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Quality, nutritional, and sensory attributes of Naked Neck chicken eggs as influenced by production systems and dietary regimens

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Abstract: This study evaluated the quality, nutritional, and sensory attributes of Naked Neck chicken eggs when birds were subjected to different housing and nutritional regimens. Birds were maintained in two rearing systems (intensive & free-range) with five dietary treatments based on commercial feed (CF) and kitchen waste (KW), i.e. 100% CF, 75% CF + 25% KW, 50% CF + 50% KW, 25% CF + 75% KW, and 100% KW. A total of 500 eggs, comprised of ten per replicate (50 per treatment) were used. Higher ($p \leq 0.05$) shell weight and thickness, shape index, egg volume, yolk index and weight, egg specific gravity, and Haugh unit score were observed in birds reared under the intensive system. Egg and shell weight, shape index, volume, yolk index and weight, specific gravity, haugh unit were higher ($p \leq 0.05$) in birds fed with 100 % KW. Egg moisture percentage was higher ($p \leq 0.05$) in birds fed with 75% KW; crude protein and ash percentage were higher in birds fed with 25 and 50 % KW, respectively. Egg taste and flavour were better ($p \leq 0.05$) in birds fed with 100% KW. It is concluded that egg quality, nutritional, and sensory attributes were improved when Naked Neck chickens were reared under the intensive system and fed kitchen waste up to 75 %.

Key words: Egg quality, naked neck chicken, nutritional composition, nutritional regimens, production systems, sensory attributes

1. Introduction

Animal protein in a bulk amount has become a fundamental necessity to accomplish the everyday demand of the ever-growing human population. More interestingly, in recent years, the demand of specific population groups for different poultry foodstuffs has driven substantial modifications in poultry marketing and farming practices [1,2]. Chicken eggs are considered an excellent source of proteins, fats, and certain health-beneficial micronutrients [3] with moderate caloric value (150 kcal/100g), with great culinary versatility [4,5]. Egg quality is a multifactorial character and influenced by breed, age, health, nutrition, and management [6,7,8,9[1],10,11]. It has been seen that the egg quality is affected by the diet, and it is limited, or overfeeding may put a negative effect on the egg quality of laying birds [12]. However, other related studies revealed the abnormality in eggs due to the supply of limited feeding as compared to unlimited feeding to the birds. Furthermore, the egg weight increased due to the unlimited feed supply. It was also observed that poultry birds yield better response regarding overall egg quality attributes in the natural environment with access to free land, fresh air, and plenty of water with unlimited feed such as pastures forages, plants, weeds, earthworms, etc. [13]. Hence, besides a significant decrease in the cost of feed, sustainable production of eggs is also ensured [14], and overall immunity against enteric diseases is also improved. Rearing conditions and management take a significant part in egg production and characteristics along with the health and well-being of the birds [15,16,17,18]. There is a commonly held belief among consumers that eggs from indigenous chicken breeds are of higher quality and taste than those of imported or commercial chicken breeds [19]. Among backyard rural poultry, Naked Neck is one of the most preferred breeds for rural poultry farmers [20]. This breed is well-known for better egg production

[1] https://www.semanticscholar.org/paper/Effects-of-housing-systems-for-laying-hens-on-egg-Cepero.

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and thermo-resistant in tropical and sub-tropical climatic zones of Pakistan; however, its performance varied among different environmental conditions as well as rearing systems. Housing systems and the feeding regimens impart a dynamic influence on egg production and quality characteristics [21]. Although literature regarding effects of housing systems and feeding regimens on the overall quality, nutritional profile, and sensory attribute of backyard type Naked Neck and crossbred chicken eggs were available, the impact of efficient utilization of kitchen waste in the diet of Naked Neck chicken and its influence on egg quality, egg nutritional profile, and sensory attributes is still silent and required further investigation. Thus, the current study was planned to assess the influence of various production systems and feeding levels of kitchen waste on egg quality characteristics, nutritional composition, and sensory attributes of Naked Neck chickens.

2. Materials and methods

This study was conducted at the Department of Poultry Production, University of Veterinary and Animal Sciences, A-Block, Ravi Campus, Pattoki, Pakistan. Pattoki is located at 31°1′0″N, 73°50′60″E with a height of 186 m. The city encounters a hot and muggy tropical climate with temperatures extending from 13 °C in winter to 45 °C in summer.

2.1. Experimental birds and ethics

Birds were maintained in two rearing systems (intensive & free-range) with five dietary treatments based on commercial feed (CF) and kitchen waste (KW), i.e. 100% CF, 75% CF + 25% KW, 50% CF + 50% KW, 25% CF + 75% KW, and 100% KW. A total of 500 birds (400 pullets and 100 cockerels) were allotted as 8 pullets and 2 cockerels in each replicate. Half of the experimental laying birds were placed under the intensive system (1260 ± 20 g) and half were placed in a free-range (1245 ± 15g) production system with an outdoor area for free movement (08:00–16:00 h) with additional feeders and drinkers. Nest boxes were provided in both production systems for easy collection of eggs. Free-range birds were shepherded to the same house (stocking density = 1.88 pullets/m^2), and rice husk was placed on the floor (15 cm) and offered commercial feed with kitchen waste throughout the experimental period (Table 1) in the morning at 8:00 and evening at 17:00. The birds were watered through the nipple system. A protective wire-mesh wall was used to save birds from wild animals (2.44 m high) adjacent to the area. Eggs were collectively selected at initial (22 weeks), middle (35 weeks), and terminal stage (45 weeks) and subjected to egg quality, nutritional composition, and sensory attributes evaluation. The laboratory analysis was performed at the egg quality laboratory at the Department of Poultry Production and Central Laboratory Complex at Ravi Campus, Pattoki,

Table 1. Proximate analysis of kitchen waste and calculated ingredient & nutrient composition of the experimental ration

Proximate	**Kitchen Waste**
Dry Matter %	35.6
Moisture %	42.86
Crude Protein %	16.5
Ether Extract %	18.03
Ash %	6.01
Feed Ingredient (%)	**Grower (7–18 weeks)**
Corn (8.5 %)	61.55
Soybean Meal (30 CP%)	31.70
Soybean Oil	3.00
DCP	1.70
NaCl	0.30
Methionine	0.12
Total	100
Nutrient composition	
Dry Matter	89.5
Crude Protein	20.02
Metabolizable Energy (Kcal/Kg)	3020
Calcium	0.91
Phosphorus	0.35
Lysine	1.09
Methionine	0.43
Feed Ingredient (%)	**Production (21–45 weeks)**
Corn	42.61
Corn Gluten (60%)	1
Soybean Meal (25%)	15.62
Wheat bran	13
Soybean Oil	3.00
Rice tips	19
DCP	1.2
$CaCO_3$	7.42
DL. Methionine	0.15
Nutrient composition	
Crude Protein	17
ME (KCal/Kg)	2750
Calcium	2.81
Phosphorus	0.34
Lysine	0.86
Methionine	0.45

UVAS, Lahore. Under the university regulatory Ethical Review Committee, UVAS, Lahore, Pakistan approved the birds handling procedures (Approval No. DR/758).

2.2. Parameters evaluated

2.2.1. Egg characteristics

Egg geometry of the experimental eggs was determined in terms of egg shape index (ESI), egg surface area (ESA), and egg volume (EV) by evaluating a total of 500 eggs (10 eggs per replicate) (50 eggs per treatment) collected at random every eight weeks from the start of egg production until the termination of the experiment. For this purpose, each egg was weighed carefully by the use of electronic balance with 0.01 g precision and then subjected to the following assessments:

Egg weight (g): a digital electronic weighing balance of 0.01 g (Wincom Company Ltd. China) was used for egg weight.

Egg shape index (ESI): It was calculated by using the following formula:

$$ESI = \left(\frac{\text{egg width}}{\text{egg length}}\right) \times 100$$

Egg surface area (cm^2): It was calculated by using the following formula:

Egg surface area = $3.9782 \times W^{0.7056}$

Egg volume (cm^3): It was calculated by using the following formula:

Egg volume = $0.519 \times$ longitudal length $\times$ transverse width^2

Egg specific gravity: It was determined through egg floatation technique using saline solutions of known specific gravity [22].

Eggshell weight (g): the weight of the eggshell (g) of each egg was also noted on the digital weighing balance.

Eggshell thickness (mm): for this purpose, a digital micrometre (ORKA) company was used. Eggshell thickness (mm) was noted at equator lines.

Haugh unit (HU): Haugh Unit score was using the following equation [23]:

$$HU = 100 \times \text{Log}\,(h + 7.57) - (1.7 \times W^{0.37})]$$

H = Observed height of the albumen in mm; W = Weight of egg (g)

Yolk index (YI): It was calculated by dividing the height of the yolk with the width of the yolk as shown below:

$$YI = \left(\frac{Yh}{Yw}\right) \times 100$$

2.2.2. Egg nutritional composition

The proximate analysis was subjected to evaluate Moisture %, Dry Matter %, Crude Protein %, Nitrogen Free Extract %, Fat %, and Ash % following AOAC guidelines [24].

