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Village chicken production and egg quality in dry and wet, resource-limited environments in KwaZulu-Natal, South Africa

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Abstract

The study investigated the quality and production of village chickens in wet and dry environments. Three hundred households were interviewed using a semi-structured questionnaire. Both external and internal characteristics were measured in 4 000 eggs using visual observation and laboratory analyses. The main source of income for the households in both environments was government grants. Village chickens were largely kept for eggs, meat, income, leisure, and rituals. The proportion of households selling eggs was low (less than 3%). Village chicken productivity was constrained by feed shortages, high disease prevalence, theft, slow growth, predation, and lack of access to the market. Feed availability varied seasonally. The dry environment produced 30% more eggs, which was an anomaly. Egg weights were larger (49.8 g) in wet than dry environments (39.6 g). It was concluded that egg quality and production were affected by feed availability. To improve egg production and quality, the environment should be improved using inputs such as feeding programs and housing.

Keywords: contribution, challenges, food, and nutrition security, productivity
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Introduction

Resource-limited households lack opportunities and information and are often food insecure. This forces migration to cities and increase the pressure of services in urban areas (Bisht, 2021). It is crucial to develop sustainable agricultural strategies for livelihoods to increase the well-being of resource-limited households. In developing countries, village chickens are predominant. Improving productivity of village chickens has a huge opportunity to enhance food and nutrition security and rural development. Crush and Frayne (2011) highlighted that households who engage in food production have better food security with a secured nutritional status than non-farming households of the same socio-economic status.

Village chickens are reared under backyard production systems for household consumption. Although they are adapted for local environments, egg quality is questionable (Sanjeewa *et al.*, 2011; Bettridge *et al.*, 2018). Village chickens meet their nutritional requirements by scavenging. As such, environmental conditions are key to their productivity. Natural environmental conditions are largely defined by rainfall, ambient temperatures, vegetation type, and parasite infestations. Low levels of management yield low input and output of village chicken products. Eggs are a good source of protein and provide essential nutrients (Schonfeldt and Hall, 2013; Vogliano *et al.*, 2021). The village chickens, however, produce low numbers of eggs. This is due to their low genetic potential, the extremely variable ambient temperatures, low levels of management, and insufficient feed resources (Desta, 2021b).

There is a need to assess the influence of these factors on village chicken productivity. In addition to productivity, there is a need to assess the quality of eggs, since they influences chick growth and survival (Fu *et al.*, 2021). The purpose of the study was to determine how village chickens can be used in resource-poor households. The study investigated the quality of eggs from village chickens in wet and dry environments of KwaZulu-Natal, South Africa. It was hypothesized that egg quality in village chickens was low and affected by the type of environment.

Materials and Methods

The study complied with the standards required by the Human Social Science Ethics Committee of the University of KwaZulu-Natal (Protocol Reference Number: HSS/1880/017M).
The study was conducted in uMgungundlovu district (29.617° S 30.383° E), KwaZulu-Natal, South Africa. KwaShange and eNtembeni villages are two environments that represent dry and wet environments, respectively (Figure 1). Participants that were rearing village chickens were selected on their discretion.

