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The effect of housing system (semi-closed barn and closed barn) on some productive and carcass traits of Awassi male lambs

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ABSTRACT

Background: Sheep are a main source for meat, and animal housing is to protect them from harsh environmental conditions and to provide an environment suitable for animal comfort and in an economical manner as possible.

Aim: The aim of this experiment was to compare the effect of two types of housing systems (semi-closed barn and closed barn) on some productive and carcass traits of Awassi male lambs.

Methods: Two groups of Awassi lambs totaling forty weaned male lambs ranging in age from 4 to 6 months were divided into two types of barns: the first was housed in a semi-open barn, and the second in a closed barn with 20 lambs for each group. In order to find an effect between the two groups and to find out the significance of these differences, the obtained data were analyzed using the *t*-test.

Results: No significant differences were observed between the two groups in productive traits and carcass, such as final weight, weight gain, feed conversion efficiency, feed intake, carcass weight, dressing percentage, and carcass residues from the head, feet, and skin. There were also no big differences in the viscera of the carcass, such as the lungs, heart, liver, spleen, kidneys, intestines, the weight of the full and empty rumen, or the weights of different fats, such as buttocks, abdomen, kidney, and heart fat. There were also no big differences in the area of the eye muscle or the thickness of the subcutaneous fat, or in the major and minor cuts. Moreover, the proportions of muscle, fat, and bone remained consistent. The net second transaction exhibits an arithmetic advantage.

Conclusion: There was an arithmetic increase in favor of the first treatment, and this may be due to the increase in feed intake in the lambs of the semi-open pens compared to the closed ones. In addition to the availability of ideal conditions for the lambs, including fresh air and better oxygen availability, air movement inside the barn, and lower temperatures compared to a closed barn, thermal stress reduces weight gain.

Keywords: Awassi lambs, Housing system, Growth performance, Carcass traits, Animal welfare.

Introduction

Sheep are often reared in villages with poor sheltering and subjected to low-quality nutrition, which can negatively affect growth and production (Vachon *et al.*, 2007). The primary purpose of a sheltering system would therefore be to reduce climatic stress and create a microclimate inside the thermal neutral zone of the animal so that maximum energy can be devoted to production processes. There would be adverse effects on production if sheep were not provided with adequate sheltering and ventilation systems (Bhakat and Nagpul, 2005; Sablik *et al.*, 2023).

Sheep and goats are raised under temperate and tropical environments, with small ruminants found in arid/semi-arid areas (Bhakat and Nagpul 2005). Every environment requires different factors for constructing proper housing for animals. The basic requirement for proper sheltering of animals relates to adaptability and

ability for protection against predators and thief attacks (Saeed, 2023). Animal sheltering requires protection against adverse climatic factors to reduce stress associated with growth and production for optimal growth and production of animals (Park *et al.*, 2020). Animal production requires considerable shelter against temperature, moisture, sunlight, wind velocity, and rainfall (Sablik *et al.*, 2023). Animal sheltering requires more emphasis on facilitating husbandry practices, such as enough feeding and watering to benefit animals (Kapgate *et al.*, 2016; Prache *et al.*, 2021).

Pens are an important part of sheep and goat production and account for a large share of capital expenditure. Well-planned pens maximize space utilization; hence, more capital can be allocated to other project expenditures (Saeed, 2023).

Shelter refers to an animal husbandry unit wherein animals are provided with shelter or accommodation and protected against external factors like heat, cold,

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rainfall, or wind (Sharma and Gupta, 2024). The animals rest or sleep depending on their type or species. While other species make use of these shelters at night or particular times of the day, others will reside in these places every day or continuously, depending on their species and production plans (Stenberg *et al.*, 2020).

There cannot be any doubt that providing animals with properly designed and well-ventilated housing that has important features and benefits for breeding and production purposes forms a vital part of caring for animals and providing them with adequate living conditions (Bhatta *et al.*, 2005).

