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Review of welfare research in the laying hen and the research and management implications for the Australian egg industry

J. L. Barnett and E. A. Newman

Agriculture Victoria, Victorian Institute of Animal Science, 475 Mickleham Road, Attwood, Vic. 3049, Australia.

Abstract. The scientific literature and research in progress since 1992 on poultry welfare were reviewed under the major headings of housing, management, health, and occupational health and safety. Throughout the review there are a number of recommendations for research and implications for the Australian egg industry arising from the current worldwide research. The main recommendations can be summarised as follows. Further economic analyses of perches in cages under Australian conditions are required if the welfare advantages of incorporating perches into cages are to be maximised by the Australian industry. To reduce bone breakage, depopulation should involve removing birds by both legs, and current research on dietary manipulation could lead to a reduction in the incidence of osteoporosis. Injuries and entrapment can be reduced by the application of an abrasive strip to limit claw length, and a simple way of reducing mortalities may be by using coloured plastic enrichment devices. If enriched modified cages are to be adopted, a survey of public attitudes on their acceptability and trialing them under Australian conditions are required. It is important that welfare recommendations from overseas research and development are validated under Australian conditions to prevent compromising bird welfare. Replicated experiments on the welfare implications of non-cage systems are urgently required.

Beak trimming remains controversial, and determining the extent of single and double beak trimming and the reasons for their practice may lead to a reduced frequency of use. If beak trimming were to be disallowed in the future, the overseas knowledge on low light levels to reduce cannibalism and intermittent light schedules to maintain production would have to be reviewed, perhaps developed, and adopted. Also, a current common housing option of open-fronted sheds and exposure of hens to ambient light would have to be reassessed. While moulting via dietary restriction is not currently considered a significant welfare issue in Australia, a more sophisticated research approach to manipulate ovarian function that does not rely on food restriction should be researched. Cooling birds by providing cool water or cool radiators may be beneficial to welfare in hot weather. The slaughter process involves a number of potential welfare issues, such as heat-related problems during transport, stunning currents, and gas stunning, that require either a survey to identify problems or assessment.

The human–animal relationship probably has an important role in poultry welfare. However, the current understanding of the human factors that regulate human–animal interactions in poultry is poor. Some basic research and considerable applied research are required in this area before it would be possible to benefit bird welfare. Flock health monitoring must be considered as an ongoing priority because of its impact on bird welfare. In the area of health and welfare, the interactions between diet and skeletal condition, disease resistance and transmission, and housing and handling and immunosuppression require further research. Any relevant improvements in technology that arise from overseas research in non-cage environments to improve working conditions should be assessed and, if appropriate, adopted by the Australian industry because of its potential impact on occupational health and safety, work ethic, and the implications this has for bird welfare.

Additional keywords: layer(s), housing, poultry, health.
Introduction

This review is based on a report that was commissioned by the Egg Industry Research and Development Council. The focus of the review is on current research and future trends, as we intended to emphasise priority areas in which Australian research can make a contribution to the national industry and provide information on likely trends in welfare that may affect the industry. Because of the political framework outlined in a Senate Report (Anon. 1990) and the recent review on layer hen housing in Australia (Anon. 1994), which has provided some stability for the industry, it was decided to review research published in bibliographies since 1992. However, because of delays in publishing research work, this time-frame probably covers research conducted from 1990. Also, where considered relevant, some earlier citations have been used. This time-frame was considered sufficient to give indicative trends of research emphasis and direction.

Since the late 1980s there have been a number of publications, including books, on alternative housing (Kuit et al. 1989) and welfare (Appleby et al. 1992a); conference proceedings and articles on the laying hen in conventional cages and alternative systems (Carter and Carter 1992), modified cages (Appleby 1993b, 1994; Appleby and Savory 1993; Sherwin 1994), and poultry welfare (Savory and Hughes 1993); and reports on welfare that are either relevant to, or commissioned by, the Australian industry (Anon. 1990, 1991, 1994; Appleby 1991; Temple 1994; Kirkden et al. 1995, which is on broiler welfare but contains sections relevant to the laying hen, e.g. transport and slaughter). In addition, there are reviews in scientific journals on poultry welfare (Mench 1992; Craig and Swanson 1994).

Thus, there is a considerable body of scientific literature accumulating on poultry welfare and some of it is reviewed here. Although the large volume of literature makes it difficult to pick all trends, the major welfare-related issue confronting the egg industry worldwide, in those countries where animal welfare is on the political and industry agenda, is poultry housing, in particular the housing of laying hens in battery cages, and this will be a focus of this review. An issue not covered in this review is that of welfare assessment. The reasons for this are 2-fold; firstly, the methodologies used are outlined in the cited literature, and secondly, it was considered that it would detract from the more issue-focused orientation of the review. Nevertheless, welfare assessment is an important issue and ongoing basic research is required if valid recommendations are to be made to industry.

The review is structured under the following main headings: Housing (which includes conventional cage, modified cage, and non-cage housing); Management (including beak trimming, molting and feed restriction, light, temperature, handling and fear, transport, and slaughter); and Health, if it appeared to relate to welfare. Occupational health and safety was also included, because whereas it does not directly affect bird welfare, poor working environments are likely to have an indirect impact on bird welfare because of a possible deterioration in work ethic (Hemsworth and Coleman 1996). In relation to health, although it could be argued that all aspects of health affect welfare, a considerable amount of research is on vaccine developments and management schedules where the emphasis is clearly health rather than welfare. Therefore, such literature has not been included in the review. Under each section of the review, an attempt has been made to provide an overview and an interpretation of the research in terms of what it means for bird welfare, likely trends for the industry to be aware of, and opportunities for research. It should be recognised that the topic headings are arbitrary. For example, beak trimming, which appears under the topic of management, is also relevant to housing, whereas weak bones are discussed under both housing (perches and bone strength) and management (handling). Similarly, issues such as fear are relevant to both housing and management (handling). Some health issues are referred to in the section on housing (e.g. bumble foot associated with perches). Nevertheless, for simplicity, most of the limited ‘health’ issues have been addressed in a separate section.

