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Faculty of Veterinary Medicine and Animal Science
Department of Animal Husbandry and Management

Broiler production in Zambia

- management, growth, diseases and welfare

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Broilerproduktion i Zambia – hantering, tillväxt, sjukdomar och välfärd

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SUMMARY

Successful broiler production in hot climates requires knowledge of how birds are affected by heat stress. It is important with access to water and good ventilation to facilitate coping with the heat. It may be useful to reduce the consumption of feed during the hottest hours of the days, which together with a few hours of extra light available could improve both productivity and animal welfare.

The vision in birds is superior to that of humans and most other mammals. Continuous light and light with low intensity can cause eye injuries, affect the eye development in young chicken negatively, as well as provide increased incidence of foot pad lesions. Access to light affects the production but also the welfare of birds. Increased number of light hours per day can increase production, but too much light can cause less growth and stress.

In order to investigate addition of light to broiler chickens in a hot climate with short daytime light hours, a study was made at Golden Valley Agricultural Research Trust premises in Batoka, Zambia, with 40 broilers and solar lamps (HiLights from HiNation). The broiler chickens were divided into two groups, both had free access to feed and water and the experimental group received two and a half hours of extra light from solar lamps each evening during 22 days. The control group received no extra light, just daylight during the same period. Feed consumption was measured the first two weeks, weight gain was measured throughout the period and Feed Conversion Ratio was calculated. The experimental group consumed more feed, gained more weight and had a lower FCR than the control group.

General conditions for broiler production in Zambia are described based on the following:

- Three small-scale broiler farmers in Batoka and Choma areas in Zambia were interviewed about management, feed, water, diseases, cleaning procedures etc.
- A large-scale broiler farmer outside the capital Lusaka was visited and interviewed regarding routines, feed, water, disease, profitability, diseases etc.
- A poultry slaughter house outside Lusaka was visited. A tour through the slaughter chain was made with an experienced employee who answered questions.

Information obtained about bird diseases in Zambia indicated problems with mainly Newcastle disease (ND), Infectious bursal disease (IBD) and Coccidiosis. Vaccination against ND and IBD occurs, but far from everybody vaccinates their broilers.

The results of the solar light study indicate that increased length of light for broiler chickens in Zambia can improve productivity, if proper management and disease control is provided.

SAMMANFATTNING

Framgångsrik slaktkycklinguppfödning i väldigt varma klimat kräver kunskap om hur fåglar påverkas av värmestress. För att underlätta hanteringen av värmen är tillgång till vatten och en bra ventilation viktigt. Det kan vara av värde att reducera foderkonsumtionen de varmaste timmarna på dagen, vilket tillsammans med några timmars extra ljustillgång kan förbättra produktivitet och djurvälfärden.

Fåglar har bättre syn än människor. Kontinuerligt ljus och ljus med för låg intensitet kan ge ögonskador, påverka ögats utveckling hos unga kycklingar negativt, samt ge ökad förekomst av fotskador. Ljus påverkar både produktionen men också välfärden hos fåglar. Ökat antal ljustimmar per dygn kan öka produktionen, men för mycket ljus kan ge mindre tillväxt och stress.

För att undersöka ökad tillgång till ljus för slaktkycklingar i ett varmt klimat med kort dagsljuslängd, gjordes en studie i lokaler hos Golden Valley Agricultural Research Trust i Batoka, Zambia, med 40 slaktkycklingar och solcellslampor (HiLight från HiNation). Djuren delades in i två grupper, båda fick fri tillgång på mat och vatten och försöksgruppen fick två och en halv timmes extra ljus från solcellslamporna varje kväll under 22 dygn. Kontrollgruppen fick endast vanligt dagsljus under samma period. Foderåtgången mättes första två veckorna, viktuppgången mättes hela perioden och foderomvandlingen räknades ut. Försöksgruppen åt mer foder, gick upp mer i vikt och hade en lägre FCR än kontrollgruppen.

Generella förhållanden för broilerproduktion i Zambia beskrivs baserat på:

- Tre småskaliga slaktkycklinguppfödare i Batoka och Chomaområdet i Zambia intervjuades om hållning, mat, vatten, sjukdomar, rengöringsrutiner mm.
- En storskalig slaktkycklinguppfödare utanför huvudstaden Lusaka besöktes och intervjuades angående rutiner, mat, vatten, sjukdomar, lönsamhet, sjukdomar mm.
- Ett fågelslakteri utanför Lusaka besöktes. En rundtur genom hela produktionskedjan gjordes med erfaren anställd som svarade på frågor.

Fågelsjukdomar som nämndes vid olika tillfällen och som verkade förekomma var Newcastle disease, infektiös bursit (Gumboro) och coccidios. Vaccination mot Newcastle disease och Gumboro förekommer, men långt ifrån alla vaccinerar.

Resultaten från studien med solcellslampan indikerar att ökad ljustillgång för broilerkycklingar i Zambia kan öka produktiviteten, förutsatt god djurhållning och sjukdomskontroll.

Content

INTRODUCTION

Bird production includes both village chicken and conventional broiler chickens. Village chicken come from the indigenous domesticated chicken *Gallus gallus domesticus* (Kitalyi, 1997) and is often free scavenging for their feed (CTA, 2004). In Zambia, it is very common and also a long tradition to keep village chicken. In year 2002 more than 93 % of the population in rural areas in Zambia kept village chicken (Chongwe, 2011). They are easy and cheap to maintain and provide the household with eggs and meat, being an important source of animal protein. It means security for food supply to own village chicken, especially in rural areas where poverty is worst (Rundquist, 2013). Broilers are not as common as village chicken in rural areas, but the production is increasing. There is a higher risk with broiler production compared to village chicken, due to more expensive investments in e.g. buildings and additionally there are costs for purchasing day old chickens and feed for the animals. Despite the higher production costs and the higher risks it is still profitable to produce broiler chickens for slaughter. In Zambia there are both small-scale broiler farmers, who keep a few birds only for their own consumption, and large-scale industrialized broiler farmers, who keep several thousands of chickens at a time, and all sizes of farms in between.

Light and its availability are very important in poultry production, especially for broilers. The length of daylight affects the birds' behaviour and eating habits. In Zambia there is approximately 12 hours of daylight, ranging between 11 h in July and 13 h in December (Time and Date AS, 2013). Most of the large-scale broiler farmers use artificial light during all night (24 h) to make the broiler chickens eat more and grow faster. Small-scale broiler farmers without access to electricity do not have that possibility to influence production with light. The idea resulting in the present project was to investigate if growth rate and production of broiler chickens kept by small-scale farmers could increase when using a solar powered light (HiLight from HiNation) for a couple of hours each night to increase the number of hours of light. This would be an easy way to increase production and profitability in an otherwise vulnerable household. The HiLight can also be used for indoor light in the family house and for charging of cell phones.

The aims of this study were to describe broiler farming in general and in Zambia in particular, both small-scale and large-scale, and examine whether increased light availability from the solar lamp HiLight has any significant impact on broiler growth under prevailing conditions in Zambia. In addition, this project also discusses how the broiler welfare may be affected by prolonged photoperiods.

Zambia

Zambia, with its approximately 14 million inhabitants, is a developing country in Southern Africa, with Malawi, Mozambique, Zimbabwe, Botswana, Namibia, Angola, Congo and Tanzania as neighbours. The country is a republic, led by the president Michael Sata. English is the official language, but there are seven other languages with official status; Tonga, Bemba, Nyanja, Lozi, Lunda, Kaonde and Luvale. Christianity is the most practiced religion. The main export commodities include copper, cobalt, cement, sugar, textiles and vegetables.

As Zambia is one of the world´s poorest countries, many inhabitants have a hard everyday life. About 66 % are extremely poor (Rundquist, 2013). In the year 2011 about 12.5 % of the population (of the people aged 15-49 years) was infected with HIV. The same year the estimated life expectancy was 49 years and infant mortality approximately 5.3 %. Only 50.1 % had, in the year 2011, access to clean water. In 2003-2005, 45 % of the population was undernourished. Animal products can be valuable supplements to the usual food that is mainly cereals such as maize and root crops. Poultry meat and eggs provide many important nutrients and it is often possible also for the less resourceful population to keep some chickens (Kitalyi, 1998). Therefore poultry has an important role in the household. It is relatively easy to take care of these animals, even people with HIV is capable of caring for them. Having poultry often assures that you get at least one egg a day, which can make a big difference in nutritious supply. According to the manager at GART (Golden Valley Agricultural Research Trust) in Batoka, David Mubita (personal communication, 2013) birds are the only animals a widow is allowed after her husband's death. Cattle, sheep and other large animals are taken care of by the dead husband's relatives.

Climate

The climate in Zambia is tropical (Landguiden, 2014). The weather is varied and divided into three seasons. The rainy season extends from December to April, when the climate is warm and humid. Northern Zambia receives the most rain, about 1 400 mm/year. May to August is dry and quite cold. September to November is dry and hot. During the warm period the temperature is 25-35° C and during the cold period 6-24° C (GoXplore, 2014).

Broiler chickens

Broiler production in Sweden

Broiler chickens originate just like other poultry species/subspecies from the red jungle fowl (*Gallus gallus*) of Southeast Asia. The ancestors to the broilers that we have today came to the Nordic countries in the 11th century with the Vikings (Branschorganisationen Svensk Fågel, 2013). Based on these individuals, different breeds have evolved; some specialized in muscular growth for meat production and some on laying eggs. It was not until the 1920-30s that breeding focused on specific properties, which resulted in the broiler chickens, layers etc.

To Sweden, breeding animals to be "grandparents" (GP) are imported from England and USA (Branschorganisationen Svensk Fågel, 2013). The birds are quarantined for 8 weeks and their

health status is followed. From GPs, parent animals are obtained and used for the production of chicken to be slaughtered. Parent stock is fed restrictively as the animals should not grow too fast; thereby the risks of osteochondrosis and welfare problems are prevented. The parent stocks are kept in one tier floors system, where the genders are mixed (Lotta Berg, SLU, lecture, 2010-05-17).

