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Comparison of Floored and Cage Housed Broiler Breeder Farms for Energy and Economic Efficiency in Pakistan: A Case Study of Broiler Breeder's Farm in District Punjab

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ABSTRACT

Research trials were conducted at commercial broiler breeder farms (n=60,000) to compare the economic and energy efficiency of floored and caged housing systems. Efficiency was evaluated by the inputs and outputs used. The egg prices were as per market rates at the time of this study. The cost for good settable eggs was 12% higher in floor-house (24.8) compared to enriched cages (22.1). The settable egg cost and the input costs during the entire egg production cycle for the floor and caged houses were human resource (labor) 3.03, 12.2% and 2.49, 11.3%; energy 0.5, 2.02% and 0.49, 2.26%; inputs purchased 11.4, 46.1% and 9.36, 42.3% and growing, rental and depreciation 9.81, 39.6% and 9.77, 44.2%, respectively. The floored flocks exhibited higher revenues when compared to caged broilers and had a total revenue of day-old chicks; 65.3, 92.6% and 53.4, 94.1%; spent birds 2.98, 4.22% and 3.12, 5.42% and manure; 2.26 and 3.2% and 0.22, 0.39% respectively. Except for spent birds, all output variables contributed more to the total higher sales revenue generated by caged flocks. Production costs per hen (4,456) and per hatched chick (33.4) at the floor houses were higher by 5.6 and 29% than the flocks housed in the enriched houses (4,219 and 25.8). Net income generated was 2.3 times higher in the enriched cages and they generated 1.67 more than floored flocks (1.27). The energy input and output values of the floored houses were 16% higher and 9% less than cage houses, respectively. Eggs were the highest energy output contributors followed by manure and meat. Energy efficiency for both types of housing were economical however, the energy used at the enriched cage housing was more efficient than in the floor pens. Specific energy use was 0.25 MJ kg^{-1} for the floor houses and 0.2 MJ kg-1 for the enriched cage houses, indicating judicious energy use in the current trials. The cost per chick is the determining factor for choosing the type of housing, considering addition to the environmental safety and bird's welfare.

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INTRODUCTION

The ability to maintain an affordable, safe, and sustainable food supply is a global challenge. Meat consumption trends are changing, with increasing preferences for cheaper andprocessed white meat and a decline in cereals share of the total food (Sefeedpari *et al*., 2013; Faridi *et al*., 2011). The consequent increases in poultry meat production by a factor of seven (3206%)

and eggs by a factor of three have overburdened sustainable production (Sousa *et al*., 2005). Economic pressures are influencing factors to minimize production cost per chick and causing competition with the other food sources (FAO, 2011; Fournel *et al*., 2012; Costa *et al*., 2012). Thus, it requires improvement in managerial practices for the technical and economic efficiency of farms (Sumner *et al*., 2008). The management of broiler breeders needs to solve several issues such as animal welfare vs. productivity, production vs. reproduction, emerging diseases vs. consumer market, and costs vs. profits. Simultaneously, economic growth should respect the environment as well (Afolabi *et al*., 2013). The main challenge faced by producers is finding the balance between these factors and fine-tuning to follow the multi-dimensional approach for sustainable production encompassing economic, environmental, social, and welfare aspects (Celik, 2003). Over the past few decades, the industry has become very successful by incorporating technical advances in genetic selection, nutrition, and disease control into their management schemes. However, bird reproduction management has not changed in developing countries. Conventional farming is mostly practiced for producing parents for breeding and product for the market (Li and Xin, 2010). Recent advances in poultry housing provides alternative methods for use within the primary breeder segment of the industry. To conform to welfare, major alternative rearing systems are used in laying hen production, such as enriched cages, aviary systems, and free range, having different technical features (Knowlton, 2000). Such systems are designed to balance animal health and welfare in accordance with the demands of consumers and the poultry sector (Heidari *et al*., 2011a). Enriched cage systems are one of the alternative systems developed to remedy the deficiencies of conventional cage systems relating to animal welfare. These systems provide each hen with a larger usable area and are furnished with equipment that helps them exhibit their natural behavior, such as nesting, scratching, and perching (Heidari *et al*., 2011b). However, average operating costs, total expenses, and investment costs per hen in enriched cage system higher than conventional cage systems (Lay *et al*., 2011). The hike in production cost will increase product price for the consumer (Kizilaslan, 2009). The economic evaluation of broiler breeder production is very challenging as many factors affect its profitability, thus making its analysis statistically difficult. In addition broiler breeder information is also hard to obtain from the breeder companies (Maba, 2008; Figueiredo *et al*., 2006). The main factors are economy of scale, farmer's age, time dedicated to farm activities, use of machinery, land productivity, application of management technologies (Groen *et al*., 1998) distance to consumer markets, processing plants and service providers, and environmental conditions (such as soil, relief, weather), possibility of placing the product in the market, possibility of using urban labor, and retirement pensions (Sariozkan and Sakarya, 2006). Production cost against the prevailing market price for a product is one of the most convenient measures of a successful enterprise because it is observable and not subject to interpretation and this allows poultry farmers to manage capital investments and to avoid market risks (Banga-Mboko *et al*., 2010). The cost per marketable chick would enable the breeder to decide which system to opt for. Hence, all possible economic benefits may be exploited by a poultry entrepreneur to add value to their business operations (Banga-Mboko *et al*., 2007). Energy use in the poultry sector has increased with expansion in the production. Global trade protocols, demand that products in large quantities are standardized and this has led to an increase in energy inputs needed to maximize growth, feed efficiency, profitability and minimize labor-intensive practices (Vaarst *et al*., 2015). Efficient energy use is significant because it can provide financial savings, preserve fossil fuel resources, and reduce air pollution (Bock, 1999). Indeed, efficient energy use, which helps to achieve increased production and productivity, and contributes to the economy and profitability, should be improved due to environmental and financial reasons (Lopes *et al*., 2014). Therefore, this study was designed to compare floor and cage house broiler breeder farms for energy and economic efficiency using broiler breeder's farm in district Qasoor, Punjab, Pakistan.

