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Article Title (within 20 words without abbreviations)	Effect of different bedding depths of rice hulls on growth performance and carcass traits of White Pekin ducks
Running Title (within 10 words)	Bedding material depth and physiological responses of the Pekin ducks
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Ethics approval and consent to participate	The experimental protocol and procedures for the current study were reviewed and approved by the Animal Ethics Committee of Chungnam National University (Protocol Number:).

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Abstract

Duck meat is recognized as a healthier poultry product that contains higher amounts of unsaturated and essential fatty acids, iron, and excellent amounts of protein. It has been found to possess the ability to reduce low-density lipoprotein cholesterol and subsequently, blood pressure in the human body; and improve the immunity system. The current study investigated the appropriate bedding depths of rice hulls as a preferred bedding material by evaluating the growth performance and carcass traits of White Pekin ducks raised for 42 days. A total of 288 one-day-old White Pekin ducklings were randomly allotted to floor cages with one of four bedding depths at 4 cm, 8 cm, 12 cm, and 16 cm. Ducklings were fed standard duck starter (days 1-21) and finisher (days 22-42) diets. The birds were stocked at a rate of 6 birds/m^2 with 6 replicates per treatment. Growth performance evaluation for the body weight, average daily gain, and average daily feed intake were measured to calculate the weekly feed conversion ratio. Breast, leg, and carcass yield were assessed as carcass traits. The muscle color and proximate composition were also analyzed for meat quality. Footpad dermatitis was also evaluated on day 42. Ducks reared on 16 cm bedding depth over the 42 days recorded higher (P < 0.05) body weight, average daily, average daily feed intake, and improved feed conversion ratios compared to other groups. The crude fat in breast meat also lowered (P < 0.05) in ducks reared at 16 cm (1.02%) when compared to ducks raised at 4 cm bedding depth (2.11%). Our results showed improved redness (P < 0.05) when the depth of bedding materials was elevated. Except for the breast meat fat, the dissimilar bedding depths did not affect (P < 0.05) the breast and leg meat composition, footpad dermatitis, and mortality for the current study. In conclusion, this study indicated that the bedding depths would directly or indirectly affect the growth performance and meat color of White Pekin ducks; and the bedding depth of rice hulls at 16 cm improved the growth performance of White Pekin ducks for 42 days.

Keywords: Bedding depth, Carcass traits, Color, Crude fat, Performance, Rice hulls

Introduction

The consumption of poultry meat and eggs has escalated in recent years regardless of the diversity of religions, cultures, and traditions all around the world. The demand for poultry meat and eggs is likely to be sustained due to population growth, a rise in incomes, and changes in consumer tastes and preferences [1]. Although the poultry industry is dominated by chickens, the ducks have also well accepted by consumers due to their reasonable nutritional properties for humans, including lower fat contents, higher polyunsaturated fatty acids (omega-6: omega-3 ratio, linolenic, linoleic, and oleic - PUFA), and well-balanced amino acid profiles [2, 3]. Furthermore, duck meat can improve human immunity [4] and increase consumer preference through intramuscular fat with red muscle fibers [3]. Cost-effectiveness, high disease resistance, and rapid growth rates are economic properties that can be obtained from rearing ducks [1]. Previously, ducks were raised under extensive rearing systems rather than intensive or semi-intensive systems [5]. However, it has changed during the past few decades. In recent years, the rearing of meat ducks is mostly carried out intensively with deep litter systems [6] aggregated with higher stocking densities of three to seven ducks per m^2 [5].

The shift towards intensive systems with deep-litter flooring necessitates the provision of bedding materials that cushion and thermally insulate the birds from cold surfaces, absorbing feces and water spills, and also diluting fecal matter [7, 8]. However, good quality bedding materials must be laid out on the floor at a reasonable height; and appropriate in size and type [9]. The ideal particle size of the bedding materials should be averaged 2-25 mm and particle sizes of more than 30 mm have been identified as having an incremental impact on litter caking [10]. Additionally, the bedding materials should be managed to ensure an ideal moisture content (20-25%), pH value of 8-10, and low ammonia level (<25 ppm) [11].