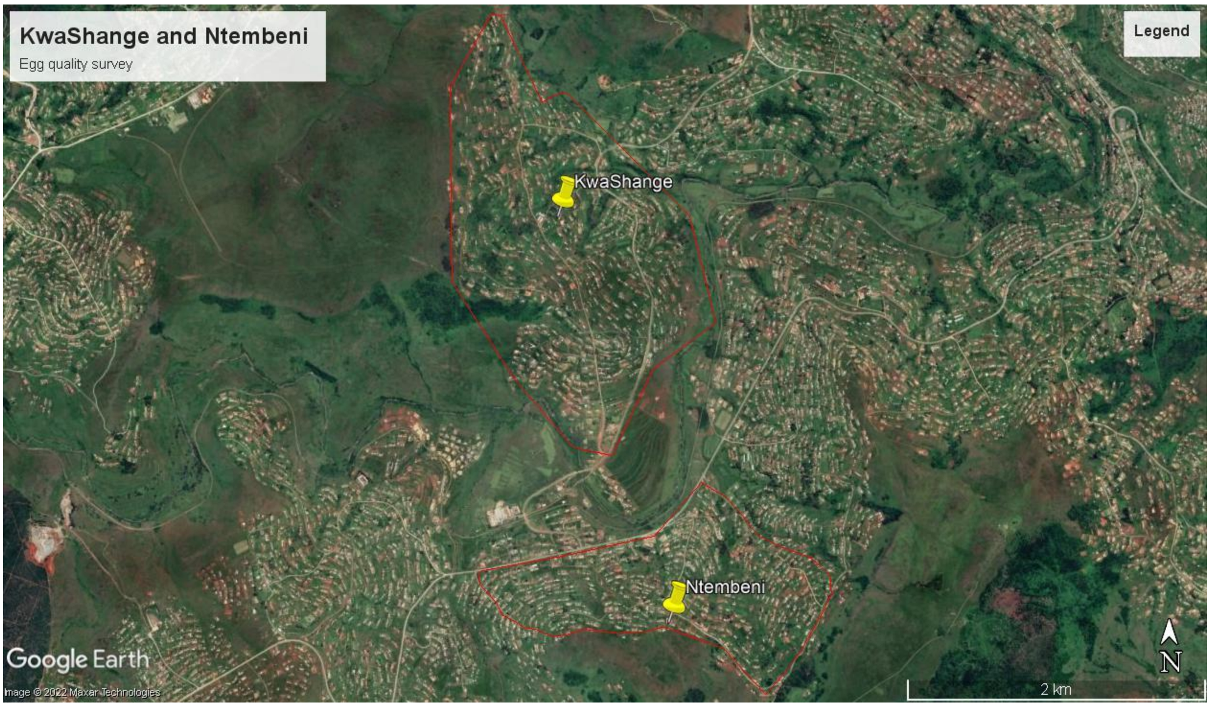

Figure 1 The regions of dry (KwaShange) and wet (Ntembeni) environments in KwaZulu-Natal, South Africa. Households that were under the KwaShange region experienced water shortages, whereas households that were under eNtembeni were classified as wet environments.

Households in the dry environments had water during the rainy season with seasonal streams and livestock had to walk long distances to get drinking water. The dry environment received rainfall of 700–800 mm per annum falling for 3–4 months. Frequent dry spells were experienced. The natural vegetation was characterized by a variety of grass species including *Eragrostis curvula, E. plana, Sporobolus africanus, S. pyramidalis,* and *Cymbopogon excavatus*.

Households in the wet environment had access to perennial rivers. They also received frequent rains with an average rainfall of 1000–1017 mm per annum falling for ~six months of the year. The vegetation in the wet environment was dense and dominated by shrubs and woody tree species including *Lasiophon triplinervis, Ocinum labiatum, Plectranthus emstili,* and *Salvia triangularis*. The soils were also deep and fertile to support cropping activities. Most households in the wet environment had home gardens where mainly maize and vegetables were planted.

The study was conducted using a snowball sampling technique (Ghaljaie *et al.*, 2017). Households that owned village chickens participated in the study. A total of 150 structured questionnaires were administered in each community and were followed by egg quality analyses. A pre-tested structured questionnaire was administered with the assistance of trained enumerators from the local villages to ensure that households were comfortable when responding to questions. The aspects captured in the questionnaire included the household demography, reasons for keeping chickens, flock composition, challenges to village chicken production, and egg quality characteristics. External egg quality was assessed by visual observation of three assistants to improve the precision of the results. Interviews were conducted in IsiZulu vernacular.