MATERIALS AND METHODS

Study location

The field study was conducted in commercial poultry farms located in the district of Qasoor, Punjab, Pakistan. The city is characterized by long (December-January) and short (August) rainy seasons. The 1st experiment was on floor-housed flocks, followed by the 2nd experiment on caged house flocks under a controlled environment. The average outside cage temperature ranged from 40 to 45 °C with relative humidity (RH) 65-90% in hot, humid July to August. The average house temperature and RH were 25-28 °C; 75-85% and 21-24°C; 50-65%, respectively during the 1st and 2nd trial.

Birds and experimental conditions

The experimental study included 60,000 Hubbard boiler breeder female day-old chicks. The chicks were first raised in floor pens on litter until 18weeks of age. On the18th week, the flock was divided into four groups. Two of the groups (each of 20,000 hens) were moved to separate sheds equipped with a cage housing system, while the other two groups (10,000 hens each) were maintained on the floor. The caged house flocks were artificially inseminated on each 5th day in one shed and on 7th in the other. One floor-housed flock was naturally mated (1:10) while the 2nd flock was artificially inseminated weekly. Each of the four sheds was of 18800 square feet of floor space. In battery cages Guangzhou Guangxing Poultry Equipment Company Limited (http://www.cnguangxing.com), hens were housed in hot dip Galvanized 3 tier cages, measuring 658 cm^2 area/ female bird and three birds/cage, 1645 cm^2 area/male bird and one male/cage (Cobb). The floor houses were equipped with semi- automated feeders, which were removed within 15 min after feeding as they were reducing the floor space requirement to 1.88 sq. ft/ bird. About 13% or greater is usually required for layers in tropicalclimate studies (Sariozkan and Sakarya, 2006; Gates *et al*., 2008). While the cage-housed hens occupied 0.89 square feet of floor area per hen. The floor pen included nests and an elevated area with a perch. Wood dust was used as a floor substrate in the pens. Each cage and each deep-littered floor pen were equipped with an automatic water supply and manual feeding troughs. Both groups were subjected to the same lighting schedule of 16 light hours with 60 LUX and eight dark hours with zero light intensity during the entire experimental period from the 40th to 65th Week.

Feeding and vaccination

Feed was formulated as per management guidelines for Hubbard breed containing 2750 Kcal Kg^{-1}, 16% crude protein, 3.5% calcium, and 0.06% methionine (Badubi and Ravindran, 2004). The floor-housed hens were fed 125 g of feed daily on the 24th week and peaked at 175g/day/hen on the 28th week. The caged house hens were fed 105 gm /hen daily, peaking at 155 g/day/hen. Immunization program was provided to the flocks against various disease.

