ESTIMATION OF THE TECHNICAL AND SCALE EFFICIENCIES OF QUAIL PRODUCTION: A STRATEGY TOWARD THE PROVISION OF SUSTAINABLE ANIMAL PROTEIN IN OYO AND KWARA STATES OF NIGERIA

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ABSTRACT

Small scale poultry production plays a major role in bridging the protein deficit and sustain rural livelihood in Nigeria. A study was conducted to estimate the technical and scale efficiencies of quail (Cortunix coturnix japonica) production a strategy toward the provision of sustainable animal protein in Nigerian diets. Data Envelope Analysis (DEA) was used to sieve efficient and inefficient quail farmers and established optimize energy. Data were collected with the aid of structured questionnaire administered to 193 quail farmers comprising of 78 battery cage system (BCS) and 115 deep litter system (DLS) operators using a multi-stage random sampling procedure. The result showed that feed, fuels and electricity gulps 63.38, 24.53 and 7.76 % of the total energy input in BCS production unit and equally constituted 65.16, 23.97 and 5.32 % in the DLS production unit. Both BCS (65.71 %) and DLS (67.90 %) used more renewable energy compared with non-renewable component. The net energy of both quail production units were positive, hence energy were gained. The results revealed that the total energy use that could be saved by converting the present units to optimal conditions were 7.80 and 6.76 % for BCS and DLS respectively. The BCS farms thrive better compared with DLS considering the results of the three efficiency parameters. The renewable energy inputs usage must be sustain and if possible increase in both sectors in order to improve the low energy productivity and increase energy output and invariably return to quail farming.

Keywords: Quail chick farmers, Battery cage system, Deep litter system, Renewable energy, Pure technical efficiency

INTRODUCTION

Poultry refers to domesticated birds such as chicken, turkey, duck, squabs, quail, geese, guinea fowls, swan and ostrich of economic value to man as source of meat, eggs, feathers, manure and other by-products. Nigeria hosts more than 45 % of the poultry industries in the West Africa sub-region and its poultry population accounted for about 58.2 % of the total livestock production consisting of 140 – 160 million comprising of 72.4 million chicken, 11.8 million ducks, 4.7 million guinea fowl, 15.2 million pigeon and 0.2 million turkeys (WHO, 2006; FAO, 2016; Oladimeji *et al.*, 2017). The finding from Food and Agriculture Organization

(FAO) records (1961 – 2016) indicated the important position of poultry sub-sector in the Nigerian livestock sector economy. Identical to other livestock products, poultry production such as egg and meat has been on increase. Nigeria poultry production of egg and meat was as low as 75,000 and 30,000 tonnes in 1961 and increase to 510,000 tonnes (580 %) and 209,149 tonnes (597.2 %) in 2017 with mean of 317,188 tonnes and 141,781 tonnes respectively (Figure 1).

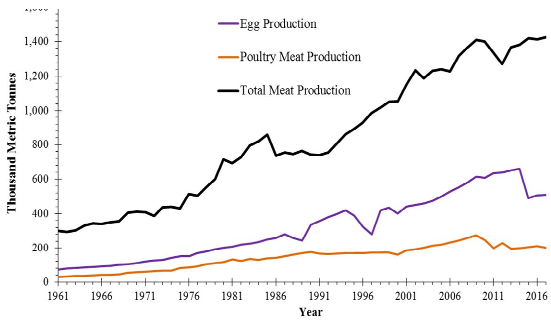

Figure 1: Trend of egg, poultry meat and total meat production in Nigeria (1961-2017). Source: FAO (2016). ***Note:*** *egg, poultry and meat production for year 2017 were projected.*

The estimated standard deviation of egg (183,492 tonnes) and poultry meat (141,781 tonnes) production or coefficients of variation of egg (57.85 %) and meat (47.48 %) production during this period attest to positive significant variation in production level .