Egg nutritional composition of birds from different production systems under different nutritional regimens were assessed in terms of Macro minerals, i.e. Na, Ca, P, Mg, and K.

Minerals were determined by the following methods:

Na, K, Ca through flame photometer [25].

Mg through spectrophotometer [26].

P through calorimeter [27].

2.2.3. Egg sensory evaluation

A total of 500 eggs comprised of ten eggs per replicate (50 eggs per treatment) were boiled in a stainless-steel pot containing 900 mL of tap water. As boiling ended water was removed from the container, and then eggs were placed for cooling and crossed tap water over them. Every participant was instructed to follow the 15 points of the hedonic scale [28]. The following sensory attributes were studied separately for egg white and yolk: (a) color (b) taste (c) flavor (d) mouthfeel (e) overall quality.

2.3. Statistical analysis

Effect of the production system and feeding regimens were evaluated on egg quality, nutritional and sensory attributes of Naked Neck chicken through factorial ANOVA. General Linear Model was applied in SAS software (version 9.1). Significant treatment means were compared through Duncan's Multiple Range test [29] considering $p \leq 0.05$. The following mathematical model was applied:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\times\beta)_{ij} + \epsilon_{ijk}$$

Where,

Y_{ijk} = Observation of dependent variable recorded on ith and jth treatment

μ = Population mean

α_i = Effect of ith production system (i = 1,2)

β_j = Effect of jth feeding regimen (j = 1,2,3, 4, 5)

$(\alpha\times\beta)_{ij}$ = Interaction effect between ith and jth treatments

ϵ_{ijk} = Residual effect of kth observation on ith and jth treatment NID ~ 0, σ^2

3. Results and discussion

Egg quality characteristics such as eggshell thickness, eggshell weight, albumen index, and yolk index are important to study as they have a critical role in the stability of egg contents [30]. These indicators are often used to differentiate the fresh and old eggs and, hence, can be important from a consumer point of view. The results of the present study revealed significant differences ($p \leq 0.05$) in egg quality characteristics, nutritional composition, and sensory attributes in Naked Neck chicken reared fed kitchen waste under different housing environments. Results revealed that the thickness and weight of the eggshell (Table 2) were higher ($p \leq 0.05$) in intensively raised chickens that can be attributed to a better ambient environment and optimized nutrition, which might have led to efficient utilization of nutrients in the formation of eggshell. Similar findings have been reported by Englmaierova et al. [31] who observed that egg internal and external quality of laying hens was higher in cage and aviary system than deep litter system, while egg albumen

Table 2. Eggshell weight and thickness of Naked Neck chicken reared under different production system and nutritional regimens.

Production System	Treatment	Shell Weight (g)			p-value	Shell Thickness (mm)			p-value
		22 weeks	35 weeks	45 weeks		22 weeks	35 weeks	45 weeks	
Free-range		$4.43^{b, y} \pm 0.17$	$7.19^{x} \pm 0.18$	$7.62^{x} \pm 0.24$	< 0.0001	$0.35^{y} \pm 0.01$	$0.33^{b, z} \pm 0.01$	$0.39^{x} \pm 0.01$	< 0.0001
Intensive		$5.16^{a, y} \pm 0.23$	$7.36^{x} \pm 0.20$	$7.62^{x} \pm 0.24$	< 0.0001	$0.34^{z} \pm 0.01$	$0.36^{a, y} \pm 0.01$	$0.40^{x} \pm 0.01$	< 0.0001
p-value		0.0024	0.5309	0.3210		0.3204	< 0.0001	0.1551	
	Commercial	$4.30^{c, y} \pm 0.21$	$7.42^{x} \pm 0.48$	$7.68^{x} \pm 0.25$	< 0.0001	0.34 ± 0.01	$0.33^{c} \pm 0.01$	$0.39^{b} \pm 0.25$	0.4112
	25 % KW	$4.38^{bc, z} \pm 0.20$	$6.95^{y} \pm 0.17$	$7.97^{x} \pm 0.34$	< 0.0001	$0.38^{x} \pm 0.01$	$0.33^{c, y} \pm 0.01$	$0.41^{ab, x} \pm 0.01$	0.0016
	50 % KW	$4.60^{bc, y} \pm 0.24$	$7.03^{x} \pm 0.13$	$7.53^{x} \pm 0.19$	< 0.0001	$0.32^{z} \pm 0.01$	$0.38^{a, y} \pm 0.00$	$0.43^{a, x} \pm 0.01$	< 0.0001
	75 % KW	$5.07^{ab, y} \pm 0.50$	$7.63^{x} \pm 0.31$	$7.88^{x} \pm 0.28$	0.0001	0.33 ± 0.01	$0.33^{c} \pm 0.01$	$0.35^{c} \pm 0.01$	0.1369
	100% KW	$5.63^{a, y} \pm 0.24$	$7.35^{x} \pm 0.25$	$7.62^{x} \pm 0.47$	0.0015	0.34 ± 0.01	$0.36^{b} \pm 0.01$	$0.38^{b} \pm 0.02$	0.1134
p-value		0.0035	0.4966	0.7517		0.4435	< 0.0001	0.0002	
Free-range	Commercial	$4.30^{y} \pm 0.36$	$6.85^{x} \pm 0.45$	$7.33^{ab, x} \pm 0.44$	0.0046	0.35 ± 0.00	$0.31^{g} \pm 0.00$	$0.36^{d} \pm 0.00$	0.4238
	25 % KW	$4.13^{z} \pm 0.35$	$7.03^{y} \pm 0.24$	$8.63^{a, x} \pm 0.18$	< 0.0001	$0.39^{x} \pm 0.03$	$0.31^{g, y} \pm 0.00$	$0.44^{ab, x} \pm 0.01$	< 0.0001
	50 % KW	$4.33^{y} \pm 0.09$	$7.15^{x} \pm 0.10$	$7.23^{ab, x} \pm 0.21$	< 0.0001	$0.32^{z} \pm 0.01$	$0.39^{a, y} \pm 0.00$	$0.41^{abc, x} \pm 0.00$	< 0.0001
	75 % KW	$4.13^{y} \pm 0.44$	$7.71^{x} \pm 0.59$	$7.98^{ab, x} \pm 0.52$	0.0033	0.33 ± 0.01	$0.32^{g} \pm 0.00$	$0.34^{d} \pm 0.01$	0.1351
	100% KW	$5.27^{y} \pm 0.29$	$7.20^{x} \pm 0.52$	$6.90^{b, x y} \pm 0.71$	0.0853	0.35 ± 0.01	$0.33^{f} \pm 0.01$	$0.38^{cd} \pm 0.03$	0.2263
Intensive	Commercial	$4.30^{y} \pm 0.29$	$7.98^{x} \pm 0.81$	$8.02^{ab, x} \pm 0.04$	0.0026	$0.33^{y} \pm 0.01$	$0.34^{ed, y} \pm 0.00$	$0.43^{abc, x} \pm 0.00$	0.0002
	25 % KW	$4.63^{y} \pm 0.09$	$6.87^{x} \pm 0.27$	$7.30^{ab, x} \pm 0.32$	0.0006	0.36 ± 0.01	$0.35^{cd} \pm 0.00$	$0.38^{bcd} \pm 0.00$	0.1250
	50 % KW	$4.55^{y} \pm 0.55$	$6.80^{x} \pm 0.40$	$7.93^{ab, x} \pm 0.31$	0.0016	$0.33^{z} \pm 0.02$	$0.37^{b, y} \pm 0.00$	$0.45^{a, x} \pm 0.00$	0.0002
	75 % KW	$6.00^{y} \pm 0.46$	$7.56^{x} \pm 0.36$	$7.77^{ab, x} \pm 0.34$	0.0353	0.34 ± 0.01	$0.34^{ef} \pm 0.00$	$0.35^{d} \pm 0.01$	0.4506
	100% KW	$6.00^{z} \pm 0.25$	$7.50^{y} \pm 0.15$	$8.34^{a, x} \pm 0.27$	0.0011	0.32 ± 0.01	$0.39^{a} \pm 0.01$	$0.38^{bcd} \pm 0.03$	0.1029
p-value		0.1085	0.4785	0.0141		0.4386	< 0.0001	0.0083	

$^{a\text{-}g}$ Superscripts on different means within column differ significantly among treatment groups at $p \leq 0.05$.
$^{x\text{-}z}$ Superscripts on different means within row differ significantly among three ages (22, 35, and 45 weeks) at $p \leq 0.05$.
KW = Kitchen waste.

Table 3. Egg weight and shape index of Naked Neck chicken reared under different production system and nutritional regimens.