Mating and insemination

One of the floor reared flocks was naturally mated, with 1:10 male to female ratio throughout the production period. The 2nd floor group was naturally mated till 39 weeks and inseminated artificially weekly from the 40th week until 65 weeks. In the3rd group, the caged housed hens were inseminated with fresh and pooled semen every 5th day throughout the production period, while the 4th caged housed group was inseminated weekly the entire production period. Semen were collected from roosters on an alternate day and then were pooled for each four cockerels, mixed with 0.4 cubic centimeter (cc) diluent finalizing a final volume of approximately 2 cc. The semen were gently stirred to inseminate 28-32 hens.

Measurements

Economic value for input variables (human resource, energy, purchased inputs and growing, rental and depreciation) and output variables (chicks hatched, spent birds and manure) were recorded in local currency and per market rates during the study period to perform the budgetary analysis. Depreciation costs was based on the economic life estimation of the tools and equipment for ten years (52). Maintenance and repair expenses consisted of the expenditures on tools and equipment in good working conditions (Alexandratoss and Bruinsma, 2012) adopted by (Carvalho *et al*., 2015).

Feed consumption

Daily feed fed to the birds were recorded separately for each bird (male and female) in grams (g). Sex-segregated data was mandatory as housing systems under study varied in the male to female ratio.

Egg production variables

Following the transfer of pullets to cages and the litter floor, daily egg production was recorded from the 24th to the 65th week. This made it easier to calculate the number of settable fertile eggs collected.

Hatchability

Eggs were set in a forced-air incubator for 18 days at 99.0-99.5 °F and 60-65% relative humidity (83-88 °F wet bulb) and transferred to the hatchery where temp and humiditywere 98.2-98.5 °F and 90%, respectively.

Analysis of energy efficiency

Energy use efficiency (EUE) analysis compares energy input and output in poultry production farms. The energy input sources for poultry production were human labor, machinery, diesel fuel, electricity, chicks, and feed; the output energy sources considered were eggs, chicken meat, and manure. The energy input sources were also classified into direct energy (DE) and indirect energy (IDE) use. All calculations were performed at the farm level on a flock production cycle basis. The energy equivalents used in this study for the estimation of energy inputs and outputs are given in Table I.

Table I. Energy equivalents of inputs and outputs.

Inputs	Unit	Energy equivalent (MJ)	References
Chick	Kg	10.33	Heidari *et al*. (2011b)
Human labor	H	2.2	Fluck (1992)
Machinery			
Galvanized iron	Kg	38	Sefeedpari *et al*. (2013)
Cage/feeder			
Electric motors	Kg	64.8	
Plastic drinkers	Kg	46.3	Heidari *et al*. (2011b)
Diesel fuel	L	47.8	Kitani (1999)
Feed	Kg	12.98	
Electricity	KWh	5.65	Uzal (2012)
Water	L	2.63	Atilgan and Koknaroglu (2006)
Outputs			
Bird	Kg	10.33	Celik (2003)
Egg	G	0.327	
Manure	Kg	8.83	Bock (1999)

Energy inputs

Energy inputs are directly used for fuel energy (FE), electricity energy (EE) and human labor energy (HLE). All these are the direct energy inputs (DEI) and includes machinery, water, and feedstock that consume energy for production. It can be calculated by following formulae (Kilic, 2016).

Fuel energy

Fuel consumption in poultry houses varied with housing type, manure removal, and management systems. FE is generally used to run a generator during off-grid hours daily and it is calculated as Equation 1:

$$FE = QF \times EE \ldots (1)$$

Where FE is the fuel energy (MJ (1000 bird) $^{-1}$), QF is the fuel consumption (L) and EEF is the energy equivalent of the fuel (MJ L^{-1}).

Electricity energy

The mechanization level of a poultry farm is the most important factor in affecting electricity consumption. Generally, poultry farms consume more EE than FE. The electric energy consumption was calculated as Equation 2:

$$EE = QE \times EEE \ \ldots (2)$$

$$EE = QE \ X \ EEF \ \ldots (2)$$

Where EE is the electricity energy (MJ (1000 bird) $^{-1}$), QE is the electricity consumption (kWh) and EEF is the energy equivalent of the fuel (MJ kWh^{-1}).