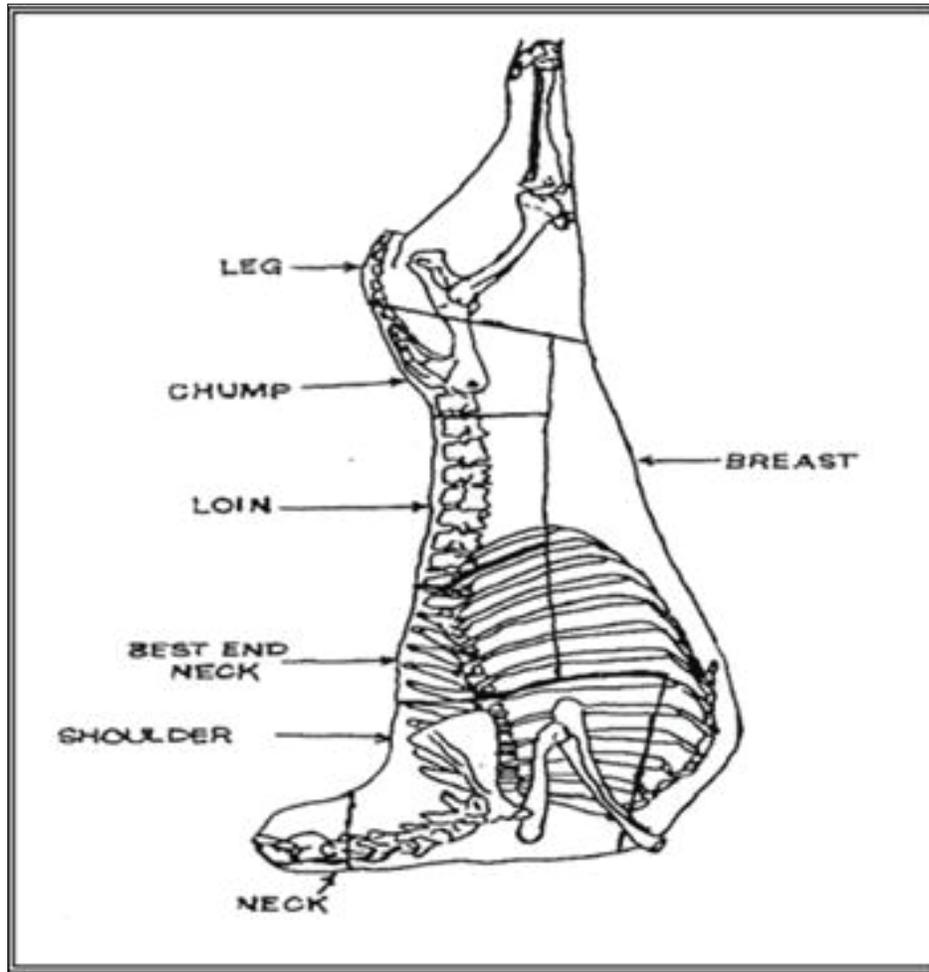


Fig. 1. Cutting the carcass according to the method of Cuthbertson *et al.* (1972).

Table 1. Components and percentage of ration used in trial.

Ration composition	Percentage
Barley	70
Bran	22
Soybean meal	7
Lime stone	0.5
Salt	0.05

Table 2. Chemical composition of experimental ration.

%Nutritional components	Percentage
Dry matter	91.8
Crude protein	14.5
Ether extract	2.3
Crude fiber	8.7
Ash	4.5
Soluble carbohydrate	61.8
Metabolizable energy Kcal/ kg dry matter	2637

It becomes imperative to identify appropriate housing that not only guards animals against environmental influences but also ensures complete comfort and sustains health and desired production (Park *et al.*, 2020). Cost factors become equally important while identifying or designing these housing systems because expenditures incurred when using these systems rank only second to those devoted to food (Kapgate *et al.*, 2016).

Therefore, housing should ideally be appropriate in terms of shape, design, and technical details to minimize labor time, increase agricultural profitability, and make animal rearing more economically feasible (Bhakat and Nagul, 2005).

Many studies have focused on the control of environmental factors to improve meat production and fattening efficiency. It has been well acknowledged that adverse environmental factors negatively impact animal performance and productivity (Carrasco *et al.*, 2009; Kaya, 2011). The aim of housing animals concerns protecting animals against adverse environmental factors and creating an economical environment amicable to animals. Some scientists assert that open pens allow more oxygen access and make animals more tolerant of heat (Karaback *et al.*, 2015b). Semi-open barns are described with only one side (or sides) up to the animals' height, with other sides open to the roof; these types of barns can tolerate hot and semi-arid climatic conditions with moderate rainfall during different seasons. It can equally tolerate hot and humid climatic conditions with certain amendments, like raised floors with contours. It can protect against climatic factors to minimize heat stress (Sharm and Gupta, 2024).

Physiological responses and production efficiency of sheep can be affected significantly by housing systems. Roofing systems can play an important role in controlling heat transfer inside sheep housing; therefore, insulation of roofing materials reduces the adverse effects of thermal forces inside sheep housing (Khalil *et al.*, 2023). Hence, the objective of this study was to evaluate and compare the performances of lambs raised under semi-open and closed housing systems and investigate their influences on specific production and carcass characteristics.

