A computer model for welfare assessment of poultry production systems for laying hens

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Abstract

A computer model for welfare assessment in laying hens was constructed. This model, named FOWEL (fowl welfare), uses a description of the production system as input and produces a welfare score as output. To assess the welfare status a formalized procedure based on scientific knowledge is applied. In FOWEL the production system is described using 25 attributes (space per hen, beak trimming, free range, etc.), each with two or more levels, together defining the characteristics of a production system. A weighting factor is used for each attribute, based on the available scientific knowledge of the effects of the attribute levels on the welfare aspects. The welfare score of a production system results from the attribute levels combined with the weighting factors. The results show that feeding level, space per hen, perches, water availability and nests were the most important attributes. The attribute free range was of minor importance. FOWEL includes a description of 22 production systems. The welfare score of cage systems was low, of barn and aviary systems medium, and of organic systems high. The presence of a free range resulted only in a small improvement in the welfare score.

Additional keywords: cage systems, barn systems, aviary systems, free range

Introduction

The welfare of farm animals has become an important issue in the last decennia. Welfare problems are recognized in intensive production systems. New legislation has been imposed to guarantee minimum welfare levels.

Welfare has many aspects, which makes it difficult to compare production systems. Based on available scientific knowledge, Bracke (2001) described a formalized procedure to assess 'objectively' the overall welfare status of farm animals in relation to the housing and management system. Bracke elaborated this procedure for pregnant sows, implemented it in the computer model SOWEL (sow welfare model) and validated it through expert opinions. In this paper a similar model for laying hens is described. This computer model, named FOWEL (fowl welfare), assigns welfare scores based on scientific knowledge to production systems for laying hens, which makes it possible to compare production systems on their welfare status. Also FOWEL was validated through expert opinions.

Materials and methods

Outline of the model

The computer model FOWEL (fowl welfare) is based on the calculation of the welfare score of a production system, using available scientific knowledge. FOWEL is similar to the model SOWEL and its description is analogous to the description of SOWEL. For details see Bracke (2001) and Bracke *et al.* (2002).

The input of FOWEL is a description of a poultry production system for laying hens and the output is a welfare score for that particular system (Figure 1). A production system is a combination of a housing system and a management system, and includes the buildings, the farmer and the hens in the system. The system is described on the basis of attributes, e.g. 'space per hen' and 'free range'. There are an integer number of levels for each attribute. For example, the attribute 'free range' has three levels: 'free range with cover', 'free range without cover' and 'no free range'. The levels are disjointed and all levels encompass the whole spectrum for that attribute. In FOWEL the level of each attribute must be specified.

The welfare status of an animal can be assessed using available scientific knowledge about the animal's biological functioning, i.e., about the degree of satisfaction and frustration of its needs (Bracke, 2001). The biological needs of poultry are known from scientific information. Scientific statements typically relate an attribute of a production system to an animal-based performance criterion. These criteria are called weighting categories and the relation between an attribute and a weighting category is a score. The linkings between scientific statements, attribute levels and weighting category scores will be explained in more detail in the section describing the model computations.

FOWEL comprises the descriptions of 22 production systems:

1. Eighteen systems from Dutch practice: 3 cage systems, 6 variations on barn systems (some free range), 8 variations on aviary systems (some free range) and 1 organic production system.
2. Two imaginary reference systems: a 12-hen system, where hens are kept in small groups under ideal conditions (this is also an organic system), and an uncultivated poultry system where hens live in free nature, like their ancestors.
3. Two production systems that were developed in the project Laying Hen Husbandry: the Roundel and the Plantation (Anon., 2004).

New production systems may be added to the model.

