

Free-range Poultry Production - A Review

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ABSTRACT : With the demand for free-range products increasing and the pressure on the intensive poultry industry to improve poultry welfare especially in western countries, the number of free-range poultry farms has increased significantly. The USA, Australia and European countries have developed Codes of Practice for free-range poultry farming which detail the minimum standards of husbandry and welfare for birds. However, the performance and liveability of free-range birds needs to be improved and more knowledge is required on bird husbandry, feed supply, disease control and heat wave management. This review examines the husbandry, welfare, nutrition and disease issues associated with free-range poultry systems and discusses the potential of incorporating free-range poultry into a crop-pasture rotation system. (*Asian-Aust. J. Anim. Sci.* 2005. Vol 18, No. 1 : 113-132)

Key Words : Forage, Nutrient Requirement, Poultry Husbandry, Animal Welfare, Free-range Egg, Free-range Meat

INTRODUCTION

There has been a resurgence of interest in free-range poultry farming in recent years in developed countries, as a result of welfare concerns associated with farming of poultry under intensive conditions. For the "best positive welfare outcome", birds should be free from hunger, thirst, discomfort, pain, injury, disease, fear and distress and able to express normal behaviours (Brambell, 1965). On the basis of these requirements, the Agricultural Committee of the Swedish Parliament defined the following four criteria for free-range birds: 1) animal health should not be worse, 2) the use of medications and chemicals should not increase, 3) the environment should not be impaired and 4) beak trimming should not be necessary (Sorensen, 1994). However, the Swedish model did not give any weight to the cost of production. Instead the top priority in assessing and comparing production systems was welfare. Stewart (2002) suggested that two more criteria should be added to the above list; 1) the natural environment be enhanced or protected and 2) product quality be maintained or enhanced. Based on these welfare criteria, the free-range system is considered the most acceptable housing system for poultry. Under free-range conditions, the birds show high vigour, a firm and strong feather coverage, warm red combs and wattles (Bogdanov, 1997). Birds show typical signs of calmness and comfort, such as dust and solar bathing, stretching wings and beak cleaning and preening (Bogdanov, 1997).

Currently, free-range is a specific term. European Union regulations demand that eggs offered for sale as free-range

must be from flocks that are kept in the following conditions:

1. The hens must have continuous daytime access to open-air runs.
2. The ground to which hens have access must be mainly covered with vegetation.
3. The maximum stocking should not exceed 1,000 birds/hectare (400 birds/acre or 1 bird/10 m²).
4. The interior of the building must conform to one of the following standards:

- Perchery (barn) - where there is a minimum of 15 cm perch space per bird and a maximum stocking density of 25 birds/m² in the building.
- Deep litter - where at least one-third of the floor area is covered with litter such as straw, wood shavings, sand or turf, and a sufficiently large part of the floor area is available to the hens for the collection of bird droppings. The stocking density should not exceed 7 birds/m² of available floor space (Thear, 1997).

Another driver for free-range poultry production worldwide is the consumer. For example in Australia it is estimated that free-range production systems account for about 6-8% of total egg production and 10-12% of supermarket shell egg sales in Australia (McMaster, 1999). The average commercial free-range flock consists of 1,000-2,000 hens. Consumers have the perception that free-range eggs are a healthy and wholesome food, low in calories and saturated fats, high in protein and vitamins. Many consumers are prepared to pay an increased price for such a product because of the higher cost of production associated with the greater land area required, increased labour output per bird, higher feed consumption and poor economies of scale in grading, packaging and distribution as compared to the cage industry. The following review was undertaken to obtain information on free-range production systems, in

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particular to identify the main management, nutritional, product quality and disease issues of concern in free-range farming.

HOUSING FOR FREE-RANGE POULTRY

Free-range farmers generally use either barns or aviaries for housing with access for the birds to the range through pop-holes, either directly or through an enclosed verandah. The free-range area can be accessed directly or via a walkway to the end of the shed to access paddocks. The pop-holes can be shut in the evening. Water is generally available outdoors. Alternatively a single pop-hole with bars, to exclude foxes, may be left open to minimise the need for after-hours labour. To minimize the amount of dirt carried back into the sheds a number of farms have wire mesh grates in front of the pop-holes. To prevent the area around sheds becoming muddy from excess bird activity, a large number of farms also have some removable material (small rocks, gravel, wood chips, wood shavings) along the length of the shed sides for about 5-10 metres away from the shed.

Both fixed and mobile shedding are commonly used in free-range systems. In Australia the sheds are open-sided with ventilation provided by adjustable blinds. The fixed sheds have litter, perches and nest boxes (either manual or automated). Paddock rotation is not routinely practised although some farms provide rotation by using electric fences. Barnett (2001) also reported that mobile sheds are used in some regions of Victoria. These house 100-500 birds and stand on a moveable sled and are towed to positions around a paddock once or twice a week. Wire floors enable droppings to fertilise the area. These sheds are generally used by grain farmers between crops. Additional light is generally not provided.

BREEDS FOR FREE-RANGE PRODUCTION

The ideal free-range egg layer should have adequate body weight at the start of lay and a good hen-housed egg production (Thear, 1997). More importantly these birds should reproduce and survive under very harsh environmental conditions (Huque, 1999). Modern strains can be successfully raised in a free-range condition with a slightly reduced rate of lay during summer (Glatz and Ru, 2002). Local breeds are inseparable from the rural scenario due to their adaptability under harsh environmental conditions. However, local breeds have low egg production and slow growth rate. Apart from these limitations, there is a good market for both meat and eggs from local breeds in both the European Union (EU) and Asia.

Selection of the breeds that are more resistant to the disease is another important strategy for free-range

production. Permin and Ranvig (2001) compared the resistance to *Ascaridia galli* infections between Lohman Brown and Danish Landrace chickens. A self-cure mechanism to *A. galli* infections was observed in both breeds. However, significantly higher worm burdens and egg excretion were found in the Danish Landrace compared to Lohman Brown chickens during primary infection. This suggests that breeding and selection of strains for resistance to diseases for free-range poultry production is possible.

Apart from the cross-breeding of local and improved strains, on-going selection and breeding for free-range production is required. Birds for free-range production should have a better feed conversion, strong plumage and not susceptible to stress. The selection against insusceptibility to stress and feather pecking are part of a breeding program, requiring data recording and selection to be carried out in an environment that resembles the production environment as closely as possible to minimise the risk of selection errors due to genotype and environment interactions. To improve egg number, shell colour and strength, the proven testing procedures established for all commercial lines are used throughout and implemented in the selection process. Optimising feed intake and egg mass output in the first third of the production cycle is the most critical trait combination in selecting birds for organic farming (Preisinger, 2001).

FREE-RANGE POULTRY MANAGEMENT

The management of free-range birds is labour intensive and very complex due to the uncontrolled environmental conditions and unpredictable diet composition. For example, the optimum temperature for a layer is 21°C, but it is impossible to maintain this optimum temperature under free-range conditions. Free-range birds forage pasture mainly within 30-40 m of the shelter and are attracted to insects (Glatz and Ru, 2001,2002). For free-range birds, trees around the paddock offer protection for foraging birds particularly from predators (Thear, 1997).

Fluctuation in temperature often affects egg production of layers. As ambient temperature declines, feed intake increases as the free-range layer consumes more energy to maintain body temperature (Portsmouth, 2000). It was also reported that in winter, for every 1°C fall in temperature from the optimum, a laying bird would need an extra 4.2 calories (Thear, 1997). However, in summer, especially under a Mediterranean environment, high temperature is one of the key factors limiting free-range production. As temperature increases, egg weight and shell thickness are reduced (Warren and Schnepel, 1940; Payne, 1966; Mowbray and Sykes, 1971) due to a reduction in energy and protein intake (Emmans, 1974; Cowan and Michie 1977). A different result was reported by Mowbray and

Sykes (1971), who found that egg production could be maintained at the same rate as that achieved by normally housed control birds when the air temperature was kept at 30°C constantly, or cycled from 30°C to 18°C or from 35°C to 13°C (10 h at the higher temperature in each case). This difference in production response of birds may be due to controlled environmental conditions used by Mowbray and Sykes (1971).

Drinking water temperature

Glatz (2001) recommends that water temperature for free-range birds should be monitored, particularly in hot weather. On free-range farms, hens should be provided cool water, particularly in hot weather. This can be achieved by regularly flushing the drinker lines, keeping incoming water lines out of direct sunlight, insulating water lines and ensuring water storage tanks are shaded. Adding ice to the header tank is another effective way of reducing water temperature in hot weather. A more expensive option is to install an external water-cooling unit to maintain incoming water below 30°C during heat waves, as water intake is reduced above this temperature. If water is too hot, birds will drink less, which will result in reduced feed intake, egg production and poorer shell quality (Glatz, 2001). During heat waves birds may not be able to keep cool in the shelter. To overcome this problem foggers can be used in shaded areas or in trees. Other options in sheds include the use of insulation on roofs, sprinklers on roofs and use of fans to increase air movement around the birds. The Australian Code of Practice (SCARM, 1995) states that the free-range housing facility must be designed to ensure adequate airflow and temperature control at maximum stocking densities when birds cluster or perch at night or during extreme weather conditions. Orientation and spacing of buildings is another important consideration to reduce the overall heat load. Planting trees around the facility also provides shade on buildings and reduces the heat load.

