# Collection, analysis and interpretation of welfare related data

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## 1. Introduction:

During the last years, reliable methods and criteria for evaluation of poultry welfare under different production systems are extensively sought. According to Broom (1991) "Welfare" refers to a state of an individual in relation to its environment and this can be measured. Researchers have searched for objective ways to evaluate welfare. As part of this evaluation, various ways to measure welfare have been proposed. Ideally, a single measure of welfare might not be a reliable indicator and it is usually more informative to combine multiple indicators of stress to assess animal welfare. Poultry welfare assessment uses integrated approaches based on different criteria. Due to its complexity, only by applying a multidisciplinary approach the overall assessment of animal welfare can be studied in to. Overall welfare depends on how the animal may perceive in its living environment, taking into account not only the physical aspects of the environment, but the social aspects as well. Aggregating relevant welfare indicators related to production system, husbandry practices, animal health and behaviour is suggested to assess the overall level of well being of the individual.

There is no established method or system for assessing animal welfare, but various frameworks have been suggested. Their application requires knowledge of animal health and production and species–typical behaviour. Any welfare assessment system should have the following qualities; 1. Scientific basis and ability to express development over time 2. Measurable on a commercial farm within a realistic framework and 3. Relevant as decision support system for the farmers. This assessment system may differ according to their potential uses like for what purpose the animal welfare is assessed.

## 2. Welfare principles and criteria:

Welfare includes, the notions of the animal in complete mental and physical health, the animal in harmony with its environment, the animal being able to adapt without suffering to an artificial environment provided by human beings, and that somehow the animal's feelings should be taken into account. Welfare of a bird, is a difficult concept to define and even more difficult to assess. Reliable welfare criteria and evaluation models in poultry production and welfare assessment models under different conditions in poultry have gained increasing importance. The different measurable aspects of welfare to be covered are turned into welfare criteria.

Nevertheless, a variety of criteria including health, productivity, behavioural and physiological characteristics commonly used to reveal this situation. Finally measures were selected to assess these welfare criteria. However, to prove and verify animal welfare requirements in practice is not simple. In intensive poultry production a large number of factors, such as stocking density, environmental deterioration, unsuitable social environments, thermal stress, or difficulties in accessing essential resources can be major sources of stress that can lead to welfare deterioration and reduced performance. Many of these factors can be controlled through well-established management practices to provide birds with an optimal environment.

**Table 1:** The different welfare principles and their assessment criteria are summarised below:

| Welfare principles | | Welfare Criteria |
|---|---|---|
| Good feeding | 1 | Absence of prolonged hunger |
| | 2 | Absence of prolonged thirst |
| Good housing | 3 | Comfort around resting |
| | 4 | Thermal comfort |
| | 5 | Ease of movement |
| | 6 | Absence of injuries |
| Good health | 7 | Absence of disease |
| | 8 | Absence of pain induced by management procedures |
| Appropriate behaviour | 9 | Expression of social behaviors |
| | 10 | Expression of other behaviors |
| | 11 | Good human-animal relationship |
| | 12 | Positive emotional state |

## 3. Measures for welfare assessment:

In last few year seeing the importance of welfare, various methods and incidences are developing to measure the welfare of animals, but while it is now widely accepted that there is no single measure that can be used by itself to assess a welfare criterion (Dawkins, 1980: Broom, 1988: Mason and Mendl 1993). Welfare assessment serves to verify that the conditions to satisfy welfare standards during production are indeed met. Welfare is a multidimensional concept. It comprises both physical and mental health and includes several aspects such as physical comfort, absence of hunger and disease, possibilities to perform motivated behaviour, etc. The importance attributed to different aspects of animal welfare may vary between different people. There is no gold standard measure of overall animal welfare and no available information on the relative importance animals attribute to the various welfare aspects, although the various attempts to assess animal welfare are described below:

### *3.1. Resource-Based Measures*

Resource-based assessment intends to warrant the provision of the necessary recourses and environmental conditions in which the animals are kept for instance the number of feeder, drinkers in a pen. As assessing minimum resource requirements is generally easier than to evaluate the impact of the production conditions on animals. This approach was largely concentrate on design or management-based characteristics (e.g. size or pen, flooring specifications etc.). However, to verify that such conditions did not compromise the welfare of animals it was essential to develop methods based on the impact over the animals themselves. Since resource-based measures (e.g. type of housing and stocking density) or management-based measures (e.g. breeding strategies and health plans) are a poor direct guarantee of good animal welfare in a particular situation, these measures are avoided within the protocols. However, when no animal-based measure is available to check a criterion, or when such a measure is not sensitive or reliable enough, measures of the resources or the management are used to check as much as possible that a given welfare criterion is met. Animal-based assessment methods (Animal Based Measures ABMs) that were later developed, such as the Welfare Quality (WQ) poultry assessment protocol provides a thorough assessment of the impact of the actual rearing conditions on poultry welfare.