In dry and wet environments, laid and non-incubated eggs (n = 4000) were purchased from participating households. The Haugh Unit was the primary method used to measure egg quality from albumen height and egg weight (Biladeau and Keener, 2009). Eggs produced per year, number of clutches per year and eggs produced at first lay were determined. Age and clutch number of each hen were recorded. Egg quality analyses were conducted at the Animal and Poultry Science Laboratory of the University of KwaZulu-Natal. The weight of each egg was measured with a sensitive digital weighing balance (Mettler Toledo, PL203 CE) with an accuracy of 0.001 g. Egg length and width were measured with a Vernier calliper (0.01 mm, Mitutoyo, Japan). The weight of the shell was obtained by incubating the open part of the shell for five minutes and weighing the dried shell on a digital weighing balance (Mettler Toledo, PL203 CE) with an accuracy of 0.001 g. The integrity of the perivitelline membrane depended on the breaking strength. The weights of the yolk and albumen were determined using a digital weighing balance (Mettler Toledo, PL203 CE) with an accuracy of 0.001 g by placing the yolk and albumen in a separate petri dishes. A tripod meter (EMT 5200, Japan) was used to measure the yolk height (mm) and albumen height. The shell thickness (mm) was measured with its intact membrane using an electronic digital micrometre (Mitutoyo UK Ltd., Andover, UK). Shell colour and shell deformation were assessed by visual observation and yolk colour was measured by the Roche rich colour fan (DSM, 2005-HMB, 51548, Basel, Switzerland).
Egg quality was measured by fitting egg weight and albumen height in the Haugh Unit equation.

$$\mathrm{HU} = 100 \text{ x} \log(\mathrm{AH} - 1.7\text{x}\,\mathrm{EW}^{0.37} + 7.6) \quad (1)$$

where AH is the albumen height (mm), and EW is the egg weight (g).

All data were analysed using SAS (2011). Associations between all characteristics and environments were analysed using chi-square tests. The PROC GLM procedure of SAS (2011) was used to test for differences in flock composition and egg quality using the following model:

$$Y = \mu + E_i + e_i \quad (2)$$

where y = dependent variable, μ = mean, E = environment, and e is the standard error.
Ordinal logistic regression was used to predict the odds of factors affecting egg production inputs within village chickens using the following model:

$$Y = B_o + B_2S^2 + B_2H^2 + B_2N^2 + B_2E^2 + B_2G^2 + e \quad (3)$$

where Y = dependent variable, B = regression coefficients, E = Independent, S = feed supplement, H = housing, N = nesting, E = employment status, G = gender of the head of household, and *e* = standard error. The phenotypic correlation values related to the internal and external egg quality characteristics were determined using the PROC CORR procedure in SAS.

Results

The demographic and socio-economic status of the households in the dry and wet environments are given in Table 1. There were more male-headed households in the wet environments (P <0.05). Government welfare grants were the major source of income in both dry and wet environments but the dry environment consisted of more employed persons than the wet environment. Livestock sales were one of the frequently-practiced sources of income in wet environments (P < 0.05). The gender of the head of the household influenced the composition of the village chicken flocks in both environments. More than 50% of the households in dry and wet environments reared village chickens in conjunction with cattle, sheep, and goats.

Table 1 Association (%) between socioeconomic status and type of environment

Characteristics	Dry environment	Wet environment	Significance
Gender			*
Male	58.3	47.6	
Female	41.8	52.4	
Age range (years)			NS
31–40	14.7	18.4	
41–70	70.1	78	
>71	13.3	3.6	
Income per annum			*
R6 000–R18 000	42	54.3	
R18 001–R42 000	14.9	31.4	
> R42 000	24.1	13.3	
Source of income (%)			*
Formal work	23	15.8	
Casual work and vending	21.6	23.1	
Government welfare grant	55.4	60.1	

The village chickens were kept for eggs, meat, income, leisure, and traditional ceremonies. The proportion of households selling eggs was less than 3% and did not differ (*P* >0.05) between the environments. More households in the wet environment reared village chickens for egg production whereas households in the wet environment kept village chickens for leisure (78%). Households in the wet environment sold live chickens to neighbours to generate income (70%).

Challenges to village chicken production are shown in Table 2. Feed shortages, high disease prevalence, theft, slow growth, predation, and lack of access to the market constrained village chicken production. The major challenge to village chicken production was feed shortage in the dry environment and predation in the wet environment, whereas endemic diseases presented little challenge in both environments. Village chickens were offered yellow maize and kitchen waste as a supplementary feed in the dry environment more than in the wet environment. Chickens were sold for eggs and meat in both environments at local pension pay points and physical locations of the households for R80/5.46 USD per live chicken and R1.50/0.10 USD per egg.

