MICRO AND MACRO CLIMATE OF ANIMAL AND POULTRY HOUSES ON ORGANISED FARMS

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ABSTRACT

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MICRO AND MACRO CLIMATE OF ANIMAL AND POULTRY HOUSES ON ORGANISED FARMS

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A study was carried out to find out the status of micro and macro climate of cattle and poultry houses on organized farms during (a) Summer: Hot dry (May and June 2003), (b) Monsoon season: Rainy-wet (August 2003), (c) Hot humid (September 2003) and (d) Mild Winter season: Cold dry (November 2003).

For the purpose of study, following cattle and poultry farms of Anand Agricultural University, Anand; (i) Two sheds, cowshed and calf pen were selected from Instructional Farm, Department of Livestock production and Management, College of Veterinary and Animal Husbandry, Anand (ii) cowshed at Livestock Research Station and (iii) cowshed at Holstein Friesian Bull Mother Farm and, (iv) at Central Poultry Research Station, three types of poultry houses namely (a) deep litter (b) cage house and (c) cage house with raised platform were selected.

Meteorological observations were recorded at 7.30 am and 14.30 hours both inside and outside of cowshed, calf pen and poultry house by (a) Digital thermo-hygrometer (J411TH) for temperature & relative humidity (Plate XI), (b) digital anemometer (Lutron-AM4201) for wind velocity, (c) digital lux meter (Masteck-ms6610) for light intensity and (d) Yash High Volume Air Sampler (Yash Engineering, Vadodara) for dust concentration in the air of houses.

The VHVAS was placed in the center of animal and poultry houses and run for 3 hrs from 10.00 to 13.00 hrs. The average the dust concentration in the animal and poultry shed was calculated by difference of final weight and initial weight of filter paper on microbalance.

The filter papers used were of Glass Microfibre Filters GF/A Cat No. 1820 866 Whatman International Ltd., England. The filter papers were packed in individual polypropylene bags. The sterilized bags were opened only at the site where it was directly placed in position in YHVAS machine with the help of sterilized forceps and run for three hours in animal and poultry sheds at 10:00 hours to 13:00 hours. The filter paper were removed and filled in the same polypropylene bags and weighed in the laboratory for difference between final and initial weights. These filter papers were used for total bacterial and fungal colony i. e. microbial colony count (*cfu*/plate).

Mean inside cow shed temperature during hottest period of the day i.e at 2.30 pm during different seasons irrespective of farms was 38.92 ± 0.26, 28.76 ± 0.42, 33.27 ± 0.18 and 32.23 ± 0.34 °C whereas outside the cow shed was 42.49 ± 0.40, 29.76 ± 0.47, 37.28 ± 0.39 and 36.76 ± 0.68 °C during hot dry (S_1), rainy-wet (S_2), hot humid (S_3) and mild winter (S_4) season, respectively. The mean difference (outside minus inside the cowshed) was 3.57, 0.75, 4.01 and 4.55°C during S_1, S_2, S_3 and S_4 season, respectively. Highest and lowest temperatures were recorded during hot dry and rainy wet season, respectively. Less difference (outside minus inside the cowshed) was observed during rainy wet. It may be due to rain and high humidity during this season, however, more difference was recorded during hot dry, hot humid and mild winter seasons. Season conflict was significant, it is bound too be. During hot dry season the inside temperature was lower by 3.57 °C than the outside intense temperature of 42.49 °C, however, inside temperature of 38.92 °C was also higher and or uncomfortable to cows.

The average temperature during summer hot dry season inside the cowshed was recorded to be 38.44 ± 0.42, 38.73 ± 0.16, 39.26 ± 0.28 and 39.25 ± 0.25°C whereas the outside 41.55 ± 0.48, 42.90 ± 0.27, 43.10 ± 0.21 and 42.44 ± 0.23 °C at FAS, IF, LRS & HF farm, respectively. The temperature difference (outside minus inside) was 3.11, 4.7, 3.84 and 5.19 at farmers animal houses (FAS), Instructional Farm (IF), Livestock Research Station (LRS) and Holstein Friesian Bull Mother Farm (HF), respectively. Average inside shed temperature was recorded higher at LRS and HF than FAS and IF farm. In spite of higher difference of 5.19 °C, The uncomfortable inside shed temperature of 39.25 °C was observed at HF farm, thus for a comfort cows use to come out under trees. It is suggested to establish a cooling system either fans or showering or plantation of trees around the cowshed.

Inside mean THI at 2.30 pm was observed to be 88.16 ± 0.42, 82.48 ± 0.63, 85.83 ± 0.34 &77.20± 0.52 whereas outside the cowshed was 91.40 ± 0.68, 83.92 ± 0.76, 91.15 ± 0.69 & 81.45± 0 during S_1, S_2, S_3 and S_4 season respectively. Highest THI was observed during hot dry and hot humid seasons and they were generally stressful seasons of the year.

The mean temperature inside the cowshed during hot humid season at 2.30 pm was 32.94 ± 0.19, 33.00 ± 0.16 and 33.56 ± 0.21°C whereas outside the shed was 36.44 ± 0.40, 37.92 ± 0.36 and 37.97 ± 0.41°C on IF, LRS and HF farm, respectively. The temperature difference (outside minus inside the shed) was 3.50, 4.62 and 3.91°C IF, LRS and HF farms, respectively. Thus, sheds had provided more comfort during hot humid season. However, the analysis of variance showed non-significant ($P < 0.05$) difference for IF, LRS and HF farms.

The mean relative humidity recorded inside cowshed on different farms at 2.30 pm during different seasons was 41.30 ± 1.60, 45.61 ± 2.07, 41.23 ± 1.99 and 41.00 ± 0.86 per cent whereas outside the cowshed was 37.76 ± 1.72, 39.69 ± 2.07, 41.00 ± 1.64 and 36.38 ± 0.74 per cent and the difference (outside minus inside) was -3.54, -5.92, -0.23 and -4.62 per cent on FAS, IF, LRS and HF farm, respectively. The differences were non-significant ($P < 0.05$).

The mean wind velocity inside cowshed at 2.30 pm during different seasons irrespective of farms was 1.09 ± 0.33, 0.45 ± 0.05, 0.12 ± 0.02 and 0.22 ± 0.05 km per hour whereas outside, 2.22 ± 0.47, 1.23 ± 0.15, 0.61 ± 0.08 and 0.46 ± 0.08 km per hour and the difference (outside minus inside the cowshed) was 1.13, 0.78, 0.49 and 0.24 km per hour during S_1, S_2, S_3 and S_4 season, respectively. Highest and lowest wind velocity both inside & outside were observed during S_1 & S_4 season, respectively. Decreasing trend was observed from hot dry S_1 to cold dry S_4 season throughout the experiment. Significant ($P < 0.05$) differences were observed for the difference (outside minus inside) mean during all S_1, S_2, S_3 and S_4 seasons.

During afternoon hours irrespective of farms mean inside light intensity of cowshed at 2.30 pm during different seasons was 4428 ± 60.78, 5600 ± 59.74, 3907 ± 63.12, and 2390 ± 18.92 (X1) lux whereas outside was 60518 ± 38.94, 33800 ± 70.24, 49809 ± 21.94, 42759 ± 18.67 (X1) lux and the difference was 56089, 28200, 45901 and 40367 (X1) lux during S_1, S_2, S_3 and S_4 season, respectively. Highest inside LI and highest outside LI were observed during S_1& S_2 season, respectively. However, during winter cold dry, being short day length it was lowest and differed significantly ($p<0.05$) from other seasons.

Mean temperature inside calf pen irrespective of farms at hottest period of day 2.30 pm during different seasons was recorded to be 38.72 ± 0.26, 28.82 ± 0.47, 33.13

± 0.15 and 32.02 ± 0.35°C whereas outside was 42.79 ± 0.30, 29.38 ± 0.54, 37.57 ± 0.38 and 36.67 ± 0.64 °C during S_1, S_2, S_3 and S_4 season, respectively. Mean difference was 4.07, 0.56, 4.44 and 4.65°C during S_1, S_2, S_3 and S_4 season, respectively. Inside & outside temperature were highest during hot dry and lowest during monsoon rainy wet seasons. The analysis of variance showed significantly ($P < 0.05$) lowest difference during S_2 than those during S_1, S_3 and S_4 seasons, which were at par.

Irrespective of houses i. e. deep litter (BDLH), cage house (CLH) and cage with raised platform (CLH + RP) mean inside temperature of poultry house at 2.30 pm afternoon during different seasons was 37.70 ± 0.23, 28.70 ± 0.40, 32.78 ± 0.15 and 33.56 ± 0.33°C whereas outside 42.87 ± 0.32, 29.78 ± 0.44, 37.49 ± 0.59 and 36.98 ± 0.62°C during S_1, S_2, S_3 and S_4 season, respectively. The difference was 5.17, 1.08, and 4.71 and 3.42°C during S_1, S_2, S_3 and S_4 season, respectively. Higher difference was observed during hot dry (S_1) and hot humid S_3 seasons than the monsoon: rainy wet (S_2) and mild cold (S_4) seasons. The analysis of variance showed significant ($P < 0.05$) lower difference during S_2 than during S_1, S_3 and S_4 seasons.

The mean inside poultry houses relative humidity percent was recorded to be 45.66 ± 1.19, 99.29 ± 1.09, 65.23 ± 0.67 and 38.05 ± 2.04 per cent whereas outside it was 39.91 ± 1.24, 90.27 ± 1.11, 61.24 ± 0.55 and 34.54 ± 1.95 per cent during S_1, S_2, S_3 and S_4 season, respectively. The difference was -5.74, -0.02, -3.99 and -3.51 percent. The RH was higher at inside the shed than outside due to output of moisture by excreta, water present inside the house and pulmonary losses. More difference was observed during summer hot dry season and least, during S_2. Highest RH was observed during monsoon rainy wet season and lowest during dry mild cold dry season. RH was higher during hot humid than hot dry season that caused more stress to birds.

Inside poultry houses the mean wind velocity km per hour at 2.30 pm was 0.44 ± 0.07, 0.21 ± 0.02, 0.09 ± 0.02 and 0.07 ± 0.02 kms per hour whereas outside it was 2.76 ± 0.39, 1.22 ± 0.12, 0.50 ± 0.09 and 0.35 ± 0.08 kms per hour and the difference (outside minus inside) was 2.35, 1.01, 0.41 and 0.28 kms per hour during S_1, S_2, S_3 and S_4 season, respectively. Highest inside and outside WV was observed during summer followed by S_2, S_4 and S_3 seasons. The analysis of variance showed significant ($P < 0.05$) difference among difference (outside minus inside) means of poultry houses during S_1, S_2, S_3 and S_4 seasons.

Irrespective of seasons the average dust concentration in animal houses and poultry houses was 38.5 and 32.8 mg/3 hrs /shed. Dust concentration was 11.74 percent more in animal houses than the poultry houses. The average microbial colony count was only 9.00-cfu/ plate in animal houses whereas it was 15 times more in poultry house i.e.140 cfu/ plate. It was much more microbial colony count in poultry houses than the animal houses. It might be due to the more closed type housing favored higher relative humidity and presence of mash feed and litter and excreta in the poultry house than the animal house.

The housing index (HI) during most stressful hot-humid season i.e. July, August 2004 was estimated on the 28-scale point for the organized farmhouses of Anand Agricultural University and rural farmers animal houses. It was observed that the housing index for cowsheds at organized farms was 22.7 points i. e. excellent whereas at farmer's animal houses 17.0 points i. e. an average. Similarly, the HI for BDLH, CLH and CLH + RP poultry houses was 26, 26 and 24 points which falls under the excellent category.

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CERTIFICATE

This is to certify that the thesis entitled "**MICRO AND MACRO CLIMATE OF ANIMAL AND POULTRY HOUSES ON ORGANISED FARMS**" submitted by **NARWADE BABAN MADHAVRAO** in partial fulfilment of the requirements for the degree of Master of Veterinary Science in Livestock Production of the Anand Agricultural University is a record of bonafide research work, carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar titles.

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Date: - 6/8/06

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ACRONYMS

&	And	SE	Standard error
%	Per cent	Wt.	Weight
Temp	Temperature	g	Gram
°F	Fahrenheit	ml	Millilitre
°C	Celsius	M	metre
RH	Relative humidity	Kms	Kilometre
THI	Temperature humidity index	Sec	Second
LI	Light Intensity (lux)	hrs	Hours
WV	Wind Velocity	mm	Millimetre
LRS	Livestock Research Station	No.	Numbers
HF	Holstein Friesian Bull Mother Farm	*et al*	And co-workers
IF	Instructional Farm	Avg.	Average
BDLH	Deep litter house for layers	*Viz.*	Namely
CLH	Cage house for layer	*Cfu*	Colony forming unit
CLH+RP	Cage house with raised platform for layers	S	Season
AM	(*Ante Meridiem*) Before noon	*ie*	That is
PM	(*Post Meridiem*) After noon		

INTRODUCTION

CHAPTER I

INTRODUCTION

Livestock contribute significantly to 100 crore humans of India in terms of income, employment and nutrition. This contribution should increase to fulfill increased demand of ever-rising population. The performance of livestock depends on both heredity and environmental factors. In general, environment of an animal is the condition to which an animal is subjected in its usual coarse of life. Keeping aside the genetic make of the individual, environment i.e. climate, feed, housing, and health care management plays an important role for exploring the potential and improving overall performance of livestock to a greater extent. India is a vast country with diverse four major geo-climatic zones comprising fifteen agro climatic zones, which have direct bearing on animal farming, housing and management. Broadly speaking, the various geo-climatic zones of Indian sub-continent are as follows:

1. Plain area with medium rainfall (Deacon Platens)
2. Arid platens (North-western parts)
3. High altitudes areas (Sub-Himalayan region) and
4. Heavy rainfall and high humidity areas (North-east and costal areas)

Similarly Gujarat is also grouped into eight agro climatic zones. Besides the differences in climate, there is a great diversity in the economic and social status of farmers in the said zones, which together determines the type of cattle sheds used by the farmers as well as the materials used for different component of housing.

In tropical climate, the high ambient temperature coupled with high humidity and solar radiation causes great amount of heat stress to animals and poultry birds. The hot summer and hot humid monsoon in Western region of India is still more stressful depressing the performance of dairy animals and poultry. For optimizing the production, microclimate of animal houses should be improved by suitable design and arrangements.

In broad sense, microclimate of an animal is the climate inside the animal house or surrounding the animal, whereas, the climate outside the house is macroclimate. The micro and macro climatic variables include ambient temperature, relative humidity, solar radiation; light intensity wind velocity and rain fall. The animals are subjected to stress under three environmental conditions (i) Winter (cold and dry) (ii) Summer (hot and dry) (iii) Rainy (hot and humid). Proper animal houses protect them from extreme climates by moderating the range of microclimate, in turn, optimizing the production. Microclimate of animal houses should be within the range in which (i) animals' health and productivity be sustained, (ii) the stockman can accomplish his task comfortably without risk to his health and (iii) buildings and equipments are protected from physical damage.

The criteria to evaluate the microclimate of animal houses include, the temperature, relative humidity and air velocity at animal height as well as concentration of gases, dust and air borne microorganisms (Wathes *et al.*, 1987).

Taking into consideration the effect of micro and macroclimate on animals'-poultry health and their production, an investigation was planned to study the status of the macro and microclimate of animal and poultry houses during different seasons with the following objectives.

1. To study the status of macro and microclimate viz. temperature, relative humidity, air velocity and light intensity in the animal and poultry houses of A.A.U. farms.
2. To study the level of dust (suspended particles) in the air of animal and poultry houses.
3. To compute the major microbial colony count in the air of animal and poultry houses and
4. To study the housing index of animal and poultry houses.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

2.1 Introduction

The weather or climate of an animal may be optimal or may impose varying degree of constraint on its normal production performance. Animal remains under stress when any combination of environmental conditions causes the effective temperature of the surrounding (microclimate) to be higher or lower than the animals thermo-neutral zone. Shade is usually a cost effective means of protecting livestock from the amplifying effect of solar radiation coupled with high air temperature. When a shade of any material or construction interrupts the direct solar radiation, it will heat up. If the lower side of material becomes hot it will then radiate heat to the animal body below (Owen, 1994). Factors that influence the effective temperature of an environment are air temperature, relative humidity, air movements and solar radiation (Buffington, *et al.*, 1981). One way to reduce the environmental stress is by physical modification of microclimate. Proper housing management can help in moderating the range of microclimate to which the animals are exposed and optimizes their production by protecting them from extreme climatic condition. The conditions inside the animal houses are affected to a considerable extent by the meteorological factors of the external environment, the construction itself (Padmanabhamurthy, 1983) and the animals housed in them. The macroclimate-microclimate relationship is different in different seasons in the same animal house also (Singh *et al.*, 1985).

Present study was undertaken to study the status of microclimate of animal and poultry houses in relation to macroclimate, dust concentration (suspended particles) in the air and microbial colony count. While reviewing the literature, an attempt has been made to emphasis more on the macroclimate and microclimate, dust concentration, microbial colony count and housing index. Hence topic is subdivided into:

2.2 Macro and microclimate of animal houses

Kelly and Bond (1958) compared the effectiveness of various shade materials with new aluminum sheets. Their results demonstrated the benefit of hay (for insulating) and white top aluminum sheet as reflective surfaces.

The most effective shade source is tree, as it provides protection from sunlight combined with beneficial cooling as moisture evaporates from the leaves. *Thach* (Hay or straw) shads are the most effective artificial material, while solid shades provided by metal sheet painted white on top is next in effectiveness (Bond *et al.,* 1961). Misra and Sengupta (1965) reported that provision of wet *khas tatti* panel hung from roof level of half wall of the sheds during summer increased the ambient temperature of sheds in the morning, but decreased it in the afternoon. The humidity level was always higher in such sheds. The microclimate in the loose house could be improved by additional shelter in the open area of the loose house along with the showering of buffalo heifers housed in them (Sastry *et al.,* 1973).

The comparative study of microclimate in open and closed sheds in relation to macroclimate at Izatnagar (semi-arid plains) was made by Singh *et al.* (1977). They observed that mean daily maximum temperature in cool season was 24.49, 22.64, 21.31°C and mean daily minimum temperature was 6.24, 8.13, 14.86°C at macro-environment, open shed and closed shed respectively. Mean daily maximum temperature was 30.02, 29.28 and 27.82°C and mean daily minimum temperature was 12.89, 14.28, 19.94 °C and in hot dry season mean daily maximum temperature 39.07, 39.59 and 36.81°C and mean daily minimum temperature was 21.51, 22.11, 27.52 °C at macro-environment, open shed and closed shed respectively. While hot humid season mean daily maximum temperature was 34.94, 34.52 and 34.24°C and mean daily minimum temperature was 24.95, 25.45, 29.04 °C at macro-environment, open shed and closed shed, respectively. The mean maximum temperature and mean minimum temperature in closed type shed were significantly higher ($P < 0.01$) than those in open type shed as well as at the open macro-environment in summer season. The mean maximum temperature of closed shed was significantly lower ($P < 0.05$) than those of the macro environment during winter.

Meteorological data from several studies on the microclimate in the open, in the loose house with brick pavement and partial asbestos-roofed shelters and in normal brick walled asbestos-roofed barns, as well as in hollow brick-roofed barns, indicated that the maximum temperature inside the barns was similar to that in the open in all seasons, but it was invariably higher in the loose house by about 2°C in all seasons. The relative humidity, though higher in the loose than in open, was highest in the barn house (Thomas *et al.*, 1978).

An investigation was carried out at NDRI, Karnal to ascertain the cause of drop in milk yield during hot and humid climatic conditions by Ludri, (1979). He observed ambient temperature of 26.6 °C and 30.5°C in thatched shed without ceiling fan and 26.4 °C and 30.2 °C in shed with ceiling fans at morning and evening, respectively. The relative humidity percent observed to be 90.00 and 90.00 and 88.00 and 89.00 percent for corresponding sheds in morning and evening, respectively.

Fuquay *et al.,* (1979) found insulation + sprinkling roof was an effective method of reducing the ambient and black globe (radiation) temperature within livestock housing, which decreased in the afternoon. Although the humidity level was always higher in such sheds. For reviewing heat stress effects on animal production, one must consider the entire scope of factor affecting thermoregulation in the body of animals.

Karki (1981) compared the effect of different housing systems viz. (i) loose housing, (ii) housing in roofed and walled shed and (iii) housing in roofed and walled shed during day and in the open during night. He found that the maximum temperature and vapour pressure were marginally higher in the loose house both during hot dry and hot humid periods of summer. Daily minimum temperature was lower in loose house than inside the shed throughout the experiment. The maximum temperature was higher (3 to 5°C) during hot-dry period in all the three locations while daily minimum temperature was higher during hot humid period (1 to 2°C). He observed that wind velocity was highest (10.05 kms/hr) in May and lowest (8.05 to 8.86 kms/hr) in July and August. During summer season WV was 5.40 kms/hr and during winter season (December to February) it was 1.7 kms/hr.

The comparison was made between three systems of housing viz. loose house, shed and shade + open for female buffalo during hot dry, hot humid and winter season by Singh (1982). He observed that the maximum temperature was consistently higher in loose house than those in shed and open, whereas, average minimum temperature was marginally lower in loose house than in shed. The daily maximum temperature was 41.05, 37.16, 26.21 and 19.47 °C in hot-dry, hot-humid, mild cold and severs cold seasons respectively. The corresponding values for minimum temperature were 25.80, 20.01, 18.00 and 8.80 °C. Hot season was significantly ($P<0.01$) different than the cold season in respect of maximum and minimum temperatures. The differences between hot dry and hot humid as well as mild-cold and sever cold seasons were not significant. The mean THI value was consistently higher in loose house than in the shed. The THI values in hot dry and hot humid season at morning and afternoon were 80.70 and 87.15 and 82.45and 86.40, respectively. The differences were not significant in summer season, however, the differences in THI in mild-cold and sever cold seasons differed significantly ($P<0.01$) at morning 9 am and afternoon 2 pm.

Mehla (1982) reported that daily maximum temperature was constant in both the houses in winter, though marginally (by 0.40°C) higher in the open than in loose house as well as inside the shed by 1.76°C. The minimum temperature was lower marginally in the loose house than inside the shed throughout. Vapour pressure values were higher during mild cold period than during the severe cold period at three different locations. There were no significant differences between shed and loose house with respect to THI values.

Three systems of housing in summer for housing buffaloes i.e. (i) conventional barn, (ii) open + shed and (iii) loose house were studied by Yadav (1982). He reported the mean values of maximum and minimum temperature in conventional barn, in the open and in the loose house to be 40.60 and 20.06°C, 40.18 and 25.38°C and 43.13 and 27.60°C, respectively. Mean maximum temperature was significantly ($P < 0.05$) higher in loose house than conventional barn and in the open, but there was no significant difference between conventional barn and open. Mean minimum temperature was significantly ($P < 0.05$) higher in conventional barn than loose house and in the open. The mean daily THI was 81.97 and 82.37 at 8.00 a.m. and 88.90 and 88.49 at 2.00 p.m. in loose house and barn, respectively. The wind velocity in open was recorded to be 8.35, 10.05, 9.35 and 8.49 km/hr during April, May, June and July, respectively.

Bempong and Gupta (1989) reported that daily mean maximum temperature was 38.52 and 39.97°C in shed and loose house of crossbred cows during summer, respectively while the minimum temperature was same for both houses (27.02°C). The relative humidity percent was observed to be 66.74 and 68.67 at 7:00 hours and 45.42 and 42.56 at 14:00 hours in shed and loose house respectively. The values for THI were 80.64, 79.81 at 7:00hours and 86.98 and 87.58 at 14:00hours in shed and loose house, respectively.

Effect of winter management system on growth performance of female Murrha buffaloes calves was studied by Chakrabarti (1991). He reported that mean maximum and minimum temperature in loose house (T1), loose housing + curtains during night (T2), loose housing + bedding (T3) and conventional barn (T4) were 23.38, 22.80, 22.96 & 22.66 °C and 6.66, 6.74, 6.82 and

7.05°C, respectively. Mean maximum and minimum temperature were highest in the month of November and lowest in the month of January in all types of housings. He further reported that the THI value in evening was more than the morning. The mean value range from 54.50 to 70.21, 53.91 to 67.78, 54.10 to 67.92 and 52.59 to 67.52 in above described four treatments, respectively.

Sarma (1991) at Hissar. He observed the temperature humidity index (THI) both inside and outside the shed in morning and evening varied from 51.12 to 80.12, 62.12 to 86.42 and 50.54 to 80.06, 63.21 to 86.97 in indoor morning, evening and outdoor morning and evening, respectively.

Effect of three housing viz. (i) reinforced cement concrete shed (RCC), (ii) thached roof shed and (iii) tree shelter and microclimate on growth of Mehsana buffalo heifers studied was at LRS GAU, Sardar Krushinagar in semi-arid region of North-Gujarat by Patel *et al.* (1995). They inferred that the minimum temperature of microclimate was significantly ($P < 0.01$) affected by housing system, while maximum temperature, relative humidity and THI did not significantly differ under different housing system.

