Development and evaluation of 4-way crossbred chicken population in Southern Ethiopia

Utvikling og evaluering av 4-veis kryssing for hønseproduksjon i det sørlige Etiopia

Philosophiae Doctor (PhD) Thesis

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Abstract/summary

Village chickens in Ethiopia are predominantly indigenous. They play an important role in the livelihood of farmers mainly by providing animal protein through meat and egg, as a source of income and family saving, and means of employment for landless farmers and women. They are believed to have valuable genetic attributes such as adaptation to harsh environment and some resistance to diseases and parasites, but they are poor in egg production and growth. In spite of their huge number and importance, very little scientific research and development activities have been done. Village chicken productivity should be improved not only genetically but also through better management practices.

This study was conducted in Ethiopia to produce a chicken population through 4-way crossbreeding using two indigenous and two exotic chicken breeds. The final 4-way chicken crosses are considered to perform better than the indigenous chicken population in egg production and body weight under village management conditions. Although they were expected to survive better than the exotic chicken, mortality was high. The two indigenous ecotypes/breeds were Naked Neck (N) and Netch (W), a white feathered chicken, used to sire the two exotic breeds: Fayoumi (F), developed in Egypt, and Rhode Island Red (R), respectively. The pure breed exotic chickens were tested under on-station in a college farm and on-farm in farmers' villages using women farmers. A local indigenous ecotype/breed called Sidancho was also tested on-farm together with the exotic breeds. The F1 produced by crossing R with W and F with N were tested only on-station. The F2 which were produced by crossing RW with FN, or their reciprocal, were tested in both on-station and on-farm management systems. Parameters measured were mortality, egg production and quality, and body weight and growth.

Genotype by environment interaction was observed in first experiment for pure exotic breeds tested under the two management systems. F already performed better than R on-station, but on-farm F performed much better than R, although the level of production was lower. F was better in egg production and survivability in both systems, but R weighed heavier and laid heavy eggs. No significant difference was observed between the F1 crosses on most of the traits measured on-station. No significant difference was found between the reciprocal crosses forming the F2. There was significant management effect on body weight and hen housed egg production of the F2. The F2 started laying eggs earlier under on-farm condition than on-station and produced

more eggs during the early egg laying period. The condition was reversed on late egg laying production where on-station chickens laid more eggs than on-farm chickens. Chick mortality was lower for on-farm than on-station, maybe due to the use of hay-box chick brooder by the farmers. But high on-farm grown chicken mortality mainly due to predator and disease was observed. In general when the F2 was compared with the indigenous Sidancho, age at first egg was reduced by almost 2 months, egg number was improved by 35% and layer body weight was increased by 100 g.

It is therefore concluded that productivity of village chickens can be improved by cross breeding and thereby can contribute to the betterment of livelihood of farmers through increased egg production. It is discussed whether this should be by use of cross breeding or the introduction of a synthetic line. However, genetic improvement should go hand in hand with better management practices such as improved housing, quality feed and disease control, so that the chickens may express their genetic potentials. Finally it was recommended that further study with more breeds together with economic analysis should be conducted to choose the best possible breed combination for both village as well as small-scale urban chicken production systems.

Sammendrag

På landsbygda i Etiopia domineres det tradisjonelle hønseholdet av gamle landraser. De utgjør et vesentlig bidrag til livsgrunnlaget for bøndene, både som en viktig animalsk proteinkilde ved forsyninger av kjøtt og egg til familien, men òg som inntektskilde og økonomisk reserve, samt sysselsetting av landløse bønder og kvinner. Landrasene har ord på seg for å ha verdifulle genetiske egenskaper slik som å være godt tilpasset marginale forhold og å ha stor resistens mot lokale sjukdommer og parasitter, men samtidig har de lav avdrått når gjelder egg- og kjøttproduksjon. Til tross for landrasenes store utbredelse og betydning, er det gjort lite forskning eller utviklingsarbeid på dem. Landrasenes produktivitet forventes å ha et potensial for forbedring ikke bare genetisk, men også ved endret driftspraksis.

Studien som presenteres her ble gjennomført i Etiopia. En populasjon ble dannet ved å krysse to landraser og to importerte kommersielle høneraser. Den etablerte 4-veiskrysningen forventes å produsere mer egg og kjøtt under de rådende forhold på landsbygda enn landrasene. Videre var det forventet at de overlevde bedre enn de rene eksotiske linjene selv om dødeligheten var høy. De to landrasene som ble benyttet som farlinjer i den første krysningen var naked neck (N), en type med fjørløs hals, samt den hvite typen netch (W). De to importerte rasene (morlinjer) var den egyptiske fayoumi (F) og en tyngre kommersiell rase rhode island red (R). De rene importerte linjene ble testet både i en testingsstasjon på et landbruksuniversitet og på landsbygda med kvinnelige bønder under marginale forhold. En lokal landrase (sidancho) ble testet hos de samme bøndene samtidig med de to importerte linjene. Første generasjon (F1) var etter kryssing mellom R (♀) og W(♂) og mellom F (♀) og N (♂). Disse to kryssingene ble bare testet på teststasjonen. Neste generasjon (F2) ble dannet ved å krysse RW og FN resiprokt og disse ble testet både på stasjonen og hos bøndene. Egenskaper som ble undersøkt var mortalitet, eggproduksjon og -kvalitet, tilvekst og levende vekt.

Samspillseffekter mellom genotype og miljø ble observert i det første forsøket for de importerte rene linjene som ble testet i begge driftsformene: på stasjonen og på landsbygda. F ga høyere produksjon enn R på stasjonen, men på landsbygda ble forskjellen mye større, selv om produksjonsnivået var lågere. F hadde høyere eggproduksjon og overlevelsesgrad i begge driftsformene, mens R veide mer og la større egg. Ingen signifikante forskjeller ble observert mellom F1-kryssingene i de fleste egenskapene som ble registrert på stasjonen. Det ble heller

ikke registrert noen forskjeller mellom de resiproke kryssingene i F2. F2-hønene startet å legge egg tidligere under landsbygdforhold enn på stasjonen og la dermed flere egg i den tidlige verpeperioden. Forholdet var motsatt når det gjaldt eggproduksjon i siste del av verpeperioden hvor høns på stasjonen la flere egg enn de som var på landsbygda. Antall døde kyllinger var færre på landsbygda enn på stasjonen sannsynligvis som en følge av oppdrettsbokser med halm som de daggamle kyllingene fikk tilgang til hos bøndene. Voksne dyr hadde imidlertid høyere mortalitet i landsbygda enn på stasjonen, hovedsakelig på grunn av predasjon og sjukdom. Men når F2-dyr ble sammenliknet med sidancho under landsbygdforhold la F2-hønene sitt første egg nesten 2 måneder tidligere enn sidancho, antall egg økte med 35 % og hønene var 100 g tyngre.

Man konkluderer derfor med at produktiviteten til landrasene under landsbygdforhold kan forbedres ved innkryssing av eksotiske linjer og slik oppnå økt eggproduksjon, og derigjennom bedre livsgrunnlaget til bøndene. Det diskuteres om dette bør skje ved kryssingsavl eller ved introduksjon av syntetisk linje. I alle fall bør genetisk forbedring gå hand i hand med bedre driftspraksis som bedre hus, bedre fôr og sjukdomskontroll, slik at kyllingene får uttrykke sitt genetiske potensial. Endelig tilrås det å teste ut flere linjer samtidig som økonomiske analyser utføres slik at den best mulige linjekombinasjonen kan velges for både landsbygdforhold og under små-skala hønsehold i urbane strøk.

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1. Introduction

1.1. Origin, domestication and distribution of chickens in the world

Chicken is one of several poultry species which is kept for its egg and meat for human consumption. There are four living wild species from which domestic chickens (*Gallus domesticus*) could have originated. They are red jungle fowl (*Gallus gallus*), Javan jungle fowl (*Gallus varius*), grey jungle fowl (*Gallus sonnerati*) and Singalese jungle fowl (*Gallus lafayetti*) which are all found in South East Asia (Payne, 1990; Crawford, 1993). The red jungle fowl is the species that most resembles chickens and is considered as the main ancestor although it may not have been the only one (Crawford, 1995). Chickens were domesticated somewhere in South East Asia although the exact location and time are not fully resolved (Payne, 1990; Crawford, 1995). However, West and Zhou (1989) on the basis of archeological evidences from various regions of the world concluded that chickens were first domesticated from the red jungle fowl in South East Asia well before the sixth millennium BC and later taken north and became established in China by 6000 BC.

Chickens are widely distributed all over the world and kept in a wide range of agro-ecological zones and production systems, and under different economic regimes. Their numbers are vast and when measured by contribution to the human diet, they are probably the most important of all domesticated birds and mammals (Crawford, 1995; Hoffmann, 2005). According to FAO (2003) world's chicken population increased from 11.5 billion in 1992 to 15.6 billion in 2002 with an average annual growth rate of 3 %. Poultry, including chickens and other domestic birds, provide an immense supply of food for the world. According to a review by Windhorst (2006) global poultry meat and egg production as well as trade with poultry products have shown a remarkable growth since 1970s. Poultry meat and hen eggs production have grown by 437 and 203 % respectively as compared with 58 and 186% for beef/veal and pig meat respectively between the years 1970 and 2005. The increase of production volume over time was very imbalanced from spatial perspectives. Developing countries surpassed the production volume of poultry meat and egg of developed countries in the 1990s. In 2005 developing countries contributed about 68% of global egg and 55% poultry meat production mainly due to the dominating role of China. In contrast to production, the contribution of developing countries to export volume of poultry products is still much lower than that of developed countries.

1.2. Poultry production systems in developing (African) countries

Hoffmann (2005) divided the global poultry sector into two distinct sub-sectors: commercial sub-sector dominated by international companies mainly from developed nations and the small-scale sub-sector that provide up to 90 percent of total poultry production in some developing countries. Commercial poultry productions system use modern highly improved chicken hybrids and involve modern technologies and management system and mainly found in developed countries. Although commercial poultry production in developing country is still in its infant stage, it shows a fast growth trend. In Ethiopia, for example, a few decades ago there were only insignificant modern commercial poultry farms but currently there are around 20 private large-scale commercial poultry production farms (Solomon, 2007). Back-yard and small-scale poultry keeping using mainly indigenous chickens still dominate poultry production systems in many developing countries. Gueye (1998) described the types of poultry husbandry mostly practiced for village poultry production in Africa as the free range and backyard systems. But there are also families who keep modern breeds in small flock sizes and use relatively improved management. Therefore, village poultry production can be classified depending on the level of inputs provided to the chickens: *the free range system* where chickens receive daily ration by scavenging, *the backyard system* where chickens are partly confined with improved overnight shelter and are fed and watered, and *the semi-intensive system* in which chickens are fed balanced diet with specialized rather than indigenous breeds of chickens (Besbes, 2009).

According to Kitalyi (1998) and Gueye (1998), Africa's village chicken production systems are based on the scavenging indigenous domestic chickens; and these chickens remain predominant in African villages despite the introduction of exotic and crossbred types, because farmers have not been able to afford the high input requirement of introduced breeds. In most African countries, chickens have no regular health control program, may or may not have shelter, and scavenge on green forages, insects, and kitchen and cereal leftovers around the homestead area for most of their nutritional needs. Kitalyi (1998) also emphasized that village chicken production systems in rural Africa as an indigenous and integral part of the farming system, low-input production system and a means of converting low-quality feed into high-quality protein.

1.3. Role and characteristics of indigenous chickens in developing countries

Indigenous chickens play an important role in the livelihood of farmers in many developing countries. They are important to rural and tribal village family poultry keeping because of their ability to adapt and produce under adverse environmental conditions (Khan, 2008). According to the review by Gueye (1998), in addition to the use of village chickens for the production of egg and meat, they are kept for a variety of other reasons such as source of money, gifts, and for religious ceremonies (sacrification). Besbes (2009) also described the importance of village poultry production in the developing country as income diversification, provision of high quality food, form of family savings and insurance. Moreover, because of higher involvement of women in poultry production, it contributes to women's empowerment. Farmers with small farm size or landless laborers, and people with low income are able to raise chickens with low inputs and produce eggs and meat (Khan, 2008).

Indigenous village chicken are characterized by variable plumage color, ranging from a simple white or black to all combinations of color including gold, silver, fawn and mottling. They are very alert and have long shanks with which to run away from predators. Due to ages of natural selection, under scavenging conditions, indigenous chickens are very robust and well adapted to harsh environmental conditions, tolerant to various bacterial and protozoan diseases as well as internal and external parasites. They can thus survive better than commercial hybrid strains under village production conditions (Gueye, 1998; Khan, 2008; Besbes, 2009). However, in contrary to the belief that native fowls is more resistant to diseases, Khan (2008) reviewed various studies which reported heavy mortality in farms where the Indian native chickens were raised. The reasons for high mortality were poor adaptation to the environment and viral disease. Gueye (1998) also reported that Newcastle disease, which is caused by virus, is the most serious endemic chicken disease in many African countries.

1.4. Status of poultry production in Ethiopia

Alemu (1995) categorized poultry production in Ethiopia into traditional, low input with low output system and more intensive systems using relatively advanced management. According to Central Statistical Agency of Ethiopia (2009-2010) the total poultry population at the country level is estimated to be about 42 million. About 96.6% of the total population is reported to be indigenous and the rest are exotic pure breeds and hybrids. There have been fluctuations in the estimation of poultry population in Ethiopia. For example Central Statistical Agency of Ethiopia reported 33.35, 37.76 and 31 million poultry in the Ethiopia in 1996, 2000 and 2005. Other organizations such as International Livestock Research Institute reported 56.5 million in 1993 (Alemu, 1995). No reasons were given for the large variations of chicken population in different years estimated by different organizations and researchers, but possible reasons could be the difference in sampling methods, sampling period of the year, absence or presence of epidemic diseases during sampling year etc. It was reported by Solomon (2008) that during some epidemic periods mortality of up to 80% was observed in village chickens which can significantly reduce chicken population. Sampling period of the year is also very important because of the sharp increase of chicken slaughtering on national holidays such as New Year, Christmas, and Easter etc.

Traditional village poultry production is practiced by almost all rural family other than the nomadic population. It is characterized by minimum input, average flock size per household of 4.1 chickens that are scavenging for most of their food, and no investment beyond the birds. Some farmers made simple separate night enclosures but most chickens stay the night in the family's house. An insignificant number of exotic breeds of chickens are distributed to farmers by Ministry of Agriculture, non-government organizations and some higher educational institutions, otherwise village farmers keep mostly indigenous chickens. Indigenous chicken ecotypes that live in different agro-climatic zones have names based on either their area of origin, plumage colors or type of combs (Alemu, 1995; Solomon, 2008; Reta, 2009). Tadelle et al. (2000) cited some research reports and the average annual egg production of indigenous chickens under village condition could be as low as 30 eggs and up to 80 eggs/year if chickens are provided with improved feed, housing and health care. Body weight for males can reach 1.5 kg at six months of age and females about 30% less. Although village poultry production may appear primitive, it can make economic sense. This is because that even if the yield from indigenous chicken is very low, the inputs are even lower and sometimes can be non-existent (Tadelle et al, 2000).

On the other hand private and government commercial poultry farms are in their early stage of growth and mainly distributed in limited urban locations due to the presence of electricity and other infrastructures. There are private large scale commercial poultry farms – some with integrated production and processing facilities (Solomon, 2008; Reta, 2009). Some of these private commercial poultry farms have their own feed processing plant, hatchery, slaughtering facility, cold storage, and transport. Some are major source of breeding stock and commercial feed for the modern private poultry farms (Solomon, 2008). A number of poultry farms owned by agricultural colleges and universities are found in different part of the country. They engage in research in the field of poultry husbandry and also supply improved chicken breeds/hybrids to urban small-scale and rural farmers.

1.5. Poultry genetic improvement

Rapid economic growth in many countries results in increasing income for the population. This leads people to spend a large share of their food budget on animal protein. The higher demand for animal protein in general and poultry meat and egg in particular is met by intensive production systems (Hoffmann, 2005). The specialization of chicken production either for egg or meat through genetic improvement also plays a significant role in meeting the high demand for poultry products. For example since the early 1960s, feed conversion in egg production in the USA and Canada has improved by almost 1 g, from 2.96 g feed per 1 g egg to 2.01 g feed per 1g egg. However, it is not possible to know exactly how much of this improvement was due to genetic and management. But it is safe to assume that a major part of the change is due to improved breeding stock (Arthur and Albers, 2003).

Modern poultry breeding was introduced in the 19th century and a wide variety of breeds has emerged by using the classic ‘pure’ breeds. Modern specialized breeds and lines have been developed since 1950s in developed countries to increase production in one or a few major traits.

Poultry breeding companies have successfully protected their intellectual property investment in superior birds by exploiting heterosis and deleterious segregation of hybrid stocks in the next generation (Hoffmann, 2005). Since 1950s poultry breeding companies have become fewer in number and much larger in size due to the high international competition and cost of maintaining modern breeding, marketing and distribution programs in comparison with potential income. A series of company sales and merger also reduced the number. (Flock and Preisinger, 2002; Arthur and Albers, 2003). For example, there were 20 breeding companies all over the world in 1980s. Currently, three groups of primary breeders dominate the international laying hen market and there are four broiler breeding companies worldwide (Flock and Preisinger, 2002; Hoffmann, 2005).

In developing countries there are few breeds that are properly described and most local breeds often have no defined phenotypic pattern except distinguished by one or more features such as naked neck or color of feather. Due to the ability of tolerating some diseases and parasites, and their ability to survive under harsh environmental condition, indigenous chickens are targeted for selection more on adaptation and resistance to disease rather than for enhanced production (Hoffmann, 2005). There is evidence to show that the performance of indigenous breeds can be improved genetically but they cannot compete with highly selected commercial hybrids under optimized conditions. The breeding goal should thus be to improve their efficiency under village condition (Besbes, 2009). There are however indigenous chicken breeds in tropical environment with special genetic attributes that have potential use in improvement of local chicken productivity. Among these chicken breeds, the Angete-Melata (Naked Neck) strain is well known for higher performance. The autosomal incomplete dominant naked neck (Na) gene is not only responsible for defeathering the neck region, but also restricts the feathering areas around the body by 20-30% in heterozygous (Nana) and up to 40% in the homozygous (NaNa) genotype. The Na gene also improves appetite which leads to higher body and egg weight, increases egg number, and also improves liveability under high temperature (Teketel, 1986; Merat, 2003; El-Safty, 2006; Islam and Nishibori, 2009). Another example of indigenous chickens that was widely studied and improved for egg production is Fayoumi. It is an Egyptian breed characterised by small body size and resistant to harsh tropical environment, producing up to 200 eggs per year under intensive management (Mukherjee, 1993; Barua et al., 1998; Hasnath, 2002). Other indigenous chicken breeds that have important genetic attributes are believed to be found in different parts of the world. Moreover, indigenous chickens may be preferred by the local population due to the taste and colour of meat and eggs. In spite of their importance indigenous chickens are under threat due to factors such as changing farming systems and indiscriminate crossbreeding (Besbes, 2009). It is therefore highly recommended that indigenous chickens should be conserved because they are reservoir of genetic diversity that could be useful in the future.

A normal crossbreeding of indigenous with improved exotic breeds of chicken can improve productivities of chickens under farmer's management conditions (Gueye, 1998; Khan, 2008). Exotic breeds with high productivity and hardiness such as Rhode Island Red (RIR), New Hampshire and Plymouth Rock are generally used (Gueye, 1998). For example in Bangladesh, a crossbred called Sonali was developed by crossing RIR cock and Fayoumi hen, and it has proved to be the highest yielding and most profitable breed combination under semi-scavenging condition (Rahman et al., 1997). Normal crossbreeding however requires regular supply of pure breeds which could be costly for many farmers in developing countries. An alternative method used to combine desirable properties from improved and indigenous breed is the development of synthetic or composite chickens, which is a single population that is a mixture of various populations produced by performing one or a few crosses between two or more populations (Syrstad, 1992; Nicholas, 2010).

Although crossbreeding can cause higher productivity, it has also resulted in a dilution of the indigenous birds and loss of some important characters such as broodiness and other morphological characteristics. Moreover, crossbreeding for village condition may be to complex where crucial inputs such as feed and medicine are not readily available (Besbes, 2009). Indiscriminate use of crossbreeding may also result in the decline or even loss of indigenous chickens before they are even described (Enyew and Workneh, 2001; IBC, 2004). Besbes (2009) therefore, suggested that the best way to improve the productivity of indigenous chicken is to select for production traits within a given population. However, due to the slow progress achieved in production traits the uses of selection schemes are limited.

The condition in Ethiopia for poultry breeding is not much different from many other developing countries. Some commercial poultry farms import fertile eggs or day old chicks to be used as parent stock from which commercial hybrid layers or broilers are produced. The layers and/or broilers are then reared in their farms or sold to other large or small-scale poultry farms. Government owned poultry breeding and rearing centers also imports parent stocks and produce dual purpose chickens – mainly RIR – to be distributed to rural or small-scale urban farmers (Solomon, 2008).

Genetic improvement of indigenous chicken is still not a well examined area of research. The few improvement programs through crossbreeding by agricultural research institutes and colleges are insignificant compared with the huge number of chickens in the country. The current study will contribute some facts to the available genetic improvement efforts and be a reference for future strategies.

In this study a chicken population was produced by using 4-way crossbreeding of two indigenous breeds: Naked Neck and Netch as sire lines; and two exotic breeds: Fayoumi and RIR. The performance of the pure lines and 4-way crossbred chickens was tested under improved management condition at the college farm (on-station) and under village farm conditions using traditional poultry husbandry practices (on-farm). The 4-way crossbred chickens will be developed to a synthetic chicken population after a series of inter se crossing and selection.