***3.2. Animal Based Measures:*** To address aspects of the actual welfare state of the animals in terms of, for instance, their behaviour, fearfulness, health or physical condition, there is an international progression to start to assess poultry welfare on farm by looking at the animals themselves (Animal Based Measures ABMs) rather than by looking exclusively at the resources provided (Resource Based Measures RBM's). The Welfare Quality set out to develop scientifically based tools to assess animal welfare. Animal Based Assessment Measures (ABM's), which includes twelve health and welfare criteria addressed by the Welfare Quality (WQ) protocol are;

a. Animals should not suffer from prolonged hunger, i.e. they should have a sufficient and appropriate diet.
b. Animals should not suffer from prolonged thirst, i.e. they should have a sufficient and accessible water supply.
c. Animals should have comfort around resting.
d. Animals should have thermal comfort, i.e. they should neither be too hot nor too cold.
e. Animals should have enough space to be able to move around freely.
f. Animals should be free of physical injuries.
g. Animals should be free of disease, i.e. animal unit managers should maintain high standards of hygiene and care.
h. Animals should not suffer pain induced by inappropriate management, handling, slaughter, or surgical procedures (e.g. castration, dehorning).
i. Animals should be able to express normal, non harmful, social behaviours (e.g. grooming)
j. Animals should be able to express other normal behaviours, i.e. it should be possible to express species-specific natural behaviours such as foraging.

k. Animals should be handled well in all situations, i.e. handlers should promote good human animal relationships.

l. Negative emotions such as fear, distress, frustration or apathy should be avoided.

The protocol for poultry includes descriptions of each of the measures to be carried out by the assessor, and information on the sampling order, sample sizes and sample duration in order to obtain scores for overall WQ assessment.

## 4. Indicators/components of welfare:

Since welfare is defined in terms of the state of the individual, it can be measured directly and indirectly. The various welfare indicators or so called component of welfare for livestock mainly includes:

***4.1. Performance Criteria:*** Performance criteria indicate what parameters of the state of an animal indicate good or poor welfare. Performance criteria are based on actual signs of reduced welfare and so can be used to check the relative adequacy of design criteria; they permit comparisons between systems. Performance criteria can help identify specific inadequacies with the environments of animals and so help guide design improvements. Egg production, body weight, feed intake, feed conversion rate and mortality are the main characteristics of performance in the domestic fowl. High egg production in layers is an indicator of undisturbed physiological function of the reproductive tract. The absence of stressors, which are known to reduce egg production, such as heat stress; stocking density, social strife is a prerequisite for high productivity throughout the laying period. The same has been reported for growth rate and feed conversion on broilers. It has been reported episodically that birds showed high production rate despite serious wounds, diseases or stress challenges. But it is unlikely that laying hens or broilers will maintain high production rates after extended periods of stress. Sub-optimal production, however, does not indicate lack of welfare. Low protein or/and high fibre/low energy diets, short lightning periods may reduce productivity without obvious welfare problems. The welfare status in broilers may even be improved by reducing the early growth rate through reduced incidence of leg problems.

It is a reasonable assumption that serious welfare problems will be apparent in reduced productivity e.g., fewer eggs laid, higher morbidity and mortality rates and, perhaps, reduced longevity. Injury and disease are clear signs of reduced welfare, and housing systems that increase the incidence of these should be viewed with concern. Therefore the interpretation of production traits in regard to welfare requires consideration of the other aspects.

***4.2. Morphological parameters:*** The various changes in the morphological conditions of the birds represent the obvious signs of impaired welfare. The frequencies and intensities of morphological damages in can easily be recorded in the form of scoring systems in layers and broilers on the farm or in the slaughter houses. Many morphological damages leads to painful suffering conditions like bone breakage, keel bone deformation, broken claws, feather damages, bumble feet, foot pad lesions etc. indicative of impaired welfare. Lack of exercise in caged hens reduces bone strength and increase the risk of breakage, fragility of bones hens in laying hens, fresh breakages are in caged laying hens. On the contrary, the bones of hens from non-cage systems are stronger, the higher risk by the movement to perches and nest boxes leads to higher incidence of breakages of the keel bones and the furculum. Minor deteriorations of the feather structure is brought about by gentle feather pecking and may not be connected with pain and suffering

***4.3. Animal health:*** Good health is considered a prerequisite for welfare. Since health problems are closely related to the morphological, physiological and psychological conditions of the animals. Physical health is relatively easy to assess in contrast to psychological health which is less easy to assess. In order to appraise the extent of welfare problems caused by diseases it would be necessary to record the type and duration of disease as well as number of diseased birds. The duration of suffering highly depends on the type of disease, culling practice and quality of medical care. With regard to the work and laboratory capacity which is required to generate such data under practical conditions we have to rely on indirect criteria. Changes in feed and water intake are directly linked with bacterial and viral infections. Since water intake can be easily recorded, it may not only serve as an early warning system for the outbreak of a disease, but also as a means to measure the incidence and duration of the disease on a flock basis.