Conventional broiler chickens are kept in farms with 20 000-120 000 chickens (Branschorganisationen Svensk Fågel, 2013). The average farmer has about 85 000 chickens per batch and rears about seven batches per year. The chickens are kept on the floor, with sawdust as bedding material. They have free access to feed and water. The temperature in the chicken house is held initially at 33-35° C, and lowered over time as the chickens grow, down to 20° C. The humidity is kept at 50-70 %. According to the Animal Welfare law in Sweden, the stocking density can be maximum 20 kg bird/m^2, but producers that comply to the Animal Welfare Program of *The Swedish Poultry Meat Association* are allowed to keep up to 36 kg/m^2. The chickens are slaughtered at approximately 35 days of age when they weigh between 1800 and 2300 grams. The farms in Sweden follow the method "all in – all out" (Lotta Berg, SLU, lecture, 2010-05-17). After each batch the stables are cleaned and disinfected. Then they are kept empty for about 1-2 weeks before new chickens arrive (Branschorganisationen Svensk Fågel, 2013). The mortality in broiler production in Sweden is approximately 3 % (Pia Gustafsson, Branschorganisationen Svensk Fågel AB, personal communication 2014-01-16). The day for broiler chickens in Sweden normally consists of 18 hours of light and 6 hours of darkness. The dark period is divided in one period of 4 hours and another period of 2 hours.

Feed

Feed production is strictly controlled in Sweden. The content of a chicken feed must be approved by the Swedish Board of Agriculture (Branschorganisationen Svensk Fågel, 2013). Feed mixes must be heat treated before use, as part of a *Salmonella control* program. Some breeders use their own grain, which they supplement with a pelleted concentrate. Commercially chicken feed contains approximately 25 % protein sources and 70-75 % cereals; wheat, barley, oats and sometimes corn/maize. The protein is taken from soy bean, canola, rapeseed, peas and faba beans. The feed also contains essential vitamins and minerals. Coccidiostats are added to the feed, but antibiotics and hormones are not allowed.

In commercial broiler production in Sweden the broiler chickens eat Starter days 0-10, Grower 1 days 11-17, Grower 2 days 18-30 and Finisher days 31-35 (Robin Kalmendal, Lantmännen, personal communication 2014-02-10). Starter contains higher levels of protein compared to Grower and Finisher. The level of protein is decreased gradually. Starter has approximately 20-22 % crude protein and Finisher approximately 18-19 %. Finisher does not contain coccidiostatics, which Starter and Grower do (Lotta Jönsson, SLU, personal communication, 2013-11-31).

Broilers are very efficient at converting feed into meat. Feed conversion ratio in Sweden is approximately 1:1.75, meaning that 1.75 kg feed gives an increase of 1 kg chicken live weight (Branschorganisationen Svensk Fågel, 2013).

Broiler production in hot climates

Broiler production in Southern Africa

Broiler production in hot climates is complex and very diverse. There are not so many studies from Zambia available but according to the Poultry Association of Zambia (Ngosa, 2011) the yearly broiler chicken production in Zambia was 36 million. In 2005, 35 % of the total animal protein came from poultry meat (Ngosa, 2010). The country is self-sufficient in poultry feed and exports the surplus (Ngosa, 2011). The main cereal in poultry feed is maize and 0.24 million tonnes maize are used per year. Maize bran is a by-product from dry milling of maize (Musukwa, 2000). Maize bran is abundant and relatively cheap in Zambia. Soybeans are the mostl common protein source in poultry feed (Ngosa, 2011), and contains satisfactory amounts of the amino acids lysine, tryptophan and threonine, but the methionine content is inadequate (Ngosa, 2010). Ngosa recommends supplements of amino acids, minerals and vitamins to Zambian poultry feed since most of the feed is based on maize and soybean, which has a low content of vitamins (A, D, B_{12} and riboflavin) in addition to the amino acid deficiency. GMO maize and soybeans in the feed industry has been illegal but the laws may be changed due to increased population growth (Ngosa, 2011).

A study, made in Botswana about small-scale broiler farmers, showed that the numbers of broiler chickens per batch were on average 640, with 4-5 batches per year (Badubi, *et al*., 2004). Cobb was the dominating variety with 72.9 % while the rest was Ross etc. The broiler chickens were sold at the age of 48.3 days when they weighed 1.79 kg (low live weight). The feed conversion ratio was in average 2.72 and the mortality was 9.15 %.

In another study (Aganga *et al*., 2000) the farmers, keeping Ross, Cobb and Indian River hybrids, had 1-8 poultry houses in the sizes of 100-1000 m^2 and four batches per year with 1000 to 10 000 broiler chickens per batch. Stocking density was on average 10 birds/m^2. 76 % of the farmers vaccinated their broilers against ND or Gumboro. All farmers gave their birds free access to feed.

Challenges in small-scale broiler production in Botswana were investigated by Moreki (2011). The results showed that slaughter hygiene was a big problem, because the majority slaughtered their chickens in the backyard without adequate slaughter facilities. The requirement on the market for halal meat aggravated the situation further. It is expensive to slaughter according to halal, since a Muslim needs to be hired, which generally costs a lot of money.

One can assume that much is similar between Botswana and Zambia, in broiler husbandry, since the countries are in the same region with similar climates (drier in Botswana).

The impact of high temperatures

Rearing broiler chickens in hot climates involve some difficulties and problems compared to rearing broiler chickens in colder regions. It is important to be aware of these and adapt the management to prevent increased mortality and reduced animal welfare. In Zambia, for example, during the warm period of the dry season it is about 25-35° C (GoXplore, 2014).

The heat affects broiler chickens and there is a risk that they suffer from heat stress and die (Daghir, 1995). When the ambient temperature is higher than the broiler chickens body temperature, heat is emitted from the bird to the environment. At high ambient temperatures body heat cannot be emitted as quickly to the environment, instead the body temperature is raised (Cahaner, 2011). Poultry, both broiler chickens and village chickens, are especially susceptible to heat stress (Lucas & Rostagno, 2013). The reason is suspected to be that today's genotype, at least for the broiler chickens, which has a higher metabolic rate activity, produces more body heat. Important factors that affect how poultry respond to heat stress are age, body size, genetic constitution and earlier exposure to high temperatures; the broiler chickens learn to adapt physiologically to heat (Teeter & Belay, 1996). Ambient temperature has great influence on feed intake and body weight gain of broilers (Daghir, 1995). At high temperatures the feed intake is significantly reduced, which results in lower weight gain. Humidity is also an important factor in broiler production. A warm climate with high humidity affects broiler growth more negatively than a warm climate with low humidity does. Likewise, it is worse with constant heat 24 hours a day, than with hot days and cold nights.

Feed

In hot countries it is recommended to feed broiler chickens a diet with relatively more energy, in the form of fat, to counteract the decline in feed intake caused by the heat (Daghir, 1995). While increasing the energy content of the diet the content of other nutrients needs to be increased, for proper proportions. Feed with lower content of protein but supplemented with the amino acids methionine and lysine works better in warm climates than a diet with generally high protein content. Increased amount of protein, without raising the amount of methionine and lysine, has been shown to decrease weight gain and feed conversion in hot climates. Broiler chickens can handle heat stress better if the feed is restricted during the hottest hours of the day. This reduces body heat and increases the chances of survival.

A hot and humid environment is also a challenge for feed storage, giving problems with rancidity after shorter storage time than in colder climates (Daghir, 1995). Therefore, feed should be purchased often rather than stored at the farm for a long time.

Table 1 shows the content of broiler feed in Zambia (according to the company Choma Millings Ltd), and the content in Sweden (Robin Kalmendal, Lantmännen, personal communication 2014-02-10). The content of energy and crude protein in the feed barely differs between the two countries. Broiler Starter contains more fat in Sweden, while Broiler Finisher contains more fat in Zambia.

Table 1. Content of broiler feed in Zambia and in Sweden

	Broiler Starter		***Broiler Grower***		***Broiler Finisher***	
	Zambia (day 0-14)	Sweden (d 0-10)	Zambia (d 15-28)	Sweden (d 11-30)	Zambia (d 29-42)	Sweden (d 30-35)
Crude protein % min	22	20-22	19	19-21 (Grower 1) 18-20 (Grower 2)	18	18-19
Crude fat % max	5	5-7	7	6-8	9	6-8
Metabolizable energy MJ/kg	12	12.3	12.5	12.4 (Grower 1) 12.5 (Grower 2)	12.5	12.5

Acid-base balance in heat stressed chicken

Heat stress makes broiler chickens pant (Lucas & Rostagno, 2013). By panting the air sacs are used to increase gas exchange and heat are released through evaporation. However, increased breathing also leads to decreased level of carbon dioxide in the blood (Toyomizu *et al.,* 2005), and higher pH and alkalosis (respiratory) (Lucas & Rostagno, 2013). To correct the alkalosis it is possible to carbonate the drinking water or add ammonium chloride in the diet or water (Daghir, 1995). At high temperatures poultry gets deficiencies in vitamins, minerals and ascorbic acid, as the mobilization and excretion from tissues increases (Abidin & Khatoon, 2013). Therefore it may be advantageous to provide vitamins and electrolytes in the drinking water, during extra hot days, which has been shown to reduce mortality (Daghir, 1995). Vitamin C (or ascorbic acid), for example, is a good complement. Ascorbic acid prevents the bird`s body temperature to increase during a heat wave, but the amount of ascorbic acid in the blood decreases when the ambient temperature is high. Poultry's ability to self-produce ascorbic acid is insufficient at heat stress (Heidari *et al.,* 2013) but ascorbic acid has an important role in the body as it is necessary for the production of hormones that are important to manage stress, and the metabolism of amino acids and minerals (Abidin & Khatoon, 2013). It is also important for the immune system.