2. Objectives of the study

The major objectives of the study were:

1. To investigate the performance of 4-way crossbred chickens under on-station and on-farm conditions.
2. To initiate developing synthetic chicken population using indigenous and exotic breeds that can perform higher in egg production and body weight under farmers' management condition.
3. To formulate baseline information for future chicken genetic improvement strategy including establishing chicken breeding center based on the conclusions of the study.

More specific objectives of the study at different stages of the experiments include:

1. Study the performance of exotic RIR and Fayoumi pure breeds under on-station and on-farm condition and compare them with results of local Sidancho ecotype which was tested only under on-farm condition.
2. Study genotype X environment interactions of the performance of the exotic pure breeds.
3. Study the performance of F1 crosses under on-station condition
4. Enhance income generation capacities of women farmers who received the experiment animals.
5. Identify other non-genetic problems associated with poor performance of indigenous chickens and suggest remedies to tackle them.

3. Thesis outline

This thesis is based on three papers from three experiments conducted on-station (college farm) and on-farm (village farms). Both college and village farms in which the experiments were conducted are typical representatives of poultry keeping today: the college farm using relatively improved poultry management systems, and village farms using traditional village poultry husbandry practiced in many parts of Ethiopia. A general introduction, objectives of the study, materials and methods, summary of the results of the three experiments, a general discussion, conclusions and recommendations, and future areas of research precedes the papers. The general introduction describes an overview of origin of chickens and their distribution, poultry production systems and status of genetic improvement in developed and developing countries in general and Ethiopia in particular. General and specific objectives were summarized under Objectives of the study. Materials and methods gives the descriptions of the sites of the experiments, animals used and the methods with which the experiments were conducted. A brief summary of the results found from each experiment and a more detailed description of implications of the results are described under summary of the results and general discussion sections respectively. Conclusions and recommendations were given based on the results found, and future areas of research were identified.

Paper I is about a performance study of pure breed exotic Fayoumi and RIR chickens tested under on-farm and on-station conditions and the indigenous Sidancho ecotype evaluated only in the on-farm. It examined genotype environment interaction of the two conditions and the two exotic chicken breeds. Paper II evaluated the performance of F1 crosses under on-station conditions. Paper III described the performance of a final 4-way crossbred chickens under both management conditions.

4. Materials and Methods

4.1. Study sites

The on-station experiment was conducted at Hawassa College of Agriculture (Hawassa University). The site is located at latitude $7^{0}3$ N, longitude $38^{0}28$ E; 275 km south of the Ethiopian capital, Addis Ababa. The elevation is 1700 m.a.s.l. and the area receives annual rainfall of 900-1100 mm with temperatures ranging from 10 to 35 ^{0}C. Figure 1 shows the relative position of the study sites. On-farm experiment was made in a farmers' village in Boricha area which is found around 20 km south of Awassa with more or less similar elevation and weather condition as Awassa.

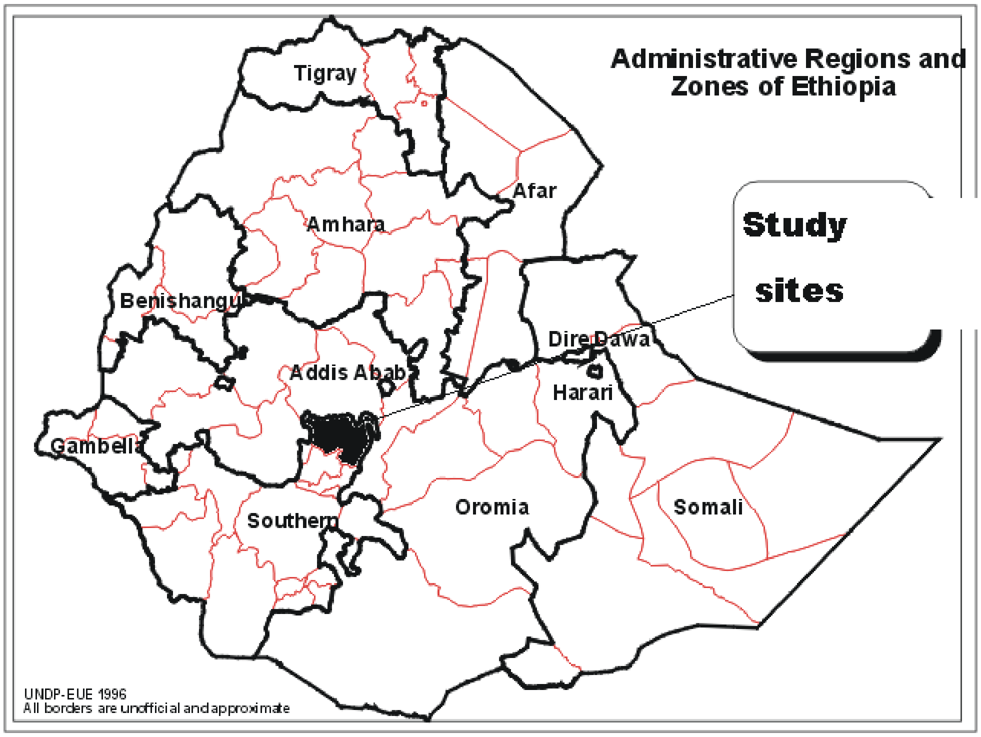

Figure 1. The location of the study sites shaded with dark color.

4.2. Sources and type of experiment animals

Fertile Fayoumi and RIR eggs were purchased and hatched in the college hatchery. Fertile local Sidancho ecotype eggs were collected from the on-farm study area and brought to the college for hatching together with the other eggs. More RIR pullets were purchased for crossing purpose in later stage of the experiment. Naked Neck and Netch cocks were purchased from local market in and around the study areas. Mating of Fayoumi hen with Naked Neck cock and RIR hen with Netch cock was made naturally by putting a cock and a hen in a separate pen until mating took place. The main reason for using the high egg producing exotic chickens as dam line was to obtain as much F1 offspring as possible. Indigenous female chickens were not tested on-station due to their poor survival rate. Moreover, their rate of egg laying is slow which in turn result in very small number of offspring in a given period of study time. Mating was done in two rounds in which a hen that was mated to a cock in the first round will be mated to another cock in the second round. By so doing more full sib and half sib families will be produced. Same mating procedure was practiced for the F1 crosses to produce the F2 chickens. Pictures of the pure chicken breeds and their crosses involved in the study are shown in Figure 2.


Naked Neck cock Fayoumi hens


Netch cock Rhode Island Red hens


Fayoumi and Naked Neck F1 crosses Rhode Island Red and Netch F1 Crosses

Figure 2. Chicken pure breeds and their crosses used for the crossbreeding experiment

4.3. Management conditions

4.3.1. On-station

The college poultry farm has a hatchery, brooding, and layer units. The hatchery has a capacity of incubating up to 6000 chicks at a time and brooding house uses electric lamps as a source of heat for growing chicks. The layer house used for on-station trial was a deep litter house with walls partially covered with strong wire mesh for natural ventilation and light. The roof was approximately 3 meters above the floor and made of corrugated iron sheet. The inside was divided into several pens by using wire mesh to assign chickens of same batch or breed. The afternoon room temperature of the layer house varied between 19 to 34^{o}C with an average of 27^{o}c and relative humidity ranged between 41 to 70 % with an average of 51%.

A set of trap nests was introduced in each pen when the chickens were about 5 months old for individual egg production record. All eggs were stored in a room with ventilator and weighed individually before incubation. The trays in the hatchery were modified in such a way that 6cm X 6cm cells made of plywood were fitted and eggs were placed in the cells (Figure 3). The cells were identified with the same information written on the egg for accurate individual pedigree record. The chicks were tagged with number after hatching and then weighed individually before they were transferred to brooding house. All chicks were vaccinated against Newcastle disease (NCD) in the hatchery. The chicks were then given starter ration which was prepared at the college feed processing unit. At the age of 8th week the lamp used for heating was removed and the pens were widened according to the number of chicks. At the 4th month the chickens were transferred to the layer house where layer ration was provided. Feeding and access to water were *ad libitum*. Eggs produced were counted daily and a week's collection of eggs from a layer was weighed every week, and the average weight per egg was used for analysis. Egg quality test was made at the age of 8 and 12 months. Body weight was measured every week up to 8 weeks of age and every month later. Mortality of the chickens was recorded every month.

Figure 3. A modified egg tray for setting eggs individually.

4.3.2. On-farm

Women farmers were given orientation about the purpose of the study, how to keep the chickens and cooperate with the data collectors. Day old chicks from the pure breed RIR, Fayoumi and local Sidancho ecotype were distributed to farmers by Assefa (2007) to study their performance from day old to the age of 4 months. Farmers were provided with a hay box brooder for growing the chicks during the brooding period (Figure 4). The hay box brooders comprise a feeding and exercise compartment, and another warm compartment stuffed with hay on the side walls, as recommended by Solomon (1995). After the brooding period the chickens were raised in a similar way as all village chickens are kept. Some farmers have separate house for their chickens but most of the chickens are staying in the family house. Farmers occasionally provide them with grains – mostly maize, and other kitchen scraps. Otherwise all chickens have to search for their daily ration from the fields around the family house (Figure 5). All chickens were leg banded to identify them either with a number or color of the leg plastic band. Farmers were told to keep the eggs separately from each chickens and egg production data was collected twice a week by development agent (trained in data collection method) living in the same area as the farmers. All data recorded under on-station system were collected in on-farm except feed consumption.

Figure 4. Hay-box brooder with two compartments (Photo from Assefa, 2007).

Figure 5. Fayoumi, RIR and local Sidancho chickens in village farm

4.4. Data analysis

Mixed procedure of Statistical Analysis System (SAS) was used to analyze the data using breed (genotype), age, sex and management systems as fixed effects and individual ID number, pens or farmers as random effects and interactions of the main effects depending on the traits under investigation.

In paper I, RIR and Fayoumi chickens were tested both on-station and on-farm. Local Sidancho ecotype was studied only in the on-farm condition. For on-station trial 60 RIR and 60 Fayoumi chickens were randomly assigned to 12 different pens where each pen had one breed. The pens were provided with trap nest for individual egg production record. On-farm trial was initially started by Assefa (2007) who studied the three breeds up to the age of 4 months using 30 women farmers. Paper I was the continuation of the study conducted by Assefa. The farmers were randomly divided into 3 groups and each group received chicks from one of the three breed. Each farmer was given 24 one-day-old unsexed chicks. After sexing of chicks at 8 weeks of age all farmers interchanged their chicks so that each farmer would keep all three breeds of chicks simultaneously. By so doing farmers could study the different attributes of each breed. All traits: egg production and quality, growth and mortality traits, were recorded in both systems.

Paper II dealt with the performance of F1 tested only under on-station condition. The FN which was offspring of Fayoumi hen and Naked Neck cock and the RW produced by crossing RIR hens and Netch cock were compared with each other and with their maternal parents of the previous experiment. The F1 FN chicks were also distributed to village farmers, but due to drought condition during the experiment period most of the chickens on-farm were either dead, consumed or sold by the farmers before data collection was finished, so this part of the experiment had to be dropped.

In Paper III results of testing 4-way crossbred chickens both on-station and on-farm sites were presented. They were produced by reciprocal crossings of the FN and RW that resulted in either FNRW or RWFN. Chicks with the same parents as those studied on-station were distributed to 10 women farmers for on-farm trial. Each farmer was given 20 chicks together with hay-box brooder, starter ration enough to feed them for about 2 weeks and some antibiotics.

5. Summary of results

Summary of results found for the three papers are given hereunder.

5.1. Paper I

Fayoumi started laying eggs more than a month earlier than RIR or Sidancho and the number of eggs laid by Fayoumi was higher than the other breeds in both management systems. Hen housed egg production (HHEP) was higher for Fayoumi than for the other two breeds in both systems. However, average egg weight and body weight for RIR was higher than for the other breeds in both systems. Although the average egg weight of Fayoumi was lower than RIR, the total egg mass by Fayoumi was higher than for RIR. In general chickens kept under on-station condition performed better than those kept on-farm except yolk colour which was higher at the on-farm using Roche colour fan scale. Mortality was lower for Fayoumi chickens than for the other breeds in both systems and Fayoumi was found to survive better than even the local Sidancho ecotype. However, Sidancho ecotype was better in body weight gain than Fayoumi. In the on-station, RIR consumed more feed than Fayoumi, but Fayoumi utilised the feed more efficiently than RIR in terms of egg production. Genotype X environment interaction was observed for all traits that were measured in both management systems.

5.2. Paper II

Hatching weight of the RW cross was higher than that of FN cross. But FN cross chicks grew faster than RW crosses and had heavier body weight than RW as they grew older. Body weight of grown chicken was not significantly different between the two crosses. No significant difference in age at first egg was observed between the two crosses, but both crosses started laying eggs earlier than their maternal parents in the previous experiment. Number of eggs laid by the two crosses was not significantly different, but FN crosses had higher hen housed egg production than RW due to higher mortality in the RW. No egg quality traits measured in the study showed any significant difference between the two crosses.

5.3. Paper III

The effect of reciprocal crossing was insignificant on almost all traits, and comparisons were made for sex, age, and management systems. Hatching weight of male and female chicks was not significantly different but male became heavier than females as they grew older. Chickens kept on-station had higher body weight than those kept on-farm condition. There was a tendency that chickens in the on-farm started laying eggs earlier than those in the on-station. As a result, on-farm chickens laid relatively more eggs than on-station chickens between the age of month 6 and month 8. The overall egg production between on-farm and on-station was not significantly different, but due to relatively early age at first egg under on-farm condition with subsequent relatively more number of eggs up to month 8 and the reverse condition during after month 8 gave rise to significant interaction between age and management system on egg production. Hen housed egg production was significantly higher for on-station chickens than on-farm chickens due to mortality. Egg yolk color was higher in on-farm chickens than on-station on Roche color fan scale. Mortality was higher in on-station than on-farm during the brooding period but the condition was reversed when the chickens had grown.

6. General Discussion

Comparison of pure breed Fayoumi and RIR chickens under on-station and on-farm management and Sidancho chickens only in the on-farm management conditions was made in paper I. The lower age at first egg found in Fayoumi chickens compared to RIR chickens was in agreement with the results found by Negussie (1999) who tested Fayoumi and RIR chickens in Ethiopia and reported that Fayoumi breed attained sexual maturity about four weeks earlier than RIR under on-station management. Similar or lower age at first egg have been reported for RIR and Fayoumi chickens kept under different management systems in Egypt and Bangladesh (Mohamed, 1997; Barua et al, 1998; Yeasmin et al, 2003; Zaman et al, 2004; Khan et al, 2006). Age at first egg for different Ethiopian chicken ecotypes was reported from 173 to 230 days under on-station and on-farm conditions (Teketel, 1986; Tadelle et al, 2003) which was lower than the one reported here for Sidancho ecotype. Variations in sexual maturity of the same breed are possible since this trait is affected by several factors in addition to genetics, such as feeding regime, intensity and duration of light, temperature etc (Negussie, 1999; Zaman et al, 2004).

The lower egg production by RIR chickens under on-station condition could be due to the infection of the chickens with Fowl Pox and subsequent reduction in egg laying, while the Fayoumi recovered more quickly and resumed laying eggs. The strong survivability of Fayoumi in both management conditions was also reflected on the results of HHEP where Fayoumi had higher HHEP than RIR due to lower mortality in Fayoumi chickens. This was in accordance with Fairful and Gowe (2003) who reported that hen housed egg production is affected by age at first egg, rate of egg production from the start of egg production, and viability including morbidity or any other factor causing production to cease. Furthermore, chickens kept under on-station condition produced higher number of eggs than those kept in the village farms. This was consistent with Dana and Ogle (2002) who reported that scavenging reduced egg production in both RIR and Fayoumi breeds in Ethiopia. As was reported by many studies the eggs of RIR chickens were heavier than the eggs of Fayoumi (El-Zarai, 1997; Negussie, 1999; Monira et al, 2003; Yeasmin et al, 2003). Although Fayoumi had lower egg weight, the higher egg mass produced by them was due to the higher egg number laid compared to RIR. Higher yolk color values for chickens on-farm was may be due to their access to green forages. The yellowness of the yolk is one of the most important quality traits appreciated by consumers in Ethiopia.

As expected, chickens kept under on-farm condition had lower egg production and body weight than those kept in the on-station. This could be due to the fact that chickens kept in the on-farm condition spent most of their time looking for their feed which results in loosing energy that could otherwise be used for weight gain as well as egg production. Moreover, the quality and quantity of feed in the village is considered to be poor with subsequent poor productivity. In this study a breed which performed better in one management system did not perform in the same magnitude in another management system which led to the phenomenon called Genotype X Environment interaction.

In general, Fayoumi chickens performed better in terms of egg production and survival ability in both systems. A survey on different attributes of the three breeds was made at the end of the experiment and 64% of the farmers responded that they prefer Fayoumi to RIR or local Sidancho mainly due to the early age at first egg, higher egg production potential and their ability to escape from predators. Due to the fact that Fayoumi is a tropical breed improved for higher egg production (Barua, 1998) they proved to survive and produce better than the others.

In general the main problem of indigenous chicken in the tropics is their poor egg production and growth. However, due to long natural and artificial selection they have higher adaptation to adverse environmental conditions such as high incidence of diseases and parasites, poor quality and quantity of feed and extreme weather conditions (Alemu, 1995; Barua et al., 1998; Gueye, 1998; Ali et al., 2000; Tadelle et al, 2000; Khan, 2008; Besbes, 2009; Islam and Nishibori, 2009). On the other hand exotic chickens have more production potential than indigenous chickens but have difficulties in adaptation to tropical environment. One can attempt to combine high productivity characteristics of exotic chickens and higher adaptation attributes of indigenous chicken by crossbreeding. Some experiments of crossing of exotic and indigenous chickens resulted high egg production and body weight in the tropics (Gueye, 1998; Rahman et al, 2004; Khan, 2008).

Paper II examined the effect of crossbreeding of exotic and indigenous chicken breeds. Two crosses were tried. The heavier and higher egg layer RIR (R) was mated to the local lighter and poor egg producer Netch (W) cock to form offspring RW; and the lighter but higher egg layer Fayoumi (F) was mated to indigenous Naked Neck (N) cock which is heavier in body weight but lower in egg production than Fayoumi, forming FN offspring. Due to the wide genetic difference between the parents it is expected that there is heterosis effect on egg production and body weight. However, in the on-station trial only performance of the pure breeds, but not the indigenous breeds was recorded and thus heterosis could not be calculated. As expected, heavier eggs from RIR gave rise to heavier RW chicks than FN chicks which were hatched from the lighter Fayoumi layers. However, as they grew older their difference in body weight became insignificant. This indicated that the different parental body weight had effect on leveling the body weight of the crosses. Egg production (percent hen day) of Ethiopian indigenous chickens including Naked Neck and Netch was studied by Teketel (1986) under on-station condition. The results found in the FN and RW crosses was higher than that of Naked Neck and Netch chickens found in Teketel (1986)'s study. This indicated that crossbreeding had improved both egg production and body weight in the crossbred compared to the indigenous chickens. However, mortality of the crosses was high especially during the brooding period. Relatively higher mortality was observed in RW crosses than in FN crosses in the present study. No difference was found in egg quality tests between the two crosses. The F1 crosses were then crossed reciprocally to produce 4-way crossbred chickens which will be dealt in paper III.

The 4-way crosses made some real improvements in village poultry production compared to the local chicken ecotypes which will be discussed later in the next section. Comparison of the 4-way crosses in the two management system revealed that some traits are better off in one or the other system. Mortality of chicks during the brooding period was higher on-station than on-farm. Although under normal conditions, those kept on-station should survive more than those kept on-farm. This should be especially true in Ethiopia where mean survival rate of village chicks could be as low as 40% (Solomon, 2007). The higher chick survival in this study was mainly attributed to the hay box brooder which proved to be very good in reducing mortality under village condition. On the other hand, the high chick mortality on-station might be due to an incidence of coccidiosis during the brooding period. Mortality of grown chickens on-farm increased mainly due to predation and disease, which are the main aspects of intervention if village poultry productivity is to be improved. Predation mainly by fox and wild cat was high due to the rehabilitation projects of the vegetation in the surrounding. Although there is no question that rehabilitation of the forest is a good sign of conservation, many wild animals have returned to the area with their subsequent effect of predation on the village chickens. Predation was not prevalent only in the village. A pen full of F1 cross chicks were killed by a wild cat which managed to sneak through the walls of the on-station poultry house. This delayed the experiment time until other batches of chicks were hatched.

As expected body weight for males was higher than for females, and chickens kept on-station weigh heavier than those kept on-farm. A more interesting result was found on-farm for the age at first egg laid. The chickens kept on-farm started laying eggs at least 20 days earlier than those kept on-station, contrary to the normal expectation. Chickens on-station with better feed and housing are expected to start laying eggs earlier than village chickens (Islam and Nishibori, 2009). The inconsistency could be explained by disease and feed. Firstly, the on-station chickens were infected with coccidiosis during their early growth period which might have delayed sexual maturity. Secondly, chickens on-farm might have found enough forage including proteinous insects and worms during the short rainy season in which they had grown.

Although the overall egg production of the 4-way crosses under the two systems was not significantly different, more eggs were laid by the on-station chickens than the on-farm chickens.

Due to the higher mortality after the brooding period on-farm, HHEP was lower than on-station. Egg weight was higher on-station than on-farm, but value for egg yolk color was higher on-farm.