A study was undertaken to know the effect of two different housing systems on physiological responses of crossbred calves by Parihar *et al.* (1992). They reported maximum temperature of 40.42 and 26.07 °C during summer and winter respectively. The relative humidity percent at 7.30 am and 3.30 pm were observed to be 41.55 and 13.66 percent and 78.17 and 32.98 percent during summer and winter, respectively. The wind velocity was 4.56 and 2.56 kms/hr during summer and winter, respectively.

Singh (1996) studied the effect of certain summer managemental practices on the performance of growing calves and recorded mean maximum temperature to be 4.06°C more in loose house having asbestos sheet roof than under modified loose house having thatched roof and thatched screen towards open area of shed. However, average minimum temperature was 2.02°C higher in modified loose house as compared to loose house.

Dahiya (1997) conducted an experiment to find out the effect of feeding two level of dietary protein and bedding on growth performance of female buffalo calves during winter season and found that the overall mean temperature was lower (1.38°C) in without bedding group as compared to with bedding. The mean maximum and minimum temperatures in sheds were 24.62 and 5.23°C respectively. The Temperature Humidity Index values were highest in February (54.88 and 53.62°C) and lowest in December (46.608 and 45.312°C).

Stowell *et al.* (1998) studied the radiant heating and thermal environment of metal roofed dairy barns and observed that air and black globe temperature at two roofing exposed to both wind and solar radiation greatly influenced the outdoor black globe temperature and roof underside temperature and considerable heating of weathered metal roofing occurred when not exposed to a good breeze.

In Northwestern Minnsota, macro & microclimatic parameters under two conditions, one barn with insulated ceiling and other metal roof without insulation, in two free-stall dairy barns were measured by Janni (1999). He observed that the monthly average temperature within two barns ranged from

15.1 and 15.8°C in May to 21.1 and 22.2°C in July. Weekly average temperature in the barn with the insulated ceiling was more uniform than the barn with the uninsulated metal roof. Hourly average ceiling level temperature in the uninsulated barn was several degree higher than those measured in the insulated barn.

Yanar *et al.,* (2000) studied the effect of two environmental conditions, having adequate temperature of 11.9 ± 2.6°C and relative humidity of 77.0 ± 2.0 per cent and having inadequate temperature of 16.0 ± 3.3°C with 85.5 ± 2.8 per cent relative humidity, on fattening performance of Brown Swiss bulls of 6-9 months and 9-12 months of age. They found that average daily weight gain (1.11 ± 0.03 kg Vs 1.03 ± 0.03 kg) and total weight gain (170.8 ± 4.5 kg Vs 158.7 ± 5.1 kg) between the two sheds differed significantly ($P < 0.05$).

Yazdani and Gupta (2000) studied the effect of housing and feeding systems on crossbred calves. They recorded higher maximum ambient temperature in loose house (42.2 °C) than thatched house (38.5°C). The THI in both types of experimental house was about 78, which was above the value of 72 at which the growth of calf is decreased.

Microclimate in loose house and conventional barn in winter season was compared by Tedla (2002). He found that the mean maximum temperature was significantly higher ($P <0.01$) in loose house (25.05 vs. 22.29°C) whereas the mean minimum temperature was significantly ($P <0.01$) lower in loose house (8.04 vs. 12.74°C) as compared to conventional barn on account of blockage effect of walls, roof and closed windows and door to the heat inside and heat released by animals during night. The morning THI was significantly higher ($P < 0.01$) in conventional barn (89.65) than the loose house (52.47) but non-significant difference was observed in evening THI values between two housing systems.

Sharma and Singh (2002) investigated the effect of three housing system viz. loose housing (control), loose housing with central shed and closed housing system during different months on micro and macro-climatic variables. In March minimum temperature (morning) was significantly ($p<0.01$) higher in closed house (12.35°C) as compared to loose house (9.5°C), and in loose house with central shed (9.12°C), While, the maximum temperature was highest in loose housing (31.0°C) compared to other housings. THI revealed that in all the shelters, animals were under thermal stress from April to September. In April, May and June the discomfort was relatively less in loose housing and loose house with central shed. Most favorable microclimate was observed in loose housing with central shed during July to October. Maximum temperature (evening) was significantly ($p<0.05$) higher in loose housing (43.25°C) as compared to both loose housing with central shed (35.67°C) and closed house (37.75 °C). In May and June, all the climatic variables recorded did not differ significantly between houses. In June, highest minimum temperature was observed in closed house (27.25 °C) while highest maximum temperature was in loose housing (43.25°C). The THI were non significant. In August, minimum temperature (25 °C), THI (90.75) and (evening) vapors pressure (40. 00 mmHg) were significantly ($p<0.01$) higher compared to loose house with central shed and closed housing. In September, highest minimum temperature was observed in closed housing system (25.6°C) while highest maximum temperature was in loose house

(43.60^0C), THI (91.47) and vapor pressure in evening (37. 50 mmHg) were highest in loose housing, where as, other variables showed non-significant between houses. The minimum temperature in closed houses was higher in November (16.25 °C), December (11.00 °C) and January (12.0 °C) than the other two housing systems. Maximum temperature was significantly ($p<0.01$, $p<0.05$) more in November (33.5°C) and February (31.0 °C) and non-significantly higher in December (23.20°C) and January (21.33 °C) in loose housing. The THI (evening) was higher ($P<0.01$) in loose housing during November (81.70) and in closed housing during December (56.42).

Sagsoz *et al.* (2003) conducted an experiment to study the effect of different housing viz. adequate (temperature 13°C, humidity 65 percent with low level of CO_2 and NH_3) and inadequate (temperature 21°C, humidity 85 percent with high level of CO_2 and NH_3) on milk production and physiological traits in Holstein Friesian cows and they found that the high temperature and relative humidity had significantly ($p< 0.05$) adverse effect on the total milk yield and the daily milk yield. The cows housed in inadequate barn produced less (0.460 Kg per day) milk than the cows kept in adequate housing condition.

Gupta *et al.* (2003) divided 20 female buffalo calves (7-9 months) into four groups of five each on the basis of body weight and age and allotted to four housing (T1 – loose house; T2 – loose house + thatch roof; T3 – loose house + mud plaster roof and T4 – conventional barn) treatments during summer season. The mean maximum temperature in T1, T2, T3 and T4 sheds was 38.71, 36.09, 36.04 and 38.06°C, respectively. This showed that provision of thatch and mud plaster on the asbestos roof improved microclimate by lowering the temperature by about 2°C.

The effect of certain summer managemental practices on the performance of buffalo heifers was investigated by Singh *et al.* (2003) and they reported that the mean maximum temperature was significantly lower ($P < 0.01$) in loose house + aluminum foils pasted roof T4 (36.72°C) and thatch roof T3 (36.26°C) as compared to loose house T1 (39.90 °C) and loose house + white painted roof T2 38.40°C. The mean minimum temperature was significantly higher ($P < 0.01$) in T2 (25.75°C) as compared to T1 and T3 (23.74 and 23.52°C). RH and morning THI were not significantly influenced by treatments. However, evening THI was more ($P < 0.05$) in T1 and T2 (85.05 and 83.97) as compared to T3 and T4 (81.06 and 80.94).

Hari om (2003) investigated certain modification in loose housing and its impact on the performance of female buffalo calves during summer and reported that overall maximum and minimum temperature were not significantly influenced by treatments T1 (loose house as control), T2 (loose house mud plastered roof) and T3 (loose house + use of waste lime on roof). However, the maximum temperature was significantly ($P < 0.05$) higher in hot dry period i.e. 42.19, 40.20 and 40.75°C in T1, T2 and T3 respectively than hot humid period i.e. 38.67, 37.11 and 37.60°C in T1, T2 and T3, respectively. The maximum temperature in hot dry and hot humid period was not significantly influenced by treatments but it was slightly lower in modified roof houses as the mud absorbed and lime powder reflected the solar radiations thereby preventing entry into the animal shed. The morning and evening mean relatively humidity in hot dry period were 59.50 and 28.79, 60.07 and 28.93 and 60.14 and 29.00 in T1, T2 and T3 respectively and corresponding values for hot humid period were 78.36 and 43.64, 78.57 and 43.50 and 78.57 and 43.71 per cent. The relative humidity was significantly lower ($P < 0.05$) in hot dry than that in hot humid period during morning and evening. Housing system in both the seasons did not significantly influence the relative humidity and THI and there was no significant difference observed between two seasons. The THI was 4 per cent higher in evening (86.59, 85.30 and 85.72 in T1, T2 and T3, respectively) as compared to morning (82.38, 81.58 and 81.99 in T1, T2 and T3, respectively) indicating that evening was more stressful as compared to morning in different houses.

2.2 Macro and microclimate of poultry houses

Gill and Kansal (1993) studied the effect of rearing system of birds i.e. cage system and deep litter system on microclimate of house. They recorded that maximum temperature was significantly ($P < 0.01$) higher in cage system than deep litter system in hot humid [July (33.41 Vs 32.46°C), August (33.02 Vs 31.71 °C), September (30.34 Vs 31.61 °C)] and winter October (28.83 Vs 28.97 °C), November (26.11 Vs 23.71 °C), December (24.31 Vs 17.66 °C) and January (23.43 Vs 22.16 °C).] The minimum temperature was significantly ($P < 0.01$) lower in asbestos roofed shed (cage system) in the months of July to January. The relative humidity (%) in sheds with cage system was significantly higher ($P < 0.01$) as compared to deep litter in hot humid months of July to November (34.79 Vs 33.25%) but was lower in December (55.59 Vs 60.89%) and January (55.44 Vs 50.40%).

The effect of fogging and roofing systems on microclimate of commercial layer shed was studied by Murlidharan *et al.* (2001) in and around Namakkal, Tamilnadu during summer. They found significantly ($P < 0.01$) lower temperature ($32.93 \pm 0.150^{o}C$) in the sheds with foggers than the sheds without foggers ($36.14 \pm 0.142^{o}C$). However, relative humidity ($53.66 \pm 0.909\%$) was higher by 10% in shed with foggers than shed without foggers ($43.69 \pm 0.687\%$). Air velocity value of 0.524 ± 0.025 m/sec and 0.357 ± 0.030 m/sec were recorded in sheds with foggers and sheds without foggers, respectively. They recorded similar temperature (34.75 vs 34.38 ^{o}C) and lower relative humidity (44.82 ± 0.832 vs 52.46 ± 1.037 per cent) in asbestos roofed shed than those in tile roofed poultry shed.

Effect of microbial quality of air in relation to the microclimatic condition on egg production was studied by Kanga *et al.* (2002). They compared three different rearing systems viz. deep litter, conventional cage and raised platform to cage arrangement. Microclimatic factors (air temperature, relative humidity and air velocity) were measured and egg production in percentage was calculated. They observed higher relative humidity (74.49 ± 1.27 percent) during morning than afternoon (59.93 ± 1.32 percent) and evening (67.62 ± 1.84 percent) hours and lower temperature ($26.06^{0}C$) than afternoon ($31.80 \pm 0.16^{0}C$) and evening ($28.27 \pm 0.21^{0}C$) hours. However, they observed higher air velocity during afternoon (0.06 ± 0.07m/Sec.) than evening (0.34 ± 0.07m/Sec.) and morning (0.23 ± 0.05m/Sec) hours. They also observed that the layer house on raised platform had significantly ($p<0.01$) higher temperature ($29.05 \pm 1.61^{0}C$), relative humidity (85.84±0.81 percent) and air velocity (0.42±0.07m/Sec) than those in cage house [temperature (28.79±1.65^{0}C), relative humidity (67.12±4.03 percent), air velocity (0.34±0.05m/Sec)] and deep litter house system [temperature (28.28±1.76^{0}C), relative humidity (64.94±4.03 percent) and air velocity (0.206±0.04m/Sec)].

2.3 Dust concentrations and microbial colony count

Total dust concentration, dust particle size, dust distribution and concentration of air borne bacteria and fungi, ammonia, CO_2, temperature, humidity and air velocity in summer and winter seasons were measured by Zeitler (1987) in a stable at night, during morning activity period and in afternoon hours. Highest dust concentration was found during morning period (2.4 mg/m^3 of air). The concentration of bacteria and fungi was 352±172 cfu/ litter of air and 170±53 /liter of air, during day activity and 116±37 cuf / litre of air and 66±25 litre of air during night, respectively.

Yasotha *et al.* (2002) compared the air pollution levels in sheep pens with slatted floor and mud floor. They measured the total dust concentration, ammonia level, microbial air pollution (total bacterial count, coliform count and mold count) and climatic variables at weekly interval at 08:00hrs and at 14:00hrs. Significantly ($p<0.01$) higher concentration of total dust concentration (1.60mg/m^3 Vs 0.72mg/ m^3), ammonia (17.51 ppm Vs 7.5 ppm), total bacterial count (42.86 *cfu*/30 l of air Vs 23.83*cfu*/30 l of air) and mould count (22.94 *cfu*/30 l of air Vs 15.0883*cfu*/30 l of air) were observed in pens with mud floor as compared to pens having slatted floor. Sheep reared on slatted floor had significant ($p<0.01$) higher body weight (24.23 kg. Vs 20.70

kg.) and body weight gain (93.63 gm Vs 57.18 gm) than those reared on the mud floor. Total dust concentration was found to have a highly significant ($p<0.01$) and positive correlation with ammonia level and mold count. However, the type of floor had no effect on coliform count and climatic variables.

Effect of microbial status of air and the microclimatic condition on egg production was studied by Kanga *et al.* (2002). They compared three different rearing systems viz. deep litter, conventional cage and raised platform with cage arrangement. Air samples were collected thrice a day in a week at 7:00 hrs, 12:00 hrs and 17:00 hrs from poultry houses using airborne bacteria sampler (casella MK II) at the rate of 30 liter per minute. They found a significant ($p<0.01$) higher total bacterial count (337.58±4.48 30 liter/minute), coliform count (225.48±28.64 30 liter/min) and mold count (29.97±2.45 30 liter/minute) in deep litter poultry house than in conventional cage system and raised platform with cage arrangement system. They also reported a significantly ($p< 0.01$) higher bacterial count; coliform count and mold count during morning than at afternoon due to higher relative humidity (74.49±1.27 percent) and lower temperature during morning hours. The higher air temperature (31.80±0.16^{0}C) and air velocity (0.06±0.07) in the afternoon while higher relative humidity (74.49±1.27 percent) were observed during morning hours. They concluded that the birds on raised platform (84.96±0.86) and conventional cage system had significantly higher egg production as compared to deep litter system (80.00±0.68) on account of hygienic practices and better management prevailing in raised platform and in conventional cage system poultry houses.

MATERIALS & METHODS

CHAPTER III
MATERIALS AND METHODS

3.1 Experimental Details and Plan of the Work

3.1.1 Experimental animal and poultry houses

For the purpose of study, following cattle and poultry farms of Anand Agricultural University, Anand; (i) Two sheds, cowshed and calf pen were selected from Instructional Farm, Department of Livestock production and Management, College of Veterinary and Animal Husbandry, Anand (ii) cowshed at Livestock Research Station and (iii) cowshed at Holstein Friesian Bull Mother Farm and (iv) at Central Poultry Research Station, three types of poultry houses namely (a) deep litter (b) cage house and (c) cage house with raised platform were selected.

Anand is located at latitude of 22.56^{0} N and longitude of 72.91 E and situated at 45.1 m above the Mean Sea level. It has a semiarid tropical climate. The southeasterly current in the summer monsoon brings rains from third week of June to the September. An average rainfall at Anand is 876 mm with 37.7 per cent coefficient of variance. From October to third week of June weather remains dry. Summer is hot and winter fairly cool.

Summer season commences from about mid-February and extends up to mid-June. April and May are the hottest months of the year. Maximum temperature, as high as 44^{0}C usually occurs in the May. December and January are the coldest months of the year. Week-wise information on mean, maximum and minimum temperatures, net radiation, sunshine hours, wind velocity, relative humidity and rainfall for last 20 years is given in Appendix-I.

The three types of animal houses studied were (I) loose house cow shed at Instructional Farm, Department of L.P.M., Veterinary College, Anand Agricultural University, Anand. The shed was with asbestos sheets dome roofed and full-length back wall with windows. The shed is one side open in East-West direction. Trees are present around the shed as shown in plate I. Calf pen of similar to cowshed except that the open paddock is cement concrete and globe type roof. Trees are present around the calf pen as shown in plate VII.

(II) Cowshed of Livestock Research Station is as shown in plate

III & IV. Direction of the cowshed is East-West, mud-tiled roof, back wall full with windows and sidewalls are with side doors.

Calf pen of LRS: is as shown in Plate VIII. Direction of shed is North-South; roof mud-tiled, floor and open paddock cement concrete. Neem tree is present in front of shed. Type of house is loose housing.

(III) Cow shed of Holstein Friesian Bull Mother Farm is as shown in Plate V & VI. Direction is East-West, asbestos roof at 25 feet height, cement concrete floor. It is a type of loose house having central shed with two sides open paddock. No trees are present.

Calf pen of Holstein Friesian Bull Mother Farm: - Direction of shed is East-West, roof - asbestos sheet globe type as shown in plate IX. Walls are full with windows on side.

(IV) Poultry Sheds of Central Poultry Research Station:

(1) Deep Litter for Layer Breeder (BDLH) birds as shown in plate XII. Direction is East-West, roof- asbestos sheet, floor cement concrete 2 feet above the ground level.

(2) Three Tier Cage Layer house (CLH) having direction East-West, asbestos sheet roof, cement concrete floor, two feet above the ground level. Trees are present around the house.

Plate I Cow shed at IF showing (a) canopy of trees
(b) Dome type roof

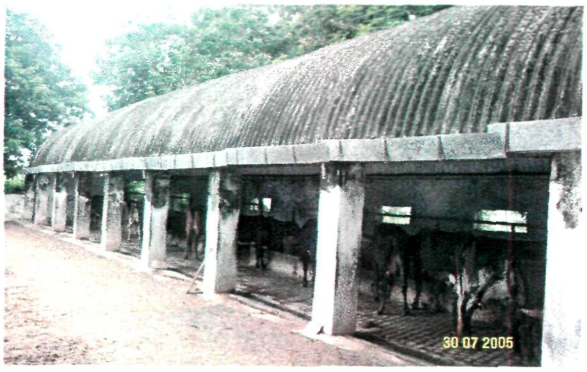


Plate II Closure view of cow shed at IF

Plate III Cow shed at LRS

Plate IV HVAS in operation in cow shed at LRS

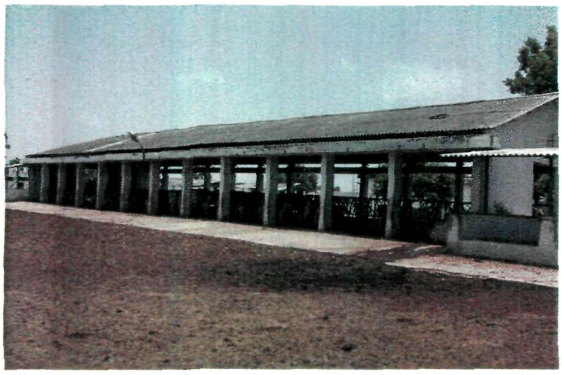


Plate V Cow shed at HF
Open high roof without trees

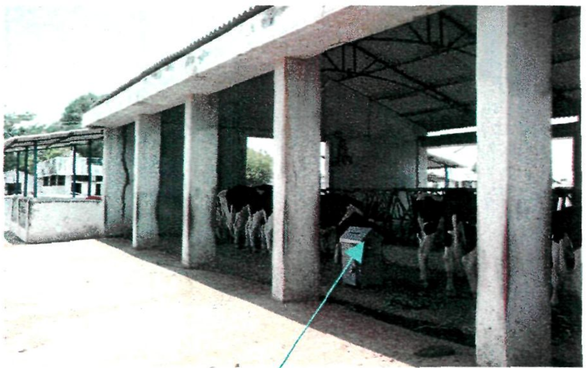


Plate VI HVAS in operation in cow shed at HF

Plate VII Calf pen at IF

Plate VIII Calf pen at LRS

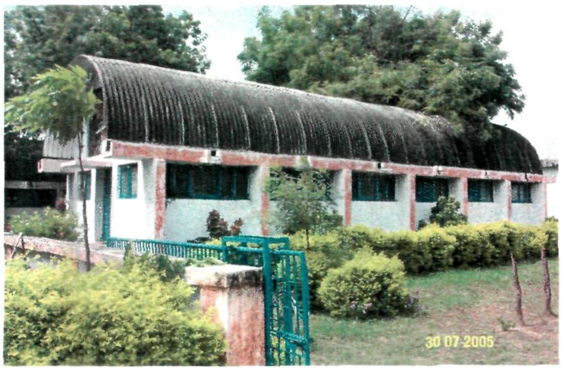


Plate IX Calf pen at HF farm external and internal view

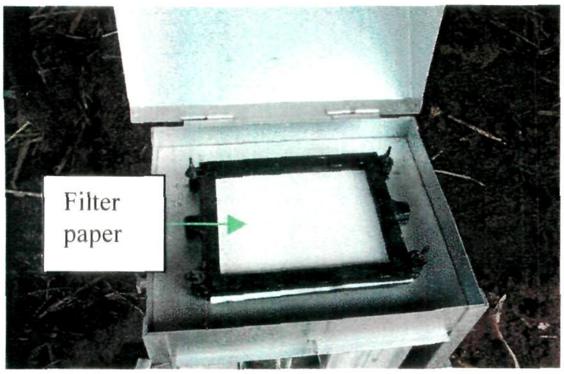


Plate X HVAS under operation

Plate XI Digital Thermo-hygro meter

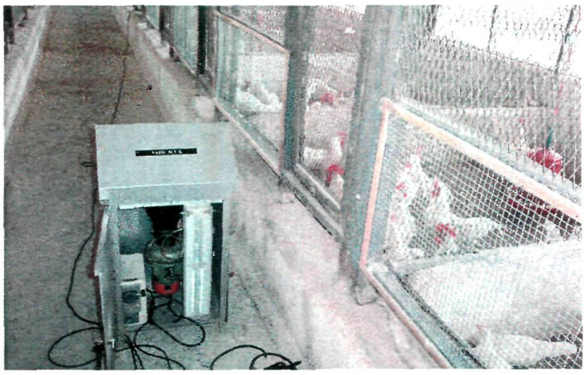


Plate XII Outside and inside view of deep litter house at poultry complex

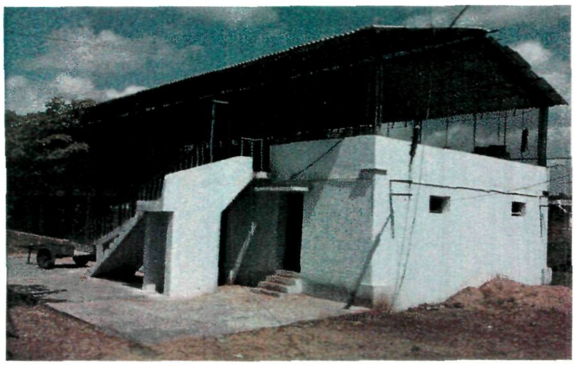


Plate XIII Raised platform cage house external & internal view

(2) Cage Layer House with Raised Plat-form (CLH+RP) as shown in plate XIII. It is in East-West direction, asbestos sheet roof, cement concrete floor and three meters raised above the ground level. Trees are present around the house.

3.1.2 Seasons

a) Summer: Hot dry (May and June, 2003)

b) Monsoon season: Rainy-wet (August, 2003)

c) Hot humid (September, 2003)

d) Mild Winter season: Cold dry (November, 2003).

3.1.3 Instruments used in the study

(a) Digital thermo-hygrometer (J411TH) for temperature & relative humidity (Plate XI), (b) digital anemometer (Lutron-AM4201) for wind velocity, (c) digital lux meter (Masteck-ms6610) for light intensity and (d) Yash High Volume Air Sampler (Yash Engineering, Vadodara) for dust concentration.

3.2 Observation to be recorded

3.2.1 Meteorological observation

Ambient temperature (^{0}C), relative humidity (%), air velocity (kms/ hr) and light intensity (lux) were recorded at 7.30 hrs and 14.30 hrs both inside and outside the houses.

3.2.2 Estimation of THI and THIS

Observations from meteorological observatory for 52 weeks of 2003 were collected from Department of Meteorology, B. A. College of Agriculture, AAU, Anand for estimation of THI and THIS at 2.30 pm.

Temperature humidity index was calculated using following formulae

$$THI=Td- (0.55-0.55RH) (Td-58)$$

And Temperature Humidity Sunshine Index

$$THSI = \frac{0.75\ 'S'\ (THI\ at 3.00\ pm) + (24 - 0.75\ 'S' \times THI\ at\ 9.00\ am)}{24}$$

Where, Td in °F, RH in decimal and 'S' is sunshine hrs. (Oliver *et al.,* 1979)

3.2.3 Dust concentration in the air (suspended particles) of animal and poultry sheds

Dust concentration (suspended particles in the air) was estimated by Yash High Volume Air Sampler. The average volume of air passed through YHVAS was calculated and the dust concentration in the animal and poultry shed was calculated by difference of final weight and initial weight of filter paper on microbalance.

