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Economic viability of newly introduced chicken strains at village level in Tanzania: FARMSIM model simulation approach

Rogers Andrew[a,*], Jeremia Makindara[b], Said H. Mbaga[c], Roselyne Alphonce[d]

[a] Department of Policy, Planning and Management, Sokoine University of Agriculture, P.O. Box 3035, Morogoro, Tanzania
[b] Department of Business Management, Sokoine University of Agriculture, P.O. Box 3007, Morogoro, Tanzania
[c] Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture, P.O. Box 3004, Morogoro, Tanzania
[d] Department of Agricultural Economics and Agribusiness, Sokoine University of Agriculture, P.O. Box 3007, Morogoro, Tanzania

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Abstract: A local chicken farming is an integral part of Tanzania's rural economy. However, despite its contributions to household economy and food security, local chicken productivity remains low because of low genetic potential, diseases and poor feeding. One of the options to increase local chicken productivity is the adoption of the chicken strains with high genetic potential. With that respect, Africa Genetic Gain project introduced Sasso and Kuroiler chicken strains for on-farm test purposes. Developmental design involved provision of 25 six weeks old chicks to 20 farmers in 12 sites making a total of 240 farmers in three regions. The study was carried out in Dodoma, Morogoro and Njombe regions to assess the effects of agro-ecological differences in the performance of these strains. The chicks were vaccinated against Mareks and Newcastle diseases at the hatchery; then against Infectious Bronchitis (IB) at 0, 7 10, 16 and 21 days. The Newcastle Disease vaccine was repeated after 10 and 21 days using LaSota vaccine. After 6 weeks, the chicks were again vaccinated against fowl pox ready for supply to farmers. A farm Simulation Model (FARMSIM) and Stochastic Efficiency with Respect to Function (SERF) were applied to access economic viability of these strains relative to local chickens. FARMSIM is a Monte Carlo Simulation Model that simultaneously evaluates a baseline and an alternative farming technology. To simulate using FARMSIM, Simulation and Econometrics to Analyse Risk (Simetar©), an excel add-in is needed as a simulating engine. Data were obtained through survey, farmers' records and simulation exercises. The results indicate that keeping Sasso strain was the most economically viable with the highest Net Present Value, Net Cash Farm Income and the highest probability of attaining economic return. Kuroiler was the second, followed by keeping local chickens without supplement and local chicken with supplement was the least economically viable enterprise. However, inclusion of risk behaviour revealed that extremely risk-averse farmers preferred mostly keeping local chickens without supplement whereas extremely risk loving farmers preferred the most Sasso strain. It is recommended that the introduced chicken strains should be promoted to increase household income and improve people's livelihoods. However, scaling up of the introduced chicken strains must be integrated with education on technical know-how for good farming practices, feed formulations, medication and shelter for improved productivity and reduced variability.

1. Introduction

A local chicken farming is an integral part of Tanzania's rural economy. About 3.8 million households keep chickens, and the country has an estimated 35.5 million local chickens and 24.5 million improved chicken breeds (United Republic of Tanzania (URT), 2015). Additionally, the sector contributes about 1% of the national Gross Domestic Product (GDP). In 2013, the estimated monetary values of meat and eggs were US$ 874 billion and 364 billion respectively (Komwihangilo, 2015).

Low genetic potential of Tanzania's local chickens has continued to contribute to low productivity of meat and eggs (Minga et al., 2003). According to URT (2012), the weight of chicken ranges between 1.6 and 2.0 kg whereas, annual eggs produced per hen are on average 36. In response to the low genetic potential of local chicken in Tanzania, the African Chicken Genetic Gains (ACGG) project introduced new chicken strains (Sasso and Kuroiler) which are deemed to perform better in Ethiopia and India respectively and hence need to be tested at village

* Corresponding author.
E-mail addresses: randrew@sua.ac.tz (R. Andrew), mbagash@sua.ac.tz (S.H. Mbaga).

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level in Tanzania. This study aimed to assess their economic viability relative to the available local chickens in different agro-ecological zones. The concept of on-farm testing adopted by the ACGG is in line with “a shift in thinking away from looking at adoption as the delivery of an external, typically science-based innovation with farmers as potential end users towards a more complex learning process involving a wide range of actors rather to allow farmers to become experts on their own farm and take decisions based on knowledgeable interference from observation and analysis through learning” (RÖling and Jiggins, 1998).

Additionally, the ACGG project responds to the fact that gateway to Africa's economic development hinges on innovation, diffusion and utilisation of Agricultural technologies (Langat et al., 2013; Shaw, 2014) to find solution to support local chickens' keepers in Tanzania through increased chicken productivity. The introduced strains include Kuroiler strain that weighs about 1.8–1.9 kg (hen) and 2.3–2.4 kg (rooster), and a hen can produce about 150 eggs per year (WSPA, 2011), and Sasso strain that weighs 2.2–2.5 kg and 1.5–1.7 kg for cock and hen respectively and can produce about 150 eggs per hen per year (Rodelio and Silvino, 2013).

However, the economic viability of these birds in Tanzania's agro-ecological zones is not known. It is acknowledged that agro-ecological differences and socio-economic landscapes may play important role in determining chickens' growth, productivity, mortality rate, diseases and time to maturity (Francis et al., 1995). Sunding and Zilberman (2000) are of the view that new innovations require assessment for their technical feasibility to provide the technical base for their adoption. In both economic and diffusion of innovations theories, farmers are presumed to be rational in making decisions based on available information, with a view to securing the optimum result possible (Simon, 1959). This study was therefore undertaken to determine economic viability of introduced strains relative to the available strains. The results are expected to help farmers and other developmental agencies to select the most appropriate innovation for village chicken production improvement.