Psychological health implies their mental well-being that every animal have their 'Five Freedoms' as per the Farm Animal Welfare Council (FAWC 1992). It means their lives are free from negative emotional states such as pain, fear, frustration, cold and hunger. Behaviour is an important adjunct to the assessment of physical health, both as a clinical symptom in its own right and also as giving early warning signs of health problems to come at a time when other symptoms may be sub-clinical, for example the use of disturbed bio-rhythms.

***4.4. Physiological parameters:*** Another approach for the study of birds' welfare in different environments is to monitor physiological parameters associated with reaction to a stressor. The physiological measures that have been used include short term responses such as increases in heart rate, body temperature, respiratory rate, increases in adrenalin secretion, corticosteroids (sometimes called "stress" hormones), plasma glucose, lactate and free fatty acids (Broom and Johnson, 1993) and longer term ones such as enlargement of the adrenal glands and depression of immune function (Moberg, 1985). Although, Corticosterone and related hormones are also involved in basic metabolic functions. In order to differentiate between normal metabolic activity such as low ambient temperature, increased exercise, and stress response it is essential to study the basal level as well as the dynamic response to challenges. Physiological criteria usually return to normal levels within a given time after challenge. The persistence of high levels of Corticosterone, for example, indicate lack of ability of adaptation and are considered as indicators of reduced welfare.

The problem with this method is that many of the physiological indicators of ‘welfare’ currently in use are in fact autonomic responses that indicate activity or arousal rather than being specific to poor welfare. Heart rate, respiratory rate and level of corticosteroids, for example, rise during coitus, exercise, and in anticipation of food. Many vary naturally with time of day, temperature, breeding condition etc. Many methods of acquiring those measures are invasive (for example, to take a blood sample) or at least intrusive (disturbing it). Collection of physiological data requires special equipment, laboratory methods and controlled environmental conditions. The criteria may not be applicable under practical husbandry conditions. Application of new technology like mapping brain activity or to use urine, saliva or faecal measurements of hormone levels (Cockrem and Rounce, 1994; Wingfield *et al.*, 1997) will overcome some of these problems in the future. As physiological variables are not easy to be precisely measured under field conditions, behavioural responses studies have acquired increasing importance in the assessment of welfare of domestic animals.

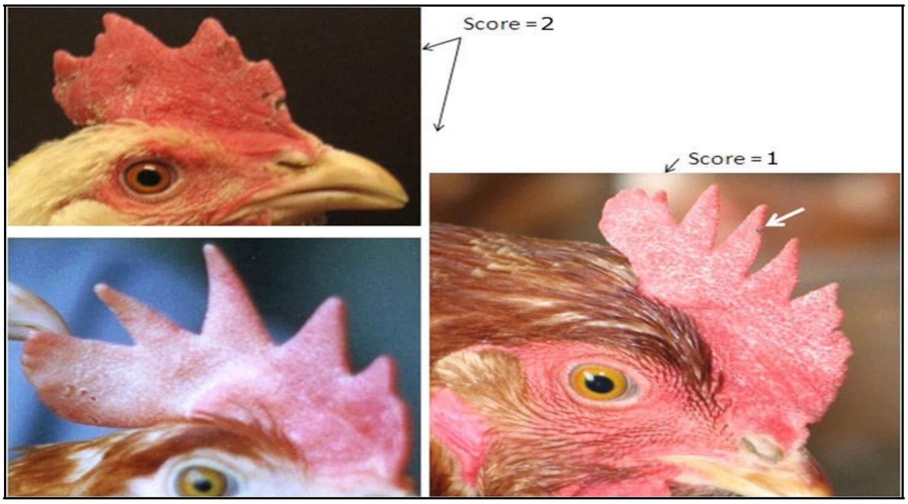
***4.5. Behavioural parameters:*** Behavioural responses are the most pertinent indicators of the well-being of an animal. (Moura *et al.* 2006). Qualitative Behaviour Assessment (QBA) considers the expressive quality of how animals behave and interact with each other and the environment i.e. their ‘body language’. The various behaviour measurements and tests, can reveal whether the animals are adapted to the given production system or showing any signs of stress. This behavioural observation should be repeatable by same observers and can be reproducible by different observer. They should be based on the animal not the environment. These are described in detail in separate chapter on “*Practicing behavioural observations for assessment of welfare in poultry”*.