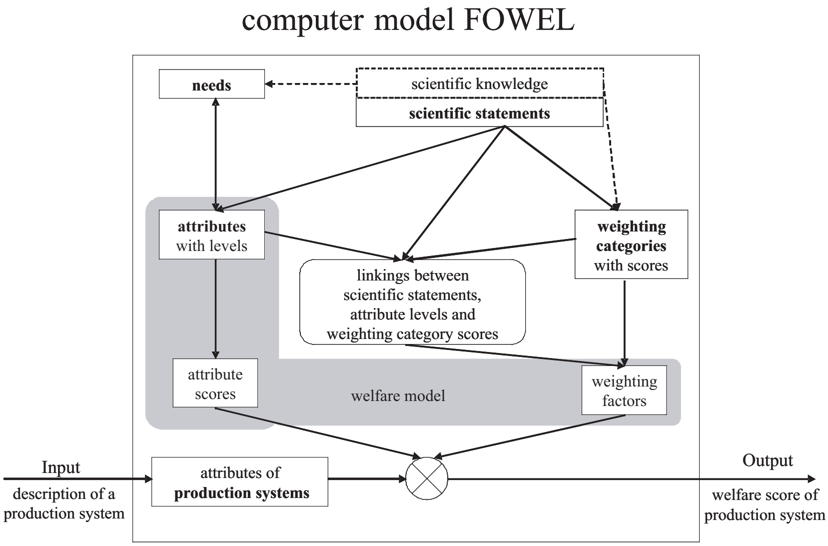

Figure 1. Structure of the computer model FOWEL for welfare assessment of laying hens, implemented as a database with linked tables. The names of the most important tables of the database are printed in bold. Dashed lines represent implicit relationships (after Bracke, 2001).

Implementation of the model

FOWEL is implemented in Microsoft Access with tables, queries, forms and reports. The tables contain all relevant data and are related (it is a relational database). For example, there is a table with attributes and a table with levels; these two tables are related to establish the levels that are related to a particular attribute. The most important tables (bold-printed in Figure 1) contain the scientific statements, the needs, the attributes, the weighting categories and the production systems. The levels of the attributes ('attribute scores') define the production systems. Queries provide a selection of data from one table or a combination of tables. Forms can be used to view and edit data in the tables. Reports provide a survey of data in the tables.

A switchboard was defined to help end-users navigate through the database. The main menu appears when the database is opened; sub-menus with access to forms, reports or system information will appear when a switchboard item is selected. All relevant elements of the database can be accessed through the switchboard.

Computations by the model

The model combines data from the tables in the relational database to compute the welfare score of a production system. The welfare score results from the attribute levels and the weighting factors. The weighting factor of an attribute is the outcome of a calculation that is explained in this section.

Table 1. Attributes used in the computer model FOWEL (in sequence of weighting factor – WF), number of levels (N), best level and worst level.

No.	Attribute	WF	N	Best level	Worst level
1	Feeding level	25	4	*Ad libitum*; enough eating places	Restricted; limited eating places
2	Space per hen	21	6	≥ 2000 cm^2	450–600 cm^2
3	Perches	18	3	Perches present (satisfying) requirements)	Perches absent
4	Water availability	17	4	*Ad libitum*; enough drinking places	Restricted; limited drinking places
5	Nests	16	7	Free to choose nest under shelter	No nests
6	Beak trimming	15	3	Beak trimming < day 8	Beak trimming ≥ day 8
7	Handling/disturbance	15	3	No sudden changes in environment	Sudden long-lasting changes in environment
8	Comfort behaviour	13	2	Enough space for comfort behaviour (e.g. preening)	Not enough space for comfort behaviour
9	Dust bathing	12	5	≥ 1m^2 per 100 hens, simultaneously	No dust bathing
10	Pecking/scratching	11	5	Scratching space < 8 hens per m^2; litter depth ≥ 10 cm	No scratching space
11	Foraging	10	2	Feed in scratching room	No feed in scratching room
12	Floor space	10	4	< 9 hens per m^2	≥ 16 hens per m^2
13	Novelty	8	3	Variation in environment	No variation in environment
14	Separation/ visual contact	8	2	Separation/fleeing possible	Separation/fleeing not possible
15	Cockerel	7	2	Cockerel present (1 per 25 hens)	Cockerel absent
16	Palatability	7	2	High palatability	Low palatability
17	Hierarchical structure	6	6	≤ 6 hens per group	> 3000 hens per group
18	Light	6	3	Light > 10 h; > 60 lux	Light ≤ 10 h
19	Free range	5	3	Free range with shelter	No free range
20	Predators	5	2	Predators absent	Predators present
21	Air quality (gasses, dust)	4	2	Within limits	Outside limits
22	Space per group	3	2	≥ 500 m^2	< 500 m^2
23	Climate	2	2	Within limits	Outside limits
24	Litter handling	2	3	Manure removal/drying > 1 per week	No manure removal/drying
25	Toe trimming	0	2	No toe trimming	Toe trimming