However, Amos (2006) and Liverpool-Tasie *et al.* (2017) stated that Nigerian poultry industry is dominated by small-holding farmers who on the aggregate raise bulk of the birds for egg production and meat, but individually rear less than 1000 birds using different production strategies in consonance with little resources available to them. The poultry industry in Nigeria has hitherto been dominated by rearing of domestic chickens. However, in recent times there have been new entrants into the sector. One of the poultry species slowly gaining prominence is the Japanese quail (*Cortunix coturnix japonica*) of Galliformes family which is suited for commercial rearing, meat and egg production under intensive management (Egbeyale *et al.*, 2013). Quails have high potential for production because of their short generational interval such as their ability to produce three to four generations per year, adaptability to laboratory conditions and high genetic polymorphism coupled with more vitamins and minerals (Kimura *et al.*, 1980; Maeda *et al.*, 1997; Kayang *et al.*, 2004; Tuleun *et al.*, 2011; Gomathi *et al.*, 2014; Thomas *et al.*, 2016). Quail egg contains 13 % protein compared to 11% in chicken eggs and helped with the natural treatment of ulcers, strengthen the immune system, increase brain activity and stabilize the nervous system and the meat of quail is lean and both eggs and meat are low in cholesterol (Schwartz and Allen, 1981; Garwood and Diehl, 1987). Therefore rapid multiplication of these birds will make their meat and eggs readily available for human consumption with less risk of public health implication.

In spite of the potentials and health benefits of quail birds and their products enumerated above, scanty data are available on energy expenditure in quail production in Nigeria. Yet the intensity of energy use on poultry farms such as quail is appreciable and studies on input output energy pattern on quail farms are very important. The available data reported in literature from previous studies are seen from other countries and not on quail production but majorly broiler production (Begum *et al.*, 2010; Heidari *et al.,* 2011 a, b; Amid *et al.*, 2016; Ebrahimi *et al.,* 2016). For example, Amid *et al.* (2016) assessed energy use pattern and optimization of energy required for broiler production in Iran using data envelopment analysis (DEA). Ebrahimi *et al.* (2016) examined energy efficiency improvement for broiler production in Iran using non-parametric techniques and Begum *et al.* (2010) calculated technical, allocative and economic efficiency of commercial poultry farms in Bangladesh using the DEA approach under constant return to scale (CRS) and variable return to scale (VRS) specification.

It is important to note that livestock in particular fishery, and may be poultry and quail production has become increasingly mechanical and electrical driven, requiring significant energy inputs at particular stages of the production cycle to achieve optimum quail meat and egg production. For example, energy is used directly as fuel to power generator or electricity to supply and maintain heat for brooding of quail during production and sometimes improvised with kerosene stove to supplement heat source in the absence of electrical energy. A digital scale (in grams) is necessary to weigh both the feed given to the quail birds daily and the left over feed that was not consumed, and used to determine the daily feed intake of birds. The digital scale can equally be used for recording the weekly weight gain of the quail birds. In addition, quail equipment included feeder, drinker, mill, mixer, electric fans and medication also required a significant energy inputs. Machinery energy included energy consumption for electric motor, steel and polyethylene used in machinery structure and also required a significant energy inputs. Hence energy analysis allows the energy cost of existing process operations to be compared with that of new or modified production lines (Jekayinfa, 2007).

It is very important to undertake in depth efficiency studies into quail production in Nigeria. This is intended towards accumulate adequate, sufficient and reliable energy data for analysis geared towards a reliable database concerning consumption of various types of energy by different users in quail production farms. The study estimated technical efficiency of quail production per 1000 bird in Nigeria using two common rearing techniques (battery cage and deep litter systems), and identify target energy requirement (optimum) and energy gaps losses and gains.

MATERIALS AND METHODS

The study Area: The research was carried out in two states, Kwara and Oyo located in north central and south west geo-political zones respectively in Nigeria. Kwara State falls within sheet 223 NW (1:50,000) (GSN) lying between Latitude 8° 10' and 19° 50' N and between Longitudes 3° 10′ N and 6° 05' E (FAO, 2013; Ojo *et al.*, 2014). It is a humid tropical area characterized with both wet and dry seasons. The mean annual rainfall is 1150 mm, while the mean annual temperature ranges from 25 – 30 °C with relative humidity that ranges from 65-80 % (NPC, 2006).

Oyo State on the other hand falls within coordinates 8° 00' N and 4° 00' E lying between Latitude 7° 50' and 60° 00' N and between Longitudes 3° 55′ and 58° 80' E (NPC, 2006). It is a humid area characterized with both wet and dry seasons. The mean annual rainfall is 12450 mm, while the mean annual temperature ranges from 21.9-30.4 °C with relative humidity that ranges from 39.1-98.20 % (NPC, 2006; FAO, 2013).