The presence of housing for chickens influenced the number of chickens and eggs per household (*P* <0.05). Housing for chickens was provided by 93% of households in both environments. Birds perched on top of trees at night in households that lacked chicken housing.

Table 2 Ranks (LSM ± SE) of challenges to village chicken production in different households

Challenges	Dry environment (rank)	Wet environment (rank)
Endemic diseases	5.88 ± 0.11 (6)	4.77 ± 0.10 (6)
Predation	2.71 ± 0.12 (3)	1.56 ± 0.13 (1)
Feed shortages	1.48 ± 0.29 (1)	3.14 ± 0.21 (3)
Slow growth rate	2.12 ± 0.15 (2)	2.33 ± 0.23 (2)
Theft	4.81 ± 0.35 (5)	4.16 ± 0.35 (5)
Lack of access to the market	3.22 ± 0.00 (4)	3.55 ± 0.00 (4)

The lower the mean value, the more important the trait. All values are least-square means ± standard error (LSM ± SE)

The odds ratio estimates of how inputs in the household's influence village chicken production are shown in Table 3. The presence of nesting, housing, provision of supplementary feeding, and employment status were important predictors of egg production in resource-limited households (*P* <0.05). The likelihood of using an extensive production system as an input that influenced production was three times higher than using a semi-intensive system (*P* <0.05). Households that were unemployed were 0.25 times more likely not to contribute to the production of village chickens compared to households with employment.

A total of 200 eggs had internal defects. Eggs collected were brown and white-shelled. Sixty five percent of the eggs in the dry environment were brown-shelled, whereas 25% of the eggs in the wet environment had white shells (P <0.05). Manure stained eggs were prevalent in both environments. In the wet environment, 46% of the eggs were clean, whereas approximately one in five eggs in the dry environment was clean. Nearly 20% of eggs collected in the dry environment had cracks. The common anomalies observed were blastocysts in the yolk, yolks that had low viscosity with blood spots, misshaped shells, and albumen that was attached to the shell.

Table 3 Odds ratio estimates lower and upper confidence interval (CI) of predictors of egg production in village chickens.

Contributing predictor	[1]Odds ratio	LCI	UCI	[2]Significance
Type of environment (wet vs dry)	3.72	1.88	7.39	*
Presence of nests (Presence vs absence)	0.08	0.02	0.28	*
Provision of housing facilities (present vs absent)	0.44	0.17	1.19	*
Provision of supplementary feeding (present vs absent)	1.07	0.41	2.81	*
Gender of the head of household (Female vs male)	0.92	0.59	1.46	NS
Employment status (employed vs unemployed)	0.25	0.11	0.56	*

[1]The higher the odds ratio estimates the greater the difference in occurrence between predictors.
[2]Significance; NS: P >0.05; *P <0.05

Table 4 shows the productivity of village chickens in a dry and wet environment. Body weight of chickens, number of eggs, and the clutch numbers did not differ between environments (P >0.05). The wet environment produced heavier eggs than the dry environment (P <0.05).

Table 4 Productivity (LSM ±SE) of village chickens in a dry and wet environment

Egg production measure	Dry environment	Wet environment	Significance
Clutch no per year	3.74	4.24	NS
Egg number per year	40.43	49.91	NS
Age at first lay (weeks)	15.74	27.78	*
Egg weight (g)	39.59	49.79	*
Live weight (kg)	1.74	2.4	NS

Levels of significance are represented by NS, not significant (P >0.05), *P <0.05

Egg quality characteristics in dry and wet environments are shown in Table 5. Egg weight, egg width, shell thickness, shell weight, yolk height, albumen height, Haugh Unit, and yolk colour differed between environments (P >0.05). Egg weight, egg width, shell weight, shell thickness, yolk height, albumen height, Haugh Unit, and yolk colour were higher in wet than in dry environments; yolk weights were similar.