The filter papers used were Glass Microfibre Filters GF/A Cat No. 1820 866 Whatman International Ltd., England. The filter papers were packed in individual polypropylene bags. These bags with were sterilized in autoclave (121.5 ^{0}C and 15 lbs) for 20 minutes. The sterilized bags were opened only at the site where it was directly placed in position in YHVAS machine (as shown in plate X) with the help of sterilized forceps. The YHVAS run for three hours in animal and poultry sheds at 10:00 hours to 13:00 hours. The filter paper were removed after 3 hours and filled in the same polypropylene bags and weighed in the laboratory. The difference between final and initial weights was taken as dust concentration.

3.2.4 Microbial colony count

After being weighed for dust concentration the filter papers were then transferred into microbiology laboratory where one filter paper was cut with sterilized scissors in half inch pieces in the germ free environment. Filter paper pieces were dissolved in 100 ml distilled sterilized water for 30 minutes. The dilution rate was one in 10,000 ml. One ml is taken for plating with nutrient agar. It was incubated for 48 hours in incubator at

37^0C temperature. After 48 hours microbial colonies were counted as per standard procedure. Total bacterial and fungal colony were taken as microbial colony count (*cfu*/plate).

3.2.5 Housing index

The housing index was calculated for rural farmers' animal houses and an organized farm on the basis of 28-scale point is given in appendix-II Patel (2004).

3.2.6 Experimental Design

The data, thus obtained from the experiment were subjected to Randomized Block Design for statistical analysis as per Snedecor and Cochran (1994).

Sevi *et al.* (2003) carried out an experiment to study the effect of litter management on airborne particulates in sheep houses and on the yield and quality of ewe milk. The treatment viz. (1) fortnightly application of 0.5 Kg granular bentonite per $m^2$of litter (BENT), (2) Litter renewal after first 4 weeks of the trial, without bentonite treatment (REN), (3) fortnightly treatment with bentonite + litter renewal (BENT+ REN) and (4) neither bentonite treatment nor litter renewal (CTRL). The concentrations of airborne microorganisms and dust in the experimental rooms were measured twice weekly. They found CTRL treatment had higher ($p< 0.01$) concentration of total dust (0.78 0.06 mg/m^3) and respirable dusts (0.53 0.04 mg/m^3) than the three other treatments (0.36 0.06 mg/m^3, 0.49 0.06 mg/m^3, 0.32 0.06 mg/-m^3) as well as in greater amounts of total bacteria (4.61 0.04log_{10} of cfu/$m^{3)}$ and of yeast/molds 2.97 0.13 log_{10} of cfu/m^3) than the BENT (bacteria 4.4 0.06log10 of cfu/m^3 , of yeast /molds 2.48 0.013 log_{10} of cfu/m^3) and BENT + REN treatments (bacteria 4.38 0.04log_{10} of cfu/m^3 ,yeast/ mould count 2.38 0.013 log_{10} of cfu/m^3).

RESULTS & DISCUSSION

CHAPTER IV

RESULTS & DISCUSSION

Results of the study are discussed under the following headings.

4.1 Status of Micro and Macroclimate at cow houses

4.2 Status of Micro and Macroclimate at calf pens

4.3 Status of Micro and Macroclimate at poultry houses

4.4 Dust concentration in the air of cow & poultry houses and calf pens

4.5 Major microbial colony count and

4.6 Housing index of animal and poultry houses

4.1 Status of Micro and Macroclimate at Cow Houses

4.1.1 Micro and Macro Temperature

The mean inside and outside cowshed temperature (°C) irrespective of farms at 7.30 am during different seasons (S_1 – Summer-hot dry, S_2 – Monsoon-rainy wet, S_3– Hot-humid and S_4– Winter cold-dry) at cow houses are presented in Table 4.1A and depicted in Fig 1. Inside average temperature was 30.70 ± 0.26, 25.27 ± 0.25, 27.01 ± 0.24 and 21.81 ± 0.59°C whereas the outside mean temperatures was 30.04 ± 0.31, 25.95 ± 0.27, 27.01 ± 0.20 and 20.47 ± 0.58°C during S_1, S_2, S_3 and S_4 season, respectively. The mean difference (outside minus inside the cowshed) was 1.44, -0.32, -0.68 and -1.34°C during S_1, S_2, S_3 and S_4 season, respectively. The outside temperature was more than inside during S_1 season; however, inside temperature was more than outside during S_2, S_3 and S_4 seasons. Analysis of variance showed significant ($P < 0.05$) difference among the difference mean (outside minus inside the shed) during S_1, S_2, S_3 and S_4 seasons.

Table 4.1A Mean micro and macroclimatic variables of cowshed during different seasons at 7.30 am

Met. Obs	Seasons											
	S1			S2			S3			S4		
	In	**Out**	**Diff.**	**In**	**Out**	**Diff.**	**In**	**Out**	**Diff.**	**In**	**Out**	**Diff.**
Temp (°C)	30.70 ± 0.26	32.04 ± 0.31	1.34	25.27 ± 0.25	24.95 ± 0.27	-0.32	27.69 ± 0.24	27.01 ± 0.20	-0.68	21.81± 0.59	20.47± 0.58	-1.34
RH (%)	63.81 ± 3.18	62.32 ± 3.15	-1.49	95.51 ± 0.75	94.27 ± 0.52	-1.24	75.09 ± 1.48	79.99 ± 1.08	4.90	46.26 ± 3.63	50.24 ± 3.55	3.97
WV (kms/hr)	0.79 ± 0.11	1.86 ± 0.33	1.07	0.25± 0.05	0.88 ± 0.16	0.63	0.096 ± 0.02	0.36 ± 0.03	0.26	0.05 ± 0.02	0.135 ± 0.04	0.085
LI (Lux)	1164 ± 113.45	10671 ± 107.12	9506	440 ± 75.86	7330 ± 80.13	6890	553.81± 71.86	4992 ± 60.80	4438	420.55 ± 56.66	2072 ± 20.36	1651
THI	81.53 ± 0.63	83.2 ± 0.74		73.38 ± 0.43	74.53 ± 0.46		78.58 ± 0.41	78.13 ± 0.36		67.65 ± 1.07	66.15 ± 10.01	

Table 4.1B Mean micro and macroclimatic variables of cowshed during different seasons at 2.30 pm

Met. Obs.	Season											
	S1			S2			S3			S4		
	In	**Out**	**Diff.**	**In**	**Out**	**Diff.**	**In**	**Out**	**Diff.**	**In**	**Out**	**Diff.**
Temp (°C)	38.92 ± 0.26	42.49 ± 0.40	3.57	28.76 ± 0.42	29.51 ± 0.47	0.75	33.27 ± 0.18	37.28 ± 0.39	4.01	32.23 ± 0.34	36.78 ± 0.68	4.55
RH (%)	42.28 ± 1.89	38.71± 1.59	-3.57	91.43 ± 1.15	92.49 ± 1.08	1.06	67.88 ± 1.27	64.88 ± 1.45	-3.00	38.74 ± 1.88	34.07 ± 1.94	-4.67
WV kms/hr	1.09 ± 0.33	2.22 ± 0.47	1.13	0.45 ± 0.05	1.23 ± 0.15	0.78	0.12 ± 0.02	0.61 ± 0.08	0.49	0.22 ± 0.05	0.46 ± 0.08	0.24
LI (Lux)	4428 ± 60	60518 ± 38	5608 9	5600 ± 59	33800 ± 70	32591	3907 ± 63	49809 ± 21	45901	2390 ± 18	42759 ± 18	40367
THI	88.16 ± 0.42	91.40 ± 0.68		82.48± 0.63	83.92 ± 0.76		85.83 ± 0.34	91.15 ± 0.69		77.20± 0.52	81.45± 0.90	

ANOVA table for cow sheds at 7.30 am

Sr. No.	Source	DF	Mean Squares			
			Temp	RH	WV	LI
1.	Replication	3	0.818	9.714	0.149	37850518
2.	Season	3	2.177*	18.331*	3.703*	187319747*
3.	Treatment (houses)	2	0.864	0.609	0.095	62981283*
4.	SXH	6	0.607	4.106	0.074	103498948
5.	Error	33	0.293	3.062	0.141	699311918

*(P<0.05)

Difference mean temperature of cow shed at 7.30 am

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
1.44^{b}	0.65^{a}	0.75^{a}	1.42^{b}	*	0.451

B) Animal houses (treatments)

IF	LRS	HF	Test	CD
1.011	1.32	0.87	NS	-

C) Season X Treatment

	IF	LRS	HF	Test	CD
S_1	1.06	2.30	0.97	NS	-
S_2	0.78	0.68	0.47	NS	-
S_3	0.54	0.84	0.85	NS	-
S_4	1.011	1.45	1.15	NS	-

Difference mean relative humidity (%) of cowshed 7.30 am

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
1.90^{a}	1.41^{a}	3.97^{b}	3.53^{b}	*	1.459

B) Animal houses

IF	LRS	HF	Test	CD
2.62	2.93	2.56	NS	-

C) Season X Treatment (house)

	IF	LRS	HF	Test	CD
S_1	2.83	1.54	1.33	NS	-
S_2	1.75	1.41	1.08	NS	-
S_3	2.42	5.50	3.99	NS	-
S_4	3.50	3.25	3.83	NS	-

Difference mean wind velocity (kms/hr) of cowshed at 7.30 am

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
1.35^c	0.54^{ab}	0.27^a	0.10^a	*	0.313

B) Treatments

IF	LRS	HF	Test	CD
0.6531	0.5175	0.54	NS	-

C) Season X Treatment

	IF	LRS	HF	Test	CD
S_1	1.63	1.18	1.25	NS	-
S_2	0.48	0.60	0.53	NS	-
S_3	0.40	0.15	0.27	NS	-
S_4	0.10	0.11	0.09	NS	-

Difference mean light intensity (lux) of cowshed at 7.30 am

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
10793^d	6561^b	8712^c	1583^a	*	1290

B) Treatments (houses)

IF	LRS	HF	Test	CD
9172	6110	5456	*	2830

C) Season X Treatment

	IF	LRS	HF	Test	CD
S_1	8933	13443	10005	NS	-
S_2	6422	6600	6662	NS	-
S_3	19525	3022	3591	NS	-
S_4	1809	1375	1565	NS	-

ANOVA Table of differences mean of cow sheds at 2.30 pm

Sr. No.	Source	DF	Mean Squares			
			Temp	RH	WV	LI
1.	Replication	3	2.510	14.367	0.340	492020
2.	Season	3	36.242*	20.543*	3.043*	15970209*
3.	Treatment (houses)	2	0.110	9.105	0.069	24787402*
4.	SXT (H)	6	0.943	8.785	0.075	12479510
5.	Error	33	0.874	2.775	0.149	5443911

*(P<0.05)

Difference mean temperature of cow shed at 2.30 pm

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
3.72^b	0.81^a	3.99^b	4.79^c	*	0.779

B) Treatments (houses)

IF	LRS	HF	Test	CD
3.42	3.3	3.26	NS	-

C) Season X Treatment

	IF	LRS	HF	Test	CD
S_1	4.19	3.51	3.46	NS	-
S_2	0.82	0.69	0.92	NS	-
S_3	3.42	4.62	3.92	NS	-
S_4	5.24	4.38	4.73	NS	-

Difference mean relative humidity (%) of cow shed at 2.30 pm

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
4.25^b	1.55^a	3.72^b	4.36^b	*	1.389

B) Treatments (houses)

IF	LRS	HF	Test	CD
4.27	2.77	3.37	-	-

C) Season X Treatment

	IF	LRS	HF	Test	CD
S_1	6.34	2.08	4.34	NS	-
S_2	3.66	0.42	0.58	NS	-
S_3	2.58	4.33	4.25	NS	-
S_4	4.50	4.25	4.33	NS	-

Difference mean wind velocity of cow shed at 2.30 p.m.

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
1.42^c	0.72^{ab}	0.48^a	0.26^a	*	0.322

B) Treatments (houses)

IF	LRS	HF	Test	CD
0.67	0.80	0.69	NS	-

C) Season X Treatment

	IF	LRS	HF	Test	CD
S_1	1.16	1.66	1.45	NS	-
S_2	0.70	0.72	0.71	NS	-
S_3	0.52	0.52	0.42	NS	-
S_4	0.32	0.27	0.18	NS	-

Difference mean light intensity of cow shed 2.30 pm.

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
6453^b	3870^a	4533^a	4226^a	*	0.779

B) Treatments (houses)

IF	LRS	HF	Test	CD
3746^b	4410^a	6156^b	*	1084

C) Season X Treatment

	IF	LRS	HF		CD
S_1	5637	6443	7278	NS	-
S_2	1730	1660	8219	NS	-
S_3	3904	5254	4440	NS	-
S_4	3712	4281	4685	NS	-

Fig 1 Temperature (°C) in cow shed

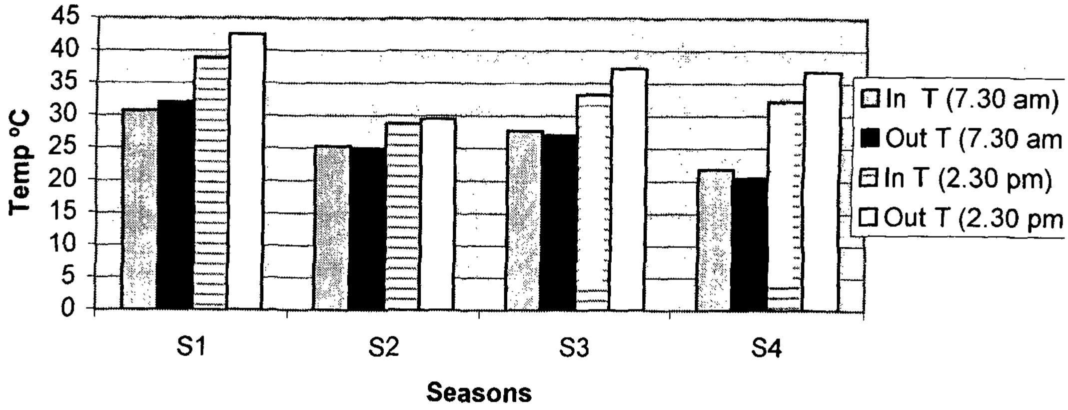


Fig 2 Temperature (°C) in calf pen

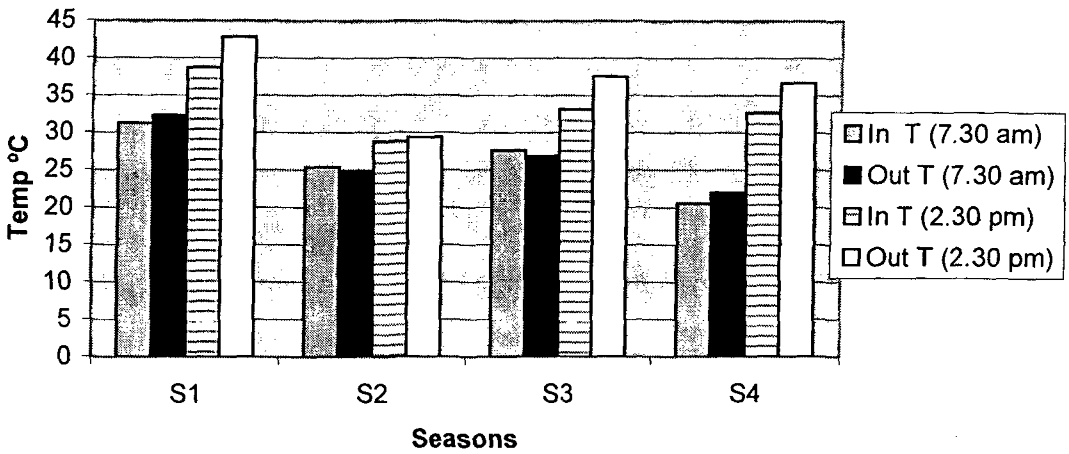


Fig 3 Temperature (°C) in poultry house

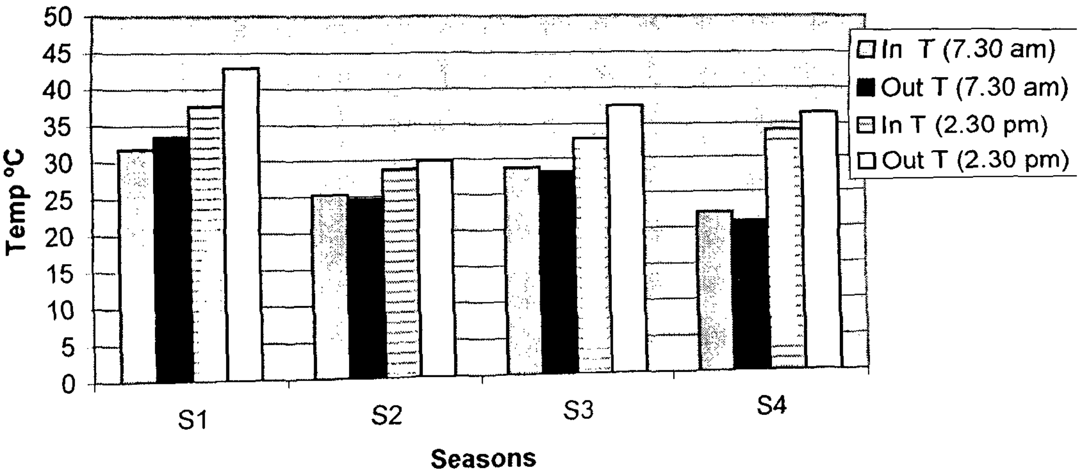


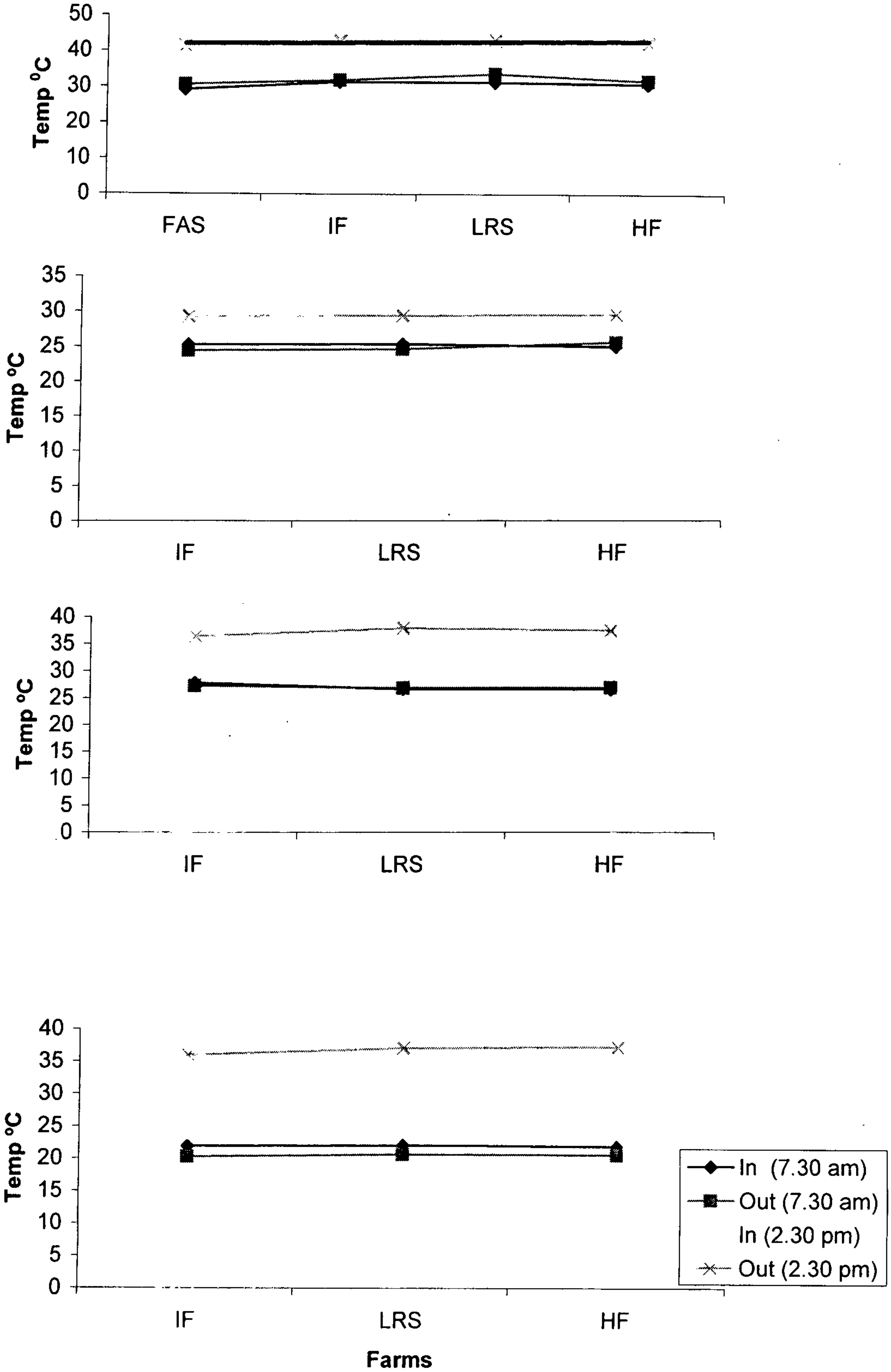
Table 4.2A Micro-macro temperature (°C) of cow shed on different farms at 7.30 am

Season/ Farm	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
FAS	29.20 ± 0.27	30.67 ± 0.42	1.47	-	-	-	-	-	-	-	-	-
IF	31.38 ± 0.32	31.94 ± 0.29	0.62	25.30 ± 0.26	24.42 ± 0.28	-0.88	27.80 ± 0.26	27.27 ± 0.26	-0.58	21.90 ± 0.58	20.27 ± 0.55	-1.63
LRS	31.34 ± 0.19	33.73 ± 0.42	2.39	25.43 ± 0.24	24.72 ± 0.26	-0.71	27.65 ± 0.15	26.86 ± 0.15	-0.79	22.02 ± 0.58	20.621 ± 0.58	-1.4
HF	30.88 ± 0.20	31.81 ± 0.21	0.93	25.09 ± 0.25	25.71 ± 0.27	0.62	27.62 ± 0.30	26.90 ± 0.20	-0.72	21.52 ± 0.62	20.52 ± 0.61	-1.0
Avg.	30.70 ± 0.26	32.04 ± 0.31	1.34	25.27 ± 0.25	24.95 ± 0.27	-0.32	27.69 ± 0.24	27.01 ± 0.20	-0.68	21.81 ± 0.59	20.47 ± 0.58	-1.34

Table 4.2B Micro-macro temperature (°C) of cow shed at 2.30 pm.

Season/ Farm	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
FAS	38.44 ± 0.42	41.55 ± 0.48	3.11	-	-	-	-	-	-	-	-	-
IF	38.73 ± 0.16	42.90 ± 0.27	4.17	28.71 ± 0.40	29.35 ± 0.49	0.64	32.94 ± 0.19	36.44 ± 0.40	3.50	31.17 ± 0.35	36.00 ± 0.72	44.83
LRS	39.26 ± 0.20	43.10 ± 0.21	3.84	28.81 ± 0.40	29.46 ± 0.48	0.65	33.00 ± 0.16	37.92 ± 0.36	4.62	32.80 ± 0.37	37.08 ± 0.71	4.28
HF	39.25 ± 0.25	42.44 ± 0.23	3.19	28.77 ± 0.45	29.71 ± 0.45	0.94	33.56 ± 0.21	37.47 ± 0.41	3.91	32.72 ± 0.32	37.27 ± 0.63	4.55
Avg.	38.92 ± 0.26	42.49 ± 0.40	3.57	28.76 ± 0.42	29.51 ± 0.47	0.75	33.27 ± 0.18	37.28 ± 0.39	4.01	32.23 ± 0.34	36.78 ± 0.68	4.55

Fig 19 Temperature in cow (°C) shed during S1, S2, S3 & S4 seasons



The mean inside and outside temperature at 7.30 am at cowshed of different farms during different seasons were recorded and are presented in Table 4.2A and depicted in Fig 19.