2. Methodology

2.1. Description of study areas

The data were collected in three sites located in three regions in Tanzania, namely Dodoma, Morogoro and Njombe in Bahi, Ifakara and Wanging'ombe districts respectively. Dodoma is a semi-arid region, which lies on latitude 6°48′S and longitude 39°17′E and an altitude of 1125 m above sea level. The annual rainfall ranges between 500 and 700 mm, and average annual temperature is 22.6 °C. Between the driest and wettest months, the difference in precipitation is 129 mm and the average temperatures vary by 5.1 °C (Climatic Data Org, 2016). Drought tolerant crops like family of sorghum, groundnuts, sunflower, and little maize mainly characterise the area. Sites in Bahi District were set in four villages, namely Mayamaya, Bahisokoni, Mudemu and Mpamatwa.

Morogoro Region is located between latitude 5°58’ 10°0’S and longitude 35°30’E and an altitude of about 525 m above sea level. The annual rainfall ranges from 600 to 1200 mm with average annual temperature of about 25 °C. The zone is characterised with an average annual rainfall of 1160 mm and average temperature of 16 °C. There are typically two distinct long and short rainy seasons, that is from March to May, and from November to January or February, but the rain sometimes falls uninterrupted from October to March. The Udzungwas and extensive river system have deposited rich alluvial sediments in the valley (Climatic Data Org, 2016). Rice and maize production, horticultural produces and bananas dominate the production system in Ifakara District. The on-farm test sites were located in four villages, namely Kibaoni, Kikwelila, Lipangalala and Lumemo.

Njombe Region is located between latitude 8°51`0′S and longitude 34°50′0′E and an altitude of about 2000 m above sea level. Its climate is classified as warm and temperate. In winter, there is much less rainfall than in summer. The average annual rainfall is 1160 mm with average temperature of 18.6 °C (Climatic Data Org, 2016). On-farm test sites were located in four villages, namely Ujindile, Uhambule, Msimbazi and Ufwala. Maize, sunflower, pulses and horticultural production dominate the farming system in the sites.

2.2. Research design

This article adopted ACGG developmental design whereby farmers were selected and provided with introduced chicken based on their farming practices, typically low input production system. Developmental research design assumes a traditional model of skill in which the unit of analysis is taken to be the individual, as if expertise in the form of explicit or tacit knowledge, skills and cognitive properties (AFNETA, 1992 and Richey, 1994). In this context, the design considered process and context of chicken keeping. Process refers to the technical requirement of chicken keeping while context stressed on the socio-economic characteristics and biophysical conditions that might affect growth and productivity. Paikoff (1996) argues that, the developmental approach can assist in determining the most effective agents of influence. The regions and districts were purposively selected to capture the effect of agro ecological difference on the performances of strains. On the other hand village were first selected purposively by considering presence of extension officers and finally randomly to select four villages from those which had extension officers. Households were first selected purposely based on the set criteria and then randomly selection from those who met the criteria. Households, recruited to receive the chickens met the following criteria:

i. Experience of chicken keeping for at least two years;
ii. Keeping at least 15 adult chickens, but not more than 50 > 50;
iii. Willingness to accept 25 birds of randomly selected strains;
iv. Commitment to provide night shelter, and a minimum supplemental feeding, and
v. Willingness to participate in the project for a minimum of 72 weeks.

Implementation of the design involved provision of 25 six weeks pre-brooded chicks to selected farmers. The chicks were vaccinated against Mareks and Newcastle diseases at the hatchery, followed by Infectious Bronchitis (IB) at 0, 7 10, 16 and 21 days. Newcastle Disease vaccine was repeated after 10 and 21 days using LaSota vaccine. Additionally, the chicks were again vaccinated against fowl pox after 6 weeks before they were supplied to farmers. Farmers continued keeping these strains based on their practices with additional supplementation and were encouraged to keep records for evaluation purposes.

2.3. Data sources

The relevant target population for the study was local chicken farmers participating in the ACGG project in the on-farm test sites. A total of 202 out of 264 targeted beneficiary households in the 12 villages were involved in the study. The households that were involved represented 76.5% of the total intervened households in the study zones. Out of the total famers, 111 farmers were Sasso strain keepers whereas 91 farmers were Kuroiler chicken strain farmers. This study used four main data sources: (a) household survey, (b) on-farm test data production and marketing data, (c) historical data especially prices of both inputs and outputs, and (d) simulation exercises. Different sources of information, including historical data, can be used to establish a stochastic simulation of net economic returns (Richardson et al., 2007a; Vorotnikova et al., 2014). Specifically, data collected include chicken production data: strains of chicken kept, number of chickens, number of eggs sold, hatched, ready for sale, number of chicks or chicken sold and ready for sale, chicken keeping inputs (amounts and prices of feeders,

Table 1
Descriptive data of chicken feeding, prices, discount rate and rate of return for an off-farm investment.

Variable						Value
Discount rate for Net Present Value (NPV)						0.10
Rate of return for an off-farm investment						0.05
Current Exchange Rate to US Dollar-Tanzania shilling (US$)						2286
Quantities of variable inputs fed to chicken strains						
Statistics	Maize bran (kg)	Rice bran (kg)	Sunflower cake (kg)	Fishmeal (kg)	Minerals (kg)	Vegetables (bundle)
Kuroiler strain						
Mean	7.49	6.58	1.83	0.65	0.55	2.27
SD	4.56	3.6	1.79	0.6	0.55	0.87
Minimum	1.01	1.69	0.11	0.1	0.02	0.85
Maximum	21	17.82	7.37	2.42	2.88	3.56
n	91	57	58	34	48	17
Sasso strain						
Mean	9.46	5.19	3.11	0.9	0.63	3.2
SD	5.03	2.12	2.23	0.68	0.59	3.02
Minimum	1.52	1.1	0.17	0.08	0.04	1.09
Maximum	26.54	8.78	11.53	2.43	2.21	16.33
n	105	17	54	16	32	25
Local chickens						
Mean	1.79	1.26	0.51	0.15	0.12	0.59
SD	1.03	0.67	0.44	0.13	0.12	0.51
Minimum	0.2	0.23	0.02	0.02	0	0.17
Maximum	5.69	3.5	2.47	0.52	0.57	3.5
n	163	71	110	50	77	43
Prices of inputs (US$)/Kg						
Statistics	Maize bran	Rice bran	Sunflower cake	Fishmeal	Minerals	Vegetables
Mean	0.16	0.05	0.32	0.61	0.64	0.09
SD	0.05	0.02	0.17	0.21	0.32	0.01
Minimum	0.10	0.02	0.04	0.22	0.13	0.09
Maximum	0.31	0.15	0.66	0.87	1.09	0.11