Housing

This section includes subsections on cage modifications and non-cage systems and includes one of the major welfare issues for poultry welfare, which is the incidence of weak and broken bones. The latter issue is also covered in a Housing subsection on perches and is also addressed in the Management section in a subsection on handling. Notwithstanding the apparent support for modifying cages to improve welfare, there is some scientific recognition of welfare advantages of both conventional and modified cages (compared with non-cage systems), particularly in terms of hygiene and small group size (Dun 1992; Reed and Nicol 1992). It must also be borne in mind that there is a recognition that no housing system, whether cage or non-cage systems, meets all aspects of welfare and production criteria (Elson 1992; Craig and Swanson 1994; Gerken 1994), and thus poultry production, as for any animal production system, involves a series of compromises that have impact on welfare, production, and economics. An issue applicable to any system, on which there appear to be no recent data, is the ease
of inspection. This is important, as compliance with recommended frequencies of inspection (e.g. at least once daily; Anon. 1992) is an important management objective that may be difficult to meet in some systems.

**Cage modifications**

Although there appears to be an inability of scientists and others to agree on the need for non-cage systems (e.g. Carter and Carter 1992), alternative housing systems are being actively promoted in some countries. For example, Switzerland has banned the battery cage; Sweden is due to ban the battery cage in 1999 (although a 1996 review by the Swedish Board of Agriculture has recommended that the ban be lifted and that cages contain improvements such as a perch and a nest; a decision is expected to be made by February 1997; R. Tauson, pers. comm.); The Netherlands have been encouraging producers to use non-cage systems; and in the UK, marketing initiatives surrounding program such as ‘Freedom Foods’ preclude the use of conventional cages. Whereas it is sometimes difficult to understand fully the motives for some of these initiatives, as they are often a complex intermingling of economics, public perceptions, and political expediency, there is a desire either to improve the welfare of birds or to remove the issue from the political agenda. Some Australian producers recognise the ‘pressures’ on conventional cage housing and are pursuing alternatives to the battery cage, e.g. barn systems.

Overseas, the proponents of alternatives to conventional cages are in 2 main camps: those proposing non-cage systems and those proposing enriched cage systems (i.e. cages that may include perches, dust baths, and nest boxes). Again, these persuasions can be affected by the political agenda. For example, in Sweden where battery cages are to be banned, there is ongoing research on non-cage alternatives (Tauson et al. 1992; Abrahamsson and Tauson 1995). Nevertheless, as Sweden does not permit beak trimming, the performance and welfare of birds in the non-cage systems (in the above studies) are poorer than in cages. The result is support, by default, for enriched modified cages as an acceptable alternative to the battery cage (Tauson and Abrahamsson 1994; Tauson 1995). In the UK, where enriched modified cages were developed (Appleby 1993b; Hughes and Sherwin 1994), there appears to be considerable support for this system(s). Also, on the basis that the 5 freedoms (see Appleby 1991) prescribed in ‘Freedom Foods’ (UK, RSPCA marketing initiative, see above) cannot all be met in battery cages (Appleby 1993a; Baxter 1994), this tends to lend support for enriched modified cages. However, it must be recognised that there is some circularity in this latter argument because included in the 5 freedoms concept is the perception that close confinement is unacceptable. In the USA the welfare pressures on the laying industry appear less than in Europe (see Craig and Swanson 1994).

**Modified cages**

There has been considerable research on modifying conventional cages. This has included simple modifications such as inclusion of a perch to reduce the risk of bone breakage by increasing bone strength or volume (Appleby et al. 1992b; Abrahamsson and Tauson 1993; Hughes et al. 1993; Sherwin 1993; Wilson et al. 1993; Alvey and Tucker 1994; Fleming et al. 1994); an abrasive strip to maintain claw length to reduce the risk of entrapment, based on the work of Tauson (1986a), Niekerk and Reuvelkamp (1994), and T. van Niekerk (unpubl. data); or modifying cage fronts, by having horizontal bars to increase concurrent feeding behaviour (Sherwin et al. 1993; Tanaka et al. 1993). There are more sophisticated systems that also include nest boxes and/or dust baths, to provide birds with the opportunity to perform nesting and dust bathing behaviours (Nicol 1992; Petersen 1992; Reed and Nicol 1992; Sherwin and Nicol 1992; Appleby et al. 1993, 1994; Sherwin 1993; Hughes and Sherwin 1994; Reed 1994; Petherick et al. 1995).

**Perches and bone strength**

There is a recent comprehensive review of perches in conventional cages, and nest boxes and dust baths in modified cages (Ekstrand and Keeling 1994); we will not reiterate that literature in this review. Those authors conclude that, because of the potential benefits of perches in relation to increasing leg bone strength, reducing feed intake, and keeping birds calmer, and their low cost of installation, cages should contain a suitable perch. However, the perch must be correctly positioned, although the data are equivocal and there is still the risk of bone breakage during the depopulation process. Abrahamsson and Tauson (1993) suggest that perches should be 17 cm from the back rather than centrally placed (24 cm from the back) to improve cage hygiene without restricting bird movement. However, Alvey and Tucker (1994) showed reduced bone breakages on depopulation when perches were 18 v. 13 cm from the back of the cage (cage dimensions were not reported). In the latter study, the presence of perches had no effect on the strength of the tibia. Thus, while the mechanism for reducing bone breakages is unclear, Knowles et al. (1993) have shown a reduced risk of bone breakages (from birds in cages) in birds with stronger bones. Also, to add to the confusion in the literature, birds
reared up to 18 weeks of age in cages had stronger humeri bones and fewer broken bones at the end of lay compared with floor-reared birds (Gregory et al. 1991).

A recent study by Barnett and Glatz (1995) confirmed that perches (21 and 24 cm from the back and front of the cage, respectively) resulted in increased strength of the tibia and also resulted in increased dirty and cracked eggs. Although placing the perch further back in the cage may reduce the incidence of dirty eggs, most studies agree that the incidence of cracked eggs is increased. An economic assessment of the production data from this experiment based on the variable egg income minus feed costs showed that perches on their own reduced the financial return compared with conventional cages (financial returns were 1.49 v. 1.52 cents/bird-day), although if solid sides were also included in the cage, returns were improved (1.68 cents/bird-day) (J. L. Barnett and P. C. Glatz, unpubl. data 1996). Further validation of this economic analysis of perches in cages under Australian conditions is required if the welfare advantages of incorporating perches into cages are to be maximised by industry.