Production System	Treatment	Egg Weight (g)			p-value	Shape Index			p-value
		22 weeks	35 weeks	45 weeks		22 weeks	35 weeks	45 weeks	
Free-range		$35.19^{z} \pm 0.87$	$47.52^{y} \pm 0.94$	$51.47^{x} \pm 0.84$	< 0.0001	$77.39^{y} \pm 1.48$	$81.73^{x} \pm 1.28$	$77.09^{y} \pm 1.44$	0.0415
Intensive		$36.49^{y} \pm 1.34$	$48.05^{x} \pm 0.54$	$50.97^{x} \pm 1.36$	< 0.0001	80.94 ± 1.88	80.29 ± 2.26	78.53 ± 1.20	0.6312
p-value		0.1348	0.5397	0.4880		0.0991	0.5600	0.4320	
	Commercial	$34.77^{b, y} \pm 1.01$	$46.54^{bc, x} \pm 1.20$	$49.30^{b, x} \pm 0.85$	< 0.0001	$79.19^{b} \pm 2.22$	80.14 ± 3.29	77.72 ± 1.21	0.7760
	25 % KW	$33.00^{b, z} \pm 1.43$	$45.39^{bc, y} \pm 0.82$	$50.83^{b, x} \pm 0.64$	< 0.0001	$77.88^{b} \pm 2.03$	76.67 ± 1.60	74.70 ± 2.44	0.5552
	50 % KW	$34.00^{b, z} \pm 1.05$	$50.66^{a, y} \pm 0.43$	$58.22^{a, x} \pm 1.33$	< 0.0001	$78.31^{b} \pm 1.49$	84.90 ± 4.71	78.23 ± 1.70	0.2323
	75 % KW	$35.30^{b, y} \pm 0.75$	$49.20^{ab, x} \pm 1.28$	$49.38^{b, x} \pm 1.28$	< 0.0001	$74.36^{b} \pm 1.21$	81.08 ± 1.50	77.23 ± 2.44	0.0559
	100% KW	$42.13^{a, y} \pm 1.75$	$47.15^{bc, x} \pm 0.91$	$48.38^{b, x} \pm 0.69$	0.0055	$86.08^{a} \pm 3.97$	82.25 ± 1.59	81.14 ± 2.13	0.4344
p-value		< 0.0001	0.0060	< 0.0001		0.0261	0.3277	0.2962	
Free-range	Commercial	$36.13^{bc, z} \pm 0.73$	$45.66^{y} \pm 2.45$	$51.10^{c, x} \pm 0.39$	0.0011	78.72 ± 3.84	86.67 ± 3.33	79.51 ± 1.80	0.2192
	25 % KW	$30.07^{bc, z} \pm 0.56$	$44.80^{y} \pm 1.56$	$51.31^{c, x} \pm 0.24$	< 0.0001	75.64 ± 2.78	76.64 ± 2.21	72.02 ± 2.90	0.4763
	50 % KW	$33.67^{cd, z} \pm 0.95$	$49.97^{y} \pm 0.47$	$56.08^{b, x} \pm 1.12$	< 0.0001	79.54 ± 1.89	81.48 ± 1.85	76.67 ± 0.57	0.1714
	75 % KW	$36.90^{bc, y} \pm 0.31$	$51.00^{x} \pm 2.21$	$51.29^{c, x} \pm 2.10$	0.0018	71.88 ± 1.10	80.79 ± 2.43	74.43 ± 4.29	0.1648
	100% KW	$39.20^{b, y} \pm 0.44$	$46.18^{x} \pm 1.47$	$47.57^{c, x} \pm 0.48$	0.0015	81.15 ± 4.73	83.06 ± 2.26	82.80 ± 2.52	0.9109
Intensive	Commercial	$33.40^{cd, y} \pm 1.65$	$47.43^{x} \pm 0.61$	$47.49^{c, x} \pm 0.45$	0.0001	79.65 ± 3.12	73.61 ± 0.71	75.93 ± 0.96	0.1632
	25 % KW	$35.93^{bc, z} \pm 1.15$	$45.97^{y} \pm 0.78$	$50.34^{c, x} \pm 1.31$	0.0002	80.13 ± 2.81	76.70 ± 2.83	77.38 ± 3.75	0.7311
	50 % KW	$33.05^{cd, z} \pm 2.95$	$51.62^{y} \pm 0.71$	$61.17^{a, x} \pm 2.63$	< 0.0001	74.84 ± 1.76	83.43 ± 14.68	77.11 ± 3.66	0.4517
	75 % KW	$33.70^{cd, y} \pm 0.38$	$47.41^{x} \pm 0.20$	$47.47^{c, x} \pm 0.27$	< 0.0001	76.84 ± 0.14	81.37 ± 2.30	80.04 ± 1.89	0.2389
	100% KW	$45.07^{a} \pm 2.54$	48.12 ± 1.03	$49.18^{c} \pm 1.24$	0.2939	91.00 ± 5.66	81.44 ± 2.63	79.48 ± 3.68	0.1955
p-value		0.0031	0.2409	0.0072		0.4241	0.1714	0.3056	

$^{a\text{-}d}$ Superscripts on different means within column differ significantly among treatment groups at $p \leq 0.05$.
$^{x\text{-}z}$ Superscripts on different means within row differ significantly among three ages (22, 35, and 45 weeks) at $p \leq 0.05$.
KW = Kitchen waste.

Table 4. Egg surface area and volume of Naked Neck chicken reared under different production system and nutritional regimens.

Production System	Treatment	Egg Surface Area (cm^2)			p-value	Egg Volume (cm^2)			p-value
		22 weeks	35 weeks	45 weeks		22 weeks	35 weeks	45 weeks	
Free-range		$49.49^{z} \pm 0.82$	$60.54^{y} \pm 0.80$	$63.88^{x} \pm 0.69$	< 0.0001	$32.13^{z} \pm 0.79$	$43.39^{y} \pm 0.86$	$46.99^{x} \pm 0.76$	< 0.0001
Intensive		$50.65^{y} \pm 1.22$	$61.02^{x} \pm 0.46$	$63.42^{x} \pm 1.11$	< 0.0001	$33.31^{y} \pm 1.23$	$43.87^{x} \pm 0.50$	$46.54^{x} \pm 1.24$	< 0.0001
p-value		0.1474	0.5175	0.4412		0.1348	0.5397	0.4880	
	Commercial	$49.11^{b, y} \pm 0.97$	$59.71^{bc, x} \pm 1.03$	$62.07^{b, x} \pm 0.72$	< 0.0001	$31.74^{b, y} \pm 0.92$	$42.49^{bc, x} \pm 1.09$	$45.01^{b, x} \pm 0.77$	< 0.0001
	25 % KW	$47.39^{b, z} \pm 1.37$	$58.73^{c, y} \pm 0.71$	$63.36^{b, x} \pm 0.53$	< 0.0001	$30.13^{b, z} \pm 1.31$	$41.44^{c, y} \pm 0.75$	$46.40^{b, x} \pm 0.58$	< 0.0001
	50 % KW	$48.38^{b, z} \pm 1.01$	$63.22^{a, y} \pm 0.36$	$69.38^{a, x} \pm 1.06$	< 0.0001	$31.04^{b, z} \pm 0.96$	$46.25^{a, y} \pm 0.39$	$53.15^{a, x} \pm 1.21$	< 0.0001
	75 % KW	$49.62^{b, y} \pm 0.70$	$61.98^{ab, x} \pm 1.06$	$62.13^{b, x} \pm 1.06$	< 0.0001	$32.23^{b, y} \pm 0.68$	$44.92^{ab, x} \pm 1.17$	$45.09^{\mathbf{b, x}} \pm 1.17$	< 0.0001
	100% KW	$55.83^{a, y} \pm 1.54$	$60.24^{bc, x} \pm 0.78$	$61.30^{b, x} \pm 0.59$	0.0053	$38.47^{a, y} \pm 1.60$	$43.05^{bc, x} \pm 0.83$	$44.17^{b, x} \pm 0.63$	0.0055
p-value		< 0.0001	0.0059	<0.0001		< 0.0001	0.0060	<0.0001	
Free-range	Commercial	$50.41^{bc, z} \pm 0.68$	$58.94^{y} \pm 2.10$	$63.59^{x} \pm 0.32$	0.0010	$32.99^{bc, z} \pm 0.67$	$41.69^{y} \pm 2.24$	$46.65^{c, x} \pm 0.35$	0.0011
	25 % KW	$44.57^{d, z} \pm 0.56$	$58.22^{y} \pm 1.35$	$63.77^{c, x} \pm 0.20$	< 0.0001	$27.45^{d, z} \pm 0.51$	$40.91^{y} \pm 1.43$	$46.85^{c, x} \pm 0.22$	< 0.0001
	50 % KW	$48.08^{cd, z} \pm 0.91$	$62.65^{y} \pm 0.39$	$67.68^{b, x} \pm 0.91$	< 0.0001	$30.74^{cd, z} \pm 0.87$	$45.63^{y} \pm 0.43$	$51.20^{b, x} \pm 1.02$	< 0.0001
	75 % KW	$51.13^{bc, y} \pm 0.28$	$63.48^{x} \pm 1.84$	$63.73^{c, x} \pm 1.74$	0.0014	$33.69^{bc, y} \pm 0.28$	$46.56^{x} \pm 2.02$	$46.83^{c, x} \pm 7.92$	0.0018
	100% KW	$53.24^{b, y} \pm 0.40$	$59.41^{x} \pm 1.27$	$60.62^{c, x} \pm 0.41$	0.0014	$35.79^{b, y} \pm 0.40$	$42.16^{x} \pm 1.34$	$43.43^{c, x} \pm 0.44$	0.0015
Intensive	Commercial	$47.80^{cd, y} \pm 1.58$	$60.49^{x} \pm 0.53$	$60.55^{c, x} \pm 0.39$	0.0001	$30.49^{cd, y} \pm 1.50$	$43.30^{x} \pm 0.56$	$43.36^{c, x} \pm 0.41$	0.0001
	25 % KW	$50.22^{bc, z} \pm 1.07$	$59.24^{y} \pm 0.67$	$62.95^{c, x} \pm 1.10$	0.0002	$32.81^{bc, z} \pm 1.05$	$41.97^{y} \pm 0.71$	$45.96^{c, x} \pm 1.20$	0.0002
	50 % KW	$47.45^{cd, z} \pm 2.84$	$64.02^{y} \pm 0.59$	$71.72^{a, x} \pm 2.07$	< 0.0001	$30.17^{cd, z} \pm 2.69$	$47.12^{y} \pm 0.65$	$55.85^{a, x} \pm 2.40$	< 0.0001
	75 % KW	$48.11^{cd, y} \pm 0.36$	$60.48^{x} \pm 0.17$	$60.53^{c, x} \pm 0.23$	< 0.0001	$30.77^{cd, y} \pm 0.35$	$43.28^{x} \pm 0.19$	$43.34^{c, x} \pm 0.25$	< 0.0001
	100% KW	$58.41^{a} \pm 2.23$	61.08 ± 0.87	$61.98^{c} \pm 1.05$	0.2960	$41.15^{a} \pm 2.32$	43.93 ± 0.94	$44.90^{c} \pm 1.13$	0.2939
p-value		0.0030	0.2467	0.0071		0.0031	0.2409	0.0072	