brooder, chicks, eggs, feeds, medicines, vaccines, labour and time spent), number of chicks or chicken mortalities, number of eggs not hatched and the cost of constructing a chicken coop.

2.4. Variables measured

Two variables i.e. chicken weight and feeds were measured by using digital weighing balance (HDB10K10N Hanging Scale). The farmers and field officers cooperated to weigh the live birds for the interval of two weeks and the records were taken for about 56 weeks. Data on feeds were obtained by weighing the quantity provided to chickens daily. Feed provision varied according to seasonal conditions. The conditions were classified as harvesting, harsh months and intermediate condition. In each condition, farmers were asked to estimate the level and frequency of providing feeds to estimate total supplement provided per cycle (12 months). Tables 1 and 2 summarise data used in this paper whereby Table 1 indicates inputs and their prices, discount rate, rate of return for off-farm investments and exchange rate whereas Table 2 summarises farm outputs and prices.

Table 2
Chicken production, sales and production expenses.

Variables/chicken technologies (scenarios)	Local chicken	Kuroiler	Sasso	Local chicken	Kuroiler	Sasso
	Hens			Pullets		
Mortality rate	0.06	0.30	0.30	0.47	0.56	0.57
Minimum price	3.06	4.37	3.94	2.19	3.94	3.50
Average price	4.37	5.25	6.12	3.94	6.12	6.56
Maximum price	6.56	8.75	8.75	5.68	7.43	7.87
	Cockerels			Roosters		
Mortality rate	0.08	0.09	0.09	0.41	0.59	0.54
Minimum price	3.06	4.37	3.50	3.06	4.37	3.50
Average price	5.25	7.87	7.43	5.25	7.87	7.43
Maximum price	8.75	13.12	15.30	6.56	7.87	8.31
Egg production and prices across				Local chicken	Kuroiler	Sasso
Minimum price of a dozen eggs (US$)				1.05	1.05	1.05
Average price of a dozen eggs(US$)				1.91	2.06	1.88
Maximum price of a dozen eggs(US$)				2.62	2.62	2.62
Egg production per hen –Minimum				28	19	20
Egg production per hen –Average				30	52	58
Egg production per hen –Maximum				42	95	109
Fraction of eggs for hatching				0.8	0.09	0.09
Cost of chicken production						
Average Annual expenses per chicken				0.52	5.08	5.63

2.5. Data analysis and Monte Carlo simulations

Farm Level Economic and Nutrition Analysis (FARMSIM); a farm level Monte Carlo simulation model (Bizimana and Richardson, 2019) was adopted to assess economic viability of introduced chicken strains in 12 villages from three regions. Simulation implies a different way of approaching a scientific research (Mwinuka et al., 2017). Simulation is an increasingly significant methodological approach to theory development in the literature that focuses on strategy and organisations (Davis et al., 2007). Therefore, economic models and micro-level simulations are in urgent need for informing decision-making (Fontana, 2005). To simulate by using FARMSIM, Simulation and Econometrics to Analyse Risk (Simetar©), an excel add-in is needed as simulating engine. A Monte Carlo simulation modelling approach was used because it is the best methodology for estimating probability distribution of unknown variables such as the rate of return on investment for a business (Richardson et al., 2007b). In other words, the greatest benefit of a Monte Carlo Simulation analysis is that the methodology explicitly incorporates the risk faced by investors to develop realistic probabilistic forecast of Key Outcome Variables (KOVs) (Richardson et al., 2007a).

FARMSIM is an extension of the Farm Level and Income Policy Simulation (FLIPSIM) model available in Microsoft Excel format which has been used extensively to simulate the impacts of alternative policies and farming systems on representative farms (Clarke et al., 2017). FLIPSIM is a FORTRAN simulation model that uses accounting equations, identities, and probability distributions to simulate annual economic activities of a representative or actual farm over a multiple year planning horizon. Richardson (2006) outlined the steps for developing a production based investment feasibility simulation model. First, probability distributions for all risky variables must be defined, parameterised, simulated and validated. Second, the stochastic values from the probability distributions are used in accounting equations to calculate production, receipts, costs, cash flows and balance sheet variables for the project. Stochastic values sampled from the probability distributions make the financial statement variables stochastic. Third, the completed stochastic model is simulated many times using random values for the key risky variables. The results of the sample provide information used to estimate empirical probability distribution for unobservable KOVs (e.g. present value of ending worth, net present value, and annual cash flows) so that investors can evaluate the probability of success for a proposed project. Fourth, the analyst uses the stochastic simulation model to analyse alternative management scenarios and provides the results to decision makers in the form of probabilities and probabilistic forecast for the KOVs. To estimate differing economic viability indicators based on chicken farming system scenario, the study compared the NPV and NCFI distributions of chicken technologies: keeping local chicken without supplementation, local chicken with supplementation, Sasso strain and Kuroiler strain (Tables 1 and 2).