**5. Welfare assessment protocols in poultry**

A. ***Physical condition of birds:*** Physical body condition of birds can be regarded as important indicator of welfare. A poor body condition may cause long-term discomfort and an increase in disease susceptibility caused by impaired immune-system. The welfare of the birds can be assessed by looking and clinical examination of the physical condition of the birds.

***2. Pecking wounds and comb abnormalities:*** Chicken is observed with respect to presence or absences of body lesions. Little wounds in a shape of punctiform pecks (holes) or scratches are not considered as lesions, but if there are 3 or more pecks and/or scratches then these are taken into account. Pick up a bird from the litter or cage. Examine the rear end and the legs of the hen for presence of skin lesions. Lift the feathers to examine the skin. Assess the individual birds according to the following: **0** – No lesions, only single (<3) pecks (punctiform damage <0.5 cm diameter) or scratches, **1**– At least one lesion <2 cm diameter at largest extent or 3 pecks or scratches, **2**– At least one lesion 2 cm diameter at largest extent

Apart from pecking wounds (these are scored separately) other comb abnormalities should be scored as well. There should be no blue or black areas present on the comb. A normal comb has an even red colour and no wounds or scratches. Hens at the peak of production may have a slightly paler comb, but combs which are very pale may indicate anaemia. If hens are dehydrated, combs may look 'dried out' and blue. The final score is based on both the inspection of the birds.




***3.*** ***Feather condition:*** The most effective means to assess feather condition is by scoring the birds at different ages. It is assessed using a five point scoring system (Abrahamsson *et al.*, 1996) for seven different areas of the body (head, neck, back, wings, tail, abdomen, and breast. The feathers of normal birds should be smooth with no signs of disturbance. All feather shafts then usually point in one direction resulting in a protective and insulating cover to the skin. Due to abrasion against wire, feather shafts can be broken. Due to pecking behaviour feathers can be disturbed, broken or even torn out. Areas where feather damage usually starts are the tail, neck and cloacal region.

**1.** Full feather cover,
**2.** Worn feathers detectable;
**3.** Small bare patches ≤ 30 mm diameter;
**4.** Large bare patches with > 30 mm diameter;
**5.** No feathers over most of the areas of head, neck, back, wings, tail, abdomen, and breast

***4.*** ***Foot lesion scoring and claw length:*** The feet of hens should have smooth skin without any wounds or abnormalities. Wire floors can cause hard patches or other proliferations (thickening) of the epithelium. Inflammation or skin damage can cause a swelling of the foot, called bumble foot. This starts with a minor swelling, but can finally result in very swollen balloon-shaped feet. A poorer hygienic surrounding for the feet to move on clearly increases the incidence of this foot damage. During assessment, pick up a bird from within the litter or cage system. Examine both feet of the hen and choose the foot with the worst condition to score (Nicol *et al.*, 2006) according to the following: **1.** Good condition; **2.** Lesions visible but not infected; **3.** Severe lesions, small but not widespread; **4.** Poor foot condition with wide spread lesions but no signs of bleeding; **5.** Very poor foot condition with severe lesions and bleeding

For claw length measurement, the middle toe of the right feet of the sampled hen is to be examined. The claws were measured in mm from the base to the tip.

| | | | | |
|---|---|---|---|---|
|  |  |  |  |  |
| **1** | **2** | **3** | **4** | **5** |

***5. Keel bone deformity:*** Keel bones are normally straight without dips, bulbs, deviation or other palpable abnormality. Abnormalities can be caused by badly shaped perches, healed breaks (fractures) or by decalcification of the keel. A keel bone deformation is any abnormality from the normal straight shape of the keel. During assessment, pick up a bird from the litter or cage. Examine the breast of the hen by looking at it (in case of featherless breast) or by running fingers alongside and over the keel bone and palpate the area. Compare to the photographic reference and assess according to the following method described by Elson and Croxall, 2006 and give them the scores as described below; **1.** Good, **2.** No skin lesion but twisted, **3.** Large deformity, **4.** Bone fracture, **5.** Bone fracture with skin lesion.

**0 *Gait performance test:*** Due to susceptibility of fast-growing broilers to pathologies of the leg bones and joints, leading to lameness, there is a need for objective methods to assess walking ability in commercial flocks. A widely used method is the gait scoring system proposed by Kestin *et al.* (1992) as Bristol gait score. With this method, walking ability is rated by a human observer by the use of six categories, ranging from completely normal to immobile. Birds with score 5 were excluded from the groups. The proportions of normal birds and total prevalence of gait problems (gait score >0) were calculated. The scoring system is as described below: 0. Sound birds; no detectable impairment of walking normal bird, 1. The bird moves fast, but a slight walking deficiency is observed, 2. The bird moves fast, but there is significant walking deficiency, 3. The bird moves fast, but it presents an important deficiency, 4. The bird moves with serious difficulty, 5. The bird barely moves and often uses the wings for crawling/ total inability of the bird to walk

However, in recent years, improvements are being proposed in current gait scoring system with automated scoring systems with a pedobarograph, a device which allows pressure patterns to be established for various regions of the foot (Corr *et al.*, 1998), or with a force plate, which measures the ground reaction force in one or more directions.