Since moisture and manure are major concerns in poultry litter management, litter caking, high ammonia emissions, the proliferation of pathogenic microorganisms, gait disorders, and respiratory diseases could be encountered with litter systems [7, 12]. However, we can overcome these associated problems through primary management practices such as frequent agitation of litter and proper water management [13].

For meat-type ducks, the selection of bedding material is crucial, the bedding material should be affordable, absorbent, readily available, free from contaminants, have low thermal conductivity and also not easily get to cake or compact [14]. In general, paper products, wood shavings, rice hulls, gypsum, cocopeat, kenaf, peanut hulls, and sand are the popular bedding material types used for broiler birds in the poultry industries [15]. Previously, we studied the types of bedding materials and their effect on the growth performances of White Pekin ducks using four types of bedding materials including cocopeat, rice husk, and sawdust. As a result, we found a positive impact of rice hull bedding materials on particular parameters, which were selected as the best for the growth performance [16]. Furthermore, rice hull is a by-product of the rice milling process and it represents about 25% of paddy [14]. Rice hulls have class "A" insulating characteristics because they are difficult to burn and unlikely to retain moisture; thus, rice hulls could be efficient at controlling the propagation of mold or fungi. In addition, rice hulls mainly contain opaline silica and lignin, which have insulating properties [17]. Although rice hulls are used as feed for livestock and poultry industries, full utilization of rice hulls limits as feed by aforementioned components. Therefore, it's currently available as bedding material in many rice-growing areas.

The tremendous impact of bedding material type and depth has been appreciated in literature [13]. However, sufficient attention has not been paid to the appropriate selection and depth determination of the bedding materials for ducks. To date, limited studies have been conducted regarding the impact of duck bedding depth on productive indices [18-20]. The hypothesis suggested that ducks, despite being stocked at the same rate and raised in identical indoor housing units, could display dissimilar reactions based on the depth of bedding they were raised on. Therefore, the objectives of this study were to investigate and recommend an appropriate bedding depth for rice hulls as a preferred bedding material for ducks by evaluating the growth performance and carcass traits of white Pekin ducks until 42 days. It was hypothesized that dissimilar bedding depths could alter the growth performance and footpad dermatitis scores of ducks without affecting carcass characteristics.

Materials and Methods

The Animal Ethics Committee of Chungnam National University reviewed and approved the experimental methodology and procedures for the current study (Protocol Number; 202304A-CNU-028). The current experiment was conducted at the Animal Research Center at Chungnam National University.

Birds, housing, and management

A total of 288 one-day-old White Pekin ducklings (47.99 ± 0.11 g) were allocated in a completely randomized design to 24-floor pens with rice hulls supplied at four dissimilar depths in this experiment. Six replicate pens (1.7 m × 1.3 m × 1.0 m) with 12 ducklings per pen were used. Three adjustable nipple drinkers and a feeder were provided in each pen and bedded with dry rice husk according to the different bedding depths of 4 cm, 8 cm, 12 cm, and 16 cm. Feed and fresh drinking water were supplied on an *ad-libitum*, with continuous lightning for 24 hours. Ducklings were fed over two phases with standard duck starter (days 1 -21), and finisher diet (days 22-42). The research unit temperature was maintained at 30-32 ℃ for the first week and then gradually decreased until it reached 25 ℃ on day 21 (room temperature).

Growth performance evaluation

Body weight was recorded at the beginning and on days 7, 14, 28, 35, and 42. The providing and remaining feed amount was recorded on the same days of every week. Using body weights and feed consumption, the average daily feed intake (ADFI), average daily gain (ADG), and feed conversion ratio (FCR) were calculated.

Post-mortem procedures and sample collection

On day 42, one duckling was selected based on closeness to the average body weight in the respective pen and euthanized using CO_2 asphyxiation for evaluating the carcass characteristics. Empty carcass weight was recorded (without evisceration) after head and leg removal from the first cervical vertebra and ankle joint, respectively. Subsequently, the leg and breast muscles were removed from the carcasses and weighed for the evaluation of their respective percentages relative to the empty carcass weight. They were then collected for further analysis. Subsequently, meat color was analyzed using a colorimeter (CM-3500d, Minolta, Tokyo, Japan) for the lightness, redness, and yellowness values (CIE L*, a*, b*, respectively). Chemical composition analyses were performed to evaluate the moisture, crude protein, crude fat, and ash content of breast and leg meat after deboning using standard procedures [21]. Eventually, footpads were independently observed for dermatitis conditions and scored according to the visual appraisal system outlined by Klambeck et al. [22].