NPV was estimated by discounting the profits; a 10% discount rate was used. To estimate profit or NCFI, the revenue was first calculated by considering production as a product of eggs and live chicken sold multiplied by price. Next, total costs were estimated as a sum of both variable and fixed costs (farm expenses). These costs include the cost of buying feeds (maize and rice brans, fishmeal, sunflower cake, vegetables and proportion of cost of house construction.

Thus, for the production season, profit or NCFI was calculated using Eq. (7). Distributions of simulated NPV of net returns were generated using Monte Carlo simulations for 500 iterations (Eq. (10). The performance of the chickens strains as estimated by each of the two indicators were displayed graphically as Cumulative Distribution Function (CDF) and the stoplight graph. Charts and probability portray more accurately the probable outcomes than single point estimation [for an investment] (Richardson et al., 2007a).

The outputs from Stoplight graphs depict the probabilities of each chicken technology being less than the lower cut-off value (the lowest mean) and greater than cut-off value (the highest mean). The probabilities of economic indicator of each technology exceeding the upper cut-off value are presented numerically and it is preconditioned to be coloured in green. The yellow segments represent the probability that values fall between the lower and upper cut-off values and the red segment presents the probability that the value is below the lower cut-off (Clarke et al., 2017; Bizimana and Richardson, 2019).

The present study used Gray-Richardson-Klose and Schuman (GRKS) distribution in simulation and estimation of economic viability indicators. The GRKS distribution is a continuous probability distribution which uses minimum, mean and maximum values of the key variables in analysis. With respect to present study, variables of interest were number of eggs, number of live birds, prices of eggs and birds, proportions of birds or eggs consumed, morality rate and costs of inputs used. Traditionally, data for simulation of KOVs in the FARMSIM (Richardson et al., 2016) and any simulation model or engine have been done using experts' knowledge, historical data (Clarke et al., 2017) to empirically ascertain the chances of an event to occur without actually incurring the risk and costs of a true business (Hasegawa et al., 1990). However, this paper advanced the approach by largely using data collected from the on- farm test and real market prices for the on-farms inputs and outputs which in turn were used to simulate the distribution of the farm economic returns.

FARMSIM model uses several equations to estimate and simulate the key outcome variables useful in comparing impact of technologies.

The following are the summary of equations:

$$\text{Estimate/Simulate it as} = \text{GKRS}(\text{Max}, \text{Mean}, \text{Min}) \tag{1}$$

$$Q_{it} = \beta_{jt} K_{jt} \tag{2}$$

Q_{it} is the total output of product for chicken j (eggs and live birds), β_{jt} is the number of chicken j (e.g. hen); K_{jt} is number of eggs and chicks per chicken in time t,

$$\text{Qit} \sim \text{GRKS}(\text{Max}, \text{Mean}, \text{Min}) \tag{3}$$

$\sim$ implies the quantity of output, Q_{it} follows GKRS distribution

$$P \sim \text{GKRS}(\text{Max}, \text{Mean}, \text{Min}) \tag{4}$$

P is the price of inputs and outputs, $\sim$implies all prices follow GRKS distribution

$$TR_t = \sum_{i=1}^{i} Q_{it} * P_{it} + \sum_{j=1}^{j} Q_{lt} * P_{lt} \tag{5}$$

TR_t is the total revenue from both crop production of crops i and livestock keeping j in time t, Qc_{it} is the number of eggs and chicken for introduced ones in time t, P_{it} is the price of introduced chicken products i, Q_{lt} and P_{lt} is the number of eggs and chicken and price respectively for local chicken in time t.

$$TC_t = FC_t + \sum_{i=1}^{i} VC_{it} + \sum_{j=1}^{j} VC_{lt} \tag{6}$$

TC_t is total cost, FC_t is fixed cost, VCc_{it} is the variable costs for introduced chicken strain i and VC_{lt} is the variable cost of local chicken in time t.

$$NCFI_{ct} = TRc_t - TC_{ct} \tag{7}$$

$NCFI_{ct}$ is the net cash income in time t for chicken outputs, TR_{ct} is the total revenue for chicken outputs and TC_{ct} is the variable total cost involved in chicken keeping.

$$CR_t = \text{If}(EC_t > = 0, EC_t, 0) \tag{8}$$

CRt is cash reserve and ECt is the ending cash both in time t

$$CFD_t = \text{If}(ECB_t < 0, (-1 * ECB_t)) \tag{9}$$

CFD_t is the cash flow deficit and ECBt is the ending cash balance in time t

$$NPV_i = \sum_{t=1}^{5} NR_{it} \Big/ (1 + r)^t + \sum_{t=1}^{5} CNW_t \Big/ (1 + r)^t \tag{10}$$

NPV_i is the net present value for chicken strain i, NR_{it} is the net return for strain i in time t, r is estimated interest rate, CWN_t is the change in net worth.

Further, risk is an inherent part of the production process and plays an important role in farmers' decision whether to adopt new agricultural technology because of risky attitude towards risk (Kumbhakar, 2002; Nalley and Barkley, 2007). The inclusion of risk measures in agricultural innovations assessment concretes right inferences on which innovation was the most preferable by which farmers based on farmers' behaviour towards risk. In other words, chances of bad versus good outcomes can only be evaluated and compared knowing the decision maker's relative preferences for such outcomes (Schumann et al., 2004). This is very important since nearly all farmers are risk-averse, i.e. most will accept fewer dollars of return for fewer dollars of variability or loss (Fathelrahman et al., 2011). Apparently, some indorsed innovations may be so risky to extent that added risk offsets the gain in income, leading to worsening the livelihoods of smallholder farmers. Richardson et al. (2008) summarise several numerical methods for ranking risky alternatives based on farmers' risk altitude, viz.; First-degree Stochastic Dominance (FSD) and Second-degree Stochastic Dominance (SSD), Stochastic Dominance with Respect to a Function (SDRF) and Stochastic Efficiency with Respect to a Function (SERF). Others include Risk Premiums, Target Probabilities for Ranking Risky