To increase feed and water intake and hence increase growth rate for the broiler chickens it is possible to add sodium bicarbonate to the feed (Daghir, 1995).

Broiler house

The main source of heat in the broiler house is the birds themselves (Daghir, 1995). To get a comfortable temperature in the room, it is important not to have too many birds in a too small area, as it could be too hot.

Ventilation is important in poultry houses to remove ammonia, excessive heat, moisture and to improve the air quality (Hybrid Poultry Farm, 2013). In the tropics the poultry houses are

open-sided and the ventilation is natural. Where natural ventilation is used, air movement can be controlled by special curtains (Daghir, 1995). The long axis of the houses should be in an east-west direction to prevent direct sunshine on the birds (Hybrid Poultry Farm, 2013). Roof insulation can be used to reduce heat stress in naturally ventilated houses (Daghir, 1995), in this way the mortality of broiler chickens can be decreased, by reducing the amount of radiated heat from the roof.

An "all in - all out" system is recommended and between cycles should a good-working disinfectant be used (Daghir, 1995). The warm ambient temperature makes the product evaporate faster than normal giving a shorter duration of action. Soil or sand floors, which are still used in some countries, make it even harder for the disinfectant to access all surfaces properly.

Water

Cold drinking water has an important role in hot weather (Daghir, 1995). If the water is warm, the broiler chickens need to drink a larger amount of water to get a cooling effect. To keep the water cold, insulation of the header tanks and piping is important. The water supply should be ad libitum and the drinking space enough according to stocking density.

Acclimatization

Broiler chickens perform better in hot temperatures through acclimatization (Daghir, 1995). Mortality is reduced by subjecting the birds to heat before the expected heat wave, e.g. by raising the house temperature. During heat acclimatization the bird`s cardiovascular and respiratory systems adapts; maximizing body water reserves. This enables evaporative cooling and maintaining blood volume.

Light

Light has a large impact on the welfare of broiler chickens and village chicken. Enough light is important, but too much is negative.

Poultry vision

Bird's vision is superior of humans and other mammals (Prescott *et al*., 2003). Differences in the eye structure results in a different view of the world and its lights. What differ are mainly spectral sensitivity, flicker sensitivity, accommodation and acuity. The spectral curve for poultry is very extensive and they can even perceive UVA-radiation (wavelength 320-400 nm). Differences in eye structure between humans and birds are mainly that birds have three kinds of photoreceptors (compared to humans two), four photo reactive pigments associated with cone cells (humans have three) and in their cone cells they have colored oil droplets, who´s function is to filter light before it reaches the photo reactive pigments.

The effects of light on production and welfare in broilers

Light affects broiler production by stimulating secretory patterns of several hormones that control growth, maturation and reproduction (Olanrewaju *et al*., 2006). Secretion of melatonin is also dependent on light; light acts inhibiting (Sjaastad *et al*, 2003). Melatonin is important

in the regulation of biological rhythms and sleeping patterns, which indirectly affects the welfare.

Ferrante *et al*., (2006) has shown benefits from holding broiler chickens in a more natural light schedule. It is better for the birds to have the day divided in light and dark periods, and not a too short dark period. Long photoperiods are not good because it affects the bird's eye development (Ferrante *et al.*, 2006) and disturbs the melatonin rhythm (Özkan *et al.,* 2006). It may also increase physiological stress by disturbing sleep and cause deprivation (Blockhuis, 1983) and fear (Bayram & Özkan, 2010). A more naturally divided day in light and darkness, for example 16 hours of light and 8 hours of darkness, gives more active birds in the light period and more of them are resting in the dark periods. The increased activity during the light hours affects the mineralization of bone in a good way (Ferrante *et al*., 2006). Short days (16 h light) result in less lame broilers than if kept in continuous light (Özkan, *et al*., 2006).

Morris (1967; see Lewis *et al*., 1998) discovered that "meat-type" poultry that are given very short photoperiods, or in darkness 24 hours a day, learn to eat in darkness, and have a feed intake and bodyweight almost the same as birds kept in 24 hours light a day (Cherry & Barwick, 1962).

Light for 16 hours a day does not mean that broiler chickens produce more; it can even be the opposite. Lewis & Gous (2007) held groups of broiler chickens in different light schedules from the age of 2 days until the age of 42 days (some groups in 8 hours light per day, some groups in 16 hours light per day and some groups had 8 hours of light per day until day 21 when they instead had 16 hours of light per day until day 42) and found that lighting did not affect feed intake, growth or feed conversion efficiency the first 21 days, but day 22-42, birds who had 8 hours light a day had higher body weight gain, more efficient feed conversion efficiency and higher feed intake than birds who had constant 16 hours of light per day.

Light intensity

Some birds are kept in dim light to improve feed efficiency and reduce mortality (due to Sudden death syndrome) and carcass damage because of reduced activity, but this has not been shown scientifically (Bayraktar *et al*., 2012). Instead it is proven that light intensity on 1-150 lux do not affect broiler performance or broiler production.

Very low light intensity is not good for the animal welfare. Dim light (<5 lux) has been linked with increased frequency of foot pad lesions, because it leads to less activity and more rest which increases the contact time between feet and litter (Bayraktar *et al*., 2012). Low light intensity has also been shown to induce buphtalmia, altered retina, choroiditis, lens damage inflammation and increased eye size and weight (Weeks & Butterworth, 2004). Dim lighting and continuous lighting can both cause buphtalmia (protruding eyes) and glaucoma (a group of eye diseases) in broiler chickens (Cummings *et al*., 1986).

Poultry diseases

Below follows a description of the avian diseases that were mentioned by broiler farmers in Zambia, and therefore seems to occur in broiler production in this country. It is very

important to have an unbroken cold chain regarding handling of vaccines (Daghir, 1995). Otherwise the vaccines can be inactivated.

Newcastle disease

Newcastle disease (ND) is caused by the paramyxovirus 1 (PMV-1); a single-stranded RNA virus (Blomqvist *et al.*, 2010). All kind of birds can suffer from PMV-1. Infection is spread directly between birds and indirectly via egg handling equipment and people. It is not transmitted from hen to egg. The virus can also be spread through the air about 70 m. Some birds can carry the virus subclinical and wild birds can spread the infection to domestic birds.

With an incubation period of 5-7 days, the disease gives disruption of egg production, nervous or respiratory symptoms and increased mortality (Blomqvist *et al.*, 2010). The latter can become very high, but it varies greatly. Young chickens are worst affected.

ND is diagnosed by autopsy, serology and virus isolation (with or without determination of pathogenicity by DNA-sequencing and analysis of amino acid sequence) (Blomqvist *et al.*, 2010). Changes noticeable at autopsy includes tracheitis, bronchitis, pneumonia, broken ovarian follicles, peritonitis caused by yolk in the abdomen, bleedings in viscera, lymphatic organs and in the glandular stomach, encephalitis and meningitis.

Differential diagnoses to Newcastle disease that should be suspected when these symptoms occur are avian influenza, Gumboro, poisonings, pasteurellosis and infectious bronchitis (Blomqvist *et al*, 2010).

Newcastle disease is not treatable why prevention is important in disease control (Blomqvist *et al.*, 2010). Vaccination prevents disease, but it is still important to have good hygiene in these herds. Vaccinated birds can spread the virus without themselves becoming sick. Poor environmental conditions where the birds are kept as well as presence of other infections increase the risk of side effects from the vaccine.

Infectious bursal disease

Infectious bursal disease (IBD), or also known as Gumboro, is caused by a Birnavirus (IBDV), which is a RNA virus that comes in two serotypes (Blomqvist *et al.*, 2010). The infection can affect chickens, ducks and turkeys, but only chickens get clinical symptoms. The incubation period is 2-3 days. At 3-6 weeks of age, when the *bursa of Fabricius* is in its largest size, the chicken is most vulnerable for the disease. Chicks older than 15 weeks do not get sick because the bursa is then almost completely degenerated. The disease is spread directly and indirectly, but not vertically to the eggs. The virus is very resistant and chickens excrete it in the faeces for up to two weeks after sickness.

Symptoms are watery white diarrhoea, appetite loss, ruffled plumage, soiled sewer feathers, trembling and closed eyes (Blomqvist *et al.*, 2010). The disease quickly leads to death. Almost all individuals in a herd get sick, but mortality varies, usually between 0-20 %, depending on the breed, age, immune status and viral virulence. The Gumboro virus reduces the capability of the immune system and increases susceptibility to other diseases.

The disease is diagnosed by autopsy, immunohistochemistry and serology (Blomqvist *et al.*, 2010). At post mortem a swollen bursa of Fabricius is seen, which is oedematous and sometimes even bleeding in the mucosa. The chicken is dehydrated. There may be a white exudate in the lumen of the bursa; comprising rejected dead cells.

Possible differential diagnoses include Newcastle disease, avian influenza and chicken infectious anaemia (Blomqvist *et al.*, 2010).

To prevent disease, it is important to have good hygiene; thorough cleaning and disinfection between batches (Blomqvist *et al.*, 2010). Vaccination against Gumboro works effectively. Vaccination of parents provide passive immunity to the chicks their first weeks by maternal antibodies from the egg. In Sweden only breeding animals are vaccinated

Coccidiosis

Coccidiosis is common in Zambia, as in many other countries of the world (Blomqvist *et al.*, 2010). Coccidia are protozoa and the most common species is *Eimeria*. Coccidia are completely species specific. The disease has a direct oral-faecal pathway. The infection is spread also indirectly, for example through people and equipment. The prepatent period is 4-7 days, but it varies between coccidian species.