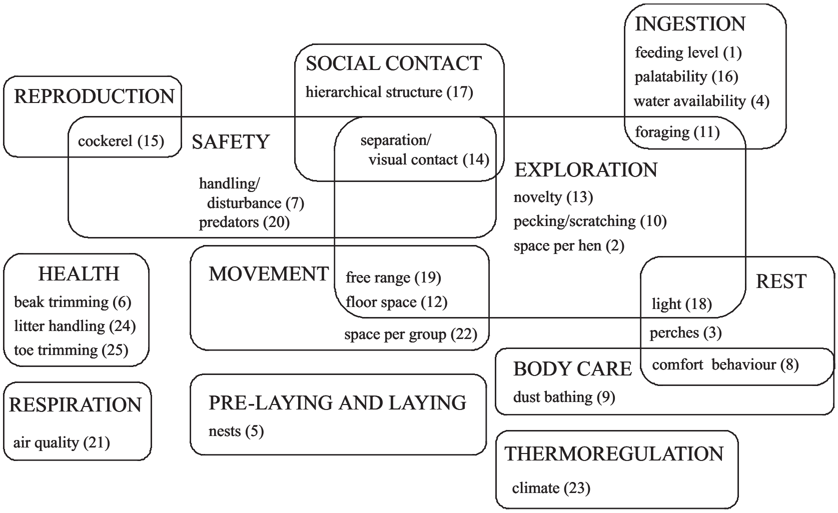

Figure 2. Diagram showing how the attributes (lower case letters) are linked to the needs (capital letters). Figures in brackets indicate the ranking of the attribute. There is no relation between frame size and importance of the need.

Attributes, attribute levels, attribute scores and needs determining welfare

The production systems are defined by attributes; each attribute has two or more distinct levels. The model includes 25 attributes (Table 1).

Each attribute has several levels (see Table 1) ranging from good to bad. This makes it possible to compute attribute scores. If an attribute has two levels, the best level gets attribute score 1 and the worst level gets attribute score 0. With three levels these scores are 1, ½ and 0. With four levels they become 1, ⅔ , ⅓ and 0, etc.

In the model, 12 needs are defined that determine the welfare of laying hens: body care, exploration, health, ingestion, movement, pre-laying and laying, reproduction, respiration, rest, safety, social contact and thermoregulation. Each attribute is related to one or more needs (Figure 2). For example, attribute 'free range' is related to the needs 'movement' and 'exploration'. The need 'movement' is not only related to 'free range', but also to the attributes 'floor space' and 'space per group'. The procedure for the definition of needs and attributes is described in Bracke (2001). The attributes represent welfare components. All attributes together represent the welfare.

Scientific statements

The weighting factors are based on scientific statements. A literature search was done to get information on welfare of laying hens. Relevant scientific statements were selected, each statement specifying some element of the welfare of laying hens under specific conditions. For instance, the statement "On the other hand, housing conditions that promote foraging behaviour are effective in reducing and preventing feather pecking" from Huber-Eicher & Wechsler (1997) specifies the effect of foraging on feather pecking (i.e., on abnormal behaviour).

Table 2. Short description of weighting categories, range of weighting scores (both after Bracke *et al.*, 2001), and number of scientific statements in the computer model FOWEL for each weighting category.

Weighting category	Description	Range of weighting score	Number of statements
Pain	Evidence of pain, including lameness and skin lesions, e.g. from aggression	−1, −3, −5	6
Illness	Evidence of health problems, including increased mortality, but excluding lameness, skin lesions and specific survival aspects	−1, −3, −5	2
Reduced survival	Evidence of reduced survival related to physiological requirements (other than through specific health problems), e.g. longevity, minimum space requirements, deprivation of feed or water, and a poor climate	−1, −3, −5	10
Decreased fitness	Evidence of decreased fitness (that is likely to indicate negative effect), including (re)production effects, but excluding specific survival aspects related to physiological necessities, HPA and illness	−1, −2, −3	5
HPA	Evidence of activation of the HPA (hypothalamic-pituitary-adrenocortical) axis indicative of stress	−1, −3, −5	3
SAM	Evidence of SAM (sympathetic-adrenal-medullary) activation (indicative of negative effect), e.g. increased heart rate and (nor)adrenaline levels	−1, −2, −3	0
Aggression	Evidence of increased aggression, excluding skin lesions (cf. pain)	−1, −2, −3	22
Abnormal behaviour	Evidence of disturbed behaviour such as stereotype, apathy and disturbed sexual behaviour	−1, −2, −3	42
Frustration and avoidance	Evidence of blocked behaviour or deprivation, including willingness to work to avoid a treatment	−1, −2, −3	34
Natural behaviour	Evidence of (potential positive reward from) behaviour as seen in (semi-)natural conditions, including time budgets and species specificity of that behaviour	+1, +2, +3	113
Preferences	Evidence from preference tests and behaviour under other than natural circumstances, including rebound effects and anticipation	+1, +2, +3	25
Demand	Evidence that animals make efforts to obtain a commodity, especially using operant conditioning	+1, +3, +5	12

