It simply may not be possible to reconcile the welfare of hens with high production in battery cages, even with adequate diet. As the AFRC 1988/89 report puts it:

> "In general, however, there is a conflict in calcium metabolism between the demands of egg-laying and those of the skeleton. Perhaps bones can be strengthened only at the expense of productivity." (Gregory, 1988/1989).

We can conclude that continuous egg production undoubtedly puts hens at risk of losing mineralised bone volume. When this risk is combined with the immobilisation of hens in battery cages, then serious osteoporosis is very likely to result.

3.3 Diet, nutrition and breeding

A number of studies of the nutrition of battery hens have shown that, when the hens are fed according to accepted standards, osteoporosis cannot be prevented by diet or supplements. A report from the Agriculture and Food Research Council summarised the situation in 1989 by saying that neither breed nor improvements in diet are likely to make an important difference to hens' bone strength and that the greatest scope for improvement is in husbandry (Gregory, 1988/1989).

It has also been suggested that there may be scope for improvement through breeding, since some individual hens are able to produce a large number of eggs and keep healthy bones, or through improved nutrition during the hen's rearing period (Whitehead, 1994).

A limited improvement in calcium uptake or bone strength has been achieved by feeding dietary supplements such as fluoride and oystershell (Whitehead, 1994), portland cement (Ferguson et al., 1974), 1,25-dihydroxyvitamin D_3 and 1α-hydroxyvitamin D_3 (Frost et al., 1990) and carbonated water during times of high temperature (Koelkebeck et al., 1993). However, the scientific consensus is that improved nutrition has little effect on slowing the loss of structural bone during the laying period and we know that it is this bone loss that leads to osteoporosis.

Consistently good nutrition is, however, essential for minimising the impact of the disease on the hens. Whitehead notes, "it would seem to be highly disadvantageous to withdraw feed from hens prior to depopulation. Production of some eggs will continue, with shell formation depleting bone calcium. Thus bone loss will be accelerated just at the time when hens are about to experience physical stresses associated with depopulation and transport, with attendant risks of bone fracture." (Whitehead, 1994).

3.4 The primary cause - lack of exercise

There is overwhelming evidence that the restriction of movement in the battery cage system is the most important reason why the bones of caged hens are so fragile compared to hens in non-cage systems. According to Fleming, writing in 1994, the response of bone to exercise or 'functional loading' is well documented and is called *adaptive bone remodelling*. In mammals, if functional loading of bones is suppressed, as in space flight or prolonged bed rest "loss of bone invariably follows" (Fleming et al., 1994).

Knowles has also spelled out the consequences for caged hens by stating that their experimental results showed:

> "the exercise taken by the caged hens was insufficient to prevent bone degeneration." (Knowles, 1990).

Several studies have shown a clear relationship between the amount of exercise taken by hens in different housing systems and the strength of their bones. Let us consider two independent reports in 1990 by Knowles and Broom in the UK and by Nørgaard-Nielsen in Denmark. These provide data on the number of steps, the number of vigorous wing movements and bone strength in perchery or deep litter systems where the hens had the most space, in more restrictive terrace or wire-floor systems and in battery cage systems (Table 4). They both found significantly more movement and stronger bones in the least restrictive systems compared to the battery cage. The humerus (wing bone) of the caged hens was only 54% of the strength of the perchery hens (Knowles and Broom, 1990) and only 57% of the strength of hens kept in a deep litter system with perches (Nørgaard-Nielsen, 1990).

It is worth recording the conclusions of these researchers on effect of restricted movement in the battery cage. Knowles and Broom state that the space allocation of the battery cage:

> "does not ensure the birds sufficient freedom of movement to allow adequate bone loading to develop normal bone strength through functionally adaptive changes in bone architecture." (Knowles and Broom, 1990).

Nørgaard-Nielsen concluded that:

> "Keeping hens in cages thus restricts their movements, especially wing movements, to the degree that bone strength is greatly reduced." Nørgaard-Nielsen, 1990).

The observations made by Knowles and Broom are very important and deserve to be pondered on by all those responsible for hen welfare. They show starkly the almost complete immobilisation of the caged hens compared to the more natural behaviour of the hens in the perchery. The caged hens took 72 steps an hour compared to over 200 in the perchery and over 1000 in the terrace. The greater amount of walking by the hens in the terrace was undoubtedly to compensate for their inability to fly or even wing-flap easily. The battery-cage hens were unable even to do this.