The other result of paper III was the non-significant difference between the reciprocal crosses on most of the economically important traits. According to Fairfull (1990) reciprocal effects are the deviations between the crosses of two parental strains or breeds in which their roles as male or female parents are reversed. They are believed to be results of sex-linked genes on the Z chromosome and maternal effects which are confounded by the W chromosome in females. In birds males have ZZ chromosomes and females have single Z and (usually) a small W chromosome (Burt, 2003, Tuiskula-Haavisto and Vilkki, 2007). Since the Z chromosome is large and carries much genetic information, reciprocal effects are frequently larger for traits such as egg production, viability, feed conversion, sexual maturity and egg weight (Gowe and Fairfull, 1995). In paper III, however, no reciprocal effect was found. This could be explained by the fact that the parents i.e. FN and RW were not significantly different for most of the traits, as shown in paper II, and thus transfer genetic information to their offspring that have more or less equal value which result in more or less similarly performing reciprocal crossbreds. In addition, there would have been probably higher performance by F1 had there been a reciprocal crossing of their parents i.e. the pure breed exotic and indigenous chickens. All F1 females carry Z chromosome originating from their low egg producing paternal indigenous chickens. If the high egg producing exotic chickens were used as sire lines, they would have transferred their Z chromosomes which carry most sex linked economically important genetic information to their female offspring with subsequent higher productivity than the ones studied in paper II. Moreover, in a study by Tuiskula-Haavisto and Vilkki (2007) it was stated that reciprocal effects are not only the results of sex-linked and/or maternal effects but also due to autosomal areas with parent-of-origin specific effects in chicken. Some quantitative trait loci (QTL) mapping revealed areas in the chicken genome with parent-of-origin effects. These QTL affect economically important traits, mainly those related with growth.

6.1. Progress achieved by 4-way cross chicken in village poultry productivity

The goal of this study is to produce 4-way cross chicken populations that perform better than the indigenous chickens under farmers' management condition. It is, therefore, very important to evaluate the merits of the new 4-way chickens by comparing them with the performance of indigenous and exotic breed under both on-station and on-farm management conditions. Table 1 shows some of the economically important traits that were recorded during the whole experiment period. The results were found at different times but all experiments were otherwise conducted as far as possible under similar environmental conditions. All hatching weight measurements were taken at the college hatchery. When the results of local Sidancho and the 4-way crosses are compared under on-farm management system there is a remarkable improvement in most of the traits considered. Body weight of layers when they are 12 months old was higher for the 4-way crosses than the local Sidancho and for Fayoumi chickens under on-farm condition. However, no clear explanation was found for the reason of lower body weight exhibited by the 4-way crosses than for Sidancho at 4 months of age.

Age at first egg laid was reduced by about 50 days for 4-way cross chickens compared to the local Sidancho ecotype under on-farm which is very important in the village conditions where the chickens have short lifespan. The age is comparable with the one found for Fayoumi and about a month shorter than for RIR under on-station condition. Lower age at first egg laid means chickens could start laying eggs early and produce more eggs during their production period. This was also reflected in the number of eggs produced during the first few months of production (between start of lay to 8 month of age) where on-farm 4-way cross chickens laid more eggs than on-station chickens. The number of eggs produced by the 4-way crosses was much higher than the number produced by Sidancho ecotypes and the RIR under on-farm condition. This is a very good improvement under the prevailing condition although the amount produced was still low. Slight improvement in egg weight was obtained by the 4-way crosses in egg weight when compared with Sidancho ecotype. Based on the results of this study it could be stated that farmers can benefit economically due to the improvement of productivity of the 4-way cross in the village. This can be explained by the following example of financial gain due to increased egg production. From Table 1 an indigenous Sidancho chicken laid about 23 eggs between start of lay and 12 months of age where as the 4-way cross chickens laid on average 31 eggs during the same period, which makes an increase of 8 eggs (35%) per chicken. If ten 4-way cross layers are kept by a farmer, they would produce 310 egg compared to 230 eggs by Sidancho ecotype. Egg price varies depending on the season/period of a year as well as if it is urban or rural places. The highest price is during national holidays such as New Year and Christmas in the cities and the lowest price during fasting period, with an overall average of about 1 Birr/egg (1 USD ~ 16.40 Ethiopian Birr). If a farmer wants to use half of the money from the egg sale, he could buy a ewe to be used as breeding stock. All this gain is with virtually no or very low cost for feed and housing as farmers do not buy feed and use locally available material to construct a house if they ever make one. However, a day old chick from the college farm may cost between 5 to 7 Birr and the hay-box chick brooder may cost between 200 to 300 Birr depending on the size and type of materials used.

As expected the pure breed Fayoumi and RIR were much better than F1 or F2 crosses in egg production per living hen and body weight because they were developed for more egg production. Comparison of F1 and F2 could only be done under on-station conditions that were tested in different times. Body weight of the layers at 4 and 12 months of age was higher for F2 than for F1. But the F1 had lower age at first egg and produce more number of eggs than F2. This result was partly in agreement with the results documented by Gowe and Fairful (1995). It was shown that heterosis due to both dominance and epistasis was very important for egg production traits which was indicated by the drop in heterosis for both hen housed and hen day egg production from 2-way cross to 4-way cross. However, there was small contribution of heterosis for traits such as age at first egg, body weight, and egg weight which was again indicated by the small drop in heterosis from 2-way cross to 4-way cross chickens. It was also clearly shown that on average the 2-way crosses were superior to 3-way crosses which were superior to 4-way crosses for egg production. These results lead to the question of which crosses i.e. F1 or F2 are economically better. Producing F2 of course increases production cost and at the same time maintaining the F1 is costly as it requires continuous supply of the pure breeds. Further selection on some traits on F2 crosses to develop synthetic chicken and stabilizing them may improve production through additive gene action rather than heterosis. Therefore, using F2 crosses might be economically feasible in a country like Ethiopia where the availability of foreign currency is limited to import exotic chickens. Moreover, the different adaptation attributes from the indigenous chicken ecotypes might be expressed in F2 which makes them adaptable in the village management conditions. However, further economic analysis is required to definitely decide which crosses are better than the other in different management conditions.

7. Conclusions and recommendations

The study indicates that it is possible to improve village poultry productivity by crossbreeding. Egg production and body weight of 4-way crossbred chickens was much better than the local chickens in Boricha farmers' village. Furthermore provision of hay box brooder has dramatically reduced chick mortality when compared with the national average under village condition. Genotype X environment interaction was observed for the breeds tested under the two management systems on-station and on-farm. Average egg production in F1 was higher than in F2, but higher body weight was recorded for F2 than F1 crosses under on-station condition. Genetic improvement by itself could not improve productivity of village poultry. This was demonstrated by the high mortality of layers with subsequent loss of production. It is therefore very important to improve the management condition to fit with the genetically improved chickens.

Based on the results found from this study recommendations with regard to improving management conditions in the village poultry husbandry are cited hereunder.

Although productivity of the chickens in the village was improved as a result of crossing, further management practices should be put into place for the chickens to express their genetic potential. The most important intervention should be proper housing to protect the chickens from predators and diseases. From the on-farm study it was clearly shown that the problem of predator is very important. Housing that keep away predators can help chickens to stay longer and produce more eggs. It also reduces the incidence of disease and parasite. When chickens are kept indoor they should be provided with appropriate amount and quality of feed which might be costly to the farmers. However, if more output in terms of egg and meat is to be expected from the improved chickens, farmers have to invest on some inputs such as feed and medicines. The traditional way of keeping chickens in the village should not continue forever and improvements that take economic strength of the farmers into account should be implemented.

8. Future area of research

The exotic chicken breeds used for crossing in this study were chosen because they are widely available in the rural area (RIR) and their ability to adapt tropical environment. Further crossing of these and other improved exotic breeds with other indigenous ecotypes in different blood levels including reciprocal crossing and testing them under different environmental condition is very important to choose suitable hybrid or breed combination both for commercial small-scale urban and village poultry husbandry. It is also worth to examine reciprocal crossing of the pure breeds used in this study. The number of experiment animals used in this study was not large and should be increased in any future study. Economic evaluation of the different crosses under different management systems should be studied.

Indigenous chicken ecotypes have some important genetic attributes which need to be studied thoroughly. Selection on the different economically important traits of these chickens and conserving them for future use is of great importance.

Establishing poultry breeding program both for commercial and village poultry husbandry is necessary for Ethiopia which has limited foreign currency to import exotic hybrids. The chickens that will be developed by the breeding program will be distributed or sold to village and small scale poultry keeper so that farmers can benefit in terms of income and animal protein.

Researchers have to develop appropriate small scale poultry house types for village poultry which could not only help in number of death due to predation, but also in reducing disease and parasites. Such a house should be made from materials that are easily available in the area and should not be very expensive.

Poultry nutritionists should work together with breeders in order to formulate poultry feed that can be easily available and can be prepared by farmers.

Table 1. Some economically important chicken traits from different experiments of the thesis work.

Traits	Sidancho	Fayoumi		Rhode Island Red (RIR)		F1 crosses (average of RW and FN)	F2 4-way cross (average of the reciprocal crosses)	
	On-farm	On-station	On-farm	On-station	On-farm	On-station	On-station	On-farm
Hatching weight [a]	28.6±3.7[b]	30.5±3.7[b]	NA	40.6±3.5[b]	NA	30.6±0.3	30.1±0.3	NA
Chick body weight at 8 week	294±14.5[b]	NA	303±14.5[b]	NA	345±14.5[b]	261.1±2.9	246.3±4.1	NA
Layer body weight at 4 month	638.2±33.3	788.8±30.4	803.8±31.6	897.6±30.4	764.8±31.4	625.2±15.9	749.9±15.8	556.4±22.3
Layer Body wt at 12 month	960.7±34.5	1111.7±37.1	1000±37.1	1377.2±30.7	1273.4±46.5	1126.7±18.4	1169.3±21.3	1058.1±47.2
Age at first egg	256.3±6.8	202.0±9.2	208.7±5.9	237.4±9.3	247.6±7.1	197.5±3.4	221.5±8.5	202.6±10.3
Egg number between 4to 8 months	6.9±4.2	29.6±3.2	16.9±2.8	9±3.3	15.6±3.9	19.7±2.3	9.2±1.2	9.7±1.7
Egg number between 9 to 12 months	15.8±3.2	62.8±3.2	23.3±2.8	34.3±3.2	16.2±3.4	34.5±2.3	26.5±1.3	20.7±1.7
HHEP between 4 to 8 months	1.6±0.9	29.6±2.1	9.1±1.1	9.7±2.1	4.5±1.3	18.6±3.8	8.9±2.5	6.9±1.9
HHEP between 9 to 12 months	4.9±0.9	62.8±2.1	10.9±1.1	33.4±2.1	5.7±1.3	33.9±3.8	25.9±2.5	12.8±1.9
Egg weight at 12 month of age	39.4±1.9	44.4±0.7	41.6±1.3	58.3±1.2	57.3±1.9	46.7±0.7	46.9±1	41.1±1.5

[a] hatching weight was measured on-station, [b] obtained from Assefa (2007), NA= Not available

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List of papers

Paper 1. Genotype X environment interaction in two breeds of chickens kept under two management systems in Southern Ethiopia. Tropical Animal Health and Production, 2009, 41:1101-1114

Paper 2. Production Performance of Dual Purpose Crosses of Two Indigenous with Two Exotic Chicken Breeds in Sub-tropical Environment. International Journal of Poultry Science, 2010, 9(7): 702-710

Paper 3. Production performance of 4-way crossbred chicken population produced by crossing of two indigenous and two exotic chicken breeds under on-station and on-farm management systems in Southern Ethiopia. (Manuscript Submitted)

Errata

In Table 7 of paper I the number of on-farm chickens at 12 month is written as 19, 11 and 23 for RIR, Fayoumi and Local, respectively. However, these numbers are dead chickens between the age of 4 and 12 month and should be replaced with the number of alive chickens at 12 months. The correct number for number of on-farm alive chickens at 12 month is 47, 68 and 74 for RIR, Fayoumi and Local respectively.

Paper I

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ORIGINAL PAPER

Genotype X environment interaction in two breeds of chickens kept under two management systems in Southern Ethiopia

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Abstract Rhode Island Red (RIR) and Fayoumi chickens were evaluated on-station in a college farm and on-farm in village farms, whereas local chickens were only tested under on-farm condition. Traits recorded are egg production and egg quality, body weight and feed efficiency at 4, 8 and 12 months of age. Significant age effect was found for most traits except for shell thickness, albumen height and egg length. Also, significant breed by management system interactions were found for all traits measured in both systems. Fayoumi chickens were higher in egg production in both management systems. Moreover, they were higher than RIR in feed efficiency. RIR were higher in most egg quality traits and had higher weight gain. Local chickens performed below the two exotic breeds in most of the traits, but had higher weight gain than Fayoumi. Chickens kept on-farm had poorer performance than those kept on-station in all traits except for yolk colour.

Keywords On-station · On-farm · Fayoumi · RIR · *Sidancho* ecotype · Genotype*environment interaction

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Abbreviations

AAFE	Age At First Egg
AEST	Average Egg Shell Thickness
AEW	Average Egg Weight
AFC	Average Feed Consumption
AH	Albumen Height
BW	Body Weight
BWG	Body Weight Gain
EL	Egg Length
EM	Egg Mass
EN	Egg Number
ESI	Egg Shape Index
EW	Egg Width
FEEM	Feed Efficiency for Egg Mass
HHEP	Hen Housed Egg Production
HU	Haugh Unit
YC	Yolk Colour
YH	Yolk Height

Introduction

Ethiopia has an estimated 56.5 million chickens, and 99% of them are kept under traditional backyard poultry husbandry. Local varieties of chicken in Ethiopia vary widely in body size, conformation, plumage colour, and other characteristics (Alemu 1995). Poultry production is practiced predominantly by the rural smallholder farmers, using local stock under scavenging management. The contribution from the commercial sector to the total poultry production in Ethiopia does not exceed 3% (Dana and Ogle 2002). Chickens are kept to supplement family nutrition with animal protein from both egg and meat, generate small cash income and play a significant role in religious, cultural life and livelihood of both the rural and urban population of Ethiopia (Tadelle et al. 1999; Dana and Ogle 2002; Halima et al. 2006). The production system under village conditions is traditionally low-input with resulting poor performance for major production traits (Alemu 1995; Mekonnen 1998). One of the reasons for this low performance is the fact that relatively little research and development work has been carried out on indigenous chickens (Tadelle et al. 1999). Moreover, low genetic potential of indigenous stock for high production also plays a major role for the low performance of the local chickens. However, indigenous chickens are believed to have advantages over exotic improved chickens in that they have evolved important adaptive traits to the local environment, such as tolerance to some diseases and better yield under low input systems. Moreover, their products are highly preferred by consumers due to egg yolk colour and flavor of the meat.

Over the last 4 to 5 decades, many exotic breeds and hybrids of chickens have been introduced into Ethiopia by different organizations to increase poultry production and up-grade local chicken breeds through crossbreeding. However, animals imported from temperate countries have usually not achieved the expected performance in the tropics, apparently due to lack of adaptation to the new environment. The failure of exotic stocks to meet expectations when raised under tropical conditions is often linked to a phenomenon termed ‘genotype by environment interaction’ (Ali et al. 2000). As stated by Essam et al (2007) permanent and biologically founded genotype x environment interaction can be employed to maximize the efficiency of poultry production in regions providing sub-optimal environments by recognizing and exploiting the genotypes adapted to such environments.

Currently, Rhode Island Red (RIR) is the major chicken breed distributed by both government and commercial poultry companies to farmers in the rural regions and small-scale poultry keepers in urban areas of Ethiopia. Some research institutes and educational organizations are distributing Fayoumi breeds in some parts of the country. Very few on-station and on-farm comparative studies have been conducted on the performance of these two breeds in Ethiopia and there have been no such experiments in southern Ethiopia. There is an on-going cross breeding study of RIR and Fayoumi chickens with indigenous chickens of Ethiopia with an objective of producing chickens that lay more eggs and weigh more than the indigenous chickens. As part of this study, RIR and Fayoumi were tested under improved management system (on-station) and under traditional backyard poultry husbandry system (on-farm). It was assumed that the exotic breeds will perform less than their potential due to the adverse environmental condition but better than the indigenous chickens in the on-farm test. The objectives of this study were to investigate and evaluate the performance of the breeds under different management systems and recommend the most suitable breed for a particular management system. Moreover, results obtained under improved conditions may not be relevant to farmers’ conditions and the genotype x environment interactions of the two exotic breeds under two management systems were therefore studied for egg production, egg quality and growth performance.

Materials and methods

Experimental sites and animals

The on-station experimental site was Awassa College of Agriculture. It is located 275 km south of the Ethiopian capital, Addis Ababa. The on-farm trial was conducted in a village called Boricha, which is 35 km south of Awassa town. The geographical information of the sites is summarized in Table 1.

RIR is a chicken breed of American origin and was developed for laying brown shelled eggs (Anil and Sharma 2004). Fayoumi chickens are small, white-egg laying and originated from Egypt (Tadelle et al.

Table 1 Geographical and meteorological information of Awassa and Boricha area

Site	Altitude (m)	Rain fall (mm)	Temperature (°C)
Awassa	1700	900-1100	10-35
Boricha	1800-1900	1400	18-25

2003a). Local *Sidancho* ecotype is a small chicken with different plumage colour that lays mainly white-shelled eggs and is found in the Sidama zone of southern Ethiopia.

RIR pullets at the age of around 3 months were obtained from a commercial farm. They were vaccinated against Newcastle Disease (NCD) and Gumboro before they were moved to Awassa College of Agriculture (ACA) poultry farm. Fayoumi eggs were purchased from Debre Ziet Agricultural Research Institute and incubated at ACA poultry farm. Fayoumi chicks were older than RIR by 3 days. Fayoumi chicks were vaccinated against NCD at the experiment site, and both breeds were vaccinated against Infectious Laryngotracheitis (ILT) when they were 6 months old.

For the on-farm experiment RIR, Fayoumi and local *Sidancho* ecotype were used. Fayoumi eggs were in this instance also purchased from Debre Zeit Agricultural Research Institute, whereas RIR eggs were obtained from Awassa's Ministry of Agriculture Poultry farm and *Sidancho* ecotype eggs were collected from Boricha village. All eggs from the three genotypes were incubated at ACA poultry farm on the same date. Day-old chicks were then distributed to village farmers together with a hay-box brooder. All chicks were vaccinated against NCD and Gumboro diseases.

Management of experimental animals

On-station

The pullets were randomly allocated to 12 pens in a deep litter house, with 10 pullets in each pen. Sixty RIR pullets were assigned to 6 pens and another sixty Fayoumi pullets were assigned to another 6 pens. The pens were divided by mesh wire and about half of the side walls of poultry house were screened by wire mesh, providing natural ventilation and light. Chickens were fed *ad libitum* with layer feed prepared at the college feed processing unit (Table 2). Drinking water was always available in each pen. All chickens were leg banded with numbers for identification. A trap nest was introduced in each pen when the chickens were about 5 months old. The trap nest closes automatically as the hen enters into the nest and can only be opened by attendants, who checked if the chickens had laid any eggs. The attendants were checking the nest for eggs 3 to 4 times a day. The date of lay and the ID number of the hen that laid the egg were written with a pencil on the egg. This system helps to accurately record individual performance of all chickens.

Table 2 Ingredient and analyzed chemical composition of layer ration used in the on-station trial

Ingredient	%
Maize	39
Wheat bran	22
Noug (*Guiziota abyssinica*) cake	25
Soya bean (roasted)	6
Salt	1
Bole (soil with limestone)	7
Chemical composition (DM basis)	
Crude protein (%)	16.8
ME (MJ/kg)	13.4

On-farm

Assefa (2007) started the on-farm performance evaluation of RIR, Fayoumi and local *Sidancho* ecotype chicks under farmers' management condition. The present on-farm study was the continuation of a previous study. A total of 30 volunteer women farmers were selected based on their experience in poultry keeping and given a one day orientation on the purpose of the study and instructed about how they should manage the chickens. The farmers were randomly divided into 3 groups. A group was given one type of breed with 24 one-day-old unsexed chicks per farmer. Farmers were also provided with a hay box brooder for growing the chicks during the brooding period. The hay box brooders comprise a feeding and exercise compartment and a warm compartment stuffed with hay on the side walls, as recommended by Solomon (1999). At 8 weeks of age, sexing of chicks based on their comb growth was made and the sexed chicks were interchanged among the farmers in such a way that each farmer would keep 4 females from each genotype/breed and 2 male chicks of any breed. Therefore, a farmer was given 12 female and 2 male chicks. The rest of the chicks that remained after redistribution were either culled or sold to other farmers. This arrangement helped each farmer to closely examine the different attributes of the three breeds at a time.

During the brooding period, chicks were given commercial chick feed supplied by the researchers. However, after 8 weeks of age the chicks had to find their own food, and additional whole maize and/or kitchen scraps were given occasionally by the farmers. Water was made available for the chicks all the time, on locally made drinkers. In order to protect the chicks from predators, farmers made day-time enclosures using branches and wire mesh.

At about 5 months of age, chickens in the village were leg banded with coloured plastic band for the purpose of identification to enable farmers to recognize each chicken by breed and the colour of leg band. Records were collected at least twice a week and each egg was labeled by pencil with breed, date and leg band colour of the hen that laid the egg.

Data collection

Body weight and feed consumption

Both in the on-farm and on-station trials, all birds were weighed individually by putting them in a basket using a battery powered digital weighing scale. After they were moved from grower's room to their experimental pens, the weights were recorded every month. In the on-farm trial, the chickens were weighed individually at the age of 8 and 12 months. However, average weight of each genotype was recorded by Assefa (2007) up to 20 weeks of age, and therefore, the body weight at the age of 4 months was obtained from the previous records. Body weight gain (BWG) was calculated as the difference between body weights measured in consecutive measurements/records.