$^{a\text{-}d}$ Superscripts on different means within column differ significantly among treatment groups at $p \leq 0.05$.
$^{x\text{-}z}$ Superscripts on different means within row differ significantly among three ages (22, 35, and 45 weeks) at $p \leq 0.05$.
KW = Kitchen waste.

Table 5. Egg yolk index and weight of Naked Neck chicken reared under different production system and nutritional regimens.

Production System	Treatment	Yolk Index			p-value	Yolk Weight (g)			p-value
		22 weeks	35 weeks	45 weeks		22 weeks	35 weeks	45 weeks	
Free-range		$44.35^{x} \pm 1.43$	$29.98^{z} \pm 1.24$	$36.58^{y} \pm 2.05$	< 0.0001	$8.76^{z} \pm 0.17$	$14.02^{y} \pm 0.20$	$15.90^{x} \pm 0.27$	< 0.0001
Intensive		$41.64^{x} \pm 1.51$	$30.26^{y} \pm 0.86$	$38.48^{x} \pm 2.38$	< 0.0001	$8.91^{z} \pm 0.21$	$14.27^{y} \pm 0.13$	$16.22^{x} \pm 0.25$	< 0.0001
p-value		0.0842	0.8438	0.3357		0.4833	0.2304	0.2608	
	Commercial	$40.65^{bc, y} \pm 1.19$	$28.96^{z} \pm 0.84$	$46.35^{a, x} \pm 2.56$	< 0.0001	$8.83^{ab, z} \pm 0.08$	$13.58^{y} \pm 0.35$	$16.40^{ab, x} \pm 0.15$	< 0.0001
	25 % KW	$48.72^{a, x} \pm 1.92$	$32.88^{z} \pm 2.66$	$41.91^{ab, y} \pm 1.42$	0.0003	$8.05^{c, z} \pm 0.33$	$14.02^{y} \pm 0.31$	$16.75^{a, x} \pm 0.44$	< 0.0001
	50 % KW	$44.82^{ab, x} \pm 1.91$	$27.70^{y} \pm 1.12$	$30.03^{c, y} \pm 2.84$	< 0.0001	$8.57^{bc, z} \pm 0.28$	$14.34^{y} \pm 0.27$	$16.62^{a, x} \pm 0.28$	< 0.0001
	75 % KW	$42.56^{ac, x} \pm 1.68$	$28.96^{y} \pm 1.27$	$38.38^{b, x} \pm 2.68$	0.0006	$9.30^{ab, z} \pm 0.12$	$14.45^{y} \pm 0.11$	$15.60^{bc, x} \pm 0.37$	< 0.0001
	100% KW	$38.24^{c, x} \pm 2.79$	$32.11^{xy} \pm 1.09$	$30.97^{c, y} \pm 2.60$	0.0853	$9.43^{a, z} \pm 0.22$	$14.33^{y} \pm 0.13$	$14.93^{c, x} \pm 0.22$	< 0.0001
p-value		0.0029	0.1282	< 0.0001		0.0038	0.0663	0.0015	
Free-range	Commercial	$38.87^{cd, x} \pm 1.45$	$27.10^{y} \pm 0.26$	$40.68^{b, x} \pm 0.17$	< 0.0001	$8.80^{z} \pm 0.17$	$12.87^{b, y} \pm 0.19$	$16.61^{x} \pm 0.27$	< 0.0001
	25 % KW	$51.47^{a} \pm 3.02$	35.04 ± 5.29	$42.43^{ab} \pm 2.88$	0.0647	$8.17^{z} \pm 0.48$	$13.93^{a, y} \pm 0.59$	$16.10^{x} \pm 0.74$	0.0002
	50 % KW	$45.47^{abc, x} \pm 2.18$	$27.89^{y} \pm 0.81$	$33.28^{cd, y} \pm 5.44$	0.0274	$8.53^{z} \pm 0.58$	$14.52^{a, y} \pm 0.16$	$16.44^{x} \pm 0.56$	< 0.0001
	75 % KW	$42.23^{bc} \pm 3.19$	29.03 ± 0.98	$39.48^{b} \pm 5.23$	0.0866	$9.20^{y} \pm 0.06$	$14.67^{a, x} \pm 0.03$	$15.73^{x} \pm 0.56$	< 0.0001
	100% KW	$43.71^{abc, x} \pm 1.45$	$30.84^{y} \pm 1.96$	$27.01^{cd, y} \pm 0.41$	0.0004	$9.10^{y} \pm 0.10$	$14.14^{a, x} \pm 0.09$	$14.65^{x} \pm 0.32$	< 0.0001
Intensive	Commercial	$42.43^{bc, y} \pm 1.35$	$30.82^{z} \pm 0.19$	$52.03^{a, x} \pm 0.65$	< 0.0001	$8.87^{z} \pm 0.03$	$14.30^{a, y} \pm 0.25$	$16.20^{x} \pm 0.05$	< 0.0001
	25 % KW	$45.96^{abc, x} \pm 1.28$	$30.71^{y} \pm 1.63$	$41.40^{ab, x} \pm 1.22$	0.0006	$7.93^{z} \pm 0.55$	$14.11^{a, y} \pm 0.36$	$17.40^{x} \pm 0.06$	< 0.0001
	50 % KW	$41.77^{bc, x} \pm 4.65$	$28.77^{y} \pm 3.45$	$27.26^{cd, y} \pm 0.01$	0.0043	$8.55^{z} \pm 0.45$	$14.00^{a, y} \pm 0.90$	$16.92^{x} \pm 0.28$	< 0.0001
	75 % KW	$42.88^{bc, x} \pm 1.97$	$28.89^{y} \pm 2.66$	$37.28^{bc, xy} \pm 2.69$	0.0194	$9.40^{y} \pm 0.23$	$14.23^{a, x} \pm 0.09$	$15.47^{x} \pm 0.61$	< 0.0001
	100% KW	$32.77^{d} \pm 2.64$	33.38 ± 0.73	$34.92^{bcd} \pm 4.25$	0.8688	$9.77^{y} \pm 0.34$	$14.52^{a, x} \pm 0.19$	$15.21^{x} \pm 0.24$	< 0.0001
p-value		0.0489	0.4392	0.0441		0.7594	0.0450	0.3035	

$^{a\text{-}d}$ Superscripts on different means within column differ significantly among treatment groups at $p \leq 0.05$.
$^{x\text{-}z}$ Superscripts on different means within row differ significantly among three ages (22, 35, and 45 weeks) at $p \leq 0.05$.
KW = Kitchen waste.

Table 6. Egg specific gravity and Haugh unit score of Naked Neck chicken reared under different production system and nutritional regimens.