***6. Bone quality test:*** Laying birds from different treatments were randomly selected and killed by cervical dislocation at 61wk of age. The bone mineral density and bone mineral content of the left tibia and humerus of each intact bird were measured using a dual energy x-ray absorptiometry x-ray densitometer. Individual body weight was recorded before each scan. Scanning began at the proximal end of the bone and lasted for approximately 10 min. The orientation of the bone was the same for each scan. After the scans were completed, the left tibia and humerus of each bird were excised, cleaned of all tissue, and subjected to bone ash analysis. The bone ash was then subjected to calcium and phosphorus analysis.

***B. Physiological parameters:*** Differential leukocyte counts and H/L ratios are determined to know level of stress in the birds. Birds were chosen at random for haematological analyses by stained-slide-method (Campbell, 1995). Blood smears for each hen are prepared immediately after blood collection and fixed with methanol. Smears were stained with Wright's and May-Grunwald stains, rinsed with distilled water and were allowed to air dry. Cells per slide were counted (100/slide) and classified using oil immersion microscopy at 1000X. Differential leukocyte counts included heterophils, lymphocytes, eosinophils, monocytes, basophils (expressed as percentages of total leukocytes) and the H/L ratio was calculated as a ratio of percentages of heterophils to lymphocytes for each hen sampled.

***C. Preference/choice tests:*** The major technique which is available to discover what is good for animals is to observe their preferences and to measure how hard they will work for the preferred event or object. One technique which has long been used is to watch the animals in an environment which is rich in the complexity of stimuli and opportunities for activities which it offers. The stimuli which are chosen and the ways in which the animals spend their time provide information about the preferences of the animals. The simplest experiment of this kind merely involves giving the animal the choice of two conditions where the choice is expressed by moving from one place to another. The animal is allowed to choose between certain aspects of its environment, and the assumption is that the animal will choose according to how it feels, that is, in the best interests of its welfare. This technique was developed by Barry Hughes and Marian Dawkins in poultry.

Preference testing is only the first step in 'asking' an animal what it feels about its environment but it has also certain limitations. The simple preference-test experiment has been criticised by Duncan (1978) who pointed out that the animal may not choose what is best for it. In most situations the repeatedly expressed choices of animals are those which increase their biological fitness, but some animals do choose to do things which harm them. Hence choice tests alone are sometimes inadequate. An individual may make a clear choice between two foods which are both very palatable and very beneficial to it. If the preferred food of these two could be obtained only by expending energy for a long time or by taking a risk, the preference might well be reversed. Hence, in order to be able to apply data from preference tests to practical situations where an improvement in welfare is sought, the strength of a preference must be assessed by discovering what costs the individual is willing to incur in order to be able to express the preference.

***D. Assessment of fearful response:***

***1. Response to a novel object:*** This test based on one first described by Hughes and Black (1974a), measures the avoidance response of birds to a brightly coloured novel object unknown to the birds of about 7 cm diameter a red coloured ball or 50 cm coloured long stick is placed by the observer in the middle of the litter area or inside the cage itself. Birds were left undisturbed for 15 minutes to get accustomed to the test-arena. The reaction of the birds is to be scored on a scale ranging from 0-4: Zero indicated no noticeable reaction and 4 meant panic among birds. Also, latency of the first bird up to 10 min to peck the novel object is to be recorded. If the bird didn't peck at all, it was given the maximum time for measuring (10 min).

**Novel object test to measure fear response in floor & cage housing system**

2. ***Tonic Immobility test:*** Tonic immobility [TI] behaviour is a reversible innate defence response characterized by profound physical inactivity and a relative lack of

responsiveness to external stimuli for example it is shown in situations of extreme, inescapable threat like in case where the chicken has been caught by a predator and by pretending to be dead chicken escape themselves from that moment (Thompson and Liebreich, 1987).

During the procedure, each individual bird is gently caught with both hands and carried to a separate room for TI measurements. Tonic immobility was induced as soon as the bird arrived in the separate room by gently restraining it on its right side and wings for 15s. The experimenter then retreated approximately 1 m and remained within the sight of the bird but made no unnecessary noise or movement. Direct eye contact between the observer and the chicken is avoided because it may prolong TI duration. A stopwatch was started to record latencies until the bird righted itself. If the bird righted itself in less than 10 s, the restraining procedure was repeated. If TI was not induced after 3 attempts, the duration of TI was considered 0 s. The maximum duration of TI allowed was 600 s. The birds were ranked from low to high (1 to 200) according to the duration of TI (Beuving *et al.*, 1989). Those birds showing the shortest TI duration and those scoring the longest durations were classified as LF or HF fear responders, respectively.