Stocking density

Another factor requiring consideration when establishing shelters for free-range birds is density, especially density in the shelter. The effect of stocking density on egg production has been well demonstrated. For example, the rate of lay can be depressed by 5 to 7% at 15 birds/m² compared with 7.5 birds/m² (Hill, 1985). The Code of Practice in most countries offers guidelines for free-range farmers on maximum stocking densities allowed. For example, the Australian Code of Practice recommends a maximum of 30 kilogram of bird/m² of available space indoors and no more than 1,500 hens/hectare (SCARM, 1995). In Victoria, Australia the Free Range Egg Producers Association (FREPA, 1998) recommends maximum stocking density of 750 birds/hectare. The UK Soil

Association requires that the stocking rates should not exceed 250 birds/acre (625/hectare) (Thear, 1997).

Nest boxes

In a small shelter, nest boxes need to be placed lower than the perches and in the darkest area of the shelter to attract the chickens to select their nest and discourage egg eating. Nest boxes should be above ground level to avoid floor-laid eggs; a common problem for free-range chickens. Loose material in the nest boxing is preferred by chickens. Thear (1997) suggested that straw is better than hay as it become mouldy, leading to respiratory problems in both birds and farm staff. The Australian Code of Practice (SCARM, 1995) recommends 7 birds/nest box. Shell grit is often used in nest boxes to ensure free-range birds obtain sufficient calcium and also to prevent development of respiratory problems.

Rotation

The production of free-range poultry is constrained by disease due to the accumulation of parasites and other pathogens in the paddock, especially when the birds have been housed and forage in the same paddock for a long period. Currently the recommendation to the free-range industry is to rotate the flock between paddocks. This rotation system reduces the danger of endoparasites, including coccidiosis (Folsch et al., 1988). Some farms utilise one paddock at a time for a 12-week period before rotating to the next paddock.

The incorporation of free-range poultry into a cropping system will be expected to assist in weed, pest and disease control in the crop phase, stabilise income (multiple enterprises), reduce chemical input, improve soil fertility and crop yield and change consumer perceptions. Glatz and Ru (2002) assessed the potential of using free-range poultry in a crop/pasture rotation system where free-range chickens were compared to sheep. In this study, Merino wethers were stocked at a rate of 6 sheep/paddock (0.5 hectares) giving almost twice the stocking rate of poultry when assessed on a kilogram/hectare basis (110 hens/hectare). The availability of pastures, weed and insect population were monitored during the season. The herbage availability was greater in the chicken paddock than in the sheep paddocks after 3 months of foraging (Table 1). Sheep grazed the medic pods heavily leaving only 30 g/m² of pods while poultry left 965 g/m². The paddocks foraged by free-range birds did not need to be resown with medics for the next pasture season given the high abundance of seeds. The snail population in this trial at the time of sampling was low probably as a result of the dry weather conditions. Likewise very few insects were also observed. Sheep, however, were very effective in grazing the wire weed which contaminated the paddocks whereas poultry avoided this weed. In contrast,

Table 1. Comparison of the agronomic, snail, weed and soil fertility in paddocks grazed by sheep and poultry (stocked at 110 hens/hectare and 12 sheep/hectare respectively) (Glatz and Ru, 2002)

Variable	Poultry (110 hens/hectare)	Sheep (12 sheep/hectare)	P
Plant biomass (g/m ²)	491	132	***
Dry matter (g/m ²)	417	109	**
Crude protein (g/m ²)	50	6	**
Organic matter (g/m ²)	374	91	**
Snails (no./m ²)	4	2	NS
Medic pods (no./m ²)	418	69	**
Wire weed (no./m ²)	23	0	**
Unidentified weeds (no./m ²)	5	16	***
Nitrate N (mg/kg soil)	18	24	NS
Ammonia N (mg/kg soil)	0	0.1	NS

*** significantly different at $p < 0.01$, ** different at $p < 0.05$.

NS: not significant.

the number of unidentified weeds in the sheep paddock were greater than the poultry paddock. This raises the possibility that sheep and poultry could be grazed together in some circumstances, to provide a method for reducing weed build up, using sheep to graze out weeds they prefer and poultry to consume weed seeds that sheep avoid. Soil fertility was not different between the sheep and poultry paddocks. The current project by Glatz and Ru (2002) is in its infancy and the effect of poultry foraging over a number of seasons of pasture and cropping is required before sustainability of this farming system can be fully assessed.

Beak trimming

Taking birds out of cages increases cannibalism (Wills, 2002). Although free-range systems enable greater freedom to express natural behaviour, vices such as feather pecking, cannibalism and mislaid eggs continue to be a problem in free-range (Keeling et al., 1988; Fiks-van Niekerk, 2001). A survey of Dutch organic farms with laying hens showed that 50% of the flocks have severe problems with cannibalism, 25% with moderate problems and only 25% have no or few problems with feather pecking (Bestman, 2000; reported by Fiks van-Niekerk, 2001). Feather pecking and cannibalism is more prevalent with a large group size. The presence of males has been an important factor in reducing this behavioural problem in females. A comparison of the management and husbandry of 112 free-range flocks in the UK revealed that feather pecking was greatest when a low percentage of the flock used the outside range (Thear, 1997).

Beak trimming is necessary to stop feather pecking and cannibalism under free-range conditions, especially when birds are overcrowded in the shelters (Thear, 1997). This has the result of increasing the stocking density within the house increasing the bird to bird interactions (Nicol et al., 2001). The use of plastic slats in the house reduces the risk of feather pecking. The Shaver bird has a low propensity to

use the outside range area. Farmers are generally reluctant to try and increase range use, although they are receptive to other management changes, like litter condition, diet and reducing the use of bell type drinkers (Green et al., 2000).

However, apart from animal welfare consideration, the impact of beak trimming on foraging ability of free-range birds needs to be assessed. Poor beak trimming often results in hens with poor beak condition (bubble beaks, split beaks and short beaks) and these birds are likely to have difficulty in foraging or feeding especially on free choice diets where particle size of the ingredients varies greatly (Glatz, 2000; Glatz, 2003).

FEEDING FREE-RANGE CHICKENS

Under natural conditions the fowl's diet is a very mixed one, comprising seeds, fruits, herbage and invertebrates (McBride et al., 1969). The bird browses on the herbage and forages by scratching at the ground exposing small food items. Juvenile birds' food consists mainly of invertebrates because growing birds require a high protein diet, while adults consume cereals in the autumn and winter and grass and herbage in the spring and summer (Savory et al., 1978). Most bird species will consume animal food in the first two weeks of life whereas by 8 weeks of age most bird species will subsist on mainly plant material (Savory, 1989). Under free-range conditions birds are capable of selecting a diet that is adequate for all their requirements (Hughes, 1984). With foraging occupying 7-25% of the birds time (Appleby et al., 1989), birds have a great potential to consume weed seeds and pests, which would be of great benefit in a crop/animal rotation system. However a factor which might contribute to poor performance is toxic plants and seeds on the range. Problem plants include vetch (*Vicia benghalensis*), canary grass (*Phalaris arundinacea*), heliotrope (*Heliotropium indicum*) and iron weed (*Vernonia noveboracensis*). According to the Australian Code of Practice (SCARM, 1995), poultry should not be kept on land which has become contaminated with poisonous plants. A large amount of information on nutrient requirements is available for various strains of birds under intensive housing system. For example, NRC (1994) recommended nutritional specifications for layers and broilers at different growing stages. However, the foraging activity and variable environmental conditions of free-range poultry makes it hard to apply the nutritional management guidelines recommended for intensive birds. More importantly, local breeds in Asian countries are widely used in free-range poultry production systems, with very limited knowledge of nutrient requirements of these breeds, although it is well known that the nutrient requirement is higher for free-range birds than those housed intensively.

