Nutrition-related opportunities and challenges of alternative poultry production systems

Murdo MacLeod, University of Edinburgh, Scotland

Introduction

A number of alternative systems for poultry have been developed or revived in recent years, largely in response to demand for improved poultry welfare (Fröhlich et al., 2012). All of these systems have nutritional implications, especially if they are combined with a demand for “organic” production. For those who are less familiar with the term, "organic" production involves requirements such as: low stocking density; access to "outdoors"; late slaughter (lower growth rate); feedstuffs preferably of local origin and grown with strictly limited use of chemicals; no use of synthetic amino acids; no use of genetically modified organisms; restricted use of pharmaceutical products. Organic feed is governed by EU directives such as EC889/2008, which can be accessed on-line at EU or national government sources. A summary of rules regarding organic feed is given in MacLeod and Bentley (2012).

We must be alert to the possibility that some alternative systems may not be in the best interests of sustainability. However, at a time of concerns about climate change, the environment and human population growth, we should be optimistic about what poultry have to offer. Publicising some of the positive features of poultry might help to counteract some of the negatives that have been allowed, almost by default, to become accepted opinion. Objective scientific analysis (Life Cycle Assessment) of the carbon, nitrogen and energy impacts of poultry meat and egg production shows that these are among the most sustainable forms of animal agriculture. It is an inherent biological advantage of poultry that the overheads of reproductive, rearing and maintenance costs are relatively low because of rapid sexual maturation, numerous offspring per parent and short time to slaughter. These features result in low biological, environmental and economic overheads compared with other agricultural species. The changes in genetics, nutrition and husbandry which poultry science and industry have produced over the years have enhanced these inherent advantages.

A dilemma for proponents of alternative systems is that breeding or feeding for lower growth rates or altering environmental conditions or behavioural opportunities may act against these benefits. Most challenges and opportunities related to alternative systems are likely to involve the application of existing knowledge rather than the development of novel nutritional principles. Many of the nutritional challenges arise because feed for some alternative systems may be governed by rules which are not evidence-based. Organic schemes are the most demanding nutritionally but there is a range of others, including certification schemes run by some large retailers. For instance, it is possible to formulate “organic” diets without animal protein, genetically modified organisms and synthetic amino acids but it is difficult to attain nutritional optima. This may lead to sub-standard performance and may even compromise health and welfare (Hadorn *et al.*, 2000). Furthermore, nitrogen excretion and the associated environmental impact will be greater if an imbalanced protein mixture has to be used to attain nutritional requirements.

Nutritional costs of alternative systems

Much of the dietary energy consumed by poultry is used for “maintenance”, i.e. to sustain the processes which keep the bird in a steady state. Any alternative system is likely to affect the bird’s maintenance requirement, particularly if locomotor activity or the thermal environment are altered by the system of housing, husbandry or nutrition. Even in the confined conditions of chamber calorimeters, about 12% of the energy expenditure of a light layer strain was attributable to locomotor activity, compared with about 5% for broilers (MacLeod *et al.*, 1982). Activity can also be predicted to produce differences in energy requirements and food intakes between different housing systems. Pre-oviposition behaviour increases heat production by about 60% over the resting value (MacLeod and Jewitt, 1985), similar to treadmill measurements of the cost of walking. Feeding, drinking and preening activity have each been shown to increase heat production by about 25% (MacLeod and Jewitt, 1985). Environmental temperature and plumage condition must also be considered in alternative systems.

A 1°C reduction in temperature will raise the energy requirement by approximately 20 kJ/d, equivalent to 1-1.5% more feed in well feathered hens in temperate climates. This effect may be twice as great if feather condition is poor (Tullett *et al.*, 1980). With increased activity and thermoregulatory costs, feed intake could, therefore, be 10-20% higher in outdoor systems. Since poultry are not always the most active of birds, differences among indoor systems may not be so great. A recent life cycle assessment of conventional and less intensive indoor systems of broiler and egg production, based on feed intake and fuel use, indicated that there was little difference in environmental impact, especially when heat exchanger ventilation was used (Leinonen *et al.*, 2013). This was a rather limited study, even in the authors' opinion, and further assessment is needed.