For ease of data collection, this study collected information from households that engaged in quail production through the states' Agricultural Development Project (ADP) and state Ministry of Agriculture. The reconnaissance survey to locate quail production respondents also passed through poultry associations of Kwara and Oyo states under the auspices of All Farmers Association of Nigeria (AFAN) in the two states. Further search of the respondents were elicited from livestock-poultry feed sellers and their agents notably Madek Livestock Feeds, Lugminat Livestock Feed, Mayfield Farm Limited, Agro Bar-magen Nigeria Limited and Agrited Feed Mill. Like broiler and layer production, the reconnaissance survey showed that majority of the quail producers diversify to this enterprise. Thus, many of the enterants into poultry production including quail in both states were civil servants retired and active, unemployed youths, students and livestock-poultry and crop farmers who wholly or partly allocate their leisure time, off days, vacations and off and full-farm season to poultry production including quails and this to many of respondents provide a supplementary income so as to cope with adverse shocks. The quail production in the study areas were mostly domicile in the urban and peri-urban locations of the study areas and much more engaged by the educated households.

Data Collection and Sampling Procedure: Both primary and secondary data were collected from 193 quail poultry farmers using structured questionnaire with personal interview method by trained enumerators. Secondary data were collected from the production records of the quail farmers. Primary data compliment with their records were search for and these include input data such as human labour, quantity of feed, water and fuels used. Output data collected include quail meat, egg and manure.

The collected data belonged to the 2017 production year. Before collecting data, a pre-test survey was conducted from a group of randomly selected quail poultry farmers in the two sampled regions. Information on socio-economic and institutional characteristics, input and output, energy input sources were obtained from the quail farmers to achieve the objectives of study.

Multistage sampling procedure was adopted for the study. The first stage involved purposive selection of two states each from north central (Kwara and Kogi States) and south western (Oyo and Ekiti/Ondo States) Nigeria due to one, predominance of poultry farmers especially quail production in the chosen states and two, availability of production records among the poultry farmers. The list of registered cooperative poultry farmers were obtained in the states' Agricultural Development Project (ADP). Thereafter, stratified sampling technique was used to sieve the quail poultry farmers from layers and broilers poultry farmers. In the next stage, all the sieved quail farmers were sampled due to small sample size. Finally, additional quail farmers were sought for using snowball sampling technique based on information from sampled farmers. This means that initially selected quail poultry farmers from ADP group provided contact of additional quail farmers who are neither a cooperative member nor a registered poultry farmer with ADP for their interviewers (Salganik and Heckathorn, 2014). Followed from above, a total of 193 quail farmers comprising of 78 battery cage system (BCS) users and 115 deep litter system (DLS) users were sampled in the chosen states.

Data Analysis: The inputs used in quail farming were specified in order to calculate the energy equivalences in the study (Table 1). The amount of energy obtainable in quail farming was expressed as total energy input per 1,000 quail (Mega Joule/unit) and total energy input per kilogram of quail produced (Joules per kg). The energy input-output analysis used standard energy conversion of previous studies also in Table 1 that obtained energy equivalences of unit inputs (Joule) by multiplying inputs with the coefficients of energy equivalent. Energy use efficiency (EUE), energy productivity (EP), specific energy (SE) and net energy (NE) for quail produced were also calculated on per 1,000 quail basis using the equations:

$$\text{Energy use efficiency} = \frac{\text{Energy output (MJ (1000 quail)}^{-1})}{\text{Energy input (MJ (1000 quail)}^{-1})} \quad (1)$$

$$\text{Energy productivity} = \frac{\text{Quail products (kg (1000 quail)}^{-1})}{\text{Energy input (MJ (1000 quail)}^{-1})} \quad (2)$$

$$\text{Specific energy} = \frac{\text{Energy input (MJ 1,000 quail}^{-1})}{\text{Quail products/output (kg 1,000 quail}^{-1})} \quad (3)$$

$$\text{Net energy} = \text{Energy output}(\text{MJ1000unit}^{-1}) - \text{Energy input}(\text{MJ1000unit}^{-1}) \quad (4)$$

Equations 1 – 4 (Source: Ebrahimi *et al.*, 2016; Amid *et al.*, 2016).