***E. Behavioural parameters*** :

Various behavioural patterns and tests can revels whether the bird are adapted to the production system or not. These are described in detail in separate chapter o "Practicing behavioural observations for assessment of welfare in poultry".

## 6. Analysis and interpretation of welfare data:

A wide range of technical developments, complex data processing, and modelling tools have emerged in the past few years with the potential to assess, control, and improve poultry welfare. However, collection and analysis of behavioural data is considered standard in the assessment of animal welfare and yet is not exploited to its full potential. The most commonly used methods for welfare assessment and analysis are described below:

***6.1. Scoring system:*** Scoring methods have been frequently used in order to assess treatment effects on welfare, e.g. housing conditions, feed composition, genotype, beak trimming, lighting programs, etc. Several methods of scoring systems have been used by various researchers as per their feasibility. For practical reasons subjective scoring is by far the most common methods. Although, there are some crucial characteristics a scoring system must fulfil: it should be simple to apply and not too time consuming as well as showing good repeatability, i.e. being able to show the same statistical differences between possible treatments compared. When used to the system scoring a bird for all characters will not exceed 30 seconds for one person. However, the intention of obtaining a high degree of precision, i.e. scoring a high number of individual body parts as well as using many scores may be perceived as more complicated and time consuming especially for non experienced scorers.

***6.1.1. Type of data:*** It is also important to consider the type of data to be analysed.

Information on welfare parameters can be obtained in the form of qualitative or quantitative data.

- ***Continuous data:*** It deals with numbers and things you can measure objectively. Continuous data means that values may vary infinitely within a range; for example in the case of observations of physical measurements (e.g. when measuring the height of two animals, the difference between them can be infinitely small, and determining this is dependent only on the accuracy of the instrument used) or how many times a behaviour is performed in a week, this would be quantitative data. It may contains numerical value; such as 'the hen ate 9 pellets of dry feed' 'the hen ate its feed for 15 minutes' and the hen dust bath for 2 times. Continuous data, could be divided and reduced to finer and finer levels. Continuous data can be described by a graph which demonstrates how many of the individuals observed are represented by each of the values observed. A curve can then be drawn to further assist in the visual representation.
- ***Discrete data:*** The opposite of a continuous value is a discrete value, which means that the value cannot be divided further (e.g. the number of individuals with a certain characteristic is a discrete number, as you cannot have half of an individual). Discrete data is a count that can't be made more precise. Typically it involves integers. It is a type of qualitative data is data which has a discrete meaning or cannot be described as a quantity, for example a hen may be feeding, drinking or resting which is most common in behavioural studies. For this generally non parametric tests are used for data analysis.

***6.2. Mathematical modelling:*** Modelling approaches can be used to enhance the application of technology in commercial poultry farms. Indeed, large sets of data produced by video recordings can be analysed by complex modelling or artificial intelligence algorithms to generate predictions or risk assessment models. Animal welfare and behaviour is complex, with simultaneously occurring, differentially contributing processes that do not follow simple linear patterns. Once all the measures have been performed on an individual unit and data is obtained, a bottom-up approach is followed to produce an overall assessment of poultry welfare on that particular unit. A mathematical model may be designed to produce the overall assessment by using following analysis or by using non-parametric (NP) statistical inference in single subject designs.

- ***Fractal Analysis:*** There are two types of behavioural data used in analysis: (i) behavioural processes scored on a binary scale and (ii) pathway analysis (using x–y coordinates). Observations of the presence or absence of a state over time form the binary scale, e.g. whether an animal is active or inactive, or fluctuation between two states.
- ***Temporal Analyses:*** As behaviour is a continuous process and yet often when it is analysed it is separated into discrete events where structural detail, such as temporal arrangement, is ignored. Temporal analyses retain information on structure, effectively reconstructing events into meaningful sequences.

- *Social Network Analysis:* Social network analysis is the study of social groups as networks of nodes connected by social ties. This approach examines individuals and groups in the context of relationships between group members. Application of social network analysis to animal behaviour can advance the field by identifying and quantifying specific attributes of social relationships, many of which are not captured by more common measures of sociality, such as group size.

### *6.3. Behaviour monitoring system and data analysis:*

The ideal behaviour monitoring system is completely automated and produces objective and reproducible measurements with a minimum of human effort. With the advancement in video technology and computer image processing enables the more widespread surveillance of the behaviour of animals with automatic recognition of behaviour. Automatic video tracking systems and computer software are available as mentioned in detail in other chapter for analysis of behavioural data starting from recording of data upto its analysis and inference which enable researchers to study behaviour in a reliable and consistent way and over longer time periods than if they were using manual recording.