Materials and Methods

For this experiment, forty male Awassi lambs at an age of 4–6 months were weighed and divided into two equal groups. The mean body weight was 21.44 ± 0.97 kg. Group one was raised in a semi-open pen (three sides closed and front open), while Group two was raised in a fully closed pen, with both systems using natural ventilation without cooling or heating systems. The pens were built using brick and cement with galvanized iron roofs. The lambs' diet consisted of unlimited concentrates. Parameters measured included body weight, feed intake, and feed efficiency ratio over a period of 100 days (Period of April to July) at Telafer,

located at the top-most part of northern Iraq, because most fattening periods in northern Iraq take place during these months due to the abundance of lambs and their low prices. The lambs were given 1.5 m^2 of space in individual pens for both Group one and Group two. At the end of these periods, 20 lambs (10 for Group 2 and 10 for Group 1) were slaughtered after withholding their feed for 12 hours. Weights were recorded before slaughtering and were used to determine dressing percentage. The lamb was dissected into buttocks and pelvis, with the separation of the kidneys, and corresponding weighing done. Instead of cutting into portions of cuts (Langlier system), dissection was done into major and minor portions using the Cuthbertson method described comprehensively by Cuthbertson *et al.* (1972) (Fig. 1). Ribs six were measured using an electronic caliper (Vernier), with the thickness of supraspinatus fats measured at the 12th rib, and the length of longissimus dorsi measured using Vernier calipers (Electronic). Area was measured using a grid system for the eye muscles at rib number 12, with computation done using the grid system. Ribs six were dissected manually into muscular tissues, fats, and bone, with corresponding percentage determination done for different tissues using dissecting principles described comprehensively using meat laboratory equipment, including knives and electronic scales.

The animals of each group were fed separately. The animals of each group were housed separately, but they were fattened and fed collectively from one trough in the same pen. The feed intake of each animal was then calculated by dividing the total and daily feed intake by the number of animals in each group. The feed was weighed and placed in the trough in the morning and remained in front of the animals all day and night. The remaining feed was collected the next morning, weighed, and subtracted from the feed provided the day before to extract the feed consumed. Experimental lambs received a concentrate ration formulated according to NRC (2007) guidelines (Table 1), with chemical composition presented in Table 2.

Feed conversion efficiency = feed intake / weight gain. The experimental design was completely random design (CRD) because it involved random assignment of lambs to treatments equally for the two housing systems to reduce bias and increase accuracy when comparing statistically. The statistical model for CRD was given by $Y_{ij} = \mu + T_i + e_{ij}$, where Y_{ij} was the value of the j th lamb under treatment i ; μ was the general mean value, while T_i was associated with its effect on housing systems; on the other hand, e_{ij} was taken to show random experimental error with equal variance and was normally distributed. The analysis of statistical significance of differences between housing systems was done with the aid of t test procedure using SAS software (version 9.4). The t -value was calculated according to the following formula:

$$t = (X_1 - X_2) / \sqrt{[S^2 \times (1/n_1 + 1/n_2)]}$$

where:

X_1 = the mean of the first sample (the half-open house treatment),

X_2 = the mean of the second sample (the treatment of the closed house),

S_2 = sample variance (population),

n_1 = the number of observations of the first sample,

n_2 = the number of observations of the second sample.

This approach allowed the detection of significant differences between the two housing environments based on the probability level adopted for statistical decision-making.

Ethical approval

This study was approved by the Ethics Committee of the College of Agriculture, University of Telafer, Telafer, Iraq (NO: AP2) (Approval date: 15-02-2025).

Results

In this experiment, there were no significant effects of housing type on production and carcass characteristics, as shown in the following:

Live weight gain

The analysis of statistical differences shown in Table 3 revealed that there were no significant differences ($p > 0.05$) between the mean daily weight gain and total weight gain of lambs of the first treatment (open barn) (128.60 gm/day and 12.86 kg) and those of the rate of lambs of the second treatment (closed barn) (118.11 gm/day and 11.81 kg), though there was an arithmetic increase in favor of the first treatment.

Fodder consumption

There was no statistical analysis carried out with regard to fodder consumption, considering that consumption was done collectively, given that the animals belonging

to each group were fed separately but were fattened and fed jointly using one trough within the same pen. The individual consumption was then determined for each animal, considering that the total daily consumption was divided by the number of animals within the group. The amount of consumption done by the lambs within the first treatment was (968.35) gm/day compared with (925.98) gm/day done by those within the second treatment, because it was mathematically superior.

Feed conversion efficiency

There was no statistical test performed on the rate of feed conversion efficiency because of the communal aspect of consumption, but it was observed that the first treatment group (half-open barn) was superior to the second treatment (closed barn).

Weight of carcass and dressing percentage

Results of analysis using statistics (Table 4) revealed that there were no differences ($p > 0.05$) between the two treatments with regard to the weight of hot carcass, with an average weight of (15.21) kgs recorded in the half-open treatment and (15.11) kgs recorded in the closed treatment. There were no differences between treatments with regard to live weight before slaughter.

Slaughter residues and internal viscera of the carcass

The outcome of the analysis shown in Tables 5–7 revealed that there were no significant differences ($p > 0.05$) between the percentages of residuals of the carcass and internal viscera (edible and non-edible) and live weight before slaughtering for each of the first treatment (half open) and second treatment (closed) because of the lack of significant differences between the weights of the carcass and dressing percentages.