Empirical Model: DEA is a non-parametric, data-oriented technique used for estimation of resource use efficiency and ranking production units on the basis of their performances. It results in a revealed understanding about each Decision Making Units (DMUs) instead of depicting the features of a mythical "average" DMU as in parametric analysis (Banker *et al.*, 1984; Chauhan *et al.*, 2006). In DEA, there are basically two kinds of models. These are CCR (Charnes, Cooper and Rhodes) and BCC (Banker, Charnes, Cooper) models. Such a model is defined as a linear divisive programming model:

$$maximise \frac{\sum_i U_i Y_{iq}}{\sum_j V_j X_{jq}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$subject\ to \frac{\sum_i U_i Y_{ik}}{\sum_j V_j X_{jk}} \leq 1\ k = 1,2,,\ldots,.n$$

Where: Y_i = Amount of outputs; X_j = Amount of inputs; U_i = Weights assigned to j-th inputs; V_j = Weights assigned to j-th outputs; Y range from 1 to k or I to q; x range from j to k

Table 1: Standard energy equivalents (eq.) used for estimated inputs in quail production

Items	Variables	Unit	Energy eq. (MJ/unit)	References
1. Inputs	Human labour	hr	1.96	Amid *et al.,* 2016; Ebrahimi *et al*., 2016
	Quail chick	kg	10.33	Heidari *et al.,* 2011a; Sefeedpari *et al.,* 2012
Machinery	Electricity	Kwh	11.93	Ebrahimi *et al*., 2016; Heidari *et al.,* 2011b
	Generator	Hp	25.25	Tyedmers, 2004
	Electric motor	kg	64.8	Heidari *et al.,* 2011a; Ebrahimi *et al*., 2016
	Steel	kg	62.7	Atilgan and Koknaroglu, 2006; Amid *et al.,* 2016
	Polyethylene	kg	46.3	Najafi *et al*., 2008; Heidari *et al.,* 2011b
	Kerosene fuel	L	46.20	Najafi *et al*., 2008; Flores *et al*., 2016
	Gasoline fuel	L	46.3	Najafi *et al*., 2008
	Battery	W	20.0	Tyedmers, 2004
Feed	Maize	kg	7.9	Amid *et al*., 2016; Sefeedpari *et al.,* 2013
	Soybean meal	kg	12.06	Ebrahimi *et al*., 2016, Amid *et al*., 2016
	Sorghum	kg	16.9	Charrondiere *et al*., 2004
	Minerals	kg	1.59	Ebrahimi *et al*., 2016, Amid *et al*., 2016
	Fatty acid	kg	9.0	Heidari *et al*., 2011a; Sefeedpari *et al.,* 2013
2. Output	Quail meat	kg	10.33	Najafi *et al*., 2008; Ebrahimi *et al*., 2016
	Egg	kg	15.4	Charrondiere *et al*., 2004
	Manure	kg	0.3	Amid *et al.* 2016; Ebrahimi *et al*., 2016

$U_1 \quad \geq \in \quad i = \quad 1,2 \ldots\ldots, s$

and $\quad V_j \quad \leq \in j = 1, 2, \ldots m$

This model can be converted into a linear programming model and transformed into a matrix maximize:

$$Z = U^T Y_q \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (6)$$

$$\text{subject to } V^T X_q = 1$$

$$U^T Y - V^T X \leq 0; \qquad U \geq; \qquad \in V \leq \in$$

Where: Z = maximize outputs or profits: Y = amount of outputs; X = amount of inputs; U^T = weights assigned to j-th inputs and T, a superscript, time = I, 2, …, n; V^T = weights assigned to j-th outputs and T, a superscript, time = I, 2, …, n. Model (5) is often called primary CCR model. To evaluate the technical, pure technical and scale efficiencies of individual farmers, DEA were used. Technical efficiency (TE) is basically a measure by which DMUs are evaluated for their performance relative to the performance of other DMUs in consideration. The TE_j measured was defined as follows:

$$TE_j = \frac{u_1 y_{1j} + u_2 y_{2j} + \cdots + u_n y_{nj}}{v_1 x_{1j} + v_2 x_{2j} + \cdots + v_m x_{mj}} = \frac{\sum_{r=1}^{n} u_r y_{rj}}{\sum_{s=1}^{m} v_s x_{sj}} \qquad (7)$$

where, u_r, was the weight given to output n; y_{rj}, was the amount of output n; v_s, was the weight given to input n; x_s was the amount of input n; r, was number of outputs (r = 1, 2,.. .,n); s, is number of inputs (s= 1, 2, .., m) and j, represents *jth* of DMUs (j = 1, 2,.. ., k). Scale efficiency is the potential productivity gain from achieving optimal size of a DMU. It shows the effect of DMU size on efficiency of system. Based on the CCR and BCC scores, scale efficiency defined (Cooper *et al*., 2006) as:

$$Scale\ Efficiency - \frac{Technical\ Efficiency}{Pure\ Technical\ Eficiency} \qquad (8)$$