Production System	Treatment	Egg Specific Gravity			p-value	Haugh Unit Score			p-value
		22 weeks	35 weeks	45 weeks		22 weeks	35 weeks	45 weeks	
Free-range		1.09^{x} ± 0.00	1.08^{y} ± 0.00	1.07^{z} ± 0.00	< 0.0001	105.59^{z} ± 0.91	108.81^{y} ± 0.55	116.35^{x} ± 0.88	< 0.0001
Intensive		1.085^{x} ± 0.00	1.080^{y} ± 0.00	1.075^{z} ± 0.00	< 0.0001	107.16^{y} ± 0.48	109.01^{y} ± 0.92	116.73^{x} ± 0.82	< 0.0001
p-value		0.5474	0.5307	0.2068		0.1055	0.8108	0.7392	
	Commercial	1.09^{x} ± 0.00	1.08^{y} ± 0.00	1.07^{z} ± 0.00	< 0.0001	105.18$^{bc, y}$ ± 1.32	106.77$^{c, y}$ ± 1.25	117.04^{x} ± 0.18	< 0.0001
	25 % KW	1.08^{x} ± 0.00	1.08^{x} ± 0.00	1.07^{y} ± 0.00	0.0118	108.26$^{ab, y}$ ± 0.40	107.35$^{bc, y}$ ± 0.88	117.68^{x} ± 2.19	0.0001
	50 % KW	1.09^{x} ± 0.00	1.08^{y} ± 0.00	1.08^{y} ± 0.00	0.0005	105.47$^{abc, z}$ ±0.61	108.67$^{bc, y}$ ± 1.08	117.08^{x} ± 0.09	< 0.0001
	75 % KW	1.08^{x} ± 0.00	1.08^{x} ± 0.00	1.07^{y} ± 0.00	0.0004	104.48$^{c, z}$ ± 1.66	109.75$^{ab, y}$ ± 0.10	117.23^{x} ± 1.54	< 0.0001
	100% KW	1.09^{x} ± 0.00	1.08^{y} ± 0.00	1.07^{z} ± 0.00	0.0001	108.49$^{a, y}$ ± 0.52	112.00$^{a, x}$ ± 1.04	113.68^{x} ± 0.94	0.0023
p-value		0.8045	0.9279	0.9895		0.0336	0.0051	0.2113	
Free-range	Commercial	1.09^{x} ± 0.00	1.08^{y} ± 0.00	1.07^{z} ± 0.00	0.0004	103.96^{y} ± 2.65	105.60^{y} ± 1.29	116.78^{x} ± 0.20	0.0036
	25 % KW	1.08 ± 0.00	1.08 ± 0.00	1.07 ± 0.00	0.0764	107.84^{y} ± 0.47	108.57^{y} ± 1.06	119.66^{x} ± 0.09	< 0.0001
	50 % KW	1.09^{x} ± 0.00	1.08^{y} ± 0.00	1.07^{y} ±0.00	0.0109	105.33^{z} ± 0.47	109.71^{y} ± 0.15	117.10^{x} ± 0.13	< 0.0001
	75 % KW	1.08^{x} ± 0.00	1.079^{xy} ± 0.00	1.074^{y} ± 0.00	0.0222	102.71^{y} ± 3.16	109.66^{xy} ±0.10	116.12^{x} ± 3.17	0.0293
	100% KW	1.09^{x} ± 0.00	1.08^{y} ± 0.00	1.08^{y} ± 0.00	0.0244	108.11± 0.75	110.50 ± 0.55	112.09 ± 1.36	0.0658
Intensive	Commercial	1.09^{x} ± 0.00	1.08^{y} ± 0.00	1.07^{z} ± 0.00	0.0069	106.40^{y} ± 0.48	107.94^{y} ± 2.19	117.30^{x} ± 0.22	0.0021
	25 % KW	1.08 ± 0.00	1.08 ± 0.00	1.08 ± 0.00	0.2842	108.69 ± 0.62	106.12 ± 1.12	115.69 ± 4.48	0.1030
	50 % KW	1.09 ± 0.00	1.08 ± 0.00	1.08 ± 0.00	0.0886	106.30^{y} ± 1.81	106.61^{y} ± 3.34	117.06^{x} ± 0.25	0.0031
	75 % KW	1.08^{x} ± 0.00	1.08^{x} ± 0.00	1.07^{y} ± 0.00	0.0439	106.24^{z} ± 0.77	109.85^{y} ± 0.17	118.35^{x} ± 0.74	< 0.0001
	100% KW	1.08^{x} ± 0.00	1.08^{x} ± 0.00	1.07^{y} ± 0.00	0.0119	108.87^{y} ± 0.82	113.50^{x} ± 1.69	115.27^{x} ± 0.16	0.0147
p-value		0.9731	0.8524	0.3189		0.7818	0.1619	0.3561	

$^{a\text{-}c}$ Superscripts on different means within column differ significantly among treatment groups at $p \leq 0.05$
$^{x\text{-}z}$ Superscripts on different means within row differ significantly among three ages (22, 35, and 45 weeks) at $p \leq 0.05$.
KW = Kitchen waste.

Table 7. Egg organoleptic of Naked Neck chicken reared under different production systems and nutritional regimens.

Production system	Treatment	Colour	Taste	Flavour	Mouthfeel	Overall quality
Free-range		6.38 ± 0.50	7.76 ± 0.57	9.26 ± 0.56	8.72 ± 0.56	10.02 ± 0.50
Intensive		6.80 ± 0.38	7.54 ± 0.54	7.90 ± 0.55	7.74 ± 0.55	9.54 ± 0.52
p-value		0.3287	0.9791	0.1046	0.2059	0.5523
	Commercial	6.84 ± 0.73	6.48^{ab} ± 0.77	7.44^{bc} ± 0.93	6.64^{b} ± 0.82	8.44^{b} ± 0.80
	25 % KW	5.14 ± 0.88	5.71^{b} ± 0.81	5.71^{c} ± 0.81	6.57^{b} ± 1.16	8.29^{b} ± 0.98
	50 % KW	7.60 ± 0.64	8.15^{ab} ± 0.87	8.80^{ab} ± 0.75	9.05^{ab} ± 0.91	10.15^{ab} ±0.72
	75 % KW	6.00 ± 0.74	8.85^{a} ± 0.90	9.55^{ab} ± 0.71	9.35^{a} ± 0.64	11.15^{a} ± 0.71
	100% KW	6.86 ± 0.49	8.71^{a} ± 0.84	10.71^{a} ± 0.74	9.38^{a} ± 0.80	10.71^{ab} ± 0.69
p-value		0.1432	0.0287	0.0013	0.0314	0.0287
Free-range	Commercial	5.90 ± 1.29	6.30 ± 1.54	6.00 ± 1.37	7.10 ± 1.37	7.60 ± 0.93
	25 % KW	5.60 ± 1.36	5.60 ± 0.88	8.20 ± 1.40	6.00 ± 1.37	9.50 ± 1.31
	50 % KW	8.00 ± 0.84	8.80 ± 1.16	9.20 ± 1.04	10.20 ± 1.12	9.60 ± 1.07
	75 % KW	5.20 ± 1.20	8.20 ± 1.20	11.10 ± 0.74	10.70 ± 0.79	11.60 ± 1.05
	100% KW	7.20 ± 0.80	9.90 ± 1.02	11.80 ± 0.74	9.60 ± 1.07	11.80 ±0.74
Intensive	Commercial	7.60 ± 1.11	6.30 ± 1.01	7.20 ± 1.44	6.70 ± 1.27	8.00 ± 1.46
	25 % KW	5.78 ± 0.70	6.67 ± 1.15	5.78 ± 1.18	6.67 ± 1.49	8.44 ± 1.24
	50 % KW	7.20 ± 1.00	7.50 ± 1.33	8.40 ± 1.11	7.90 ± 1.40	10.70 ± 0.99
	75 % KW	6.80 ± 0.85	9.50 ± 1.17	8.00 ± 1.03	8.00 ± 0.84	10.70 ± 0.99
	100% KW	6.55 ± 0.61	7.64 ± 1.26	9.73 ± 1.21	9.18 ± 1.22	9.73 ± 1.08
p-value		0.5518	0.3393	0.6585	0.6428	0.6601

Superscripts on different means within column differ significantly at $p \leq 0.05$.
KW = Kitchen waste.

Table 8. The nutrient of egg albumen in Naked Neck chicken reared under different production systems and nutritional regimens.