If given the opportunity, hens will use all the space available to them. A Swedish study in 1995 looked at how hens used space in their percheries. They found that in the daytime, 75% of hens spent the time feeding and nesting on the lower levels or on the litter floor, while at night 93% of them occupied the upper level, mostly on perches. This study also found that the wing bone strength of the perchery hens was double that of the caged hens (Abrahamsson and Tauson, 1995).

The effect of increased exercise can be almost immediately beneficial. We have seen that the only treatment for osteoporosis in its early stages is to remove hens from their cages. Similarly, research in the 1970s and 1980s showed that moving laying hens from the floor to cages (Harms and Arafa, 1986) or from cages to floor (Meyer and Sunde, 1974) can cause decrease or increase in bone strength within just a few weeks.

Table 4. Amount of exercise taken by hens in cage and non-cage systems. Data from (a) Knowles and Broom, 1990; (b) Nørgaard-Nielsen, 1990

(a)

Types of wing movement and steps per hen per hour					
	stepping	ruffling	stretching	flapping	flying
cage	72	1.3	4.0	none	none
terrace	1058	0.9	0.1	0.2	none
perchery	208	0.3	none	1.9	0.4

(b)

system	density	vigorous wing movements per hour	humerus breaking strength (kg) 52 weeks	72 weeks
cage	5 hens/cage	none	18.7	23.4
wire floor system	10 hens/m^2	1 - 1.5	31.4	37.4
litter with perches	7 hens/m^2	2 - 3	34.5	41.1

4. Catching, transport and slaughter

4.1 Handling and broken bones

Because of the economic importance of the subject, as well as the welfare implications, there have been numerous scientific studies of the number of broken bones that spent hens suffer in depopulation, transport, slaughter and processing (see Knowles and Wilkins (1999) for a recent review). Almost invariably, they show that battery hens suffer more than twice as many broken bones than hens from non-cage systems and that the amount of bone breakage is correlated with bone strength.

The process of catching and removal from their cages is a traumatic experience for hens. Current UK voluntary guidelines state that hens should be pulled out of the cage entrance individually by holding both legs. However, previous commercial practice has been to put either one or two hands into the cage, grasp two or three hens by one leg each with one hand and pull them out of the cage together (Gregory et al., 1992). This is because single-leg 'picking' is easier and quicker for the picker, who is often on piece-work. The hens are then carried upside down out of the shed and packed into crates for transport, often several hens at a time. In this hurried and often rough handling many of their fragile bones are broken, often as they strike the sides of the cage entrance as they are pulled out. Hens are more likely to suffer bone breaks in this process if their bones are already weakened by spending a year in a battery cage.

There is a wide variation in the proportion of hens who have bones broken in the process of catching and crating for transport. The amount of damage depends very much on the individual handler and how much care is taken not to hurt the hens. A 1989 study by Gregory and Wilkins of hens from 8 farms found that the average number of hens suffering breaks could be almost halved, from 24% to 14%, by careful handling of hens individually, as opposed to using the 'commercial' method of holding three or four hens per hand. The range of breakage was between 7% and 41% (Gregory and Wilkins, 1989). Subsequent research has found the percentage of hens suffering broken bones in catching to be 5-14% (Gregory and Wilkins, 1992; Knowles, 1994), 17% (Knowles et al., 1993) and 3-14% (Gregory et al., 1992).

A study by Knowles and coworkers found that hens with the weakest bones were the most likely to suffer bone breaks during removal from their cages and it was concluded:

> "The results show that differences in bone strength due to the type of housing system in which birds are kept are great enough to affect the ease with which bones are broken during bird handling during removal from cages at the end of lay." (Knowles et al., 1993).

They continue:

> "A housing system which results in a greater likelihood of bone breakage is clearly undesirable." (Knowles et al., 1993).

Unloading at the slaughterhouse and shackling causes more breaks. Gregory and Wilkins report that on average 29% of the live battery hens arriving at slaughterhouse have at least one freshly broken bone. Removing them from the crates and hanging them by their legs onto the shackle before they are stunned increases the proportion of hens with broken bones to 45%. The total number of broken bones is also increased by 60% to almost one per hen (Gregory and Wilkins, 1989; Gregory, 1994). This massive amount of damage is done when the hens are still fully conscious, before they have been stunned.

The devastating effects of handling at slaughter have led one poultry expert at the University of Bristol to advocate gas-stunning in the transport crates as “the answer to some of the welfare problems seen in the unloading bay at processing plants.” (Gregory, 1994).

4.2 Failures in hen husbandry

It is important to distinguish broken bones which occur as a result of osteoporosis from broken bones which happen to normal hens kept in non-cage systems. These are usually due to failures in handling and housing.