Table 3. Effect of housing system on production performance and growth rate of Awassi male lambs.

Parameters	Semi-open barn	Closed barn
Initial body weight (kg)	21.32 ± 0.92 ^a	21.56 ± 1.02 ^a
final body weight (kg)	34.18 ± 1.21 ^a	33.37 ± 1.39 ^a
Total weight gain (kg)	12.86 ± 1.05 ^a	11.81 ± 1.11 ^a
Daily weight gain (kg)	128.60 ± 9.32 ^a	118.11 ± 10.51 ^a
Daily feed intake (g)	968.35 ^a	925.98 ^a
Feed conversion efficiency	7.53 ^a	7.84 ^a

^aMeans within the same row with different superscripts differ significantly ($p < 0.05$). Values with the same superscript indicate no significant difference ($p > 0.05$).

Table 4. Effect of housing system on some carcass characteristics of Awassi male lambs.

Parameters	Semi-open barn	Closed barn
Slaughter weight (kg)	32.01 ± 1.98 ^a	31.88 ± 2.06 ^a
Hot carcass weight (kg)	15.21 ± 1.35 ^a	15.11 ± 1.22 ^a
Dressing percentage%	47.52 ± 0.86 ^a	47.41 ± 0.97 ^a

^aMeans within the same row with different superscripts differ significantly ($p < 0.05$). Values with the same superscript indicate no significant difference ($p > 0.05$).

Taking measurements of longitudinal carcass dimensions

The outcome of the statistical analysis revealed that there were no significant differences ($p > 0.05$) between the longitudinal dimensions of the carcass measurements, such as length of carcass, breast circumference of carcass, thigh circumference of carcass, and breast depth of carcass (Table 8).

Separate fats

Results of statistical analysis showed that there were no significant differences among percentages of separate body fats such as buttock fat, fat around the abdomen, fats of kidneys, heart fats, and total separate fats despite being mathematically higher in the semi-open house system, which could be due to an increase in fodder intake.

Area of the eye muscle

The outcomes of statistical analysis showed that there were no significant differences at ($p > 0.05$) between the eye muscle area in the first treatment, which was (11.78) cm², and the eye muscle area of the second treatment, which was (10.53) cm², as shown in Table 10.

Thickness of subcutaneous fat

There were no differences ($p > 0.05$) between the first treatment and the second treatment with regard to this variable (Table 10). The thicknesses were 7.24 mm and 8.12 mm, respectively.

Major and minor cuts

The outcome of statistical analysis shows that there are no differences ($p > 0.05$) between the first treatment and the second treatment for major and minor cuts (Tables 11 and 12).

Percentages of muscle, bone, and adipose tissue

The outcome of the statistical test showed that there were no significant differences ($p > 0.05$) in the percentage composition of muscles, bones, and fats when separating the six-rib cut from the carcass (Table 13).

Discussion

Local sheep varieties can adapt easily to local environmental factors and shorter periods of food accessibility. In addition to this, local sheep can easily withstand disease and difficult rearing conditions. An example of local sheep varieties found in this region is Awassi sheep, which is an ancient local breed of

Table 5. Effect of housing system on slaughter residues of the carcass of Awassi male lambs.

Parameters	Semi-open barn	Closed barn
Head %	7.11 ± 0.23 ^a	7.00 ± 0.18 ^a
Feet %	2.54 ± 0.09 ^a	2.46 ± 0.12 ^a
Skin %	9.96 ± 0.75 ^a	9.76 ± 0.81 ^a

^aMeans within the same row with different superscripts differ significantly ($p < 0.05$). Values with the same superscript indicate no significant difference ($p > 0.05$)

Table 6. Effect of housing system on internal edible organs percentage of the carcass of Awassi male lambs.

Parameters	Semi-open barn	Closed barn
Lungs %	1.77 ± 0.84 ^a	1.82 ± 1.02 ^a
Heart %	0.41 ± 0.04 ^a	0.43 ± 0.05 ^a
Liver %	1.68 ± 0.0 ^a	1.59 ± 0.07 ^a
Testis %	0.43 ± 0.08 ^a	0.39 ± 0.09 ^a
Spleen %	0.19 ± 0.03 ^a	0.16 ± 0.01 ^a
Kidney %	0.34 ± 0.02 ^a	0.33 ± 0.01 ^a

^aMeans within the same row with different superscripts differ significantly ($p < 0.05$). Values with the same superscript indicate no significant difference ($p > 0.05$)

Table 7. Effect of the housing system on the percentage of internal inedible organs in the carcass of Awassi male lambs.