Statistical analysis

Obtained data were analyzed according to a completely randomized design using a general linear model procedure of one-way ANOVA using SPSS software (Version 26; IBM, Armonk, NY, USA). Each pen was used as the experimental unit to measure all productive parameters. Individual sacrificed ducks were considered the experimental unit for the carcass traits and chemical composition analysis of breast and leg meat. When the treatment effect was observed significant ($P < 0.05$), means were separated using Tukey’s multiple range test. All parameters were evaluated at 95% confidential levels.

Results

Growth performance

In response to the bedding depths of rice hulls, the body weight (BW), average daily gain (ADG), and average daily feed intake (ADFI) of White Pekin ducks varied until 42 days of the study period (See Table 1). On day 1, the initial body weight of ducklings was similar regardless of treatments for the current experiment. Eventually, we were able to find a significant difference ($P < 0.05$) in the live weights of ducklings from day 7 to the end date, and ducklings raised on 16 cm bedding depth showed significantly higher body weights for the entire rearing period. However, ducklings raised on bedding depth of 4 cm had the lowest body weight results. Additionally, ducks reared at 16 cm and 4 cm bedding depths recorded 3057.29 g and 2717.03 g respectively as their final body weights.

Focus on weight gain results, a significant difference ($P < 0.05$) was noted only for the first two weeks whereas the remainder of the rearing period was not affected by the depth of the rice hull beddings. From days 7 and 14, improved daily weight gain was observed with the supply of bedding depth at 16 cm. However, there was no significant difference found for the rest of the weeks. Feed intake was also impacted ($P < 0.05$) by the depth of rice hull beddings only on day 7 and 42. However, feed conversion ratio and mortality percentages were not affected ($P > 0.05$) by the depth of the rice hull beddings for the entire study period.

Carcass traits and chemical analysis

As shown in Table 2, no differences were noted for the carcass yield, leg meat, and breast meat percentages of ducks reared on the different depths of rice hull beddings. Similarly, crude protein, moisture, and ash contents of the leg and breast meat samples were not impacted by the bedding depths of rice hulls. However, ducklings reared on the bedding depth of 4 cm was higher ($P < 0.05$) in crude fat content of breast meat samples compared to other treatments. Furthermore, 12 cm and 16 cm bedding showed the lowest values for the same parameter at the end of the experiment.

Meat color

From the analyzed meat samples, the meat color of leg meat samples was not significantly impacted by the dissimilar bedding depths of the rice hulls. From the breast meat samples, lightness (L*) and yellowness (b*) were not affected by the bedding depths, and redness (a*) significantly differed ($P < 0.05$) among treatments. Furthermore, ducks from 16 cm bedding depth resulted in elevated amounts of redness on day 42 (Fig. 1).

Footpad dermatitis

On day 42, ducks reared at higher bedding depths (12 and 16 cm) did not result in any footpad dermatitis conditions. On contrary, 4 and 8 cm treatments showed the footpad dermatitis score, and they were not significantly differed for the current study.

Discussion

The current study was conducted to determine the effect of dissimilar bedding depths for rice husks as a preferred bedding material for White Pekin ducks. Based on the current study, higher growth performance was noted in ducks reared in higher bedding depths (i.e., over 8 cm). The current observation could be due to the increased dryness and comfort from higher bedding depths (12 and 16 cm) compared to lower depths (4 and 8 cm). It is well established that higher bedding depth that could be associated with more dryness could improve the growth performance; and influence the behavior and welfare of ducks [19]. Higher dryness (75 - 80%) could be a crucial factor in deep-litter systems that can be used to improve the health and growth performance of meat ducks [23].