Human labor energy (HLE)

In poultry production farms, human labor is required for egg collection, feed distribution, flock care and equipment maintenance. HLE for the poultry production systems was calculated as Equation 3:

$$EHL = nHL \times nd \times h \times ecHL \ldots (3)$$

Where EHL is the human labor energy (MJ), nHL is the number of laborers, nd is the days of production, h is the work hours of labor in a day (h), and ecHL is the energy equivalent of labor (1.96 MJ h^{-1}).

Machinery energy

Machinery energy consists of the conversion of electrical energy by equipment such as the egg collection lift, feeder, drinker, mill, mixer, radiant and ventilation fans. It includes the energy consumption of all these implements in the poultry houses. The equivalency of machinery energy is provided in Table I per 1000 birds.

Feed stock energy (FSE)

The feed is formulated according to flock maintenance and production requirements in the perspective of the enterprise. The feed formula contains sufficient energy, minerals,protein, vitamins, and proper supply of water for supporting vital body functions and productivity. The amount of energy in the feed is in units of metabolizable energy per Kg feed**,** e.g., kilo joules per Kg (kJ Kg^{-1}), and was calculated by Equation 4:

$$EFS = QFS \times EEFS \ldots (4)$$

Where EFS is the feedstock energy (MJ), QFS is the feed consumption (Kg) and EEFS is the energy equivalent of the fuel (MJ Kg^{-1}).

Energy outputs

The output energy parameters for laying flocks are eggs, spent birds' meat and manure. Among animal manures, poultry manure has the highest nitrogen and mineral concentrations. It is also an important organic fertilizer for farmers due to its high nutrient content, though it may easily lose its nutrients depending on the storage time and removal interval from the farm. The energy output was calculated by multiplying the egg and meat production amount with the equivalent energy. All calculations performed were farm-based.

Energy usage indicators

Following the analysis of energy input and output values, energy indicators, such as (EUE; Equation 5), energy productivity (EP; Equation 6) and net energy gain

(NEG; Equation 7) were calculated based on their energy equivalents (Zangeneh *et al*., 2010; Kilic, 2016).

$$\text{Energy use efficiency} = \frac{\text{Energy output MJ 1000 bird} - 1}{\text{Energy input MJ 100 bird} - 1} \quad ...(5)$$

$$\text{Energy productivity} = \frac{\text{Yield (Kg (1000 bird)} - 1}{\text{Energy input (MJ (1000 bird)} - 1} \quad ...(6)$$

$$\text{Net energy gain} = \frac{\text{Energy output (MJ (1000 bird)} - 1)}{\text{Energy (MJ (1000 bird)} - 1} \quad ...(7)$$

Statistical analysis

Data was processed by SPSS software version 22. Mean values obtained from the floor pen groups and the battery cage groups compared the economic and energy efficiency of the two housing systems. Net profit/loss was calculated by subtracting the total costs from sales income (Harper *et al*., 2010). The production cost per chick was calculated by subtracting the revenues from the grand total cost and dividing it by the total amount of chicks hatched. These calculations were used to gauge the effect of different housing systems on the unit cost of chick production, production cost per flock of 10,000 hens, production cost per hen and total costs. The results were compared using descriptive analysis and were grouped in tables to allow a better visual comparison, discussion, and presentation of results (Ellen, 2005).

Table II. Cost and return structure per 10,000 hens housed on floor or enriched cages.

Main variable	Sub variable	Variable value/ settable egg		Variable value (% of total)	
		Floor	Enriched cages	Floor	Enriched cages
Human resource	Skilled labor	----	0.24	0.00	1.07
	Unskilled labor	0.333	0.157	1.35	0.71
	Head office administration	1.20	0.60	4.85	2.71
	Hatchery administration	1.50	1.50	6.06	6.78
	Total	3.03	2.49	12.2	11.3
Energy	Electricity	0.361	0.368	1.46	1.66
	Fuel	0.139	0.131	0.56	0.59
	Total	0.500	0.499	2.02	2.26
Purchased inputs	Pullets	0.083	0.079	0.34	0.36
	Cockerel feed	0.812	0.130	3.28	0.59
	Hen feed	10.526	8.983	42.5	40.6
	Insemination	----	0.169	0.00	0.76
	Total	11.42	9.36	46.12	42.31
Fixed costs	Farm rent	0.07	0.03	0.27	0.14
	Depreciation	1.24	1.24	5.01	5.60
	Pullet growing	4.20	4.20	16.96	18.98
	Eggs hatching	4.30	4.30	17.36	19.43
	Total	9.81	9.77	39.61	44.17
Total cost	Per settable egg	24.76	22.13	100	100
	Per Chick	33.37	25.84	---	---
	Per 10,000 flock	44,561,412	42,186,456	---	---
	Per hen housed	4,456	4,219	---	---
Sales revenue	Chicks	53,417,617	65,303,547	94.12	92.58
	Spent birds	3,115,211	2,975,049	5.49	4.22
	Manure	222,750	2,257,931	0.39	3.20
Total revenue	Per 10,000 flock	56,755,577	70,536,527	100	100
	Per hen housed	5,676	7,054	---	---
Net income	Per 10,000 flock	12,194,165	28,350,071	---	---
	Per hen housed	1,219	2,835	---	---
Return on investment		1.27	1.67	---	---