The average temperature recorded during summer hot-dry (S_1) season inside the cowshed was 29.20 ± 0.27, 31.38 ± 0.32, 31.34 ± 0.19 and 31.81 ± 0.21°C whereas outside the shed was 30.67 ± 0.42, 31.94 ± 0.29, 33.73 ± 0.42°C and 31.81 ± 0.21°C at FAS, IF, LRS and HF farm respectively. The differences (outside minus inside) were 1.47, 0.62, 2.39 and 0.93°C at FAS, IF, LRS and HF farm, respectively. The difference was less at IF & HF farm than FAS & LRS cowshed. However, the analysis of variance showed non-significant difference among cowsheds of IF, LRS and HF farms. Inside temperature was lower than outside. Singh *et al.* (1977) also observed higher mean daily minimum temperature inside the sheds (open shed 22.11, closed shed 27.52 °C), than at macro-environment (21.51°C). Karki (1981) observed daily minimum to be lower in loose house than inside the shed. Yadav (1981) found mean minimum temperature was significantly higher in conventional barn than open and Singh (1982) observed minimum temperature marginally lower in loose house than the shed while Bempong and Gupta (1989) observed same minimum temperature (27.02 °C) for both shade and loose house.

The mean temperature recorded during monsoon rainy wet (S_2) season inside the cowshed was higher 25.30 ± 0.26, 25.43 ± 0.24 & 25.09 ± 0.25 °C whereas outside the shed was 24.42 ± 0.28, 24.72 ± 0.26 & 25.71 ± 0.27°C and the difference (outside minus inside) was -0.88, -0.71 & 0.62 °C at cowshed on IF, LRS and HF farm, respectively. The cow shed of IF had higher inside temperature than outside, however, LRS & HF cow sheds had higher outside temperature than inside the shed. Higher inside temperature was more comfortable in rainy season rather than lower temperature. However, the analysis of variance showed non-significant differences for cowsheds of IF, LRS and HF farms.

The mean temperature recorded inside the cowshed during hot humid (S_3) season was 27.80 ± 0.26, 27.65 ± 0.15 and 27.62 ± 0.30°C whereas outside 27.27 ± 0.26, 26.86 ± 0.15 and 26.90 ± 0.20°C of cowshed on IF, LRS & HF farm, respectively. The inside temperature was higher on all farms by 0.68, 0.79 and 0.72°C at IF, LRS and HF, respectively. However, non-significant ($P < 0.05$) differences were observed among the difference mean (outside minus inside) of cow shed on IF, LRS and HF farms. Singh *et al.* (1977) observed mean daily minimum temperature was 24.95, 25.45, 29.04 °C at macro-environment, open shed and closed shed, respectively. Similarly Singh (1982) recorded minimum temperature to be 25.80, 20.01, 18.00 and 8.80 °C during hot-dry, hot-humid, mild cold and severs cold season, respectively and Karki (1981) also observed higher minimum temperature in hot humid season than the hot dry season in all types animal houses.

The mean temperature inside the cowshed during mild winter cold-dry (S_4) season was recorded to be 21.90 ± 0.58, 22.02 ± 0.58 and 21.52 ± 0.62°C and outside 20.27 ± 0.55, 20.62 ± 0.58 and 20.52 ± 0.61°C. As a seasonal trend, the outside temperature was lower by 1.63, 1.4 and 1.0°C at cowshed on all IF, LRS and HF farms, respectively. It is desirable to be warmer inside cowshed during morning hours of cold dry season. At IF and LRS sheds were more warmer, a desirable character than on HF farm. It may be due to type of cow shed on HF farm i.e. central shed house. However, the differences among the difference mean of cow shed on IF, LRS and HF farms were at par.

Mean inside and outside cow shed temperature during hottest period of the day i.e at 2.30 pm during different seasons irrespective of farms are presented in

Table 4.1B and depicted in Fig 1. Inside the cowshed mean temperature was 38.92 ± 0.26, 28.76 ± 0.42, 33.27 ± 0.18 and 32.23 ± 0.34 °C whereas outside the cow shed was 42.49 ± 0.40, 29.76 ± 0.47, 37.28 ± 0.39 and 36.76 ± 0.68 °C during S_1, S_2, S_3 and S_4 season, respectively. The mean difference (outside minus inside the cowshed) was 3.57, 0.75, 4.01 and 4.55°C during S_1, S_2, S_3 and S_4 season, respectively. Highest and lowest temperatures were recorded during hot dry and rainy wet season, respectively. Less difference (outside minus inside the cowshed) was observed during S_2. It may be due to rain and high humidity during this season, however, more difference was recorded during S_1, S_3 and S_4 seasons. Season conflict was significant and it is bond to be. During hot dry season the inside temperature was lower by 3.57 °C than the outside intense temperature of 42.49 °C, however, inside temperature of 38.92 °C was also higher and uncomfortable to cows. One should add cooling system on shed like ceiling fans, showering of water or plantation of trees.

The mean temperature at 2.30 pm inside and outside cowsheds on different farms during different seasons are presented in Table 4.2B and depicted in Fig 19. The average temperature during summer hot dry (S_1) season inside the cowshed was recorded to be 38.44 ± 0.42, 38.73 ± 0.16, 39.26 ± 0.28 and 39.25 ± 0.25°C whereas the outside 41.55 ± 0.48, 42.90 ± 0.27, 43.10 ± 0.21 and 42.44 ± 0.23 °C at FAS, IF, LRS & HF farm, respectively. The temperature difference (outside minus inside) was 3.11, 4.7, 3.84 and 5.19 at FAS, IF, LRS and HF farm, respectively. Average inside shed temperature was recorded higher at LRS and HF than FAS and IF farm. In spite of higher difference of 5.19 °C, inside shed temperature of 39.25 °C was observed at HF farm was uncomfortable and for comfort cows used to come out under trees. It is suggested to establish a cooling system either ceiling fans or showering or plantation of trees around the cowshed. The 39°C temperature adversely affect the feed consumption and digestibility in turn milk production and reproduction of animals. The mean temperatures (outside minus inside) of cowsheds on IF, LRS and HF farms were at par.

Sastry *et al.* (1973) suggested that microclimate in the loose house could be improved by additional shelter in the open area of the loose house along with the showering of animals housed in them. Singh *et al.* (1977) observed mean daily maximum temperature of 39.07, 39.59 and 36.81°C in hot dry season at macro-environment, open shed and closed shed respectively. Thomas *et al.*, (1978) reported maximum temperature inside the barns was similar to that in the open in all seasons, but it was invariably higher in the loose house by about 2°C in all seasons. Ludri, (1979) investigated that hot and humid climatic conditions were main causes of drop in milk yield at NDRI, Karnal. Fuquay *et al.* (1979) found roof sprinkling + insulation, as an effective method of reducing the ambient and black globe (radiation) temperature within livestock housing. For reviewing heat stress effects on animal production, one must consider the entire scope of factors affecting thermoregulation in the body of animals. Karki (1981) found the maximum temperature to be marginally higher in the loose house both during hot dry and hot humid periods of summer. The maximum temperature was higher (3 to 5°C) during hot-dry period in all the three houses viz. (i) loose housing, (ii) housing in roofed and walled shed and (iii) housing in roofed and walled shed during day and in the open during night. Singh (1982) recorded daily maximum temperature to be 41.05°C in. loose house during hot-dry season. Yadav (1982) observed that mean maximum temperature was significantly ($P < 0.05$) higher in loose house (43.13 °C), than conventional barn (40.60 °C) and in the open (40.18 °C). Bempong and Gupta (1989) reported that daily mean maximum temperature was 38.52 and 39.97°C in shed and loose house of crossbred cows during summer, respectively. Patel *et al.* (1995) inferred that minimum temperature in microclimate was significantly ($P < 0.01$) affected by housing system, while maximum temperature, relative humidity and THI did not significantly differ under different housing system. Sharma and Singh (2002) reported that maximum temperature (evening) was significantly ($P < 0.05$) higher in loose housing (43.25°C) compared to both loose housing with central shed (35.67°C) and closed house (37.75 °C) and inferred that in April, May and June the discomfort was relatively less in loose housing and loose house with central shed than the closed house. Singh *et al.* (2003) reported that the mean maximum temperature was significantly lower ($P < 0.01$) in loose house + aluminum foils pasted roof T4 (36.72°C) and thatch roof T3 (36.26°C) as compared to loose house T1 (39.90 °C) and loose house + white painted roof T2 38.40°C.

The mean temperature inside the cowshed during monsoon rainy wet (S_2) season was 28.71 ± 0.40, 28.81 ± 0.40 and 28.77 ± 0.45°C whereas outside 29.35 ± 0.49, 29.46 ± 0.48 and 29.71 ± 0.45°C on IF, LRS and HF farm, respectively. The temperature difference (outside minus inside) at cowshed was 0.64, 0.65 and 0.94°C on IF, LRS and HF farm, respectively. The cowsheds reasonably maintained the inside temperature. Mean temperature of cowshed on IF, LRS and HF farms were at par.

The mean temperature inside the cowshed during hot humid S_3 season was 32.94 ± 0.19, 33.00 ± 0.16 and 33.56 ± 0.21°C whereas outside the shed was 36.44 ± 0.40, 37.92 ± 0.36 and 37.97 ± 0.41°C on IF, LRS and HF farm, respectively. The temperature difference (outside minus inside the shed) was 3.50, 4.62 and 3.91°C IF, LRS and HF farms, respectively. Thus sheds had provided more comfort during hot humid season. However, the analysis of variance showed non-significant ($P < 0.05$)

difference for IF, LRS and HF farms. Singh (1977) reported mean daily maximum temperature during hot humid season 34.94, 34.52 and 34.24°C at macro-environment, open shed and closed shed, respectively. Ludri (1979) observed ambient temperature in hot humid climatic conditions of 30.5 °C in thatched without ceiling fan shed and 30.2 °C in shed with ceiling fans. Karki (1981) found the maximum temperature to be marginally higher in the loose house during hot humid periods.

The mean temperature recorded inside the cowshed during winter cold dry S_4 season was 31.17 ± 0.35, 32.80 ± 0.37 and 32.72 ± 0.32°C and outside the cowshed was 36.00 ± 0.72, 37.05 ± 0.71 and 37.27 ± 0.63°C and the difference (outside-inside the cowshed) was 4.83, 4.28 and 4.55 on IF, LRS and HF farm, respectively. Average inside and outside temperatures were recorded lower on IF than those on the LRS and HF farm. It may be due to trees surrounding the cow house, lower relative humidity and wind velocity at IF. However, the analysis of variance showed non-significant ($P < 0.05$) difference among the difference (outside minus inside) mean of cowshed on IF, LRS and HF farms. Singh (1977) found the mean maximum temperature of closed shed (21.31°C) was significantly lower ($P < 0.05$) than those of the macroclimate (22.64 °C) in winter season. Mehla (1982) reported that daily maximum temperature was constant in both the houses in winter, though marginally (by 0.40°C) higher in the open than in loose house as well as inside the shed (by 1.76°C).

.2 Micro and Macro Relative Humidity

Mean inside and outside the cow shed relative humidity at 7.30 am irrespective of farms during different seasons (S_1 – Summer-hot dry, S_2 – Monsoon-rainy wet, S_3 – Hot-humid and S_4 – Winter-cold dry) recorded at cow houses are presented in Table 4.1A and depicted in Fig 4. Inside mean relative humidity was 63.81 ± 3.18, 95.51 ± 0.74, 75.09 ± 1.48 and 46.26 ± 0.59 per cent whereas outside

Table 4.3A Micro-macro relative humidity (%) of cow shed on different farms at 7.30 am

Season/ Farm	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
FAS	50.85 ± 2.57	48.15 ± 2.94	-2.7	-	-	-	-	-	-	-	-	-
IF	70.00 ± 3.37	68.53 ± 3.35	-1.47	95.32 ± 0.72	96.40 ± 0.52	1.08	76.85 ± 1.16	79.57 ± 1.02	2.72	46.22 ± 3.64	50.16 ± 3.52	3.94
LRS	67.00 ± 2.34	66.00 ± 2.16	-1.00	95.24 ± 0.75	95.88 ± 0.61	0.64	72.21 ± 1.83	0.35 ± 0.99	8.14	45.78 ± 3.61	50.05 ± 3.51	4.27
HF	67.38 ± 3.60	66.61 ± 3.15	-0.77	95.96 ± 0.74	90.52 ± 0.58	-5.44	76.21 ± 1.46	80.07 ± 1.23	3.86	46.78 ± 3.64	50.5 ± 3.64	3.72
Avg.	63.81 ± 3.18	62.32 ± 3.15	-1.49	95.51 ± 0.74	94.27 ± 0.57	-1.24	75.09 ± 1.48	79.99 ± 3.60	4.90	46.26 ± 3.63	50.24 ± 3.55	3.97

Table 4.3B Micro-macro relative humidity (%) of cow shed on different farms at 2.30 pm

Season/ Farm	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
FAS	41.30 ± 1.60	37.76 ± 1.72	-3.54	-	-	-	-	-	-	-	-	-
IF	45.61 ± 2.07	39.69 ± 1.42	-5.92	91.12 ± 1.12	93.44 ± 0.90	2.32	68.50 ± 1.113	68.07 ± 0.91	-0.43	40.05 ± 2.10	34.61 ± 2.11	-5.39
LRS	41.23 ± 1.99	41.00 ± 1.64	-0.23	90.92 ± 1.11	91.2 ± 1.16	0.28	66.64 ± 1.112	62.28 ± 1.79	-4.36	37.61 ± 1.75	33.38 ± 2.02	-4.23
HF	41.00 ± 0.86	36.38 ± 0.74	-4.62	92.24 ± 1.23	92.84 ± 1.20	0.60	68.50 ± 1.61	64.28 ± 1.65	-4.22	38.55 ± 1.81	34.22 ± 1.70	-4.33
Avg.	42.28 ± 1.89	38.71 ± 1.59	-3.57	91.43 ± 1.15	92.49 ± 1.08	1.06	67.88 ± 1.27	64.88 ± 1.45	-3.00	38.74 ± 1.88	34.07 ± 1.94	-4.67

Fig 4 Relative humidity (%) in cow shed

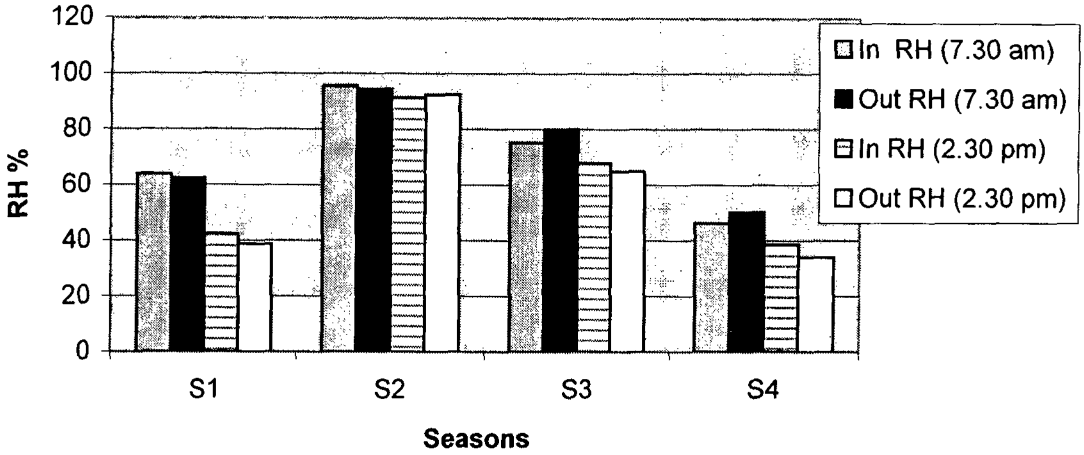


Fig 5 Relative humidity (%) in calf pen

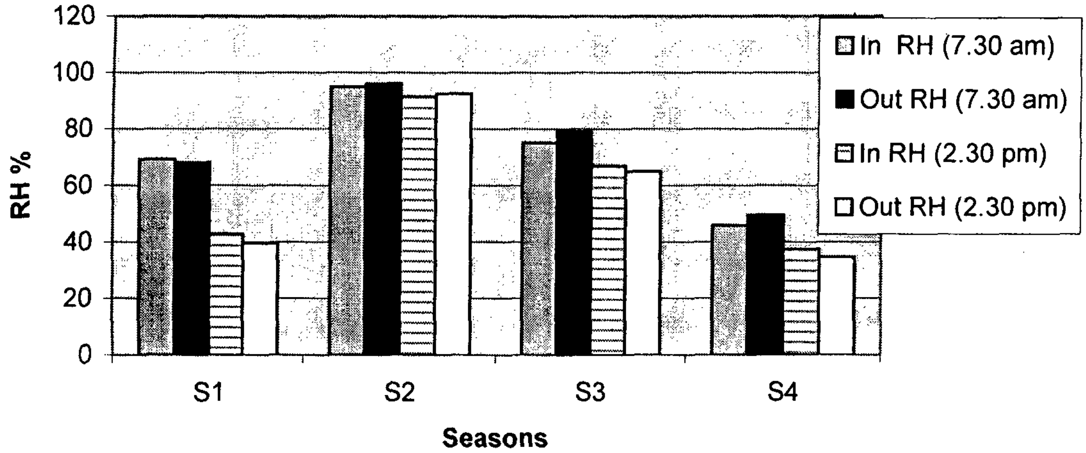


Fig 6 Relative humidity (%) in poultry house

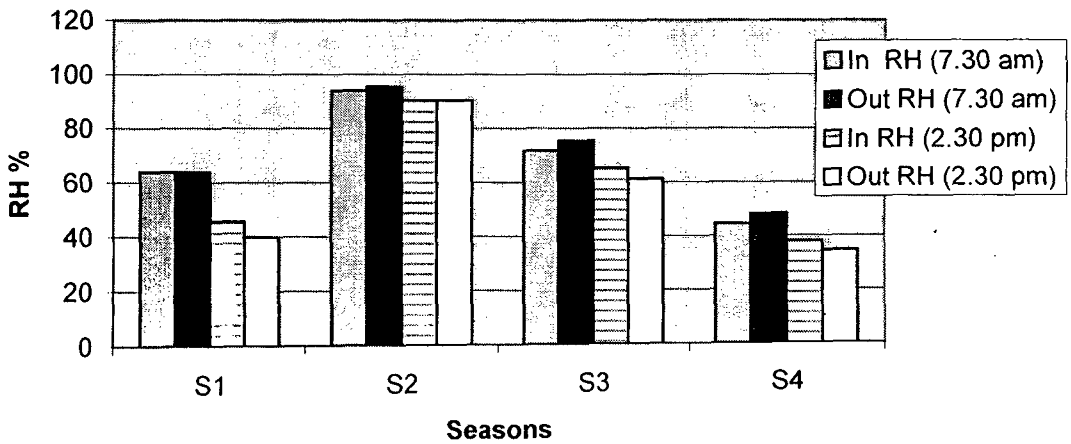
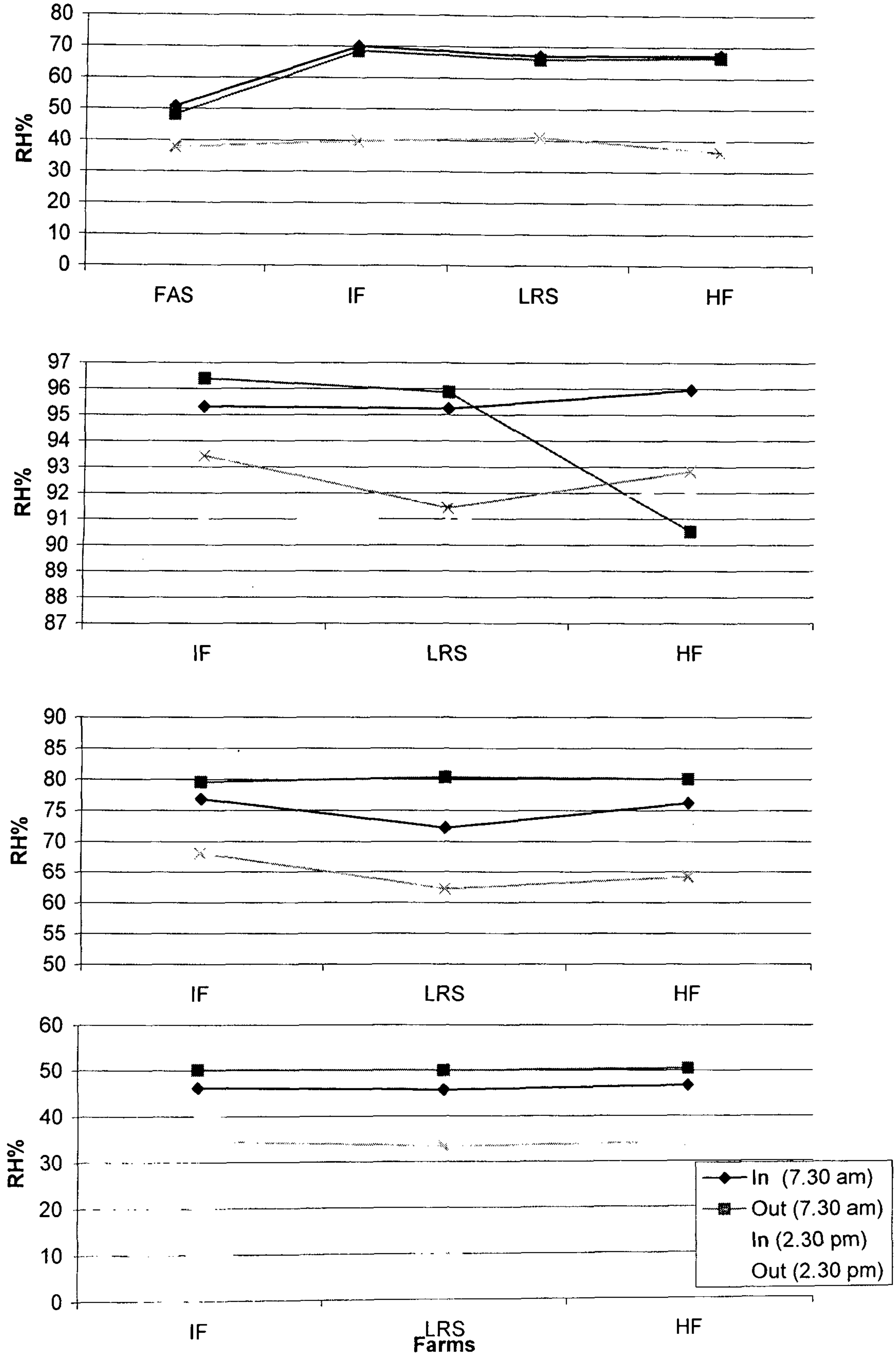


Fig 20 Relative humidity (%) in cow shed during S1, S2, S3 & S4 seasons



the cowshed was 62.32 ± 3.15, 94.27 ± 0.57, 79.09 ± 1.08 and 50.24 ± 3.55 per cent and the difference (outside-inside the cow shed) was -1.49, -1.24, 4.90 and 3.97 per cent during S_1, S_2, S_3 and S_4 season, respectively. As a principle, highest relative humidity percent ($P < 0.05$) both inside & outside the cowshed were observed during monsoon wet (S_2) however, lowest during cold dry (S_4) and hot dry (S_1) seasons. It may be due to seasonal variation in relative humidity.

Sharma and Singh (2002) observed during August evening vapors pressure (40. 00 mmHg) was significantly ($p<0.01$) higher in loose house than those central shed and closed housing. In September, vapor pressure in evening (37. 50 mmHg) was highest in loose housing.

The mean relative humidity were recorded at 7.30 am inside and outside the cowshed during different seasons on different farms are presented in Table 4.3A and depicted in Fig 20.The average inside relative humidity during hot dry (S_1) season was 50.85 ± 2.57, 70.00 ± 3.37, 67.00 ± 2.34 and 67.38 ± 3.60 per cent whereas outside was 48.15 ± 2.94, 68.53 ± 3.35, 66.00 ± 2.16 and 66.61 ± 3.15 per cent and the difference (outside minus inside the cowsheds) was -2.7, -1.4, -1.00 and -0.77 percent at cowshed on FAS, IF, LRS, HF farm, respectively. Lower relative humidity observed outside the shed, might be due to evaporative losses as well as higher temperature than inside shed during the summer season. The average difference (outside minus inside the cowshed) was more at cow shed on FAS than on IF, LRS, HF farm. Among the organized farms lowest difference was observed on HF might be due to the type of house i.e. central shed house. However, the difference was non-significant. Bempong and Gupta (1989) observed relative humidity percent 66.74 and 68.67 at 7:00 hours in shed and loose house, respectively. Singh *et al.* (2003) reported that morning relative humidity was not significantly influenced by different types of roof housing.

The mean relative humidity during monsoon rainy wet (S_2) season inside cowshed was 32 ± 0.72, 95.24 ± 0.75 and 95.96 ± 0.74 per cent whereas outside 96.40 ± 0.52, 95.88 ± 0.61 and 90.52 ± 0.58 per cent and the difference was 1.08, 0.64 and -5.44 per cent at IF, LRS and HF farm, respectively. During this season outside relative humidity observed higher than inside at cowshed on IF and LRS farm, however, inside relative humidity was higher by 5.44 percent than outside at cow shed on HF farm. However, the analysis of variance showed non-significant ($P < 0.05$) difference among the differences.