Weighting categories, weighting category scores and weighting factors

In general, a statement specifies the effects of a certain level of an attribute on a weighting category. The effect can be positive or negative. According to Bracke *et al.* (2002), the weighting categories classify welfare performance criteria that have been measured in the various welfare disciplines, i.e., veterinary science (with the weighting categories ‘pain’ and ‘illness’), evolutionary biology (‘reduced survival’, ‘decreased fitness’), stress physiology (hypothalamic-pituitary-adrenocortical - HPA, sympathetic-adrenal-medullary - SAM), and ethology (‘aggression’, ‘abnormal behaviour', 'frustration and avoidance', 'natural behaviour', 'preferences' and 'demand '). A list of weighting categories is presented in Table 2.

The scientific statements relate the attribute levels to the weighting categories. When the database of FOWEL was completed, a score was given to each relation, depending on the strength of the statement: a minimum, an average or a maximum effect. For weighting categories with a negative influence on welfare, this score is translated into a negative number: –1, –3 or –5 (for the main weighting categories) and –1, –2 and –3 (for the other weighting categories). For weighting categories with a positive influence on welfare the numbers are: 1, 3 or 5 (for 'demand') and 1, 2 or 3 (for 'natural behaviour' and 'preferences'). If it can be concluded from a statement that there is no relation to an attribute level, the score 0 can be given.

The definition of attributes (and levels), the weighting categories (and scores) and scientific statements on welfare of laying hens now make it possible to calculate the weighting factor per attribute. The scientific statements are related to attribute levels and to weighting categories (with a score), so a list of all statements can be made with scores per weighting category for each attribute level. The 'weight' of an attribute level is defined as the sum of the maximum scores per weighting category for statements related to this level. The weighting factor of an attribute is defined as the maximum difference between the weights of the levels of the attribute. This procedure for calculating the weighting factors has been applied to each attribute. The results are presented in Table 1.

Absolute welfare scores of production systems

The welfare score of a production system is computed by combining the attribute scores with the weighting factors. The absolute welfare score of production system *s* is defined as the sum over all attributes *a* of the attribute score of production system *s* and attribute *a* multiplied by the weighting factor of attribute *a* (WF_a, values given in Table 1), according to the following equation:

$$\text{absolute score (system } s) = \sum_{a=1}^{25} (\text{attribute score}_a^s \,.\, WF_a)$$

For example, for production system 1 (cage system) the absolute score is the sum of:
attribute score 1 for 'feeding level' multiplied by the weighting factor 25, is 25;
attribute score 0 for 'space per hen' multiplied by the weighting factor 21, is 0;
etc.
attribute score 1 for 'litter handling' multiplied by the weighting factor 2, is 2;
attribute score 1 for 'toe trimming' multiplied by the weighting factor 0, is 0.
So the absolute score of production system 1 is: 25 + 0 + ... + 2 + 0 = 55.67.

Relative welfare scores of production systems

The absolute welfare scores of production systems are transformed into relative welfare scores on a scale from 0 to 10. The relative welfare score 0 is assigned to the system with the lowest absolute welfare score (production system 1, 'cage system' with 55.67 as absolute score) and 10 to the system with the highest absolute welfare score (production system 19, '12-hen system' with 216.63 as absolute score). Only 20 production systems have been taken into account for setting the highest and lowest absolute welfare scores; the two production systems from the Laying Hen Husbandry project were not included. An intermediate value proportional to the absolute value is assigned as the relative welfare score, which for all systems is:

$$\frac{(\text{absolute score }(s)-55.67)}{(216.63-55.67)}.10$$

where s is the number of the production system.

For example, the absolute score of production system 4 (barn system, no free range) is 150.43. So the relative score is:

$$\frac{(150.43-55.67)}{(216.63-55.67)}.10 = 5.9$$

Results and discussion

The data entered in the database of the model FOWEL include 12 needs, 25 attributes, 22 production systems, 300 relevant scientific statements and 12 weighting categories. The scientific statements were related to weighting categories and scores. This information was combined with the attributes and their levels to compute the weighting factors per attribute. The data obtained (Table 1) are an important result from FOWEL. The attribute 'feeding level' has the highest weighting factor and is thus the most important attribute. Other important attributes are 'space per hen', 'perches', 'water availability' and 'nests'. With 5 as weighting factor, the attribute 'free range' is of minor importance, ranking 19th on a sorted list of 25 attributes.