In DEA, an inefficient DMU can be made efficient either by reducing the input levels while holding the outputs constant (input oriented), or symmetrically, by increasing the output levels while holding the inputs constant (output oriented). The choice between input and output orientation depends on the unique characteristics of the set of DMUs under study. In the agricultural production, a farmer has more control over inputs rather than output levels, and as a recommendation, input conservation for given outputs seems to be more reasonable (Ebrahimi *et al*., 2016). From foregoing, the study employed the input–oriented slacks-based measure of efficiency CCR model.

RESULTS AND DISCUSSION

Structure and Energy Inputs in Quail Farming Systems: The distribution of inputs, output and energy parameters for quail production systems indicated that the total inputs' energy consumption in BCS, (124,491.92 MJ 1000 bird^{-1}) was lower compared with production in DLS, (134,201.4 MJ 1000 bird^{-1}) (Table 2). The average energy consumption in BCS production unit was highest for feed (78,905.98 MJ 1000 bird^{-1}) and this accounted for over two third (63.38 %) of the total energy input in this unit followed by fuels (gasoline and kerosene) and electricity that gulps 24.53 % and 7.76 % respectively. Likewise, feed, fuels and electricity constituted 65.16 %, 23.97 % and 5.32 % of the total inputs' energy consumption in DLS production unit, followed the same trend in BCS. It is of interest to note that feed, fuels and electricity inputs dominated the share of energy inputs accounting significantly 96.67 % and 94.45 % respectively in BCS and DLS. The results also showed that the energy inputs for human labour (0.33 %), quail chick (0.74 %), machinery (0.04 %). water (1.26 %) and battery (0.97 %) had paltry share of the total energy input in both BCS (3.33 %) and DLS (5.55 %) production units. The majority of machinery in the quail production was used in the feed preparation and feeder equipment. The results of high energy usage of fuels and feed and low energy human labour are consistency with findings that the fuel and feed were high energy consumption in quail production (Heidari *et al*., 2011; Amid *et al*., 2016; Ebrahimi *et al*., 2016). Conversely the total energy output for quail meat (kg), egg (kg) and manure (kg) in Table 2 were higher in BCS production unit (153,746.6 MJ 1000 quails^{-1}) than in DLS (137,561 MJ 1000 quails^{-1}) production unit.

The EUE (return on energy invested), EP, SE and NE gained of the two units in quail poultry production are depicted in Table 3. The EUE in BCS and DLS production systems were found to be 1.24 and 1.03 respectively, indicating the efficiency use of energy in both quail bird production units. The EUE obtained could help improve energy use savings in the two production systems. It can be concluded that EUE can increase if quail products comprising meat, egg and manure increases or energy input consumption decreases. This result was in contrast to the values reported by Heidari *et al*. (2011), Amid *et al*. (2016) and Ebrahimi *et al*. (2016) for broiler production to be 0.15, 0.18 and 0.26 respectively. The higher EUE obtained from quail production compared with several studies of broiler production may not be unconnected with (i) quail products comprising meat, egg and manure and (ii) higher energy potency (15.4 MJ/kg) associated with quail egg. The average EP of BCS and DLS quail production units were 0.089 kg/MJ and 0.083 kg/MJ. This means that 0.089 and 0.083 units output was obtained per unit energy respectively. The result was comparable with the studies of Heidari *et al*. (2011), Amid *et al*. (2016) and Ebrahimi *et al*. (2016). The NE of both quail production units were positive (29,254.68 MJ/1000 birds and 3,359.6 MJ/1000 birds) which was an indication that energy was gained but in sharp contrast to the findings of Heidari *et al*. (2011) that reported negative NE of -159,424.66 MJ.