Production system	Treatment	Moisture %	Crude Protein %	Ash%
Free-range		$81.46^{a} \pm 1.06$	73.39 ± 0.83	$4.48^{a} \pm 0.13$
Intensive		$77.44^{b} \pm 1.74$	73.40 ± 0.83	$4.24^{b} \pm 0.10$
p-value		< 0.0001	0.9848	0.0004
	Commercial	$72.87^{d} \pm 2.79$	$70.51^{c} \pm 1.59$	$4.18^{b} \pm 0.23$
	25 % KW	$76.97^{c} \pm 0.96$	$76.80^{a} \pm 0.14$	$4.11^{b} \pm 0.13$
	50 % KW	$80.09^{b} \pm 2.03$	$73.65^{b} \pm 0.54$	$4.89^{a} \pm 0.19$
	75 % KW	$86.09^{a} \pm 1.29$	$75.06^{ab} \pm 0.25$	$4.39^{b} \pm 0.08$
	100% KW	$80.53^{b} \pm 1.62$	$70.97^{c} \pm 1.51$	$4.24^{b} \pm 0.19$
p-value		0.0003	< 0.0001	0.0304
Free-range	Commercial	$80.03^{bcd} \pm 0.79$	$73.63^{b} \pm 1.25$	$4.59^{b} \pm 0.33$
	25 % KW	$79.46^{cd} \pm 0.22$	$76.78^{a} \pm 0.26$	$4.44^{b} \pm 0.04$
	50 % KW	$83.35^{abc} \pm 1.55$	$73.95^{ab} \pm 1.03$	$5.17^{a} \pm 0.31$
	75 % KW	$87.95^{a} \pm 2.33$	$75.38^{ab} \pm 0.12$	$4.45^{f} \pm 0.08$
	100% KW	$76.53^{ed} \pm 1.24$	$67.22^{c} \pm 1.02$	$3.75^{c} \pm 0.05$
Intensive	Commercial	$65.72^{f} \pm 1.25$	$67.39^{c} \pm 1.94$	$3.77^{c} \pm 0.15$
	25 % KW	$74.48^{e} \pm 0.39$	$76.82^{a} \pm 0.15$	$3.78^{b} \pm 0.06$
	50 % KW	$78.25^{ed} \pm 3.53$	$73.36^{b} \pm 0.51$	$4.60^{b} \pm 0.13$
	75 % KW	$84.24^{abc} \pm 0.28$	$74.75^{ab} \pm 0.45$	$4.32^{b} \pm 0.15$
	100% KW	$84.53^{ab} \pm 0.29$	$74.71^{c} \pm 0.50$	$4.74^{ab} \pm 0.01$
p-value		< 0.0001	< 0.0001	< 0.0001

Superscripts on different means within column differ significantly at $p \leq 0.05$.
KW = Kitchen waste.

and shell qualities were higher in conventional cage system, whereas yolk index was higher in hens of enriched cages system and aviary system. In another previous study, higher eggshell strength and lower eggshell thickness were observed in the eggs of chickens reared in the cage system compared to the floor system [10,32]. Usman et al. [33] reported that egg weight was higher in the enriched cage system than in aviary and conventional cages, while higher egg surface area and egg volume were observed in enriched cages than in conventional cages and aviary system. The study of Ledvinka et al. [34] also explained the influence of the housing system as well as feeding regimens on the eggshell strength, weight, and thickness. Furthermore, eggshell density, thickness, and weight were lower in birds reared on the free rage system [35]. It has been reported that albumen height and eggshell thickness were higher in eggs of birds reared in free-range than in cage systems [36]. However, eggshell strength, shell ratio, yolk ratio, colour, and immunoglobulin IgY(ug) did not differ among birds reared under the free-range and cage system [36].

Another study reported that higher shell weight and thickness in birds reared under the free-range system [37]. Similarly, larger-sized eggs with high albumen to yolk ratio were noted by Pistekova et al. [38] in birds reared under the litter system. Mohammed et al. [39] noticed the dark yellow colour of yolk with low-quality albumen when birds were given access to the free-range system. The dark yellow colour could be attributed to the utilization of green forages [40]. Abou-Elezz et al. [41] reported higher shell thickness in eggs from free-range birds and stated that higher thickness is due to consumption of calcium through soil sources. Furthermore, Mutayoba et al. [42] reported that the provision of supplementary diets (Scavenging + commercial feed) to laying hens significantly improve growth, egg production, and egg quality. It has been also described by Karcher et al. [43] that manipulation in the feeding system can directly affect the egg quality characteristics. Stanley et al. [44] observed significant variation in egg weight between cage and barns system. However, Jones et al. [45] noticed that those

Table 9. The nutrients of egg yolk in naked neck chicken reared under different production systems and nutritional regimens.

Production system	Treatment	Moisture%	Crude Protein %	Fat%	Ash%
Free-range		44.10^{b} ± 1.45	30.44^{b} ± 0.87	49.50^{b} ± 1.42	3.34^{a} ± 0.13
Intensive		46.16^{a} ± 0.84	30.62^{a} ± 0.53	50.21^{a} ± 1.96	3.12^{b} ± 0.14
p-value		0.0002	0.0022	< 0.0001	0.0011
	Commercial	44.54 ± 2.17	29.24 ± 1.47	42.48 ± 3.01	3.20 ± 0.32
	25 % KW	42.63 ± 0.84	32.50 ± 0.38	58.08 ± 2.28	3.18 ± 0.09
	50 % KW	41.01 ± 2.20	27.55 ± 1.30	49.34 ± 2.56	3.87 ± 0.21
	75 % KW	48.90 ± 1.32	32.81 ± 0.34	51.78 ± 0.35	2.76 ± 0.08
	100% KW	48.57 ± 0.88	30.57 ± 0.43	47.59± 0.46	3.15 ± 0.06
p-value		0.0810	0.8345	0.6547	0.1402
Free-range	Commercial	42.40^{ab}± 4.26	29.93 ± 2.93	47.59^{b}± 4.49	3.73^{ab} ± 0.37
	25 % KW	44.78^{bc}± 0.30	31.59 ± 0.31	52.87^{b}± 0.31	3.37^{abc} ± 0.11
	50 % KW	36.17^{d}± 2.60	26.52 ± 2.59	47.64^{b}± 5.31	3.69^{ab} ± 0.37
	75 % KW	50.78^{a}± 1.68	33.13 ± 0.05	52.19^{b}± 0.26	2.76^{c} ± 0.12
	100% KW	46.39^{ab}± 0.65	31.05 ± 0.77	47.21^{b}± 0.92	3.16^{bc}± 0.06
Intensive	Commercial	46.69^{ab}± 0.89	28.55 ± 1.08	37.38^{b}± 0.66	2.68^{c}± 0.37
	25 % KW	40.47^{cd}± 0.28	33.42 ± 0.13	63.28^{a}± 2.48	3.00^{bc} ± 0.02
	50 % KW	45.84^{abc}± 0.38	28.58 ± 0.69	51.03^{b}± 0.72	4.04^{a} ± 0.23
	75 % KW	47.03^{ab}± 1.73	32.49 ± 0.68	51.37^{b}± 0.62	2.76^{c} ± 0.12
	100% KW	50.75^{a}± 0.15	30.09 ± 0.35	47.97^{c}± 0.23	3.13^{bc} ± 0.13
p-value		0.0019	0.5763	0.0054	0.0514

Superscripts on different means within column differ significantly at $p \leq 0.05$.
KW = Kitchen waste.

eggs from aviaries and furnished cages were significantly heavier than from conventional cages systems. Laywel et al. [46][2] also observed heavy eggs in both conventional and furnished cages.

As far as feeding regimens are concerned, the results of a recent study showed that egg surface area, shape index, egg volume, shell thickness, yolk weight, and Haugh unit score (Table 2,3,4,5,6) were higher ($p \leq 0.05$) in birds fed 100% kitchen waste. Çatlı et al. [47] reported higher eggshell breaking strength in laying hens fed with meat and bone meal (MBM) when compared with oyster shell meal (OSM). On the other hand, Ukachukwu and Akpan [48] described that the quality characteristics of an egg were not influenced by the various feeding levels in pullets. Richards et al. [49] explained the lower quality of eggs with restricted feeding than limited feeding in broiler breeders. Oyedeji et al. [50] reported that the weight of the egg was higher with limited feeding in laying hens.

Robinson et al. [51] reported that different sources of feeding influenced the different factors of egg quality and composition. Though, analyses of productive traits need to consider the relative allocation of nutrients [52]. The influence of restricted feed and additional feed on the quality and size of eggs have been described in laying birds [53].

In terms of sensory evaluation, egg taste, flavour, and mouthfeel (Table 7) were higher ($p \leq 0.05$) in birds fed with 100% kitchen waste; however, the overall organoleptic quality was higher in birds fed with 75% kitchen waste. Similarly, the study of Hayat et al. [54] used the feed treatment of flaxseed in the diet of hens. Trained and untrained panellists were selected to test the flavour, aroma, and overall quality of eggs. The untrained panel couldn't observe the taste aroma and overall differences in the egg while the trained panel was identified the taste aroma and overall quality of eggs in birds fed with 10% of flaxseed in the diet. Rossi [55] carried out different experimental trials on egg organoleptic evaluation of hard boil eggs from the different production systems commented no effect on egg taste.

However, the study of Drazbo et al. [56] reported that feeding treatments did not affect the properties of sensory

[2] http://www.laywel.eu/web.

Table 10. The content of Egg mineral elements in Naked Neck chicken reared under different production systems and nutritional regimens.