The severity of the symptoms depend on infectious dose, immune status, type of coccidian, and possible secondary infections, but ranges from mild diarrhoea, blood in the feces, poor general conditions to sudden death (Blomqvist *et al.*, 2010). Even subclinical infections occur. All sorts of coccidian infections damage the intestine. Diagnosis is made by post mortem examination and direct smear from the damaged intestine. The coccidian species can be determined by PCR. At autopsy you can find different types of intestinal damage, depending on which coccidian species it is; including for example lesions in the jejunum, thickened/dilated intestinal wall, mucus and blood in the intestines, petechial bleeding, white spots and necrotizing/mucohaemorrhagic enteritis.

Necrotic enteritis (*Clostridium perfringens*) and Histomaniasis are important differential diagnoses (Blomqvist *et al.*, 2010).

Very strict hygiene is an important prophylactic measure (Blomqvist *et al.*, 2010). There are also vaccines available for hens and broilers. In Sweden, as in many other countries, coccidiostats are added to the broilers feed.

In Sweden coccidiosis is treated with coccidiostats, either chemical substances or ionophores, e.g. sulfaclozinsodium (Esbetre vet) or toltrazuril (Baycox) (Björn Engström, SVA, lecture, 2011-12-06). Esbetre vet is given in the drinking water for three consecutive days (Blomqvist *et al*, 2010). In Zambia the parasite is treated for example with oxytetracycline (personal observation).

Sudden Death Syndrome

Sudden Death Syndrome (SDS), which is also called Acute Death Syndrome (ADS) or “flip-over”, is a syndrome and not a disease, which affects about 2-3 weeks old broiler chickens

(Blomqvist *et al.*, 2010). It is mostly fast growing cockerels that are affected. The causes of the condition are not known but it goes hand in hand with rapid growth. Broiler chickens that receive their feed as pellets are more affected than those who get meal feed, probably because by eating pelleted feed the birds ingest more feed in less time.

The only thing that is seen at post mortem is pulmonary oedema and severe stasis, possibly renal bleeding (Blomqvist *et al.*, 2010). Diagnosis is based on symptoms. Important differential diagnosis is pulmonary hypertension syndrome. As prophylaxis one can reduce the chickens' energy intake, reduce occupancy and increase the length of the dark periods. The condition is not treatable, as the chickens are already dying as soon as they are affected.

Pulmonary hypertension syndrome and ascites

It is believed that rapid growth can lead to pulmonary hypertension syndrome (PHS) and ascites (Blomqvist *et al.*, 2010). High growth rate increases demand for oxygen, which makes the heart work harder in the pulmonary circulation. The lungs cannot keep up with the circulatory and gas exchange demands, leading to oxygen deficiency and increased erythropoiesis. The blood becomes thick and viscous and the pressure in the lungs gets higher. The pulmonary hypertension provides increased resistance for the heart; hypertrophy and dilatation of the right ventricle follows. This leads to congestion and oedema of the lungs. The change in the heart gives an insufficiency of the valves between the right atrium and ventricle. It results in a back flow of blood to the right atrium, and eventually cardiac failure. The heart failure leads to increased pressure in the vena cava and portal vein, which in turn results in stasis in the liver and if this becomes chronic, ascites will develop.

Affected chickens are usually four weeks or older (Blomqvist *et al.*, 2010). If the syndrome arises acutely there are no symptoms seen, the chicken is found dead. If the condition has become chronic, the symptoms are abdominal distension, clumsy walk, cyanosis or hyperaemia of the skin. A post mortem, which is diagnostic, of a chronic PHS, shows hydropericard, ascites, stasis in liver and in the intestines, thickened and/or dilation of the heart wall in the right ventricle and thickened right atrioventricular valves.

Important differential diagnoses for PHS is Sudden Death Syndrome, cholangiohepatitis caused by *Clostridium perfringens* and right sided valvular endocarditis caused by *Enterococcus hirae* (Blomqvist *et al.*, 2010).

There is no treatment for the condition, one can only act prophylactically (Blomqvist *et al.*, 2010). As prevention against PHS, good ventilation in the houses is important, and also to use chicks with good genetic constitution, feeding restrictions to prevent a too rapid growth and avoid too much NaCl in the feed and drinking water. It has also been shown that the risk of PHS is reduced by supplement of the amino acid L-arginine.

MATERIALS AND METHODS

A minor field study was carried out during approximately two months in Zambia; in the capital Lusaka, in Chibombo north of Lusaka and in Batoka and Choma areas, in the Southern province of Zambia. The visit took place in September and October, during the dry season,

when it is about 25-35° C and no rain, usually (GoXplore, 2014). The sun rises at 6 am and sunset is 6 pm, which gives twelve hours of daylight (Time and date, 2013).

1. Solar lamp experiment with broilers on GART

Birds and management

A study was carried out including 40 broiler chickens of the hybrid Cobb at the Golden Valley Agricultural Research Trust (GART) premises outside Batoka in the southern Province of Zambia. The broiler chickens were bought from GART and compared to GART's own broiler chickens from the same batch. The broiler chickens were 20 days old at the start of the experiment and 42 days old when the experiment stopped, after 22 days. GART provided facilities and electricity for free.

The broiler chickens were divided into two groups, 20 broilers in each group. The experimental group was marked with red tags around the legs, and the control group was marked with blue tags. The broiler chickens were kept on a floor of concrete, with long-fibre straw as bedding. The area was about 12 m^2 for each group and the stocking density was as most about 4.5 kg/m^2, see figure 1. The experimental and the control groups were divided from each other with a wall, about 1.5 m high, built from chicken wire and black plastic, see figure 2. Each group had one big feeder and two drinkers. Each group had a large window approximately 1 m^2 big that was covered with chicken wire. The ventilation was poor and the birds were panting all hot days, especially when it was extra hot outdoors (about 36-38 °C). To facilitate, they always had plenty of water and the door, out to a bigger room, were left open during the days.

Figure 1. Control group in its first accommodation. Photo: Johanna Lindell.

Figure 2. The wall dividing the two groups. Photo: Johanna Lindell.

The experimental group was given light from the solar lamp Hi-Light, from the Swedish company HiNation (see appendix 2), every evening from 06.00 to 08.30 pm, see figure 4. The first night only one lamp was used, but the following nights 3-4 lamps were used (since it did not seem to be enough with only one lamp). The control group received no extra light, just daylight. Both groups had free access to feed and water for 24 h a day.

The control group, see figure 3, was moved from its original place to another room in the same poultry house at the age of 33 days, because the light from the experimental groups' lamps was found to leak in to the control group, i.e. it was not dark enough. The new location was part of a large room, about 12 m^2 of 500 m^2. The space was enclosed by black plastic and large bricks. The ventilation in the new room was better than in the old, because of many large windows along the side walls in the new room.

Figure 3. The broiler chickens in the control group at the age of 20 days. Photo: Johanna Lindell.

Figure 4. Use of the solar lamps in the experimental group (25 days old). Photo: Johanna Lindell.

Experimental diets and registrations

Before the study, the 40 broiler chickens used in the present study, was kept together with GART's other broiler chickens, a total of 1020 birds. The first two weeks of life, they were kept in a small room, approximately 18 m^2 large, and had IR-light 24 hours a day. They were fed Broiler Starter the first two weeks of their lives. They were moved to a larger room when they were about two weeks old, and there they had regular artificial light, instead of IR-light, 24 hours a day. The 40 broilers used in the study were taken from here after about 1 week, when they were 20 days old.

The stocking density for GART's broiler chickens appeared to be higher and the competition at the feeders was greater (personal estimation based on density) than for the experimental and control groups.

Twenty randomly selected broiler chickens at GART, at the same age as the broiler chickens in the experimental and control group, were weighed at the age of 29 and 35 days, for comparison. This group of broiler chickens were provided with artificial light 24 h a day since their arrival to GART as day old chicks.

The feed for GART's broiler chickens was in mashed form. The switch from Broiler *grower* to Broiler Finisher for GART broiler chickens was made approximately a week earlier than for the experimental and control group. The feed supply to GART's broilers was not optimal the last week as the feeders were found empty some days (exact information is not available).

GART's broiler chickens were vaccinated against ND a few days before the experimental and control group, approximately at the age of 21 days.

At the age of 20 to 38 days the birds were given Broiler Grower and at the age of 39 to 42 days Broiler Finisher, from the Zambian company *Choma Milling Ltd*. See the nutritional content of the different feeds in Table 2. The feed was pelleted. Feed intake was recorded, during the first two weeks of the study, and the feed conversion ratio (FCR) for this period was calculated. FCR means the amount of feed used per kg growth. The experimental and control group's feed was in pelleted form.

Table 2. Content in Broiler feed according to Choma Milling Ltd guidelines and analysis of feed sample conducted at SLU in Sweden

	Starter	**Grower**		**Finisher**	
	Choma Milling Ltd	*Choma Milling Ltd*	*SLU analysis*	*Choma Milling Ltd*	*SLU analysis*
Crude protein % min	22	19	22.5	18	18.1
Crude fat % max	5	7	5.9	9	8.0
Linoleic acid % max	1	1		1	
Crude fibre (max)	5	5	3.3	5	6.2
Metabolizable Energy mJ/kg	12	12.5		12.5	
Metabolizable Energy kcal/kg (min)	2870	3000		3100	
Calorie: protein ration	135	160		182	
Moisture % max	12	12		12	
Coccidiostat	yes	yes		yes	
Minerals					
Calcium % min	0.9	0.9		0.9	
Total Phosphorus % min	0.42	0.42		0.42	
Salt %	0.3-0.45	0.3-0.45		0.3-0.45	
Sodium % min	0.18	0.18		0.18	
Potassium % min	0.65	0.65		0.65	
Magnesium % min	0.06	0.06		0.06	
Chloride %	0.18-0.27	0.18-0.27		0.18-0.27	
Amino Acids % (min)					
Arginine	1.28	1.28		0.96	
Lysine	1.2	1.01		0.94	
Methionine	0.47	0.44		0.38	
Methionine + Cystine	0.92	0.82		0.77	
Tryptophan	0.22	0.19		0.18	
Threonine	0.78	0.76		0.7	

The birds were weighed at the age of 20, 28, 35 and 42 days. At the weighing, the broiler chickens were captured one by one and put into a sack and weighed by help of an electronic

device. It was a necessary procedure and the broilers did not seem traumatized by the incident (personal observation).