Parameters	Semi-open barn	Closed barn
Intestine %	7.89 ± 0.36 ^a	7.65 ± 0.53 ^a
Full rumen %	11.16 ± 0.72 ^a	10.86 ± 0.87 ^a
Empty rumen %	4.25 ± 0.26 ^a	3.98 ± 0.37 ^a

^aMeans within the same row with different superscripts differ significantly ($p < 0.05$). Values with the same superscript indicate no significant difference ($p > 0.05$)

Table 8. Effect of housing system on some carcass length measurements.

Parameters	Semi-open barn	Closed barn
Carcass length (cm)	95.22 ± 1.02 ^a	94.15 ± 1.11 ^a
Chest perimeter (cm)	73.51 ± 0.82 ^a	72.68 ± 0.91 ^a
Hind quarter perimeter (cm)	58.72 ± 0.72 ^a	57.43 ± 0.75 ^a
Chest depth (cm)	26.83 ± 0.34 ^a	26.13 ± 0.52 ^a

^aMeans within the same row with different superscripts differ significantly ($p < 0.05$). Values with the same superscript indicate no significant difference ($p > 0.05$).

Table 9. Effect of housing system on total separate fat percentage.

Parameters	Semi-open barn	Closed barn
Tail fat %	5.12 ± 0.51 ^a	6.61 ± 0.46 ^a
Pelvic fat %	0.48 ± 0.08 ^a	0.62 ± 0.09 ^a
Kidney fat %	0.23 ± 0.05 ^a	0.31 ± 0.04 ^a
Heart fat %	0.06 ± 0.01 ^a	0.09 ± 0.01 ^a
Total fat %	5.89 ± 0.56 ^a	7.63 ± 0.57 ^a

^aMeans within the same row with different superscripts differ significantly ($p < 0.05$). Values with the same superscript indicate no significant difference ($p > 0.05$).

Table 10. Effect of housing system on eye muscle area and subcutaneous fat thickness.

Parameters	Semi-open barn	Closed barn
Eye muscle area (cm ²)	11.78 ± 2.05 ^a	10.53 ± 1.92 ^a
Subcutaneous fat thickness (mm)	7.24 ± 0.72 ^a	8.12 ± 1.54 ^a

^aMeans within the same row with different superscripts differ significantly ($p < 0.05$). Values with the same superscript indicate no significant difference ($p > 0.05$).

sheep found locally. Conditions under which sheep can be easily raised and maintained can easily affect their welfare. Well-placed sheep rearing facilities with a good micro-climate system, with easy access to pasture lands and adequate nutrition, can easily lead to improved sheep welfare. Intensive sheep rearing requires rearing sheep within enclosures that can easily offer improved micro-climate control and nutrition systems.

For live weight gain, these findings were found to be consistent with Prawl *et al.* (1998), Diaz *et al.* (2002), Lupton *et al.* (2008), Kay (2011), Kuźnicka and Rant (2013), Honeyman *et al.* (2014), Karaback *et al.* (2015a) and Karaback *et al.* (2015b), and those who found that there was no significant effect of type of analgesic on live weight gain. However, other research findings showed significant superiority in weight gain in favor of open barns, like Pusillo *et al.* (1991), Birkelo and Lounsbery (1992), Koknaroglu *et al.* (2008), Ripoll *et al.* (2014). Additionally, other research findings showed significant superiority in favor of closed barns, like Lupton *et al.* (2007) and GURSOY *et al.* (2011).

Khalil *et al.* (2023) found that there was an increase in weight gain for individual lambs within the same sheep house; however, there were no statistically significant

differences among different houses. There were no statistically significant differences among various houses for weight gain in the first and third months of the experiment. Weight gain was significantly ($p < 0.01$) lower in the first month compared to weight gain recorded in the second and third months.

Xiao *et al.* (2024) found that when lambs were reared outside under cold climatic conditions, their growth rate and immune response/antioxidant system were adversely affected, but indoor rearing (house and plastic tunnel) helped overcome these kinds of problems. The plastic tunnel would affect lambs' immunity more than either the house or outside rearing because of the presence of radiant heat. Mean weight gain and scalp and ear skin temperature were lower for lambs outside than inside the pen. Since it was colder and more windy outside, heat loss would increase, resulting in low temperatures and a low growth rate because more heat would be needed to keep their bodies warmer. There were no differences between trials for core body temperature; hence, sheep were thermally stable.

Although there was an arithmetic increase for the benefit of the first treatment, this could be attributed to the increase in feed intake among lambs under semi-open pens compared with the closed ones. In

Table 11. Effect of housing system on major cuts percentage.

Parameters	Semi-open barn	Closed barn
Major cuts %	64.43 ± 3.05 ^a	62.18 ± 1.21 ^a
Leg %	24.51 ± 0.82 ^a	23.9 ± 0.75 ^a
Chump %	6.38 ± 0.41 ^a	5.81 ± 0.32 ^a
Loin %	6.91 ± 0.72 ^a	6.21 ± 0.85 ^a
Best end neck %	5.41 ± 0.14 ^a	5.12 ± 0.25 ^a
Shoulder %	21.22 ± 0.84 ^a	21.14 ± 0.97 ^a

^aMeans within the same row with different superscripts differ significantly ($p < 0.05$). Values with the same superscript indicate no significant difference ($p > 0.05$)

Table 12. Effect of housing system on minor cuts percentage.