Many hens from non-cage systems also have their bones broken in the process of catching, transport and slaughter due to rough handling. Moreover, the amount of routine bone breakage in all hen husbandry systems is unacceptably high. Studies of old (healed) breaks in the bones of hens at end of lay show that the amount of breakage during a hen’s laying life is actually greater in non-cage systems than in battery cages.

A survey of 42 flocks in 1991, by Gregory and Wilkins from Bristol University School of Veterinary Science, found that on average 20% of perchery hens, 10% of free-range hens and 6% of battery cage hens had broken a bone while in the laying unit (Gregory and Wilkins, 1991a). While the egg industry likes to point to such findings as demonstrating the welfare benefits of the battery cage, in fact the lower incidence of breaks among the caged hens is simply because their movement is so restricted.

The relatively high incidence of breaks in the perchery, which are likely to be due to flight or landing accidents or to fights, compares unfavourably with the 5% incidence of breaks found in feral pigeons in Bristol (Gregory and Wilkins, 1991b). It suggests strongly that the space allocation per hen is too low or that the perchery design is flawed. There was a very wide variation in the amount of breakage between the best and worst managed flocks in all three systems, suggesting considerable scope for improvement. Significantly, the first publication of similar results by Gregory and Wilkins in 1990 raised objections from the poultry industry.

That hens with normal bone strength suffer so many broken bones which are left untreated during their laying life is an indictment of current standards of hen husbandry. As Knowles reminds us:

> “There can be no doubt that welfare is poor if bones are broken in a live bird.” (Knowles et al., 1993).

These failures in hen husbandry point to an urgent need for improvement in design and management of some non-cage systems. They cannot be seen as providing any sort of endorsement for the battery cage system.

5. Solutions

5.1 The extent of the problem

The scientific evidence leaves no doubt about the reality and severity of the welfare problem of weak bones caused by osteoporosis in caged laying hens.

Table 5 summarises the data we have surveyed in this report on the relative bone strength and number of bone breaks during processing that have been found for caged hens compared to hens in non-cage systems. These results over nearly 25 years have shown consistently that caged hens have weaker bones and more breaks. Although there is considerable variation, the caged hens have leg bones that are only 80% as strong as non-cage hens and wing bones that are just over half as strong as non-cage hens. The incidence of broken bones among non-cage hens in catching, transport, slaughter and subsequent processing is also about half the incidence for caged hens.

It is important to note that the wing strength of caged hens is greatly reduced and the number of broken wings is greatly increased, compared to the non-cage hens. This is grim evidence of the effect of the restriction of wing movement in the battery cage on the welfare of hens.

The total number of hens affected by osteoporosis in the UK is very large. Let us try to quantify the problem at various points during the laying cycle, catching, transport and slaughter, using the available scientific evidence.

(i) A 1996 study found that 35% of the deaths of hens during the laying cycle were due to CLO (McCoy et al., 1996). The generally accepted UK industry figure for mortality during lay is about 5%. Translated to the UK battery cage hen population of about 26 million, this means that almost half a million UK battery hens per year may die from osteoporosis during their laying life.

(ii) It is generally accepted that about 30% of hens arrive at slaughterhouses with freshly broken bones. About 26 million spent battery hens are transported to slaughter yearly. This means that 8 million UK battery hens per year arrive at slaughterhouses with broken bones. In the process of shackling prior to stunning, the number of fully conscious hens with broken bones rises to 12 million per year.

(iii) An estimated 1 in 200 of transported hens arrive dead at the slaughterhouse (Knowles, 1994). A 1994 study showed that 74% of the battery hens found dead on arrival had died from the effects of broken wings or legs in catching, crating and transit (Van Niekerk and Reuvenkamp, 1994). This translates to over 96,000 UK battery hens per year dying in transit from broken bones.

Table 5. Summary of data on bone strength and bone breaks during processing for non-caged and caged hens. The non-cage systems may be floor or litter, or perchery. Measurements made at 72 weeks unless otherwise stated in the footnotes to the table. Values may be averages over more than one set of comparable data from the same source.