Alternatives and Target Quantiles for Ranking Risky Alternatives. The review of literature indicates that SERF is superior to others (Schumann et al., 2004; Hardaker and Lien, 2010; Fathelrahman et al., 2011 and Asci et al., 2014). SERF is a procedure for ranking risky alternatives based on their certainty equivalents (CE) for alternative Relative Risk Aversion Coefficient (RRACs). A certainty equivalent (CE) is equal to the amount of certain payoff an individual would require to be indifferent between that payoff and a risky investment (Watkins et al., 2008). It can be applied for any utility function form based on the full range (i.e. from negative to positive) of a Relative Risk Aversion Coefficient (RRACs). Lastly, it is one of a few risk analysis techniques that can be used to easily visualise the stochastic frontier across the entire r range, where preferences for a particular alternative may be illustrated (Fathelrahman et al., 2011).

This study applied the Exponential Utility Function built in Simetar@ 2006 as shown hereunder:

$$U(w) = -\exp(-r_a, w) \tag{11}$$

where r_a is RRACs and w is maximum NCFI attained for keeping strained chicken.

3. Results and discussions

3.1. Economic viability of introduced chicken strains

3.1.1. Net present value (NPV) for chicken strains

The Cumulative Distribution Function (CDF of NPV values for introduced chicken technologies are illustrated in Fig. 1. Overall, the NPV results indicate clearly that Sasso chicken is the most economic viable with the highest probability of gaining more income for improved livelihood. Local chicken production has the lowest mean (7.16) and the least risk (lowest standard deviation (20.47)). Keeping Sasso strain has the CDFs which indicate the possibility of getting NPV up to US$306.08 with a flock of 60 chickens. However, the application of input is very crucial for the economic potential of Sasso chicken strain. This is indicated by its NPV distribution, which lies mostly to the left with negative NPV of about US$153.04.

Kuroiler was the second strain with its CDF distribution lying between Sasso and local chicken strain along the positive NPV scale. However, the CDF distribution lies to the left of local chickens along the negative side of the NPV scale. This implies that the economic viability of Kuroiler strains is greater than that of local chicken but with higher probability of loss due to mortality rate than local chicken. The average cumulative mortality recorded at farmers' level, condition after 6 weeks old till the age of 68 weeks was 27.0% and 27.1% for Sasso and Kuroiler respectively. The mortality of Sasso strain was somehow higher than the mortality recorded Ethiopia whereby mortality at farmer level condition after 45-day old till the age of production was 25% (Getiso et al., 2017). The highest mortality was observed at the age between 26 and 42 weeks. Kuroiler and Sasso strains showed the highest mortality rate of 5% and 3.5% between 26 and 42-week age. Farmers and extension officers reported the signs of egg peritonitis and related infections as the plausible causes of mortality between that age interval. Egg

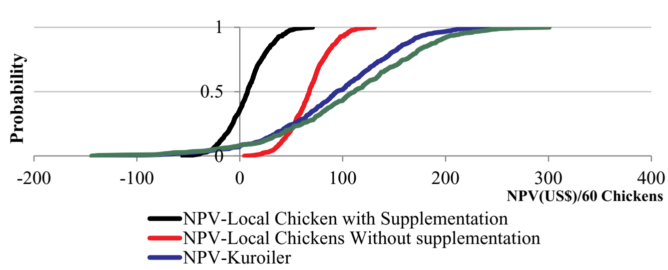

Fig. 1. Cumulative density function of net present value (NPV).

yolk peritonitis is the inflammatory reaction of peritoneum caused by the presence of yolk material in the coelomic cavity (Srinivasan et al., 2013). This is in line with Srinivasan et al., (2013) who reported that egg peritonitis was responsible for 15.39% of the reproductive tract abnormalities in commercial layers between 21 and 80 week of age. Other recorded causes of mortality included diarrhoea, Cannibalism, Coryza, fowl cholera, typhoid, toxic, accident and respiratory infections. Generally, the total mortality was found to be 27% and 27.1% for Sasso and Kuroiler, respectively.

In three sites, local chickens were kept by both purely extensive and semi extensive (some with supplementation). Fig. 1 shows that the NPV ranges between negative US$55.58 and US$ 70.78 and between US $4.53 and US$130.89 for local chicken with supplementation and with no supplement, respectively. This indicates that supplementation is costlier, given the low genetic potential of local chicken. However, the variation for local chickens was lower which implies that the probability of getting higher profit or loss is low if the strain is kept under pure extensive system. The CDF graph in Fig. 1 indicates NPV for Sasso chicken lies to the right of others. However, the both Table 3 and Fig. 1 show the minimum NPV being negative in both introduced chicken strains and in local chicken with supplementations. The negative NPV for introduced strains was due to the high mortality, which was associated with diseases, cannibalism and unexpected low egg production whereas for local chicken, the negative NPV was mainly due to expenditure on feeds. For Sasso, the high prices of the live birds and many eggs positioned them with higher NP. Based on the summary statistics in Table 3 supported by the CDF graph, it is plausible to conclude that keeping Sasso chicken is more economically viable, Kuroiler being the second most followed by local strain without supplementation and lastly local chicken with supplementation.

The stoplight chart (Fig. 2) presents the probabilities of NPV which is less than US$ 7.16 (red), greater than US$ 106.41 (green), and between the two target values (yellow) for the five-year planning horizon. The target values are the average of NPV for the lowest performing strain (local chicken with supplementation) for the lower bound; and the average of NPV for the best-performing strain (Sasso) for the upper bound. For the local chicken with supplement scenario, there was a 49% chance that NPV was < 7.16% and 0% chance that NPV would exceed US$106.41. For the local chicken without supplementation, there was 96% probability of having NPV ranging between US$7.16 and 105.97 and only 03% probability to exceed US$106.41. For the Kuroiler and Sasso chicken keeping, there was 44% and 52% probability of generating NPV greater than US$106.41. These results suggest that investments in both Kuroiler and Sasso strains would increase productivity, offset the costs, and pay large dividends by increasing income.