The weighting factors per attribute and the attribute scores of the production systems have been combined to compute the welfare scores of the production systems. The resulting relative welfare scores and the absolute welfare scores are presented in Table 3. The latter are also depicted in Figure 3. From this figure it can be seen how the absolute score is composed of attribute score × weighting factor.

Production system 1 (cage system) appears to be the production system with the lowest absolute welfare score. Production system 19 (12-hen system) is the system with the highest absolute score: 216.63. There is no actual production system with all attributes at the highest level. A hypothetical production system with all attribute scores equal to 1 would get 246 as the absolute score. This system is included in Figure 3 with the name '0: Maximum'.

The relative scores (Table 3) are derived from the absolute scores: the relative score is 0 for the system with the lowest absolute score (cage system) and the relative score is 10 for the system with the highest absolute score (12-hen system). The relative scores of the other systems are between 0 and 10 in proportion to their absolute score.

The welfare scores of the 22 production systems resulted in the following classification:

1. A minimum score for cage systems and a low score for the enriched cage.
2. A medium score for all barn and aviary systems; the mutual differences have

Table 3. Relative (scale 0–10) and absolute welfare scores (based on attribute scores and weighting factors) computed with the computer model FOWEL for 22 poultry production systems, in sequence of score.

No.	Production system	Welfare score	
		Relative	Absolute
1	Cage system	0.0	55.67
2	Cage system, lower density	0.3	59.87
3	Enriched cage system	2.3	92.82
10	Aviary system, semi-intensive, no free range	5.8	149.77
4	Barn system, no free range	5.9	150.43
11	Aviary system, extensive, no free range	6.1	153.10
12	Aviary system, semi-intensive eggs, free range	6.1	154.27
14	Aviary system, semi-intensive, covered free range	6.3	156.77
16	Aviary system, semi-intensive, covered and uncovered free range	6.3	156.77
5	Barn system, semi-intensive eggs, free range	6.3	157.43
7	Barn system, semi-intensive eggs, covered and uncovered free range	6.5	159.93
6	Barn system, semi-intensive eggs, covered free range	6.6	162.18
13	Aviary system, free-range eggs	6.7	163.10
8	Barn system, free-range eggs, intensive	6.7	163.27
9	Barn system, free-range eggs, extensive	6.7	163.27
17	Aviary system, free-range eggs, covered and uncovered free range	6.8	165.60
15	Aviary system, extensive, covered free range	7.0	167.85
18	Organic production, barn or aviary system, free range	7.8	181.37
20	Uncultivated poultry (chickens, pheasants)	8.7	196.00
21	Plantation (Laying Hen project)	9.2	204.17
22	Roundel (Laying Hen project)	9.6	209.67
19	12-hen system	10.0	216.63

little influence on the welfare score.

3. A high score for organic systems.

The model FOWEL makes it possible to compare production systems on welfare. However, the minimum level for welfare is not evident. The model cannot be used to set the minimum level; it is up to the government to regulate production systems or to the consumer to choose eggs from preferred production systems.

The results of the FOWEL computations were validated with expert opinions on the welfare status of production systems. There was a substantial agreement between the experts and the model on the ranking of attributes and systems (De Mol *et al.*, 2004).

The weighting factor resembles the relative weight of an attribute for the welfare of laying hens. According to Table 1, the five most important attributes were feeding level, space per hen, perches, water availability and nests. Free range is one of the least important attributes. This is remarkable, as it is a major issue in discussions on the