Furthermore, the distribution of inputs used in both quail production systems were classified as either renewable and non-renewable or direct and indirect energy groups was presented in Table 3. The total consumed energy input in BCS was renewable energy (65.71 %) and non-renewable energy (34.29 %) or direct energy (35.85 %) and indirect energy (64.15%). Similarly, energy consumed in DLS unit was renewable energy (67.90%) and non-renewable energy (32.10 %) or direct energy (34.22 %) and indirect energy (65.78%). The results revealed that the two production systems in the study area were in sharp contrast with the Amid *et al*., 2016, and Ebrahimi *et al*. (2016) on broiler production. By the same token, both BCS and DLS production units also used more of indirect energy (64.15

Table 2: Amounts of inputs, output and energy parameters for quail production systems

Variables	Battery Cage Production Unit			Deep Litter Production Unit		
	Qty/1000	TEE	%	Qty /1000	TEE	%
Inputs						
Human labour, hour	210.12	411.84	0.33	276.98	542.88	0.41
Quail chick, kg	88.74	916.68	0.74	79.03	816.38	0.61
Feed, kg	9586.52	78905.98	63.38	10008.64	87442.07	65.16
Machinery, kg	14.16	43.98	0.04	3.89	17.32	0.01
Water, L	1537.92	1568.68	1.26	2276.01	2321.53	1.73
Electricity, Kwh	810.06	9664.02	7.76	598.47	7139.75	5.32
Gasoline fuel, L	530.8	24576.04	19.74	433.76	20083.09	14.96
Kerosene, L	155.92	7203.50	5.79	261.83	12096.55	9.01
Battery, W	60.06	1201.2	0.97	187.09	3741.8	2.79
Total Energy Input		124491.9	100.0		134201.4	100
Quail meat, kg	267.92	2767.62	1.8	248.01	2561.94	1.86
Egg, kg	9784.06	150674.5	98	8725.29	134369.47	97.68
Manure, kg	1014.71	304.413	0.2	2098.65	629.6	0.46
Total Energy Output	11066.7	153746.6	100	11071.95	137561	100

TEE denote Total Energy Equivalent, MJ (1000 quails)$^{-1}$

Table 3: Energy parameters in quail farming production system per 1000 birds

Energy types	Unit	BCS (n=78)	DLS (n=115)
Quail output	Kg	11066.69	11071.95
Energy input	MJ 1000^{-1}	124491.92	134201.4
Energy output	MJ 1000^{-1}	153746.6	137561
Energy use efficiency	-	1.24	1.03
Energy productivity	Kg MJ^{-1}	0.089	0.083
Specific energy	$MJKg^{-1}$	11.24	12.12
Net energy	MJ 1000^{-1}	29254.68	3359.6
Renewable energy	MJ 1000^{-1}	81803.18 (65.71)	91122.86 (67.90)
Non-renewable energy	MJ 1000^{-1}	42688.74 (34.29)	43078.51 (32.10)/
Direct energy	MJ 1000^{-1}	44625.80 (35.85)	45925.6 (34.22)
Indirect energy	MJ 1000^{-1}	79865.66 (64.15)	88275.77 (65.78)

Source*: Field survey, 2016; Note: the figure in parenthesis are %;* ***direct energy*** *include: human labour, gasoline, battery, water, electricity and kerosene;* ***indirect:*** *chick, feed, building and machinery;* ***renewable****: feed, water, human labour;* ***non-renewable:*** *gasoline, kerosene, electricity, battery, building and machinery*

% and 65.78 %) compared to direct energy (35.85 % and 34.22 %). The findings are consistent with studies of Amid *et al*. (2016) and Ebrahimi *et al*. (2016) on broiler production in Iran. It is suggested that the present energy management should be intensify to tilt the production to more of renewable and direct energy usage.

Efficiency Estimation of Quail Farmers using DEA: The results of efficiency score distribution of quail production farmers in BCS and DLS based on CCR and BCC DEA models are illustrated in Table 4. The results showed that more than half 41(52.56 %) of farms in BCS were operating technical efficiency of between 0.61 – 0.80. Equally, 55(47.83 %) of farms in DLS operated technical efficiency of between 0.41 – 0.60. However, two farms (2.57 %) operated pure technical efficiency of 1 (one) in BCS production unit and none could attain pure TE of one in DLS production unit. Majority of the farms in BCS and DLS, 60(77.69 %) and 76(66.09 %) respectively ranged between 0.41 – 0.80 scale efficiency parameter. It therefore implies that BCS farms perform fairly better considering the results of the three efficiency parameters.