3.2. Cash farm income (NCFI)

Annual NCFI measures the amount of profit generated by the farm for each chicken technology. The summarised results (Table 4) indicate that in terms of mean NCFI, Sasso chicken had the largest mean NCFI (US$29.41) followed by Kuroiler strain (US$23.50). Local chicken without supplementation performed thirdly with NCFI (US$ 22.79) whereas local chicken with supplementation generated the lowest mean NCFI (US$2.62). Further, CDF for NCFI (Fig. 3) shows that both Sasso and Kuroiler chicken strains generated higher NCFI than local chicken strain under different management systems. However, both the introduced strains had minimum NCFI with negative values. Farmers explained that main problems they faced in keeping the introduced chicken strains were mortality rate, delayed eggs production and high expenditure on feeding and medicines.

The stoplight chart for NCFI shows that, keeping local chicken without supplementation, there was 06% probability that NCFI would be less than US$2.62 and 44% probability that NCFI would exceed US$ 29.41. In contrast, there was a 51% chance that annual NCFI was less

Table 3
Summary statistics for NPVs (US$) of chicken technologies

Statistics	NPV-local chicken extensive	NPV-local semi-extensive	NPV-Kuroiler	NPV-Sasso
Mean (US$)	7.16	67.28	92.05	106.41
SD (US$)	20.47	21.39	63.55	74.08
Minimum (US$)	−55.58	4.53	−126.66	−144.05
Maximum (US$)	70.78	130.89	254.60	300.74

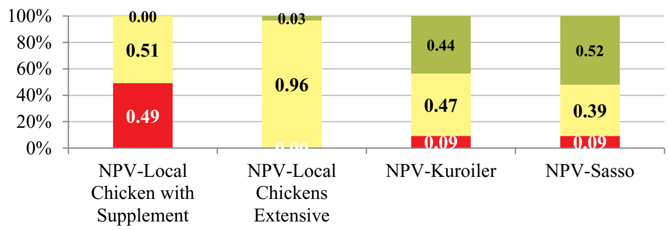

Fig. 2. Stoplight chart for probabilities of NPV less than US$ 7.16 and greater than US$106.41

Table 4
Summary statistics for NCFI for chicken strains.

Summary statistics	Local chicken extensive	Local chicken semi- intensive	Kuroiler	Sasso
Mean (US$)	22.79	2.62	23.50	29.41
Standard Deviation (US$)	9.41	8.54	37.55	46.11
Minimum (US$)	−4.04	24.21	−199.34	−245.89
Maximum (US$)	50.21	30.04	82.62	113.38

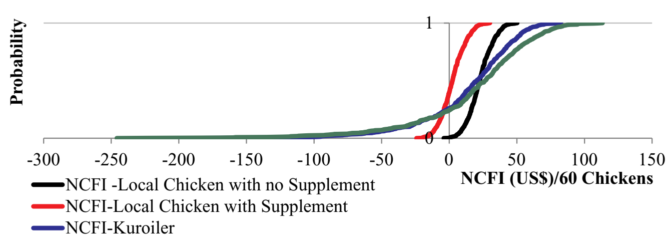

Fig. 3. Cumulative density function of net cash farm income (NCFI) (US$).

than US$2.62 and 0.2 possibility of having NCFI greater than US$29.41 for keeping local chicken with supplementation. For Sasso and Kuroiler chicken strains, there were 26% and 27% chances of getting NCFI less than US$2.62 respectively. Also, there were 53% and 47% respectively of probability of achieving NCFI greater than US$29.41. However, there was high variability in NCFI of Sasso and Kuroiler strains compared to NCFI for local chickens. The observed variability was due to high mortality rate, delayed egg production and high expenditure on feeding introduced strains. For example, in Sasso strain, farmers probably could get loss of US$ 250 (Fig. 3) for just keeping 60 chickens. These results suggest that keeping introduced chicken strains is riskier than local chickens.

3.3. Effect of agro-ecological differences on performance of introduced chicken strains

Kuroiler strain performed the best in Wanging'ombe (Tables 5 and 6, Figs. 5, 6 and 7) sites compared to Ifakara and Bahi sites. However, there is no performance gap (NPV and NCFI) between Bahi and Ifakara. This implies that the performances of Kuroiler in Bahi and Ifakara sites were likely similar.

The stoplight chart for NCFI (Fig. 6) shows that, for Kuroiler farming in Ifakara, the probability that NCFI would be less than US$16.60 is

Table 5
Summary statistics for NCFI (US$) Kuroiler chicken strain.

Statistics	Ifakara	Wanging'ombe	Bahi
Mean (US$)	106.62	240.20	112.80
Standard Deviation (US$)	87.09	113.35	70.83
Minimum (US$)	−215.44	−184.80	−133.59
Maximum (US$)	304.64	490.56	283.77

Table 6
Summary statistics for NCFI (US$) Kuroiler chicken strain.

Statistics	Ifakara	Wanging'ombe	Bahi
Mean (US$)	16.54	53.51	18.44
Standard Deviation (US$)	39.82	54.22	33.42
Minimum (US$)	−204.10	−257.46	−160.36
Maximum (US$)	72.62	129.33	68.74

36% and 7% probability that NCFI would exceed US$53.67. In Bahi District, there was 35% possibility that annual NCFI would be less than US$16.60 and just a 5% probability that NCFI would be greater than US $53.67. In Wanging'ombe sites, there was 18% probability that NCFI would be less than US$16.60 and 65% probability that annual NCFI would exceed US$53.67. With this regard, Kuroiler performed the best in Wanging`'ombe sites.