Feed consumption was recorded for each pen and Average Feed Consumption (AFC) per bird was calculated after correcting for mortality at entry into the experiment pens (4 months), 8 months and 12 months of age. Feed efficiency for egg mass (FEEM) was calculated as the amount of feed consumed, in gram, divided by the amount of egg mass output in gram during the same period.

$$AFC = \frac{\textit{Feed consumed by hens in a pen/month}}{\textit{30 days} * \textit{Average number of hens}}$$

$$FEEM = \frac{\textit{Feed consumed by hens in a pen/period}}{\textit{Egg mass produced by hens in a pen/period}}$$

Egg production and quality

Age at first egg laid was recorded in days as the difference between the date of hatch and date of their first egg. Egg production was measured as hen-housed egg production, which is the number of eggs that a hen lays after placement in the laying house. Hens that died subsequent to placement in the laying house, and hens that never laid, were part of the hen-housed population, as much as they contributed to the hen-housed egg production although their records are near or at zero (Fairful and Gowe 2003). Average egg weight in the on-station test was measured for each bird/month, and egg mass of all eggs produced by each bird in a month was also calculated. Actual egg number of the chickens in both management systems was also presented for comparison. Average egg weight for chickens in the on-farm test was measured when eggs were collected for quality testing on the 8th and 12th month of age.

$$HHEP = \frac{\textit{Number of eggs produced by hens housed}}{\textit{Number of hens housed in a pen or individual farmer's house}}$$

The following egg quality traits were recorded: shell thickness in mm, yolk colour using Roche colour fan scale (1 = very pale to 16 = deep orange), albumen height (mm), yolk height (mm), Haugh Unit (HU) and egg shape index. For albumen and yolk height measurements, the eggs were broken out on a flat glass and then the maximum albumen and yolk heights were measured with a tripod micrometer. Individual Haugh Unit was calculated as:

$$\mathrm{HU} = 100\ \log\left(\mathrm{AH} + 7.57 - 1.7\mathrm{EW}^{0.37}\right)$$

Where, AH = observed albumen height in mm and EW = egg weigh in gram

Egg shape index was calculated as:

$$\textit{Egg Shape Index} = \frac{\textit{Width of egg (mm)}}{\textit{Length of egg (mm)}} \times 100$$

Egg shell thickness was measured on the side and at each end of the egg using digital caliper and the average was calculated. The average grading for egg colour made by three different persons by the Roche colour fan was used. Also for the on-farm trial, the same traits were recorded, except feed consumption and feed efficiency for egg mass.

Statistical analysis

All traits measured both in the on-station and on-farm trials were analyzed using Mixed Model procedure of the Statistical Analysis System (SAS) (SAS 2001) using age and breed*system as fixed effects. Individual farmer or pen within management system was taken as random effect as was individual ID number of chickens. The following general model 1 was used for analysis:

$$Y_{ijklmn} = \mu + A_i + B_j * M_k + FP_l(M_k) + ID_m + e_{ijklmn} \quad (1)$$

Where,

- Y_{ijklmn} individual observations of egg production and quality, body weight and growth measured in on-station and on-farm management systems
- μ over all mean
- A_i fixed effect of age *i*, *i*=1-2 (8 and 12 months) for egg quality traits and *i*=1-3 (4, 8, and 12 months) for body weight and (start of lay to 8, start of lay to 12 and 8 to12 months) for egg number and egg weight traits.
- B_j*M_k interaction of fixed effects of breed *j*, and management system *k*, j=1-3 (Fayoumi, RIR and local, where local chickens were tested only on on-farm) and *k*=1-2 (on-farm and on-station)
- FP_l (M_k) random effect of farmer or pen with in a management system, *l*=1-36 (6 pens/breed and 30 farmers)
- ID_m random effect of individual ID number of chickens, *m* = varies from 117 to 359
- e_{ijklmn}, random error related to individual observation *n=2 repeated measurement for egg quality traits and 3* repeated measurements for egg production and body weight measurements

Depending on the type of the trait model 1 was modified to models 2, 3 and 4 given below. Model 2 was used to estimate individual observation of age at first egg and therefore, the effect of age and random effect of individual ID number were removed because it is measured only once. Model 3 was used to estimate hen housed egg production per pen and farmer. Model 4 was used to estimate individual effects of egg mass, feed consumption/bird/day and feed efficiency for egg mass in on-station.

$$Y_{jkln} = \mu + B_j * M_k + FP_l(M_k) + e_{jkln} \quad (2)$$

$$Y_{ijkln} = \mu + A_i + B_j * M_k + FP_l(M_k) + e_{ijkln} \quad (3)$$

$$Y_{ijln} = \mu + A_i + B_j + P_l + e_{ijln} \quad (4)$$

All descriptions of random and fixed effects are similar with model 1 except:

- Y_{jkln} individual observation of age at first egg measured in on-station and on-farm
- Y_{ijkln} individual observation of hen housed egg production per pen and farmer measured both on-station and on-farm
- Y_{ijln} individual observation of egg mass, feed consumption/bird/day, and feed efficiency for egg mass measured in the on-station.
- P_l random effect of pen, *l*=1-6 pens
- e_{jkln} random error related to individual observation *n*=1 observation on age at first egg
- e_{ijkln} random error related to individual observation *n*=3 observation on hen housed egg production
- e_{ijln} random error related to individual observation *n*=3 repeated measurements on average feed consumption/bird/day, egg mass and feed efficiency for egg mass

The general effects of breed and management system were not possible to compare because of the absence of local chicken on-station. The effect of Fayoumi was estimated by taking average of Fayoumi in both management systems and the same is true for RIR. The average for the local chickens comes only from the on-farm trial. The effect of management system was found by taking the average of Fayoumi and RIR within each management system, excluding the local chickens. Least square means of breed and management system for RIR and Fayoumi were obtained by using Estimate statement under mixed model procedure.

Results

Egg production and quality

There were significant effects of age as well as breed * system interaction for all egg production traits for the breeds tested on-station and on-farm (Table 3). Figure 1a shows the average of Fayoumi kept both on-station and on-farm started laying eggs more than a month earlier than the average of RIR chickens. Moreover, on average Fayoumi and RIR chickens kept on-station started laying eggs about 10 days earlier than those kept on-farm (Fig. 2a).

More eggs were laid between 8 to 12 months of age than between start of lay to 8 months of age. Moreover, chickens also laid heavier eggs at 12 months of age than at 8 months of age. Actual egg number was more than hen housed egg production in all age groups except between start of lay to 8 months of age (Table 3). However, the observed means of egg number and hen housed egg production for age between start of lay to 8 months were 20.92 and 6.6 respectively. The average of Fayoumi breed kept in both systems was about twice the number of eggs produced by the average of RIR breeds kept in both systems (Fig. 1b and c). Hen housed egg production and actual egg number were higher for chickens kept on-station than the chickens kept on-farm excluding the local ecotypes. But the egg number and hen housed egg production were unchanged on-station while the hen housed egg production was much lower under on-farm conditions (Fig. 2b and c). Figure 1d shows that RIR chickens laid heavier eggs than Fayoumi chickens. The average egg weight of Fayoumi and RIR chickens kept on-station was heavier than those kept on-farm (Fig. 2d). Local chickens performed more poorly than Fayoumi and RIR chickens in both hen housed egg production and average egg weight.

The effect of age was significant for most egg quality traits and there was significant breed*system interaction for all traits (Table 4). Figure 3a shows that among all the egg quality traits, Fayoumi chickens were higher than RIR only for AEST. Chickens kept in the on-farm trial were higher only for YC compared to those kept in the on-station trial (Fig. 4b).

Body weight and gain

Age had significant effect on both BW and BWG. In general, chickens grew faster between the age of 4 and 8 months but BW declined between 8 and 12 months of age. Significant breed*system interaction

Table 3 Least square means (±s.e.) and variance components of age at first egg (AAFE in days), egg number (EN), hen housed egg production (HHEP) and average egg weight (AEW in g) at different ages of chickens kept both on-station and on-farm

Effects and levels	AAFE	EN	HHEP	AEW
Age		***	***	***
Start of lay–8 months		9.7±1.97	16.8±1.47	45.0±0.48
8-12 months		30.9±1.88	22.4±1.47	
Start of lay -12 months		45.9±1.86	29.3±1.47	47.9±0.53
Breed*system	***	***	***	***
Fayoumi				
On-station	202.0±9.19	61.5±3.29	61.5±3.03	42.6±0.51
On-farm	208.7±5.93	25.1±2.52	12.9±1.39	40.6±0.76
RIR				
On-station	237.4±9.27	29.7±3.34	28.8±3.03	57.8±0.58
On-farm	247.6±7.05	16.7±3.15	6.6±1.46	52.9±1.04
Local				
On-farm	256.3±6.82	11.0±1.03	4.3±1.39	38.7±1.25
Variance components				
Farmer & pen(system)	429.8	48.3	18.9	0.03
ID number		104.6		0.00
Residual	756.7	196.3	107.7	26.4

*** P≤0,001

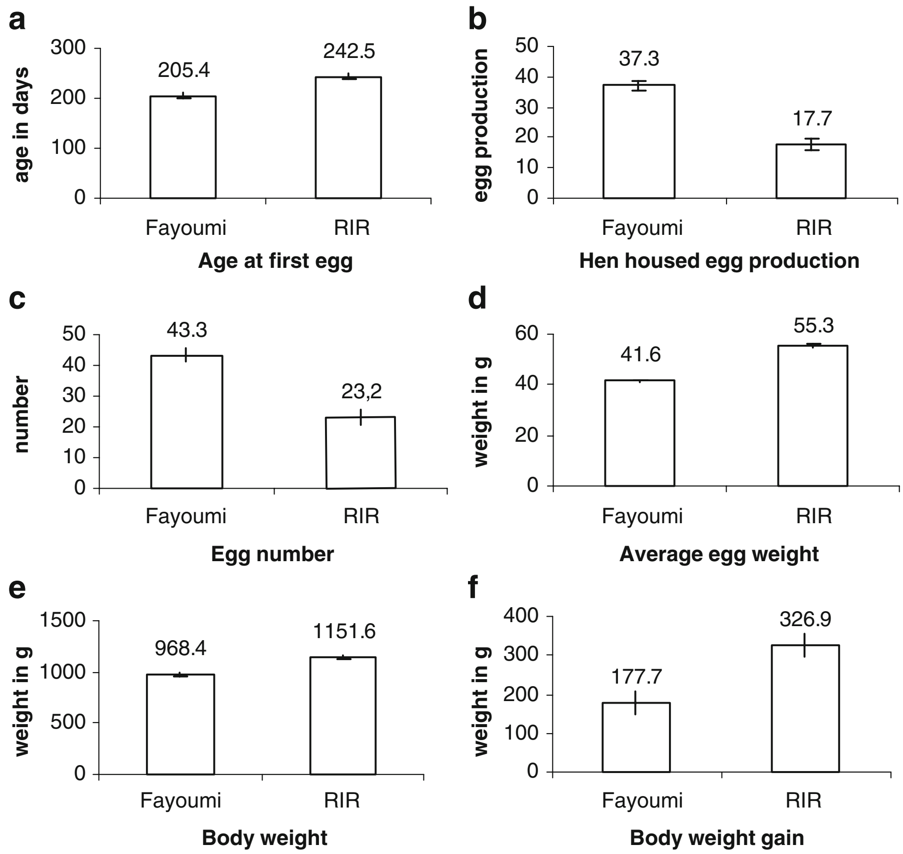


Fig. 1 Average least square means of Fayoumi and RIR kept both on-station and on-farm for egg production and body weight traits

was observed for both BW and BWG (Table 5). In the village farms RIR performed better than Fayoumi and local chickens in both BW and BWG. Fayoumi had higher BW than local chickens, but local chickens had higher BWG than Fayoumi.

As shown in Fig. 1e, the average BW of RIR chickens kept in both systems was higher than Fayoumi chickens. Chickens kept in the on-station were heavier than those kept on-farm excluding local chickens (Fig. 2e).

Feed consumption and feed efficiency

Feed consumption, egg mass and feed efficiency were measured only for chickens kept on-station. There was a significant effect of age and breed on feed consumption and egg mass (Table 6). Chickens consumed more feed as they grew older and EM was higher between 8 to 12 months of age than between 4 to 8 months of age. There was big variation of FEEM due to age and breed difference. Chickens used feed more efficiently between 8 to 12 months of age than 4 to 8 months of age. RIR chickens consumed more feed than Fayoumi and Fayoumi was higher in EM and utilised feed more efficiently.

Discussion

Age at first egg laid was earlier for Fayoumi chickens than RIR chickens, both on-station and on-farm. Local chickens started laying eggs a few days later than RIR chickens. This is comparable to what Negussie (1999) found in his study of on-station performance of Fayoumi and RIR in Ethiopia, where he reported that Fayoumi breed attained sexual maturity about four weeks earlier than RIR. Similar or lower age at first egg have been reported for RIR and Fayoumi chickens kept under different management systems in Egypt and Bangladesh (Mohamed 1997; Yeasmin et al. 2003; Zaman et al. 2004). Age at first egg for different Ethiopian chicken ecotypes was reported varying from 173 to 230 days under on-station and on-farm conditions (Teketel 1986; Tadelle

Fig. 2 Least square means of on-station and on-farm containing the average of Fayoumi and RIR for egg production and body weight traits

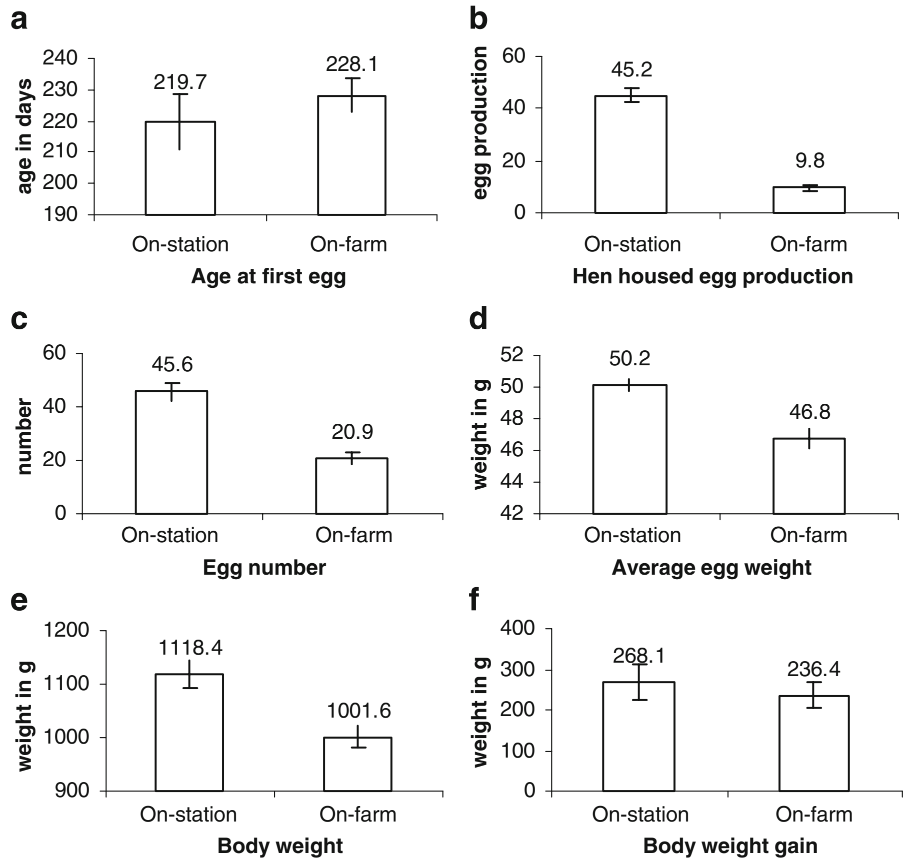


Table 4 Least square means (±s.e.) and variance components of egg quality traits of chickens kept on-station and on-farm

Effects and levels	AEST	YC	YH	AH	EL	EW	ESI	HU
Age	ns	*	***	ns	ns	**	**	*
8	0.30±0.004	6.16±0.16	16.32±0.12	6.21±0.17	52.70±0.32	39.41±0.20	74.92±0.39	81.66±1.08
12	0.29±0.005	5.82±0.17	15.78±0.13	6.0±0.19	52.56±0.34	40.06±0.22	76.38±0.42	78.62±1.17
Breed*system	***	***	***	***	***	***	**	***
Fayoumi								
On-station	0.33±0.005	4.88±0.25	16.58±0.12	5.37±0.21	50.22±0.51	38.57±0.31	76.88±0.48	77.76±1.4
On-farm	0.31±0.006	6.62±0.23	15.15±0.19	4.79±0.27	50.53±0.45	37.47±0.29	74.43±0.63	74.53±1.69
RIR								
On-station	0.29±0.006	4.61±0.26	18.23±0.14	9.7±0.23	56.59±0.53	43.24±0.32	76.57±0.53	97.72±1.5
On-farm	0.27±0.009	6.91±0.29	15.43±0.26	6.17±0.36	54.57±0.59	41.91±0.39	76.85±0.85	78.24±2.24
Local								
On-farm	0.29±0.01	6.91±0.34	14.88±0.29	4.49±0.41	51.24±0.66	37.47±0.45	73.52±1.01	72.45±2.52
Variance components								
Farmer & pen(system)	0.00008	0.3	0.007	0.12	1.26	0.41	0.47	6.34
ID number	0.00009	0.007	0.07	0.00	0.17	0.34	3.04	0.00
Residual	0.001	1.2	1.36	2.62	4.94	2.15	11.39	94.14

***P≤0,001, **P≤0,01, * P≤0,05, [ns] not significant, [AEST] average egg shell thickness, [YC] yolk colour, [YH] yolk height, [AH] albumen height, [EL] egg length, [EW] egg width, [ESI] egg shape index, [HU] Haugh unit

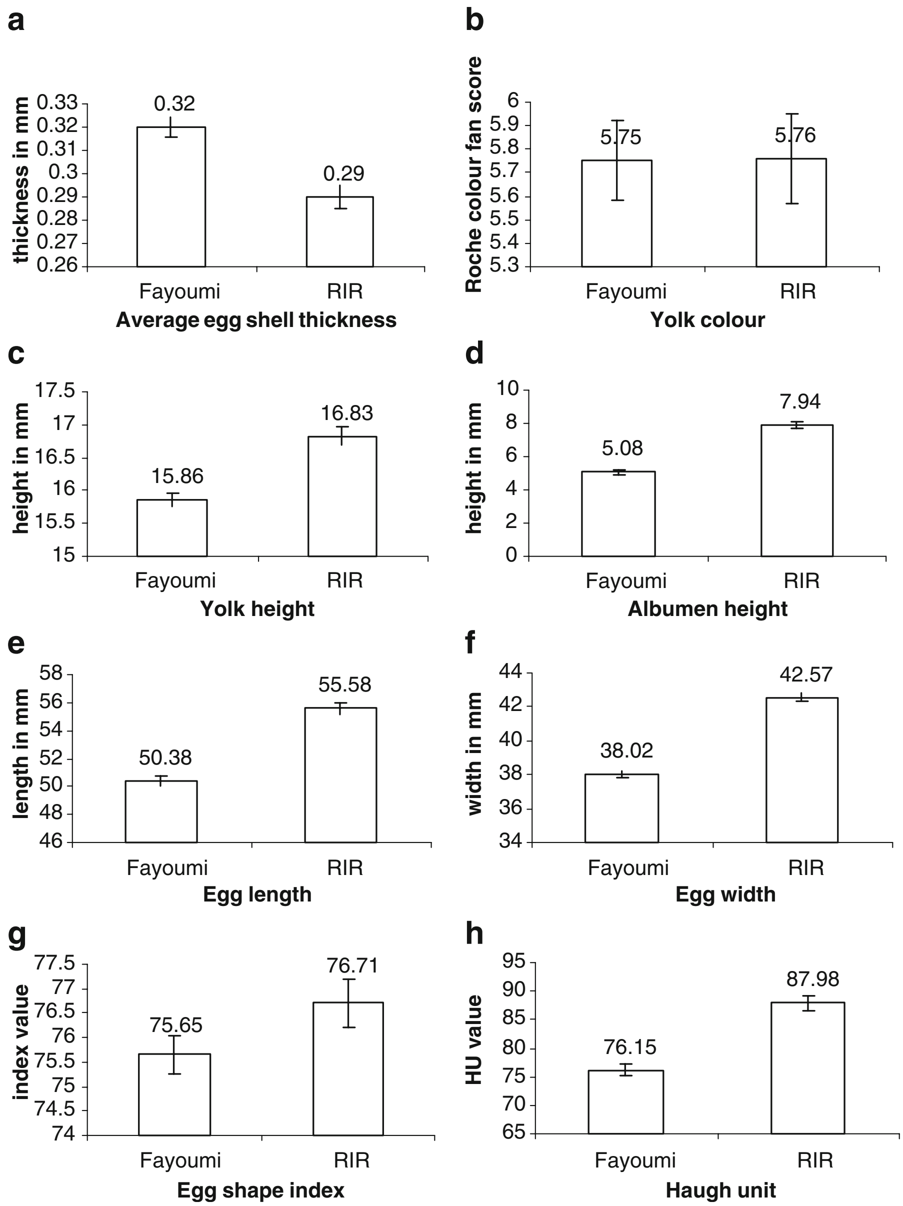
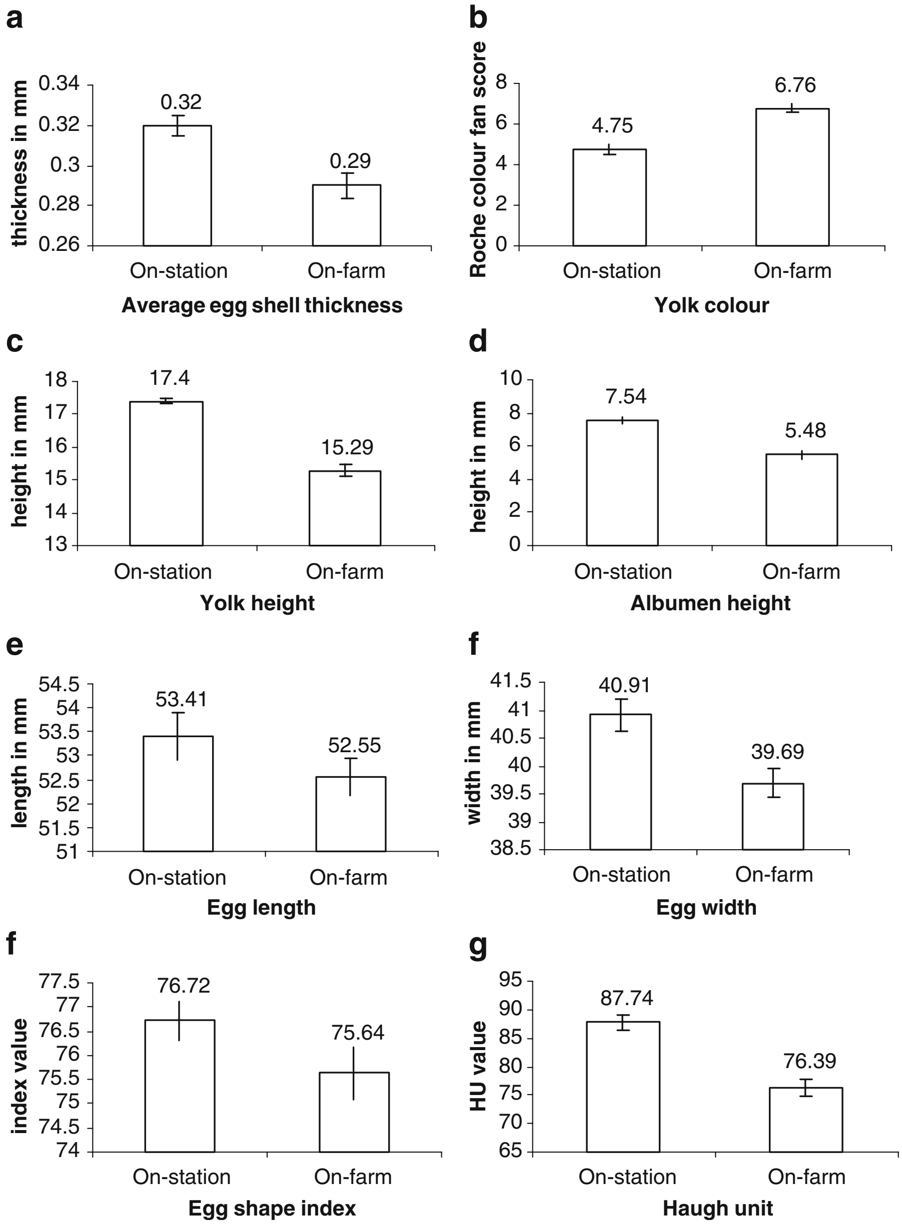