Moreover, bedding material supplied at the appropriate depths should have a reasonable drying time and fast drought, for facilitating water absorption on floor cages [19]. Notably, the dryness of the bedding surface could ameliorate footpad dermatitis in birds as previously reported [24, 25]. Several studies have been conducted to determine the impact of bedding material depths on footpad dermatitis as well as growth performance, carcass characteristics, and meat quality [19, 26]. Shepherd et al. [27] have reported that bedding depths of 7.6 cm at least could inhibit footpad dermatitis with profound impacts on growth performance as corroborated by Hashimoto et al. [28]. The occurrence of footpad dermatitis in conditions of lower bedding depths may further explain the growth impairment in birds reared under those depths below 8 cm.

The chemical composition can vary in duck meat due to several factors including the anatomical location, genotype, sex, age, and diets of the birds [29, 30]. Thus, variations with previous reports of crude fat contents were observed [31, 32]. Nevertheless, the proximate analysis of current study showed similarities to the figures reported by Huang et al. [33]. Additionally, the crude fat content is one of the vital components that impact the quality and sensory properties of poultry meat [34]. Nonetheless, numerous stressors of birds could alter the general lipid metabolism in their bodies and result in higher lipid contents as reported by Lu et al. [35]. Supporting those findings, Zaytsoff et al. [36] also identified that physiological stressors could increase hepatic lipid deposition by upregulating the expression of lipid synthetic genes in poultry. In the current study, we observed physiological stressors such as ammonia emission and the presence of wet condition in bedding materials [7] that similarly could be the reason for this fat deposition. On the other hand, Oketch et al. [16] reported that poultry consumed a significant portion (4%) of bedding materials which tended to increase crude fat levels. It was supported by Diarra et al. [14]. Herein, lower bedding depths that resulted in higher crude fat contents, might be due to the wet bedding increased bedding material consumption. However, Demirulus [13] also observed the same pattern of fat deposition in chickens that were reared on different bedding depths.

Generally, meat color is categorized under the subjective character which has a good potential of influencing consumer preference via visual interpretations. Meanwhile, meat properties such as total haem, myoglobin, and pH; genetics properties like age, sex, and breed; management properties like rearing method, gaseous environment, and pre-slaughter handling can be recognized as predisposing factors in meat color [37]. Unexpectedly, significantly lowered (P < 0.05) redness values for the breast meat were observed at lower bedding depths in the current experiment. Generally, lower bedding depths in duck cages can influence temperature increments, as poultry bedding has been identified as a determining factor for temperature [38].

Consequently, the incident of pale soft exudative (PSE) meat could potentially be attributed to a combination of lower bedding depths and other stress factors. It is worth noting that the current study showed numerically higher lightness values for birds reared at lower bedding depths, which aligns with previous findings of Kokoszyński et al. [32]. However, since PSE meat is known to be a color defect [39], pH, temperature, and myoglobin content like PSE-associated factors should be further investigated to prove this assumption. Additionally, measuring stress-indicating hormones (i.e., cortisol, corticosterone, and thyroid) has been widely used to determine stress levels in poultry [12, 19] in recent research. Building on this concept, further investigation is needed to explore the relationship between these hormones and both PSE (Pale, Soft, Exudative) meat and hepato-lipid deposition.

Finally, this study had similar color ranges referring to Ali et al. [40] and Wołoszyn et al. [41] for breast and leg meat analyses of their studies. The overall conclusions of this study allude to the impact of the depth of the bedding materials to alter the growth performance of White Pekin ducks directly or indirectly, and 16 cm bedding depth resulted in higher ducks' growth performance and is therefore recommended as the appropriate bedding depth for White Pekin ducks reared with rice hulls.

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Tables

Table 1: Effect of rice hull bedding depths on growth performance of White Pekin ducks until 42 days of age