Parameters	Semi-open barn	Closed barn
Minor cuts %	35.57 ± 0.98 ^a	37.12 ± 0.84 ^a
Breast %	22.01 ± 0.24 ^a	20.59 ± 0.27 ^a
Neck %	3.25 ± 0.92 ^a	3.12 ± 0.90 ^a
Tail %	10.31 ± 0.95 ^a	13.51 ± 0.84 ^a

^aMeans within the same row with different superscripts differ significantly ($p < 0.05$). Values with the same superscript indicate no significant difference ($p > 0.05$)

Table 13. Effect of housing system on lean, bone, and fat percentages.

Parameters	Semi-open barn	Closed barn
Lean %	49.35 ± 3.25 ^a	47.23 ± 3.77 ^a
Bone %	24.21 ± 0.78 ^a	25.32 ± 0.58 ^a
Fat %	26.44 ± 1.86 ^a	27.45 ± 2.04 ^a

^aMeans within the same row with different superscripts differ significantly ($p < 0.05$). Values with the same superscript indicate no significant difference ($p > 0.05$)

addition to having ideal circumstances for lambs with fresh air and improved oxygen accessibility, there is air circulation inside the barn and lower temperatures compared to those under the closed system because heat stress impedes weight gain.

For fodder intake, these findings were consistent with those of Hoffman and Self (1970), Pussillo *et al.* (1991), Prawl *et al.* (1998), Zervas *et al.* (1999), and Koknaroglu *et al.* (2008), suggesting that open barns were superior to closed ones with regard to feed intake. Since animals can segregate and perspire to lose heat; therefore, this can lead to the reduction of feed intake, especially under warmer climatic temperatures (Pusillo *et al.*, 1991) because according to Hegg *et al.* (1974), heat stress can increase significantly the amount of high-energy rays given off among animals and at faster rates; therefore, this will cause an increase in the temperature inside the closed structure; consequently increasing heat stress on animals; and therefore, you will decrease feed intake, but not with regard to analgesic types because these findings agreed with Leu *et al.* (1977), Muhamad *et al.* (1983) which did not find

any significant effect on feed intake, or with GURSOY *et al.* (2011), Kay (2011) and Honeyman *et al.* (2014), who also found no effect between analgesic types and feed intake.

Regarding feed conversion efficiency, these findings were almost similar to those reported by Hoffman and Self (1970), Hegg *et al.* (1974), Pusillo *et al.* (1991), and Koknaroglu Oglu *et al.* (2008) because these studies confirmed that semi-open housing was significantly superior to closed housing. Since there was an arithmetic superiority of the weights of the first group over those of the second group. Owing to the afore-mentioned reasons, because of which there were more preferable conditions for lambs reared in semi-open houses; hence, there were positive effects on their productive properties, though insignificantly because of their low cost. Although other studies reported significant superiorities of closed barns, such as Prawl *et al.* (1998) and Zervas *et al.* (1999), other studies revealed insignificant effects of barn types, such as Leu *et al.* (1977), Muhamad *et al.* (1983), Koknar Oglu

(2011), Kaya (2011), Honeyman *et al.* (2014), Nojoka *et al.* (2015), and Karaback *et al.* (2015a).

Provision of fresh air

It should be noted that providing animals with fresh air inside their barns is compulsory. In other words, if adequate ventilation is not provided inside the barns, somehow the air inside these infrastructural units becomes stale and warmer with high humidity levels and higher amounts of dust, ammonia, and microorganisms. On the other hand, if adequate ventilation is not provided inside the barns, heat stroke occurs among animals due to low appetite and intolerance to weather patterns or because of susceptibility to cold shock and respiratory ailments. Because most fattening periods in northern Iraq take place during these months due to the abundance of lambs during this period and their low prices, and because temperatures rise significantly during these periods, the heat becomes very high in closed barns and stressful for the animals, in addition to the weak thermal insulation of buildings in these areas and the lack of use of cooling system.

On the other hand, more ventilation translates to more air currents inside the building; hence, there will be more heat loss from the animal's body, making animals more vulnerable to cold shocks and impairing animals', especially calves', resistance to disease.

Feeding behavior showed an increase and decrease in variable patterns among different types of housing systems and was not dependent on the type of housing. It can be attributed to the reason that when food was available, there was an increase in feeding behavior, and it has been reported that when animals were fed in pens, they were able to get more time to consume the allowed diet (Keskin *et al.*, 2010). Additionally, the sheep were fed *ad libitum*; therefore, it can be said that the sheep's feeding pattern could be affected by this, and increasing the number of times they eat and providing daily rations in small amounts at shorter periods of time normally exerts a stabilizing effect on rumen fermentation (Swelum *et al.*, 2017). Casamassima *et al.* (2001) found that Comesana ewes' feeding behavior was not influenced by housing in indoor and outdoor groups, indicating that the housing system had little or no effect on ewes' welfare and production.