Mortality was registered daily and one out of two birds that died during the experiment was autopsied.

Both groups of broiler chickens were vaccinated against Newcastle disease (in the drinking water) at the age of 25 days.

At the age of 28 days, the application of the solar lamps for the experimental group was delayed for various reasons. The lights were therefore on between 07.20 and 09.30 pm (instead of 06.00-08.30 pm).

At the age 37 to 42 days the management of the broilers and the lamp was completely taken care of by employees on GART, according to specific instructions.

After the end of the experiment the broiler chickens were sold to GART, who sold them in their turn to GART employees and others.

2. Smallholder broiler farmers in Batoka and Choma area

Three small-scale broiler farmers in Batoka and Choma area, in the southern province of Zambia, were visited and interviewed. Farmer two and three kept the hybrid Tiger while the kind of broiler hybrid kept was not known for farmer number one (numbering of farmers used in Table 3.). Farmer number three has had the hybrid Ross previously. They were asked questions about management, food, water, diseases, slaughter etc. according to a questionnaire (see appendix 1). The questionnaire emanated from another questionnaire, which was made for interviews with village chicken farmers, which my companion used for another study (Lindell, 2014). The goal was to find out how the birds were managed, but also how much knowledge the owners had about broiler health and management. The driver acted as interpreter when there were language barriers. Photos were taken, and also some short videos, after approval from the broiler farmers.

3. Large-scale broiler farmer outside Lusaka

A large-scale broiler farmer outside Lusaka, the capital of Zambia, was visited. An employee at the farm demonstrated the production system by showing the facilities and answering questions.

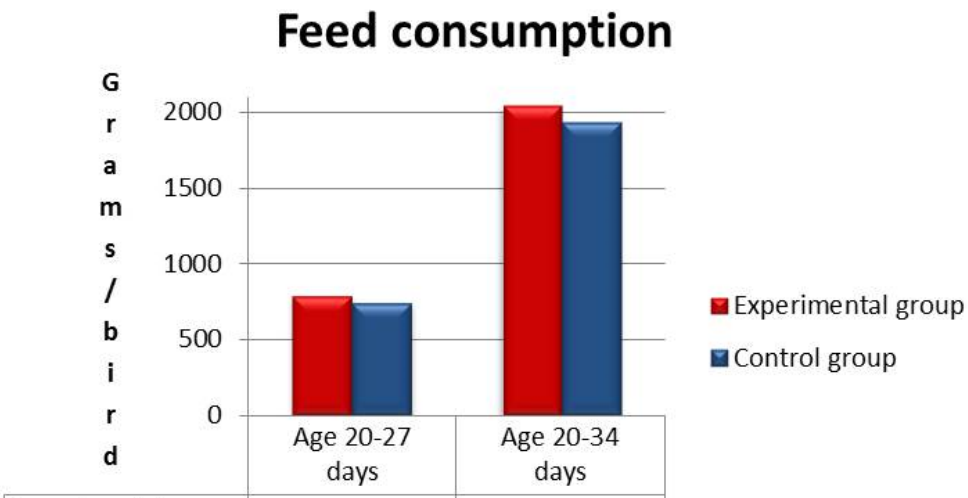
4. Broiler slaughter house outside Lusaka

A guided tour was given on a large slaughterhouse for broiler chickens, just outside Lusaka, in the same enclosure as the above described large-scale broiler farm. Photography was not allowed inside the slaughterhouse. The whole chain was demonstrated backwards (clean to dirty); chilling to packed goods, up cutting, evisceration, culling, live animals.

RESULTS

1. Broiler study at Golden Valley Agricultural Research Trust

Feed consumption



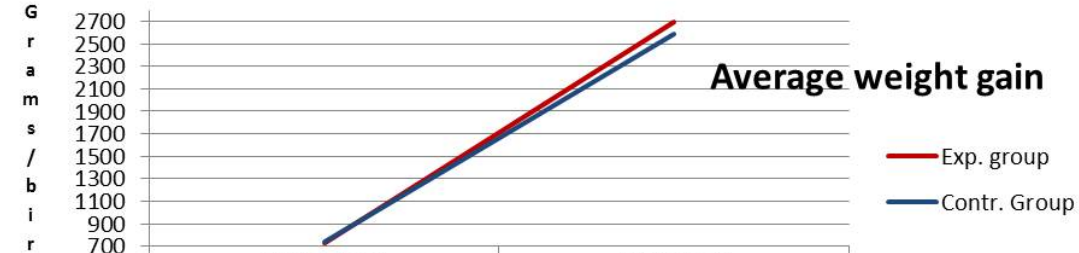
	Age 20-27 days	Age 20-34 days
Experimental group	790	2043
Control group	747	1932

Figure 5. Accumulative feed consumption per chicken at the ages 20-27 days and 20-34 days.

Figure 5 shows in average the accumulative feed intake per chicken in the experimental and control groups during the first two weeks of the study, when the chicken are 20-34 days old.

During the first two weeks the broiler chickens in the experimental group consumed more feed (per bird) than those in the control group did. The weight gain (per bird) during the same period was also higher in the experimental group than in the control group. The experimental group had a lower FCR (food conversion ratio) than the control group, see figure 6. FCR in the age of 20-34 days was for the experimental group 1.53 and for the control group 1.67.

Weight and growth rates



	20 days old	42 days old
Exp. group	729	2694
Contr. Group	742	2586

Figure 6. Average weight per broiler chicken in the experimental and control group during the study period.

The growth rate of the control group was in average over the whole study period 83.8 grams per day and bird, compared to the experimental group's average growth rate of 89.3 grams per day and bird. The broilers with the solar lamps grew overall 6.5 % more during the study period. The highest growth rate was during the age of 28-35 days; control group 102 g/d*bird and experimental group 115.8 g/d*bird.

The average weight of 20 of GART`s broiler chickens (same age as the others) was higher at the age of 29 days than the experimental and control groups the day before. At the age of 35 days GART's broiler chickens weighed apparently less than both the experimental group and the control group.

Deaths and post mortem

One broiler chicken in the control group was found dead when it was 22 days old (two days after the start of the study). An autopsy was conducted, but it showed no pathological changes. The only remarkable thing that was found was some dark red areas in the liver, approximately 1 cm in diameter. It was evaluated as post-mortem changes.

Another broiler chicken in the control group died when it was 41 days old (one day before the end of the study). It was not autopsied.

After the end of the study (the same day and the day after) two more broiler chickens died, one day apart. No autopsies were done.

At the age of 41 days (one day before the end of the study) most animals of both groups of broiler chickens got green faeces. It was considered to be caused by the feed Broiler Finisher, which they began to eat two days earlier, and not due to any disease.

Sometimes it looked like some birds wanted to start a fight with each other but neither fights nor injured birds were seen.

Absence of replicates in the study allowed only descriptive presentation and thus there was no possibility to calculate analyses of variance.

2. Smallholder broiler farmers in Batoka and Choma area in the southern province of Zambia

See the different answers to the questionnaire (appendix 1) from the three small-scale farmers in table 3 above.

All the farmers kept their birds indoors 24 hours a day. None of them had seen any behavioral problems amongst their birds, nor did they have any problems with predators.

At slaughter all of them cut the throats of the birds without anaesthesia.

Table 3. Answers from small-holder broiler farmers

	Farmer 1	***Farmer 2***	***Farmer 3***
Number of broilers	*200*	*181*	*425*
Broiler hybrid		*Tiger*	*Tiger*
Experience in broiler production	*1 year*	*10 years*	
Other poultry	*Village chicken and layers*	*No*	*No*
Where do you buy broiler chickens	*Choma*	*Choma*	
Cost broiler chickens each	*4.15 K*	*4.5 K*	*4 K Tiger (Ross 4.14)*
Feed	*Broiler Starter 2 weeks, Grower 2 w, Finisher 2 w*	*Broiler Starter 2 w, Grower 2 w, Finisher 2 w and a few days*	*Broiler Starter (Crumbles) 21 d, Broiler Grower (Pellets) d 22-33, Broiler Finisher (Pellets) d 34 until finished*
Free access to feed	*Yes*	*Yes*	
New water frequency	*2 times a day*	*3 times a day*	*3 times a day when hot, more often if they are big*
Water source	*Tap*	*Well*	*Tap*
Electricity	*Yes*	*No*	*Yes*
Heat source	*IR-light in the nights for six weeks, and on the day if it is cold*	*Charcoal grills if it is cold and in the nights if necessary*	*IR-light 24 hours a day the first week and for 3-4 weeks if it is cold*
Extra light	*Light from bulbs all night*	*No*	*Regular bulbs when not using IR-light*
Cleaning frequency	*Biweekly*	*Every fourth day*	*Between batches*
Cleaning method	*Sweeping*	*Shovels, fresh bedding*	*Rinsing with water, disinfectant*
Cleaning between batches	*Sweeps and sprays*	*Shovels, fresh bedding*	*Rinsing with water, disinfectant*
Time empty chicken-house between batches	*1 w*	*2-3 w*	*> 2 w*
Mortality rate	*1.5-2.5 %*	*1.2-7 % (a guess)*	*10 % (this batch so far)*
Outbreak disease	*Yes, coccidiosis*	*Sick, outbreak unclear*	*No*

Disease, symptoms	*Swollen eyes, soft faeces, unable to move*	*Diarrhoea, cough*	
Actions at outbreak	*Moves the broilers, sprays the room, moves sick birds and sprays on them with medicine, do not give medicine*		
Occurring diseases	*Coccidiosis and ND*		*Ascites (water bellies)*
Occurrence of ND	*Yes*	*No*	
Management sick broilers chickens	*Same as when outbreak*	*Gives medicine (do not know what kind)*	*Post mortem at the veterinary office, does not give any medicine*
Vaccination	*Yes, ND and Gumboro*	*No*	*Yes, ND and Gumboro*
Age at vaccination	*ND when 1 week old, Gumboro when 3 weeks old*		*7, 14, 21 days of age*
Deworming		*Sometimes*	*No*
Duration of keeping broilers chickens	*6 w*	*6 w*	*It depends, sometimes hard to sell all at once*
Broilers chickens destiny	*Sale at market*	*Sale to anyone*	*Sale to schools, mostly teachers*
Price for your broilers chickens	*30 K*	*30 K*	*35 K now (because of expensive feed), otherwise 33 K*
Weight at sale	*2.3-3.5 kg*	*Do not know*	*1.5-2 kg*
Own consumption	*Yes, saves about 7.5-10 %*	*Sometimes a few*	*No*
Income enough to live on	*Yes*		*No, would need 600-1000 for that*

3. Large-scale broiler farmer outside Lusaka

Hybrid Poultry Farm

Figure 7. The farm Country choice chicken gets its chickens from the company Zambia's finest chicken. Photo: Cecilia Andersson.