Theoretically, the amount of feed offered to foraging

Table 2. Effect of season on crop contents of scavenging local hens (physical observation) (Tadelle and Ogle, 2000)

Season	No. of birds	Physical components (% fresh basis)				
		Seeds	Plants	Worms	Insects	Others
Short rainy	90	37.5	22.5	2.6	14.6	22.7
Rainy	90	25.8	31.8	11.2	7.7	23.4
Dry	90	29.5	27.7	6.2	11.1	25.6
Means±se	270	30.9±7.9	23.3±6.0	6.7±4.5	11.1±4.5	23.9±4.6

Table 3. Effect of altitude on crop contents of scavenging local hens (physical observation) (Tadelle and Ogle, 2000)

Season	No. of birds	Altitude (m)	Physical components (% fresh basis)				
			Seeds	Plants	Worms	Insects	Others
High	90	2,780	33.2	28.2	9.0	8.8	20.8
Medium	90	1,850	32.0	27.9	5.9	11.5	22.7
Low	90	1,550	27.7	25.8	5.1	13.1	28.3
Means±se	270		31.0±3.6	27.4±0.8	6.8±2.2	11.2±2.3	23.6±3.4

Table 4. Chemical composition of the crop contents of scavenging hens, overall means, SD and range from three of the seasons and study sites (Tadelle and Ogle, 2000)

	Chemical composition (%)	
	Means±SD (270)	Range (270)
Dry matter (DM)	50.7±12.5	26.4-85.8
As % of dry matter		
Crude protein (CP)	8.8±2.3	4.3-15.4
Crude fibre (CF)	10.2±1.6	6.5-14.0
Ether extract (EE)	1.9±0.9	0.3-4.7
Ash	7.8±2.7	1.6-15.7
Calcium (Ca)	0.9±0.4	0.2-1.9
Phosphorus (P)	0.6±0.3	0.1-2.4
Energy	2,864.3±247	2,245.1-3,528.1

birds should be the amount of feed required minus the intake from foraging. The amount of feed required changes with season and ranging conditions such as the energy cost for maintaining body temperature in winter. High temperature in summer often reduces the intake, consequently rate of lay and egg size. Increasing nutrient density (amino acids and essential fatty acids) in supplementary feed can increase the nutrient intake (Portsmouth, 2000). The amount and type of nutrients foraged by free-range birds is a mystery which limits the capability of nutritionists to formulate supplementary diets to maintain high production and egg size. Hughes and Dun (1983) reported that medium hybrid hens in small flocks on free-range with access to mash feed eat at least 50 g of pasture dry matter/day, but the actual nutrients ingested depend on the diet composition which is influenced by the type of crop, pastures, weeds and insects available in the paddock.

The amount of feed available for foraging in relation to the carrying capacity of the land areas and flock dynamics across the different seasons and agro-ecologies has not been quantified. A study in Ethiopia revealed that the materials present in the crop were seeds, plant materials, worms, insects and unidentified materials (Tables 2 and 3) (Tadelle

and Ogle, 2000). During the short rainy season, the percentage of seeds in the crop content was higher due to the increased availability of cereal grains and low availability of plant materials. There was more vegetative plant materials in the crop content during the rainy season because of the increased availability of plant materials, especially the green shoots which are palatable to the birds. However, the largest proportion of worms and insects in the crop contents were found during the rainy season.

The energy and protein supplied from the forage resources, as determined from chemical analyses of crop contents, were 11.97 MJ/kg and 8.8%, respectively (Table 4). The protein content was even lower during the short rainy and dry seasons, while the energy supply was more critical in the drier months (Tadelle and Ogle, 2002). These values were below the protein requirement of free ranging local hens in the tropics, estimated at about 11 g/bird/day, and the ME supply could only meet the requirement of a non-laying hen (Scott et al., 1982), indicating limitations of the foraging feed resources in terms of nutrient supply to increase productivity (Tables 2, 3 and 4).

While an understanding of the seasonal forage intake of free-range birds is essential for developing effective supplementary feeding strategies, it is difficult to measure the intake of foraging birds due to the lack of an appropriate method. While the visual separation of crop contents can give some guidelines on the diet composition, it cannot be used to further quantify the pasture species ingested by birds. Measuring the availability and botanic composition of pastures pre- and post foraging might indicate the preference of foraging birds over pasture species, but the result is influenced by the sampling method, regrowth of pastures and patchy foraging. Currently a method using plant alkanes as a marker has been developed to measure forage intake of grazing sheep (Dove and Mayes, 1991) and deer (Ru et al., 2002). N-Alkanes are long-chain (C25-35) hydrocarbons, predominantly with odd-numbered carbon chains, which occur in the cuticular wax of most plant material including cereal straws. Dove and Moore (1995)

showed that the species composition of the herbivore diet could be estimated from the pattern of alkanes in each diet component and the faeces of the animal consuming them. If pigs or chickens are dosed orally with synthetic even-chain alkanes, total intake and whole diet digestibility can be calculated. This provides information about total intake, the intake of different diet components and their effects on whole diet digestibility, in relatively undisturbed animals. This technique can then be used to assess other factors that may influence feed intake.

Fundamental to the use of n-alkanes to measure feed intake and diet composition of monogastrics is recovery of the marker from the faeces and consistent passage through the digestive tract. Choct and van Barneveld (1995) demonstrated total recovery of n-hexatriacontane relative to acid-insoluble ash in both ileal and faecal samples of pigs fed diets containing lupins (and hence high levels of dietary fibre) included at levels of 0, 12, 24 and 36%. Dove and Mayes (1991) also cited evidence that hydrocarbons are not utilized or metabolized in monogastric species. Wilson et al. (1999) demonstrated that recoveries of n-alkanes were consistent in pigs, did not vary systematically with increasing chain length of the alkane and were unaffected by dietary lipid content. More importantly, if only diet composition and digestibility are considered, there is no need to dose synthetic even-chain alkanes to animals. However, this method needs to be developed and validated for measuring intake and diet composition of free-range birds.

Generally, the supplementary feed should be fed outside, in a different area every day to encourage birds to forage. This is a biosecurity concern as it also provides food for wild birds which could be a source of disease (Thear, 1997). The feeding time could vary, depending on the objectives. Feeding birds in the morning outside the shelters encourages birds to forage further, but feeding birds in the afternoon in the shelter assists in getting birds back from the paddock. Bogdanov (1997) fed 150 g of cereals (wheat, corn and barley) plus 30 g/hen fresh sliced nettle in late afternoon and obtained a good laying rate (57%) for 164 days. The egg quality (normal shells, firm egg whites and yolk colour) was ideal, despite the imperfect diet. The contribution of insects, seeds and other materials to nutrient requirement of birds is significant, but the contribution of hindgut fermentation of fibrous materials to the energy requirement of birds is not clear. Most researchers believe that the energy produced by hindgut cannot be used by chickens even though Kass et al. (1980) reported that VFA produced in the large intestine of pigs can provide up to 6.9, 11.3, 12.5 and 12.0% of energy required for maintenance in the 48 kg pigs, respectively when fed 0, 20, 40 and 60% lucerne meal in the diets. However, the extent of hindgut fermentation is much less for chickens than pigs.

Biobalanced feed management systems have been developed to decrease the costs of feed for free-range poultry. This system uses the biological processes to improve the balance between the environment (especially the feed) and the bird, and between the bird (especially its excreta) and the environment. A diet made of pure nutrients mixed in the quantities required by the bird with no waste would be a perfectly biobalanced feed without environmental pollution, but it would not be economic if cheaper resources are available. The objectives of this feed management system is to reduce wastage and to provide only enough nutrients for the animal's use for maintenance and production. The reduction of the waste of resources is achieved by 1) decreasing the level of all nutrients in the diet, especially protein; 2) formulating diets to contain just the level of nutrients required by the stock by using neutral ingredients, but no supplement or premixes, and 3) assuming that free-range birds can get enough vitamins and minerals from green feed, faeces and soils. Apart from using the locally available cheaper feed resources, this system also saves the cost on feed by not processing feedstuffs (e.g. grinding, mixing, pelleting) (Dingle and Henuk, 2002) and increases the digestibility of nutrients and decreases the amount of waste excreted by 1) adding enzymes to the feed, such as phytase to reduce P output; 2) uses prebiotics and probiotics to condition the gut to more readily absorb nutrients and avoid the use of antibiotics, and decreases the nutrient partitioning that may be the reason for low productivity and 3) encourages caecal fermentation so that more B vitamins are produced there (Dingle and Henuk, 2002).

Feeding chicks

The utilisation of fat is poor for chicks in the first week of age. Application of vegetable oils such as soybean or canola oil has limited value. The inclusion of palm oil and animal fats in the diet can limit the uptake of essential elements (e.g. Ca, P) and many of the trace elements due to the formation of insoluble soaps with minerals. The diet in the first few weeks should be palatable and rich in digestible carbohydrates. Maize is a good source of carbohydrate, but is not a common ingredient in poultry diets in Australia. Wheat is used in most situations in Australia, especially in conjunction with enzymes (e.g. xylanase). Grit should be available in the paddock to stimulate early gizzard development (Portsmouth, 2000). The diet specification recommended by Portsmouth (2000) for free-range birds is listed in Table 5.