Fig. 3 Average least square means of Fayoumi and RIR kept both on-station and on-farm for egg quality traits

et al. 2003b). Variations in sexual maturity of the same breed are possible since this trait is affected by several factors such as feeding regime, intensity and duration of light, temperature etc (Negussie 1999; Zaman et al. 2004). The higher age at first egg in the on-farm condition is thus not unexpected considering the management system that the chickens were subjected to.

Fayoumi chickens were higher in HHEP than RIR both on-station and on-farm. Local *sidancho* ecotype performed lower than both Fayoumi and RIR on-farm. The actual egg number produced per bird was presented and it shows that Fayoumi was higher than RIR then followed by local chickens. This was not in agreement with results reported by Akhtar et al. (2007) where RIR was higher in egg number than Fayoumi. As the layer feed used in the on-station trial had no significant deficiency in protein and energy (Table 2), poor feed quality might not be the reason for lower egg production of RIR chickens. However, there was an outbreak of Fowl Pox during the period of 8 to 12 months of age and the disease significantly

Fig. 4 Least square means of on-station and on-farm containing the average of Fayoumi and RIR for egg quality traits



reduced egg production in both breeds. Fayoumi recovered from the disease more quickly than RIR chickens and the mortality in RIR chickens in the on-station was associated with this disease. Moreover, recording of egg production stopped while the chickens were still laying eggs and it could be argued that had the recording continued for more time RIR would have produced higher egg number than Fayoumi. For on-farm trial Fayoumi was better than RIR because Fayoumi is a tropical breed and can adapt to the on-farm environment better than RIR chickens. Although the observed mean egg number was higher than hen housed egg production, the least square mean from mixed model equation gave opposite result (Table 3). A possible reason for the discrepancy between observed mean and least square mean might have been happened due to the unbalanced population as well as the large variation in egg numbers, which ranged from 0 to more than 50 eggs. This was because chickens, especially in the on-farm trial, started laying eggs very late and there were many chickens that did not produce eggs between the

Table 5 Least square means (±s.e.) and variance components of body weight (BW in g) and body weight gain (BWG in g) of chickens kept on-station and on-farm

Effects and levels	BW		BWG
Age	***	Age	***
4 months	766.7±16.26	4-8 months	378.1±26.48
8 months	1,148.5±16.4	8-12 months	-0.9±27.65
12 months	1,139.2±17.23	4-12 months	359.8±27.43
Breed*system	***		***
Fayoumi			
On-station	1,001.9±26.22		216.2±47.5
On-farm	934.9±24.96		139.2±36.69
RIR			
On-station	1,234.8±26.27		319.9±47.58
On-farm	1,068.3±25.42		333.7±38.79
Local			
On-farm	850.8±25.58		219.3±36.59
Variance components			
Farmer & pen(system)	29,74.3		119,333.0
ID number	4,271.3		5481.5
Residual	21,595.0		31,299.0

*** P≤0,001

period of start of lay to 8 months of age. According to SAS (1999) user's guide least square means are predicted population margins-that is, they estimate the marginal means over a balanced population. When the data is balanced and has small variation, the value of mean and least square mean agree; but large differences could be observed when the data is unbalanced and when there is big variation between the measurements. The actual egg number and hen housed egg production on-station did not change because there was little mortality (Table 7) but hen housed egg production in the on-farm reduced very much because of high mortality and less egg production due to sub-optimum management condition. This is in agreement with Fairful and Gowe (2003) who explained that hen housed egg production is affected by age at first egg, rate of egg production from the start of egg production, and viability

Table 6 Least square means (± s.e.) and variance components of average feed consumption/bird/day (AFC/b/d in g),egg mass per pen (EM/pen in g) and feed efficiency for egg mass per pen(FEEM/pen in g) of chickens kept on-station

Effects and levels	AFC/b/d		EM/pen	FEEM/pen
Age	***	Age	***	ns
4 months	105.6±1.42	4-8 months	8,805.2±1,380.5	40.3±16.49
8 months	120.5±1.42	8-12 months	23,351.0±1,380.55	7.5±16.49
12 months	153.4±1.42	4-12 months	32,147.0±1,380.55	9.2±16.49
Breed	*		***	ns
Fayoumi	124.7±1.18		25,959.0±1,268.42	7.3±13.57
RIR	128.3±1.18		16,917.0±1,268.42	30.7±13.57
Variance components				
Pen number	0.6		6,088,961.0	52.2
Residual	22.3		10,692,932.0	3,157.0

***P≤0,001, *P≤0,05, ^{ns} not significant

Table 7 Number of chickens available at entry (4 months old) and end of experiment (12 months) in the two locations

Location		RIR	Fayoumi	Local
On-station	4 month	60	60	-
	12 month	57	60	-
	Loss (%)	5%	0	-
On-farm	4 month	66	79	97
	12 month	19	11	23
	Loss (%)	29%	14%	24%

including morbidity or any other factor causing production to cease. Furthermore, chickens kept under on-station condition produced higher number of eggs than those kept in the village farms. This was consistent with Dana and Ogle (2002) who reported that scavenging reduced egg production by both RIR and Fayoumi breeds in Ethiopia. Both RIR and Fayoumi chickens are known for their higher egg production in their own environments. However, as expected when they are kept in a different environment such as in village farms in the current study, they showed decreased egg production, which indicates existence of genotype by environment interaction.

The eggs of RIR chickens were heavier than the eggs of Fayoumi, which is consistent with many previous studies (Mohamed 1997; Negussie 1999; Monira et al. 2003; Yeasmin et al. 2003; Akhtar et al. 2007). The present study shows that eggs from RIR chickens were better in all the egg quality traits, except shell thickness. Chickens kept on-station were better in all egg quality traits except YC, which is consistent with previous studies (Zaman et al. 2004; Negussie 1999; Monira et al. 2003). Eggs from RIR chickens were higher than Fayoumi in weight and height related egg quality traits due to the fact that the size of RIR egg was much larger than that of Fayoumi. Table 8 shows correlations among different egg quality traits. Traits like AH, YH, EL, EW and HU were medium to highly correlated to AEW and most of these traits were also highly correlated with each other. All these characteristics gave eggs from RIR higher in most of egg quality traits.

The higher YC score in the on-farm trial could be due to better access of village chickens to green forages than those kept on-station, and there were larger differences in YC between on-station and on-farm as compared to smaller differences in YC among eggs from the three breeds that were kept on-farm. AH, YH and HU were higher in eggs from on-station than on-farm, which may be because of longer holding period of eggs at the farms before the

Table 8 Correlations with *p* in bracket of egg quality traits

	AEST	YC	AEW	AH	YH	EL	EW	ESI	HU
AEST	1	-0.16 (0.01)	-0.20 (0.001)	-0.26 (<.0001)	-0.005 (0.94)	-0.28 (<.0001)	-0.16 (0.01)	0.15 (0.02)	-0.23 (0.0002)
YC	-0.16 (0.01)	1	-0.20 (0.001)	-0.18 (0.004)	-0.23 (0.0002)	-0.11 (0.09)	-0.22 (0.0007)	-0.14 (0.03)	-0.17 (0.006)
AEW	-0.20306 (0.001)	-0.2 (0.001)	1	0.66 (<.0001)	0.54 (<.0001)	0.79 (<.0001)	0.88 (<.0001)	0.15 (0.02)	0.52 (<.0001)
AH	-0.26 (<.0001)	-0.18 (0.004)	0.66 (<.0001)	1	0.69 (<.0001)	0.55 (<.0001)	0.63 (<.0001)	0.12 (0.06)	0.96 (<.0001)
YH	-0.005 (0.94)	-0.23 (0.0002)	0.54 (<.0001)	0.69 (<.0001)	1	0.42 (<.0001)	0.5 (<.0001)	0.12 (0.07)	0.67 (<.0001)
EL	-0.28 (<.0001)	0.11 (0.09)	0.79 (<.0001)	0.55 (<.0001)	0.42 (<.0001)	1	0.74 (<.0001)	-0.3 (<.0001)	0.44 (<.0001)
Ewd	-0.16 (0.0126)	-0.22 (0.0007)	0.88 (<.0001)	0.63 (<.0001)	0.50 (<.0001)	0.74 (<.0001)	1	0.4 (<.0001)	0.5 (<.0001)
ESI	0.15 (0.02)	-0.14 (0.03)	0.15 (0.02)	0.12 (0.06)	0.12 (0.07)	-0.3 (<.0001)	0.4 (<.0001)	1	0.09 (0.19)
HU	-0.23 (0.0002)	-0.17 (0.006)	0.52 (<.0001)	0.96 (<.0001)	0.67 (<.0001)	0.44 (<.0001)	0.5 (<.0001)	0.09 (0.19)	1

AEST average egg shell thickness, YC yolk colour, AEW average egg weight, YH yolk height, AH albumen height, EL egg length, EW egg width, ESI egg shape index, HU Haugh unit analysis. Eggs from the on-station trial were analyzed the next day after they were collected. This is in agreement with Monira et al. (2003) who reported a decrease in AH and HU as the holding period increases. Moreover, these traits are positively correlated with egg weight (Table 8) and egg weight on-station was higher than in the on-farm trial.

As expected, both Fayoumi and RIR chickens kept on-station gained more BW than those kept on-farm. This could be due to the fact that chickens kept in the on-farm condition spent most of their time looking for their feed which results in loosing energy that could otherwise be used for weight gain as well as egg production. RIR chickens were much heavier than the other two breeds and were expected to gain more body weight than the other two. However, although local chickens were lighter than Fayoumi, they achieved better body weight gain, possibly due to their ability to adapt to the local environment as well as better utilization of the available feed.

FEEM was found to be not significant, while there was a large variation due to age and breed difference (Table 6). The non-significance could be due to the larger standard error which could occur from wide variation of egg production among the chickens in different pens. Fayoumi were found to have had higher EM than RIR, possibly due to the fact that they had laid more eggs and started laying earlier than RIR. As a result Fayoumi was efficient in feed utilization owing to their lower consumption of feed but heavier egg mass. This was consistent with Dana and Ogle (2002) who reported Fayoumi was better in feed conversion than RIR. The higher FFEM/pen between 4 to 8 months could be due to lower egg production during this period.

In all traits measured in the on-station and on-farm trials significant breed * system interaction was observed, which indicates that there was significant genotype X environment interaction. A breed which performed better in one system may not perform better in another system in the same magnitude. In general, the chickens that were kept on-station performed better in most of the traits than those kept on-farm. Performance of RIR and Fayoumi breeds in the village farms could be improved by reducing mortality and improving management conditions such as better housing to protect the birds from predators and supplementation of chickens with cereals and other household food scraps. Fayoumi chickens were better both in the on-station and on-farm trials in egg production. They also survived better in both management systems indicating that they are sturdier chicken breed than the other two breeds. RIR chickens were better in body weight and growth parameters. Local chickens showed their ability to achieve better body weight gain in the village. The use of RIR and Fayoumi chickens as parents to cross with local chickens may improve egg and meat production in the village poultry production and is an area of further investigation.

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Paper II

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Production Performance of Dual Purpose Crosses of Two Indigenous with Two Exotic Chicken Breeds in Sub-tropical Environment

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Abstract: An ongoing crossbreeding experiment is being conducted with the objective of producing dual purpose synthetic chicken for village poultry production in Ethiopia. The two exotic chicken breeds used were the Fayoumi (F) and Rhode Island Red (R) as dam line, whereas the two indigenous chicken breeds used were the Naked neck (N) and local Netch (W); a white feathered chicken. The indigenous breeds were used as sire line to produce the hybrids FN (F♀ X N♂) and RW (R♀ X W♂). Growth and egg production performance of the crosses were compared with each other and with the exotic pure line performance. Both body and egg weight of FN was improved while body weight of RW was reduced and age at first egg was significantly reduced, compared to their respective dam line. Egg production for the crosses was lower than for their maternal lines. Although FN cross chicks weighed more and grew faster than RW chicks during the brooding period, the difference became insignificant as they grew older. However, the higher overall average body weight gain of RW crosses that was observed was mainly due to higher weight gain for the RW cocks. No significant differences were observed in overall egg production and quality traits between the two crosses, but significant age effect within crosses was found. Mortality in the FN cross was lower than in the RW cross. These F1 crosses will be used as parents to produce a 4-way synthetic crossbred chicken.

Key words: Two-way crossing, egg production, egg quality, body weight

INTRODUCTION

It has been reported by researchers that the main problem of indigenous chickens in the tropics is that they are poor producer of egg and meat (Alemu, 1995; Gueye, 1998; Tadelle *et al*., 2000). But even if they show low productivity, they are well adapted to the tropics, resistant to poor management, feed shortages and tolerate some of the most common diseases and parasites. On the other hand, improved exotic chickens produce higher number of eggs and more meat than the indigenous chicken breeds, but tropical climate is a great challenge. They are not adapted to adverse environmental conditions, such as high temperature, disease and shortage of feed (Barua *et al*., 1998; Ali *et al*., 2000; Islam and Nishibori, 2009).

However, the genetic diversity of indigenous and exotic chicken breeds could be utilized by cross breeding schemes. The goal will then be to get a new breed or hybrid that is resistant to harsh tropical conditions and at the same time produces a reasonable amount of egg and meat (Barua *et al*., 1998; Iraqi *et al*., 2005; Mekki *et al*., 2005). Breeding programs for local chicken breeds are difficult to set-up because of the competition with commercial breeding companies, which often have access to expensive technology and also benefit on economics of scale (Saady *et al*., 2008).

Studies in Bangladesh indicated that the egg production at smallholder level could be doubled in the existing production system through intervention of crossbreeding in a semi-scavenging poultry model (Rahman *et al*., 2004). Moreover, in an evaluation of the egg production performance of crossbreeds between local and exotic birds, conducted by different research and development organizations in Ethiopia, it was showed that the overall performance of the crosses was better than either of the native or exotic parents under the prevailing production condition (Alemu 1995; Tadelle *et al*., 1999).

There are indigenous chicken breeds in tropical environment with special genetic attributes that have potential use in improvement of local chicken productivity. Among those chicken breeds, the Angete-Melata (naked neck) strain is well known for better performance. Teketel (1986) reported that the Angete-Melata strain had significantly larger body weight, higher egg production associated with heavier eggs and higher egg mass output. Several researchers have investigated how the naked neck gene is associated with high egg and meat production. The autosomal incomplete

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dominant naked neck (Na) gene is not only responsible for defeathering the neck region, but also restricts the feathering areas around the body by 20-30% in heterozygous (Nana) and up to 40% in the homozygous (NaNa) genotype. The Na gene and its effect on heat dissipation positively affect appetite. i.e. increased feed intake, resulting in higher body weight, egg size and liveability under high temperatures (Islam and Nishibori, 2009). In a review by Merat (1990) it is stated that the most likely use of the naked neck gene is at high mean ambient temperatures, i.e. 25°C and above, where it may lead to higher growth rate, slaughter yield, meat yield, and resistance to acute heat stress. In addition El-Safty (2006) concluded that incorporating Na gene in a breed increases the egg weight, egg number, egg mass and shell strength.

In this study indigenous Naked Neck and the white feathered (Netch) cocks were used. They are prevalent in the experiment area and assumed to be highly adapted to the environment. Body weight of Netch strain is comparable or even better than other indigenous strains of Ethiopia except the Naked neck (Teketel, 1986). Between the exotic lines used in this experiment, Fayoumi is an Egyptian breed developed for egg production and known to be adapted to tropical environment (Barua *et al*., 1998) and RIR is an exotic breed characterized by high productivity and hardiness (Gueye, 1998).

The work presented here is part of an on-going project to produce a synthetic chicken population by using 4-way cross breeding scheme. The objective of the present study is to evaluate the performance of the F1 crosses with each other and their maternal parents. The crosses will also be used as parents for the final synthetic chicken population.

MATERIALS AND METHODS

Experimental site: The cross breeding of chicken breeds was conducted at Awassa College of Agriculture (Hawasa University). The site is located at latitude 7°3 N, longitude 38°28 E; 275 km south of the Ethiopian capital, Addis Ababa. The elevation is, 1700 m.a.s.l; and the area receives annual rain fall of 900-1100 mm with temperatures ranging from 10-35°C.

Development of the F1-crosses: Two exotic chicken breeds, Fayoumi (F) and Rhode Island Red (R), were used as female lines and crossed with two local chicken breeds, Naked neck (N) and Local *Netch* (W), as male line, with the objective of producing two F1 crossbreds that later would become parents for a four way final crossbred. Fayoumi hens were mated to Naked neck cocks to produce FN crosses and Rhode Island Red hens were mated to local *Netch* cock to produce RW crosses. The mating of heavier Rhode Island Red also called as RIR to the lighter local *Netch* and the heavier local naked neck to lighter Fayoumi chickens would help to increase body weight of the offspring from a lighter breed and at the same time improve egg production by the local breed.

The source and growth of pure bred Fayoumi and RIR chickens was described by Fassill *et al*. (2009). Naked neck and local *Netch* cocks were purchased from local markets in Awassa, Arba Minch and other surrounding towns and villages. Adult average body weight of Naked Neck and *Netch* cocks used for crossing was 1890 and 1400 g, respectively. For each mating, 50 hens and 25 cocks were used, i.e. each cock was mated with two hens. All chickens were leg-banded with number for identification and individual records were collected. One hen and one cock were placed into a pen and kept there until mating had taken place. The first hen was then taken out and replaced with the second hen. Every hen was mated 3 times a week to ensure better fertilization. The mating was conducted in two rounds. Each cock was mated to two hens in the first round and the same cock was then mated to another two hens in the second round, i.e. the hens mated to a cock in the first round would be mated to another cock in the second round. There was a pause of 4 weeks between the consecutive crossings to clear any live sperm cell from the previous mating.

Management of experiment animals: Trap nests were provided in pens of both the two parent lines and the two F1 crosses and individual egg recordings could thus be performed. The date of each lay and ID number of the hen that laid the egg were written on all eggs. Eggs from the parents were collected from the pens and stored in ventilated room until they were incubated. Because of the small number of eggs collected per day from the few parent hens, the eggs were incubated in 6 different batches. All eggs were weighed individually at setting. At the 18th day of incubation the eggs were candled and eggs with live embryo transferred to the hatchery. The trays in the hatchery were modified by fitting 6 cm x 6 cm cells made of plywood and individual eggs were placed in each cell. Each cell was identified with the same information that was written on the egg shell. The tray was also covered with a wooden frame with mesh wire to avoid mix-up of chicks at hatching and during tagging. Each chick was individually tagged with a unique number, weighed individually and transferred to the brooding houses. Chicks from the same batch with different dams and sires but of the same line-cross were placed in the same pen within the brooding house, and they were also moved as one unit to one pen in the layer house when they were 4 months old.