As mentioned previously, the risk of bone breakage is still generally apparent when cages are depopulated, notwithstanding the presence of a perch. Removing birds from cages by both legs significantly reduced the percent of femur breakages from 7.4 to 0.6% of birds (Gregory et al. 1992) and, if validated in the Australian industry, should be a recommended procedure during depopulation. Other factors such as lighting regimes have not affected bone strength (Gregory et al. 1993), and using drugs (bisphosphonates) developed for treatment of osteoporosis in humans improves bone morphology (Thorpe et al. 1993). In addition, a study by Koelkebeck et al. (1993a) showed an increase in bone strength by providing carbonated drinking water during warm weather. Also, the relationships between diet, growth rate, egg production, and osteoporosis, being developed into a model of osteoporosis by Parkinson et al. (1996), should result in practical methods of dietary manipulation to reduce the incidence of osteoporosis. Innovations such as these should be researched to help minimise the impact of low bone strength on bird welfare.

Current recommendations for perches are for elliptical wooden perches with flattened tops and bottoms (vertical cross section of 3-1 cm and horizontal cross section of 3-6 cm) installed 17 cm from the back of a 48-cm-deep cage and 7-7.5 cm above the floor and with sufficient perch space [15-18 cm per hen, although Appleby (1995) indicates that 14 cm is adequate for medium weight hybrids] so that all birds can perch simultaneously. This shape of perch reduces the incidence of bumble foot compared with rectangular perches. Plastic perches increase the incidence of bumble foot (Oester 1994). In the study of Glatz and Barnett (1996) where rectangular perches were used, the foot condition, which was subjectively assessed using the 4-point scoring system of Tauson (1984), was worse in cages with perches, but the differences were only small (3.6 v. 3.8 for birds in cages with and without perches, respectively).

Nest boxes, dust baths, and environmental enrichment

The review by Ekstrand and Keeling (1994) also provides evidence to support the inclusion of nest boxes and dust baths in cages, i.e. enriched modified cages. Duncan (1992) considers that the lack of a nest site in conventional cages is the biggest welfare problem in this system of housing. The importance of the nest box is based on evidence of preference tests and evidence of frustration in the absence of a nest box (see review by Ekstrand and Keeling 1994), and the strong motivation of hens to use a nest (Smith et al. 1990). Cooper and Appleby (1995) have considered the controversy over whether animals can be frustrated or experience a sense of deprivation by not having certain resources that they have never experienced. For nestling, they found no differences in the motivation of birds to use a nest between birds experienced or inexperienced with a nest, although it is not known if this leads to chronic frustration. However, Hughes et al. (1994) showed that naive birds did not recognise a visual stimulus with some features of a nest, although it must be recognised that the birds in this study were unable to interact physically with the ‘nest’. A study by Webster and Hurnik (1994) suggests that birds may synchronise their behaviours within cages and this may have welfare implications if nest sites are limited. However, as indicated above, although there has been considerable work on nest boxes, there are no current clearly accepted design recommendations that satisfy both the hen and industry requirements. Aspects examined have been nesting material, where a preference was shown for artificial-turf nests over roll-away nests or those with litter (Appleby et al. 1993), nest floor preferences (plastic floors were preferred, although there was no aversion to wire floors; Sherwin and Nicol 1994), and size and quantity of nests, nest height, nest floor surface, and nest partitions (Reed 1994). The latter author has provided design recommendations on a nest/cage design for 4 birds: 3 nests were incorporated at the rear of the cage, in the form of pre-moulded, roll-away, plastic, flat-floored nests with hollows (25 by 31 cm/nest) and with the floors flush with the cage floors. Attractiveness was enhanced by
lining the hollows with smooth neoprene rubber. To compensate for the lack of a peckable substrate, strips of artificial grass were attached to the rear of each nest. A perch was provided to reduce nest soiling.

Nevertheless, in spite of the above recommendations, the problems to be overcome include roosting in the nest boxes, laying eggs outside of nest boxes, the higher incidence of cracked eggs, and using the nesting material, when it is provided, for a dust bath. To reduce the use of the nest box as a dust bath, dust baths have generally been provided in enriched modified cages, although the welfare evidence for their inclusion appears less than for nest boxes. For example, Petherick et al. (1993) suggest that birds are not highly motivated to dustbathe, whereas Liere (1992) suggests that dust baths are essential to maintain feather integrity and for welfare. Notwithstanding any possible direct effects of dust baths on welfare, dust baths appear to increase the effectiveness of nest boxes, by separating nesting and dust bathing behaviours to different areas of the cage. Studies have shown that hens do not make any great effort to obtain access to litter or sand (Faure 1991; Faure and Lagadic 1994), although they prefer litter to wire mesh (Lagadic 1992). Also, in experiments with young chickens, Sanotra et al. (1995) indicate a risk of pathological feather pecking when straw or wood-shavings are used as a substrate, although Norgaard-Nielsen et al. (1993) showed that rearing with access to sand or peat reduced subsequent feather pecking and that access to straw, as an environmental enrichment during the layer phase, also reduced feather pecking. Rudkin (1996) has also shown positive effects of hay, during both rearing and the laying period, in reducing feather pecking. Other forms of environmental enrichment, such as adding objects to feed troughs, are considered to improve welfare (Sherwin 1995), and coloured plastic enrichment devices placed in cages reduced mortalities through a redirection of pecking behaviour (Bell et al. 1995; G. Gvaryahu, pers. comm. 1995). If these enrichment devices are practical, they may be a simple way of reducing mortalities.