Inside the fence are hybrid broiler chickens, hybrid layers and a slaughterhouse for broiler chickens. In this whole area 200 people work. The company "*Zambia´s finest chickens"* provides the Hybrid Poultry Farm with new chicks each round. This farm is the largest that "*Zambia´s finest chicken*" provide chicks to, see figure 7. According to them, they have the best growing broiler chickens in Zambia.

Hygiene

The representative of Hybrid Poultry Farm claimed that their success is due to their strict rules, especially regarding hygiene. Visitors are normally not allowed. To get into the Broiler chicken area you first have to go through a footbath containing the disinfectant *Biosept plus* (20 % Glutaraldehyde), then you must shower and change your clothes. You do not need to wash your hair and you are allowed to take notepads, pens and valuables with you over to the other side of the hygiene border. The showers are the hygienic border, as you enter from one side and go out on the other side. Outside the showers it is another footbath. Inside the area large gum boots and white coat will be used.

Figure 8. One out of ten broiler chicken houses at the farm. With its 750 m^2 it fits 10 000 broilers in the winter. Photo: Cecilia Andersson.

Buildings, birds and management

The broiler chicken department consists of ten large houses, each 10 x 75 m, see figure 8. Each house can accommodate 10 000 birds. In the winter there is 10 000 birds in each house, with a stocking density of 13.4 birds/m^2, approximately 24 kg/m^2. In the summer there is only 7 500 birds in each house and an occupancy rate of 10 birds/m^2, stocking density approximately 17.9 kg/m^2, because of the heat. When the farm is about to start a new batch, they buy 20,000 new day-old chicks in three sets with two days between each set. This method results in three different age-groups on the farm, but never different ages in the same house. They follow the "all in all out"-method. Two employees are responsible for each house, and they do not run in and out of the other houses unnecessarily. The hybrids used are Ross and Cobb 500, but they are not mixed. Three houses were at our visit filled with Ross hybrids and seven houses harboured Cobb 500. They have both hybrids because there is market value of both, with different advantages. According to our guide Ross grows faster and has a lower mortality, while Cobb gives a bigger fillet. They are sold as whole birds.

Figure 9. Inside one of the broiler chicken houses. Photo: Johanna Lindell.

Outside each aviary there is a footbath with disinfectant, which is changed every day. The houses are heated with charcoal. The ventilation is natural, see figure 9. The walls of the houses consist of green plastic that they fold up and down depending on the outside temperature and the behavior of the birds. In the winter it is about 12° C at night, according to our guide. There are no problems with ammonia levels in the houses. If there is a power shortage a reserve power system starts automatically. To secure the production success, routines are very strictly followed.

Figure 10. "Cotton house", which is used as litter for the broiler chickens. Photo: Cecilia Andersson.

The chicken houses are empty during a period of 2 weeks between batches. At the beginning the chickens do not have access to the whole area, but as they grow they get access to larger and larger area. An area is cordoned off because the chickens are so small from the beginning. As they grow, the border is moved. "Cotton house" is a material that is used as litter, see figure 10. According to our source it has many advantages. It has good availability, absorbency, and it is cheap.

Mortality and assortment

Registrations about mortality are done every day, 6.7 % is accepted as normal mortality the first seven days, but it is usually less. If the mortality gets too high they have a local lab that takes samples and does autopsies. 10-15 % of the birds are weighed every day, to get an average weight. The first 14 days the employees inspect the stock and pick out and slaughter the chickens that they do not think will survive, e.g. those who are lame or apparently smaller than the others. These birds are not included in the mortality figure; distinction is made between the ones that die naturally and the ones that are sorted out.

Food and water

The birds have free access to feed and water at all times. The feed consists of Broiler Starter, Broiler Grower and Broiler Finisher.

See Table 2 for Choma Milling's information and SLU's analysis of the content in the feed from Choma Milling Ltd.

Before the broiler chickens learn how to eat from the troughs, they get food in small bowls and on widespread paper, see figure 11.

Water is available from nipples. The water is tested in a local lab twice a year. Before the birds learn how to drink from the nipples they also get water in bowls.

Food and water fills up in the troughs and nipples automatically from a system of pipes. If the weather is hot it is important that too much water does not fill up in the bowls, see figure 12, because if the water gets warm, they do not want to drink it. The water coming from the nipples is always cold.

Figure 11. Feeders and nipples for the broiler chickens. Photo: Johanna Lindell.

Figure 12. The drinking device includes a small bowl. Photo: Cecilia Andersson.

Vaccination

The birds are vaccinated against Newcastle disease and Gumboro. Both vaccines are given in the drinking water. At the age of 13 and 21 days they are vaccinated with ND-vaccine and at 10 and 16 days with Gumboro-vaccine (different strains).

They do not give any antibiotics to the birds, neither do they deworm them. Worms are not a problem, because of the short lifetime of the broiler chickens.

Diseases

Figure 13. Marabou stork. Photo: Johanna Lindell.

Diseases are not a big problem. There is minimal movement in the area and not so many visitors. The only problem they have is the big wild bird, Marabou stork, see figure 13, which flies between farms spreading infections. It is prohibited by the government to shoot the storks.

If one broiler chicken gets sick, it is moved and killed. If a few birds get sick, tests are taken by the local lab. They have never had an outbreak of ND or Gumboro. When birds have been sick it has been caused by lameness and dehydration. Sometimes breathing difficulties can occur, if it is hot outside, even if they have removed the plastic cover on the sides of the houses, the birds can die from heatstroke.

They have not noticed any behavioural problems amongst the broilers. Picking on each other only occur sometimes if a bird gets hurt so it bleeds, then the others want to pick on the wound out of curiosity.

Slaughter and sales

The birds are slaughtered when they are 35 days old, with a live weight of 1.79-1.8 kg and the carcass 1.3-1.4 kg (depending on how much of the body parts that are removed). The market does not want to have extremely big birds, middle-size is preferred.

The broiler chickens are sold to different stores, for example SPAR, PicknPay and Shoprite, but also to the public. When the birds are sold to the processing plant they cost 10 Kwacha/kg (alive). The plant in its turn sells the broilers to the shops for 16 K/kg (carcass).

There is a lot of competition these days for the company Zambia's finest chicken, by for example Zambeef, Rossbreeders, Tigerchicken, local/village chickens and Chinese broiler chickens. To become better than the competitors, they are raising their standards.

Cleaning procedures

After a batch the houses are carefully cleaned. The manure is taken out in bags, and sold to flower farms. The floors are swept and all remaining manure is taken out. Then they clean with water and soap, which is dissolving, followed by flushing with water. The next step is to apply disinfectant mixed with water in a pressure washer. The houses stand empty for 14 days before a new batch starts.

General

At the farm they have their own veterinarian, whom they consult about different issues.

To be allowed to work here completion up to 12th grade in school is required, but the employees are also trained at the farm when they start.

4. Broiler slaughter house outside Lusaka

Before you are allowed to enter the slaughterhouse you must change clothes, put on a hair net, dip your boots in a foot bath and wash and disinfect your hands.

The work at the processing plant starts at 6-7 am.

Transport

Usually the chickens are fasted 8-10 hours before transport to the slaughterhouse. Our guide did not know how long time it takes to transport the broiler chickens from the farmers to the slaughter house, but some farms are situated quite far away. Mortality rate during transport is < 5 %.

Euthanasia

The chickens are hung upside down on a conveyor belt that puts the heads in a water bath with electricity. The water bath does not work as stunning, though the voltage is only 40 V for 11 seconds. The purpose is to paralyze the chickens so that they are easier to handle (according to a local source). The animals can still feel pain when they are passed on to the killing station, where the throats are cut up mechanically, so they bleed to death. This process is monitored by a Muslim representative to ensure that it is approved halal slaughter.

Evisceration

The visceral organs are removed and then the carcass is washed on the inside and outside with water.

Storage

Fresh products are cooled in the chiller at 0-5° C.

The processing plant has three blast freezers, where the chickens are kept before storing, and two holding freezers, where the products are stored. In all freezers the temperature is kept between -18° to -12° C. At the slaughter house the HACCP-system (Hazard Analysis and Critical Control Points) is followed.

Up cutting and packaging

The chickens are packaged both whole and cut up and packaged in pieces such as drumsticks, wings, thighs, fillets etc. A whole packed chicken weighs about 0.8-2.2 kg. At the visit it was 14.6° C in the cutting department. The temperature should be kept at 12-15° C (goes up to 15° C if it is very hot outside).

Almost everything from the chickens is used. Certain organs such as liver and heart are sold with whole chickens. Feathers, blood and chickens that died during transport are thrown away.

DISCUSSION

1. Broiler study at GART Batoka

The experimental group had better outcome than the control group in terms of feed consumption, growth and FCR, but how did the increased duration of light affect the welfare, how was the general welfare for the experimental and control groups, during the study, and is there any profitability in using solar lamps to broiler chickens in Zambia during the prevailing conditions?