The mean relative humidity during hot humid (S_3) season inside the cowshed was 76.85 ± 1.16, 72.21 ± 1.83 and 76.21 ± 1.46 per cent whereas outside 79.57 ± 1.02, 80.35 ± 0.99 and 80.07 ± 1.23 per cent and the difference (outside minus inside the cowshed) was 2.72, 8.14 and 3.86 per cent at IF, LRS and HF farm, respectively. Inside RH of cowsheds was lower and more difference was observed on LRS than on IF and HF farm, but showed non-significant ($P < 0.05$) difference.

The mean relative humidity during S_4 season inside the cowshed was 46.22 ± 3.64, 45.78 ± 3.61 and 46.78 ± 3.64 per cent whereas outside the cowshed was 50.16 ± 3.52, 50.05 ± 3.51 and 50.50 ± 3.64 per cent and the difference (outside minus inside) was 3.94, 4.27 and 3.72 per cent at cowshed on IF, LRS, HF farm, respectively and they were at par. They retained comfortable RH during morning hours.

During noon hours at 2.30 pm mean inside and outside the cow shed relative humidity irrespective of farms during different seasons S_1, S_2, S_3 and S_4 were recorded and are presented in Table 4.1B and depicted in Fig 4. Inside mean relative humidity was 42.28 ± 1.89, 91.43 ±1.15, 67.88 ± 1.27 and 38.74 ± 1.88 per cent whereas outside the cowshed was 38.71 ±1.59, 92.49 ± 1.08, 64.88 ± 1.45 and 34.07 ± 1.94 per cent led to a difference (outside minus inside) of -3.57, 1.06, -3.00 and -4.57 per cent during S_1, S_2, S_3 and S_4 season, respectively. Highest and lowest RH recorded during rainy wet and cold dry season, respectively. As usual RH was more during hot humid than hot dry season. During hot humid season high RH (67.88%) coupled with high temperature (33.27 °C) and lower air movement may exert more stress than hot dry season in which temperature may be high but low RH and air movement also observed more. The analysis of variance showed significant ($P < 0.05$) difference among the difference (outside minus inside) mean during S_1, S_2, S_3 and S_4 seasons. The RH level was observed higher in the morning (7.30 am) than the afternoon (2.30 pm) in all seasons. This might be due to higher temperature, wind velocity during daytime that leads to more vapor loss as well as from drying of floor of shed. RH seasonal differences results matches to the results obtained by Singh (1977), Ludri (1979), Karki (1981), Singh (1982) and Sharma and Singh (2002).

The mean relative humidity was recorded inside and outside of cowshed on different farms at 2.30 pm during different seasons on different farms are presented in Table 4.3B and depicted in Fig 20. The average relative humidity during hot dry (S_1) season inside cowshed was 41.30 ± 1.60, 45.61 ± 2.07, 41.23 ± 1.99 and 41.00 ± 0.86 per cent whereas outside the cowshed was 37.76 ± 1.72, 39.69 ± 2.07, 41.00 ± 1.64 and 36.38 ± 0.74 per cent and the difference (outside minus inside) was -3.54, -5.92, -0.23 and -4.62 per cent on FAS, IF, LRS and HF farm, respectively. Inside RH observed more than outside during this season on all farms. Lowest difference was observed at cow shed on LRS, while the highest, difference (outside minus inside) at cowshed on IF farm. The differences were non-significant ($P < 0.05$). Thomas *et al.* (1978) observed higher relative humidity in the loose than in open, was highest in the barn house. Ludri (1979) observed higher relative humidity in water sprinkled sheds. Fuquey (1979) also reported sprinkling of water in thatch roof sheds increased the relative humidity in the shed. Singh (2003) observed that morning RH was not influenced by the type of roof, however, evening RH was significantly more in without white painted roof than white painted roof as compared to thatch roof and foil pasted roof.

The mean relative humidity during monsoon - rainy wet (S_2) - season inside the cowshed was 91.12 ± 1.12, 90.92 ± 1.11 and 92.24 ± 1.23 per cent whereas outside was 93.44 ± 0.90, 91.2 ± 1.16 and 92.84 ± 1.20 and the difference (outside minus inside) was 2.32, 0.28 and 0.60 per cent at IF, LRS and HF farm, respectively. The RH ranged from 90.92 to 93.4 percent at all farms and showed non-significant ($P < 0.05$) difference among the differences.

The mean relative humidity inside the cowshed during hot humid (S_3) season was recorded to be 68.50 ± 1.11, 66.64 ± 1.11 and 68.50 ± 1.61 per cent whereas outside, 68.07 ± 0.91, 62.28 ± 1.79 and 64.28 ± 1.65 per cent and the differences was -0.43, -4.36 and -4.22 per cent at cowshed on IF, LRS and HF farm, respectively.

Ludri (1979) observed morning relative humidity 90.00 and 89.00 percent in sheds with thatch without ceiling fan and with ceiling fan during hot humid season. Karki (1981) found that maximum temperature and vapor pressure was marginally higher in loose house during hot humid season than the roofed and walled shed. Sharma and Singh (2002) recorded highest vapor pressure in loose house than the closed types of houses in the evening hours. Sagsoz (2003) observed inadequate condition i.e. temperature 21 °C and 85 % RH and concluded that high temperature and relative humidity had significant adverse effect on total milk yield and daily milk yield.

During clod dry (S_4) season at 2.30 pm the mean relative humidity inside the cowshed was 40.05 ± 2.10, 37.61 ± 1.75 and 38.55 ± 1.81 whereas outside 34.61 ± 2.11, 33.38 ± 2.02 and 34.22 ± 1.70 per cent and the differences -5.39, -4.23 and -4.33 percent at IF, LRS and HF farms. The cowshed on IF showed less difference as compared to LRS and HF farms. However, the analysis of variance showed non-significant ($P < 0.05$) difference among the difference (outside minus inside) mean of cow shed on IF, LRS and HF farms.

1.3 Micro and Macro THI

During morning hours 7.30 am and noon hours at 2.30 pm mean THI inside and outside the cow shed irrespective of farms during different seasons S_1, S_2, S_3 and S_4 were recorded and are presented in Table 4.1A & 4.1B and depicted in Fig 7. The THI and THSI calculated from data collected from Meteorology Laboratory are given in Table 4.24.

Table 4.24 THI and THSI from data of Meteorology Laboratory, AAU, Anand.

Season	St. Week	Maxi T °C	Min T °C	THI at 7.30 am	THI at 2.30 pm	THSI
Summer hot dry	21, 22, 23, 24.	39.29	26.59	79.36	87.36	3.19
Monsoon rainy wet	31,32,33,34.	31.83	25.34	77.52	82.39	1.59
Hot humid	36,37,38,39,40	33.48	24.78	75.90	83.21	2.05
Mild Winter	44,45,46, 47.	32.64	24.04	67.96	81.18	3.08

Inside mean THI at 2.30 pm was observed to be 88.16 ± 0.42, 82.48 ± 0.63, 85.83 ± 0.34 & 77.20± 0.52 whereas outside the cowshed was 91.40 ± 0.68, 83.92 ± 0.76, 91.15 ± 0.69 & 81.45± 0 during S_1, S_2, S_3 and S_4 season, respectively. Highest THI observed during hot dry and hot humid seasons, as they are the stressful seasons of the year. Farm wise THI are presented in Table 4.4A & 4.4B. The differences were

Table 4.4A Micro-macro THI of cow shed on different farms at 7. 30 am

Season/ Farm	S_1		S_3		S_3		S_3	
	In	Out	In	Out	In	Out	In	Out
FAS	77.39 ± 0.50	78.91 ± 0.70	-	-	-	-	-	-
IF	83.52 ± 0.82	84.12 ± 0.83	73.50 ± 0.45	75.19 ± 0.48	78.97 ± 0.36	78.49 ± 0.40	67.75 ± 01.04	65.87 ± 0.96
LRS	82.91 ± 0.60	86.24 ± 0.76	73.50 ± 0.41	75.28 ± 0.44	78.15 ± 0.38	77.94 ± 0.29	67.86 ± 01.04	66.32 ± 1.01
HF	82.29 ± 0.61	83.53 ± 0.66	73.15 ± 0.42	75.11 ± 0.46	78.61 ± 0.48	77.97 ± 0.29	678.34 ± 1.09	66.25 ± 1.06
Avg.	81.53 ± 0.63	83.2 ± 0.74	73.38 ± 0.43	74.53 ± 0.46	78.58 ± 0.41	78.13 ± 0.36	67.65 ± 1.07	66.15 ± 10.01

Table 4.4B Micro-macro THI of cow shed on different farms at 2.30 pm

Season/ Farm	S_1		S_2		S_3		S_4	
	In	Out	In	Out	In	Out	In	Out
FAS	87.21 ± 0.50	91.11± 0.65	-	-	-	-	-	-
IF	88.59 ± 0.46	90.08 ± 0.65	82.35 ± 0.61	83.80 ± 0.79	85.53 ± 0.39	90.64 ± 0.62	78.83 ± 0.52	82.94 ± 1.08
LRS	88.62 ± 0.46	92.22 ± 0.38	82.50 ± 0.61	83.63 ± 0.74	85.72 ± 0.29	91.92 ± 0.77	73.55 ± 0.34	77.10 ± 0.62
HF	88.23 ± 0.52	92.22 ± 0.40	82.60 ± 0.67	84.34 ± 0.74	86.43 ± 0.34	91.29 ± 0.77	79.84 ± 0.63	84.32 ± 0.99
Avg.	88.16 ± 0.42	91.40 ± 0.68	82.48 ± 0.63	83.92 ± 0.76	85.83 ± 0.34	91.15 ± 0.69	77.20 ± 0.52	81.45 ± 0.90

Fig 7 THI during hot dry & hot humid season in cow shed

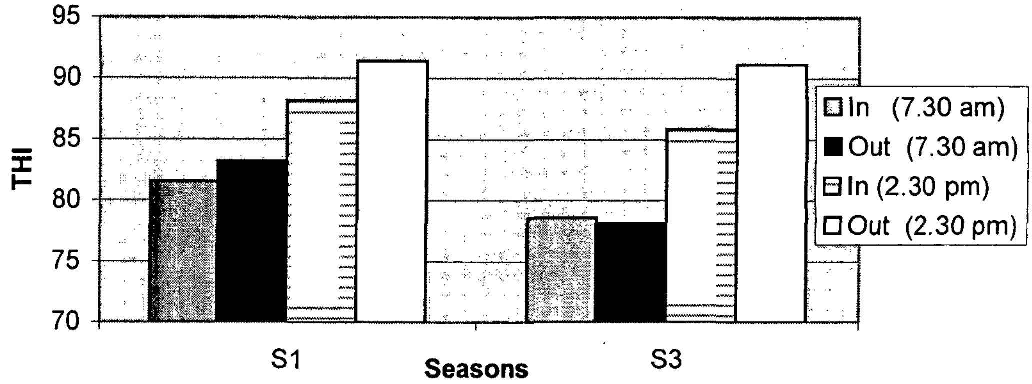


Fig 8 THI during hot dry & hot humid season in calf pen

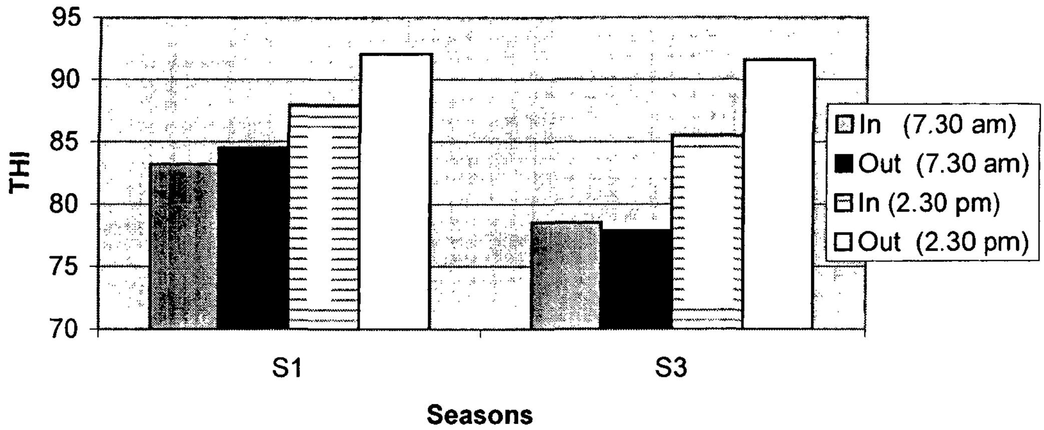
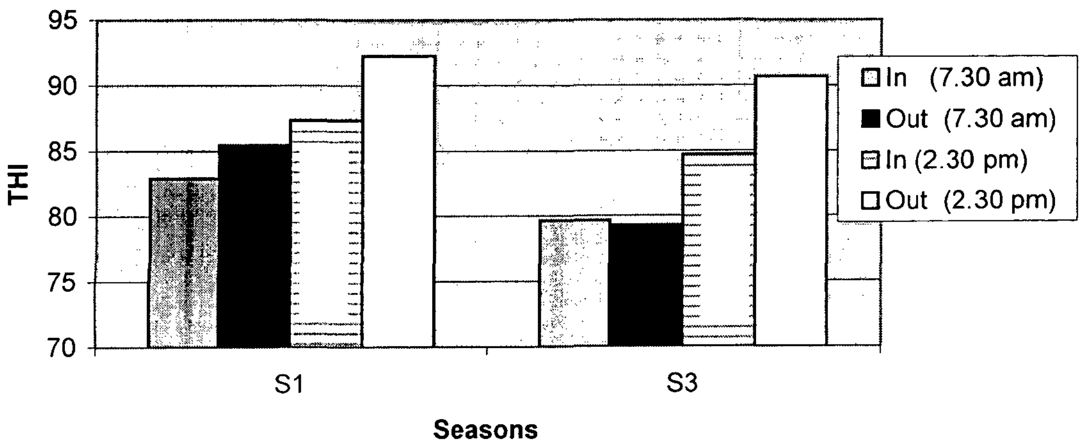


Fig 9 THI during hot dry & hot humid season in poultry house



non significant (81.18 to 87.36 %) at 2:30 pm between the cowshed on FAS, IF, LRS and HF farms.

Singh (1982) observed that mean THI value was consistently higher in loose house than in the shed. The THI values in hot dry and hot humid season at morning and afternoon were 80.70 and 87.15 and 82.45and 86.40, respectively. The differences were not significant in summer seasons, however, the differences in THI in mild-cold and sever cold seasons differed significantly ($P<0.01$) at morning 9 am and afternoon 2 pm. Bempong and Gupta (1989) reported that the values for THI were 80.64, 79.81 at 7:00hours and 86.98 and 87.58 at 14:00 hours in shed and loose house, respectively.7:00 hours and 14:00 hours in shed and loose house, respectively. Patel *et al.* (1995) inferred that minimum temperature in microclimate was significantly ($P < 0.01$) affected by housing system, while maximum temperature, relative humidity and THI did not significantly differ under different housing system viz. (i) reinforced cement concrete shed (RCC), (ii) thach roof shed and (iii) tree shelter.

4.1.4 Micro and Macro Wind Velocity

Mean inside and outside cowshed wind velocity (kms/hr) at 7.30 am during different seasons were recorded irrespective of farms and are presented in Table 4.1A and depicted in Fig 10. The inside wind velocity was 0.79 ± 0.11, 0.25 ± 0.05, 0.10 ± 0.02 and 0.05 ± 0.02 km per hour whereas outside it was 1.86 ± 0.33, 0.88 ± 0.16, 0.36 ± 0.03 and 0.135 ± 0.04 km per hour and the difference (outside minus inside) was 1.07, 0.63, 0.26 and 0.085 km per hour during S_1, S_2, S_3 and S_4 season, respectively. Highest wind velocity was observed during hot dry summer (S_1) and lowest during mild winter cold dry (S_4). It is a desirable sign for both the seasons

Table 4.5A Micro-macro wind velocity (kms/hr) of cow shed on different farms at 7.30 am

Season/ Farm	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
FAS	0.29 ± 0.08	0.85 ± 0.15	0.56	-	-	-	-	-	-	-	-	-
IF	0.86 ± 0.10	2.49 ± 0.31	1.63	0.20 ± 0.04	0.78 ± 0.18	0.58	0.128 ± 0.02	0.52 ± 0.12	0.39 2	0.033 ± 0.016	0.105 ± 0.03	0.072
LRS	0.95 ± 0.14	1.93 ± 0.36	0.98	0.168 ± 0.34	0.79 ± 0.14	0.62	0.05 ± 0.02	0.17 ± 0.05	0.12	0.038 ± 0.01	0.15 ± 0.04	0.112
HF	1.09 ± 035	2.19 ± 0.53	1.1	0.39 ± 0.09	1.06 ± 0.18	0.67	0.11 ± 0.02	0.38 ± 0.05	0.27	0.083 ± 0.026	0.15 ± 0.04	0.067
Avg.	0.79 ± 0.10	1.86 ± 0.33	1.07	0.25 ± 0.05	0.88 ± 0.16	0.63	0.096 ± 0.02	0.36 ± 0.30	0.26	0.05 ± 0.02	0.135 ± 0.04	0.085

Table 4.5B Micro-macro wind velocity (kms/hr) of cow shed on different farms at 2.30 pm

Season/ Farm	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
FAS	0.024 ± 0.06	0.62 ± 0.12	0.38	-	-	-	-	-	-	-	-	-
IF	0.68 ± 0.12	1.80 ± 0.29	1.12	0.39 ± 0.04	1.19 ± 0.15	0.80	0.18 ± 0.02	0.66 ± 0.099	0.48	0.11 ± 0.02	0.38 ± 0.07	0.27
LRS	1.04 ± 0.18	2.67 ± 0.43	1.63	0.315 ± 0.03	1.09 ± 0.11	0.77	0.05 ± 0.02	0.60 ± 0.94	0.55	0.13 ± 0.04	0.43 ± 0.07	0.30
HF	2.41 ± 0.98	3.78 ± 1.06	1.37	0.64 ± 0.08	1.42 ± 0.19	0.78	0.13 ± 0.02	0.56 ± 0.08	0.43	0.43 ± 0.10	0.56 ± 0.10	0.13
Avg.	1.09 ± 0.33	2.22 ± 0.47	1.13	0.45 ± 0.05	1.23 ± 0.15	0.78	0.12 ± 0.02	0.61 ± 0.08	0.49	0.22 ± 0.05	0.46 ± 0.08	0.24

Fig 10 Wind velocity in cow shed

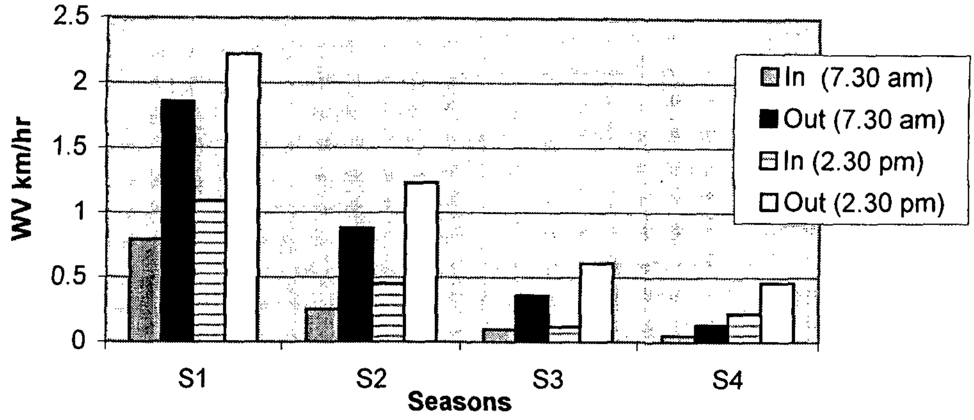


Fig 11 Wind velocity in calf pen

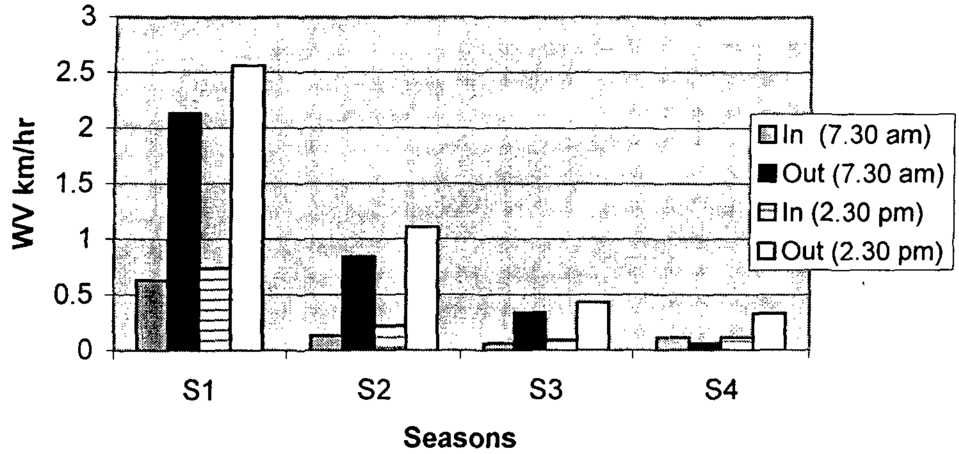


Fig 12 Wind velocity in poultry house

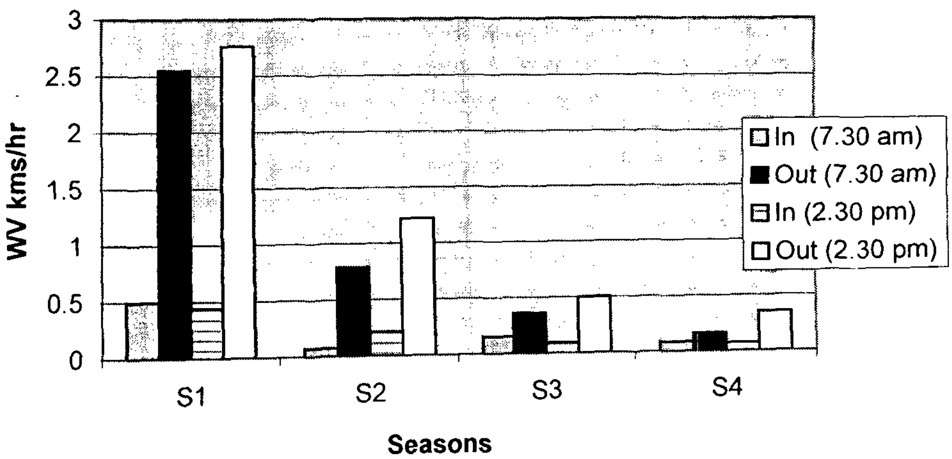
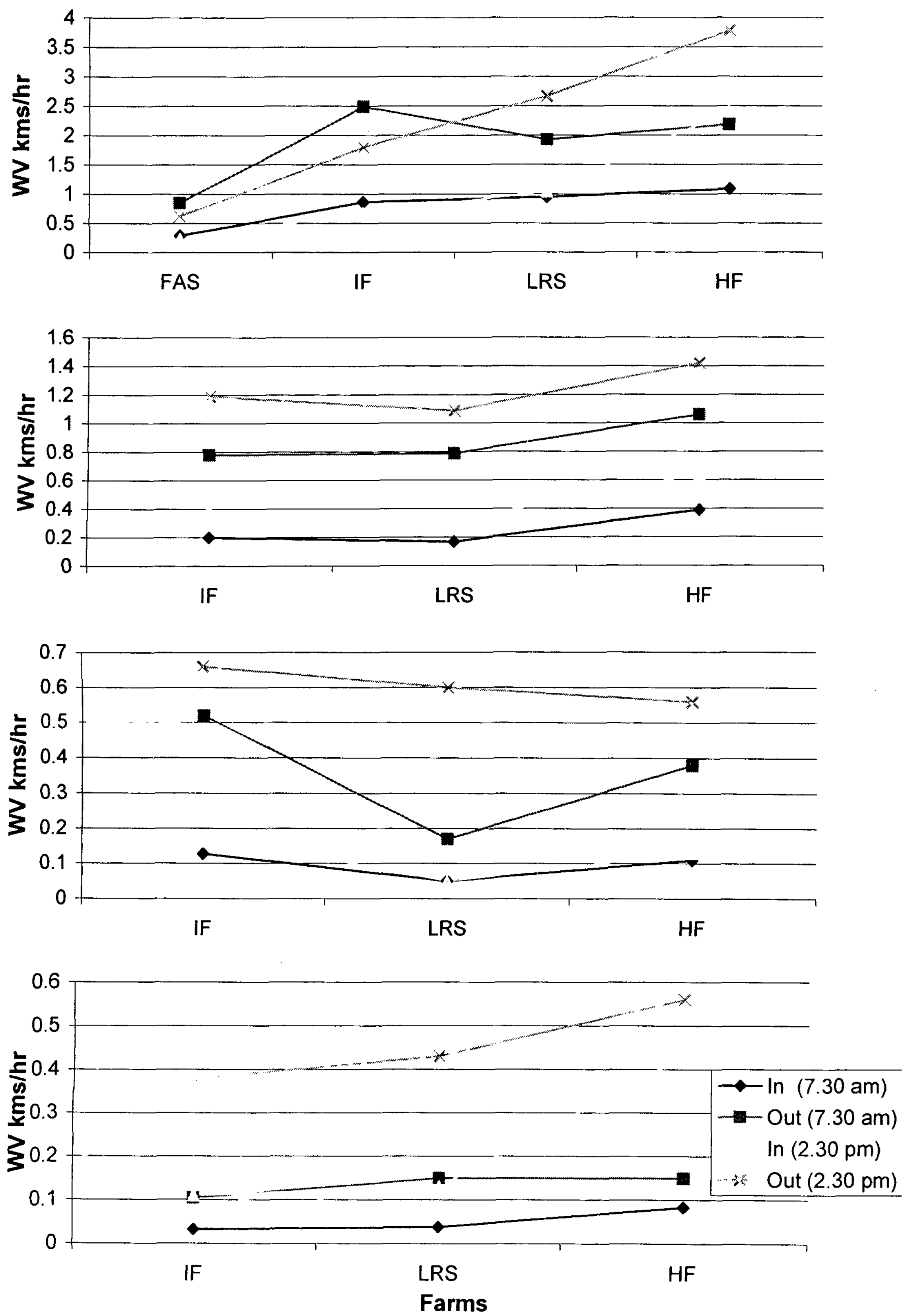


Fig 21 Wind velocity in cow shed during S1, S2, S3 & S4 seasons



from comfort point of view of heat dissipation and retention from the body of animals. Decreasing trend was observed from S_1 to S_4 season during the entire period of the experiment. The analysis of variance showed significant ($P < 0.05$) difference among the difference mean behavior S1, S_2, S_3 and S_4 seasons.