		% bone strength of cage compared to non-cage hens		% breaks in processing in non-cage compared to cage hens		
Reference	Date	humerus	tibia	all breaks	humerus/ wing	leg
Rowland et al.	1972		83			
Rowland and Harms	1972 (1)		80			
Meyer and Sunde	1974 (2)		83	71	0	
Harms and Arafa	1986 (1)		75			
Arafa and Harms	1987 (3)		56	57	45	
Nørgaard-Nielsen	1990	57	88			
Knowles and Broom	1990	54	93			
Van Niekerk and Reuvenkamp	1994	68	79		45	25
Fleming et al.	1994	52	76			
Abrahamsson and Tauson	1995 (4)	49	77		36	33

(1) at 32 weeks (2) at 52 weeks (3) at 64 weeks (4) at 80 weeks

These figures imply an enormous amount of suffering routinely inflicted on hens in the battery egg industry. However, those in charge of the care of battery hens may not even be aware of it. The normal instinctive behaviour of a hen suffering from pain or fear is to sit still and quietly, giving the impression of calm (Hughes, 1988/1989). However, a study by Broom found that at the time of catching and crating the hens' levels of corticosterone, a stress hormone, were increased tenfold (Broom, 1990).

5.2 'Enriched' cages: a non-solution

In recognition of the restriction of movement and natural behaviour in the conventional battery cage, the current EU proposals for amendment of the Battery Hens Directive include an increase in the minimum cage area per bird from 450 cm^2 to 800 cm^2, a minimum cage height of 50 cm (currently 40 cm over 65% of the cage and 35 cm over the rest of the cage) and suitable perches.

These proposals are essentially for so-called 'enriched cages', which have been developed since the 1970s and have attracted considerable interest recently, with recent research work on Modified Enriched Cages continuing at Edinburgh and Bristol Universities. The cages in recent trials at ADAS Gleadthorpe Poultry Research Centre measure 100 cm x 50 cm, have a maximum height of 60 cm and include perches. 5, 7 and 8 hens per cage, representing a space allocation of 1000 cm^2, 714 cm^2 and 625 cm^2 , have been tested (SVC, 1996).

One of the intentions of the enriched cage designs is to improve a hen's opportunity for exercise and so improve bone strength. However, they have so far failed to demonstrate success. According to Appleby , enriched cages still provide a restrictive environment in which hens

> "do not have freedom to carry out large-scale locomotion. This affects bone strength." (Appleby, 1994).

The space allocation per bird in the Gleadthorpe trials does not compare favourably with the average area used by hens to wing-flap, wing-stretch or turn, which are 1876 cm^2 , 893 cm^2 and 1272 respectively (Dawkins and Hardie, 1989). Importantly, this area does not include the extra space that hens may *perceive* to be necessary in order to encourage them to take enough exercise to remain healthy.

Hughes and coworkers have made several investigations on the effect of perches on hens' bone strength. Although they originally reported an increase in tibia breaking strength of up to 19% for hens in cages with perches 7.5 cm off the ground (Hughes and Appleby, 1989, 1990) they were subsequently doubtful about the meaning of these results; later experiments showed that although there was a positive correlation between the amount of time a hen perched and the trabecular (structural) bone volume in the lower leg and foot region, *all the hens were considered to be osteoporotic* and there was no significant increase in bone breaking strength (Wilson et al., 1993; Hughes and Wilson, 1993). These studies concluded that while trabecular bone loss may be reduced if caged hens have perches,

> "substantial bone loss occurs even in those birds provided with perches. It is unknown whether the relatively minor beneficial effects of perch provision are sufficient to lead to a subsequent reduction in fracture incidence". (Wilson et al., 1993).

5.3 Non-cage systems are essential

There is no evidence that perches in cages can provide any real benefit for hens in terms of bone strength. Such perches may exercise the hen's legs but they do not improve *general* bone strength. In particular, perches do not exercise the hen's wings. As Fleming stated in 1994, "the humerus was the bone showing the largest responses to husbandry system. For the battery-caged birds, the strength and radiographic density of the humerus was lower by 40 to 50%" compared to perchery hens who had the opportunity for wing-flapping and flight (Fleming et al., 1994).

Knowles and Broom, who also found that the humerus strength of caged hens was only half that of perchery hens, comment that “the humerus appeared to be most affected by confinement and is one of the bones most frequently broken when hens are transported” (Knowles and Broom, 1990).

Several of the studies we have already mentioned have shown that when hens have wing exercise in non-cage systems they also have stronger bones (Abrahamsoon and Tauson, 1995; Nørgaard-Nielsen, 1990; Knowles, 1990; Knowles and Broom, 1990). The hens with strongest bones were kept in percheries where they could also fly. As Broom stated, “hens should be housed in such a way that exercise including walking and wing-flapping is possible” (Broom, 1990). These requirements clearly rule out any kind of cage system, whether ‘enriched’ or not.