Growth rate

The results show that the experimental group consumed more feed than the control group during the age of 20-34 days. Unfortunately, no data on feed consumption exists for the last period of the study. Also weight gain was greater for the experimental group, throughout the full experimental period, at the age of 20-42 days. However it should be remembered that growth and growth rate were not measured between the ages of 0-20 days of the chickens and comparison with this period can therefore not be made.

The experimental group had a lower FCR than the control group. This means that the utilization of the feed was better for the birds in the experimental group and that it takes less feed for them to grow to a certain weight than for those in the control group. Thereby, this experiment indicates that the costs to produce chicken meat could be decreased by using additional light, in terms of feed cost. The experimental group ate more feed, but they utilized it better. The fact that we only measured FCR for two weeks of the growth period, makes this result not completely trustworthy, the FCR could have been both better and worse if measured over the whole lifespan. More studies need to be done.

How can the FCR-results for both the experimental and control group be so good (experimental group 1.53 and control group 1.67, compared to FCR 1.75 in Sweden), in spite of the heat that could have impaired it significantly?

The gasping observed testifies that the broiler chickens were affected by the heat. When the groups' FCR are compared with Swedish dimensions it should be remembered that the groups' FCR was calculated for a short period, 20-34 days of age, while 1.75 in Sweden is the FCR for the entire rearing period 0-35 days of age. This is the most likely explanation to the FCR results.

Things that can affect FCR are for instance if the chickens have free access to feed or not. All small-scale broiler chicken farmers in Zambia may not give free access to feed (two out of three of those interviewed broiler farmers in Batoka and Choma areas do). The stocking density for the experimental and control groups were low and the chickens had a short distance to get to the feed and water, which may have given these good results. Perhaps the

genotype of the hybrids used was suitable, and after all could cope with the heat- without any greater impact.

Another explanation are incorrect results due to a misleading scale, the scale should have been control weighed to be sure that it weighed right and that it got the correct results. For future studies, use of a control weight is suggested, to control that factor.

Both Broiler Grower and Broiler Finisher contain sodium, potassium, calcium, phosphorus and magnesium, along with coccidiostats. This may have helped the broiler chickens to cope with the heat since supplements of vitamins and minerals are shown to have a positive effect on broiler chickens exposed to heat stress. Coccidiostats may have prevented an outbreak of coccidiosis and thus contributed to good growth.

As the housing was adjusted after some time, the difference in growth rate between the two groups might have been larger if the ventilation would have been the same for both groups throughout the whole study period.

How could GART's broiler chickens have gained less in weight than the experimental and control group in the end of the study when they received light 24 hours a day compared to 14.5 hours and 12 hours a day?

It can be due to many factors. The broiler chickens in our trial received their feed in the form of pellets and GART's broiler chickens got mash. It is easier to eat more feed, and thereby energy and proteins, when it is packed tightly. GART changed from Broiler Grower to Broiler Finisher earlier than we did for the experimental and control groups. Broiler Grower contains more protein and less fat than Broiler Finisher, both according to Choma Milling Ltd and SLU analyses. Our broiler chickens thereby got larger proportions of proteins for a longer time. More fat in the feed manage the broiler chickens to handle the heat better, but they must still have enough protein to grow. However too much protein can possibly reduce growth, because energy is required to dispose excessive protein, perhaps especially in hot climates. Since the experimental and control groups' growth were so much better than for GART's broiler chickens, the amount of protein in the feed cannot have been too large, but maybe the difference was large enough to make the experimental and control group grow more than GART's broiler chickens.

The occasional feed shortage for GART's broiler chickens had undoubtedly also an impact on their growth. The stocking density for GART's broiler chickens was higher and competition at the feeders was more common. This had probably also an effect on the growth rate of GART's broiler chickens. The long photo period may have contributed negatively on production, but it is likely that the high stocking density, the fact that they did not get their feed in pelleted form, and did not get so much feed the last week, probably influenced the outcome more. The weight of the experimental and control groups compared to GART's broiler chickens' weight indicates the importance of a low stocking density, free access to feed throughout the rearing period, the feed form and naturally divided days into light and dark periods (with not too long light periods).

Animal welfare and light

How did the longer photoperiod affect the experimental group during the study, both regarding production and welfare? How are GART's broiler chickens affected by their continuous photoperiod?

It has been known for a long time that increased access to light stimulates the birds' activity, gives larger feed intake and hence higher live weight (Jönsson, 1966), but too much light will jeopardize the birds' well-being (Ferrante *et al.*, 2006), and may have a negative effect on production (Lewis & Gous, 2007). The results from our two groups are consistent with that research. The experimental group that received a longer daily photo period had eaten and grown more, and had a better FCR than the control group. It can be concluded that the extra two and a half hours of light per day has been enough to affect production positively, but it does not provide a too long photo period to give any negative effects. Although we have not examined the eye status of the birds or made any detailed behavioural studies to detect stress and fear, we can definitely state that the extra light has not had any negative effect on the productivity.

GART's broiler chickens, which received light 24 hours a day, could be negatively affected by the light. There were lame birds in the group that was moved to another room or euthanized, but the prevalence of lame birds is unknown. There is a great risk that their eyes did not develop properly, or that their bone health was bad. However, our experimental and control group lived under the same conditions as GART's broiler chickens their first 20 days of life. It is possible that our broiler chickens would have grown better if they did not have light 24 hours a day the first 20 days. The long photo period, along with other factors, may have contributed to the fact that GART's broiler chickens grew less than the experimental and control groups in the end. Chicken producers who currently use 24 h light could increase their production and get better animal health if they give the animals some darkness.

Animal welfare of the experimental and control broiler chickens

What factors besides light may have affected the experimental and control groups' general welfare?

Animal welfare is important to consider in animal husbandry. Heat can be a problem in hot climates, as in Zambia. The ventilation in the rooms was not the best. The few windows were not enough and the air flow was disturbed by the partitioning of the room to divide the broiler chickens into two groups. Most days it was at least 30 degrees outside, sometimes up to 36° C and the poor ventilation did not help the broiler chickens to cope with the heat. Most of them were panting the hot days. As the control group was moved into a larger room, the ventilation was better for them than for the experimental group. This room was considerably larger and had many big windows. This difference in the ventilation may have affected the conditions for the animals and given the control group an advantage.

Heat can be an animal welfare problem. Stressful moments become more stressful than usual in hot climates (Daghir, 1995) and the broiler chickens were subjected to the weighing, which was necessary for the project but could be stressful. However, the broiler chickens did not

seem to be affected for any long period afterwards (personal observation). The stocking density, 4.5 kg/m^2, was not too high compared to Swedish dimensions, 20-36 kg/m^2 (Branschorganisationen Svensk Fågel, 2013), or the Hybrid Poultry Farm, 17.9-24 kg/m^2, i.e. the birds had plenty of room.

The birds had always free access to feed, and more than enough space at the feeders per bird (one feeder with a diameter of approximately 30 cm, per group of 20 birds) which leads to good animal welfare. In Sweden, each chicken must have at least 8 mm surface at the feeders, if they have free access to feed (SJVFS, 2010:15). If they do not have free access to feed they need 20 mm (12 mm at the age of 0-7 weeks) per bird, if the feeder is round.

As the birds became older and grew, they also became less active. At the end of the study, they were very heavy, in average 2 694 g for the experimental group and 2 586 g for the control group which is considerably more than what is usual in Zambia. Perhaps the study should have been completed earlier, given the fact that it is hard for fully grown broiler chickens to cope with a hot climate (Daghir, 1995) and that the ventilation was poor. The heavy bodies contributed negatively to the welfare of the chickens.

Profitability

Is it profitable to use solar lamps in broiler chicken production in Zambia?

The use of solar lamps in the present study resulted in a more rapid growth of the experimental broiler chickens. Broiler chickens to be sold at a particular weight instead of a certain age can be ready for sale earlier by using light e.g. solar lamps, a few hours per evening. However, it is important that they have free access to feed; otherwise the extra light has no effect on the production. If the broiler chickens should be sold at the weight of 2 kg, calculated on the basis of the average growth rate and weights of the two groups, the broiler chickens in the experimental group would be ready for sale 34 days old and broiler chickens of the control group at the age of 35 days. The question is how much profit it can bring. Shorter rearing period give more batches of broilers per year and thus greater profit is possible. However, the solar lamps used in this study are relatively expensive (HiNation AB, 2014). For the rural population in a developing country it may be very difficult to invest so much money or find financial support. In our study we needed four lamps for 20 broiler chickens. Larger groups would need to have many more lamps and the cost to purchase the lamps would be high. Using the lamps for broiler production would be viable, if we put aside the cost for the lamps. However, this particular lamp could also be used for cell phone charging etc. via a USB-port and if that capacity in combination with light for the broiler chickens as well as indoors in the late evening would be worth the investment for a family lacking electricity has to be further investigated.

Deaths and mortality

During the study, up to 42 days of age, the mortality was 5 %. If the period after completion of the study, up to 44 days of age is included, the mortality was 10 %. A mortality < 5 % is normal, but when it becomes higher, something could be wrong. The birds that died at the end of the study and shortly afterwards were not autopsied. The heavy bodies and the warm

weather may have been the cause of death, since these broiler chickens were very big at the end. If the feed had been changed from Broiler Grower to Broiler Finisher some days or one week earlier, maybe the broiler chickens had coped better with the heat, since Broiler Finisher contains more fat, which is beneficial at heat stress (Daghir, 1995), if it was heat stress the last ones died from.

If high mortality is a problem in hot climates it may be a good idea to hold back the feed during midday, the hottest days, and allow free access again in the evening, when light, e.g. the solar lamps are used, since it is proved that broiler chickens handle heat stress better if they are restrictively fed during the hottest hours of the day (Daghir, 1995).