The layer house was a deep litter house with pens divided by wire mesh. Only 6 pens for the 6 different batches of chickens were used. Part of the walls of the house was made of strong wire mesh window for natural ventilation. The ceiling was corrugated iron sheet approximately 3.5 meter above the floor.

Table 1: Ingredient and analyzed chemical composition of chick and layer rations used in the trial

Ingredient	Chick ration	Layer ration
Maize	32%	39%
Wheat bran	29%	22%
Noug (*Guiziota abyssinica*) cake	19%	25%
Soya bean (roasted)	18%	6%
Salt	1%	1%
Bole (soil with limestone)	1%	7%
Chemical composition (DM basis)		
Crude protein (%)	17.4	16.8
ME (MJ/kg)	13.2	13.4

Feed for both the chicks and the grown chicken was prepared at the college feed processing unit. Type and amount of ingredients used for chick and layer ration, analyzed Crude Protein (CP) and Metabolizable Energy (ME) are presented in Table 1. Feeder and waterer were placed in each pen and feeding was ad libitum. Clean drinking water was always available for the chickens, and all chicks were vaccinated against Newcastle Disease (NCD).

Parallel on-farm experiment was started with 200 chicks distributed to 10 women farmers in a village called Boricha. However, due the prevailing draught in the area, the chickens were either deceased or consumed by the farmers before data collection was completed.

Traits recorded

Hatching weight and growth: Hatching weight of each chick was recorded. Individual body weight of the chicks was recorded every week until they were 8 weeks old and every 30 days after the 8th week. Body Weight Gain (BWG) was calculated as the difference between weights measured in consecutive measurements.

Mortality: Mortality of chickens was calculated when a particular chicken was missing at one of the regular weighing days, i.e. every week up to 8 weeks of age and every 30 day then after.

Egg production and quality: Age at First Egg laid (AAFE) was recorded as number of days between date of hatching and date of their first egg. Thereafter total Egg Number (EN) produced per chicken and Hen-housed Egg Production (HHEP) were recorded, the latter being the number of eggs that a hen lays after placement in the laying house (Fairful and Gowe, 1990). HHEP was calculated as the number of egg produced in a period divided by the number of hen originally housed in a pen. The time of placement of the chickens in the layer house was at 4 month of age and egg production was then recorded up until they were 12 months of age. Mortality of chickens was recorded at all recording times. Percent Hen-Day Egg Production (HDEP) was also calculated as the number of eggs produced by the number of chickens alive on a particular period. All eggs laid by chickens were weighed every week and Average Egg Weight (AEW) and Egg Mass (EM) per bird were calculated every 30 days.

The following egg quality parameters were recorded: Average Egg Shell Thickness (AEST) in mm, Yolk Colour (YC) using Roche colour fan scale (1 = very pale to 16 = deep orange), Albumen Height (AH) in mm, Yolk Height (YH) in mm, Haugh Unit (HU) and Egg Shape Index (ESI). For the albumen and yolk height measurements, the eggs were broken out on a flat glass and then the maximum albumen and yolk heights were measured with a tripod micrometer. Individual Haugh Unit was calculated using formula cited by Tulin and Ahmet (2009):

$$HU = 100 \log (AH + 7.57 - 1.7EW^{0.37})$$

Where, AH = observed albumen height in mm and EW = egg weight in grams.

ESI was calculated as:

$$\text{Egg shape index} = \frac{\text{Width of egg (nm)}}{\text{Length of egg (nm)}} \times 100$$

Egg shell thickness was measured on the side and at each end of the egg using digital calliper and then the average of the three sites was calculated. The average grading for egg colour was made on the basis of three different persons' grading using a Roche colour fan.

Statistical analysis: The data were analysed using Mixed Model procedure of the Statistical Analysis System (SAS) (SAS, 2002-2003). The data from the parents (Fayoumi and RIR females) and F1 (FN and RW) crosses were analysed separately using different models because the experiments were done at different times but under the same management condition and the parents were hatched in a single batch whereas the F1 individuals were hatched in several batches, which had significant effect on most traits. Moreover, the body weight of F1 crosses was measured on both sexes while only female body weight was measured on parent chickens. The genotype (strain) was used as fixed effect in parent chicken models and batch was added as fixed effect in the F1 crosses. In both parents and the F1 crosses, ID number of each chicken and the pen number, in which groups of chickens were housed, were used as random effect when there were repeated observations per animal or per pen. Although group of chicks were distributed to farmers for on-farm testing, the experiment under on-farm condition failed and genotype X environment interaction could thus not be estimated.

Table 2 shows the different models used to analyze the different traits. The models were modifications of a single model depending on the type of trait to be analysed. All models include the general mean (μ) and random error.

Table 2: The different models used during analysis with levels of main effects in bracket and 'X' where there is interactions between the effects

			Fixed effects				Random effects		Interactions		
	Model No.	Traits	Ai[1] (Age)	Gj (Genotype)	Bk (Batch)	Sl (Sex)	Pm (Pen)	IDn (ID number)	Ai (Gj)	Sl (Gj)	Sl*Ai (Gj)
Parent	1	Egg production, egg quality, body weight		(F, R)			(1-6)	(1-120) hens	X		
	2	Age at first egg		(F, R)			(1-6)				
	3	HHEP		(F, R)			(1-6)		X		
F1 crosses	1	Egg production and egg quality		(FN, RW)	(1-6)		(1-7)	(1-82) chickens	X		
	2	Body weight of chicks and grown chickens		(FN, RW)	(1-6)	(m,f)		(1-166) chickens			X
	3	Age at first egg		(FN, RW)	(1-6)		(1-7)				
	4	Hatching weight		(FN, RW)	(1-6)			(1-166) chickens		X	
	5	HHEP		(FN, RW)			(1-7)		X		

F = Fayoumi, R = RIR, FN = Cross of Fayoumi and Naked neck, RW = Cross of RIR and local *netch*, m = male, f = female

[1]Age of chickens was not used as a main effect in the models but as interaction with G and S. The age varies from 2 to 3 groups for both parents and F1 crosses depending on the type of trait to be analysed.

1. (1-2) for egg number i.e. start of lay to 8 months and from 8 to 12 months
2. (1-2) for egg quality i.e. at 8 months and 12 months
3. (1-3) for body weight i.e. at 4, 8 and 12 months
4. (1-2) for body weight gain i.e. from 4 to 8 months and from 8 to 12 months
5. (1-3) for chick body weight i.e. at weeks 1, 4 and 8
6. (1-2) for chick body weight gain i.e. from hatching to 4 weeks and from 4 weeks to 8 weeks

RESULTS

The results of the two separate experiments with the parent lines and the F1 crosses is used for comparison. The experiments were made under the same management conditions but at different times. In the parent lines only the exotic female parents were tested which was not enough to estimate heterosis.

Hatching weight and chick body weight: Significant difference was observed between hatching weights of the two crosses and between male and female (Table 3). Hatching weight of RW crosses was found to be higher than for FN crosses, whereas chick body weight and body weight gain were significantly higher for FN crosses than for RW crosses (Table 3). Figure 1 shows the body weight and weight gain of the two crosses at different ages. The standard errors in Fig. 1a varies from ±12.6 g for FN male at week 1 to ±4.8 g for FN female at week 4.

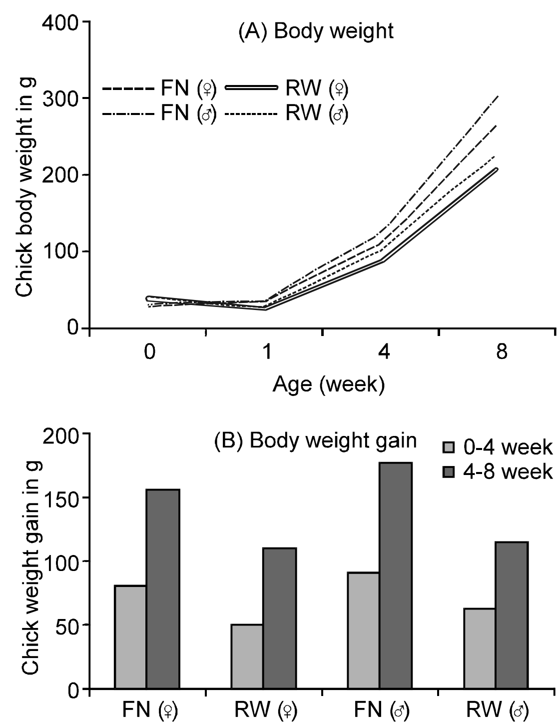

Fig. 1: Chick body weight and gain of the two F1 crosses at different ages

Grown chicken body weight and gain: Average body weight after 8 weeks was not significantly different between the two crosses. But still body weight gain was significantly higher in the RW crosses than in the FN crosses (Table 3). Males weighed more and gained higher weight than females (Fig. 2). At 4 months of age, the FN crosses of both sexes weighed more than the RW crosses, but after 8 months of age, the difference between females of the two crosses became small but the males were much heavier than the females (Fig. 2A). The standard errors for body weight in Fig. 2A varies from ±17.4 for FN female at 4 months of age to ±46.4 for RW male at 12 months of age. The pure breed Fayoumi parent females were lighter than the two crosses and RIR were heavier than all genotypes (crosses). Body weight gain for the F1 crosses was higher than for the

Table 3: Least square means (±s.e.) of F1 Hatching Weight (HW), Chick Body Weight (CBW) and Chick Body Weight Gain (CBWG), grown Chicken Body Weight (BW) and chicken Body Weight Gain (BWG) of the two crossings

Effects and level	HW	CBW	CBWG	BW	BWG
Genotype	***	***	***	NS	**
FN	28.8±0.3	144.9±2.9	126.5±3.3	1110.7±12.4	327.8±13.1
RW	39.2±0.6	112.2±5.2	85.2±5.9	1095.9±22.7	405±24.6
Sex	**	*	NS	***	***
Male	35.0±0.5	135.3±4.8	112.0±5.6	1272.2±20.5	484.9±21.6
Female	33.1±0.4	121.8±3.4	99.7±3.9	934.3±15.5	247.9±17.3
Sex Age (Genotype)		***	***	***	***
Sex (Genotype)	*				
Variance component					
IdNo		290.0	148.9	8426.4	0
Residual	9.0	1568.8	1876.7	14934	26955

*** = p≤0.001, ** = p≤0.01, * = p≤0.05, NS = Not Significant

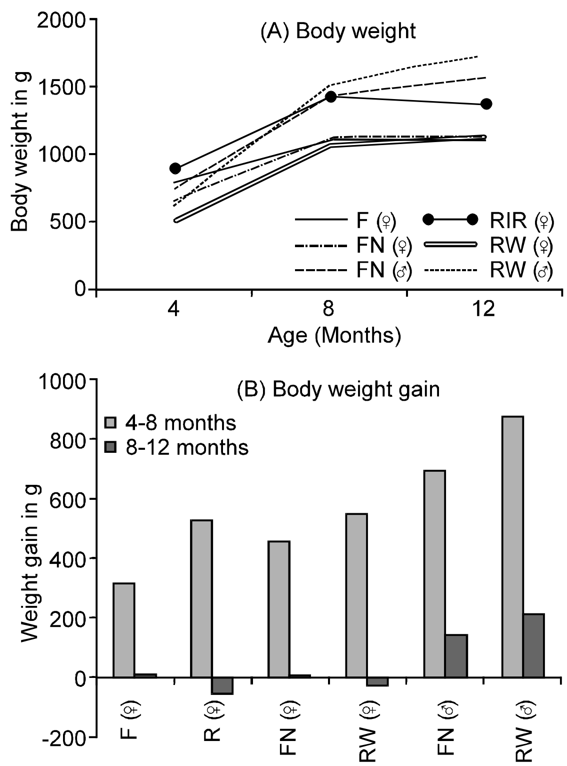

Fig. 2: Body weight and gain of adult parent breeds and their F1 crosses at different ages

purebred parents (Table 3 and 7). Body weight gain between 4-8 months of age was much higher than between 8-12 months of age for all genotypes (Fig. 2B).

Egg production and quality: Table 4 and 7 show egg production traits of the F1 crosses and their parents. Age at first egg laid was not significantly different between the two F1 crosses, but lower than for the parent breeds. There was also no significant difference in the overall average for egg number, egg weight and egg mass between the F1 crosses, but the FN cross was significantly higher in HHEP than RW due to low mortality in the FN cross. In the parental generation

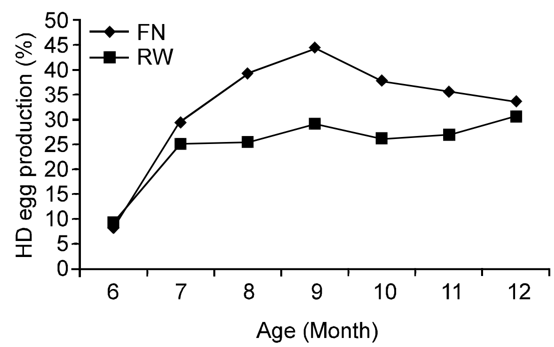

Fig. 3: Percent hen day egg production from 6 to 12 months of age for the two crossings

Fayoumi laid more eggs with higher HHEP and egg mass but RIR laid heavier egg. Significant difference in age with genotype interaction was observed for EN and HHEP in the F1 crosses. Percent hen-day egg production for the F1 crosses is presented in Fig. 3.
There was no significant difference between the two F1 crosses in any main effects of the egg quality traits measured, but significant interaction between age and crosses were observed for some of these egg quality traits (Table 5). Significant difference in egg quality traits was observed in the Fayoumi and RIR parents test, except for yolk colour and egg shape index (Table 6).

Mortality: Table 8 shows that there is little difference in percent mortality between the two crosses up to the age of 8 weeks. However, between 4-12 months of age, mortality percentage for FN was lower than for RW.

DISCUSSION

Body weight and growth: Eggs with heavier weight were hatched to heavier chicks. The relationship between egg weight and hatching weight for different poultry species has been studied by several researchers, who concluded that egg weight is positively correlated with hatching weight. They also suggested that hatching weight can be predicted by some physical egg characteristics and mainly egg weight measured prior to

Table 4: Least square means (±s.e.) of F1's Age at First Egg (AAFE) in days, Egg Number (EN), Hen Housed Egg Production (HHEP) and Egg Mass (EM) in g

Effects and levels	AAFE	EN	HHEP	EM
Genotype	NS	NS	*	NS
FN	195.8±4.9	29.5±2.4	29.0±2.1	1245.6±107.31
RW	198.3±8.9	29.1±4.3	19.6±3.3	1268.6±187.5
Age (Genotype)		***	**	***
Start of lay to 8 months (FN)		20.5±2.6	20.2±3.0	813.8±114.0
8 months to 12 months (FN)		38.5±2.6	37.9±3.0	1677.4±114.0
Start of lay to 8 months (RW)		21.6±4.5	14.9±4.6	913.1±198.6
8 months to 12 months (RW)		36.5±4.9	24.4±4.6	1624.0±214.9
Variance component				
Pen	87.1	24.1	0	47979
IdNo		89.7		175004
Residual	700.0	103.5	63.9	192291

*** = p<0.001, ** = p<0.01, * = p<0.05, NS = Not Significant

Table 5: Least square means (±s.e.) of egg quality traits of F1 chickens

Effects and levels	AEST	EW	YC	YH	AH	EL	EWd	ESI	HU
Genotype	NS	NS	NS	NS	NS	NS	NS	NS	NS
FN	0.3±0.004	43.7±0.8	5.9±0.1	15.9±0.2	4.9±0.3	51.7±0.3	38.9±0.2	75.3±0.5	73.5±1.9
RW	0.29±0.01	45.4±2.1	5.5±0.3	16.1±0.6	6.2±0.8	52.7±0.7	39.6±0.5	75.6±1.2	81.1±4.9
Age (Genotype)	NS	***	NS	**	NS	***	***	*	NS
FN (8 month)	0.31±0.01	41.1±0.9	6.1±0.1	15.6±0.3	5.2±0.3	50.5±0.3	38.2±0.2	75.8±0.5	75.5±2.1
FN (12 month)	0.30±0.01	46.3±0.9	5.9±0.2	16.3±0.3	4.8±0.3	52.9±0.4	39.5±0.2	74.7±0.6	71.5±2.3
RW (8 month)	0.30±0.01	41.9±2.1	5.9±0.3	15.5±0.6	6.6±0.8	50.4±0.8	39.1±0.5	77.9±1.3	84.6±5.2
RW (12 month)	0.27±0.02	48.9±2.4	5.1±0.4	16.6±0.8	5.8±0.9	54.9±1.0	40.1±0.6	73.4±1.7	77.6±6.3
Variance component									
Pen	0	4.7	0	0.3	0.4	0	0.1	0	11.8
IdNo	0.0002	3.5	0	0.1	0.3	1.7	0.6	4.0	17.6
Residual	0.001	9.1	1.0	1.2	2.1	3.8	1.2	11.5	123.7

*** = p<0.001, ** = p<0.01, * = p<0.05, NS = Not Significant, AEST = Average Egg Shell Thickness, EW = Egg Weight, YC = Yolk Colour, YH = Yolk Height, AH = Albumen Height, EL = Egg Length, EWd = Egg Width, ESI = Egg Shape Index, HU = Haugh Unit

Table 6: Least square means (±s.e.) of egg quality traits of parent chickens

Effects and levels	AEST	EW	YC	YH	AH	EL	EWd	ESI	HU
Genotype	***	***	NS	***	***	***	***	NS	***
F	0.33±0.01	42.5±0.5	4.9±0.1	16.6±0.1	5.4±0.2	50.2±0.2	38.6±0.2	76.9±0.5	78.1±1.1
R	0.29±0.01	58.0±0.6	4.7±0.1	18.2±0.1	9.6±0.2	56.7±0.2	43.4±0.2	76.6±0.5	96.8±1.1
Age (Genotype)	*	NS	**	***	***	**	***	**	***
F (8 month)	0.33±0.01	40.6±0.7	5.0±0.2	17.0±0.2	5.9±0.3	49.9±0.3	37.9±0.2	75.9±0.6	82.4±1.5
F (12 month)	0.34±0.01	44.4±0.7	4.7±0.1	16.1±0.2	4.9±0.3	50.5±0.3	39.2±0.2	77.7±0.6	73.7±1.4
R (8 month)	0.31±0.01	57.3±0.9	5.1±0.2	18.6±0.2	9.3±0.3	57.3±0.4	43.5±0.3	75.9±0.7	95.7±1.9
R (12 month)	0.29±0.01	58.7±0.7	4.3±0.2	17.9±0.2	9.9±0.3	56.1±0.3	43.3±0.2	77.3±0.6	97.9±1.4
Variance component									
Pen	0.0001	0	0	0	0.1	0	0.01	0.5	3.1
IdNo	0.0003	0	0.1	0.2	0^2	0.1	0.7	3.4	0
Residual	0.001	26.4	1.2	1.1	2.8	4.5	1.7	10.4	80.3

*** = p<0.001, ** = p<0.01, * = p<0.05, NS = Not Significant, AEST= Average Egg Shell Thickness, EW = Egg Weight, YC = Yolk Colour, YH = Yolk Height, AH = Albumen Height, EL = Egg Length, EW = Egg Width, ESI = Egg Shape Index, HU = Haugh Unit

setting (Shanawany, 1987; Narushin and Romanov, 2002; Khurshid *et al*., 2003; Saatci *et al*., 2005).

Although RW crosses had higher hatching weight, the growth of FN cross chicks were much faster than RW crosses, which resulted in higher body weight and body weight gain for FN cross chicks (Table 3 and Fig. 1). However, as both crosses grew older, the difference in body weight became smaller and insignificant. Grown RW crosses had relatively lower body weight than FN crosses, but they still had significantly higher body weight gain (Table 3); this may be due to the relatively higher body weight gain of male RW crosses (Fig. 2). The reason for the zero variance estimated in BWG for the effect of IDNo in Table 3 and likewise the zero variance component results in other tables, may be due to no or little relationship between the variance component and the different measurement periods.

The final body weight of crosses from lighter Fayoumi dam was expected to be low compared to the crosses with heavier RIR dams. However, in the present study Fayoumi was mated with much heavier and fast growing Naked Neck cocks while RIR was mated to lighter and

Table 7: Least square means (±s.e.) of Age at First Egg (AAFE) in days, Egg Number (EN), Hen Housed Egg Production (HHEP), Egg Mass (EM), Body Weight (BW) and Body Weight Gain (BWG) of parent chickens

Effects and levels	AAFE	EN	HHEP	EM	BW	BWG
Genotype	***	***	***	***	***	***
F	201.9±3.2	46.2±1.7	46.2±1.9	1946.9±76.5	1001.7±14.9	163.5±17.3
R	236.9±3.3	23.2±1.8	21.6±1.9	1375.5±80.6	1235.2±15.0	238.9±17.4
Age (Genotype)		***	***	***	***	***
Start of lay to 8 months (F)		29.6±1.9	29.6±2.3	1188.5±88.4		
8 months to 12 months (F)		62.8±1.9	62.8±2.3	2705.3±88.4		
Start of lay to 8 months (R)		12.1±2.2	9.9±2.3	720.1±99.9		
8 months to 12 months (R)		34.4±1.9	33.3±2.3	2030.4 ±89.5		
Variance component						
Pen	16.9	6.2	13.8	11651	242.3	838.7
IdNo		51.9		117710	7026.3	0
Residual	449.2	104.7	17.3	234353	11908	18797

*** = $p \leq 0.001$, NS = Not Significant

Table 8: The number of chickens alive at different stages of growth

	FN crosses	Mortality (FN)	RW crosses	Mortality (RW)
Number of hatched chicks (male and female)	221		196	
Number of chicks alive at 8 weeks of age	178		161	
Mortality in number and % (0-8 weeks)		43 (19%)		35 (18%)
Number of layers at 4 months of age	58		20	
Number of layers alive at 12 month of age	53		12	
Mortality in number and % (4-12 months)		5 (9%)		12 (40%)

slower growing *Netch* cocks. This might have led to a boost in the final body weight of Fayoumi crosses and likewise a decrease for RIR crosses, which eventually made the body weights of the two crosses insignificantly different. In a study by Zaman *et al*. (2004) crosses of Fayoumi and Naked Neck resulted in insignificant body weight compared with crosses of RIR and Naked Neck genotypes on 2 out of 3 measurements done at different ages. This is comparable with the present study in that Fayoumi crosses grew faster and reached nearly the body weight of RIR crosses. This is also in agreement with the conclusions given by various researchers that chickens carrying Naked neck have relatively high growth rate (Merat, 1990; El-Safty, 2006; Islam and Nishibori, 2009).