For carcass weight, these results were consistent with Leu *et al.* (1977), Muhamad *et al.* (1983), Prawl *et al.* (1998), Koknar Oglu *et al.* (2005), Lupton *et al.* (2008), Carrasco *et al.* (2009), Gursoy *et al.* (2011), Honeyman *et al.* (2014) and Karaback *et al.* (2015b), Ripoll *et al.* (2014), who found no significant difference among different types of housing on carcass weights. Although this experiment failed to concur with Pusillo *et al.* (1991) and Karaback *et al.* (2015a), who found significant superiority in favor of half-barns. Zervas *et al.* (1999), Diaz *et al.* (2002) and Lupton *et al.* (2007) confirmed that closed housing was significantly superior. Since the fattening period overlaps with spring periods and climatic conditions were rather

equal, there were no significant differences between slaughter or carcass value of Akarman lambs raised under indoor and outdoor systems. It would appear that the advantage of outdoor systems over indoor systems could be more apparent with summer lamb finishing systems. For these circumstances, it could be concluded that outdoor systems would provide an advantage over indoor systems with regard to construction cost. For these circumstances, only the construction cost provided an advantage with outdoor systems. Consequently, shelter can be recommended for breeders under outdoor systems. In conclusion, regardless of breed or species used important starting point would be to prioritize factors related to welfare and cost efficiency level, respectively, according to Karabacak *et al.* (2015b). Results obtained with 2-year experiment held 2 years consecutively with lambs weaned at 2 weeks of age reared under a cold environment showed that growth performances and carcass characteristics were not adversely affected when compared with those reared under a warmer environment. The findings of this experiment revealed that lamb breeders could utilize these techniques for decreasing production cost because building a structure under a cold environment was significantly cheaper when compared with heated facilities.

For longitudinal carcass measurements, these findings agreed with Lupton *et al.* (2007), Lupton *et al.* (2008), Kuźnicka and Rant (2013), and Karaback *et al.* (2015a), who found there was no significant effect of types of shed on longitudinal carcass measurements. Although Gursoy *et al.* (2011) and Ripoll *et al.* (2014) found that there was no significance of carcass measurements, except that breast depth and carcass thickness were significant. However, Carrasco *et al.* (2009) found that most of the longitudinal carcass measurements were significant.

Statistical analysis of segregated body fats (buttock, abdominal, perirenal, and cardiac) revealed no significant differences ($p > 0.05$) between housing systems, although values were numerically higher in the semi-open system, likely attributable to greater feed intake and consequently higher digestible energy availability promoting adipose deposition. These findings are consistent with previous studies reporting no significant effect of housing type on segregated fat deposition, including Leu *et al.* (1977), Muhamad *et al.* (1983), Koknaroglu *et al.* (2005), Carrasco *et al.* (2009), Ripoll *et al.* (2014), and Karabacak *et al.* (2015a) who found no significant effect on all separated fats. However, other studies pointed that percentage of separated fat was significantly higher on closed housing systems rather than open housing systems such as those studies of Zervas *et al.* (1999), Diaz *et al.* (2002), Joy *et al.* (2008) and Gursoy *et al.* (2011) because of lack movement of animals in closed housing system rather than open housing system and reduce temperatures in open housing system leading to increase oxidation of fats. Fat oxidation refers to how the body can break down fats (triglycerides) into simpler substances like free

fatty acids and glycerol that can then be used as fuel or energy for different bodily processes. It happens mainly inside the mitochondria of every cell. It is an important aspect of physiological energy metabolism. According to current tendencies, the quality of animal products becomes increasingly important for consumers and markets requiring lean meat. The growth rate and quality of lambs' carcasses are determined by environmental factors when they gain weight. Since lambs held in warmer barns require lower amounts of energy for warming their bodies, this excess amount of energy translates into storing adipose tissues. Lower temperatures increase maintenance requirements and could limit the deposition of these fats when lambs graze. The expenditure of energy due to ambulatory activity translates into lower deposition of adipose tissues, too. The amount of fats within the carcasses of lambs that underwent walking exercise was lower compared to those held in barns (Kuźnicka, 2006).

For the eye muscle area

These findings were consistent with Leu *et al.* (1977), Muhamad *et al.* (1983), Prawl *et al.* (1998), Koknaroglu *et al.* (2005), Kuźnicka and Rant (2013), and Honeyman *et al.* (2014) because they found no significant effect of analgesic type on eye muscle area. Karabacak *et al.* (2015a) showed that the fattened lambs reared in an open dwelling were significantly superior to those reared in closed barns, while others, such as Gursoy *et al.* (2011), showed that those reared in closed barns were significantly superior to those reared in open dwellings.