However, different technologies are still facing major limitations for their implementation at a commercial scale. Indeed, data collection and processing refinement is still needed along with cost-efficient. Major technical and software advances have yet to take place that provide reliable results.

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# Welfare of birds reared under high altitude conditions

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## 1. Introduction:

Efficient poultry production much depends on local circumstances like environmental conditions, nutritional availability, altitude etc. High altitude conditions which are characterized by extreme climatic conditions, hypobaric hypoxia and unavailability of feed (Biswas et al., 2011) are more difficult than at plain areas often encountering a number of production, health, and mortality problems. At high altitudes, hypoxia which is caused by the fall in barometric pressure with increasing altitude and consequently lowers oxygen content in the inspired air compared to sea level is a typical stress, (Beall, 2006). Low partial pressure of oxygen in the inspired air refers to hypoxia which threatens the survival, development, and reproduction of animals (Jia *et al.,* 2016; Rostami *et al.,* 2016; Li *et al.,* 2014) because of its physiological challenges on the body. Much of these problems could, however, be alleviated when proper management and feeding conditions are duly adopted. This is particularly true in areas of very high altitudes, where the adaptive mechanisms of birds may not be sufficient enough to cope with such adverse conditions.

## 2. Problems associated with high altitude:

Previous studies have shown that hatchability reduced by 10% at altitude of 305 meters, and by 30% at 2,130 meters of chicken eggs above sea level. Three hatching-related factors come into play at high altitudes:- reduced $O_2$ availability or atmospheric $O_2$ tension, excessive loss of carbon dioxide ($CO_2$) and excessive water/weight loss by the incubating embryos. Growth increases the need for $O_2$ consumption (Beker *et al.,* 2003), and growing stage broiler chickens need $O_2$ to fulfill high metabolic requirements (Julian *et al*., 1989). Fast growing birds requires more oxygen at the tissue level to sustain fast growth (Decuypere *et al.,* 2005). Chronic hypoxia at altitude increases mortality and decreases growth during incubation as a result of adaptation (Julian, 2000; Villamor *et al.,* 2004) which leads to decrease chick weight (Dzialowski *et al*., 2002). High altitude coupled with hypoxia affects the body metabolism, which causes negative energy balance due to the reduction in energy intake and an increase in energy expenditure, so the overall growth rate is decreased (Balog *et al.,* 2000). This reduced body weight gain might be due to a reduction in the nutritional energy intake or intestinal energy uptake as a result of impaired intestinal function and increased energy expenditure. Hypobaric hypoxia creates an imbalance between oxygen intake and oxygen requirement which leads to ascites and reduced growth rate (Julian, 1993) and fall in the immunity makes them susceptible to numerous microbial diseases, including coccidiosis (Lee *et al.,* 2007; Balog *et al.,* 2000). However, Bahadoran *et al.,* (2010) found that bodyweight of newly hatched chicks from a high-altitude incubator was significantly higher than that of chicks incubated in a low-altitude one. Additionally, Giussani *et al*., (2007) showed that $O_2$ supplemention of eggs incubated at sea-level could prevent high-altitude induced growth restriction completely.

Oxygen concentration plays an important role in the onset of ascites; reduction in atmospheric $O_2$ concentration effectively induces ascites. Keeping the $O_2$ concentration above 19.6% can minimize ascites-related anomalies and maximize performance (Beker *et al.,* 2003). Fast-growing chicken are prone to suffer from ascites due to high demand of $O_2$ for their rapid growth and high metabolic rate (Acar *et al.,* 1995). A higher metabolic rate is associated with increased secretion of the hormones, thyroxine (T4) and triiodothyronine (T3), which are important growth promoters in chickens (Luger *et al.,* 2001). Thyroid hormones regulate the metabolic rate during the post-hatch period (Decuypere *et al.,* 2000) and are linked with ascites susceptibility (De Smit *et al.,* 2005). This becomes even more apparent under adverse environmental conditions, such as high altitude. The peak of ascites incidence occurs during weeks 5 to 6 of the growing period (Coleman & Coleman, 1991). Before a bird exhibits gross ascites syndrome lesions, commonly the right ventricle to total ventricle (RV:TV) ratio, changes in the concentrations of haemoglobin (Hb), haematocrit (PCV) (Wideman *et al.,* 1998), glucose in the liver (Diaz-Cruz *et al*., 1996), blood gases and other parameter changes can be detected (Huchzermeyer & DeRuyck, 1986). It is generally accepted that the greater right ventricle to total ventricle ratio (RV:TV) (0.29 vs. 0.20) is an indication of ascites (Julian, 1993). Depending on the higher incidence of ascites, high-altitude incubated chickens had a different growth pattern during their post-hatch growing period and reached their maximum growth at 6 weeks old (Bahadoran *et al.,* 2010).