The growing stage

The energy level in the diet is critical during the post chick feeding stage, particularly in the period from ten weeks to the start of lay. Maintaining optimum stocking

Table 5. Chick starter and pre-lay feed specifications (Portsmouth, 2000)

Nutrient	Chick starter specification	Pre-lay specification
Protein, %	20-21	16-17
ME (MJ/kg)	12.0	11.5
Lysine (total), %	1.15	0.75
Lysine (avail.), %	0.99	0.65
Methionine (total), %	0.50	0.34
Methionine (avail.), %	0.45	0.31
Methionine+cystine, %	0.83	0.60
Tryptophan, %	0.20	0.17
Threonine, %	0.73	0.50
Calcium, %	0.90	2.0
Avail. phosphorous, %	0.45	0.40
Sodium, %	0.20	0.16
Linoleic acid, %	1.25	1.25
Added fat/oil	Optional	2-3%

density is important to ensure that all birds have access to feeders and drinkers to avoid uneven growth. Low energy diets from 6 to 15 weeks should be avoided. The inclusion of enzymes in the free-range poultry ration could improve the energy utilisation efficiency, especially when a large amount of fibre is consumed from foraging pastures.

Pre-lay to early lay

This is a very critical period and many free-range flocks are held back by poor pre-lay nutrition. The requirements for pre-lay are listed in Table 5. Calcium is important for the development of medullary bone, but only 2% is recommended for the pre-lay diet (Portsmouth, 2000). It was found that increasing Ca to 3% in the pre-lay diet did not enhance bone development and an excessive amount of calcium can have a negative effect on feed intake. Oyster shell is better Ca source than limestone granules because the rate of limestone going into solution is too rapid to maximise blood calcium levels over long periods (Bogdanov, 1997; Portsmouth, 2000).

DISEASE CONTROL

Mortality is high for free-range chickens in comparison with intensively housed birds (Maphosa et al., 2002),

especially during the first 6 to 8 weeks of life (Rodriguez, 2002). One of the major reasons for high mortality is disease. Free-range chickens and their eggs are more likely to be infected by pathogens than caged birds and their eggs. These chickens are susceptible to the same metabolic diseases affecting intensively kept birds, but the environment can influence their severity and make the birds susceptible to syndromes rarely found in caged layers (Mostert et al., 1995). Pennycott and Steel (2001) surveyed 27 sites in England and Wales for endoparasites and found 43% per cent of flocks were positive at 20 weeks of age, 62% were positive at 33 weeks of age, 79% at 46 weeks of age, and 81% at 59 weeks of age. In this survey, 13 flocks were not wormed at all during lay, and the results from these flocks demonstrated a similar pattern. Overall 38%, 46%, 77%, 92% of flocks were positive for worm eggs at the week 20, 33, 46 and 59 respectively (Portsmouth, 2000). Martin (1999) also found that viral infections present in free-range poultry included infectious bronchitis, infectious bursal disease, infectious laryngotracheitis and Marek's disease. A prevalence study of gastrointestinal helminths in Danish poultry production systems also confirmed the high risk of helminth infections in free-range system (Permin et al., 1999; Table 6).

There is a difference in the prevalence of ecto-, endo- and haemoparasites between sexes/ages of free-range chickens. A study conducted in Zimbabwe showed all chickens harboured ecto- and endoparasites, and 32% were infected with haemoparasites (Permin et al., 2002). The prevalences of *Cnemidocoptes mutans*, *Goniocotes gallinae* and *Menopon gallinae* were higher in adults compared to young chickens. The young chickens had higher prevalences of *Ascaridia galli* and *Raillietina echinobothrida* compared to adults, but lower prevalence of *Gongylonema ingluvicola* and *Skrjabinia cesticillus*. Similar result was reported by Magwisha et al. (2001). It is also clear that the sex of the chickens can influence the burdens of *Heterakis brevispiculum*. Dahl et al. (2002) found an interaction effect such that growing males and adult females had statistically higher ($p < 0.05$) burdens of *T. tenuis* and *A. suitoria*, respectively.

Diseases can be transmitted to free-range chickens by

Table 6. Sample size, prevalence of gastrointestinal helminth infections in Danish poultry (Permin et al., 1999)

Helminths	Free-range/organic (n=69)	Deep-litter (n=62)	Battery cages (n=60)	Parents (broiler) (n=61)	Backyard (n=16)
Farm sampled	4	4	4	4	16
<i>Ascaridia galli</i>	63.8*	41.9	5.0	-	37.5
<i>Heterakis gallinarum</i>	72.5	19.4*	-	-	68.8
<i>Capillaria obsignata</i>	53.6	51.6	-	1.6**	50.0
<i>Capillaria anatis</i>	31.9	-	-	-	56.3
<i>Capillaria caudinflata</i>	1.5	-	-	-	6.3
Cestode ⁺	-	-	3.3	-	0

N: number of animals examined, -: no helminths identified, ⁺ Cestodes were either the *Raillietina cesticillus* or *Choanotaenia infundibulum*.

* Significantly different compared to other systems ($p < 0.05$), ** significantly different compared to other systems ($p < 0.01$).

Table 7. Drug sensitivity tests on 1,248 *E. coli* strains isolated from university battery poultry, 2,196 strains from commercial battery poultry, 1,220 strains from free-range town poultry and 1,064 strains from village poultry in tropics (Ojeniyi, 1985)

	% resistant			
	A (n=1,248)	B (n=2,196)	C (n=1,064)	D (n=1,220)
Colistin	2	2	0	0
Nitrofurantoin	2	2	0	0
Nalidixic acid	0	0	0	0
Ampicillin	22	24	0	0
Chloramphenicol	11	12	0	0
Streptomycin	100	100	0	0
Sulphonamide	100	100	0	0
Tetracycline	100	100	4	6

A: *E. coli* isolates from university modern battery poultry.

B: *E. coli* isolates from commercial farm battery poultry.

C: *E. coli* isolates from free-range town poultry.

D: *E. coli* isolates from village poultry.

old flocks, wild birds, drinking water in the paddock and predators, and this is hard to control. To offer maximum protection to free-range birds, all relevant and available vaccines should be used. These include Infectious Bronchitis, Newcastle Disease, Egg Drop Syndrome (carried by wild ducks into water), Infectious Laryngotracheitis, Cholera (Pasteurella infection, carried by wild ducks), Coryza, Marek's disease, Fowl Pox (carried by mosquitos in certain areas of Australia) (Wills, 2002). Other strategies include 1) the frequent rotation of the free-range birds before the build up of parasites, 2) keeping the new birds separate from older ones (Thear, 1997) and 3) rearing chicks in confinement for the first 8 weeks of age. For the latter, the question is whether this rearing system influences the learning capability of chicks from mother hens on how to scavenge and survive in a harsh environment, although there is no clear understanding of the degree of inheritance for scavenging traits (Rodriguez, 2002).

Malnutrition of the host might influence the population dynamics of parasites in the gastrointestinal tract (Bundy and Golden, 1987; Michael and Bundy, 1991). Bundy and Golden (1987) suggested 3 major mechanisms whereby the nutritional status of the host might influence the helminth parasites, including 1) a change in the host immune system mediated by nutrition, 2) malnutrition of the helminths and 3) changes in the gut environment caused by diet. Their research also showed that the extent of parasitism increases as a result of an immunosuppressive effect caused by malnutrition in the host. The research by Permin et al. (1998) indicated that the amount of protein in the diet might have an effect on the establishment of *A. galli* infections in the gut of laying hens under free-range conditions. Raising the protein content from 14% to 18%, without changing other parameters of the diet increased the mean worm burden from 7.2 to 11.5. These differences might arise from the nutritional requirements of *A. galli*. A moderate decrease

in the protein content of the diet resulted in a significantly lower number of adult worms in the gut, but did not affect egg production.

While the application of antibiotics can control diseases effectively for free-range chickens, the wide spread use of antibiotics may lead to the emergence of resistant bacterial populations in poultry and other animal species. Ojeniyi (1985) examined the sensitivity of *E. coli* strains isolated from commercial battery poultry and free-range poultry in Nigeria. It was found that all *E. coli* strains from free-range poultry were sensitive to drugs tested except for tetracycline, while all the *E. coli* strains isolated from battery poultry were resistant to most of the drugs tested (Table 7).

PERFORMANCE OF FREE-RANGE POULTRY

Generally, the free-range poultry production system is characterised by low productivity and low input. The productivity is dependent on the genetics of the stock, the effectiveness of disease control, the quality of supplementary feeds and the availability of pastures. Egg production fluctuates with season under the free-range system because egg laying is controlled by follicle-stimulating hormones (FSH) and luteinizing hormone (LH) produced by the pituitary gland (Manser, 1996), in response to the photoperiod.

Light (natural or artificial) has a stimulating effect on the pituitary, resulting of secretion of FSH and LH, which activates the ovary. One major effect of light is altering the age of sexual maturity of pullets. It is not the intensity of light that causes the difference, but change in day length that alters the age that the first eggs are laid. The length of the day light should not be decreased for laying pullets. If pullets reach sexual maturity too early, an excessive number of small eggs and an increased incidence of prolapse will be a result (North and Bell, 1990). As day length declines, so does egg production under the influence of the pituitary gland. The number of eggs laid falls and laying may cease altogether.