Table 4: Efficiency score distribution of quail production systems

Efficiency score	TE Frequency		Pure TE Frequency		Scale Efficiency Freq.	
	BCS	DLS	BCS	DLS	BCS	DLS
0.10-0.20	-	6 (5.22)	-	-	-	-
0.21-0.40	15 (19.23)	37 (32.17)	19 (24.36)	29 (25.22)	11 (14.10)	14 (12.17)
0.41-0.60	13 (16.67)	55 (47.83)	18 (23.08)	41 (35.65)	31 (39.74)	49 (42.61)
0.61-0.80	41 (52.56)	14 (12.17)	27 (32.05)	33 (28.70)	29 (37.95)	27 (23.48)
0.81-<1.0	9 (11.53)	3 (2.60)	14 (17.95)	12 (10.43)	7 (8.97)	25 (21.74)
1.0	-	-	2 (2.57)	-	-	-
Total	78 (100.0)	115 (100.0)	78 (100.0)	115 (100.0)	78 (100.0)	115 (100.0)

Note: BCS denote Battery Cage System and DLS: Deep Litter System; Figure in parenthesis are %

Amid *et al*. (2016) opined that farmers that achieved the efficiency score of one do not have any potential improvement on energy use.

The summarized central tendencies; average, standard deviation, minimum and maximum efficiency parameters for the two quail farming systems are presented in Figure 2.

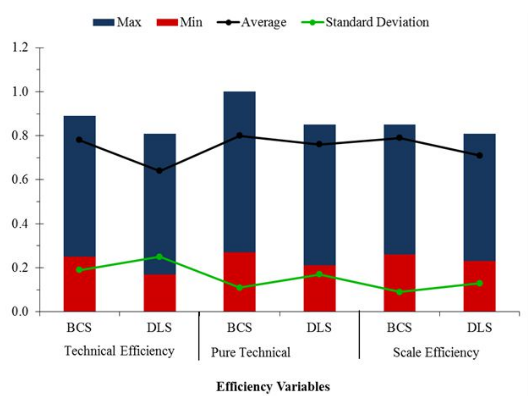

Figure 2: Average technical, pure and scale efficiency in quail farming systems

The results revealed that the average values of technical, pure technical and scale efficiency scores were 0.78, 0.80 and 0.79 in BCS unit and 0.64, 0.76 and 0.71 respectively in DLS. Out of the three efficiency measurement, average pure TE was the highest in both BCS (0.80) and DLS (0.76) quail farming systems. The coefficients of variation (CV) of TE, pure TE and SE for BCS were 24.3, 13.75 and 11.39 %, while that of DLS were 39.06, 35.53 and 36.62 % respectively. The standard deviation (SD) and CV showed that there was a mild variation in the three efficiency parameters in BCS farm with scale efficiency having the lowest SD and CV of 0.09 and 11.39 % respectively.

It can be inferred from the result that farmers thrive better in pure TE compared with TE and SE parameters. The CV results in the three efficiency measurements of BCS and DLS farms implied that not all farmers were fully aware of the best production techniques or did not apply them at the proper time and in the optimum quantity. Amid *et al*. (2016) reported that the average technical, pure technical and scale efficiency scores of broiler farmers in Iran were 0.88, 0.93 and 0.95 respectively.

Optimum Energy Requirement and Saving Energy: The optimum energy requirement and saving energy of various inputs for BCS and DLS Quail production using BCC model is presented on Table 5. The results revealed that the total optimum energy requirement for BCS and DLS quail production were 114,786.3 MJ (1000 quail)$^{-1}$ and 125,130.7 MJ (1000 quail)$^{-1}$ respectively. The percentage of energy saving in total optimum energy were estimated to be 7.80% for BCS unit and 6.76 % for DLS unit, indicated that following the results of this study, on the average, about 9705.65 MJ (1000 quail)$^{-1}$ and 9070.71 MJ (1000 quail)$^{-1}$ of total input energy could be saved, while holding the constant output level of each quail production unit. Furthermore, the results also revealed that in BCS production unit, fuels (46.05 %) and feed (40.02 %) accounted for about 86 % of total energy saving and similarly feed (48.92 %) and fuels (32.63 %) constituted 81.55 % of total energy saving in DLS production unit. Therefore, if feed and fuels are targeted in energy saving as shown in the result, the amount of energy expenditure in non-renewable resources could be reduced.