Egg production and quality: Age at first egg was reduced by a few days in the FN crosses and by more than a month in the RW crosses, compared to their respective female parents. Related studies have also reported that age at first egg was reduced by a few days in crosses of Fayoumi and RIR with Naked Neck chickens (Zaman *et al*., 2004, Islam and Nishibori, 2009).

The overall mean of egg number produced from start of lay to 12 months of age was not different between the F1 crosses, but different from the parent breed. Egg number of FN crosses was lower than Fayoumi hens (Table 4 and 7). In a study by Zaman *et al*. (2004) the egg number in Fayoumi X Naked Neck was reduced by almost half compared to the pure Fayoumi parent. However, HHEP was significantly higher for FN than RW crosses and likewise for Fayoumi than RIR. This was due to lower mortality in Fayoumi (Fassill *et al*., 2009) and in FN crosses (Table 8).

Egg number for RIR hens was lower than for their RW crosses (Table 4 and 7). Moreover, the number of eggs produced by FN crosses was lower than by RW crosses between 4 and 8 months (Table 4). The reason for the increase in egg number for RW crosses could be due to the reduction in age at first egg, which made them start laying earlier and enabled them to produce higher number of eggs between 4 and 8 months of age. But FN crosses produced more eggs than RW crosses between 8 and 12 months of age. Similar difference was observed for egg mass and this was due to the difference in number of eggs produced at different age (Table 4).

Percent hen-day egg production in Fig. 3 shows that both F1 crosses reaches a peak in production at the age of 9 months, although RW shows a slightly higher peak at the age of 12 months. As the recording stopped after 12 months of age it is not possible to predict what the egg production trend would be for the next few months.

There was no significant difference in any egg quality trait between the two F1 crosses, whereas RIR was higher in most of these traits when compared to Fayoumi (Table 5 and 6). Crossing of Fayoumi and RIR with Naked neck and Netch cocks respectively reduced the mean value of most egg quality traits, except yolk colour for both F1 crosses and egg length and egg weight for FN crosses. Zaman *et al*. (2004) also recorded an increase in yolk colour based on Roche colour fan scale but a reduced value for other egg quality traits for Fayoumi X Naked Neck cross. Although the improvement in yolk colour was in accordance with the consumer preference in Ethiopia for yellowish yolk colour; this trait is probably more easily affected by the type of feed the chickens are consuming (Fassill *et al*., 2009).

Mortality: Mortality records showed that FN crosses were found to survive better than RW crosses. Since anti-bacterial and anti-coccidial medicines were provided as soon as signs of illness were observed, no prevalent infectious diseases were identified during the whole experimental period. The death of chickens was mainly due to some bacterial and/or coccidial infections just before administering the medicines. Moreover, although heritability of total mortality in chickens is low (Gavora, 1990), this experiment shows that there is a relationship in mortality percentage between female parent breeds and F1 crosses. According to Fassill *et al*. (2009) there was no mortality in Fayoumi chickens compared to RIR chickens during the experiment laying period, which may be related with relatively lower mortality in FN than RW crosses.

Conclusion: Egg production and body weight of F1 crosses were higher than for the local chickens kept under farmer's condition (Fassill *et al*., 2009), which indicates that cross breeding has potential for improving economically important traits. This improvement is likely to be very important since farmers in the village will economically benefit from both the increased egg production and the heavier body weight of the chickens. FN crosses survived better than RW, which in turn resulted in higher egg productivity expressed as HHEP. The study also generated useful information that will be utilized in the analysis of the performance of the final 4-way synthetic chicken population. Because of the genetic difference between local and exotic chicken breeds it was expected that heterosis in some of the production traits would be found. In the present study, however, no on-station production data was available on indigenous chickens and it was thus not possible to compare the crossbreds with the indigenous parental lines and consequently heterosis could not be evaluated. The F1-crosses will be used to produce synthetic breed, which will be tested both on-farm and on-station.

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Paper III

Production performance of 4-way crossbred chicken population produced by crossing of two indigenous and two exotic chicken breeds under on-station and on-farm management systems in Southern Ethiopia.

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Abstract

A four way crossbred chicken population was produced from two indigenous chicken breeds: Naked neck (N) and local white (W) feathered chicken called *Netch* as sire lines and two exotic chicken breeds: Fayoumi (F) and Rhode Island Red (R) as dam lines. They were tested under on-station conditions in a college farm and under on-farm condition at several typical village farms. Mortality during brooding period was lower under on-farm than on-station conditions, which may be due to housing of the chicks in hay box-brooder on-farm and the coccidiosis infection on-station. However, higher mortality on-farm was observed during the laying period than on-station; mainly due to predation. There was a significant difference between the two systems in recorded body weight from early age to maturity. Age at first egg was lower on-farm than on-station. Average number of egg produced was not significantly different although chickens on-station laid more eggs than those on-farm. Hen housed egg production was lower on-farm than on-station due to higher mortality in the on-farm system.

Key words: reciprocal crossing, village poultry, mortality, egg, body weight

Introduction

More than 80 % of the world poultry population is in village poultry production systems contributing up to 90% of poultry products in some developing countries. Village poultry mainly consists of indigenous or local breeds. But commercial hybrids and crosses between indigenous and hybrids also exist (Besbes, 2009). Village chickens contribute to household food security in many ways including supplying high quality animal protein, generate income, as household savings and insurance. They also play important roles in religious and cultural life of the society in most of developing countries (Tadelle et al., 2000, Nasrollah, 2008; Besbes, 2009). Moreover, the genetic attributes of indigenous chickens in terms of tolerance to some diseases and parasite and adaptation to harsh environmental conditions make them important as gene pool source for improvement of village poultry production (Nasrollah, 2008; Saady et al., 2008; Besbes, 2009).

Rural poultry production in Ethiopia contribute to the national economy in general and the rural economy in particular, representing 98.5% and 99.2%, respectively, of the national egg and poultry meat outputs as cited by Tadelle et al. (2000). However, the per capita egg and poultry meat consumptions in Ethiopia are among the lowest in the world. One of the reasons for low productivity from traditional poultry farming is the fact that comparatively little research and development work has been carried out on indigenous chickens (Tadelle et al., 2000). Village poultry occupies a unique position in rural communities as there are few alternative animal protein sources and no cultural taboos related to the consumption of egg and poultry meat unlike those from pig meat. Moreover, village poultry can be reared by women and resource poor farmers and does not require large investments (Tadelle et al., 1999).

Production superiority of improved commercial breeds and poultry hybrids under low input village production systems is very much decreased due to the prevailing environmental conditions. There are very few examples of breeding programs for indigenous poultry breeds around the world, and those that exist are mainly in Europe and for specialized production traits only. Indigenous poultry breeds are most often dual purpose; therefore, improving their performance will be achieved through increasing growth and egg production. Moreover, survival or longevity under village condition is also very important for the output and should be used as an important selection criterion (Besbes, 2009).

Crossbreeding of indigenous with improved exotic breeds is one of the tools for improving village poultry productivity which requires continuous supply of pure lines. An alternative to regular crossing is to perform one or a few crosses between two or more populations to produce a single population of animals containing a mixture of genes from each population which is called synthetic or composite animal. One of the main advantages of synthetic is that only one population has to be maintained, rather than the two or more parental populations required for regular crossing program.

In this study a 4-way cross bred chicken population using two indigenous and two exotic chicken breeds was produced and evaluated under on-station in the college farm and on-farm in village farm conditions. The indigenous Naked Neck (N) and *Netch* (white feathered)(W) were used as sire pure lines and the exotic Rhode Island Red (R) and Fayoumi (F) were used as dam pure lines. The 4-way cross bred chickens will be developed to synthetic chicken after crossing within the 4-way cross bred population. The different attributes of the four breeds are expected to be expressed in the final synthetic population. This study was therefore, conducted with the objectives of producing synthetic chicken population and compare their performance under on-station and on-farm management systems.

Materials and Methods

Experiment sites and animals

The on-station experiment was conducted at the poultry farm of Hawassa University, College of Agriculture, which is located 275 km south of the Ethiopian capital Addis Ababa. The on-farm trials were done with farmers in the Boricha village, 20 km south of Hawassa.

The experimental chickens were a result of 4-way crossing using 2 indigenous male chicken breeds; Naked Neck (N) and local white, a white feathered chicken called *Netch* (W), and 2 exotic female breeds; Fayoumi (F) and Rhode Island Red (R). Among the local chickens in Ethiopia, Naked neck ecotype is known for its high egg production and heavy body weight, which is some what better than that of the other local breed *Netch* (Teketel 1986). Specifically, chickens carrying the Na (naked neck) gene have been known to have higher growth rate and egg production under high ambient environment (Merat, 2003, El-safty, 2006, Islam & Nishibori, 2009). The *Netch* is, on the other hand, widely available in the experiment area and considered to be highly adapted to the environment. Fayoumi is an Egyptian breed developed for high egg production and is believed to withstand harsh tropical condition, whereas Rhode Island Red is a dual purpose chicken breed characterized by hardiness and high productivity (Gueye, 1998). Reciprocal crossing were done for comparison. Figure 1 shows the 4-way crossing scheme of the breeds used.

Crossing was conducted at the college poultry farm at the Hawassa University. Mating was done in two rounds; each cock mated with two hens in the first round and with two other hens in the second round. The hens and cocks were housed separately and mating was facilitated by bringing a hen and a cock from their pens and putting them in a separate pen. After the first hen had been successfully mated, she would be taken out and the second hen would be introduced to the pen with the cock.

Trap nests were provided in pens for both the F1 and F2 crosses so that individual egg production could be recorded. The date of lay and ID number of the hen that laid the egg were written on all eggs during collection. Eggs from the parents (F1) were collected from the pens and stored in a room with a ventilator for up to ten days. All eggs were weighed individually at setting. At the 18^{th} day of incubation the eggs were candled and eggs with live embryo were transferred to the hatchery. The trays in the hatchery were modified by fitting 6cm X 6cm cells, made of plywood, and individual eggs were placed in the cells. Each cell was again identified with the same information found on the egg to avoid confusion if the information written on the egg shell was lost during hatching. The tray was covered with a wooden frame with mesh wire to avoid mix up of chicks at hatching and during tagging. The chicks were individually tagged. They were then weighed and vaccinated against New Castle Disease (NCD) before transferred to the brooding house. The chicks were hatched in batches because of the small number of eggs produced during the ten days collection period. The eggs would be spoiled if more days were added to incubate more eggs. Chicks from the same batch were placed together in separate pens within brooding house and were moved to layer pens together when they were 4 months old.

Management of experimental animals

On-station

The chicks were provided with starter ration until they were 4 months old. At the age of 8 week, the lamps used for heating were removed and the pens were widened proportionate to the number of chicks in the batch. After 4 month the chickens were transferred to the layer house where a layer ration was provided. The layer house was a deep litter house divided into several pens using mesh wire. The walls of the house were partially made of thick mesh wire for natural ventilation and light. The type and composition of rations used are presented in Table 1. Feeders and waterers were placed in each pen and feeding was ad lib. Trap nests with four separate compartments were provided in each pen so that individual egg production could be recorded.

On-farm

One-day old fullsibs and half sibs of the on-station chicks were distributed to 10 women farmers. All chicks were vaccinated against NCD and leg banded with ID number. Hay box brooders were provided, and they consisted of two parts: a brooder box stuffed with hay and a box used for exercise. Starter ration for at least 2 weeks was also given to the farmers to help the chicks adapt to the village conditions. Farmers will give the chicks local bread softened with water, ground maize or other kitchen scraps. Water was provided with containers such as old plastic, clay or metal containers . A broad spectrum antibiotic medicine was also given to the farmers with instructions on how to administer the medicine in case of disease symptoms. The chicks were released to the field within a few weeks after their arrival at the farm, but placed in the brooder box during night and cold times. After the chicks had grown larger, i.e. at 3 to 4 months, farmers placed them either in separate house built for chickens or they stayed in the farmers' house during the night.

All chicks were identified with plastic leg band with number which was used until the end of the experiment. The plastic band was replaced at least twice as the chick's leg grew. Data were collected twice a week or once a month, depending on the trait recorded.

Data collection

Hatching and growth

All chicks were weighed upon hatching before they were transferred to the brooding house. They were hatched in 6 different batches and chicks of the same batch were housed in the same pen for ease of management. The chicks in some batches were more numerous and thus they were divided into more than 1 pen. The chicks were weighed every week until they were 8 weeks of age and monthly thereafter. All chicks were weighed individually by using a digital weighing scale powered both by electricity and battery. Body weight gain was calculated as a difference between consecutive body weight measurements.

Mortality

Chicken mortality was recorded during weighing day i.e. any chicken not alive for weighing on a particular weighing day was considered as dead. No postmortem analysis was made for on-farm dead chickens but occasional postmortem analysis was made for on-station dead chickens. Structured questionnaire was prepared to collect information about the causes of mortality under on-farm condition.

Egg production and quality

Age at first egg (AAFE) was recorded in days for both on-farm and on-station chickens. Egg number produced by each chicken was recorded individually every day in the on-station trial and at least twice a week in the on-farm trial. Egg production recording under the on-farm condition was done by a development agent stationed in the farmers' village. Three types of egg production analysis were made for both management systems; egg number (EN) is the average number of eggs produced by a layer in a particular period; hen housed egg production (HHEP) is calculated as the total number of egg produced divided by the number of hens originally housed in a pen or farmer's house; and hen day egg production (HDEP) in percent is calculated as the number of eggs produced in a particular time dived by the number of layers alive on that particular time. Calculation of HHEP was started from the month at which the layers were first housed in a pen, i.e. at 4 months of age. The number of live layers was calculated as the average number of layers at the beginning and end of a particular recording period. Moreover, percent HHEP was also calculated for comparison with percent HDEP.

$$HHEP = \frac{Number\ of\ eggs\ produced}{Number\ of\ hens\ originally\ housed\ in\ a\ pen\ or\ farmer's\ house}$$

$$HDEP(\%) = \frac{Number\ of\ eggs\ produced}{Number\ of\ live\ hens\ in\ a\ pen\ or\ farmer's\ house} X100$$

Internal and external egg quality in both management systems were recorded at age 8 and 12 months on-station, but only at 12 month on-farm. The eggs were weighed individually using a digital weighing scale, and average egg weight was calculated for each pen/farmer. Average egg shell thickness (mm) was measured using digital caliper at broad, narrow and middle side of each egg, and the average of three measurements was used for statistical analysis. Yolk color was measured using Roche color fan scale (1=very pale to 16=deep orange). It was measured by 3 people and the average of them was used for further analysis. Albumen and yolk height (mm) were measured using tripod micrometer after the egg was broken out on a flat glass. Egg length and width (mm) were measured by digital caliper and egg shape index was calculated as the ratio of egg width over egg length. Haugh Unit was calculated using the formula:

$$HU = 100 \log (AH + 7.57 - 1.7EW^{0.37})$$

Where, AH = observed albumen height in mm and EW = egg weigh in gram

Statistical analysis

All traits were analysed using the mixed model procedure in the software package SAS (Statistical Analysis System) (SAS, 2002-2003) using sex, age, management system and their interactions as fixed effects, depending on the trait in question. Pen number, individual farmer and Id number of chickens were all used as random effect, depending on the model. The effect of reciprocal crossing on almost all traits was insignificant and it was thus removed from the models.

Model 1 was used to analyze body weight traits, using sex and management system as fixed main effects and fixed interaction effect of sex and management systems at different ages.

$Y_{ijn} = \mu + S_i + M_j + S_i (M_j) + e_{ijn}$…………………….………………………...1

Where;

Y_{ijn} =Individual body weight and body weight gain of chickens in both on-station and on-farm

μ= Overall mean

S_i =Fixed effect of sex *i*, *i*=1-2 (male and female)

M_j= Fixed effect of management system *j*, *j*=1-2 (on-station and on-farm)

$S_i (M_j)$= Effect of sex unique to each management systems

e_{ijn}= random error

Egg number was analyzed by model 2 using age and management systems as fixed main effects and fixed interaction effect of age and management systems. Moreover, Id number of chickens and pen or farmer were used as random effects. There is no repeated records for AAFE and thus effect of age and individual ID number were removed from the model. Hen housed egg production was calculated per pen or farmer in which they were kept, therefore the random effect of ID was not used in the model.

$Y_{ijkln} = \mu + A_i + M_j + A_i (M_j) + ID_k + PF_l + e_{ijkln}$……………………………...2

Where all effects and levels are the same as model 1 except

Y_{ijkln}= Egg production and in both on-station and on-farm

A_i= Fixed effect of age *i*, *i*= 1-2 (between 4 to 8 months and 9 to 12 months)

A_i (M_j)= Effect of interaction between age and management systems

ID_k= Random effect of individual chicken

PF_l= Random effect of farmer or pen *m*, *m*=1-10 pens or 1-10 farmers

e_{ijkln}= random error

Model 2 was modified to model 3 to analyse egg quality traits because of unequal number of measurement times in the two systems.

$Y_{ijkln} = \mu + M_j + A_i (M_j) + ID_k + PF_l + e_{ijkln}$……………………..…………………...3

Where all other effects and levels are the same as model 1 and to except

Y_{ijkln}= Egg quality in both on-station and on-farm

A_i= Fixed effect of age *i*, *i*= 1-2 (at 8 and 12 months on-station and at 12 month on-farm)

Results

Mortality

Mortality during the brooding time was higher on-station than on-farm. Most of the mortality on-station occurred during the early stage of the growth period. Mortality decreased during the laying period on-station, but increased over the same period on-farm (Table 2). The cause of mortality in different age groups under the on-farm management system is presented in Table 3 and chickens that were lost for unknown reasons were not included in the mortality. All mortality on-station was due to disease.

Body weight and gain

Body weight of chicks measured at different ages are presented in Table 4. The average hatching weight for the male and female was not significantly different. Likewise the difference in body weight of chicks from week 1 to week 7 was not significant for males and females, but the gap became widened every week until it was significantly higher for males at week 8. Management system had significant effect on body weight of chicks after week 2, but no significant interaction was observed between sexes and management systems. Weekly body weight gain of chicks was not significant for the males and females but difference due to management systems was increasingly significant as age increases (Table 5).

Body weight of grown chicken was significantly higher for males than females, as was chickens kept under on-station compared to on-farm (Table 6). Although body weight gain of male chickens was significantly higher than females, the difference decreases and eventually disappeared after month 8. But in general, there is a trend of higher body weight gain for males than for females, especially for chickens kept under on-farm condition compared to those kept under on-station condition (Table 7). Figure 2 and 3 show body weight and daily body weight gain of chickens during the entire measurement period. As described above the increasing gap in body weight between the management systems started at early age but became stabilized as the chickens grew older.

Egg production and quality

Although no significant difference in AAFE between the management systems was found it is worth noting that on-farm chickens started laying at 203 days as compared to 222 for on-station chickens. The number of eggs laid in the first period, between the age at which the chickens were housed in layer’s pen (months 4) and month 8, was lower than the number of eggs produced in the last period, i.e. between month 9 and end of the recording period (i.e. month 12) in both management systems. Management system had no significant effect on the average egg number produced, but there was an interaction effect between age and management, since slightly more eggs were laid between months 4 to 8 on-farm than on-station, whereas the reverse happened between months 9 to 12. However, HHEP was significantly higher for chickens kept under on-station conditions compared to those kept under on-farm conditions. Egg mass was only calculated for chickens kept under on-station condition. (Table 8). Percent HDEP and HHEP are presented in figure 4. No significant difference in egg quality traits were found caused by management system, except for yolk color. But higher egg weight and egg length was found on-station (Table 7).

Discussion

The higher chick mortality on-station was mainly due to coccidiosis that occurred on chicks that were hatched in the second round. Due to shortage of brooding pens the chicks were housed in pens close to the layers, and this may have facilitated transmission of the disease. On the other hand the relatively low mortality of chicks kept on-farm may be attributed to provision of chick brooder box for the farmers, which has proved to be effective in reducing chick mortality in village poultry keeping condition. Solomon (2007) found that mortality of chicks reared on-farm up to 8 weeks of age using hay box chick brooder was 10%, compared to 14% mortality for chicks kept on-station using an infra red electric brooder. It has also been reported that in Ethiopia, survival rate of chicks reared to an age of 3 months under natural brooding condition reaches up to 40%, and the results found in the present study might thus be considered as satisfactory. In addition to the hay box brooder, some farmers had constructed day-time shades to protect the chicks from predators. As the chicks grew older, mortality on-station was reduced due to provision of anti-coccidial treatment and also control of other diseases and parasites. On the other hand, mortality of chickens on-farm increased very much in the same period, mainly due to attack by predators. After the brooding period the chickens are left outside to search for feed in the backyard vegetable farm, and this makes them an easy prey to stalking predators such as fox and wild cats. Cause for mortality on farm is summarized in Table 3, which was obtained by questionnaires answered by the farmer at the end of the experiment.