Items	**Bedding depths**				**SEM[1]**	***p*-value**
	4 cm	**8 cm**	**12 cm**	**16 cm**		
Body weight, g						
Day 1	47.95	48.09	47.86	48.05	0.117	0.908
Day 7	254.87^{a}	253.17^{a}	256.41^{ab}	263.87^{b}	1.341	0.014
Day 14	678.00^{a}	684.67^{a}	686.57^{a}	734.07^{b}	6.671	0.003
Day 21	1266.45^{a}	1272.43^{ab}	1287.38^{ab}	1322.84^{b}	7.910	0.040
Day 28	1627.76^{a}	1630.32^{a}	1693.41^{a}	1806.77^{b}	18.874	0.000
Day 35	2169.34^{a}	2174.67^{a}	2219.42^{ab}	2353.29^{b}	24.635	0.017
Day 42	2717.03^{a}	2727.91^{a}	2797.57^{ab}	3057.29^{b}	44.906	0.013
Average daily gain, g/d						
Day 7	36.16^{a}	36.41^{a}	36.63^{ab}	37.69^{b}	0.191	0.015
Day 14	64.64^{a}	60.45^{a}	61.45^{a}	67.17^{b}	0.821	0.007
Day 21	73.47	73.55	75.10	73.59	0.771	0.874
Day 28	59.65	60.21	67.67	80.65	2.388	0.148
Day 35	77.76	77.46	75.145	78.07	2.285	0.973
Day 42	79.03	78.14	82.59	100.57	3.745	0.503
Day 1-21	174.90	174.07	177.07	182.11	0.993	0.239
Day 22-42	207.92	207.22	215.74	247.77	0.185	0.558
Day 1-42	382.83	381.29	392.81	429.89	5.294	0.222

Average daily feed intake, g/d						
Day 7	34.36[a]	34.86[a]	38.65[ab]	41.82[b]	0.814	0.001
Day 14	79.60	76.80	80.33	85.29	1.392	0.185
Day 21	132.88	131.89	138.98	145.95	2.208	0.078
Day 28	156.54	156.88	157.02	159.18	1.336	0.909
Day 35	145.20	151.07	152.86	171.65	3.800	0.067
Day 42	179.37[a]	181.87[a]	191.73[ab]	222.15[b]	5.229	0.006
Day 1-21	243.55	246.85	257.96	273.10	2.138	0.279
Day 22-42	489.82	481.13	501.61	551.01	6.023	0.907
Day 1-42	733.38	727.98	759.57	824.11	6.915	0.479
Feed conversion ratio, g/g						
Day 7	0.94[a]	0.96[a]	1.05[ab]	1.11[b]	0.020	0.003
Day 14	1.18	1.14	1.21	1.21	0.014	0.258
Day 21	1.26	1.24	1.26	1.33	0.015	0.184
Day 28	1.66	1.64	1.61	1.59	0.009	0.057
Day 35	1.75	1.69	1.71	1.70	0.014	0.544
Day 42	1.86	1.84	1.81	1.75	0.019	0.219
Day 1-21	1.11	1.12	1.17	1.21	0.039	0.755
Day 22-42	1.72	1.75	1.71	1.68	0.028	0.975
Day 1-42	1.41	1.44	1.44	1.44	0.067	0.514
Mortality, %	2.77	4.16	4.16	1.38	0.840	0.628
Footpad dermatitis, %	0.66	0.16	0	0	0.840	0.234

1) Standard error of means

ab) Means in the same row with different superscripts are significantly different (*P* < 0.05)

Table 2: Effects of rice hull bedding depths on carcass traits and chemical composition of White Pekin ducks on day 42

Items	Bedding depths				SEM[1]	*p*-value
	4cm	8cm	12cm	16cm		
Carcass percentage						
Carcass	89.55	89.78	89.82	90.30	0.521	0.975
Breast meat	17.13	17.81	17.40	17.52	0.357	0.936
Leg meat	13.04	12.70	13.34	12.27	0.205	0.104
Proximate composition of breast meat, %						
Moisture	77.13	77.58	76.83	77.44	0.205	0.605
Crude protein	18.85	19.30	20.07	19.64	0.199	0.170
Crude fat	2.11[b]	1.37[ab]	1.02[a]	1.02[a]	0.142	0.010
Ash	1.61	1.52	1.53	1.53	0.023	0.500
Proximate composition of leg meat, %						
Moisture	73.95	74.16	75.13	73.85	0.191	0.059
Crude protein	20.96	21.34	20.60	20.78	0.185	0.572
Crude fat	3.33	2.76	2.03	2.72	0.176	0.068
Ash	1.40	1.53	1.55	1.52	0.027	0.184