Although many of the practical problems of nest boxes and dust baths have been overcome, enriched modified cages appear to require some development prior to their introduction into the commercial industry. Studies are currently underway in the UK in a semi-commercial environment (M. Appleby, pers. comm. 1995). It has been estimated (Elson 1994) that these modifications will increase egg production costs by 10–20% over conventional cages. Also, surveys of public opinion suggest that modified cages are only slightly more acceptable than conventional cages (Rogers et al. 1989) and this should be taken into account in a cost–benefit analysis for the Australian industry, although as indicated by Duncan (1992), more focus should be put on bird welfare rather than public perceptions. If enriched modified cages are adopted overseas, the Australian industry will probably find itself under pressure to follow suit.

**Applicability of overseas research to Australian conditions**

As well as the above recommendations, another recommendation, based on the work of Tauson (1986a), is the inclusion of abrasive strips on the manure deflector in front of the feed trough, to reduce the risk both of entrapment and of claws overgrowing and breaking; the strip should be 8 mm wide. Some recent work by T. G. C. M. van Nickerk (unpubl. data) attempted to reduce the labour inputs associated with putting abrasive strips in cages by using a perforated egg baffle. However, this modification had no effect on claw length. There would appear to be no reason why a method, based on Tauson’s work (1986a), to reduce claw length should not be applied to the Australian industry.

Since the work of Tauson (1984) on solid sides in cages to improve feather condition, the only work on this modification has been that of Barnett and Glatz (1995) and Glatz and Barnett (1996). Although solid sides improved welfare by reducing the level of stress, this modification under Australian conditions of an open-fronted, naturally ventilated shed, resulted in higher mortalities, particularly in hot weather, unless a perch was also included in the cage, and thus cannot be currently recommended unless a perch is also incorporated into the cage. Although solid sides do result in improved feather condition and there is undoubtedly a relationship between feather condition and cover and production efficiency, the relationship between feather condition and welfare has been questioned (Appleby 1991; Barnett and Glatz 1995). However, Biedermann et al. (1993) showed that plumage condition was related to mortality, egg production, and egg quality, although at high temperatures, partial or complete feather loss improved production (Peguri and Coon 1993). The above study on modifying cages by replacing conventional mesh partitions with solid sides indicates that it is important that recommendations from overseas are validated under Australian conditions for their impact on bird welfare. This finding has obvious relevance to other overseas recommendations on enriched modified cages.

**Non-cage systems**

Unfortunately, research on non-cage systems has been considerably less thorough, with a major emphasis being on the solving of practical problems
rather than developing an understanding of some of the principles through a systematic scientific approach. Although this may be understandable because of both the politics of apparent urgency and the expense and time involved in researching non-cage systems, the end result is a dearth of reliable data. With the exception of the studies by Tauson et al. (1992) and Abrahamsson and Tauson (1993, 1995), which are replicated experiments, most of the other studies have either minimal or no replication (Methling and Grunwoldt 1992; Engstrom and Schaller 1993; Swiss Society for the Protection of Animals 1994; Taylor and Hurnik 1994) and thus it is difficult to draw rigorous conclusions from them, and Elson (1992) recommends considerable caution. Nevertheless, there is considerable support for these non-cage systems, in part on the basis of the increased behavioural repertoire they permit (Tanaka for these non-cage systems, in part on the basis of the increased behavioural repertoire they permit (Tanaka 1992; Taylor and Hurnik 1994) and lower levels of fear in the tonic immobility test (Hansen et al. 1993). A number of alternative systems, including details of economics, advantages, and disadvantages, are described in Kuit et al. (1989).

Although there is a lack of scientific knowledge of these systems as a whole, there is considerable industry experience, particularly with the use of the barn system, which is based on some traditional elements of poultry husbandry that were in use prior to the introduction of the battery cage. Also, some of the components of the system have been systematically studied, e.g. see the citations in the previous section on bone strength, although it has been identified that all systems with perches result in keel bone deformation (Engstrom and Schaller 1993). Other aspects that have been or are being studied are spacing between perches (Scott and Parker 1994; their data suggest that birds are less successful negotiating distances >1·0 m), space allowances for different behaviours (the frequency of walking and ground pecking were reduced as space allowance decreased; Keeling 1994), and rearing conditions (low density rearing results in less feather pecking prior to the laying phase; Hansen and Braaastad 1994). Whereas it has been shown that hens prefer to congregate with familiar rather than unfamiliar birds, although the unfamiliar birds become familiar with experience (Bradshaw 1992), the relevance of this to welfare and housing design is unknown. There is an urgent need for replicated experiments on a number of welfare variables in non-cage systems. Industry statistics on mortalities could be collected, from both overseas and locally, to provide limited information on welfare and additional information on production, floor eggs, egg quality, etc., which may be used to encourage producers to use these alternatives. With estimates of 9% of eggs sold from non-cage systems in Denmark (Simonsen 1992) and 5% of eggs produced in the UK in barn-type or more sophisticated tiered systems (Scott and Parker 1994), and other estimates of 12–15% (Elson 1991) for the ‘Freedom Foods’ type of market and, similarly, with a number of producers in The Netherlands using these systems, these statistics should be relatively easy to collect.

**Space allowance**

Although the issue of space allowance is controversial, it is effectively not a current issue in the Australian industry because of a recent review (Anon. 1994) which endorses, with some restrictions, 450 cm²/hen. Also, the issue has recently been reviewed (Temple 1994). Nevertheless, this issue is likely to remain controversial, in particular, the interactions between space allowance and group size need resolving, as there is limited evidence that increasing space may not improve welfare, on the basis of the level of stress (Barnett 1994; Barnett and Glatz 1995). The work of Faure (1994) shows the large individual group differences in preferred space allowance and should be extended.