Table 5: Egg quality (LSM ± SE) characteristics in dry and wet environments

Parameters	Dry environment	Wet environment	Standard error
Egg weight (g)	39.59[a]	49.79[b]	1.40
Shell thickness (mm)	0.98[a]	1.17[b]	0.09
Shell weight (g)	7.77[a]	8.70[b]	0.10
Egg width (mm)	63.21[a]	65.90[b]	0.53
Egg length (mm)	80.03	82.90	0.88
Yolk weight (g)	24.15	25.75	1.79
Albumen weight (g)	34.69	32.61	2.30
Yolk height (mm)	4.09[a]	15.20[b]	0.51
Albumen height (mm)	3.40[a]	4.85[b]	1.31
Haugh Unit	64.04[a]	71.87[b]	1.07
Yolk colour	8.5[a]	11.57[b]	1.45

Values in the same row with the same superscripts are similar (P >0.05); All values are least-square means ± standard error (LSM ± SE)

Table 6 Correlation coefficients between external and internal traits of egg quality traits

Traits	EWt (g)	EWd (mm)	EL (mm)	SI (%)	AH (mm)	YH (mm)
EWd (mm)	0.84**					
EL (mm)	0.63**	0.41**				
SI (%)	0.17	0.26**	0.22**			
AH (mm)	0.70**	0.72**	0.22			
YH (mm)	-0.12	-0.15	0.15	-0.53**	-0.42**	
HU	-0.29	-0.26	-0.29	0.61**	-0.21	
YW (g)	0.39**	0.4688	0.28*	0.44**	0.48**	-0.32
AW	0.62**	0.72**	0.25**	0.13	0.69**	-0.17

[1]Traits EWt = Egg weight, Ewd = Egg width, EL= Egg length, SI = Shape index, AH = Albumen height, YH = Yolk height, HU = Haugh Unit; **P <0.01

Table 6 shows the correlation between external and internal egg quality characteristics. Egg width, egg length, albumen height, yolk weight, and albumen weight were positively related to egg weight. Egg length, shape index, albumen height, and albumen weight were positively related to egg width. Shape index, yolk weight, and albumen weight were positively related to egg length. Yolk height, yolk weight, and Haugh unit were negatively related to shell index.

Discussion

The egg quality of village chickens is rarely assessed (Yurtseven *et al.*, 2021). Village chickens are used as a tool to alleviate food and nutrition insecurity. Therefore understanding egg quality, egg defects, and production in resource-limited households is important (Das and Samanta, 2021). Desta (2021b) suggested that to improve livelihoods, inputs are needed to maximize production in village chickens. The predominance of village chickens, compared to other livestock, can be ascribed to the ease of management and low requirement of inputs to rear village chickens.

The socioeconomic status of households influenced the use of village chickens in both the dry and wet environments. The use of village chickens depended on the income of the household, suggesting that income is required to source supplementary feeds and veterinary treatments. The greater involvement of women in egg production, feeding, and housing of village chickens concurs with earlier reports (Desta, 2021a). The development of village chicken programmes, therefore, supports transformation and women empowerment.

Moser *et al.* (2018) reported that women were involved in feeding, biosecurity, and marketing of village chickens and Tarwireyi & Fanadzo (2013) reported that women were responsible for almost all homestead-related issues. The higher egg weight, egg width, number of eggs produced per year, clutch numbers, and body weight in the wet environment highlights the role that vegetation and rainfall play in broadening the scavengeable feed resource base for village chickens. Village chickens are kept mainly for eggs, meat, income, leisure, and rituals in both environments. These findings correspond with those of Hailemichael & Gebremedhin (2020), who reported that village chickens played nutritional, economical, and socio-cultural roles. Terfa *et al.* (2019) concurred that village chickens play an irreplaceable role in resource-limited households, and their eggs are considered as the most important source of protein (Magdelaine, 2011).