RESULTS

Table II show the results regarding the entire production cycle for both floor and enriched cage housing. Human resource were 3.03 (12.2%) and 2.49 (11.3%); Energy 0.5 (2.02%) and 0.49, (2.26%); purchased inputs 11.4 (46.1%) and 9.36 (42.3%) and growing, rental and depreciation 9.81 (39.6%) and 9.77 (44.2%) in the floor and enriched cage housing, respectively. Per settable cost was 12% higher in floor house (24.8) compared to enriched cages (22.1). Higher revenues were generated (million rupees) by the floored flocks compared to the enriched cage-housed flocks. Their revenue in value (million) and percentages were as follows: Day-old chicks; 65.3 (92.6%) and 53.4, (94.1%); spent birds 2.98 (4.22%) and 3.12 (5.42%) and manure; 2.26 (3.2%) and 0.22 (0.39%), respectively. Except for spent birds, all output variables contributed to the total higher sales revenue generated by enriched cage-housed flocks than floored flocks. Production costs per hen housed (4,456) and per chick hatched (33.4) in the floored system were higher by 5.6% and 29% than flocks housed in the enriched houses (4,219 and 25.8). Net income generated by each hen housed in the cages (2,835) was 2.3 times (132%) higher than the floored hen (1,219).

Consequently, each rupee invested in the enriched cage housing benefitted more (1.67) than the floored flocks (1.27). Table III indicates the results of energy inputs and outputs in floor and enriched cage poultry houses. The energy output values obtained from the floored houses were 9% less than enriched cage housings. The distribution of output energy in the floor and enriched cage house were (3,824,799; 4,052,633) for eggs, (41,257; 39,400) for meat (hens+roosters) and (65,563; 199,375) for manure. Eggs were the highest energy output contributors, followed by manure and meat. Table IV comprehensively summarizes the average energy inputs for the floor and enriched cage houses. The average total energy consumption was 851,459 MJ (by 1000 birds) for enriched cage houses and 990,157 MJ (for 1000 bird) in the floor system. According to the results, DE inputs were almost similar in the two housing systems, while IDE was 16% higher in the floor than in cage houses. Within a housing system, the IDE input was more than the DE input for both housing types. Results for the energy efficiency at the floor and enriched cage poultry houses is shown in the Table V. The analysis of EUE in the production system considers energy balance and energetic parameters, e.g., energy productivity (EP), specific energy (SE) and net energy gain (NEG). The goal of this analysis was to assess the production systems.

Table III. Energy inputs and outputs (1000 birds)-1 in floor and enriched cage poultry houses.

Inputs	Unit	Energy equivalent (MJ)	Floor			Enriched Cages		
			Number	Energy	Energy per 1000 birds	Number	Energy	Energy per 1000 birds
Chick	Kg	10.33	450	4,649	465	900	9,297	465
Human labor	H	2.20	2,240	4,928	493	2,800	6,160	308
Machinery (galvanizediron cage/ feeder)	Kg	38.00	462	17,538	1,754	15,000	570,000	28,500
Electric motors	Kg	64.80	20	1,296	130	36	2,333	117
Plastic drinkers	Kg	46.30	240	11,112	1,111	20	926	46
Diesel fuel	L	47.80	3,087	147,559	14,756	6,174	295,117	14,756
Roosters' feed	Kg	12.98	36,535	474,226	47,423	12,435	161,407	8,070
Hens' feed	Kg	12.98	473,600	6,147,328	614,733	856,000	11,110,880	555,544
Electricity	kWh	5.65	25,008	141,295	14,130	54,000	305,100	15,255
Water	L	2.63	1,122,297	2,951,642	295,164	1,736,870	4,567,969	228,398
Total					990,157			851,459
Outputs								
Hens	Kg	10.33	35,770	369,504	36,950	74340	767,932	38,397
Roosters	Kg	10.33	4168.6	43,062	4,306	1943.315	20,074	1,004
Egg	G	0.327	116,966,316	38,247,985	3,824,799	247,867,476	81,052,665	4,052,633
Manure	Kg	8.83	74,250	655,628	65,563	451,586	3,987,507	199,375
Total	--	--	--	--	3,931,618	--	--	4,291,409

Table IV. Energy consumption (1000 birds)-1 in floored and enriched cage poultry houses.