The mean wind velocity inside and outside the cowshed recorded at 7.30 am during different seasons on different farms are presented in Table 4.5A and depicted in Fig 21. The average wind velocity during hot dry (S_1) season inside the cowshed was recorded to be 0.29 ± 0.08, 0.86 ± 0.10, 0.95 ± 0.14 and 1.09 ± 0.35 km per hour whereas outside the cowsheds it was 0.85 ± 0.15, 2.49 ± 0.31, 1.93 ± 0.36 and 2.19 ± 0.53 km per hour and the differences (outside minus inside the cowshed) were 0.56, 1.63, 0.98 and 1.1 km per hour at FAS, IF, LRS and HF farm, respectively. In spite of highest WV observed at cow shed on HF farm than on FAS, IF& LRS farms, the inside temperature was highest with high RH 67.38 % The analysis of variance showed non-significant ($P < 0.05$) difference among the difference (outside minus inside) mean of cow shed on IF, LRS and HF farms. Karki (1981) observed that wind velocity was highest (10.05 kms/hr) in May and lowest (8.05 to 8.86 km/hr) in July and August

The mean wind velocity inside the cowshed during S_2 season was 0.20 ± 0.04, 0.16 ± 0.03 and 0.39 ± 0.09 km per hour whereas outside the cowshed was 0.78 ± 0.18, 0.79 ± 0.14 and 1.06 ± 0.18 km per hour and the difference was 0.58, 0.62 and 0.67 km per hour at IF, LRS and HF farm, respectively. Inside WV was higher at cow shed on HF farm than on the other farms. It might be due to the type of cow house at HF farm. The analysis of variance showed non-significant ($P < 0.05$) difference among the difference (outside minus inside) mean of cow shed on IF, LRS and HF farms.

The mean wind velocity inside cowshed during hot humid (S_3) season was 0.128 ± 0.02, 0.05 ± 0.02 and 0.11 ± 0.02 km per hour whereas outside 0.52 ± 0.12, 0.17 ± 0.05 and 0.38 ± 0.05 km per hour and the difference (outside minus inside the cowshed) was 0.39, 0.12 and 0.27 at IF, LRS and HF farm, respectively. Inside WV was more at cowshed on IF and HF than on the LRS, due to site of cowshed at LRS farm. The analysis of variance showed non-significant ($P < 0.05$) difference among the difference (outside minus inside) mean of cow shed on IF, LRS and HF farms.

The mean wind velocity inside cowshed during winter cold dry (S_4) season was recorded to be 0.033 ± 0.016, 0.038 ± 0.01 and 0.083 ± 0.026 km per hour whereas outside 0.105 ± 0.03, 0.15 ± 0.04 and 0.15 ± 0.04 km per hour and the difference was 0.072, 0.112 and 0.067 km per hour at IF, LRS and HF farm, respectively. The non-significant ($P < 0.05$) differences were observed. Karki (1981) recorded wind velocity of 1.7 kms/hr during winter.

The mean wind velocity inside and outside cowshed at 2.30 pm during different seasons irrespective of farms are presented in Table 4.1B and depicted in Fig 10. Mean wind velocity inside the cowshed was 1.09 ± 0.33, 0.45 ± 0.05, 0.12 ± 0.02 and 0.22 ± 0.05 km per hour whereas outside, 2.22 ± 0.47, 1.23 ± 0.15, 0.61 ± 0.08 and 0.46 ± 0.08 km per hour and the difference (outside minus inside the cowshed) was 1.13, 0.78, 0.49 and 0.24 km per hour during S_1, S_2, S_3 and S_4 season, respectively. Highest and lowest wind velocity both inside & outside were observed during S_1 & S_4 season, respectively. Decreasing trend was observed from hot dry S_1 to cold dry S_4 season throughout the experiment. Significant ($P < 0.05$) differences were observed for the difference (outside minus inside) mean during S_1, S_2, S_3 and S_4 seasons.

The mean wind velocity inside and outside cowshed of different farms are presented in Table 4.5B and depicted in Fig 21. The average wind velocity inside the cowshed during hot dry (S_1) season was 0.024 ± 0.06, 0.68 ± 0.12, 1.04 ± 0.18 and 2.41 ± 0.98 km per hour whereas outside it was 0.62 ± 0.12, 1.80 ± 0.29, 2.67 ± 0.43 and 3.78 ± 1.06 km per hour and the difference was 0.38, 1.12, 1.63 and 1.37 km per hour at farmers, IF, LRS and HF farm, respectively. Highest inside wind velocity was observed at cowshed on HF, however inside temperature was higher to the tune of 39.25 °C and RH 41%. Higher difference was observed at cow shed on LRS followed by HF, IF and FAS. The analysis of variance showed non-significant ($P < 0.05$) difference for difference mean. Yadav (1982) recorded wind velocity in open was 8.35 10.05, 9.35 and 8.49 kms/hr during April, May, June, and July, respectively. Stowell (1998) reported that air movement greatly influenced indoor and outdoor temperature and relative humidity.

The mean wind velocity inside the cowshed during monsoon rainy wet (S_2) season was 0.39 ± 0.04, 0.315 ± 0.03 and 0.364 ± 0.08 km per hour whereas outside was 0.66 ± 0.09, 0.60 ± 0.09 and 0.56 ± 0.08 km per hour and the difference (outside minus inside) was 0.48 ± 0.55 and 0.43 km per hour at IF, LRS and HF farm, respectively. The non-significant ($P < 0.05$) difference among the difference was observed of cow shed on IF, LRS and HF farms.

The mean wind velocity inside the cowshed during hot humid (S_3) season recorded to be 0.18 ± 0.02, 0.05 ± 0.02 and 0.13 ± 0.02 km per hour whereas outside was 0.66 ± 0.09, 0.60 ± 0.94 and 0.56 ± 0.88 km per hour and the difference was 0.48, 0.55 and 0.43 km per hour IF, LRS and HF farm, respectively. Highest and lowest inside wind velocity observed at cowshed on IF and LRS farm, respectively. Lower difference was at cow shed on HF than on LRS & IF farms. The analysis of variance showed non-significant ($P < 0.05$) difference among the difference (outside minus inside) mean of cow shed on IF, LRS and HF farms.

The mean inside wind velocity of cow shed during mild winter cold dry (S_4) season recorded 0.11 ± 0.02, 0.13 ± 0.04 and 0.43 ± 0.10 km per hour whereas outside 0.38 ± 0.07, 0.43 ± 0.07 and 0.56 ± 0.10 km per hour and the difference was 0.27, 0.30 and 0.13 km per hour at cow house on IF, LRS and HF farm, respectively. The analysis of variance showed non-significant ($P < 0.05$) difference among the difference (outside minus inside) mean of cow shed on IF, LRS and HF farms.

4.1.5 Micro and Macro Light Intensity

Mean inside and outside light intensity (lux) in cowshed at 7.30 am during different seasons irrespective of farms are presented in Table 4.1A and depicted in Fig 13. The mean inside light intensity was 1164.43, 440.53, 553.81 and 420.55 (X1) lux whereas outside 10671.1, 7330.6, 4992.7 and 2072.2 (X1) lux and the difference was 90671.1, 6890.14, 4438.8 and 1655.65 (X1) lux during S_1, S_2, S_3 and S_4 season, respectively. Highest LI both inside and outside were observed during summer hot dry and lowest during winter cold dry season, respectively. It was due to higher intensity of day light length during summer. The differences ($P < 0.05$) were significant.

The mean light intensity inside and outside cowshed were recorded at 7.30 am during different seasons and are presented in Table 4.6A and depicted in Fig 22. The average light intensity inside the cow sheds on different farms during summer hot dry (S_1) season was 1175.38 ± 107.78, 1232.30 ± 127.98, 968.46 ± 104.59 and 1281.53 ± 112.23 (X1) lux whereas outside 673.07 ± 55.83, 1110.00 ± 77.51, 1413.86 ± 68.15 and 1071.53 ± 119.89 (X10) lux and the difference (outside was inside) was 5555.3, 9867.7, 13170.1 and 9433.7 (X1) lux at cow shed on FAS, IF, LRS and HF farms

Table 4.6A Micro-macro light intensity (lux) of cow shed on different farms at 7.30 am

Season/ Farm	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
FAS	1175.38 ± 107.78	673.07 ± 55.83	5555.3	-	-	-	-	-	-	-	-	-
IF	1232.30 ± 127.98	1110.00 ± 77.51	9867	444.6 ± 77.53	672.00 ± 72.30	6275	397.14 ± 69.38	624.28 ± 82.73	5845	332.22 ± 43.32	222.22 ± 24.26	1890
LRS	968.46 ± 104.59	1413.86 ± 68.15	13170	414.4 ± 74.43	692.40 ± 80.23	6509	667.14 ± 79.50	349.28 ± 32.63	2825	363.88 ± 45.74	190.00 ± 19.14	1536
HF	1281.53 ± 112.23	1071.53 ± 119.89	9433	463.60 ± 75.63	834.80 ± 87.87	7884	597.14 ± 66.71	523.26 ± 67.05	4645	565.55 ± 80.93	209.44 ± 17.68	1528
Avg.	1164.43 ± 113.45	1067.11 ± 107.12	9506	440.53 ± 75.86	733.06 ± 80.13	6890	553.81 ± 71.86	49927 ± 60.80	4438	420.55 ± 56.66	20722 ± 20.36	-

Table 4.6B Micro-macro light intensity (Lux) of cow shed on different farms at 2.30 pm

Season/ Farm	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
FAS	703.07 ± 76.53	383.07 ± 20.42	31276	-	-	-	-	-	-	-	-	-
IF	537.69 ± 86.98	616.15 ± 40.58	56238	549.6 ± 91.63	347.2 ± 52.56	29224	378.57 ± 73.04	451.42 ± 24.01	41356	172.77 ± 11.34	388.33 ± 18.59	37105
LRS	269.23 ± 46.40	660.00 ± 45.23	63307	578.80 ± 86.56	313.20 ± 53.57	25572	301.42 ± 21.73	549.28 ± 17.07	51913	197.22 ± 13.81	423.88 ± 17.5	40415
HF	261.53 ± 33.22	761.53 ± 49.54	73537	555.2 ± 105.76	353.20 ± 104.59	29768	492.14 ± 94.59	493.57 ± 24.73	44435	347.22 ± 31.61	470.55 ± 19.92	43582
Avg.	442.88 ± 60.78	605.18 ± 38.94	56089	560.0 ± 59.74	338.00 ± 70.24	28200	390.71 ± 63.12	498.09 ± 21.94	45901	239.07 ± 18.92	427.59 ± 18.67	40367

Fig 22 Light intensity (inside) at 7.30 am during S1, S2, S3 & S4 seasons

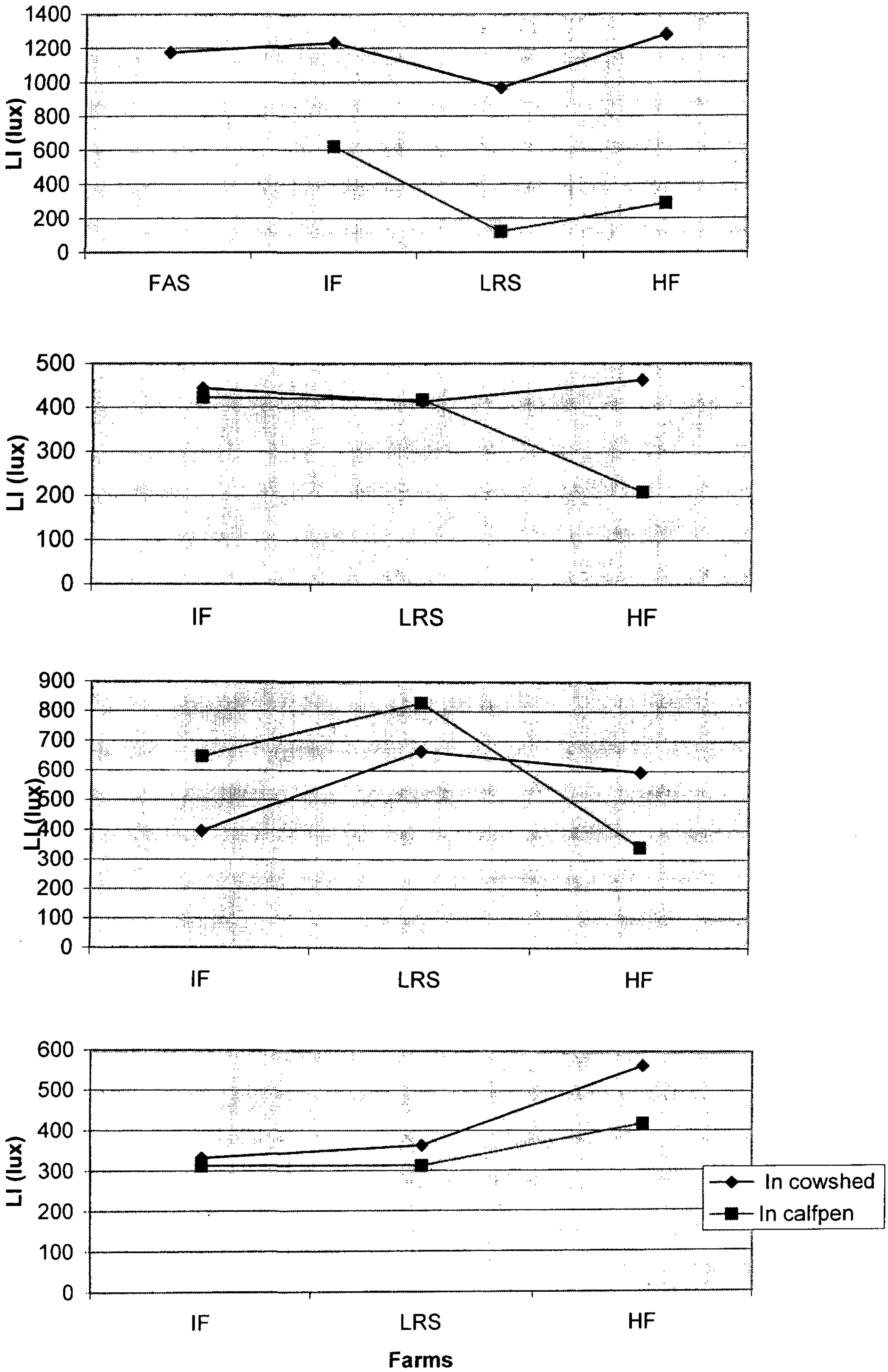


Fig 13 Light intensity (lux) in cow shed at 7.30 am

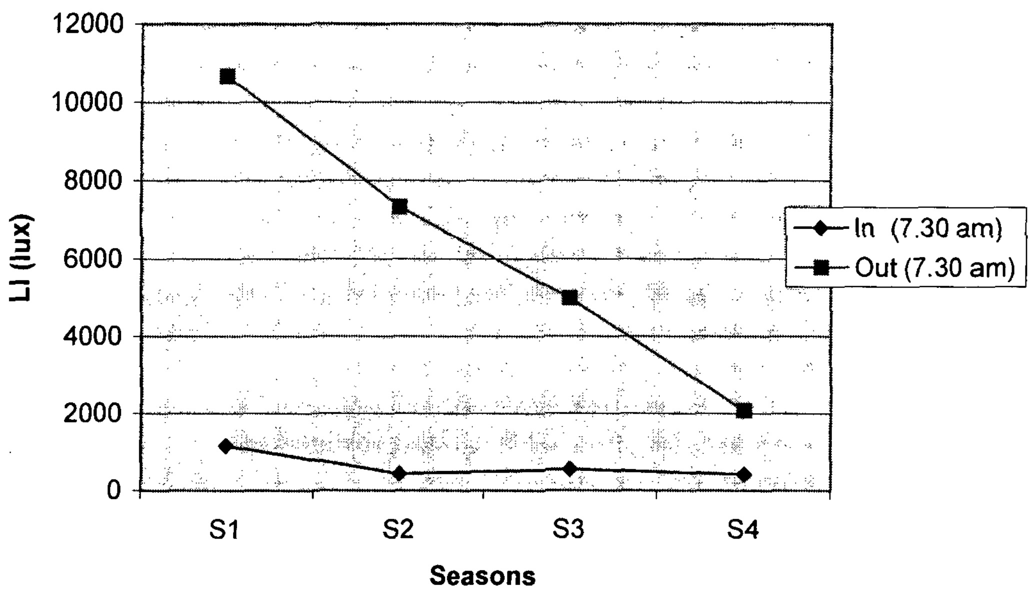
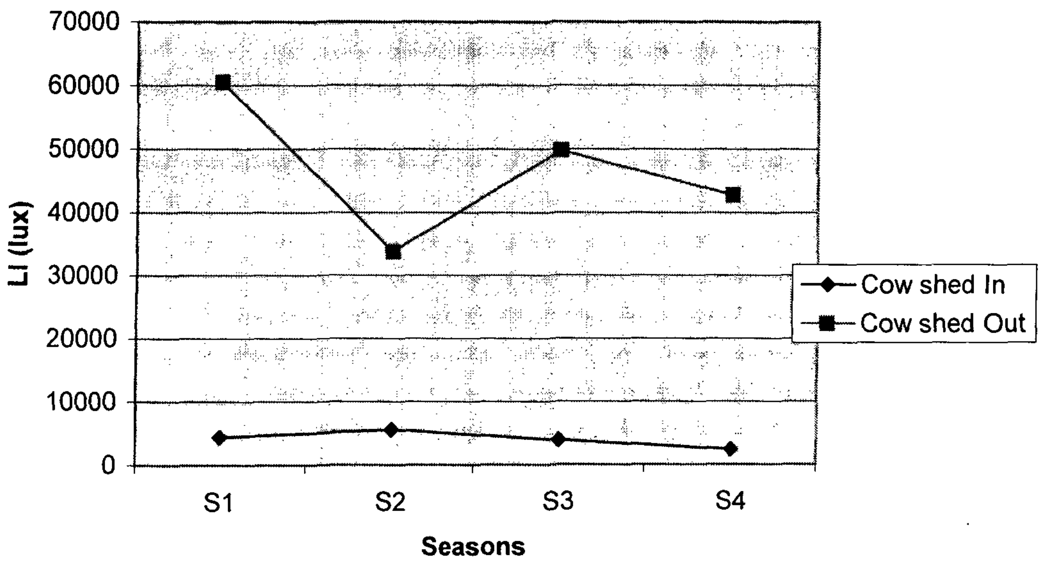


Fig 14 Light intensity (lux) in cow shed at 2.30 pm



respectively. Highest & lowest inside LI observed at cowshed on HF & LRS, respectively. The difference was lowest at cowshed on FAS than the cowshed on other farms. However, the difference mean were non significant ($P < 0.05$) between the cowsheds on IF, LRS and HF farms.

The mean light intensity inside the cow shed during monsoon rainy wet S_2 season were recorded to be 444.6 ± 77.55, 414.4 ± 74.43, 463.60 ± 75.63 (X1) lux whereas outside 642.00 ± 72.30, 692.40 ± 80.23 and 834.80 ± 87.87 (X10) lux and the difference was 6275.4, 6509.6, 6884.4 (X10) at cowshed on IF, LRS and HF farm, respectively. The differences (outside minus inside) mean of cow shed on IF, LRS and HF farms were at par.

The mean light intensity inside the cowshed during hot humid (S_3) season recorded 397.14 ± 69.38, 667.14 ± 79.50 and 597.14 ± 66.71 (X1) lux whereas outside the cowshed was 624.28 ± 82.73, 349.28 ± 32.63 and 523.26 ± 67.05 (X10) lux and the difference was 5845.6, 2825.6, 4645.4 (X1) lux at IF, LRS and HF farm, respectively. The lower inside LI was observed at cowshed on LRS, however, the outside LI was higher than the LI on the IF and HF farm. However, differences were non-significant for IF, LRS and HF farms.

The mean light intensity inside the cowshed during winter cold dry (S_4) season was observed to be 332.22 ± 43.32, 363.88 ± 45.74 and 565.55 ± 80.93 (X1) lux whereas outside the cow sheds was 222.22 ± 24.26, 190.00 ± 19.14 and 209.44 ± 17.68 (X10) lux and the difference was 1890, 1536.12, and 1528.85 (X1) lux at IF, LRS and HF farm respectively. The lowest inside LI was observed at cowshed on HF than LI on the IF and LRS farm, however, outside LI was lowest at cowshed on LRS followed by IF and HF farms. The analysis of variance showed non-significant (P <

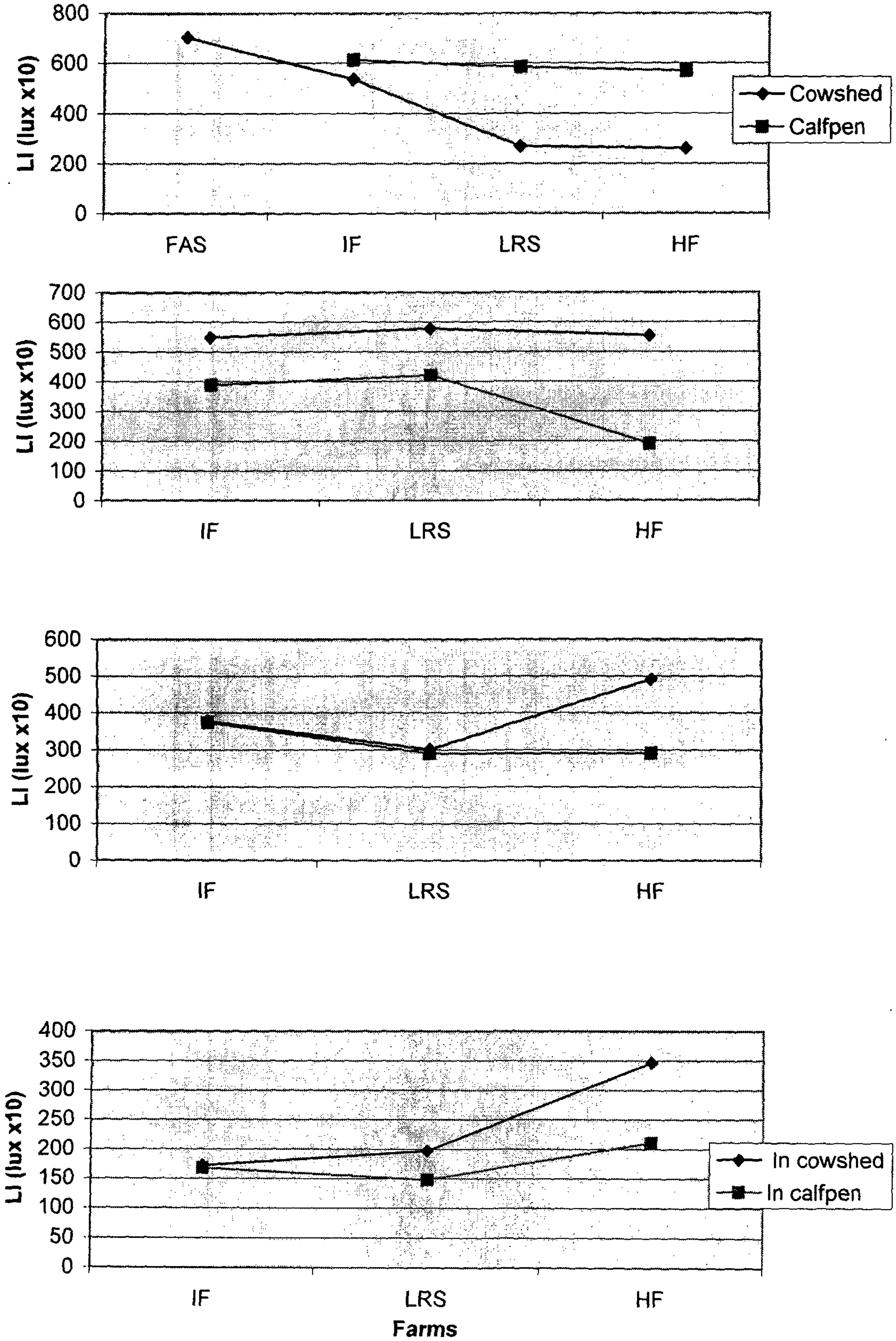
0.05) difference among the difference (outside minus inside) mean of cow shed on IF, LRS and HF farms.