High altitude areas are commonly cold prone than plain areas and characterized with extreme environmental conditions, including low oxygen content, low barometric pressure, and great temperature fluctuations on a daily basis. Poultry reared in cold stress conditions during the winter period in temperate areas affect adversely the welfare and productivity of birds (Sahin *et al.,* 2002). Within the range of thermal comfort zone (18 to 22°C), poultry maintain their thermoregulation without facing any problems. Low ambient temperature at high altitude is a common cause of poor welfare in fowls that triggers a chain of non-specific reactions and systemic mechanisms of defense. The stress response in birds is mediated mainly by activation of the hypothalamic-pituitary-adrenal axis, the orthosympathetic nervous system and poultry behavior changes (Puvadolpirod and Thaxton, 2000) to overcome the stress. Under the influence of low ambient temperatures the hypothalamus is triggered, the adrenal gland cortex is activated and reacts by enhanced secretion of glucocorticoids, the major among which in birds is corticosterone (Siegel, 1995). These events further generate numerous biochemicals, behavioural, immunological and productive alterations resulting in worsened welfare of birds. The feed consumption and locomotion level are increased whereas water drinking and the behaviour linked to heat loss like wing spreading, feather cleaning, dust bathing etc. are reduced (Sahin *et al*., 2003).

High altitudes hypoxic environment is the main ecological factor with a negative impact on the animal's health and a threat to their survival at high altitudes affects severely to chickens that are not well adapted to high altitude (Li *et al.,* 2014). Continuous exposure to high altitude leads several physiological responses to make it possible to live birds in a low $O_2$ environment. Red blood cell number (RBC) and amount of hemoglobin (Hb) increases are the most important hematological acclimatization responses which appears after 1-2 weeks. These changes increase oxygen-carrying capacity of blood to act as a compensatory mechanism against the stimulus of reduced oxygen saturation. Further, at high altitude, there is a decrease in mean cell volume (MCV), so the total surface of RBC is enlarged, which is advantageous for hemoglobin to bind oxygen, and helps prevent the increase of blood viscosity that results from polycythemia. Numerous studies have highlighted the role of hypoxia in initiating the expression of hypoxia-induced factor-1 (HIF-1α) and further inducing the expression of target genes such as vascular endothelial growth factor (VEGF) and its receptors, which promote various systemic physiological changes including angiogenesis and vascular development (Befani *et al.,* 2013; Chen *et al.,* 2015). Angiogenesis plays a crucial role in the homeostatic mechanisms associated with the vascular oxygen supply in hypoxia.

## 3. Amelioration of high altitude stress:

Adaptive broiler strains could be less susceptible to high altitude mediated adverse problems and therefore will have better growth rate (Kalia *et al.,* 2017). RIR cross-bred is suitable for rearing in high altitude regions and probiotic supplementation has no beneficial effects on production performance of broilers at high altitude. However, probiotic supplementation indicated lesser loss due to mortality of birds (Kalia *et al.,* 2017). Coenzyme Q supplementation improves the performance broilers under high altitude induced hypoxia (Huang *et al.,* 2011). Supplementary L-carnitine demonstrated antioxidant effects in thermoneutral broilers (Jia *et al.,* 2013), low-temperature stressed broilers, inducing ascites (Wang *et al.,* 2013) and high altitude broilers, inducing ascites (Yousefi *et al.,* 2013), by virtue of its free radical scavenging properties (Packer *et al*., 1991). Zinc is used as an antistress feed supplement of poultry to meet their specific needs in cold stress (Sahin & Kucuk, 2003). Sahin *et al.*, (2002) reported that the addition of 30 mg Zn/kg feed in laying hens submitted to cold stress (6.8 °C) decreased blood corticosterone, glucose and cholesterol. During the cold period, the poultry welfare (PW) score of control breeders was PW=40%, of the Zn-supplemented flock – PW=60% and of zinc and vitamin C supplemented flock – PW=73.33%. The poultry welfare improvement was due to the stress-reducing effect of both Zn and vitamin C supplements. The combined supplement had a better alleviating stress effect due to synergic action of its ingredients.

There are many constraints at high altitude for poultry industry like lack of commercial broiler/layer feed that can meet the maintenance and productive requirement of birds at high altitude, lack of the appropriate strains of broiler birds to cope with stress full environmental conditions of high altitude, prevailing harsh environmental condition at high altitude stress, high mortality of birds, diseases etc.

## 4. Conclusion:

In conclusion, unsatisfactory growth performance of poultry at high altitude can be overcome by identifying appropriate strains of broiler chicken having more adaptability under hypoxic conditions. Dietary supplementation of feed additive in broiler diet could be a valuable source for improvement in their survivability rate and save the loss due to high mortality at high altitude. However, more additional knowledge is required on feed additive to counteract the negative effect of high altitude stress.

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