Qualitative control of feed and nutrient intake

Selecting among food sources so as to obtain the appropriate mixture of nutrients is essential for birds living under natural conditions. This ability is of such fundamental evolutionary advantage that it seems unlikely to have been eliminated from domestic poultry by generations of breeding on compound diets. The persistence of this ability has been tested many times in poultry, with variable results (Rose and Kyriazakis, 1991; Henuk and Dingle, 2002), although choice feeding was common practice before requirements had been sufficiently well defined to allow the formulation of nutritionally complete diets. However, the re-ascendancy of free-range poultry husbandry raises the possibility of birds obtaining a supplementary source of feed items from the range or pasture.

Supplementary range feeding

A much-desired advantage of access to outdoor areas is the availability of supplementary feed, whether animal, vegetable or mineral. However, this advantage can be difficult to quantify since it depends on ecological factors, such as the quality and biodiversity of the "range" area, stocking density and also on behavioural factors such as the readiness and ability of the birds to move over the area and select from its resources. Knowing the intake and composition of forage has the potential to allow fine-tuning of the main (farmer-provided) diet, although there is so much scope for variation between and within farms that it may not always be economically justifiable to do so.

Assessing the contribution of foraging to nutrient intake may have to rely on methods such as sampling of crop contents (Antell and Ciszuk, 2006). Horsted *et al.* (2007) used this technique to assess the intake of different forages when hens were given either a typical organic layer concentrate (184 g crude protein /kg dry matter) or a nutrient-restricted diet consisting of whole wheat (120 g CP/kg DM) and oyster-shell grit. The latter diet was intended to encourage foraging and did indeed produce significant effects, being associated with greater crop contents of plant materials, oyster shell, insoluble grit and soil. There was no significant difference in intakes of animal matter, such as earthworms and larvae, which might have been expected if the birds were "adjusting" their nutrient intake. However, the authors suggested that the range area had already been depleted of such items before the measurements started, illustrating a source of variation which can potentially be controlled if sufficient land is available.

Results from an invertebrate-rich pasture are described by Sun *et al.* (2013). A suitably managed pasture can be seen as a source of materials other than the obvious macro-nutrients. Ponte *et al.* (2008) studied some of the effects of a legume-rich pasture (clover, etc.) on broiler performance and meat quality and found generally positive effects. Positive effects of forage plants on egg quality have also been described (Hammershøj and Steenfeldt, 2012). However, poorly designed or poorly managed systems can lead to overloading of the pasture with nitrogen and phosphorus and increase losses of nitrogen and phosphorus to the environment (Dekker *et al.*, 2012).

Yolk colour

Yolk colour is an aspect of product quality that can be expected to improve with access to suitable pasture. Especially when diets are based on wheat or barley, synthetic or concentrated xanthophyll supplements may be added to the feed in conventional systems, to give the preferred intensity of yolk colour (Nys, 2000). The plant pigments are natural derivatives of β-carotene. They are present at high concentrations in plant materials such as marigold meal and some species of algae but are also present at practically useful concentrations in many potential forage plants.

Whole grain feeding
Feeding whole grain may occur as part of the nutritional strategy in alternative systems. This has several potential advantages: it provides a form of environmental enrichment for the bird (Picard *et al.*, 2002), it encourages muscular development of the gizzard and it reduces feed processing costs. Grain (e.g. wheat, barley, oats) can be provided separately in a choice feeding system, mixed with mash or fed at alternating times to a compound diet (sequential feeding; Rose *et al.*, 1995). Starch digestibility is improved by the addition of whole wheat (Hetland *et al.*, 2002). The gizzard has a well-developed ability to grind down larger particles such as whole grains and increased gizzard size and activity may increase the opportunity for enzymatic digestion. However, not all whole grain systems have given positive results (Bennett and Classen, 2003). It should be noted that simply adding whole cereal grains to an existing compound diet will dilute many nutrients. This may be advantageous if maintenance energy requirements have increased (e.g. under more extensive systems), since energy intake will be allowed to increase without excessive additional intake of the more expensive components of the diet. Umar Faruk *et al.* (2010) noted that loose-mix feeding of grain with a compound "balancer" diet had no effect on ME intake. However the loose-mix treatment reduced feed and protein intake due to lower intake of the balancer diet, resulting in lower egg production and lower egg and body weights than sequential feeding. Sequential feeding of whole grain and a concentrate resulted in similar egg-laying performance to conventional feeding and thus could be used to advantage in situations where it is applicable.