Input type	Floored house		Enriched cages	
	Energy MJ	%	Energy MJ	%
Direct energy inputs				
Chicks	465	0.047	465	0.054
Human labor	493	0.050	308	0.036
Diesel fuel	14,756	1.490	14,756	1.719
Electricity	14,130	1.427	15,255	1.777
Total	29,844	3.014	30,784	3.585
Indirect energy inputs				
Machinery	2,995	0.30	28,663	3.34
Feed	662,155	66.90	570,799	66.50
Water	295,164	29.80	228,398	26.60
Total	960,314	97	827,860	96.438
Grand total	990,158	100	858,644	100

Table V. Energy efficiency at the floor and enriched cage poultry houses.

Parameter	Unit	Floor	Enriched cages
Energy use efficiency	--	4.01	5.04
Energy productivity	Kg MJ^{-1}	156,905	324,151
Specific energy	Kg MJ^{-1}	0.25	0.20
Net energy	MJ (1000 birds)$^{-1}$	2,981,858	3,439,949
Total energy input	MJ (1000 birds)$^{-1}$	990,157	851,459
Total energy output	MJ (1000 birds)$^{-1}$	3,972,015	4,291,409

The EUE for the floor and enriched cage-housed farms were 4 and 5, respectively. Both types of housing were efficient, but the enriched cage housing was more efficient regarding energy usage. The EUE for the floor housing can be increased by increasing the egg yield and decreasing energy consumption. The EP obtained in the study for the floor farms (0.16 Kg MJ^{-1}) was half as of the cage-housed flocks (0.38 Kg MJ^{-1}). Evaluating the EUE in production systems, SE consumption is one of the most important indicators. This value consists of energy use per unit of physical output of the production system. In our study, the SE use was 0.25 MJ Kg^{-1} for the floor houses and 0.2 MJ Kg^{-1} for the enriched cage houses. The reported values were less than the 3.09 MJ Kg^{-1} value for European farms, which indicates that energy use efficient in this study.