**Management**

**Beak trimming**

Beak trimming is a prophylactic measure against cannibalism in laying hens. Recent studies, as with many earlier studies, have shown that beak trimming reduces mortalities (Craig 1992; Carey and Lassiter 1995). Beak trimming is a central issue to the type of housing that can be used for laying hens. For example, the research of Tauson (see Housing section), using birds that were not beak-trimmed, suggests that if beak-trimming is not permitted, it is unlikely that non-cage systems will be effective. There has been considerable work on beak trimming in Australia, particularly by Glatz and Lunam. This work has shown that beak-trimming may not be as painful, in terms of chronic pain, as originally thought (Lunam and Glatz 1993, 1995; Glatz and Lunam 1994). Nevertheless, based on the early work of Gentle (see Gentle 1992 for a review), with birds that were 5 weeks old, there is a very strong belief that beak-trimming is painful. The studies of Glatz and Lunam suggest that it is the age and amount of beak removed that are the major determinants of persistent neuromas and supposed chronic pain in adult hens. Other studies have shown that a single trim at 10 days of age is as effective in terms of production criteria as trimming at 10 days and again several weeks later (Craig et al. 1992; Carey and Lassiter 1995). Struwe et al. (1992) suggested that beak trimming resulted in reduced overall chronic stress levels, on the basis of reduced adrenal gland weights, and that short-term problems associated with beak...
trimming, at 10 days of age, were of less consequence than later potential problems associated with intact beaks. Behavioural studies have shown that birds that are beak-trimmed at 6 weeks are less responsive to preening a novel stimulus attached to their feathers (27 v. 8 s to commence preening) (Liere 1995). The author interprets the reduced responsiveness as indicative of reduced welfare, although another explanation is that beak-trimmed birds may preen less. It is yet to be determined if a single trim will prove as effective in Australia as trimming several weeks apart. Although this research may result in a reduced frequency of the practice, the issue of beak trimming remains controversial.

An alternative approach is the breeding of strains of birds that do not require beak trimming and yet still have the required production attributes. A program has been underway at Purdue University over the last 12 years (i.e. 6 generations of hens) to select hens for production traits in multiple-hen cages (Muir 1994; Craig and Muir 1995). Preliminary results suggest that selection for general survival and increased egg production of intact-beaked hens in multiple bird cages resulted in reduced mortality from cannibalistic pecking and improved feathering; overall mortalities to 44 weeks of age were 8 and 22% for selected and unselected treatments. There is also the suggestion, based on survivability and mortality, that well-being of the selected line was improved (Muir and Liggett 1995). These data show some potential benefit in genetic improvement by housing birds in appropriate environments (i.e. cages) for the purposes of selection. If these birds become available commercially, it would obviously be of value to import and trial these birds under Australian conditions.

Moulting and feed restriction

Current and recent research in this area is mostly on economical and practical ways of moult and post-moult feeding to induce a moult and recovery of egg production in laying hens (Bell and Kuney 1992; Scholtysshek et al. 1992; Koelkebeck et al. 1993b; Ruszler 1996). However, there has also been some work on the length of fasting necessary to induce an effective moult. Koelkebeck et al. (1992) have shown that fasting for less than 10 days can produce satisfactory egg production and egg weight, but eggshell quality may be improved by fasting for longer periods. Findings by Rolon et al. (1993) on the economic impact of moulting methods involving shorter periods of feed withdrawal and different compositions of moulting diets have welfare implications as they suggest that periods of feed withdrawal of 24 h or less can be as effective (economically) as conventional methods using longer periods of feed withdrawal. This approach would at least limit the time that hens are continuously being fed ‘inadequate’ diets that are novel and/or unpalatable.

Other work that may eventually have an impact on welfare is that attempting to gain a better understanding of some of the mechanisms that regulate ovarian function in poultry (Petitte and Etches 1991; Dickerman et al. 1992; Johnson and Brake 1992; Advis and Contijoch 1993; Hocking 1994; Vanmontfort et al. 1994). For example, the in vitro study of Johnson and Brake (1992) showed that whereas adding zinc to the diet induced moulting primarily by reducing feed intake, lower concentrations (2·8 v. 10·0+ ng/g ) may have a direct effect on granulosa cell function, and Advis and Contijoch (1993) have shown that changes in facilitatory to inhibitory inputs on luteinising hormone neuronal terminals in the median eminence may account for differential effects of feed restriction at the start and end of lay. Thus, direct manipulation of ovarian function may be a more acceptable alternative to feed restriction and moulting. Tilbrook et al. (1992) have shown that manipulation of the hypothalamic–pituitary–ovarian axis with an agonist of gonadotrophin-releasing hormone reduced the secretion of luteinising hormone and caused a pause in egg production, although this was not as large as in feed-restricted birds. The fall in egg production was achieved without affecting feather condition and cover or body weight. Development of this methodology could make a contribution to the welfare concerns surrounding current feed-restriction procedures. Another reason for pursuing an alternative method of moulting induction is that this procedure appears to suppress the immune system, as demonstrated by the increased risk of infection in moulted versus non-moulted birds (Holt 1995). Similarly, introducing new birds into an established flock or withdrawal of feed and water for 2 days increased shedding of infectious organisms (Salmonella enteritidis; Nakamura et al. 1994). Induced moulting via dietary restriction is not currently considered to be a significant welfare issue in the Australian political environment (Anon. 1990).

Light (and cannibalism)

As for the studies on moulting and associated feed restriction in the previous section of this review, most studies on the effects of light refer to the effects on production parameters, although there is some impact on welfare, particularly the lower mortalities associated with lower light levels or intermittent lighting regimes (Lewis et al. 1992). There is also interest in the effects of light and its interaction with feed restriction on egg production (Lien and Roark 1993; Morris 1994). The interest in light and its relationship with mortality
is particularly relevant in those countries where beak trimming is not a requirement because of the use of environmentally controlled sheds and low light levels that can reduce cannibalism. Nevertheless, in Sweden, which does not allow beak trimming, there is also a requirement for sheds built after 1993 to have windows (Wachenfelt and Jonsson 1993); this may lead to increased variation in mortalities between flocks. Some of the possible factors involved in cannibalism, such as a change in diet and feed palatability, have been briefly discussed (Curtis and Marsh 1993). In Australia, the relevance of light to welfare (and production) is less because many sheds are open to ambient light and birds are beak-trimmed. If beak trimming were to be prohibited in the future, the overseas knowledge on low light levels to reduce cannibalism and intermittent light schedules to maintain production would have to be reviewed and adopted. Also, a current housing option using open-fronted sheds and exposure of hens to ambient light would have to be reassessed.