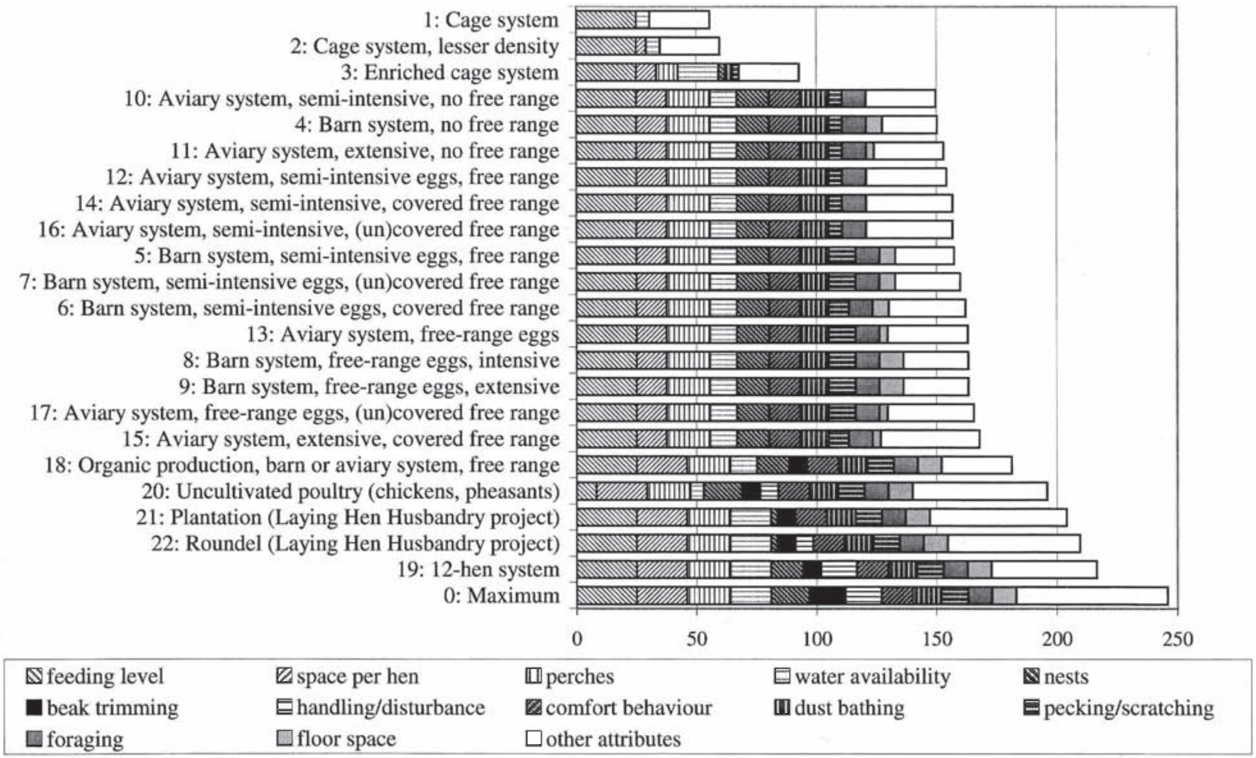

Figure 3. Absolute welfare scores calculated with FOWEL of 22 poultry production systems (and a hypothetical system 0 with maximum levels for all attributes), using the contributions from the 12 most important attributes and from the 13 other attributes (including free range) ranked by weighting factor. Production systems ranked in order of increasing relative welfare score.

welfare of laying hens. The scientific evidence for this concern appears to be missing. Weighting factors may change if new scientific information becomes available and new statements are included in the model with other scores per weighting factors of attribute levels.

The procedure for relating statements to attribute levels and weighting categories was adopted from Bracke (2001) with one minor change. Bracke further elaborated the procedure by introducing types of a weighting category, e.g. for the weighting category 'abnormal behaviour' two types are 'stereotypic behaviour' and 'abnormal sexual behaviour'. This differentiation is not adopted here as it makes the computation more complicated with only minor effects on the results.

The relative welfare score was derived from the absolute welfare score, 0 for the worst system, 1 for the best system and the other ones proportionally. The resulting scores with this method depend on the set of available production systems. The results would have been different if, for example, the cage systems had not been included, as they will be banned in the future. The ranking of the other systems will not change, but the level of the scores would have been different. An alternative transformation is relating the relative score 0 to the absolute score 0, and relating the relative score 10 to the absolute score 246 (i.e., the score for a hypothetical ideal system). This alternative might be preferred as the results can be interpreted like school marks.

Conclusions

The computer model FOWEL makes it possible to compare poultry production systems for laying hens on welfare status, using available scientific knowledge. The method, which was developed for and applied to pregnant sows (Bracke, 2001) is also applicable to laying hens. It is possible to add new knowledge to FOWEL or to compute the welfare scores of other production systems.

FOWEL was used to compute the welfare scores of 22 different poultry production systems:

1. A low score was calculated for cage systems, although an enriched cage system scored slightly better.
2. A moderate score was calculated for barn and aviary systems; the mutual differences were small.
3. A high score was calculated for organic production systems.

Feeding level, space per hen, perches, water availability and nests are important attributes for welfare. Free range is one of the least important.

FOWEL cannot be used to define the minimum acceptable welfare level. This is a task of politicians and consumers. New scientific information should be included in FOWEL as scientific statements to keep the system up to date.

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