Production system	Treatment	Mg (ppm)	Na (ppm)	K (ppm)	Ca (ppm)	P (ppm)
Free-range		12.96 ± 0.19	141.40 ± 1.09	138.20 ± 1.04	55.00 ± 1.15	198.40 ± 0.99
Intensive		12.40 ± 0.28	141.40 ± 0.72	138.53 ± 0.83	55.87 ± 1.03	197.67± 0.79
p-value		0.1084	1.0000	0.8072	0.5905	0.5961
	Commercial	12.95 ± 0.24	142.17 ± 1.42	137.33 ± 0.61	54.00 ± 1.84	198.83 ± 1.87
	25 % KW	12.21 ± 0.56	141.17 ± 1.66	137.67 ± 2.01	56.17 ± 1.54	199.00 ± 0.89
	50 % KW	13.02 ± 0.53	139.67 ± 1.17	139.83 ± 1.89	52.83 ± 1.92	196.17± 0.91
	75 % KW	12.38 ± 0.30	141.83 ± 1.83	137.00 ± 0.97	57.33 ± 1.28	199.50 ± 1.96
	100% KW	12.83 ± 0.23	142.17 ± 1.25	140.00 ± 1.37	56.83 ± 1.66	196.67 ± 0.80
p-value		0.4628	0.7821	0.4787	0.3462	0.4408
Free-range	Commercial	12.85 ± 0.43	141.67 ± 2.03	137.00 ± 1.00	52.33 ± 2.03	198.33 ± 3.76
	25 % KW	12.41 ± 0.19	140.67 ± 3.48	137.00 ± 3.51	55.67 ± 2.85	199.67 ± 1.20
	50 % KW	14.07 ± 0.18	139.67 ± 2.33	139.00 ± 2.89	53.33 ± 3.53	196.67 ± 1.76
	75 % KW	12.44 ± 0.31	141.00 ± 3.21	135.67 ± 1.45	58.33 ± 2.03	200.33 ± 2.91
	100% KW	13.02 ± 0.26	144.00 ± 2.08	142.33 ± 0.88	55.33 ± 2.60	197.00 ± 1.53
Intensive	Commercial	13.04 ± 0.31	142.67 ± 2.40	137.67 ± 0.88	55.67 ± 3.18	199.33 ± 1.76
	25 % KW	12.01 ± 1.21	141.67 ± 1.20	138.33 ± 2.73	56.67 ± 1.86	198.33 ± 1.45
	50 % KW	11.69 ± 0.81	140.50 ± 1.50	138.50 ± 3.50	50.00 ± 1.00	195.00± 1.00
	75 % KW	12.32 ± 0.58	142.67 ± 2.40	138.33 ± 0.88	56.33 ± 1.76	198.67 ± 3.18
	100% KW	12.63 ± 0.39	140.33 ± 0.33	137.67 ± 1.76	58.33 ± 2.19	196.33 ± 1.45
p-value		0.2669	0.7729	0.4734	0.7746	0.9752

Superscripts on different means within column differ significantly at $p \le 0.05$.
KW = Kitchen waste; Mg = magnesium; Na = sodium; K = potassium; Ca = calcium; P = phosphorus.

evaluation of eggs, except the colour of egg yolk. Sensory analysis revealed that yolk colour was most intense in eggs from hens fed 20% blue lupine seeds (group L20) ($p \le 0.05$). However, the addition of the blue lupine seeds in the diet of layer birds did not influence the taste, aroma, and structural characteristics of eggs. The source of protein in feed anyhow, positive aspects such as that egg-aroma and egg- taste influenced in all samples.

In this experiment, higher ($p \le 0.05$) albumen ash and moisture % (Table 8) in the free-range system might be due to increased movement of birds and better utilization of feed ingredients that ultimately improved egg size and internal quality. Moreover, yolk moisture, crude protein, and fat % were higher ($p \le 0.05$) in intensive rare birds, and this could be attributed to a better realization of genetic potential, as birds were provided with an ideal environment that improved health status especially ovary of birds, hence, improved yolk quality (Table 9). The egg mineral composition was consisting of phosphorus (198 mg) calcium (55 mg), potassium (138 mg), magnesium (12 mg), and sodium (141 mg) per 100 g of the whole egg (Table 10). However, egg mineral profile did not differ significantly ($p > 0.05$) among treatment groups regarding housing systems, dietary regimens, and their interaction. The concentration of mineral contents was retrieved from an agriculture research service that identified the values for mineral composition for phosphorus (198 mg) calcium (56 mg), potassium (138 mg), magnesium (12 mg), and sodium (142 mg) per 100 g of the whole egg [57].

4. Conclusion

It can be concluded that Naked Neck chicken perform better in the intensive system, whereas feeding kitchen waste up to 75% may enhance egg quality characteristics including egg weight, shape index, surface area, volume, shell weight, yolk weight, yolk index, and Haugh units as well as sensory attributes like taste, flavour, and mouthfeel. On the other hand, in free-range system feeding chickens, the kitchen waste up to 75% may enhance the nutritional composition of eggs.

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References

1. Krawczyk J, Gornowicz E. Quality of eggs from hens kept in two different free-range systems in comparison with a barn system. European Poultry Science. 2010; 74 (3): 151-157.
2. Henchion M, Hayes M, Mullen AM, Fenelon M, Tiwari B. Future protein supply and demand: strategies and factors influencing a sustainable equilibrium. Foods. 2017; 6: 53 (6): 1-21. doi: 10.3390/foods6070053
3. Miranda JM, Anton X, Redondo VC, Roca-Saavedra P, Rodriguez JA et al. Egg and egg-derived foods: effects on human health and use as functional foods. Nutrients. 2015; 7 (1): 706-729. doi: 10.3390/nu7010706
4. Roberts JR. Factors affecting egg shell and internal egg quality. Journal of Poultry Science. 2010; 41 (3): 161-177. doi: 10.2141/jpsa.41.161
5. Carrillo S, Rios VH, Calvo C, Carranco ME, Casas M et al. N-3 fatty acid content in eggs laid by hens fed with marine algae and sardine oil and stored at different times and temperatures. Journal of Applied Phycology. 2012; 24 (3): 593-599. doi. 10.1007/S10811-011-9777
6. Islam MS, Dutta RK. Egg quality traits of indigenous, exotic and crossbred chickens' in Rajshahi, Bangladesh. Journal of Life Earth Science. 2010; 5 (1): 63-67. doi: 10.3329/jles.v5i0.7352
7. Jones DR, Musgrove MT, Anderson KE, Thesmar HS. Physical quality and composition of retail shell eggs. Poultry Science. 2010; 89 (3): 582-587. doi: 10.3382/ps.2009-00315
8. Isidahomen CE, Njidda AA, Olatunji EA. Egg quality traits of indigenous and exotic chickens as influenced by specific genes. Journal of Biology Agriculture Healthcare. 2013; 3 (1): 53-57
9. Cepero R, Hernándiz A. Effects of housing systems for laying hens on egg quality and safety. XVI European Symposium on the Quality of eggs and Egg Products, Nantes, France, Book of Abstracts, World's Poultry Science Journal. 2015; 71 (1): 23.
10. Popova T, Petkov E, Ayasan T, Ignatova M. Quality of eggs from layers reared under alternative and conventional system. Brazilian Journal of Poultry Science. 2020; 22 (1): 1-8. doi: 10.1590/1806-9061-2019-1172
11. Tufarelli V, Baghban-Kanani P, Azimi-Youvalari S, Hosseintabar-Ghasemabad B, Slozhenkina M et al. Effects of horsetail (Equisetum arvense) and spirulina (Spirulina platensis) dietary supplementation on laying hens productivity and oxidative status. Animals. 2021; 11 (2): 335. doi: 10.3390/ani11020335
12. Simeneh G. Review on the effect of feed and feeding on chicken performance. Animal Husbandry, Dairy and Veterinary Science. 2019; 3 (4): 1-4. doi: 10.15761/AHDVS.1000171
13. Sekeroglu A, Sarica M, Demir E, Ulutas Z, Tilki M, Saatci M, Omid H. Effect of different housing systems on different traits and egg quality of laying hens. Journal of Animal Advances. 2010; 9 (12): 1739-1744. doi.10.3923/java.2010.1739.1744
14. Lay DCJR, Fulton RM, Hester PY, Karacher DM, Kjear JB et al. Hen welfare in different housing systems. Poultry Science. 2011; 90 (1): 278-294. doi: 10.3382/ps.2010-00962
15. Yousif IA, Eltayeb NM. Performance of Sudanese native Dwarf and Bare Neck chicken raised under improved traditional production system. Agriculture Biological Journal of North America. 2011; 2 (5): 860-866.
16. Olaniyi OA, Oyenaiya OA, Sogunle OM, Akinola OS, Adeyemi OA et al. Free range and deep litter housing systems: effect on performance and blood profile of two strains of cockerel chickens. Tropical and Subtropical Agroecosystems. 2012; 15 (3): 511-523. doi: 10.1007/s11250-012-0213-2
17. Ojedapo LO. Effect of two housing systems (cages vs deep litter) on external and internal egg characteristics of commercial laying birds reared in derived savanna zone of Nigeria. Transnational Journal of Science and Technology. 2013; 3 (7): 25-34.
18. Canogullari S, Baylan M, Bulancak A, Ayaşan T. Differences in performance, carcass characteristics and meat quality between fast- and slow-growing broiler genotypes. Progress in Nutrition. 2019; 21 (3): 558-565, doi: 10.23751/pn.v21i3.7747
19. Johnston NP, Jefferies LK, Rodriguez B, Johnston DE. Acceptance of brown-shelled eggs in a white-shelled egg market. Poultry Science. 2011; 90 (5): 1074–1079. doi.org/10.3382/ps.2010
20. Sadef S, Khan MS, Rehman MS. Indigenous chicken production in Punjab: a detailed survey through participatory rural appraisals. Journal of Animal and Plant Sciences. 2015; 25 (5): 1273-1282.
21. Chen X, Jiang W, Tan HZ, Xu GF, Zhang XB et al. Effects of outdoor access on growth performance, carcass composition, and meat characteristics of broiler chickens. Poultry Science. 2013; 92 (2): 435-443. doi: 10.3382/ps.2012-02360
22. Bell DD, Weaver WD. Commercial chicken meat and egg production. Springer Science & Business Media, LLC. New York, USA. ebook, 2002; 46-48.
23. Haugh RR. The Haugh unit for measuring egg quality. US Egg Poultry Magazine. 1937; 43 (1): 552- 555.
24. Association of official analytical chemist. Official method analytical chemist Washington DC. 1990.
25. Tuba K, Asad KT, Majid M, Sara A. Analysis of essential elements in commercially important Lobster species collected from coastal areas of Karachi city, Pakistan. Journal of Pharmacy and Nutrition Science. 2015; 5 (2): 103-113. doi: 10.6000/1927-5951.2015.05.02.2
26. Adeyeye EI. Comparative study on the characteristics of egg shells of some bird species. Bulletin of Chemical Society of Ethiopia. 2009; 23 (2): 159-166. doi: 10.4314/bcse.*v23i2*.44957
27. Al-Yasiry ARM, Kiczorowska B, Samolińska W. Nutritional value and content of mineral elements in the meat of broiler chickens fed Boswel-lia serrata supplemented diets. Journal of Elementology. 2017; 22 (3): 1027-1037. doi: 10.5601/jelem.2017.22.1.1294