Light has its influence on the bird via the eye, optic tract and possibly the hypothalamus and pineal (Gilbert, 1971). Shellabarger (1953) demonstrated that ablation of pineal at an early age caused in increase in testes and comb weight, and simultaneous increase in gonadotrophic potency of the pituitary. The pineal gland is probably responsible for circadian rhythms (24 h cycles) in physiological activity. The pineal gland is stimulated by photoperiods releasing melatonin which acts as a neuroendocrine interface. Melatonin acts on the ovaries to inhibit the oestrus cycle and has wider effects on other neuroendocrine systems. Melatonin synthesis is inhibited by nerve impulses to the pineal gland. The frequency of impulses is inversely related to the amount of visible light reaching the retinas of the

Table 8. Production performance of free-range birds compared to strain specifications over 18-40 weeks (Glatz and Ru, 2002)

Treatment	Mortality and culls (%)	Rate of lay (%) (22 weeks)	Rate of lay (%) (30 weeks)	Rate of lay (%) (40 weeks)	Egg weight (g) (40 weeks)	Body weight (kg) (40 weeks)
Free-range	9.1	72	89	79	57.2	1.93
Standard	1.2	75	94	93	63.9	2.17

eyes. High melatonin concentrations are measured during dark period and low levels are observed during the light period (http://www.aps.uoguelph.ca/~swatland/ch1_7.htm).

In practice, uneven light intensity in the house will result in birds grouping in certain areas. This tends to lead to the development of vices and disease, particularly respiratory disease (Sainsbury, 2000). During the hot periods of the day, laying hens are not provided with artificial lights in naturally ventilated sheds, since this will help hold down body temperature (Daghir, 2001). While the extra lights can be supplied in the shelters at night for free-range chickens, the following rules should be followed.

- Do not provide extra light too early, before point of lay pullets have grown adequately, or they will lay early and the eggs will be small. They may also have problems of coping with laying large eggs later if they are young.
- Increase the period of light gradually until the maximum of 15-16 hours is reached.
- Do not allow the day length to shorten once the birds are laying (Thear, 1997).

In most situations, free-range farms house about 500-7,000 birds. The feed intake is about 120 g/day, and egg production about 270 eggs per year, equivalent to a rate of lay 75% (Folsch et al., 1988). However, these parameters vary between breeds. Isa Brown birds can consume over 130 g feed/day and produce eggs over 63 g (Thear, 1997), but most local breeds used in Asian countries can only produce 50-60 eggs per year per hen with a high mortality resulting from poor management and disease (Nessar, 2002).

The performance of hens under different housing systems has been investigated by many researchers. Mostert et al. (1995) compared the performance of layers housed in a battery system (stocking density 0.1 m²/hen), a floor house system (stocking density 0.2 m²/hen) and a free-range system (stocking density 3.9 m²/hen). The free-range system had a lower egg production than both the battery and floor housing system although the egg mass of free-range and battery systems was higher than the floor housing system (60.52 and 60.98 g vs. 59.94 g). The feed conversion (defined as kg eggs/kg feed) was better for the battery system (2.355) than both the floor house (2.535) and free-range (2.604) systems (Mostert et al., 1995). Similar results were observed by Leyendecker et al. (2001b) with white layers (Lohmann Selected Leyhorn, LSL) and brown layers (Lohmann Tradition LT), where free-range birds had a poorer feed conversion and a higher mortality in comparison with cage and aviary pens. However, Gibson et

al. (1984) reported that from 20 to 72 weeks of age, production was similar for free-range birds and caged birds (283 vs. 280). Feed intake was higher for free-range birds than caged birds at 36 weeks (152.4 vs. 119.8 g/day/bird) and at 70 weeks (142.9 vs. 123.0 g/day/bird). In this study, herbage intake of free-range birds, (estimated using an exclusion technique, Hughes and Dun, 1983), was 24-48 g DM/day/bird at 46, 48 and 51 weeks of age. These values are likely to be overestimated, although birds consumed considerable quantities of grass (Hughes et al., 1985).

Free-range systems produce more soiled eggs than the other systems due to contamination from soil and excreta. Pavlovski et al. (1981) (cited by Mostert et al., 1995) found that there was more dirt on eggs from extensive production (8.89%) than on eggs from intensive production (1%). On farm quality control procedures in some countries prohibit the sale of dirty eggs. Dun (1992) believed that eggs from caged layers are laid into a cleaner environment and the risk of egg shells and their content becoming contaminated is much lower than in alternative.

In Australia, Glatz and Ru (2002) assessed the production of layers (Hyline Brown) in the free-range system during summer. Production was compared with the specifications published by the Hyline company for the same strain housed in cages. The free-range birds showed a higher level of mortality (mainly from culling of bullied birds) and lower rates of lay, egg weight and body weight over the period 18-40 weeks (Table 8). During the experimental period, South Australia experienced its hottest summer in a century with a maximum temperature recorded in the shelter being over 47°C. Overall, there were 17 days when the temperature exceeded 37°C in the shelter. The reduction in performance of birds relative to the cage benchmark was expected considering the heat wave conditions experienced and the reduction in the natural daylight hours after the summer solstice. However, the performance by free-range birds was similar to the data reported by Barnett (1999) on the experience with free-range egg production in Europe. The level of floor laying was less than 1% of egg production, but dirty (20%) and broken eggs were initially a problem, which was overcome by collecting eggs twice daily. Egg weight and body weight were lower than the benchmark but this was expected as birds were very active in the free-range environment.

An analysis of the direct and indirect use of fossil fuel energy in three systems of egg production (battery cages, straw yards, and free-range) showed no difference in the use of energy between systems (Wathes, 1981; Table 9). Indian

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Table 9. Edible energy outputs and efficiencies of usage of fossil fuel energy (Wathes, 1981)

	Battery cage	Straw yard	Free-range
Outputs			
Egg (y ⁻¹) hen-housed	250	235	220
Egg mass (kg) 17.13 eggs/kg, 88% edible	12.84	12.07	11.30
Carcase live weight (kg)	2.25	2.75	3.0
Mortality (%)	8	10	12
Egg energy (MJ) 6.7 MJ/kg	86.0	80.9	75.7
Carcase energy (MJ) 16.7 MJ/kg, 54% edible	18.7	22.3	23.8
Egg protein (kg P) 11.9% by weight	1.53	1.44	1.34
Carcase protein (kg P) 20.8% by weight	0.23	0.28	0.30
Efficiencies			
Energy out/in, E	0.165	0.163	0.147
Energy in/protein out, P (MJ/kg)	360	367	412

Table 10. Mean values of nutrient (per kg egg, edible weight^a) in eggs under different systems of management (Tolan et al., 1974)

Nutrient	No. of samples	Battery	No. of samples	Deep litter	No. of samples	Free-range
Moisture (g)	68	747	49	751	32	746
Fat (g)	68	109	49	107	32	111
Nitrogen (g)	68	19.7	49	19.6	32	19.8
Protein (N×6.25) (g)	68	123	49	122	32	124
Cholesterol (mg)	68	4,350	49	4,480	32	4,690
Ash (g)	36	9.3	25	9.1	17	9.2
Sodium (mg)	36	1,390	25	1,390	17	1,360
Potassium (mg)	36	1,350	25	1,340	17	1,380
Calcium (mg)	36	550*	25	510	17	510
Iron (mg)	36	20.6	25	19.3*	17	20.8
Thiamin (mg)	35	0.91	18	0.88	12	0.90
Riboflavin (mg)	35	4.7	18	5.0	12	4.5
Nicotinic acid (mg)	35	0.68	18	0.65	12	0.70
Nicotinic acid equivalents (mg)	35	37.4	18	33.9	12	35.7
Pantothenic acid (mg)	35	17	18	18	12	18
Folic acid						
<i>Streptococcus faecalis</i> (µg)	68	60*	49	100	32	90
<i>Lactobacillus casei</i> (µg)	68	250*	49	320	32	390
Vitamin B ₁₂ (µg)	68	17*	49	26*	32	29*
Tocopherols (total) (mg)	68	15	49	18*	32	15
Retinol (µg)	68	1,400	49	1,380	32	1,450

^a A 2 oz. Egg 'as purchased' has an edible weight of approximately 50 g.

* Differences between this and other systems significant at the 1% level (p<0.01).

researchers showed that for free-range poultry, the feed cost accounted for 40.3% of total production cost, and vaccination and medication accounted for 7.1%. The overall benefit cost ratio was about 3:1 when the labour cost was not considered.