From a direct welfare viewpoint the impact of compact fluorescent lights has been assessed to determine whether laying hens find the associated ‘flicker’ aversive (Widowski et al. 1992). The authors concluded that as birds chose to spend more time under fluorescent light (73 v. 27% for fluorescent and incandescent light sources, respectively), either the birds did not perceive the flicker of the fluorescent lights or perceived the flicker and did not find it aversive, or they found some aspects of the fluorescent light more attractive than incandescent light. On the basis of this study, producers may find the compact fluorescent lights of economic benefit which may also benefit bird welfare, although why the birds prefer this light source is unknown.

Another study that may have indirectly manipulated light levels compared birds fitted with red plastic contact lenses in an attempt to eliminate cannibalism (Adams 1992). However, this manipulation significantly increased mortality, thought to be due to the inability of many birds to locate the feed.

**Temperature and cooling birds in hot weather**

It is again unclear whether research in this area has been because of welfare concerns or because of the detrimental effects of hot environmental conditions on appetite and production. Nevertheless, the research on temperature–nutrition interactions probably has some potential welfare benefits. For example, in hot conditions, adding vitamin C to diets minimised the fall in egg production and appeared to have some positive implications for health by preventing reductions in bactericidal and phagocytic activity of blood (Abramyan and Kostanyan 1990), and increased shell thickness (Mandlekar 1994). In hot conditions, adding sodium bicarbonate had a similar beneficial effect on egg production (Bonsembiante et al. 1991), and protein intake was increased if birds were given free-choice diets (Sulandari et al. 1994). There appears to be no advantage in rearing birds in hot compared with temperate environments on their subsequent acclimatisation and performance in hot environments (Njoya and Picard 1994).

Housing birds in cages compared with floor pens may be detrimental in hot weather unless the shed is adequately shaded (Alawadi et al. 1995), although this is unlikely to be a problem in the Australian industry, where sheds invariably have blinds to provide shade. Preliminary work by Harrison et al. (1993) has shown that at 35°C, birds will spend 54% of their daily time budget in contact with a conductive cooling apparatus (water-cooled metal pipe) if the circulating water is at 20°C, compared with 4% of their time when water was not circulated through the pipe. There was a concomitant increase in production and a decrease in metabolic heat load by 20%. Similarly, some current work by Glatz (1996) indicates benefits of providing birds with cool drinking water (20°C), particularly as water temperature in some sheds can exceed 30°C. However, no advantage of providing cool water was apparent when ambient temperatures were in the range of 25–28°C (Damron 1991). Temperatures in Australia regularly exceed the upper critical temperature of hens (37°C; Appleby et al. 1992a), and hence, methods of cooling birds may be beneficial to welfare. Other research has shown that evaporative cooling should be used in conjunction with increased ventilation rates when ambient temperatures exceed 35°C (Timmons and Hillman 1993). The Australian industry would probably benefit from development work in the area of building design to produce some cheap, practical, and reliable systems to cool birds. Improved design features, e.g. through the use of reflective paints (Bucklin et al. 1993), are also relevant. Temperature and humidity are also an issue in non-cage systems (Sreenivasaiithal and Appannavar 1993).

**Handling (including fear, transport, and bone strength)**

There are a number of times that birds are physically handled, mostly involved with the slaughter process, including removal from cages, movement to the truck(s), transport *per se*, unloading at the abattoir, and shackling prior to slaughter. One issue, bone breakages due to weak bones at the end of lay, in particular associated with conventional cages, has been partly addressed in the section on housing. Nevertheless, the fact that 29% of laying hens from cages and 14% from free-range systems have a broken bone by the
time they reach the waterbath stunner at the abattoir, as a consequence of handling and transport (Gregory and Wilkins 1989a; Gregory et al. 1990), is a major welfare issue that must be addressed. Some of these problems occur as a result of cage design, and certainly improved door design, for example S-shaped, full width doors as described in Tauson (1986b) and Elson (1990), should improve access and reduce the risk of bone breakages when removing birds from cages. However, changing the design of the door to reduce the chance of breaking bones during handling may not be a very acceptable solution to the problem. It would obviously be preferable if bone strength and handling at depopulation were improved so that the risk of broken bones is reduced. The provision of perches in conventional cages improves bone strength (Gregory et al. 1991), although there can be detrimental consequences on production or egg quality (Ruszler and Quisenberry 1970; Tauson 1986b; Abrahamsson and Tauson 1993); perches have been reviewed in the section on housing. However, although there appear to be clear advantages to the strength of the leg bones by provision of perches, the effects of perches on non-load-bearing bones are unclear. These latter bones may derive no benefit from perches (Barnett and Glatz 1995) or be adversely affected by perches; Appleby (1993a), Appleby et al. (1993), Abrahamsson and Tauson (1993), and Engstrom and Schaller (1993) reported damage to the sternum due to perches.

As the range of bone damage between flocks varies from 0 to 53%, this suggests that an understanding of the factors involved will reduce the magnitude of the problem (Gregory and Wilkins 1992). Factors determined to date that can reduce the incidence of broken bones are rearing pullets in cages instead of on deep litter (although this may pose other welfare concerns; see Housing section), delayed onset of sexual maturity, opportunity to exercise, depopulating cages by catching and holding birds by 2 legs, and modifications (as yet undetermined) to the shackling procedure (Gregory and Wilkins 1992). The effects of diet have been discussed in an earlier section of this review, Perches and bone strength.

Mechanised handling

In attempts to reduce the trauma associated with manual handling, mechanised handling systems have been developed (Moran et al. 1993; Moran and Scott 1993; Scott 1993). The welfare implications of mechanical systems have been assessed on the basis of fear responses of hens when being moved horizontally or on an incline and their responses to humans (Scott and Moran 1992, 1993a; Moran et al. 1993), as well as responses to noise and motion (Rutter et al. 1993; Scott and Moran 1993b). On the basis of a longer duration of tonic immobility responses following manual conveyance and shackling, Scott and Moran (1993a) suggest that these procedures were aversive and that there are potential benefits of mechanical systems for welfare. Although mechanical systems may be a reality of the future, including robotic shackling, they require considerable research and development and it is unlikely that humans will not be involved in manual handling for some considerable period of time. Alternative methods to reduce fear of humans (see following section) may have significant implications to improving welfare when handling is required. For example, Jones (1992) has shown that rough handling, similar to that which can occur prior to transport, is associated with higher fear responses, as demonstrated by the duration of tonic immobility. Also, Jones (1994) recognises the importance of fear of humans to the welfare of chickens, for example through its impact on panic reactions, and sees that its reduction is an important objective for both welfare and productivity.