During afternoon hours irrespective of farms mean inside and outside light intensity of cowshed at 2.30 pm during different seasons are presented in Table 4.1B and depicted in Fig 14. The mean inside light intensity was 4428 ± 60.78, 5600 ± 59.74, 3907 ± 63.12, and 2390 ± 18.92 (X1) lux whereas outside was 60518 ± 38.94, 33800 ± 70.24, 49809 ± 21.94, 42759 ± 18.67 (X1) lux and the difference was 56089, 28200, 45901 and 40367 (X1) lux during S_1, S_2, S_3 and S_4 season, respectively. Highest inside LI and highest outside LI were observed during S_1 & S_2 season, respectively. However, during winter cold dry, being short day length was lowest. It differed significantly ($p<0.05$) from other seasons.

The mean light intensity recorded at 2.30 pm at cow shed on different farms during different seasons are presented in Table 4.6B and depicted in Fig 23. The mean light intensity during hot dry monsoon rainy wet (S_1) season was inside the cowshed was 703.07 ± 76.53, 537.69 ± 86.98, 269.23 ± 46.40 and 261.53 ± 33.22 (X10) lux whereas outside the cowshed was 383.07 ± 20.42, 616.15 ± 40.58, 660.00 ± 45.23 and 761.53 ± 49.54 (X100) lux and the difference was 31276.3, 56238.0, 63307.0 and 73537.7 (X1) lux at FAS, IF, LRD and HF farm, respectively. Inside LI observed highest at cow shed on FAS than on the IF, LRS and HF farm, however, outside LI was higher at cowshed on HF than the any above farm. The differences were significant ($P < 0.05$) difference among the (outside minus inside) mean of cowsheds on IF, LRS and HF farms.

The mean inside light intensity of cowshed during monsoon rainy wet (S_2) season recorded 549.6 ± 91.63, 578.80 ± 86.56 and 555.2 ± 105.76 (X10) lux whereas outside the cowsheds was 347.2 ± 52.56, 313.60 ± 53.57 and 353.20 ± 104.59 (X100)

Fig 23 Light intensity (inside) at 2.30 pm during S1, S2, S3 & S4 seasons



lux and the difference was 29224, 25572 and 29768 (X1) lux at, IF, LRS and HF farm, respectively. Inside LI observed highest and lowest outside LI at cow shed on LRS than on the IF, and HF farms. The difference were non-significant ($P < 0.05$) for cowsheds on IF, LRS and HF farms.

The mean light intensity during hot humid (S_3) season inside the cowshed was 378.57 ± 73.04, 301.42 ± 21.73 and 492.14 ± 94.59 (X10) lux whereas outside the cowsheds was 451.42 ± 24.01, 549.28 ± 17.07 and 493.57 ± 24.73 (X100) lux and the difference was 41356, 51913.9 and 44435.6 (X1) lux at IF, LRS, HF farm, respectively. Inside and outside LI observed higher at cow shed on HF being taller and open from both side than on IF and LRS farm. The analysis of variance showed non-significant ($P < 0.05$) difference among the difference (outside minus inside) mean of cowshed on IF, LRS and HF farms.

The mean light intensity inside cowshed during winter cold dry (S_4) season recorded 172.77 ± 11.34, 197.22 ± 13.81 and 347.22 ± 31.61 (X10) lux whereas outside 388.33 ± 18.59, 423.88 ± 17.5 and 470.55 ± 19.92 (X100) lux and the difference (outside minus inside) was 37105.3, 40415.8 and 43582.8 (X1) lux at IF, LRS and HF farm, respectively. Inside outside and the differences were observed higher at cowshed on HF than on the IF & LRS farms though, they were non-significant. It was observed that the inside LI of cowshed at IF, LRS and HF was satisfactory and provided sufficient light to cows.

4.2 Status of micro and macroclimate in calf pens

4.2.1 Micro and macro temperature

Irrespective of farms mean temperature inside and outside calf pens at 7.30 am during different seasons are presented in Table 4.7A and depicted in Fig 2. Inside the calf pen mean temperature was recorded to be 31.25 ± 1.28, 25.41 ± 0.29, 27.65 ± 0.23 and 20.52 ± 0.62°C whereas outside was 32.28 ± 1.40, 24.67 ± 0.29, 26.90 ± 0.20 and 21.95 ± 0.57°C during S_1, S_2, S_3 and S_4 season, respectively. The temperature difference (outside minus inside calf pen) was 1.03, -0.74, -0.75 and 1.42°C during S_1, S_2, S_3 and S_4 seasons, respectively. Inside temperature observed was more during S_2 & S_3 season than outside, however, during S_1 and S_4 seasons outside temperature was higher than inside temperature. The analysis of variance showed significant ($P < 0.05$) higher temperature difference during S_4 than during S_1, S_2 and S_3 seasons that were at par.

Mean temperature at 7.30 am inside and outside the calf-pen on different farms during different season are shown in Table 4.8A and depicted in Fig 24. The average temperature recorded during summer hot dry season inside the calf pen was 31.45 ± 3.43, 31.09 ± 0.19 and 31.20 ± 0.23 where as outside the calf-pen was 31.75 ± 3.32, 33.51 ± 0.58 and 31.59 ± 0.31 at IF, LRS and HF farm, respectively. The difference of temperature (outside minus inside) was 0.30, 2.42 and 0.39°C respectively. Inside temperature was higher at calf-pen on IF than HF & LRS farms, however, outside temperature was higher on LRS than HF & IF farms. The difference was more at calf-pen on LRS than on IF & HF farms. The differences were non-significant for calf-pen on IF, LRS and HF farms.

Singh (1996) studied the effect of certain summer managemental practices on performance of growing calves and average minimum temperature recorded was

Table 4.7A Mean micro and macroclimatic variables of calf pens during different seasons at 7.30 am

Met. Obs.	Season											
	S1			S2			S3			S4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
Temp (°C)	31.25 ± 1.28	32.28 ± 1.40	1.03	25.41 ± 0.29	24.67 ± 0.29	-0.74	27.65 ± 0.23	26.90 ± 0.20	-0.75	20.52 ± 0.62	21.95 ± 0.57	1.42
RH (%)	69.33 ± 3.31	68.08 ± 3.37	-1.25	94.98 ± 0.81	95.93 ± 0.67	0.95	75.21 ± 1.42	79.09 ± 1.26	3.88	45.85 ± 3.69	49.60 ± 3.55	3.75
WV (kms/hr)	0.61 ± 0.15	2.13 ± 0.44	1.51	0.13 ± 0.03	0.84 ± 0.19	0.71	0.059 ± 0.01	0.34 ± 0.06	0.278	0.114 ± 0.01	0.06 ± 0.02	0.054
LI (Lux)	376 ± 83	9233 ± 103	8856	350 ± 59	5139 ± 92.07	4788	606 ± 78	4821± 62	4214	347 ± 59.57	1405± 18	1057
THI	83.18 ± 0.73	84.51 ± 0.96		77.19 ± 0.49	75.98 ± 0.50		78.53 ± 0.33	77.85 ± 0.33		65.98 ± 0.97	68.03 ± 0.96	

Table 4.7B Mean micro and macroclimatic variables of calf pens during different seasons at 2.30 pm

Met. Obs.	Season											
	S1			S2			S3			S4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
Temp (°C)	38.72 ± 0.26	42.79 ± 0.30	4.07	28.82 ± 0.47	29.38 ± 0.54	0.56	33.13 ± 0.15	37.57 ± 0.38	4.44	32.02 ± 0.35	36.67 ± 0.64	4.65
RH (%)	42.77 ± 1.44	39.53 ± 1.04	-3.24	91.47 ± 1.26	92.24 ± 1.20	0.77	66.87 ± 1.14	64.93 ± 1.40	-1.94	37.49 ± 1.60	34.68 ± 1.88	-2.81
WV (kms/hr)	0.74 ± 0.17	2.56 ± 0.55	1.84	0.22 ± 0.03	1.11 ± 0.03	0.89	0.09 ± 0.02	0.43 ± 0.08	0.34	0.11 ± 0.02	0.33 ± 0.06	0.22
LI (Lux)	2061 ± 43	58961 ± 38	5689 9	3312 ± 51	25158 ± 27	21845	3192 ± 65	52880 ± 36	49687	1762 ± 14	38611 ± 18	36849
THI	87.94 ± 0.42	92.04 ± 0.39		82.59 ± 0.72	83.67 ± 0.87		85.51 ± 0.32	91.58 ± 0.65		79.11 ± 0.61	83.74 ± 1.03	

ANOVA table for difference mean of calf pens at 7.30 am

Sr. No.	Source	DF	Mean Squares			
			Temp	RH	WV	LI
1.	Replication	3	1.077	8.558	0.799	14786932
2.	Season	3	1.669*	14.585*	4.207*	162470342*
3.	Treatment (houses)	2	0.969	0.230	0.637	18533897
4.	SXH	6	1.549*	3.751*	0.080	15684648*
5.	Error	33	0.544	1.007	0.228	6198046

*(P<0.05)

Difference mean temperature of calf pens at 7.30 am.

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
1.19^a	0.90^a	0.73^a	1.58^b	*	0.62

B) Treatments (calf pens)

IF	LRS	HF	Test	CD
0.82	1.28	1.21	NS	-

C) Season X Treatment

	IF	LRS	HF	Test	CD
S_1	0.46	2.43	0.68	NS	-
S_2	0.81	0.68	1.22	NS	-
S_3	0.53	0.69	0.99	NS	-
S_4	1.50	1.82	1.95	NS	-

Difference mean relative humidity (%) of calf pens 7.30 am

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
2.33^b	1.17^a	3.47^c	3.47^c	*	0.837

B) Treatments (calf pens)

IF	LRS	HF	Test	CD
2.75	2.54	2.54	NS	-

C) Season X Treatment

	IF	LRS	HF	Test	CD
S_1	2.49^c	3.41^b	1.08^a	*	1.449
S_2	1.58	1.08	0.83	NS	-
S_3	3.16	3.41	3.83	NS	-
S_4	3.75	2.25	4.42	NS	-

Difference mean wind velocity (kms/ hr) of calf pens at7.30 am

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
1.48^{c}	0.62^{ab}	0.30^{a}	0.16^{a}	*	0.398

B) Treatments (calf pens)

IF	LRS	HF	Test	CD
0.601	0.46	0.85	NS	-

C) Season X Treatment

	IF	LRS	HF	Test	CD
S_1	1.51	1.09	1.84	NS	-
S_2	0.49	0.58	0.77	NS	-
S_3	0.34	0.11	0.44	NS	-
S_4	0.07	0.05	0.36	NS	-

Difference mean light intensity (lux) calf pens at 7.30 am

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
10159^{c}	4613^{b}	4084^{b}	1390^{a}	*	2075

B) Treatments (calf pens)

IF	LRS	HF	Test	CD
5581^{ab}	5780^{a}	3824^{a}	*	2145

C) Season X Treatment

	IF	LRS	HF	Test	CD
S_1	11113^{bc}	12152^{b}	7211^{a}	*	3594
S_2	3067	6868	3903	NS	-
S_3	6815	2803	2634	NS	-
S_4	1328	1294	1548	NS	-

ANOVA table for difference mean of calf pen at 2.30 pm

Sr. No.	Source	DF	Mean Squares			
			Temp	RH	WV	LI
1.	Replication	3	1.358	2.410	0.541	478802
2.	Season	3	48.210*	19.918*	6.115*	28653185*
3.	Treatment (houses)	2	0.080	11.325	0.086	1374962
4.	SXH	6	1.219	4.304	0.041	824096
5.	Error	33	0.906	1.505	0.266	839523

*(P< 0.05)

Difference mean temperature of calf pen 2.30 pm

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
4.07^b	0.65^a	4.49^{bc}	5.14^c	*	0.793

B) Treatments (calf pens)

IF	LRS	HF	Test	CD
3.57	3.53	3.67	NS	-

C) Season X Treatment

	IF	LRS	HF	Test	CD
S_1	4.34	3.65	4.21	NS	-
S_2	0.83	0.69	0.45	NS	-
S_3	3.57	4.91	5.00	NS	-
S_4	5.53	4.87	5.01	NS	-

Differences mean relative humidity (%) of calf pens at2.30 pm

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
3.36^c	0.89^a	2.91^b	3.80^c	*	1.023

B) Treatments (calf pens)

IF	LRS	HF	Test	CD
3.22^b	1.77^a	3.23^b	*	0.886

C) Season X Treatment

	T_1	T_2	T_3	Test	CD
S_1	4.99^b	1.00^a	4.08^b	*	1.771
S_2	1.16	0.58	0.91	NS	-
S_3	2.41	2.08	4.25	NS	-
S_4	4.33	3.41	3.66	NS	-

Difference mean wind velocity (km/hr) calf pens at 2.30 pm

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
1.80^c	0.74^b	0.32^a	0.26^a	*	0.40

B) Treatments (calf pens)

IF	LRS	HF	Test	CD
0.83	0.70	0.83	NS	-

C) Season X Treatment

	IF	LRS	HF	Test	CD
S_1	1.89	1.75	1.78	NS	-
S_2	0.66	0.68	0.91	NS	-
S_3	0.41	0.28	0.28	NS	-
S_4	0.35	0.09	0.33	NS	-

Difference mean light intensity (lux) of calf pens 2.30 pm

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
5880^d	2321^a	5046^c	3857^b	*	763.83

B) Treatments (calf pen)

IF	LRS	HF	Test	CD
4197	4031	4601	NS	-

C) Season X Treatment

	IF	LRS	HF	Test	CD
S_1	5900	5930	6111	NS	-
S_2	2120	2325	2519	NS	-
S_3	4944	5213	4983	NS	-
S_4	3824	2955	4790	NS	-

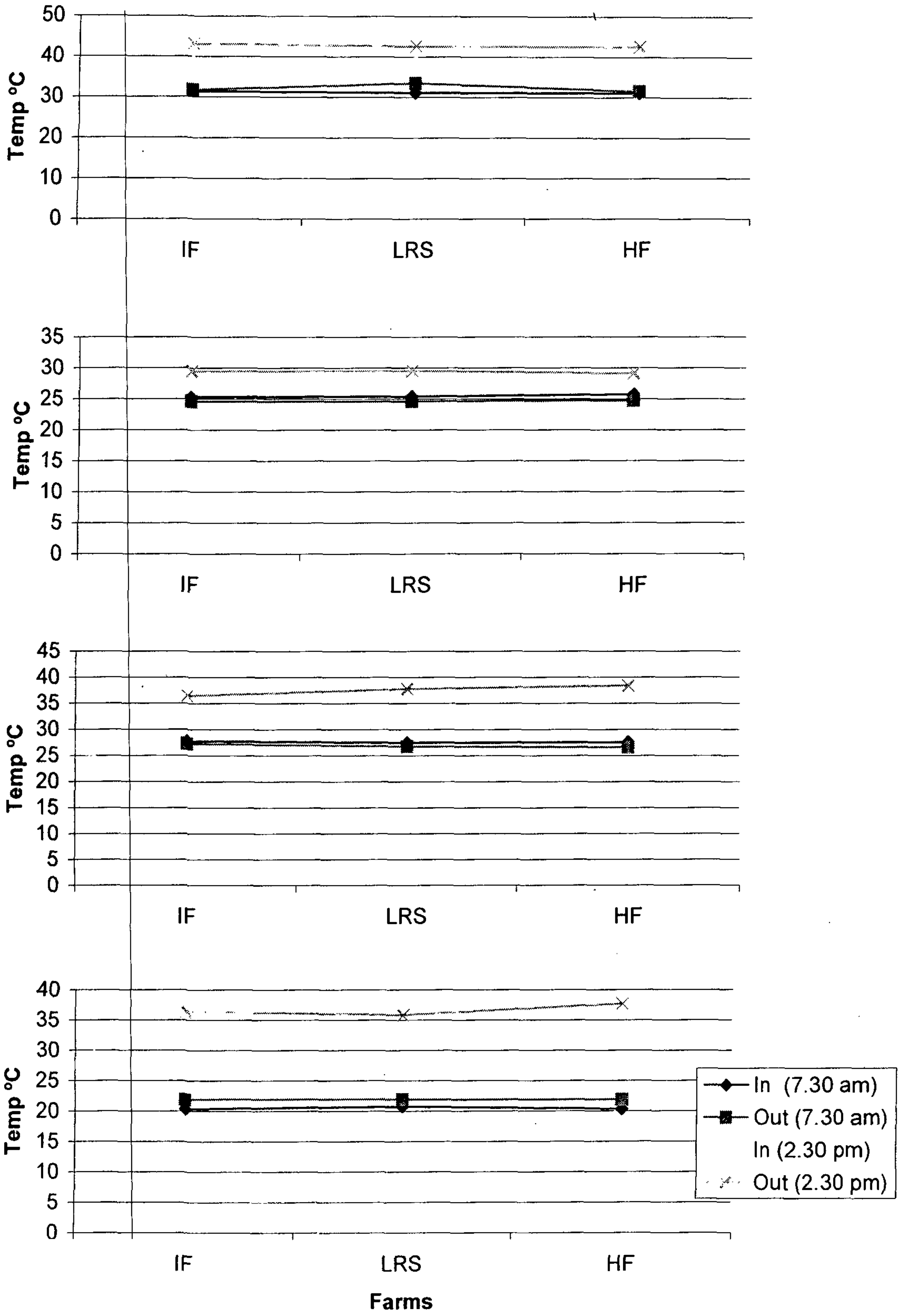
Table 4.8A Micro-macro temperature (°C) of calf pen on different farms at 7.30 am.

Season/ Farm	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
IF	31.45 ± 3.43	31.75 ± 3.32	0.30	25.35 ± 0.31	24.60 ± 0.30	-0.75	27.83 ± 0.28	27.29 ± 0.27	-0.54	20.39 ± 0.60	21.95 ± 0.59	1.56
LRS	31.09 ± 0.19	33.51 ± 0.58	2.42	25.41 ± 0.29	24.63 ± 0.29	-0.78	27.51± 0.17	26.81 ± 0.13	-0.70	20.80 ± 0.51	21.97 ± 0.55	1.17
HF	31.20 ± 0.23	31.59 ± 0.31	0.39	25.47 ± 0.27	24.77 ± 0.29	-0.70	27.62 ± 0.25	26.61 ± 0.20	-1.01	20.36 ± 0.75	21.92 ± 0.58	1.56
Avg.	31.25 ± 1.28	32.28 ± 1.40	1.03	25.41 ± 0.29	24.67 ± 0.29	-0.74	27.65 ± 0.23	26.90 ± 0.20	-0.75	20.52 ± 0.62	21.95 ± 0.57	4.42

Table 4.8A Micro-macro temperature (°C) of calf pen on different farms at 2.30 pm.

Season/ Farm	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
IF	38.80 ± 0.16	43.15 ± 0.36	4.35	28.76 ± 0.48	29.49 ± 0.52	0.74	32.89 ± 0.18	36.46 ± 0.41	3.57	31.59 ± 0.38	36.43 ± 0.67	4.84
LRS	39.07 ± 0.34	42.65 ± 0.31	3.58	28.98 ± 0.45	29.56 ± 0.48	0.58	33.14 ± 0.14	37.82 ± 0.36	4.68	32.38 ± 0.34	35.85 ± 0.73	3.47
HF	38.28 ± 0.29	42.58 ± 0.24	4.3	28.72 ± 0.49	29.09 ± 0.63	0.37	33.36 ± 0.14	38.44 ± 0.39	5.08	32.10 ± 0.34	37.74 ± 0.54	4.84
Avg.	38.72 ±0.26	42.79 ± 0.30	4.07	28.82 ±0.47	29.38 ± 0.54	0.56	33.13 ±0.15	37.57 ± 0.38	4.44	32.02 ± 0.35	36.67 ± 0.64	4.65

Fig 24 Temperature (ºC) in calf pen during S1, S2, S3 & S4 seasons



2.02°C higher in modified loose house (thatched roof and thatched screen) as compared to loose house.

During monsoon rainy wet season mean inside temperature of the calf-pen was 25.35 ± 0.31, 25.41 ± 0.29 and 25.47 ± 0.27°C whereas, outside was 24.60 ± 0.30, 24.63 ± 0.29 and 24.77 ± 0.29°C and the difference was -0.75, -0.78 and 0.70°C at IF, LRS and HF farm, respectively. They ware at par.

The average temperature recorded inside the calf-pen during hot humid season was recorded to be 27.83 ± 0.28, 27.51 ± 0.17 and 27.62 ± 0.25°C whereas outside was 27.29 ± 0.27, 28.81 ± 0.13 and 26.61 ± 0.20°C at IF, LRS and HF farm, respectively. The inside temperature was higher by 0.54, 0.70 and 1.01°C at IF, LRS and HF farm, respectively. During this season temperature was more inside the calf-pen than the outside. However, the differences were mean of calf-pen on IF, LRS and HF farms were at par. Hari om (2003) reported that minimum temperature was not significantly influenced by treatments T1 (loose house as control), T2 (loose house mud plastered roof) and T3 (loose house + use of waste lime on roof).

During winter cold dry season the average temperature inside the calf-pen was 20.39 ± 0.60, 20.80 ± 0.51 and 20.30 ± 0.75°C whereas outside was 21.95 ± 0.59, 21.97 ± 0.55 and 21.92 ± 0.58°C at calf-pen on IF, LRS and HF farm, respectively. The difference (outside minus inside) was 1.56, 1.17 and 1.56°C at calf-pen on IF, LRS and HF farm, respectively and they differed non-significantly. Chakrabarti (1991) reported that mean minimum temperature during winter in loose house of buffaloes calves (T1), loose housing + curtains during night (T2), loose housing + bedding (T3) and conventional barn (T4) were 6.66, 6.74, 6.82 and 7.05°C, respectively. Mean minimum temperature was highest in the month of November and lowest in the month of January in all types of housings.

Mean temperature inside and outside calf pen irrespective of farms at hottest period of day 2.30 pm during different seasons are presented in Table-. and depicted in Fig 4.7B and depicted in Fig 2. Inside the calf-pen mean temperature was recorded to be 38.72 ± 0.26, 28.82 ± 0.47, 33.13 ± 0.15 and 32.02 ± 0.35°C whereas outside was 42.79 ± 0.30, 29.38 ± 0.54, 37.57 ± 0.38 and 36.67 ± 0.64 °C during S_1, S_2, S_3 and S_4 season, respectively. Mean difference (outside minus inside) was 4.07, 0.56, 4.44 and 4.65°C during S_1, S_2, S_3 and S_4 season, respectively. Inside & outside temperature observed highest during hot dry and lowest during monsoon rainy wet seasons. Season conflict was significant, it is bond too. During hot dry season the inside temperature was lower by 4.07 °C than the outside intense temperature of 42.79 °C, however, inside temperature of 38.72 °C was also higher and uncomfortable to calves. They might add cooling system on shed like ceiling fans showering of water. The analysis of variance showed significantly ($P < 0.05$) lowest difference during S_2 than during S_1, S_3 and S_4 seasons, which were at par.

The average temperature inside the calf-pen during hot dry season was recorded to be 38.80 ± 0.16, 39.07 ± 0.34 and 38.28 0.29 whereas outside was 43.15 ± 0.36, 42.65 ± 0.31 and 42.58 ± 0.24°C and the average difference (outside minus inside the calf-pen) was 4.35, 3.58, 4.30°C calf pen on IF, LRS and HF, respectively (Table 4.8B and Fig 24. The inside temperature was lower at calf-pen on HF than the on IF and LRS. High outside temperature might be due to the cement concrete floor (open) at calf-pen on IF. The differences were non-significant ($P < 0.05$) for calf-pen on IF, LRS and HF farms.