QUALITY OF FREE-RANGE PRODUCTS

Eggs

The specifications for a free-range egg for the British consumer include:

- a guarantee that the eggs have been produced by non-caged hens, allowed access to outside runs,
- an assurance that a part of the diet may have been obtained from natural organic sources,

- clean and freshness, uniformity and good size, preferably brown in colour,
 - free from cracks, taint and unsightly inclusions, e.g. blood spots,
 - a firm egg shell,
 - air space within the egg not exceeding 4 mm,
 - non-watery, firm white (the height of the white as related to weight gives a measure called the Haugh Units. The higher the Haugh Units the firmer the white. Fresh eggs from young hens produced eggs of 80-90 Haugh Units. Consumer resistance can be expected if Haugh Units are below 60),
 - rich yellow/orange yolk and
 - an affordable price (Armstrong and Cermak, 1989).
- While most of the eggs produced under free-range

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Table 11. Fatty acid composition (g/kg total fatty acids) of the yolk fat from hens mixed feed in cages (MF) or mixed feeds and grass under free-range conditions (FR) (n=22) (Lopez-Bote et al., 1998)

Fatty acids	MF	FR	SEM	p>F ^a
C14:0	0.32	0.39	0.006	0.003
C14:1	0.04	0.06	0.004	NS
C15:0	0.09	0.10	0.012	NS
C16:0	24.04	27.00	0.225	0.001
C16:1 (n-9)	0.70	0.26	0.042	0.002
C16:1 (n-7)	2.27	2.65	0.085	NS
C18:0	13.11	14.05	0.692	NS
C18:1 (n-9)	35.98	36.91	0.794	NS
C18:1 (n-7)	0.08	0.10	0.003	0.071
C18:1 (n-6)	18.70	12.00	0.488	0.001
C19:0	0.11	0.11	0.003	NS
C18:3 (n-3)	0.39	0.99	0.070	0.065
C20:0	0.02	0.04	0.001	0.001
C20:1 (n-9)	0.25	0.26	0.006	NS
C20:3 (n-9)	0.19	0.22	0.022	NS
C20:4 (n-6)	2.11	2.01	0.041	NS
C20:5 (n-3)	0.02	0.15	0.021	0.044
C22:1 (n-9)	0.01	0.11	0.029	NS
C23:0	0.02	0.01	0.005	NS
C22:4 (n-6)	0.19	0.28	0.005	0.001
C22:5 (n-6)	0.58	0.43	0.024	0.028
C22:5 (n-3)	0.13	0.31	0.029	0.032
C22:6 (n-3)	0.62	1.57	0.063	0.001
Σ(n-3)	1.16	3.02	0.162	0.001
Σ(n-6)	21.59	14.72	0.491	0.001
Σ(n-6)/Σ(n-3)	18.73	5.21	0.449	0.001
Σsat	37.71	41.68	0.763	0.072
Σmono	39.34	40.35	0.836	NS
UI ^b	95.08	91.01	1.497	NS

conditions can meet the above specifications, the actual value of free-range eggs is also reflected in their nutritional quality for consumers. A comparison of nutrient composition of eggs produced under different housing systems showed that the concentration of most nutrients were similar for eggs produced in battery, deep litter and free-range systems except for some vitamins (Table 10). Free-range eggs contained 50% more folic acid than battery eggs. The B₁₂ content was 29 µg/kg for free-range eggs and only 17 µg/kg for battery eggs. The higher concentrations of vitamin B₁₂ in the free-range may result from an increased amount of this vitamin, which was available for absorption from microbial synthesis within the birds themselves and also from litter, herbage and soil. However, no difference was found in the fat content of eggs produced under the different systems, with a mean of 109 g fat/kg egg (Tolan et al., 1974). Krieg (1963; cited by Tolan et al., 1974) reported that iron concentration were significantly higher in battery eggs (9.2 g/kg) than in deep litter (8.1 g/kg) and free-range eggs (7.6 g/kg), probably due to the ingestion of iron from parts of the cages, feed and water

Table 12. Quarterly mean values (per kg egg, edible weight) for nutrients which showed a significant seasonal pattern in UK (Tolan et al., 1974)

Nutrient	Jan-Mar*	Apr-Jun	Jul-Sept	Oct-Dec
Roboflavin (mg)	4.3	4.7	4.7	5.5
Folic acid (µg)	300	250	300	400
Vitamin B ₁₂	23	23	27	23

* Means of 1967 and 1968.

troughs.

In recent years, the lipid composition of chicken egg has been a primary area of consumer's concern due to the relationship of specific dietary lipids with the development of coronary heart disease and some forms of cancer (Simopoulos and Salem, 1992). Lopez-Bote et al. (1998) found that eggs from chickens grazed on a natural grassland legumes and herbs (supplemented with 50 g of mixed feed daily) had a higher concentration of total (n-3) fatty acids (p<0.05) and α -tocopherol (p<0.01) than eggs from hens fed the commercial diet. No differences in initial values or rate of oxidation were observed between treatments (Table 11). This research suggests that some constituents of grass may be of interest for the production of eggs rich in (n-3) fatty acids, without adverse oxidative effects. Coppock and Daniels (1962) reported that there were no significant differences in the fatty acid composition of the eggs produced under free-range, battery or deep litter systems.

Tolan et al. (1974) found that the amino acid composition of egg protein did not appear to be affected by the management system in the UK, but the content of some vitamins, especially for riboflavin, folic acid and B₁₂ varied over the year. The general tendency was for these three vitamins to be greater in the second half of the year (July to December, in UK). The highest was obtained in the last quarter of the year for both riboflavin and folic acid (Table 12). This seasonal change may have been related to the age structure of the flocks and seasonal intake of these vitamins. It is more difficult to produce a consistent quality of free-range eggs across the industry because of the differences in breeds, feed, age of birds, and management factors on different farms (Tolan et al., 1974). Smith et al. (1954) also reported that environmental temperature affects the mineral composition of eggs.

It is expected that the interaction in egg quality between poultry strain and housing system would occur in practice. However, Leyendecker et al. (2001b) found no consistent differences in egg quality of white layers (Lohmann Selected Leghorn, LSL) and brown layers (Lohmann Tradition, LT) in battery cages, aviary and free-range systems. Both layer lines exhibited higher Haugh Units in the aviary. The highest yolk colour was found in the free-range system for LSL-hens and in battery cages for LT-hens. The number of meat spots was significantly lower in eggs of the LT-hens kept in the free-range system.

Table 13. Pesticide residues (ppm) in eggs from agricultural institute farms without thermal vaporisers (Holmes et al., 1969)

System	Samples		a-BHC	pp'-DDE	pp'-DDT
Battery	86	Mean	0.02	0.02	0.03
		Range	0-0.30	0-0.20	0-0.37
Deep-litter	54	Mean	0.04	0.02	0.04
		Range	0-0.33	0-0.13	0-0.31
Free-range	33	Mean	0.04	0.36	0.54
		Range	0-0.40	0.01-2.8	0-3.8

Shell thickness

Shell thickness is one of the major egg quality parameters and is influenced by a number of factors including housing system. Early research demonstrated that shell thickness was greatest on free-range, intermediate on deep litter and least in battery cages (De Jong, 1963; Pavlovski et al., 1981; cited by Mostert et al., 1995). This finding has been further confirmed by Mostert et al. (1995), who reported that shell thickness of eggs produced in the free-range system was 1um and 0.94 µm thicker than that of eggs produced in the battery and floor house systems, respectively. Hughes et al. (1985) found that shell strength was slightly greater in eggs from hens on range. Shell deformation was less in eggs from range, but the differences were small.

Meat

The appearance and colour of meat is a primary quality trait considered by consumers when making purchase choices. It has been realised that there is considerable variation in colour of breast fillets of commercial broilers. However, there is little information on the colour of free-range chicken meat. It is expected that a seasonal change in meat colour should occur given that seasonal changes in feed supply for free-range chickens. This seasonal effect was clearly demonstrated in turkey, where meat colour was lowest in winter and highest in summer, although the magnitude of these differences was small (McCurdy et al., 1996; cited by Barbut, 1998). However, Wilkins et al. (2000) found no seasonal effect on breast fillet colour although two free-range flocks produced breast fillets slightly, but significantly lighter and less red compared with intensively housed birds.

Dunn et al. (1993) compared the texture of chicken meat produced by free-range chickens and chickens housed in cages. The outcomes of this study showed no significant difference in mean ultimate pH values of the breast muscle of the free-range and standard broilers. Free-range meat tended to be low in pH with 46% of these birds having pH below 5.6. In comparison, only 25% of standard broilers had pH values below 5.6. Free-range and standard broiler muscle had similar mean sarcomere lengths, cooking loss and shear force. However, the comparison in this study may

not be valid because free-range birds were all female with an average age of 60 days whereas the standard broiler birds were predominantly male with an age of 45 days. The sex and age effect on texture of chicken meat could not be differentiated from the housing effect.

Residues in free-range eggs

Free-range chickens are able to express their foraging behaviour, but can also have access to the herbicide and insecticide applied to pastures and/or crops. Consumers are becoming more concerned about residues of these products in free-range eggs. Early study by Holmes et al. (1969) showed that the compounds most frequently detected in the eggs were gamma-BHC, pp'-DDT and pp'-DDE, which is the first toxic metabolite or breakdown product of DDT. The free-range eggs had much higher DDT compounds (Table 13). Nevertheless, nearly 60% of these eggs contained residues which did not exceed 0.05 ppm. Only 3 samples contained 0.12-0.40 ppm gamma BHC, and 8 samples contained 0.15-3.8 ppm pp'-DDT. This suggests the careful management of free-range birds is required to avoid eggs being contaminated with chemicals.