Specific nutrient appetites
It may be possible to cater for specific nutrient appetites in some alternative systems. A calcium appetite is particularly clear in the laying hen (Mongin and Sauveur, 1979) and separate feeding of a calcium source is one form of free choice feeding that is reliably successful. It has the advantage over feeding calcium only as part of a complete compound diet that the intake of calcium is dissociated from energy and protein intake and can occur at the time of maximum physiological demand (e.g. for egg shell deposition).

Nutrient effects on behaviour
It has sometimes been asserted that a lack of animal protein in the diet makes pecking damage more likely; this has not been supported by controlled experiment (McKeegan *et al.*, 2001). However, an imbalanced diet (independently of whether animal protein is included) may induce such behavioural effects (Elwinger *et al.*, 2008).

Feeding programmes in alternative systems

Diets and feeding programmes are usually devised from tables of recommended nutrient concentrations. Such tables have wide applicability for conventional systems, because these use standardised environments, common genotypes, consistent feed presentation and well defined ingredients, none of which are always guaranteed in alternative systems. This severely reduces the direct application of general nutritional tables to alternative systems, which require a more flexible, iterative, approach, involving reliable feedback about performance from the producer to the nutritionist (MacLeod and Bentley, 2012). This may allow the formulation of diets specifically for an individual flock but this will depend on the scale of the production and feed mill operations. Tailoring the diet for a specific flock may often entail adapting the use of a standard commercial feed.

Environmental impacts of nutrition in alternative systems

This subject is discussed in greater detail in MacLeod and Bentley (2012). Organic poultry meat and egg production increase "fuel" energy use by about 30% and 15%, respectively, compared with conventional systems (Williams *et al.*, 2006; Bokkers and de Boer, 2009; Leinonen *et al.*, 2012). This is because the lower energy cost of producing organic feed is counteracted by lower bird conversion efficiency, which results in higher feed intake. Providing optimally balanced protein is usually practicable only with supplemental amino acids (currently not permitted in organic diets) and is well known to reduce nitrogen (N) losses. (e.g. Kim and MacLeod 2001; Table 1):

Table 1: Nitrogen retention and loss by broiler chickens on diets with the same lysine concentration but a wide range of crude protein content

Diet	1	2	3	4	5
Metabolisable energy MJ/kg	13.4	13.4	13.4	13.4	13.4
Crude protein (CP) g/kg	180	210	240	270	300
Lysine concentration g/kg	11	11	11	11	11
Lysine : CP ratio	0.061	0.052	0.046	0.041	0.037
N intake (g/bird.d)	4.10	4.18	5.29	5.90	6.18
N retention (g/bird.d)	2.68	2.43	2.60	2.61	2.60
N loss (g/bird.d)	1.41	1.75	2.68	3.29	3.59
Efficiency of N retention	0.66	0.58	0.49	0.44	0.42

This experiment showed N retention efficiency (N retained in body/N intake) falling from 0.66 on a near-ideal protein to 0.42 on an imbalanced diet. N retention was held constant, because of a constant and limiting dietary lysine concentration, but there was a 2.5-fold increase in N excretion.

There are further possible environmental consequences of restrictions on the use of “non-organic” raw materials. IFEU (2002), for example, showed that 1 kg synthetic DL-methionine requires only 16% of the energy needed to provide the same amount of methionine from soybean or rapeseed meal. The degree to which a perfectly balanced (ideal) protein is used is an economic or legislative matter, because the relevant science is clear. As well as reducing nitrogen losses to the wider environment, it may improve bird welfare by improving floor and litter conditions and may also reduce ammonia concentration in the house environment.