28. Hayat Z, Nasir M, Rasul H. Egg quality and organoleptic evaluation of nutrient enriched designer eggs. Pakistan Journal of Agriculture Science. 2014; 51 (4): 1085-1089.

29. Duncan DB. Multiple range and multiple F tests. Biometrics. 1955; 11 (1): 1-42.

30. Cimrin T, Tunca Rİ, Avsaroglu MD, Ayasan T, Kücükersan. Effects of an antibiotic and two phytogenic substances (cinnamaldehyde and 1,8-cineole) on yolk fatty acid profile and storage period-associated egg lipid peroxidation level. Revista Brasileira de Zootechnia. 2020; 49: e20190270. doi: 10.37496/rbz4920190270

31. Englmaierová M, Tůmová E, Charvátová V, Skřivan M. Effects of laying hens housing system on laying performance, egg quality characteristics, and egg microbial contamination. Czech Journal of Animal Science. 2014; 59 (8): 345–352.

32. Tumova E, Englmaierova M, Ledvinka Z, Charvatova V. Interaction between housing system and genotype in relation to internal and external egg quality parameters. Czech Journal of Animal Science. 2011; 56 (11): 490-498. *doi:* 10.17221/8596-CJAS

33. Usman M, Mahmud A, Hussain J, Javid A. Performance of Rhode Island Red, Black Australorp, and Naked Neck crossbreds under alternative production systems. South African Journal of Animal Science. 2020; 50 (4): 564-577.

34. Ledvinka Z, Tůmová E, Englmaierová M, Podsedníček M. Egg quality of three laying hen genotypes kept in conventional cages and on litter. European Poultry Science. 2012; 76 (1): 38-43.

35. Roll VFB, Ricardo CBG, Adolfo ML. Floor versus cage rearing: effects on production, egg quality and physical condition of laying hens housed in furnished cages. Ciência Rural Santa Maria. 2009; 39 (5): 1527-1532. doi: 10.1590/S0103-84782009005000034

36. Yang HMZ, Yang W, Wang ZY, Wang HN, Sun XJ et al. Effects of different housing systems on visceral organs, serum biochemical proportions, immune performance and egg quality of laying hens. European Poultry Science. 2014; 78 (1): 1-9. doi: 10.1399/eps.2014.48

37. Lewko L, Gornowicz E. Effect of housing system on egg quality in laying eggs. Journal of Animal Science. 2011; 11 (4): 607-616. doi: 10.2478/v10220-011-0012-0

38. Pistekova V, Hovorka M, Vecerek V, Strakova E, Suchy P. The quality comparison of eggs laid by laying hens kept in battery cages and in a deep litter system. Czech Journal of Animal Science. 2006; 51 (7): 318-325.

39. Mohammed KAF, Franco LS, Ricalde RS, Sanchez JFS. Egg production, egg quality and crop content of Rhode Island Red hens grazing on natural tropical vegetation. Tropical Animal and Health Production. 2013; 45 (2): 367-372. doi.10.1007/s11250-012-0225-y

40. Mahboub HDH, Muller J, Von-borell E. Outdoor use, tonic immobility, heterophil/lymphocyte ratio and feather condition in free range laying hens of different genotype. British Poultry Science. 2004; 45 (6): 738-744. doi: 10.1080/00071660400014267.

41. Abou-Elezz FMK, Franco LS, Ricalde RS, Sanchez FS. Nutritional effects of dietary inclusion of Leucaena leucocephala and Moringa oleifera leaf meal on Rhode Island Red hens' performance. Cuban Journal of Agricultural Science. 2011; 45 (2): 163-169.

42. Mutayoba SK, Katule AK, Minga U, Mtambo MM, Olsen JE. The effect of supplementation on the performance of free range local chickens in Tanzania. Livestock Research for Rural Development. 2012; 24 (5).

43. Karcher DM, Jones DR, Abdo Z, Zhao Y, Shepherd TA et al. Impact of commercial housing systems and nutrient and energy intake on laying hen performance and egg quality parameters. Poultry Science.2015; 94 (3): 485–501. doi: 10.3382/ps/peu078

44. Stanley VG, Nelson D, Daley MB. Evaluation of two laying systems (floor vs. cage) on egg production, quality, and safety. Agrotechnology. 2013; 2 (1):109. **doi**: 10.4172/2168-9881.1000109

45. Jones DR, Karcher DM, Abdo Z. Effect of a commercial housing system on egg quality during extended storage. Poultry Science. 2014; 93 (5): 1282-1288. doi: 10.3382/ps.2013-03631

46. Laywel Project. Welfare implications of changes in production systems for laying hens. Deliverable 2006; 6.2: Report on production and egg quality.

47. Catli AU, Bozkurt M, Kuckyilmaz K, Cinar M, Bintas E et al. Performance and egg quality of aged laying hens fed diets supplemented with meat and bone meal or oyster shell meal. South African Journal of Animal Science. 2012; 42 (1): 74-82. doi: 10.10520/EJC118968

48. Ukachukwu SN, Akpan VO. Influence of level and duration of quantitative feed restriction on post-restriction egg-laying characteristics and egg quality of pullets. International Journal of Poultry Science. 2007; 6 (8): 567-572.

49. Richards MP, Poch SM, Coon CN, Rosebrough RW, Ashwell CM et al. Feed restriction significantly alters lipogenic gene expression in broiler breeder chickens. Journal of Nutrition. 2003; 133 (3): 707-715. doi: 10.1093/jn/133.3.707

50. Oyedeji JO, Orheruata AM, Omatsuli M. Effects of feed rationing on the laying performance of 40 weeks in lay hens. Journal of Food, Agriculture and Environment. 2007; 5 (2): 301-303.

51. Robinson FE, Zuidhof MJ, Renema RA. The reproductive efficiency and metabolism of female broiler breeders as affected by genotype feed allocation, and age at photo stimulation. 1. Pullet growth and development. Poultry Science. 2007; 86(10): 2256-2266. doi: 10.1093/ps/86.10.2256

52. Simeneh G. Review on the effect of feed and feeding on chicken performance. Animal Husbandry and Dairy Veterinary Science. 2019; (3): 1-4. doi: 10.15761/AHDVS.1000171

53. Ruuskanen S, Darras VM, de Vries B, Visser ME, Groothuis TGG. Experimental manipulation of food availability leads to short-term intra clutch adjustment in egg mass but not in yolk androgen or thyroid hormones. Journal of Avian Biology. 2016; 47 (1): 36-46. doi: 10.5061/dryad.hb349

54. Hayat Z, Cherian G, Pasha TN, Khattak FM, Jabbar MA. Sensory evaluation and consumer acceptance of eggs from hens fed flax seed and 2 different antioxidants**. Poultry** Science. 2010; 89 (10): 2293–2298. doi: 10.3382/ps.2009-00575

55. Rossi M. Influence of the laying hen housing on table egg characteristics. Proc. XII European. Symposium on the Quality of Eggs and Egg Products, Prague. 2007; 49-51. doi: 10.3390/su12197884

56. Drazbo A, Mikulski D, Zdunczyk Z, Szmatowicz B, Rutkowski A et al. Fatty acid composition, physicochemical and sensory properties of eggs from laying hens fed diets containing blue lupine seeds. European Poultry Science. 2014; 78 (1): 1-14. doi: 10.3382/ps/pev092

57. Sophie RG, Nicolas G, Yves N. The golden egg: nutritional value, bioactivities, and emerging benefits for human health. Nutrients. 2019; 11 (3): 684. doi: 10.3390/nu11030684