DISCUSSION

Each input variable, cost more in the floored flocks than caged flocks. Settable egg cost was 12% higher in floored houses (24.8) than enriched cages (22.1). Various factors were comparatively higher in floored flock, including feed consumption per hen, cumulative feed consumed by cockerels (for mating), occupied covered area, and human resources. Feed cost has been reported to be around 70% for layers (Kozłowski, 2008; Tschirley *et al*., 2013). The skilled monitor could supervise a farm with either housing systems for equal hours to reduce bird cost especially in double stocking density of hens in the enriched cage houses. The high stocking density halved the farm rentals n the enriched cages. The floor- housed naturally mated required 10% roosters against 4.5% for artificial insemination in the enriched cage housing. The energy costs were almost similar for the two housing types. The cooling fans had to run longer period in the cages to exhaust excessive heat produced; thus, high stocking density could not reduce the energy cost. The heat production depends on the flock live weight rather than the covered area (Gocsik *et al*., 2015; Yassin *et al*., 2012; Uzal, 2012). The purchased inputs' cost during the floor and enriched housing study was 46.1 and 42.3%, respectively. Enriched cages for layers accounts for 66% of the total cost in Sweden, 70% in Belgium and 79% in the United Kingdom (Chisanga *et al*., 2017). The main reason for such variation in those countries can be the different prices of the feed supply (Ali and Hossain, 2010). Higher revenues were generated (million rupees) by the floored housed flocks compared to the enriched cage-housed flocks. Their percent contribution to the total revenue were day-old chicks; 65.3, 92.6% and 53.4, 94.1%; spent birds 2.98, 4.22% and 3.12, 5.42% and manure; 2.26 and 3.2% and 0.22, 0.39% respectively. Except for spent birds, all output variables contributed more to the total sales revenue generated by enriched cage housed flocks than floored flocks. Spent birds contributed more to the sales revenue than floored-flocks because more roosters were required for floor-mated reproduction than enriched houses. Chicks and manure contributed to higher sales revenue by enriched cage houses due to better hatch and manure obtained from the enriched cages (163 chicks/hen; 451 tons) compared to floor houses (133 chicks/hen; 7.4 tons). Most of the manure is lost in the form of gases in the floored pens, which accumulates until the flock retires from production increasing the localized nitrogen loading in the houses (Acil, 1980). Whereas manure can be easily collected several times a day with an automatic manure removal machine in the enriched cages. It can be done at the farmer's convenience, which is a less labor intensive method (Coufal *et al*., 2006). There is a shift in global farming production systems from deep-pit housing systems to manure belt housing systems (Esengun *et al*., 2007) to reduce ammonia emissions by 58–76% (Matthews and Sumner, 2015). Production costs per hen (4,456) and hatched chick (33.36) at the floor houses were higher by 5.6 and 29% than the caged houses (4,219 and 25.84). All the input variables except farm-based labor and insemination expenses raised the production cost in the floored houses. In a study in turkey by Carvalho *et al*. (2015), the production cost for layer flock in the enriched cage was 2.03% higher than in conventional cages. Farm Input prices play a significant role in the variation in production costs (Chisanga and Zulu-Mbata, 2017; Ali and Hossain, 2010). Net income generated by each hens housed in the enriched cages (2,835) was 2.3 times (132%) higher than hens in the floored housing (1,219). Consequently, each rupee invested in the enriched cage housing returned more (1.67) than floored flocks (1.27). The low input cost and high revenue generated by enriched cages contributed to the higher income from enriched cages than the floored pens. The live performance of the flock directly affects farmer's pay (Ali and Hossain, 2010), each 1% increase in electricity cost (Fluck, 1992) and feed intake (Sumner *et al*., 2008) reduces the profitability by 0.45% and 1.12% respectively. The IDE input in the floor and enriched cage housings comprised of approximately 97% and 96% of the total energy use, respectively. Electricity and fuel are the highest inputs which counts for 1.7% of the total energy inputs in both housing systems. Electricity is normally utilized by automatic watering system, mechanical ventilation, heating and cooling systems, manure removal and lighting equipment. Natural or artificial lighting was the most critical for producing optimum egg laying. Feed energy was the highest input among the IDE inputs, at 66% for floor-enriched cage houses. Similar results in layer and broiler farms for the IDE inputs (Kilic, 2016) and in dairy farms have been reported (Bock, 1999). The output energy of the floored farms was 9% less than the enriched cage houses, because the caged houses facilitate 6 times more manure collection. While in the floored houses, most of the manure is lost in the form of gases as it lies inside the shed till the end of the production cycle of the flock. The observed feed energy in our study is consistent with different animal's production systems: (69 %) (Van Horne, 2003). The feed is mainly composed of protein, carbohydrates and fats. Birds must consume feed with a high energy content to provide sufficient metabolic energy for production. The required mechanical energy on the floor and enriched cage houses was 0.30 and 3.33% of the total energy inputs, respectively. The enriched cage houses are more mechanized than conventional floored pens. Managerial practices (feed and water distribution, manure, and egg collection) require energy. Water is the second highest energy input. When comparing the floor and enriched cage house energy inputs and outputs, the total energy inputs of the floor houses were 15% higher than the enriched cage houses. The calculated values in our study for energy efficiency and energy usage indicators appear to be comparable to those reported by (Kilic, 2016) and (Aral *et al*., 2017), respectively.

CONCLUSION

Caged housed flocks cost lower per hen to manage and generated more revenue per hen, produced cheaper chicks, returned higher per unit investment and was efficient energy users compared to the floored flocks. In caged housing, both the input and output variables contributed to enhancing revenue generation and energy efficiency. Since production cost is the decisive factor for entrepreneurs in opting for the housing type, aviary systems or enriched cage housing ensuring environmental safety and bird's welfare may be preferred in commercial businesses.

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IRB approval

The experimental work was approved by the Advanced Studies and Research Board (No.521/DASAR/AUP) dated 07/09/2016, The University of Agriculture Peshawar, KP, Pakistan.

Ethical statement

The university departmental ethical committee approved the experiment before practical execution of this experiment.

Statement of conflict of interest

The authors have declared no conflict of interest.

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