WELFARE AND BEHAVIOUR OF FREE-RANGE CHICKENS

As discussed in the previous sections, free-range systems allow birds to express their natural behaviours with the main feature being freedom of movement, choice of nesting site, space to escape or chase other birds during a social encounter and choice of neighbour (Armstrong and Cermak, 1989). However, it is difficult to judge the housing conditions at farm level from an animal welfare point of view due to many variable factors on farms. An animal needs index was developed by Bartussek in 1985 and updated many times since (Bartussek, 1999). One principle of the index system is unfavourable conditions in one area may be balanced to a certain extent by better conditions in another area. Horning et al. (2001) assessed the housing conditions of 63 hen houses using this index system. He found that the deep litter system achieved fewest points, followed by aviaries and free-range systems. Farms with both a covered run and free-range scored most points (Horning et al., 2001). Within this scoring system, high scores were given for optimum density, ability of birds to access feed, water, perches, nests, outdoor runs, litter scratching areas and plumage condition. However, in this scoring system it was surprising that little importance was given to bird health and air quality.

Pecking

Feather pecking in laying hens is a serious animal

Table 14. Effects of foraging material and food form on the percentages of hens engaged in different activities in scan samples. Means as well as minimum and maximum values (in parentheses) of 4 pens per housing condition, P values derived from ANOVA (Aerni et al., 2000)

Behaviour	Housing conditions				P values		
	Pellets/straw	Mash/straw	Pellets/no straw	Mash/no straw	Foraging material	Feed form	Interaction
Foraging	31.3 (23.3, 37.8)	22.4 (15.3, 28.8)	10.3 (8.7, 12.1)	8.8 (6.5, 10.6)	<0.0001	<0.05	NS
Feeding	17.1 (15.6, 20.7)	29.3 (25.3, 32.4)	18.2 (16.1, 21.3)	32.3 (28.3, 35.4)	NS	<0.0001	NS
Preening	2.1 (1.6, 3.5)	1.7 (1.4, 1.9)	4.8 (2.6, 6.6)	2.8 (1.9, 3.1)	<0.0002	<0.05	NS
Dustbathing	2.1 (1.0, 3.9)	3.1 (1.8, 5.7)	0.2 (0, 0.6)	0.3 (0, 0.6)	<0.0001	NS	NS
Moving	2.0 (1.5, 3.2)	1.6 (1.3, 2.0)	4.7 (2.4, 6.8)	2.7 (1.8, 3.1)	<0.002	<0.05	NS
Perching	16.4 (8.3, 27.4)	13.3 (6.1, 22.8)	34.2 (26.1, 40.3)	19.7 (19.1, 20.5)	<0.005	<0.03	NS

welfare problem in poultry housing, as it may lead to feather damage, injuries and mortality (Hughes and Duncan, 1972; Allen and Perry, 1975). Recent studies show a positive correlation between feather pecking and egg production (Kjaer et al., 2001), indicating that a continuous selection for higher productivity results in birds having an increasing tendency to perform feather pecking unless precaution is taken to reduce it (Kjaer and Sorensen, 2002). Apart from breeding and selection, nutritional factors also contribute to the feather pecking. If hens are offered feed that does not meet their requirement of one or more specific nutrients, the level of feather pecking and cannibalism will be increased (Neal, 1956; Siren, 1963; Ambrosen and Petersen, 1997). However, Kjaer and Sorensen (2002) suggested that the dietary level of methionine+cystine, light intensity during rearing and age at access to the range area, had minor effects on the pecking behaviour. Higher levels of fear have been associated with higher levels of feather pecking (Blokhuys and Beutler, 1992).

Feather pecking should be regarded as redirected foraging behaviour (Huber-Eicher and Wechsler, 1997) and can be reduced if layer birds are provided with incentives that elicit foraging behaviour, such as litter (Hughes and Duncan, 1972; Simonsen et al., 1980; Blokhuys and Arkes, 1984; Blokhuys, 1986), longcut straw from perforated plastic baskets (Norgaard-Nielsen et al., 1993) or polystyrene blocks (Huber-Eicher and Wechsler, 1997; Wechsler and Huber-Eicher, 1998). Despite the provision of straw materials, feed form also has a significant effect on the feather pecking (Aerni et al., 2000; Table 14). Chicks that could use both sand and straw from day 1 on did not show high rates of feather pecking, and no injuries were observed in these groups. On the other hand, foraging activity was inversely related to the rate of feather pecking, and the occurrence of feather pecking could be delayed from week 4 to week 7 by postponing procedures that led to

changes in foraging behaviour. Based on these research outcomes, free-range systems that promote foraging behaviour are effective in reducing and preventing feather pecking (Huber-Eicher and Wechsler, 1997). Housing conditions and suitable pastures for free-range production that promote foraging behaviour, such as the provision of litter or floor grain, are effective in reducing feather pecking, although there is a risk of pathological feather pecking occurring when straw or wood shavings are used as litter. Also, in barn and free-range systems, birds that are dustbathing flick litter or dust onto their backs and this can attract the attention of other birds resulting in pecking of the particles. This can lead to pecking around the base of the tail (near the preen gland) and may result in the development of cannibalism.

Layout of house and free-range : To solve the problems of feather pecking and cannibalism the layout of the house and the free-range is being examined. In particular changing the position of nests, perches and feeders in the house have shown some potential. Flocks that use the outside area well showed less tendency to feather peck (Fiks van-Niekerk, 2001). Hofner and Folsch (2001) reported a trial where small trees provided hens a shelter belt and variety of food including fruits and small leaves. The cover in the outside area resulted in hens spending more time outside. In trials with 10 breeds more cannibalism was recorded in the nest boxes with sloping floors compared to groups with flat littered nests. Presumably cannibalism was initiated due to the more restless behaviour of hens using sloping nests (Keppler et al., 2001b).

Group size : Work continues in Europe examining optimum group size for free-range hens. Birds utilising the outdoor area decreases as the group size increases (Keeling et al., 1988).

Genetics : There is evidence of an additive genetic effect underlying feather pecking behaviour with

heritability ranging from 0.1-0.4. For cannibalism there is an indication of one or more major genes having influence. The likely candidate is the glucocorticoid receptor gene. Selection lines differing in the propensity to feather peck or engage in cannibalistic pecking have been developed with a heritability of around 0.2-0.7 respectively (Kjaer, 2001). Molecular studies are aiming to identify genes that cause differences in feather pecking (Korte et al., 1997).

Breed has an influence on feather pecking and cannibalism in laying hens. Mortality from cannibalism was considerably higher in the imported strains (imported from the northern hemisphere into Australia) than local strains (Australia) (Cumming et al., 1998). Five breeds of brown egg laying hens exhibited differences in intensity of feather pecking and the occurrence of skin injuries in the laying period (Keppler et al., 2001a) suggesting use of birds in alternative systems can be successful provided the disposition of the breed to feather pecking and cannibalism is low.

An enormous research effort is being directed toward improving the rate of genetic progress by developing a simple quick test, which predicts a bird's likelihood of developing feather pecking. This will eliminate the need to observe feather pecking of the hen throughout the laying cycle. Studies indicate the degree of avoidance of a novel object (brown ceramic bowl, loose bundle of straw and loose bundle of feathers) was not predictive of the tendency to peck in ISA Brown hens (Albertso and Nicol, 2001).

Vocalisation : High feather pecking lines vocalise more than low feather pecking lines offering a measure for detecting the potential of feather pecking (Koene et al., 2001).

Behaviour studies

Behaviours related to traits such as fear, sociality, coping style are being measured together with observations on feather pecks and pulls and by electronic recording of strong pecks and pulls. The results suggest that feather pecking and cannibalism are not closely related to these behavioural characteristics (Hocking et al., 2001). In contrast Savory and Mann (1997) showed performance of certain behaviours (feeding, preening) may attract feather pecking and that feather peckers tend to be more active. Hens direct ground pecking behaviour to feathers of pen mates when they are deprived of access to litter or forage (Kim-Madslien and Nicol, 1998). Increased stress associated with frustration may be responsible for the initial difference in pecking rates, although it appears to be more stimulated by increased ground pecking motivation (Kim-Madslien and Nicol, 2001).

Familiar odours : Olfactory memory exists in domestic chicks and could be used as reassuring agents when chickens are exposed to otherwise unfamiliar and

frightening situations. For example imprinted odorants might serve to reduce the reluctance for poultry to venture into an unfamiliar and exposed area like a free-range (Jones et al., 2001).