Transport

Most work on transport has been with broilers, presumably because of their greater value than layers, and this research has been recently reviewed by Kirkden et al. (1995). General reviews referring to broilers and/or laying hens are those of Broom (1990) and Nicol and Saville-Weeks (1993). Nevertheless, many of the principles will be similar and the findings for broilers probably can be extrapolated to laying hens. Heat stress is a major cause of broiler mortality in the UK (Bayliss and Hinton 1990) and, hence, is likely to have greater implication in Australia and is also of likely importance for laying hens. A thorough research program to define and solve the problems associated with high heat loads during transport has been undertaken (Kettlewell and Moran 1992; Kettlewell et al. 1993; Mitchell and Kettlewell 1993; Webster et al. 1993). This work has resulted in improvements in vehicles such as fully enclosable truck bodies, by moveable curtains that automatically respond to temperature and humidity within the load, to adjust the ventilation rate, to maintain the thermal environment within the birds’ thermal limits, and the provision of real time thermal data to drivers (G. Mitchell, pers. comm. 1995). Other possible improvements are the inclusion of fans to maintain air flow in the vehicle at rest (Webster et al. 1993). Within the Australian environment, heat problems can be addressed, in part, by transporting birds at night and completing the slaughter process by mid-morning. Nevertheless, night-time temperatures can still be high and the birds themselves are a considerable source of heat that
must be dissipated to avoid distress and death. It is likely that the Australian industry could benefit from a survey of transport times and time of day of transport and any associated problems. It is unlikely, because of the sophistication of the overseas research on transport, that a similar research effort is warranted in Australia. Nevertheless, the applicability of the overseas findings to the local environment should be reviewed by comparing the overseas recommendations on temperatures and humidities with the upper levels of ambient temperature/humidity encountered during transport periods in Australia. It is recommended in the UK (for broilers) that 2-kg birds should have 160 cm²/kg during transport, which is similar to the Australian recommendations of 182 cm²/kg in hot weather and 167 cm²/kg at other times, and that every crate in a vehicle should be protected from adverse weather and be adequately ventilated, which is probably different from the current Australian situation.

Handling by, and fear of, humans

An important aspect of the slaughter process is handling by humans and this area has received little attention. This is surprising as it is known that physical handling of poultry, presumably via changes in stress physiology, can affect growth rate either positively or negatively (McPherson et al. 1961; Reichmann et al. 1978; Freeman and Manning 1979; Gross and Siegel 1979, 1980; Jones and Hughes 1981; Collins and Siegel 1987). The concern for welfare of birds during slaughter is that handling may result in high fear levels and that these fear levels may produce substantial stress responses. It is likely that the nature of the interaction with humans (i.e. whether it is perceived positively or negatively) affects level of fear of humans. It has been shown both experimentally and in commercial environments that there is a negative relationship between fear of humans and productivity of laying hens. The experimental study showed that fear of humans accounted for about 21% of the variation between birds in hen day production and egg mass output (Hemsworth and Barnett 1989). In a study involving 16 sheds at 14 commercial farms, behavioural responses to humans accounted for 23–63% of the variation in a number of production variables, including peak hen day production and the duration of a high level of production (within 2 or 5 percentage points of peak hen day production; Barnett et al. 1992). Also, similar associations were found in both open-fronted and controlled-environment sheds. The results of this study, at commercial farms, demonstrate that level of fear of humans affects the productivity of poultry; when fear is high, productivity is low. Poor handling may be indicative of other welfare problems such as inadequate surveillance and work ethic.

Preliminary research has been conducted to determine whether this fear–productivity relationship in poultry is a ‘cause and effect’ relationship and certainly, under experimental conditions, manipulating the amount (and nature) of human contact, i.e. lowering fear of humans by increasing the amount of (positive) human exposure, improved the responsiveness of the immune system, lowered the level of stress, and improved production (Barnett et al. 1994). However, our current understanding of the human factors that regulate fear in poultry is poor and some basic research and considerable applied research is required in this area before it would be possible to attempt to manipulate human–bird interactions to improve bird welfare.

Slaughter

As with transport, most work on slaughter has been with broilers rather than laying hens; again this is probably because of their value and the incidence (and cost) of birds that are dead on arrival at the abattoir. There were no references to ‘dead on arrival’ for laying hens in the literature searched. Stunning and slaughter of broilers has been well reviewed by Kirklen et al. (1995) and it is not necessary to repeat all the findings in this review. Nevertheless, the issues are likely to be similar in broilers and laying hens, namely the efficiency of the stunning procedure, the duration of insensibility, and the use of gas stunning as an alternative procedure. The major problem with electrical stunning is that the water-bath stunners, invariably used in Australia, are designed to generate a fixed voltage (Sparrey et al. 1992, 1993). Therefore, the same voltage will produce substantially different current levels in different birds because of the varying impedance of individuals. It has been recommended that a stunner be developed that is capable of delivering a constant current to individual birds (Sparrey et al. 1992). An alternative is to use high voltage stunning to induce cardiac arrest and death, although this is associated with serious carcass defects (Gregory and Wilkins 1989b). To avoid carcass damage, particularly to the breast, they recommended a maximum stunning current of 120 mA. Nevertheless, it is estimated that this would only kill 87% of birds outright compared with a 99% kill rate which would require a minimum stunning current of 131–164 mA. There is little doubt that in Australia, many birds are ineffectively stunned. Because of the low value of the laying hen carcass, stunning currents that effectively kill them before severing blood vessels should be considered.