For the thickness of subcutaneous fat, these results were consistent with Leu *et al.* (1977), Muhamad (1983), Prawl *et al.* (1998), Koknaroglu *et al.* (2005), Lupton *et al.* (2008), Carrasco *et al.* (2009), Kuźnicka and Rant (2013), Honeyman *et al.* (2014), Karaback *et al.* (2015a), who found that there were no significant differences because of the variation related to the type of analgesic used. Conversely, these findings were not supported by Diaz *et al.* (2002), Lupton *et al.* (2007), Joy *et al.* (2008), who confirmed that this property was significantly superior among fattened lambs under closed housing systems, while Gursoy *et al.* (2011) proved that fattened lambs under closed housing were superior.

In major and minor cuts, the outcomes of this experiment were consistent with Kuźnicka and Rant (2013), which showed that there were no significant differences among any of the major and minor parts of the carcass, while Carrasco *et al.* (2009) showed that there were no significant differences among all parts except the breast part. The outcomes showed consistency with other studies initiated by Gursoy *et al.* (2011) and Karaback *et al.* (2015a), which showed that there were no significant differences among all parts of the carcass except for the thigh part, which was significant. The outcomes were not consistent with those of Joy *et al.* (2008), which showed that there were no significant differences among parts of

the carcass except for the thigh part in favor of closed housing systems. Karabacak *et al.* (2015b) pointed out that lambs reared indoors received lower oxygen but higher humidity compared to those reared outdoors. Results of heart, lungs, and liver measurements were higher in lambs reared indoors than those reared outdoors ($p < 0.05$). In addition, weight and percentage of foreleg ribs were lower compared to lambs reared outdoors ($p < 0.05$). It can therefore be concluded that because of lower oxygen and higher humidity inside the shelter, lamb muscles reared outdoors were more efficiently grown.

For percentages of muscle, bone, and fat tissues, these findings were in line with those concluded by Gursoy *et al.* (2011), Nudda *et al.* (2013), and Karaback *et al.* (2012, 2015a) and those who said they could not find any differences between the two types of barns concerning any of the proportions of carcasses, but Lupton *et al.* (2007) found a significant superiority for the half-open barn with regard to the proportion of muscle tissues, while the similar result of this research showed by Joy *et al.* (2008) and Kuznicka and Rant (2013). The superiority of the closed system was significant with regard to fat tissues because of the lack of movement of the animal inside the barn.

Conclusion

Expanding production to meet future global demand for meat as an added source of protein included in human nutrition is one of the important challenges facing the sheep industry. Early studies on different housing systems and their impact on sheep productivity under harsh climatic conditions have yielded mixed results. From the above-mentioned explanation of the different climatic conditions, we find that ventilation is indispensable whether in extreme cold or extreme heat. Therefore, we can, to some extent, determine the housing system according to the prevailing weather, but we may need to switch from one system to another during the breeding period and sometimes even during the same day. How each system works, and when and how to determine the preference for the use of one system over another. The answer is comfort inside its housing based on the animal's optimum needs for heat and humidity. You will need to know more about the mechanism of operation of each system and what it can provide the animal in terms of heat and humidity, how they affect the animal, and how the animal deals with them.

Poor ventilation puts the sheep at a higher risk of respiratory infections and heat stress, both very important aspects of sheep welfare in barns. With poor ventilation, there is a buildup of noxious gases, such as ammonia and carbon dioxide, and particulate matter, which elevates physiological stress signs, suppresses behavioral activity, including feeding behavior, immune responses, and performance.

One of the most important means of welfare assessment is monitoring animal behavior. Farmers

should regularly monitor the behaviors of their animals because it provides real information about their welfare and needs.

It will be necessary to choose an appropriate design for the farm, usually related to the type of production, the environmental conditions surrounding the area, and the agricultural situation. Sheep are very tolerant of different weather conditions and do not require expensive housing. Wool is a protective cover for sheep against winter cold and rain. Sheep can also stay outside buildings in pastures for long hours.

As most of the fattening operations in this area, i.e., Telaar, take place in the spring and summer, because sheep births are seasonal and the availability of a sufficient number of fattening lambs is available during this period, cheap and easy-to-build sheep pens are the best for fattening lambs in this region, and there is no need for expensive enclosed housing.

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Conflict of interest

The authors declare that there is no conflict of interest.

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Authors' contributions

Ahmed Mazen Ali: Supervision, Statistical Analysis, Validation. Nawfal Mohammed Ameen Saaed: Conceptualization, Methodology, Formal analysis, Writing—Original Draft. Sinan Essam AL Deen Salah: Investigation, Data Collection, Writing—Review & Editing. Mothana K. Rashid: Literature Review, Data Curation, Visualization.

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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