Table 5: Optimum energy requirement and saving energy for quail production systems using CCR model

Input	Battery Cage System (MJ 1000^{-1})			Deep Litter System (MJ 1000^{-1})		
	OER	Energy save	ESTR (%)	OER	Energy save	ESTR (%)
Human labour, hr	359.04	52.8	0.54	495.92	46.96	0.52
Quail chick, kg	884.05	32.63	0.34	754.07	62.31	0.69
Feed, kg	75004.22	3901.76	40.2	83004.92	4437.15	48.92
Machinery, kg	36.91	7.07	0.07	16.04	1.28	0.01
Water, L	1403.31	165.37	1.7	2200.21	121.32	1.34
Electricity, Kwh	9006	658.02	6.78	6442.02	697.73	7.69
Gasoline fuel, L	21008.54	3567.5	36.76	18221.34	1861.75	20.52
Kerosene, L	6302.11	901.39	9.29	10998.43	1098.12	12.11
Battery, W	782.09	419.11	4.32	2997.74	744.06	8.2
Total Energy Input	114786.3	9705.65	7.80	125130.7	9070.71	6.76

Note: OER denote Optimum Energy Requirement ***(MJ 1000^{-1}) and*** *Energy Saving Target Ratio, % (ESTR): The total reducing amount of input that could be saved without decreasing output*

Ebrahimi *et al*. (2016) opined that the reduction in diesel and gasoline fuels also has multiplier effect on environment through minimizing greenhouse gas (GHG) emissions and environmental impacts. In addition, the shares of other energy inputs such as quail chicks, human labor and machinery were relatively low, which was an indication that they have been used in the right proportions by almost all the farmers. Ebrahimi *et al*. (2016) observed that poultry farmer has more control over inputs than output levels. Therefore, this amount of energy could be saved, while holding constant output level.

The improvements of energy indices for the two quail production systems are presented in Table 6. The result revealed that EUE, SE and EP for target use of energy in BCS production were 1.34, 10.37 and 0.10 indicating improvement by 7.46, 8.39 and 11.0 % respectively. Similarly, EUE, SE and EP for target use of energy in DLS production were 1.10, 11.30 and 0.09 signifying improvement of 12.73, 7.26 and 7.78 % respectively. Furthermore, the result also revealed that renewable, non-renewable, direct and indirect energy were decrease by different magnitude. Hence, the shares of indirect and renewable energy with respect to total energy input increased. The reduction of fuels consumption for target units was the main reason for high difference in direct energy consumption in the two units.

Critical Issues and Limitations of Quail Production: Quails life expectancy unlike broiler and layer is averagely two to two and half years (Schwartz and Allen, 1981; Garwood and Diehl, 1987). However, for this study, only one cycle of production records (inputs and outputs) varies between 145 – 280 days (Kayang *et al*., 2004; Tuleun *et al*., 2011; Thomas *et al*., 2016) were considered for this research work.

Conclusion: Based on the findings of this study, the following conclusions may be drawn: (i) the estimated energy input of BCS is lower than that of DLS quail production system. However the total energy output is higher in BCS than DLS production unit, (ii) the EUE, EP, NE in BCS production system were found to thrive better compared to DLS production unit, (iii) the two production systems depended largely on renewable and indirect energy, (iv) using CCR model, the percentage of energy saving in total optimum energy was higher in BCS compared with DLS and (v) it is pertinent to note that if fuels are targeted in energy saving as shown in the result, the amount of energy expenditure in non-renewable resources could be reduced. The reduction in diesel and gasoline fuels also has multiplier effect on environment through minimizing greenhouse gas (GHG) emissions and environmental impacts. There is need also to found a way of

Table 6: Improvement of energy parameters for Quail farming production systems

Energy indices	Unit	Battery Cage System		Deep Litter System	
		Optimum quantity	Difference (%)	Optimum quantity	Difference (%)
Energy use efficiency	-	1.34	7.46	1.10	12.73
Specific energy	$MJKg^{-1}$	10.37	8.39	11.30	7.26
Energy productivity	$Kg\ MJ^{-1}$	0.10	11	0.09	7.78
Net energy	$MJ\ 1000^{-1}$	38960.3	24.91	2430.3	72.97
Renewable energy	$MJ\ 1000^{-1}$	77650.62 (67.65)	-14.17	86455.12 (69.09)	-5.4
Non-renewable energy	$MJ\ 1000^{-1}$	37135.65 (32.35)	-14.95	38675.57 (30.19)	-11.38
Direct energy	$MJ\ 1000^{-1}$	38861.09 (33.86)	-14.83	41355.66 (33.05)	-14.83
Indirect energy	$MJ\ 1000^{-1}$	75925.18 (66.14)	-5.19	83775.03 (66.9)	-4.93

increasing renewable energy through more usage of renewable inputs in both BCS and DLS production units in order to improve the low EP and sustain positive NE output and invariably quail farming.

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