Because of the problems of electrical stunning and the handling system that requires individual removal from transport crates and shackling, considerable effort has been put into developing gas stunning systems
Health

Because of the emergence of relatively new disease conditions such as hepatitis-liver haemorrhage syndrome (Vaillancourt et al. 1990), this has been reviewed (Mohan Raj 1993; Kirkden et al. 1995). The problems with gas stunning are that high concentrations of carbon dioxide are aversive to the birds (Mohan Raj and Gregory 1991), but this can be overcome by using a mixture of argon with 35% carbon dioxide or preferably argon alone as it is not aversive to the birds (Mohan Raj 1993). Nitrogen is also acceptable, but probably impractical because it is difficult to contain. It is also recommended that birds be killed in the gas stunner because of the quick recovery time. Modification of currents in existing stunners or the development and introduction of constant current stunners may be less costly alternatives that should be examined.

Occupational health and safety

Although occupational health and safety is not strictly a welfare issue, working conditions for staff are closely related to the type of housing system used. For example, in Sweden, where conventional cage systems are to be banned, any alternative system must meet strict occupational health and safety requirements. There seems to be widespread agreement that dust levels and ammonia concentrations (and possible human pathogens such as fungi, bacteria, and endotoxins) are generally higher in non-cage systems (Lyngtveit 1992; Drost and Drift 1993; Hauser and Folsch 1993; Koerkamp and Drost 1993; Methling et al. 1994). The emphasis on ammonia concentrations in Europe is due to European requirements to reduce ammonia emissions associated with animal production systems, because of environmental concerns. Although not included in this review, if this becomes an issue in Australia, there is a large body of literature that could be applied locally. It has been estimated it will be possible to achieve a 70% reduction in ammonia emissions (in Europe) by the year 2000 by changing over to systems that produce dry manure (Horne 1993). Similarly, technology currently exists such as ionisers (Lyngtveit and Eduard 1992) and foggers and litter replacement (Carlucci et al. 1994) to reduce dust levels. As well as a poorer environment in aviary systems, it has been calculated in Swiss non-cage systems that labour requirements are considerably increased (Huber and Amgarten 1992), although it must be remembered that these units generally only comprise 2000 hens. Other research and development currently underway that is applicable to all poultry housing systems is an attempt to control fly numbers using light generation technology (Pickens-Lawrence 1994).

Conclusions and implications for the Australian industry

The major recommendations for research needs and the implications for the Australian industry follow. Although some of the issues may be in hand, this was not apparent from the literature searched. In relation to cage housing, further economic analyses of perches in cages under Australian conditions are required if the welfare advantages of incorporating perches into cages are to be maximised by industry. To reduce bone breakage, depopulation should involve removing birds by both legs. Injuries and entrapment can be reduced by the application of an abrasive strip, and a simple way of reducing mortalities may be by using coloured plastic enrichment devices. The model currently being developed on the relationships between diet, growth rate, egg production, and osteoporosis could result in practical methods of dietary manipulation to reduce
the incidence of osteoporosis. If enriched modified cages are adopted overseas, the Australian industry will probably find itself under pressure to follow suit and it is necessary to include a survey of public attitudes on acceptability of these modified cages for bird welfare as well as trialing them under Australian conditions. In relation to non-cage housing, it is urgent that replicated experiments on non-cage systems are conducted, and industry statistics from the non-cage systems in use overseas should be collected on mortality to provide some limited information on welfare and additional information on production, floor eggs, egg quality, etc., if producers are to be encouraged to use these alternative housing systems. Some cage modifications recommended overseas have been examined under Australian conditions and indicate some adverse effects, and thus it is important that welfare recommendations from overseas are validated under Australian conditions to prevent compromising bird welfare.

Research is required to resolve the interactions between space allowance and group size. Beak trimming remains controversial and determining the extent of single and double beak trimming and the reasons for their practice may lead to a reduced frequency of use. Current research should lead to recommendations (both locally and internationally) on the age and procedures to adopt that minimise the development of chronic pain associated with beak trimming. Birds have been selected overseas, in environments that may be appropriate for the Australian industry, for reduced cannibalism and low mortalities without a requirement for beak trimming. If these birds become available commercially, it would obviously be of value to import and trial these birds under Australian conditions. If beak trimming were to be disallowed in the future, the overseas knowledge on low light levels to reduce cannibalism and intermittent light schedules to maintain production would have to be reviewed and perhaps adopted; however, this may preclude a current housing option that commonly uses open-fronted sheds and exposure of hens to ambient light.

Although moulting via dietary restriction is not currently considered to be a significant welfare issue in Australia, a more sophisticated research approach to manipulate ovarian function that does not rely on food restriction should be researched. Birds appear to prefer compact fluorescent lamps as a light source, although the reasons for this are unknown. Producers may find the compact fluorescent lights of economic benefit and there may be some benefit to bird welfare. Cooling birds by providing cool water or cool radiators may be beneficial to welfare in hot weather.

Although mechanical systems for slaughter may be a reality of the future, including robotic shackling, they require considerable research and development and it is unlikely that humans will not be involved in manual handling for some considerable period of time. The Australian laying hen industry could benefit from a survey of transport times and time of day of transport and any associated problems. If heat-related problems become evident, there is considerable overseas technology available. The applicability of extensive overseas research on transport to the Australian industry should be reviewed in terms of the range of temperatures and humidities researched and ambient temperature/humidity during transport periods in Australia. A survey of stunning currents used for laying hens should be undertaken, and if practical, a high stunning current should be recommended for stunning laying hens, as the issue of meat quality is considerably less important for laying hens than for broilers. Although industry developments in Australia on gas stunning should be supported as they will benefit bird welfare, modification of currents in existing stunners or the development and introduction of constant current stunners may be less costly alternatives.

The human-animal relationship probably has an important role in poultry welfare. However, the current understanding of the human factors that regulate fear of humans in poultry is poor. Some basic research and considerable applied research is required in this area before it would be possible to benefit from training packages targeting those attitudes and behaviours that affect fear of humans and productivity and welfare of the laying hen.

Flock health monitoring must be considered an on-going priority because of its impact on bird welfare. In the area of health and welfare, the interactions between diet and skeletal condition, disease resistance and transmission, and housing/handling and immunosuppression require further research. Any relevant improvements in technology that arise from overseas research in non-cage environments, to improve working conditions, should be assessed and, if appropriate, adopted by the Australian industry because of the potential impact of working conditions on work ethic and the implications this has for welfare.

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