On the other hand, the NPV for Sasso (Table 7 and Fig. 8) indicates that the strain performed well in Bahi sites followed by Wangingòmbe and Ifakara was the least. Keeping about 60 Sasso chickens, the enterprise can generate a mean of NPV about 88.87, 152.07 and US$77.73 (Table 6) in Bahi, Wanging'ombe and Ifakara respectively. Nevertheless, keeping Sasso strain in Wanging'ombe District has the highest possibility of generating loss with NPV 268.73 per 60 flock. Table 8 and Fig. 9 detail the performance trends of Sasso strain across the three agro-ecological zones.

The NCFI results (Table 8 and Fig. 9) highlight the superior performance of Bahi sites to Wanging'ombe and Ifakara sites. Keeping about 60 Sasso chickens, the enterprise can generate a mean NCFI 30.59, 16.23 and 10.15 US$ in Bahi, Wanging'ombe and Ifakara respectively.

The stoplight chart for NCFI (Fig. 10) shows that there was 25% probability that NCFI would be less than US$23,151 and the 58% probability that NCFI exceeds US$30.59 in Bahi sites. In contrast, in Wanging'ombe sites, the probability that annual NCFI would exceed US $ 30.59 is 44% and the probability that NCFI would fall between US $10.15 and 30.59 was 21%. In Ifakara sites, there was on average 36% probability that NCFI exceeds US$ 30.59 and a 24% probability that annual NCFI would fall between 10.15 and US$30.59. Overall, keeping

Table 7
Summary statistics for NPV (US$) for Sasso chicken strain.

Summary statistics	Ifakara	Wanging'ombe	Bahi
Mean (US$)	77.69	88.83	152.01
Standard Deviation (US$)	89.97	96.44	92.37
Minimum (US$)	−252.25	−268.62	−183.70
Maximum (US$)	285.09	295.05	372.79

Table 8
Summary statistics for NCFI for Sasso chicken strain.

Summary statistics	Ifakara	Wanging'ombe	Bahi
Mean (US$)	10.15	16.22	30.58
Standard Deviation (US$)	46.70	49.81	45.66
Minimum (US$)	−255.42	−263.81	−215.81
Maximum (US$)	91.39	105.48	118.92

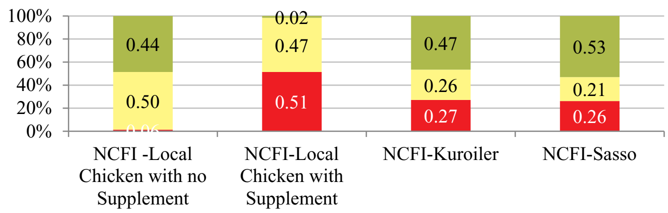

Fig. 4. Stoplight chart for probabilities of NCFI less than US$2.62 and greater than US$29.41.

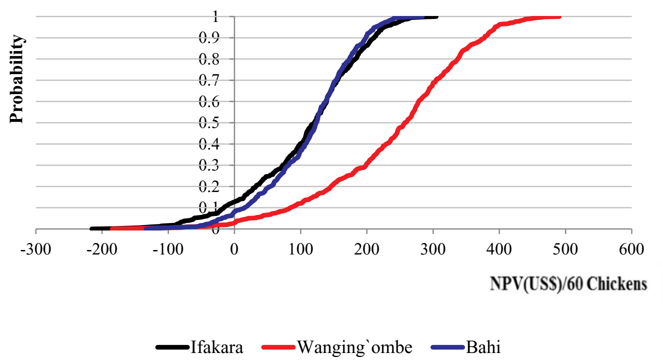

Fig. 5. NPV for Kuroiler across three agro-ecological zones.

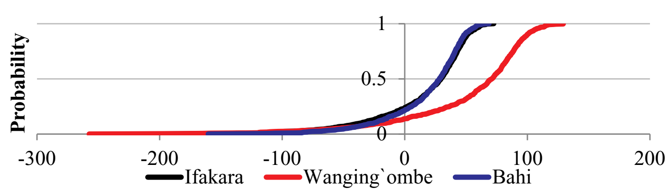

Fig. 6. NCFI for Kuroiler across three agro-ecological zones (US$).

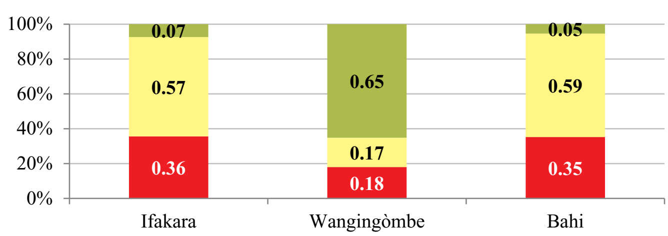

Fig. 7. Stoplight chart for probabilities of NCFI less than US$ 16.60 and greater than US$ 53.67.

Sasso strain was the most economically viable enterprise in Bahi District.

Comparatively, Sasso strain is recommendable to all sites as the performance differences were found small (Table 7, Figs. 9 and 10) compared to performance differences of Kuroiler across three sites (Table 6, Figs. 7 and 8). Generally, higher economic returns of introduced chicken strains were noted fairly influenced by higher average eggs per hen and higher prices of the live birds compared to the local

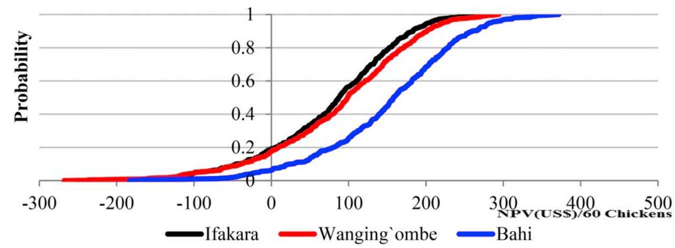

Fig. 8. NPV for Sasso across three agro-ecological zones.