[1)] Standard error of means

[ab)] Means in the same row with different superscripts are significantly different ($P < 0.05$)

Figures

Fig. 1: Effect of rice hull bedding depths on the breast meat color of White Pekin ducks on day 42

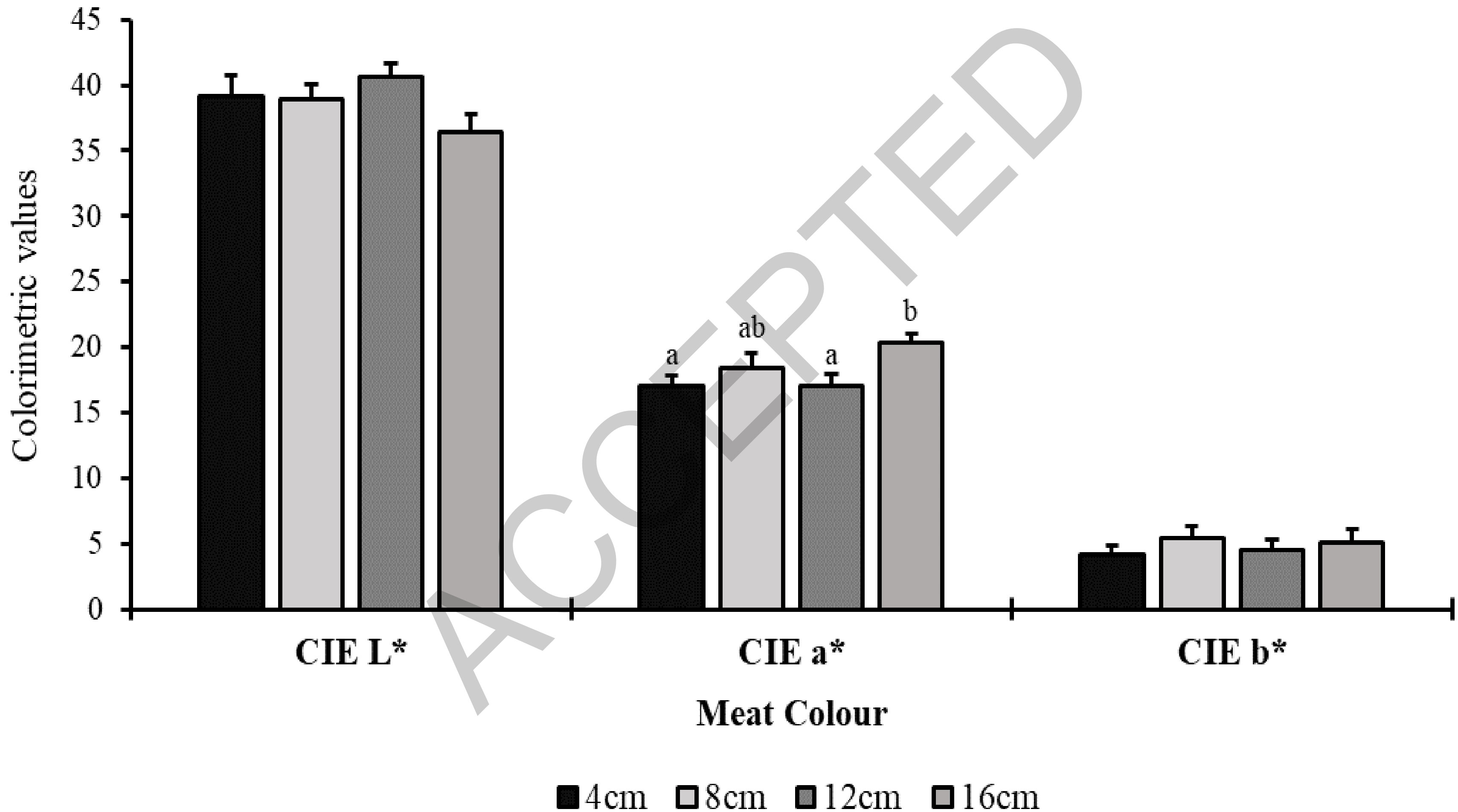

Fig. 2: Effect of rice hull bedding depths on the leg meat color of White Pekin ducks on day 42