No cause of death was determined for the broiler chicken in the control group who died 22 days old. The post mortem showed only dark red areas in the liver. I suspect that the broiler chicken died from heatstroke as it was very hot the day before it died, though it does not provide any obvious traces at autopsy.

The green diarrhoea outbreak the day before the study ended was not found to be linked to the deaths. As the feed was changed from Broiler Grower to Broiler Finisher two days before the green faeces appeared, and all the broiler chickens (both groups) were affected, any substance in the Broiler Finisher is suspected to have caused the green diarrhoea, but without causing any disease or major injury.

2. Smallholder broiler farmers in Batoka and Choma area

It has been difficult to get an overall picture and draw general conclusions from the small-scale broiler farmers, as only three of them were interviewed and since there are several differences also between these three.

Some language difficulties made it difficult to ensure certain details.

Disease and knowledge

The knowledge about diseases, treatments and generally about broiler chicken management seemed to be limited. The farmers do what they think is right, what they can afford and what they are able to manage by themselves.

Farmer 1 says that she had “outbreaks” of coccidiosis among her broiler chickens and that the symptoms were swollen eyes, soft faeces and that the birds could not move. In the outbreak about 2.5 % of the birds were affected. To be classed as an outbreak a greater proportion of the flock should be sick. However, it is more a matter of definition and may not have a significant impact for the small-scale broiler farmer. However, a good knowledge about diseases can increase the chance that the treatment is correct. Swollen eyes do not sound like coccidiosis. Inability to move could be because they died (due to severe coccidiosis) or a very poor general health, but it appears more like they were lame for any other reason. Soft faeces could be the diarrhoea from coccidiosis. Capacity to deal with diseases differs much amongst the farmers. Among the interviewed only one farmer gave medicine when the birds were sick and he did not know what it was. Proper knowledge about diseases and how to treat them, and

also some biosecurity, would be beneficial and save money for both the individual farmer and on society level (diseases would be treated and spread of infection would be prevented better). Increased knowledge could also be beneficial for the prevention of antibiotic resistance, as at the moment anyone in Zambia can walk in to a drug store and buy broad-spectrum antibiotics when they think it is necessary. Many people may not know what antibiotic resistance is and that it is a threat to the public health. Even the well-educated people in Zambia seem to have the attitude that some antibiotics cannot hurt (personal observation).

Animal welfare

The animal welfare at the different broiler farms was similar to that of western broiler production. One of the few things that differed was mainly the slaughter when the birds were killed by cutting the throats without stunning. This is a big negative factor for animal welfare. In a western slaughter house the birds are stunned before killing with either electrical water bath or carbon dioxide, and the animals are checked (random samples) before killing, that they are sufficiently stunned.

Production

Two of the small-scale broiler farms provided free access to feed, the third one did not answer on that aspect, and all of them used Choma Millings Broiler feed. Their animals should have the same capability to grow as the broiler chickens at GART, provided that they have the same good genes, since they eat the same feed. Inadequate vaccination coverage, lack of treatment for sick broiler chickens and insufficient cleaning routines are probably factors with major negative impacts on their production. Maybe they do not always have enough feed, or realise how important it is. By starting up in small-scale and having the right priorities, a small business can grow and eventually the extra profitable things can be affordable.

At sale the weights of the broiler chickens are between 1.5-3.5 kg. If the farmers get paid according to the weight or sell the chickens at a specific weight they may earn more money by improving growth by help of solar light provided that they have free access to feed.

3. Large-scale broiler farmer outside Lusaka

In the large-scale broiler farm that was visited, there was a good awareness on hygiene, diseases and how to take care of broiler chickens in the best way. They have fixed routines for vaccinations, treatments, cleaning etc. When there is a power-cut, the backup power plant starts automatically. It is obvious that they have a very controlled production skilled eye, but maybe they have to when it is such a large-scale production and much money invested. If anything goes wrong, it can have tremendous consequences and the company will lose a lot of money. This is probably why they leave nothing to coincidence and has control over every step in the production process.

The low incidence of diseases and the fact that no outbreak of ND or Gumboro had occurred, is probably due to their strict hygiene routines, vaccination programmes and prompt actions if any bird gets sick. As described earlier, strict hygiene is one of the most important factors in the prevention of the most common diseases.

The stocking density at the large-scale broiler farmer outside Lusaka was 24 kg/m^2 and 17.9 kg/m^2 in the dry season, and were thereby lower than at large-scale commercial broiler farms in Sweden (24-36 kg/m^2) (Branschorganisationen Svensk Fågel, 2013). The stocking density used in the present study at GART was much lower (4.5 kg/m^2). The density at the small-scale broiler farms is unknown, but based on personal observations it was quite high.

4. Broiler slaughter house outside Lusaka

The management and routines of the slaughter house was impressing. They had knowledge of the importance of good hygiene and refrigeration temperatures and also followed HACCP, just like Swedish slaughter houses. The work along the slaughter line seemed to work smoothly without problems.

The shortcomings at this slaughter house were the animal welfare. The broiler chickens are slaughtered without stunning and no one checked if the birds were dead before they were blanched. This could be discussed from an animal welfare perspective. They had electric water bath, but not strong enough to stun. The aim was to make the birds easier to deal with. It was very important that the slaughter was done according to halal and they had a religious person to control and approve the slaughter, even though only a minority of the inhabitants in Zambia is Muslims. The transport of the broilers that came to the slaughter house may also have been deficient, but the low mortality, if it is true, indicated acceptable conditions.

The slaughter house had come a long way but they were just not there yet, from a Swedish and animal welfare viewpoint. They did not see the animals as living creatures and how to treat them with respect. They will hopefully soon realize the importance of humane treatment of animals, as part of the development of the country.

Animal welfare in general

A common issue is the lack of animal welfare in Zambia. No one seems to care whether or not the animals have a good life. It may be understandable that a country that has so many other problems, people who are starving and are sick, do not think of the animals first. Only when people have a decent life themselves they have the energy to start caring about the animals and their welfare. It is terrible but true. In Zambia almost everybody lifts both broiler chickens and village chickens in the wings (personal observations). Despite the screams of pain, nobody thinks it is an issue. In a country where many people do not have so much money there is a risk that animals are kept alive for a little too long and suffer unnecessary, because of its economic or social value.

However, there are many things that can be changed, that do not take such a big effort. Some examples could be to avoid lifting the birds in the wings, do not bring chickens on the bus for three hours in 30° C heat and hit the hen's head in a stone before cutting the throat at slaughter. A few small things or actions can result in considerable differences but changing people's habits is usually not easy and therefore information and education are needed in order to influence traditions and attitudes.

Conclusions

This study indicates that broiler chickens receiving increased light period using solar lamps grow faster, have a better FCR and larger feed consumption. The welfare of the broiler chickens were not apparently affected by increasing the light period of 2.5 hours per day. More studies are needed, involving more broiler chickens, more replicates and the studies need to follow the whole rearing period from hatchery to slaughter day, for conclusions to be scientifically based.

It could be profitable to use solar lamps in the broiler chicken production, if it is possible to bring down the cost of the solar lamps in any way, for example by charity, loans or any other means. The lamps can also be used for other things like charging of cell phones, fans, radios etc. that is of both economical and practical value for the user.

In conclusion there is a wide variation in how broiler chicken production is performed in Zambia. Heat stress is a problem, at least during the warmest periods of the year, and the knowledge about diseases among the small-scale farmers interviewed was very low.

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APPENDIX 1

Questionnaire small-scale broiler farmers

1. How many broiler chickens do you have?
2. Do you have other kinds of poultry?
3. Where do you buy the chickens from?
4. How much do you pay for one broiler chicken?
5. What kind of broiler chickens do you have?
6. What kind of food do you give them?
7. How much food do you give them?
8. How often do the chickens get new water?
9. From where do you take the water?
10. How often do you clean after the broiler chickens/at their space?
11. How do you clean?
12. Approximately how many of the broiler chickens die, out of how many, per batch?
13. For how long have you been keeping broiler chickens?
14. Have you ever had an outbreak of disease amongst your broiler chickens?
    a. What disease?
    b. What symptoms?
    c. What do you do at an outbreak?
15. Do you vaccinate the broiler chickens?
    a. Against what?
    b. At what age?
16. Do you deworm the broiler chickens?
17. What do you do with birds that get sick?
18. What diseases have you had amongst your broiler chickens?
    a. Have you had Newcastle disease?
19. For how long do you keep your broiler chickens?
20. What do you do with them when they are finished?
21. How much do you sell them for, per bird?
22. What do your broiler chickens weigh when they are sold?
23. Do you have electricity?
24. Do you have any heat source for the broiler chickens?
25. Do they have any extra lighting?
26. Are there a lot of predators around, which takes broiler chickens from you?
27. Are the broiler chickens kept inside 24 hours a day?
28. Do you think any broiler chicken has ever been sick anytime because of the feed?
29. Do you think any broiler chicken has ever been sick anytime because of the water?
30. Do you keep any birds for own consumption?
31. Is the income from the broiler chickens enough to live on?
32. Do you clean after the broiler chickens between rounds? How do you clean?
33. Does the broiler chicken house stand empty between rounds? For how long?
34. Have you ever observed any behavioural problems amongst your broiler chickens?
35. How are the broiler chickens euthanized at slaughter?

APPENDIX 2

HiLight from HiNation

HiLight is a solar powered lamp (see figure 14) from the Swedish company HiNation (HiNation AB, 2014). The lamp consists of a high-efficiency solar cell and a LED diode. It is robust, quite water resistant and weighs only ~430 grams. After a charging period of 10 hours in sunlight it gives about 20 hours of light. HiLight can be used, in addition to as a lamp, to charge cell phones, GPS, MP3, digital cameras, and also be connected to and power radio, fans etc.

Figure 14. The solar lamp HiLight from HiNation and a fan that is connected to the lamp. Photo: Cecilia Andersson.