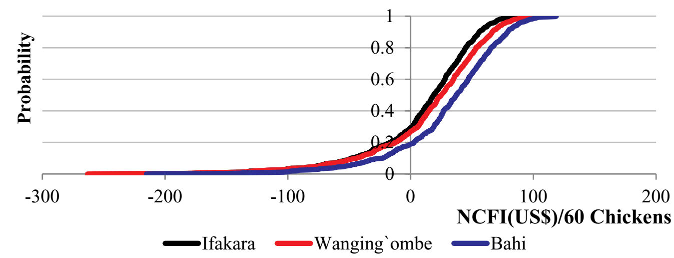

Fig. 9. NCFI for Sasso across three agro-ecological zones.

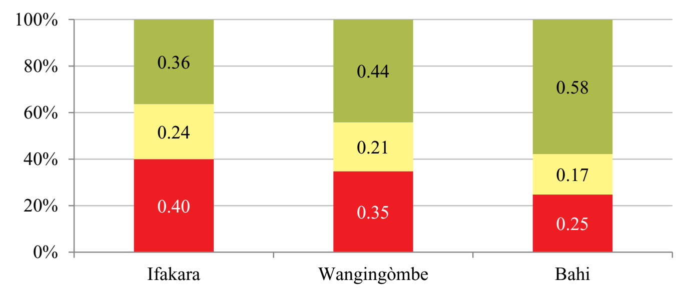

Fig. 10. Stoplight chart for probabilities less than US$ 10.15 and greater than US$ 30.59.

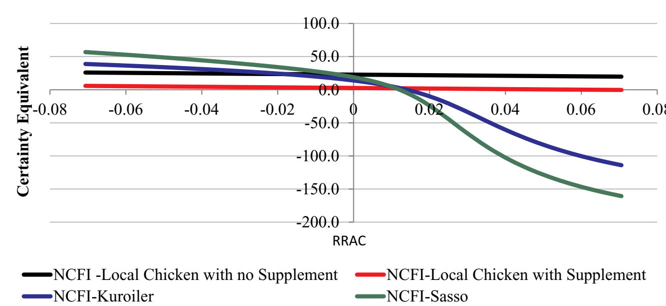

Fig. 11. SERF chart for net cash farm income for chicken strains.

chickens. On the other hand, the current study noted that the economic return stability in the local chicken enterprise was due to low variation in egg production, output selling prices and low variation in mortality rate (Table 2).

3.4. *Chicken strains preference with respect to farmers' risk attitude with SERF*

As a reminder, SERF is used to determine the preferred strain under various risk preferences. SERF analyses (Fig. 11) indicate that for the extremely risk -averse and moderately risk-averse farmers, local chicken without supplement was most preferred. Local chicken with supplement was the second most preferred followed by Kuroiler strain. Sasso strain was typically the least preferred system by the extremely risk-averse and moderately risk-averse farmers. Fig. 11 indicates that, the extremely risk-averse farmers would need to receive about US$170 and US$130 for keeping about 60 Sasso strain and Kuroiler strain respectively to be indifferent between keeping introduced strains and local chickens without supplement (highest ranked).

Normal slightly risk aversion and risk neutral farmers preferred the most keeping local chicken without supplement. Sasso was the second followed by Kuroiler and local strain was the least preferred. Nearly risk neutral farmers at both extreme were likely indifferent between Sasso, Kuroiler and local chicken strain since the gaps between the lines is very narrow. Sasso strain was preferred the most by strongly risk loving individuals whereas Kuroiler strain was the second. Local chicken was the third preferred most whereas local chicken with supplement was the least. Using stoplight charts (Fig. 4), Sasso strain was found providing higher probability of gaining more income (53%) compared to local chicken without supplement (44%). In conjunction with risk behaviour of farmers towards these strains, only very extreme risk loving farmers would go for the Sasso strain whereas the rest would maintain their status quo. As detailed (Figs. 3 and 4), the performance of Sasso strain is so risky due to higher performance variability compared to local chicken without supplement. With this regard, efforts to reduce variability in performances for Sasso and Kuroiler strains is very important for harnessing the potential of the new strains to benefit the majority.

4. Conclusions and recommendations

This paper contributes to the production economics, adoption and poultry farming literature by integrating on-farm test and economic viability assessment based on the farm test data by establishing economic viability of introduced chicken strains relative to available local chickens in different agro-ecological zones. The article evaluated the economic viability of introduced chicken strains relative to the available local chickens in Ifakara, Wanging'ombe and Bahi districts. Local chicken strains were compared with two strains namely Kuroiler and Sasso. Overall, Keeping Sasso strain generated the most Net Present Value, Annual Net Farm Income and the highest probability of attaining more income from keeping chicken. Kuroiler is the second performer regardless of the agro-ecological zones. The results rank third local chicken without providing supplements whereas the provision of supplement scored the least. However, the results indicate that there is high variability in economic viability of Kuroiler and Sasso strains. The variability realised was due to mortality rate and delay and unexpected stop laying of hens. The performance across agro-ecological zones depicts that Kuroiler performed the best in Wangingòmbe sites followed by Bahi sites and Ifakara site was the least. Sasso strain performed the best in Bahi followed by Wanging'ombe and Ifakara was the least. Inclusion of risk behaviour analyses revealed that extremely risk-averse farmers preferred most keeping local chickens without provision of supplements whereas extremely risk loving farmers preferred the most Sasso strain followed by Kuroiler. The present study recommends that the introduced chicken strains have to be promoted for adoption to increase household income for improved livelihood. However, scaling up of the introduced chicken strains must be integrated with education on technical know-how on good farming practices; feed formulations, medication and shelter for improved productivity.

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