Conclusions

All the classical rules of nutrition apply to alternative systems, but there are differences in the way they have to be applied. There is certainly a need for good channels of communication between the producer and the nutritionist. Because of the variables affecting alternative systems, such as climatic environment and locomotor activity, the optimal application of nutritional principles requires observation and recording of flock performance against defined targets, with iterative adjustment of nutrition as required. There are nutritional advantages or opportunities to be tested in alternative systems. These include such things as: supplemental feeding on plants and invertebrates by free range poultry; effects of supplemental feedstuffs on product quality; choice or sequential feeding to meet the birds’ varying requirements; whole grain feeding. Organic nutrition has the undoubted advantage of avoiding the release of pesticides and herbicides into the environment but also has environmental costs; there is increased environmental impact because of reduced feed conversion efficiency related to deliberately reduced rates of production; current regulations prevent the use of supplemental amino acids, usually resulting in increased nitrogen losses and pollution. The strategy which should benefit all husbandry systems is to continue breeding for efficient utilisation of nutrients. Genetic selection may be less immediate than nutritional methods but it has the advantages of “permanency” and, potentially, a degree of independence from diet composition. The latter may be particularly valuable when there are impediments to formulating a balanced amino acid composition, such as might occur with organic diets or if there is an increasing tendency to use imbalanced protein co-products from biofuel production.

Zusammenfassung

Bedarfsgerechte Ernährung von Geflügel in alternativen Haltungssystemen - eine Herausforderung für Forschung und Praxis

In den letzten Jahren wurde die Haltung von Legehennen in vielen Betrieben von Käfighaltung auf Bodenhaltungssysteme umgestellt, vor allem um Forderungen nach mehr Tierwohl zu erfüllen. Das erfordert Anpassungen in der Fütterung, die vor allem bei der Produktion von Bioeiern nicht einfach zu erfüllen sind. Angesichts steigender Weltbevölkerung und drohender Erderwärmung scheint die Forderung nach optimaler Nutzung begrenzter Ressourcen schwer mit der Bioproduktion vereinbar, aber die Produktion von Geflügelfleisch und Eiern wird ihren Wettbewerbsvorteil gegenüber anderen Formen der tierischen Veredlung hinsichtlich Nachhaltigkeit behalten. Dank der hohen Reproduktionsrate und des schnellen Wachstums sind der Erhaltungsbedarf und damit die Umweltbelastung relativ gering. Die biologischen Vorteile konnten durch Selektion und verbesserte Ernährung und Haltungstechnik weiter ausgebaut werden.

Ein Dilemma für die Befürworter alternativer Haltungsverfahren ist, dass mit der Forderung nach langsamerer Gewichtszunahme, Verzicht auf leistungssteigernde Futterkomponenten und mehr Bewegung die Erfolge von Züchtung und Ernährung teilweise aufgehoben werden. Die meisten Fütterungsempfehlungen für alternative Haltung beruhen auf der Anwendung bekannten Wissens und sind nicht ganz neu. Viele Probleme ergeben sich aus gesetzlichen Vorgaben und Spezialanforderungen großer Handelsketten, die keine wissenschaftliche Basis haben. Biofutter muss sich an die EU Richtlinie EC889/2008 halten; eine Zusammenfassung der Regeln wurde kürzlich von MacLeod und Bentley (2012) veröffentlicht. Z.B. kann man "Biofutter" ohne tierisches Eiweiß, GM Getreide und synthetische Aminosäuren formulieren, aber die Optimierung bleibt schwierig. Das kann dann zu Minderleistung und sogar Beeinträchtigung der Gesundheit und des Tierwohls führen (Hadorn u.a., 2000). Außerdem führt die Einhaltung der Bio-Richtlinien zu einer höheren Umweltbelastung infolge höherer N-Ausscheidung, weil zur Bedarfsdeckung mehr Protein verfüttert wird als bei ausgewogenem Aminosäurenprofil erforderlich und bei Intensivhaltung üblich ist.

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Author's address:

Dr M G MacLeod
4 Waulkmill Drive
Penicuik
Midlothian EH25 9PS
Scotland
murdomacleod@hotmail.co.uk