6. Summary and conclusions

6.1 How osteoporosis takes its toll on battery hens

- About 85% of UK laying hens are housed in battery cages which are too small for a single hen to fully stretch her wings. With 5 hens per cage, the floor space allowance per hen is less than an A4 sheet of paper. This prevents hens from exercising either their legs properly or their wings.

- Hens kept in battery cages suffer from Caged Layer Osteoporosis (CLO), which results in fragile, easily broken bones or death. The acknowledged primary cause of this is lack of exercise. Numerous scientific studies over many years have shown that the bone strength of battery hens may be only half that of hens in non-cage systems such as percheries, where hens have the opportunity to walk, wing-flap and fly.

- The problem of weak bones is widespread. A 1993 UK experiment found that all the caged hens in the study could be considered to be osteoporotic by the end of their laying cycle.

- 35% of the battery-caged hens who die during their laying life die of CLO, according to one study. In UK terms, this would be almost half a million deaths of caged hens per year. This is often a slow death from paralysis and starvation at the back of the cage.

- Large numbers of hens have their bones broken during catching, transport and slaughter at the end of their laying life. About 30% of hens arrive at the slaughterhouse with broken bones. This is about 8 million UK hens per year. Nearly 100,000 UK battery hens a year may die in transit to the slaughterhouse from the effect of broken bones. Hens from non-cage systems suffer around half the number of breaks of caged hens.

• CLO is also a commercial problem because the fragile bones of caged hens disintegrate during processing, leaving splinters of bone in the meat products. Processors may refuse to buy ‘spent hens’.

• In view of the acknowledged need for exercise if hens are to keep healthy bones throughout their highly productive laying life, ‘enriched cages’ must be regarded as a non-solution. The solution is non-cage housing with adequate opportunity for exercise of legs and wings.

• The effect of CLO on caged hens has been described graphically as follows: “They may lose control of their legs and lie on their sides, indicative of a type of paralysis…Some of the bones may be fractured, some will break when the bird is handled…The birds appear healthy but they die due to starvation later on if left in their cages in a recumbent position. The bones …[are] so brittle that the ribs give way causing the heart to be punctured”. (Bhat, 1993).

6.2 Time’s up for the battery cage

• This report shows that the main cause of Caged Layer Osteoporosis is the confinement of hens in battery cages and that this disease inflicts needless suffering on millions of hens every year. Together with the evidence given in CIWF’s previous report *Beyond the Battery - a Welfare Charter for Laying Hens* (Lymbery, 1997), it provides an overwhelming case against the battery cage system in terms of the health and welfare of hens.

• The general public are showing by their choices in the supermarkets that they also believe that the battery cage system is cruel and unnecessary. CIWF surveyed nine major supermarkets in January-April 1998. More than two-thirds of these companies reported that over 30% of their total egg sales come from non-cage systems. One third of the companies reported that over 50% of their egg sales from non-cage systems. One major company, Marks & Spencer, has responded to public opinion by stocking only free-range eggs.

• CIWF believes that the current European Commission proposals for ‘enriched cages’ are an insufficient response to the welfare problems of the battery cage system. There is no evidence that enriched cages can provide enough exercise for laying hens. The EU must fulfil the requirement of the Protocol annexed to the Treaty of Amsterdam that full regard must be paid to the welfare requirements of animals when formulating agricultural policy. In our view this should entail including a phase-out of battery cages in any proposals for change.

• CIWF believes that the only solution to the health and welfare problems of laying hens is an urgent phase-out, throughout the European Union, of the battery cage system. In parallel with this, there must be a concerted research and development effort in order to raise welfare standards in the alternative non-cage systems.

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Glossary

bone mineral: the hen's bone has two components, a mineral component and a network of organic fibres. The mineral component is rigid and formed of calcium and phosphate.

cortical bone: the hard outside wall of the bone, providing mechanical support. Together, the cortical and trabecular bone constitute the structural bone of the hen's skeleton.

humerus: upper wing bone.

laying cycle: the (usually) 52 weeks during which caged hens are laying continuously, from about 20 to about 72 weeks of age.

medullary bone: a type of bone of crumbly texture which exists only in sexually mature hens and serves as a source of calcium for the formation of egg-shells. It has little supportive function.

osteoporosis: a skeletal disease in which there is loss of structural bone (cortical and trabecular bone) in the hen's skeleton, resulting in thin and brittle bones.

pullet: immature hen.

tibia: lower leg bone.

trabecular bone: the internal supporting framework of the bone. Together with the cortical bone, this provides the structural bone of the hen's skeleton.