The finding that feed shortages and predation were major constraints suggests that intensification of village chicken production should be considered in resource-limited communities (Desta, 2021a). The slow growth rate in both environments would have influenced egg and body weight of the chickens. Moser *et al.* (2018) recommended that supplementary feeding be provided to achieve a greater body and egg weight and improve egg quality of village chickens. Supplementing chickens with maize alone is insufficient to improve egg production and quality. Protein-rich sources may also be required, and these should be locally sourced if the intensification is to be sustainable (Malatji *et al.,* 2016; Crnčan *et al.,* 2018). Intensification reduces predation and theft. The provision of housing can improve the health status and welfare of the flock by reducing parasites and pathogens (Desta, 2021a). The resource-limited households rear village chickens using indigenous knowledge without the possession of conventional skills of poultry production.

It was expected that the dry environment would be conducive to a higher egg production. The village chickens from the dry environment laid eggs at a younger age than chickens in the wet environment. Yurtseven *et al.* (2021) indicated that egg weight increases with age of the chicken. Desta (2021a) also revealed that village chickens could be affected by adverse weather conditions. Egg quality offers a substantial benefit to consumers (Chukwuka *et al.*, 2011). Environmental factors can be conducive to potential toxins that may result in serious public health issues (Giri and Singh, 2019). The quality of eggs is affected by the nutrients that village chickens consume during scavenging. Wang *et al*. (2017) indicated that temperature also contributed to poor egg quality. Egg yolk colour is an important egg quality characteristic that influences consumer preferences.

Egg defects of village chickens in the current study included dirty, contaminated eggs; cracks; blastocysts in the yolk; albumen and yolks with a watery viscosity; misshapen, dirty shells with cracks; blood spots on the yolk; and attachment of albumen to the shell. Wolc *et al.* (2012) found that defective eggs in layer chickens were bloody, broken, dirty, double-yolked, misshapen, shell-less, and soft-shelled. Eggs with no uniform colour may result from long-term stress or respiratory disease (Chukwuka *et al.*, 2011). Misshapen shells are usually caused by high temperatures (Bari *et al.*, 2020). Soft shells and low viscosity of the albumen are caused by diseases such as Newcastle disease and infectious bronchitis (Roh *et al.*, 2013). Blood spots on the yolk usually occur during or before ovulation and may be due to haemorrhage (Barna *et al.*, 2020). Kaya and Yildirim (2011) showed that pale, yellow yolks were due to lack of xanthophyll. Eggs with soft shells indicate low calcium levels and disease (Igwe *et al.*, 2018). These defects can be minimized by improving levels of management. Poor egg quality results in low hatchability and low egg production (Geleta *et al.*, 2013). Albumen weight, height, and Haugh Unit are the main indicators of egg quality (Lewko and Gornowicz, 2011). Storage time and conditions may contribute to poor egg quality (Feddern *et al.*, 2017), although this was not assessed in the current study.

The positive relationship between egg weight and other egg quality characteristics highlights that these determinants of egg quality need to be considered simulataneously. The strong association between egg weight, albumen height, yolk weight, and albumen weight indicates that improvement in any of these parameters through balanced nutrition can improve other traits. Strategies for minimizing incidences that result in egg defects and poor quality are required. Interventions using technologies for animal health and feed can improve the performance of village chickens to enhance food and nutrition security for resource-poor households that keep village chickens.

Conclusions

Egg quality is influenced by management and inputs. Village chickens should be reared correctly with inputs such as housing, a nutritional programme, and disease control. Egg quality and production characteristics of village chickens in resource-limited households are relatively poor. Nutritional deficiencies, high disease prevalence, and poor housing conditions should be addressed to improve egg production under village conditions. Improving village chicken productivity is likely to have a huge impact on empowerment of women and girls.

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Author contributions

TT (orcid.org/0000-0001-8121-2643) conducted the experiment, analyzed data, and completed the manuscript. LC (orcid.org/0000-0002-4315-3889) assisted in preparing, drafting, proofreading, and correcting the manuscript. MC (orcid.org/0000-0002-3206-3191) supervised the experiment, critically analyzed, reviewed, and supported in the final compilation of the manuscript.

Conflict of interest

The authors declare no conflict of interest relative to the content of this paper.

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