Husbandry : The sides of a brooder covered with feathers (0.5 lux) versus open sided brooders (5-6 lux) with and without food deprivation were tested to determine the number of feather pecks (severe and gentle) in Lohmann untrimmed chicks (Johnsen and Kristensen, 2001). No differences were found in plumage condition of birds at 30 days of age and rearing with a dark brooder did not prevent development of feather pecking. Food deprivation increased the level of severe feather pecking and reduced dustbathing although it is unclear whether this is a result of misdirected ground pecking or redirected dustbathing pecks.

Feed structure : Fine feed encourages hens to feed longer than coarse feed decreasing the incidence of feather pecking and resulting in better plumage cover (Walser and Pfirter, 2001). Fine feed had a low percentage (0-13%) of feed particles with a diameter greater than 2 mm compared to the coarse feed (33-55%). An optimal feed structure consists of particles between 0.25-2.00 mm for birds in alternative systems.

Nutrition : Early studies in Switzerland indicated that increased levels of dietary fibre and magnesium content may reduce the incidence of feather pecking and cannibalism. However more recent work suggests that increasing the Mg content from 0.135% to 0.27% and fibre from 2.5% to 4% had no major effect in lowering the incidence of cannibalism in brown laying hens (Hadoorn et al., 2001). In contrast Choct et al. (2002) reported a reduction in cannibalism in birds fed diets with higher levels of fibre. Hadoorn et al. (2001) suggest that low dietary levels of methionine and linolenic acid may be more important in increasing feather pecking and cannibalism. Whole wheat feeding of Lohman Leghorn and brown hybrid from 8-16 weeks had no influence on plumage condition or mortality rate (Hadoorn and Wiedmer, 2001).

Foraging behaviour

Very limited data is available on the foraging behaviour of free-range chickens. A study conducted in a dry summer in South Australia showed that birds were very active in the paddock during overcast conditions and also when light drizzly rain was falling. It was apparent that birds were attracted to the insects which were more active during this period. Birds foraged mainly within 30-40 m of the shelter but would also forage further out into the paddock especially when attendants were present. As the birds moved further out into the paddock they tended to leave clumps of pasture. Keppler and Folsch (2000) directly observed the locomotive activity of hens and cocks in aviary systems with and without free-range. The hens in the

aviaries without free-range moved between 340 m and 634 m per day. The cocks moved larger distances when foraging (795 m-1445 m). The hens moved greater distances to obtain food (13-31%) than the cocks (1.3-13.7%). The hens in the aviary with free-range moved distances of 1,800 m and 2,500 m per day. This study showed that hens and cocks show an extensive locomotive behaviour under free-range conditions. Further research on foraging behaviour of free-range chickens is required as the outcomes of this type of research will assist free-range producers to develop management strategies to improve foraging ability of chickens.

Temperature

In modern housing under intensive conditions, the birds are housed in a temperature-controlled shed. This prevents stress caused by low or high temperatures and enables the bird to achieve maximum production. However, under free-range conditions, birds are exposed to extremely high or low temperatures, which not only influences the performance of birds but also the welfare. The use of water spray to cool birds is one of the strategies to reduce the impact of temperature on foraging birds.

In winter, free-range chickens might need more protection from cold weather, which might not be so crucial in Australia where the winters are not as cold as those in Europe. Ward et al. (2001) found no difference in resistance to heat loss attributable to rearing environment for plumage from the back and leg, but a significant difference in the pectoral region. Free-range birds had a thicker plumage and a higher total resistance to heat transfer in the pectoral region, despite showing a lower resistance per unit depth than broiler birds. Free-range birds can behaviourally thermoregulate by remaining inside the hen house to reduce heat losses.

Predators

It is recognised that free-range birds are under the risk of predation from foxes, wild cats, eagles and hawks. It is not clear whether this should be a welfare issue for free-range poultry because birds are subject to similar risk under natural conditions. In UK, some farmers allow birds to have access to paddocks during all of the daylight hours and in some instances this involves a farmer being present late in the evening to shut the pop-holes. One farm in the UK shut the pop-holes at the end of the working day, but left a single pop-hole open. This pop-hole had bars about 10-12 cm apart to exclude foxes. This apparently worked well unless there was an identified fox problem, in which case control programmes were required (Barnett, 1999). While the establishment of proper fence may prevent birds from fox and cat attacks, predation by the owl, eagle and hawk are difficult to control.

Bone development

Currently leg weakness in layers is a welfare concern in cage production system. High energy and protein levels in the diet to maximise production and lack of physical exercise contribute to the problem. Free-range offers the freedom for chickens to exercise in the paddock, which might reduce leg weakness problems and improve the development of the bone. Gregory et al. (1990) found a higher incidence of broken bones in birds in battery cages compared to free-range and perchery systems. It was revealed that battery birds had a higher incidence of recently broken bones than perchery and free-range birds. However, the perchery and free-range birds had more old breaks than battery birds. The pain and discomfort associated with the old breaks was borne over a longer period than the breaks which occurred during depopulation of birds from the battery system. Leyendecker et al. (2001a) also reported that the bone breaking strength was consistently higher for hens kept in the aviary or in free-range system compared to battery cages. Pathology and histology studies proved that free-range hens, and deep litter hens suffered from pododermatitis, keel bone deformation and amputated beaks in addition to pecking wounds. In caged hens, however, severe fatty liver syndromes, injuries of the claws and inflammation of the feather follicles were mainly found (Keutgen et al., 1999).

CONCLUSION AND FUTURE DEVELOPMENT

Free-range growers need to have a good knowledge of stockmanship and animal health management, as the birds being used at the present time are not hardy enough for climatic extremes and lack the immunity to the wild strains of common diseases. With a strong demand by consumers for free-range egg products, there is a need to develop new strains that will handle harsh environmental conditions with a reasonable production capability. Asian researchers have already started to crossbreed their local strains with commercial ones. The outcomes of these breeding programs will have a significant impact on free-range production. European poultry breeding companies are also developing birds more suited to free-range. Within these breeding programs, metabolic stability, strong plumage and docile behaviour continue to be selection priorities.

It is well known that the production of free-range birds fluctuates with the season more than the birds kept in cage and barn production systems because of the better control over the hen's environment and nutritional intake. High temperature in summer in Australia is one of key factors causing low egg production under free-range conditions. While a number of strategies are already applied by free-range farmers, other new products available on market for reducing heat stress (e.g. betafin) should be assessed for

free-range chickens.

The diet composition that free-range birds consume is complex. Birds can forage soil, pebbles, grass, weed, crop seeds and insects in the paddock. This makes it difficult to develop a supplementary feeding strategy to meet their nutrient requirements. Ideally, the amount of supplement required should be based on the amount of nutrient foraged and the total requirement. However, there is limited information on the forage intake of free-range birds during the season. A better understanding of foraging behaviour and forage intake of free-range chicken will enable producers to develop an economic feeding system. Given that free-range birds consume a significant amount of forage, the nutritive value of forages for free-range birds will be crucial for the development of a supplementary feeding system. In addition, there is a trend of increasing the dietary fibre content in the poultry diet in intensive systems to reduce pecking problems and improve animal welfare. The evaluation of fibre resources for poultry production is required by the industry.

Exposure of free-range birds to diseases contributes to a high mortality under free-range systems. Vaccination of the common diseases is an effective strategy, but it is unlikely to control the diseases spread by wild birds. More importantly, the accumulation of parasites in the paddock presents a risk to the free-range birds, but the frequent rotation system could effectively stop the disease transmission. Incorporation of free-range chickens into a crop/pasture rotation system will be a potential strategy to increase the profitability of farmers who can use chickens in the pasture phase in much the same manner sheep are used. Preliminary research in Australia showed that egg production under this system is lower than the traditional intensive system. Soil fertility was not different between the sheep and poultry paddocks. Sheep and chickens had different preferences for weeds and pasture species. This raises the possibility that sheep and poultry could be grazed together in some circumstances, to provide a method for reducing weed build up. However, many issues in this production system need to be resolved. The seasonal forage intake of free-range chickens, the cost effective supplementary feeding strategies, the best pasture species for the free-range poultry in a crop/pasture rotation system and the long-term sustainability of this system require further assessment.

Improving poultry welfare is one of the key reasons for the re-development of free-range poultry production in Europe. Beak trimming is a routine practice in intensive poultry production systems especially where light intensity cannot be controlled (Glatz, 2000). However, when beak trimming is practised to control cannibalism in free-range birds, the beak shape is changed which may restrict the bird's ability to forage and catch insects. The foraging

ability of beak trimmed free-range layers needs to be assessed relative to untrimmed control hens.

There are some potential biosecurity issues for both human health and bird health associated with free-range production and some of the marketing requirements of the systems, especially in Europe. There are also some environmental risks when the free-range birds are not managed properly and the potential exists for contamination of free-range products by the residues of agricultural chemicals. However, the level of these risks does not appear to be known. The bird health and product hygiene risks associated with different production systems should be evaluated and an effective control programme developed.

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