Hatching weight and body weight up to week 7 were not significantly different for males and females, but the males had significant higher body weight after week 8. Also Mohammed et al.,

(2005) reported insignificant difference in body weight at hatching between males and females but as the chicks grew, males were significantly higher than females in body weight due to the presence of sexual dimorphism. Interaction of sex of chicken with management system was shown in Figure 2.

The higher body weight by on-station chickens is most likely due to the fact that the chickens reared on-station were fed on formulated ration throughout the whole experiment period. Formulated feed were provided with the chicks to the farmers to feed the chicks for at least 2 weeks, but the farmers then had to provide their own feed, which mainly consisted of crushed maize and other kitchen scrapes. This feed may not supply enough nutrients for growth. Moreover, after some weeks farmers also released the chicks outside the brooding boxes for a few hours per day, and when they were fully grown they stayed out all day to look for food, which in turn increases exercise and resulted in loss of energy. In a study by Dou et al. (2009) chickens kept in the free range system had lower body weight compared to those kept in-door. They concluded that the performance of chickens kept in free-range system would be inferior to that of a controlled environment because of fluctuating temperature and increased exercise.

Significant body weight gain after month 4 leads to a widening of the gap between male and female body weight, as shown in Figure 2. This figure also shows that the difference in body weight between chickens kept in the two systems is most pronounced at 4 months of age. Higher body weight gain during early stage of growth in chicks kept on-station than on-farm (Figure 3) has practical significance for future management. Chambers (1993) reported that it is necessary in applied poultry breeding to evaluate growth during juvenile stages to permit choice of actions long before maturity. Actions such as provision of better management practices such as better feed and disease control in the on-farm system during early stage of growth could increase body weight and could narrow the difference in body weight of chickens in the two systems during the rest of the production period.

Age at first egg was lowered by about 20 days in chickens under on-farm conditions compared to those kept on-station. This is reflected in the average number of eggs laid, which is slightly higher on-farm than on-station (Table 8) and the relatively higher HDEP(%) up to 8 months of age (Figure 4). Early laying is considered to be important for the farmers because a chicken should produce as much eggs as possible before disease or predation terminates the production under these difficult conditions. Chickens kept under relatively better feed and management conditions (on-station) is expected to have a lower age at first egg than scavenging chickens reared on-farm. Islam and Nishibori (2009) reported that exotic and crossbreds of indigenous naked neck with exotic chickens kept under scavenging system showed delayed age at sexual maturity and lower egg production. Age at first egg depends on the type of feed the chickens had in their early growth stage, length and intensity of light etc. Therefore, a possible reason for the result may be that there was enough forage in the backyard during the short rainy season in this important early life phase of the chickens. Moreover, the chicks on-station were infected with coccidiosis during the first few weeks, which may have had negative influence on age at first egg. Although average number of egg produced per bird was not significantly different between the two systems, there was a relatively higher egg production under the on-station management system. This was expected because scavenging chickens produce lower egg number compared to those kept in intensive management systems (Hossain, 1992; Solomon, 1996; Dana & Ogle, 2002). As expected HHEP was lower on-farm than on-station due to higher mortality in the former system during the laying period. Figure 4 consequently shows relatively smaller difference in HDEP (%) between the two systems than in HHEP(%). In general, egg production in this study was lower than expected in both management systems. However, it is reasonable to believe that selection at all levels of crossing would have improved the production potential of the synthetic breed, and this will thus be the done for the coming generations.

Egg weight and egg length at the age of 12 month was higher on-station than on-farm. A higher egg length is expected to give heavier egg, as the two is highly correlated (Fassill et al,, 2009). Egg weight is also affected by the type and amount of feed consumed, which was superior in the on-station system. Hossain (1992) also reported a relatively higher egg weight from chickens kept under intensive than rural conditions. As expected yolk colour was more yellow and therefore superior on-farm compared to on-station, mainly due to the consumption of green forages by the chickens in the backyard vegetable farms.

Although the effect of reciprocal crossing was insignificant on almost all traits recorded, it has practical importance to this project in that it is possible to produce more number of offspring, i.e. with the use of both crossings.

Conclusions

As expected performance of the chickens under on-station management system where there is better feed and housing was higher than those kept under on-farm condition. Compared to a study by Fassill et al. (2009), the current study showed a substantial improvement in egg production of local chickens under farmer's management condition. Age at first egg laid was shortened. Body weight of chickens was also improved by the 4-way cross bred chickens compared to local chickens. However, much has to be done to reduce mortality during laying period under on-farm condition. Overall performance of the 4-way cross bred chicken under on-farm condition could further be improved by providing better housing in order to protect the chickens from predators, extreme temperatures, diseases and parasites. Moreover, supplementing the chickens with relatively quality feed ingredient especially during growing period could improve production performance in later ages. Further study on crossbreds of different blood levels of indigenous and exotic chickens under on-station and on-farm systems should be made in order to choose the best possible combinations for each system. Selection at all levels of crossing would increase production. Economic study should also be included in the study.

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Table 1. Ingredient and analyzed chemical composition of chick and layer rations used in the trial.

Ingredient	**Chick ration**	**Layer Ration**
Maize	32 %	39 %
Wheat bran	29 %	22 %
Noug (*Guiziota abyssinica*) cake	19 %	25 %
Soya bean (roasted)	18 %	6 %
Salt	1 %	1%
Bole (soil with limestone)	1%	7 %
Chemical composition (DM basis)		
Crude protein (%)	17.4	16.8
ME (MJ/kg)	13.2	13.4

Table 2. Mortality of chickens under on-station and on-farm condition at different ages

	On-station		On-farm	
	Alive	Mortality	Alive	Mortality
Number of hatched chicks (both sexes)	450		180	
Number of chicks alive up to 8 weeks of age (both sexes)	322		153	
Mortality in number and percentage from hatching to 8 weeks		128(28%)		27(15%)
Number of chickens alive up to 4 months of age (both sexes)	275		106	
Mortality in number and percentage from 8 weeks to 4 months		47(15%)		47(31%)
Number of layers at 4 months of age	88		64	
Number of layers alive up to 8 months of age	86		37	
Mortality of layers from 4 to 8 months in number and percentage		2(2.3%)		27(42%)
Number of layers alive up to 12 months of age	81		28	
Mortality of layers from 9 to 12 months in number and percentage		5(6%)		9(24%)

Table 3. On-farm chicken number of deaths with percentage due to disease and predator.

	Between hatching and month 4	Between month 4 and 12
Chickens alive	180 (at hatching)	106 (at month 4)
Death due to diseases	27(15%)	15(14%)
Death due to predator	17(9%)	22(21%)

Table 4. Least square means with standard error of chick body weight (g) from hatching to 8 weeks of age.

	Chick Body weight								
Effects and levels	Hatching wt	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Sex	NS	NS	NS	NS	NS	NS	NS	NS	**
Female	30.6±0.2	41.9±0.4	54.0±0.9	72.3±1.2	90.1±1.9	112.8±2.1	137.6±3.8	164.6±3.6	237.7±5.7
Male	30.3±0.3	42.5±0.5	56.2±0.9	74.5±1.5	93.6±2.1	115.6±2.4	144.3±4.2	172.3±4	255.0±5.8
Management		NS	***	***	***	***	***	***	
On-station	30.5±0.2	42.7±0.3	57.3±0.6	78.9±1.0	98.9±1.3	125.3±2.7	160.4±2.7	201.2±2.9	246.3±4.1
On-farm		41.8±0.5	52.9±1.1	67.8±1.6	84.7±2.5	103.3±2.4	121.5±5.0	136.2±4.6	
Sex(Management)		NS	NS	NS	NS	NS	NS	NS	
Female(On-station)	30.6±0.2	42.2±0.5	56.1±0.6	77.2±1.4	96.6±1.8	123.4±2.4	155.3±3.7	194.9±4.1	237.7±5.7
Male(On-station)	30.3±0.3	43.2±0.5	54.4±0.6	80.8±1.5	101.4±1.9	127.4±2.4	165.6±3.8	207.4±4.2	255.0±5.8
Female(On-farm)		41.8±0.6	51.9±1.5	67.5±2.1	83.6±3.3	102.5±3.5	119.9±6.7	134.3±5.9	
Male(On-farm)		41.7±0.8	53.9±1.7	68.2±2.6	85.8±3.7	104±4.2	123.1±7.5	138.1±6.9	

*** =P≤0,001, NS= not significant

Table 5. Least square means with standard error of chick body weight gain (g) from week 1 to week 8

	Chick Body weight gain							
Effects and levels	Week1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Sex	NS	NS	NS	NS	NS	NS	NS	NS
Female	10.3±0.5	12.3±0.6	19.0±1.1	17.2±1.1	22.3±1.2	25.3±2.2	28.4±2.0	42.7±2.4
Male	11.3±0.5	13.9±0.7	18.8±1.3	18.5±1.2	21.9±1.2	28.6±2.4	29.3±2.2	47.2±2.5
Management	*	**	**	**	***	***	***	
On-station	12.2±0.3	14.6±0.4	21.6±0.8	20.0±0.7	26.2±0.8	34.9±1.5	40.7±1.4	44.9±1.7
On-farm	9.5±0.6	11.8±0.8	16.2±1.5	15.6±1.4	17.9±1.5	18.9±2.9	16.9±2.7	
Sex(Management)	NS	NS	NS	NS	NS	NS	NS	
Female(On-station)	11.6±0.4	13.9±0.6	21.0±1.1	19.4±1.0	26.8±1.1	31.9±2.1	39.7±1.9	
Male(On-station)	12.8±0.5	15.2±0.6	22.3±1.1	20.6±1.0	25.6±1.1	37.6±2.2	41.8±2.0	
Female(On-farm)	9±0.9	10.8±1.1	17.1±1.9	14.9±1.8	17.8±2.0	18.6±3.8	17.1±3.6	
Male(On-farm)	9.9±0.9	12.7±1.2	15.3±2.3	16.3±2.1	18.1±2.2	19.3±4.3	16.9±3.9	

*** =P≤0,001, ** =P≤0,01, *= P≤0,05, NS= not significant

Table 6. Least square means with standard error of chicken body weight (g) from 4 to 12 months of age.

	Chicken Body weight								
Effects and levels	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12
Sex	***	***	***	***	***	***	***	***	***
Female	653.2±13.6	860.9±19.9	988.5±19.5	1057.5±20.4	1070.0±25.0	1117.3±197	1108.2±32.9	1103.8±23.2	1113.7±25.9
Male	725.2±15.6	1003.7±22.3	1223.3±24.4	1362.2±27.55	1421.0±31.9	1559.0±23.5	1474.5±36.0	1506.5±29.9	1533.7±40.9
Management	***	***	***	**	**		**	***	**
On-station	797.5±11.3	1015.9±20.9	1167.8±13.5	1259.8±14.6	1309.9±14.6	1338.2±15.3	1363.2±14.6	1377.5±15.5	1391.3±17.3
On-farm	580.9±17.4	848.8±23.9	1043.9±28.2	1159.9±31.0	1181.2±37.8		1219.7±46.6	1232.7±34.6	1255.9±45.2
Sex(Management)	NS	NS	NS	*	*		*	NS	NS
Female(On-station)	749.9±15.8	912.4±23.8	1020.8±18.5	1069.3±19.6	1084.0±18.9		1141.1±25.8	1146.6±19.4	1169.3±21.3
Male(On-station)	845.1±16.3	1119.4±26.9	1314.9±19.5	1450.3±21.6	1535.8±22.2		1594.9±22.8	1608.5±24.1	1613.4±27.3
Female(On-farm)	556.4±22.3	809.5±31.9	956.2±34.2	1045.8±35.8	1056±46.3		1085.2±63.3	1060.9±42.1	1058.1±47.2
Male(On-farm)	605.4±25.7	888.1±26.7	1131.7±44.7	1274.1±50.7	1306.3±59.7		1354.2±68.3	1404.5±54.9	1453.9±77.2

*** =P≤0,001, ** =P≤0,01, *= P≤0,05, NS= not significant

Table 7. Least square means with standard errors of chicken body weight gain (g) from 5 to 12 months of age

	Chicken Body weight gain							
Effects and levels	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12
Sex	***	***	*	NS	NS	NS	NS	NS
Female	183.1±11.7	133.9±11.7	73.3±12.5	22.3±12.8	25.7±7.6	8.3±8.2	19.7±12.5	12.7±12.0
Male	250.8±12.8	200.7±14.8	115.6±16.8	49.5±16.3	21.8±9.2	14.4±10.1	40.1±15.3	13.8±18.9
Management	**	NS	NS	NS			*	NS
On-station	191.1±8.3	171.6±8.0	88.6±8.9	38.0±7.5	23.7±5.9	11.3±6.5	8.9±5.3	9.9±8.0.6
On-farm	242.8±15.3	162.9±17.0	100.3±18.9	33.8±19.4			50.9±19.0	16.6±20.9
Sex(Management)	*	NS	NS	NS			NS	NS
Female(On-station)	136.1±11.4	126.2±11.0	54.9±11.9	6.6±9.7			10.8±6.6	22.3±9.9
Male(On-station)	246.1±11.9	217.1±16	122.2±13.3	69.5±11.4			6.9±8.2	-2.5±12.6
Female(On-farm)	230.1±20.5	141.6±20.6	91.6±21.9	37.9±23.7			28.6±24.1	3.1±21.9
Male(On-farm)	255.5±22.7	184.3±27.2	108.9±30.9	29.6±30.6			73.3±29.5	30.1±35.8
Variance component								
Residual	13391	11831	8427.9	8427.9	5027.5	5554	3475.6	7672.8

*** =P≤0,001, ** =P≤0,01, *= P≤0,05, NS= not significant

Table 8. Least square means with standard error and variance components for age at first egg (AAFE) in days, egg number (EN), hen housed egg production (HHEP) and egg mass.

Effects and levels	AAFE	Egg Number	HHEP	Egg mass
Age		***	***	***
4-8 months		9.5±1.0	7.9±1.4	492.5±61.2
9-12 months		23.6±1.0	18.9±1.4	1200.8±56.9
Management	NS	NS	*	
On-Station	221.5±8.5	17.8±1.2	16.1±1.6	846.7±50.7
On-farm	202.6±10.3	15.2±1.4	9.8±1.6	
Age(Management)		*	*	
4-8 months(On-station)		9.2±1.2	8.9±1.9	
9-12 months (On-station)		26.5±1.2	25.0±1.9	
4-8 months(On-farm)		9.7±1.7	6.9±1.9	
9-12 months (On-farm)		20.7±1.7	12.8±1.9	
Variance components				
Farmer or pen	521.8	7.8	21.5	12181
IDNo		18.3		29728
Residual	835.6	65.3	18.5	116279

*** =P≤0,001, *= P≤0,05, NS= not significant

Table 9. Least square means with standard error and variance components for egg quality traits.

Effects and levels	EW	AEST	YC	YH	AH	EL	EWd
Management	*	NS	***	NS	NS	*	NS
On-station	45.2±0.9	0.297±0.004	5.2±0.1	14.3±0.3	5.1±0.3	52.8±0.3	39.4±0.2
On-farm	41.1±1.5	0.299±0.008	8.3±0.3	14.4±0.4	4.9±0.4	50.7±0.7	38.4±0.4
Age(Management)	***	NS	NS	***	***	***	NS
8 months(On-station	43.3±0.9	0.302±0.004	5.3±0.2	13.3±0.3	4.2±0.3	51.9±0.4	39.1±0.3
12 months (On-station)	46.9±1.0	0.292±0.005	5±0.2	15.3±0.3	6.1±0.3	53.7±0.4	39.6±0.3
12 months (On-farm)	41.1±1.5	0.299±0.008	8.3±0.3	14.4±0.4	4.9±0.4	50.7±0.7	38.4±0.4
Variance component							
Pen	5.8	0.0	0.06	0.6	0.5	0.3	0.3
IdNo	9.1	0.0	0	0	0	1.8	0.4
Residual	15.9	0.001	1.4	1.9	2	7.3	1.9

*** =P≤0,001, ** =P≤0,01, *= P≤0,05, NS= not significant, EW= egg weight, AEST= average egg shell thickness, YC=yolk colour, YH=yolk height, AH=albumen height, EL=egg length, EWd=egg width, ESI=egg shape index, HU=Haugh unit

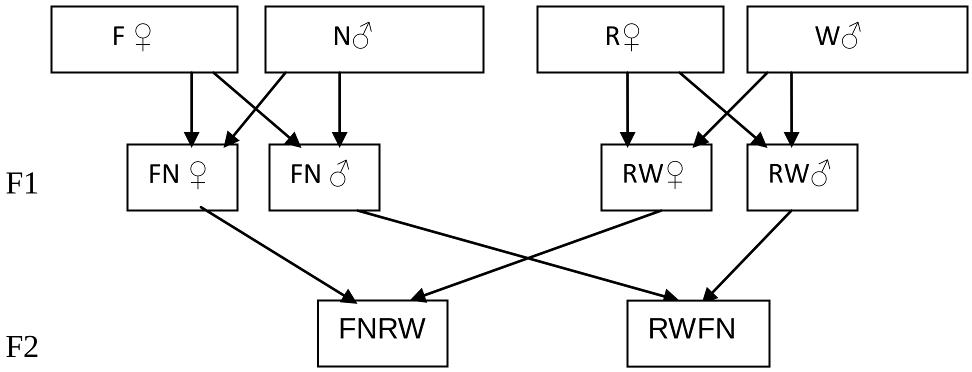

Fig. 1. Schematic representation of the 4-way crossing used in the experiment.

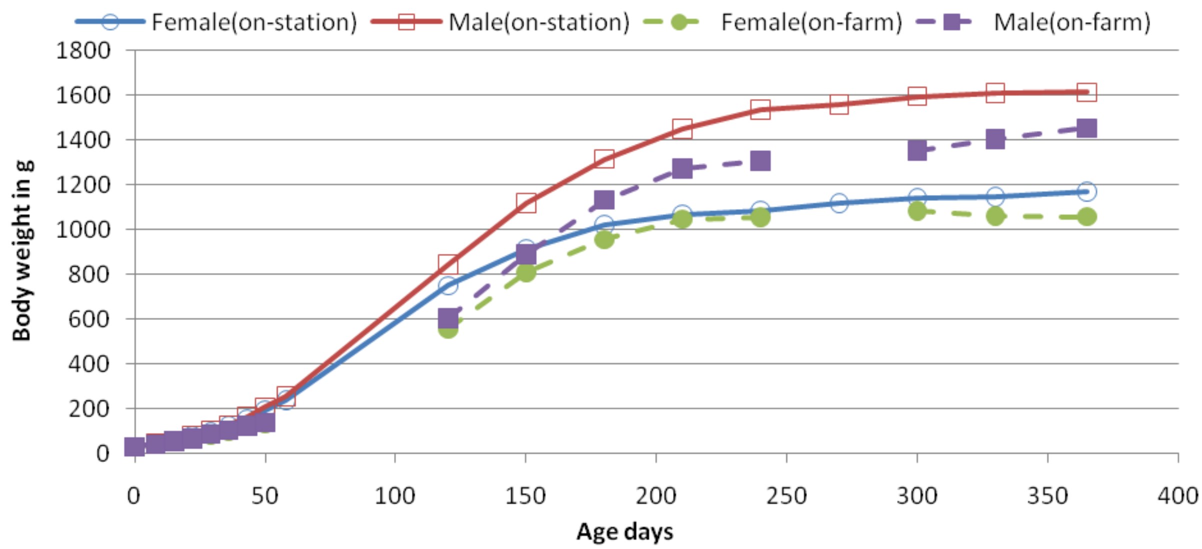

Fig 2. Body weight of chickens at different weeks of age

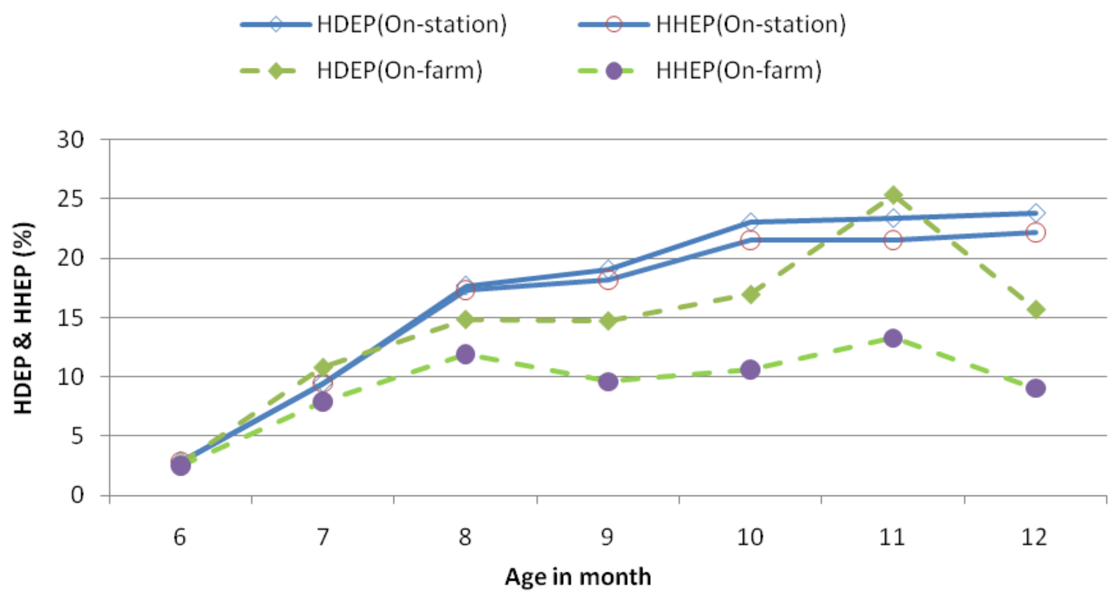

Fig 3. Hen day egg production (HDEP) and Hen housed egg production (HHEP) for one day at different age in the two management systems