A study was undertaken to know the effect of two different housing systems on physiological responses of crossbred calves by Parihar *et al.* (1992). They reported maximum temperature of 40.42 and 26.07 °C during summer and winter respectively.

Yazdani and Gupta (2000) studied the effect of housing and feeding systems on crossbred calves. They recorded higher maximum ambient temperature in loose house (42.2 °C) than thatch house (38.5°C). The THI in both types of experimental house was about 78, which was above the value of 72 at which the growth in calf is decreased.

Hari om (2003) investigated certain modification in loose housing and its impact on the performance of female buffalo calves during summer and reported that overall maximum temperature was not significantly influenced by treatments T1 (loose house as control), T2 (loose house mud plastered roof) and T3 (loose house + use of waste lime on roof). However, the maximum temperature was significantly ($P < 0.05$) higher in hot dry period i.e. 42.19, 40.20 and 40.75°C in T1, T2 and T3 respectively than hot humid period i.e. 38.67, 37.11 and 37.60°C in T1, T2 and T3, respectively. The maximum temperature in hot dry and hot humid period was not significantly influenced by treatments but it was slightly lower in modified roof houses due to the fact that the mud absorbed and lime powder reflected the solar radiations thereby preventing entry into the animal shed. The THI was 4 per cent higher in evening (86.59, 85.30 and 85.72 in T1, T2 and T3, respectively) as compared to morning (82.38, 81.58 and 81.99 in T1, T2 and T3, respectively) indicating that evening was more stressful as compared to morning in different houses.

Gupta *et al.* (2003) reported that the mean maximum temperature was recorded 38.71, 36.09, 36.04 and 38.06°C, in loose house, loose house + thatch roof; loose house + mud plaster roof and conventional barn, respectively. And inferred that provision of thatch and mud plaster on the asbestos roof improved microclimate by lowering the temperature by about 2°C.

The mean temperature inside the calf-pen during monsoon rainy wet season was recorded to de 28.76 ± 0.48, 28.98 ± 0.45 and 28.72 ± 0.49 whereas the outside was 29.49 ± 0.52, 29.56 ± 0.48 and 29.09 ± 0.63°C and the difference (outside minus inside the calf-pen) was 0.74, 0.58 and 0.37°C at IF, LRS and HF farm, respectively. Lowest difference observed at calf-pen on HF than on the IF and LRS.

The mean temperature inside the calf-pen during hot humid season was 32.89 ± 0.18, 33.14 ± 0.14 and 33.36 ± 0.14 whereas outside the calf-pen was 36.46 ± 0.41, 37.82 ± 0.36 and 38.44 ± 0.39°C and the difference (outside minus inside) was 3.57, 4.68 and 5.08°C at IF, LRS and HF farm, respectively. Inside temperature of the calf pen on HF was higher than IF & IRS and difference was also observed higher at calf pen on HF. It might be due to more closed house than calf pen on other farms. It is not desirable during hot humid season. It imposes more stress on the calf due combined effect of high inside temperature coupled with high humidity and very low speed of wind movement prevailed in the house. The difference were non-significant for calf-pen on IF, LRS and HF farms.

Hari om (2003) investigated certain modification in loose housing and its impact on the performance of female buffalo calves during summer and reported that overall maximum was not significantly influenced by treatments T1 (loose house as control), T2 (loose house mud plastered roof) and T3 (loose house + use of waste lime on roof). However, the maximum temperature was significantly ($P < 0.05$) higher in hot dry period i.e. 42.19, 40.20 and 40.75°C in T1, T2 and T3 respectively than hot humid period i.e. 38.67, 37.11 and 37.60°C in T1, T2 and T3, respectively. The maximum temperature in hot dry and hot humid period was not significantly influenced by treatments but it was slightly lower in modified roof houses due to that the mud absorbed and lime powder reflected the solar radiations thereby preventing entry into the animal shed. The THI was 4 per cent higher in evening (86.59, 85.30 and 85.72 in T1, T2 and T3, respectively) as compared to morning (82.38, 81.58 and 81.99 in T1, T2 and T3, respectively) indicating that evening was more stressful as compared to morning in different houses.

The mean temperature inside the calf pen during mild winter cold dry season was recorded to be 31.59 ± 0.38, 32.38 ± 0.34 and 32.10 ± 0.34°C whereas outside was 36.43 ± 0.67, 35.85 ± 0.75 and 37.74 ± 54°C and the difference was 4.84, 3.47 and 4.84°C at calf pen on IF, LRS and HF farm, respectively. Mean inside temperature was observed higher at calf-pen on LRS than on IF & HF, however, outside calf pen temperature was higher on HF than IF & LRS farm. The difference was observed lower at calf pen on LRS than on IF & IF farms. The difference was at par.

Chakrabarti (1991) reported that mean maximum temperature in loose house of buffaloes calves (T1), loose housing + curtains during night (T2), loose housing + bedding (T3) and conventional barn (T4) were 23.38, 22.80, 22.96 & 22.66 °C and THI value in evening was more than the morning. The mean value range from 54.50 to 70.21, 53.91 to 67.78, 54.10 to 67.92 and 52.59 to 67.52 in above described four treatments, respectively. Parihar *et al.* (1992) reported maximum temperature of 40.42 and 26.07 °C during summer and winter respectively. Dahiya (1997) conducted an experiment to find out the effect of feeding two level of dietary protein and bedding on growth performance of female buffalo calves during winter season and found that the overall mean temperature was lower (1.38°C) in without bedding groups as compared to with bedding. The mean maximum temperature in shed was 24.62 °C. The Temperature Humidity Index values were highest in February (54.88 and 53.62°C) and lowest in December (46.608 and 45.312°C). Microclimate in loose house and conventional barn in winter season was compared by Tedla (2002). He found that the mean maximum temperature was significantly higher ($P < 0.01$) in loose house (25.05 vs. 22.29°C). The morning THI was significantly higher ($P < 0.01$) in conventional barn (89.65) than the loose house (52.47) but non-significant difference was observed in evening THI values between two housing systems.

4.2.2 Micro and macro relative humidity

Irrespective of farms mean inside and outside relative humidity percent of calf pens at 7.30 am during different seasons are presented in Table 4.7A and depicted in Fig 4. Mean inside the calf pen relative humidity was recorded to be 69.33 ± 3.31, 94.98 ± 0.81, 75.21 ± 1.42 and 45.85 ± 3.69 per cent whereas outside the calf pen was 68.08 ± 3.37, 95.93 ± 0.67, 79.09 ± 1.26 and 49.60 ± 3.55 per cent and the difference was -1.25, 0.95, 3.88 and 3.75 per cent during S_1, S_2, S_3 and S_4 season, respectively. Highest relative humidity was observed during monsoon rainy wet season and lowest RH was observed during mild winter cold-dry season. The analysis of variance showed significantly ($P < 0.05$) higher difference during S_3 and S_4, than S_1 and S_2 seasons that were at par.

The mean relative humidity percent inside calf pen at 7.30 am on different farms during different seasons are presented in Table 4.9A and depicted in Fig 25. The mean relative humidity inside the calf pen during hot dry summer season was recorded to be 71.25 ± 3.71, 69.66 ± 2.87 and 67.08 ± 3.36 per cent whereas outside was 71.08 ± 3.74, 66.33 ± 2.56 and 66.83 ± 3.81 per cent and the difference was (outside minus inside the calf pen) -0.17, -3.33 and -0.25 per cent on IF, LRS and HF farm, respectively. During this season morning RH was higher than afternoon. During morning hours RH was higher outside than inside the calf pens whereas, during afternoon hours inside RH was observed higher than outside the calf pens. The

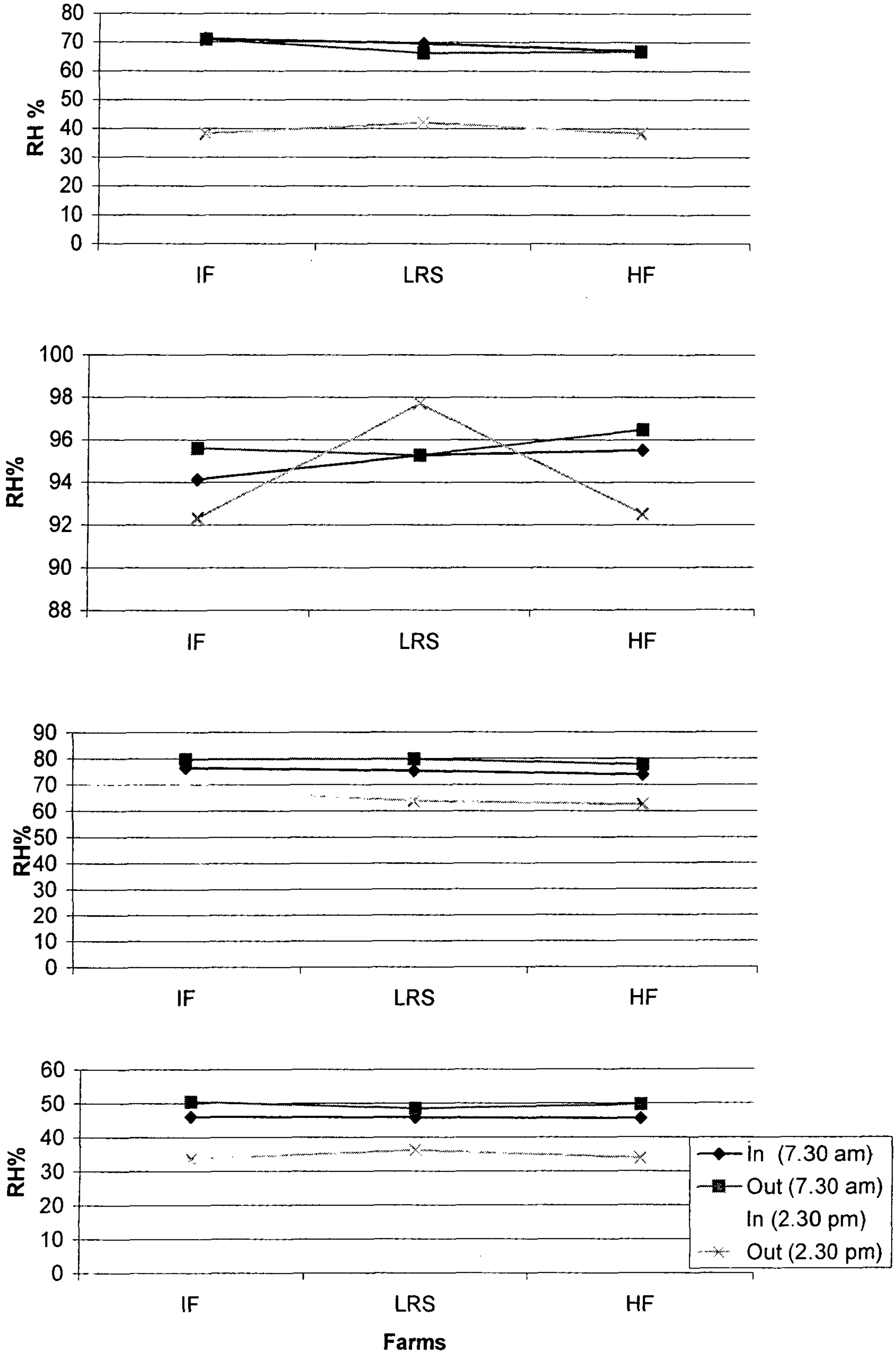
Table 4.9A Micro-macro relative humidity (%) of calf pen on different farms at 7.30 am

Season/ Farm	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
IF	71.25 ± 3.71	71.08 ± 3.74	-0.17	94.14 ± 0.85	95.61 ± 0.67	1.47	76.50 ± 1.09	79.78 ± 1.03	3.28	46.11 ± 3.73	50.53 ± 3.58	4.42
LRS	69.66 ± 2.87	66.33 ± 2.56	-3.33	95.28 ± 0.83	95.71 ± 0.75	0.43	75.28 ± 1.16	79.78 ± 1.14	4.5	45.83 ± 3.66	48.55 ± 3.57	2.72
HF	67.08 ± 3.36	66.83 ± 3.81	-0.25	95.52 ± 0.76	96.47 ± 0.61	0.95	73.85 ± 2.02	77.71 ± 1.62	3.86	45.61 ± 3.57	49.72 ± 3.51	4.11
Avg.	69.33 ± 3.33	68.08 ± 3.37	-1.25	94.98 ± 0.81	95.93 ± 0.67	0.95	75.21 ± 1.42	79.09 ± 1.26	3.88	45.85 ± 3.69	49.60 ± 3.55	3.75

Table 4.9B Micro-macro relative humidity (%) of calf pen on different farms at 2.30 pm.

Season/ Farms	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
IF	43.58 ± 1.26	38.25 ± 0.78	-5.33	91.33 ± 1.28	92.33 ± 1.14	1.00	68.78 ± 1.18	68.36 ± 1.15	-0.42	37.61 ± 1.89	33.76 ± 1.95	-3.85
LRS	42.41 ± 1.93	42.08 ± 1.67	-0.33	91.57 ± 1.13	97.71 ± 1.18	0.14	64.78 ± 1.03	63.85 ± 1.40	-0.93	37.05 ± 1.18	36.28 ± 2.00	-0.77
HF	42.33 ± 1.10	38.25 ± 0.69	-4.08	91.52 ± 1.38	92.67 ± 1.29	1.15	67.07 ± 1.21	62.57 ± 1.66	-4.50	37.83 ± 1.74	34.00 ±1.70	-3.83
Avg.	42.77 ± 13.44	39.53 ± 1.04	-3.24	91.47 ± 1.26	92.24 ± 1.20	0.77	66.87 ± 1.14	64.93 ± 1.40	-1.94	37.49 ± 1.60	34.68 ± 1.88	-2.81

Fig 25 Relative humidity %)in calf pen during S1, S2, S3 & S4 seasons



differences were non-significant for calf pens on IF, LRS and HF farms. Hari om (2003) investigated certain modification in loose housing and its impact on the performance of female buffalo calves during summer and reported morning and evening mean relatively humidity in hot dry period to be 59.50 and 28.79, 60.07 and 28.93 and 60.14 and 29.00 in (loose house as control), T2 (loose house with mud plastered roof) and T3 (loose house + use of waste lime on roof) respectively and corresponding values for hot humid period were 78.36 and 43.64, 78.57 and 43.50 and 78.57 and 43.71 per cent. The relative humidity was significantly lower ($P < 0.05$) in hot dry than that in hot humid period during morning and evening. Housing system in both the seasons did not significantly influence the relative humidity and THI and there was no significant difference observed between two seasons.

During monsoon rainy wet season inside mean relative humidity of the calf pen was recorded to be 94.14 ± 0.85, 95.28 ± 0.83 and 95.52 ± 0.76 per cent whereas outside was 95.61 ± 0.67, 95.71 ± 0.75, 96.47 ± 0.61 per cent and the difference was 1.47, 0.43 and 0.95 per cent at IF, LRS and HF farm, respectively. The differences were at par.

The mean relative humidity inside the calf pen during hot humid season recorded 76.50 ± 1.09, 75.28 ± 1.16 and 73.85 ± 2.02 per cent whereas outside was 79.78 ± 1.03, 79.78 ± 1.14 and 77.71 ± 1.62 per cent and the difference was 3.28, 4.5 and 3.86 at IF, LRS and HF farm, respectively. Inside and outside relative humidity was observed lower at calf pen HF than on IF and LRS, however, higher difference (outside minus inside the calf pen) observed at calf pen on LRS. The differences were non-significant for calf pens on IF, LRS and HF farms.

Hari om (2003) reported morning and evening mean relatively humidity in hot humid period were 78.36 and 43.64, 78.57 and 43.50 and 78.57 and 43.71 per cent. in (loose house as control), T2 (loose house mud plastered roof) and T3 (loose house + use of waste lime on roof) respectively. The relative humidity was significantly higher ($P < 0.05$) during hot humid than hot dry period in morning and evening hours. Housing system in both the seasons did not significantly influence the relative humidity and THI and there was no significant difference observed between two seasons.

During monsoon rainy wet season inside mean relative humidity of calf pen was recorded to be 46.11 ± 3.73, 45.83 ± 3.66 and 45.61 ± 3.57 per cent whereas outside was 50.53 ± 3.58, 48.55 ± 3.57 and 49.72 ± 3.51 per cent and the difference was 4.42, 2.72 and 4.11 at IF, LRS and HF farm, respectively. The difference was observed lower at calf pen on LRS than on IF and HF. It might be due to tree in front of the calf pen paddock, however, analysis of variance showed non-significant ($P < 0.05$) difference between the differences mean of calf pens on IF, LRS and HF farms.

During noon hours at 2.30 pm mean inside and outside relative humidity of calf pen irrespective of farms during different seasons are presented in Table 4.7B and depicted in Fig 5. Inside the calf pen mean relative humidity was recorded to be 42.77 ± 1.44, 91.47 ± 1.26, 66.87 ± 1.14 and 37.49 ± 1.60 per cent whereas outside was 39.53 ± 1.04, 92.24 ± 1.20, 64.93 ± 1.40 and 34.68 ± 1.88 per cent and the difference was -3.24, 0.77, -1.94 and -2.81 percent at IF, LRS and HF farm, respectively. Inside RH observed higher than outside during all seasons except monsoon rainy wet that was rainy-wet season. Highest RH was observed during monsoon rainy wet whereas, lowest RH was observed during mild cold dry season. The analysis of variance showed significant ($P < 0.05$) lower RH difference during monsoon rainy wet (S_2) than the others. The RH difference during S_1, S_3 and S_4 were at par.

The mean relative humidity at 2.30 pm at calf pens of different farms during different seasons are presented in Table 4.9B and depicted in Fig 25. The mean relative humidity inside the calf pen during summer hot dry was recorded to be 43.58 ± 1.26, 42.41 ± 1.93, and 42.33 ± 1.10 per cent whereas outside was 38.25 ± 0.78, 42.08 ± 1.67 and 38.25 ± 0.69 per cent and the difference (outside was inside) was – 5.33, -0.33 and -4.08 at IF, LRS and HF farm, respectively. Significantly ($P < 0.05$) lowest difference was observed at calf pen on LRS than the calf pen on both IF and HF. It might be due to tree in front of calf pen paddock.

During monsoon rainy wet season the mean relative humidity inside the calf pen was recorded to be 91.33 ± 1.28, 91.57 ± 1.13 and 91.52 ± 1.38 per cent whereas higher outside was 92.33 ± 1.14, 97.71 ± 1.18 and 92.67 ± 1.27 per cent and the difference was 1.00, 0.14 and 1.15 per cent at IF, LRS and HF farm, respectively. The difference was less at calf pen on LRS than on IF and HF and they were at par.

The mean relative humidity during hot humid season inside the calf pen was 68.78 ± 1.18, 64.78 ± 1.03 and 67.07 per cent whereas outside was 68.36 ± 1.15, 63.85 ± 1.40 and 62.57 ± 1.66 per cent and the difference was -0.42, -0.93 and -4.50 per cent on IF, LRS and HF farm, respectively. Inside RH was higher than outside. Least difference observed at calf pen on IF than LRS. Higher difference at calf pen on HF. However, they were non-significant ($P < 0.05$) for calf pens on IF, LRS and HF farms.

During mild cold dry season the mean relative humidity inside the calf pen was recorded to be 37.61 ± 1.89, 37.05 ± 1.18 and 37.83 ± 1.74 per cent whereas outside was 33.76 ± 1.95, 36.28 ± 2.00 and 34.00 ± 1.70 per cent and the difference was -3.85, -0.77 and -3.83 per cent at IF, LRS and HF farm, respectively. Inside RH was more than the outside. Outside RH was higher at calf pen on LRS. However, the difference at HF was lower than the calf pen on IF & on HF also. Analysis of variance showed non-significant ($P < 0.05$) difference among the differences (outside minus inside) mean of calf pens on IF, LRS and HF farms. Significantly lower difference was found at LRS than at IF and HF during seasons. The differences at IF and HF were at par.

4.2.3 Micro and macro THI

During morning hours 7.30 am and noon hours at 2.30 pm mean THI inside and outside the calf pen irrespective of farms during different seasons S_1, S_2, S_3 and S_4 were recorded and are presented in Table 4.7A & 4.7B and depicted in Fig 8. The THI and THIS calculated from data collected from Meteorology Laboratory are given in Table 4.24. Inside mean THI at 7.30 am was 83.18 ± 0.73, 77.19 ± 0.49, 78.53 ± 0.33 & 65.98 ± 0.97 whereas outside was 84.51 ± 0.96, 75.98 ± 0.50, 77.85 ± 0.33 & 68.03 ± 0.96 during S_1, S_2, S_3 and S_4 season, respectively. During hottest period of the day at 2.30 pm the average THI in side the calf pen was 87.94 ± 0.42, 82.59 ± 0.72, 85.51 ± 0.32 & 79.11 ± 0.61 whereas outside was 92.04 ± 0.39, 83.67 ± 0.87, 91.58 ± 0.65 & 83.74 ± 1.03. Highest THI observed during hot dry and hot humid seasons that were stressful seasons of the year. Farm wise THI are presented in Table 4.10A & 4.10B. There was not much difference between the calf pen on IF, LRS & HF farms.

Hari om (2003) investigated certain modification in loose housing and its impact on the performance of female buffalo calves during summer and reported that the THI was 4 per cent higher in evening (86.59, 85.30 and 85.72 in loose house as control, loose house mud plastered roof and loose house + use of waste lime on roof, respectively) as compared to morning (82.38, 81.58 and 81.99 in T1, T2 and T3, respectively) indicating that evening was more stressful as compared to morning in different houses.

Table 4.10A Micro-macro THI of calf pen on different farms at 7.30 am

Season/ Farm	S_1		S_2		S_3		S_4	
	I	O	I	O	I	O	I	O
IF	83.84 ± 0.91	84.26 ± 0.95	76.98 ± 0.49	75.82 ± 0.51	78.97 ± 0.38	78.54 ± 0.38	65.84 ± 0.96	68.10 ± 0.99
LRS	83.01 ± 0.69	86.07 ± 10.17	77.22 ± 0.49	75.89 ± 0.49	78.30 ± 0.20	77.79 ± 0.23	66.28 ± 0.84	68.00 ± 0.94
HF	82.68 ± 0.58	83.21 ± 0.75	77.36 ± 0.49	76.23 ± 0.52	78.31 ± 0.42	77.22 ± 0.38	65.81 ± 1.11	68.00 ± 0.96
Avg.	83.18 ± 0.73	84.51 ± 0.96	77.19 ± 0.49	75.98 ± 0.50	78.53 ± 0.33	77.85 ± 0.33	65.98 ± 0.97	68.03 ± 0.96

Table 4.10B Micro-macro THI of calf pen on different farms at 2.30 pm

Season/ Farm	S_1		S_2		S_3		S_4	
	I	O	I	O	I	O	I	O
IF	88.22 ± 0.21	92.10 ± 0.30	82.46 ± 0.73	83.87 ± 0.81	85.51 ± 0.34	90.75 ± 0.69	78.31 ± 0.64	83.27 ± 1.05
LRS	88.30 ± 0.64	92.58 ± 0.51	82.88 ± 0.67	83.92 ± 0.87	85.14 ± 0.32	91.70 ± 0.57	79.11 ± 0.55	83.14 ± 1.12
HF	87.30 ± 0.42	91.45 ± 0.36	82.42 ± 0.75	83.21 ± 1.02	85.89 ± 0.31	92.30 ± 0.68	79.92 ± 0.64	84.81 ± 0.64
Avg.	87.94 ± 0.42	92.04 ± 0.39	82.59 ± 0.72	83.67 ± 0.87	85.51 ± 0.32	91.58 ± 0.65	79.11 ± 0.61	83.74 ± 1.03

4.2.4 Micro and macro wind velocity

During morning hours at 7.30 am mean inside and outside wind velocity (kms/hr) of calf pens irrespective of farms during different seasons at are presented in Table 4.7A and depicted in Fig 11. Mean wind velocity inside the calf pen was recorded to be 0.61 ± 0.15, 0.13 ± 0.03, 0.059 ± 0.01and 0.114 ±0.01 km per hour whereas outside the calf pen was 2.13 ± 0.44, 0.84 ± 0.19, 0.34 ± 0.06 and 0.06 ± 0.02 km per hour and the difference was 1.51, 0.71, 0.278 and 0.054 km per hour during S_1, S_2, S_3 and S_4 season, respectively. Highest & lowest WV observed during summer hot dry & mild cold dry season, respectively. Decreasing trend observed from S_1 to S_4 season during the entire period of experiment. The analysis of variance showed significant ($P < 0.05$) higher difference during S_1 than S_2, S_3 and S_4 seasons. During S_2, the difference was higher than S_3 and S_4 that were at par. Lower WV is desirable sign for cold dry & during hot dry season but lower WV during hot humid season increases more stress due to difficulties in thermoregulation by less dissipation of heat from the body of animal to the environment. For reviewing heat stress effects on animal production, one must consider the entire scope of factor affecting thermoregulation in the body of animals (Fuquay *et al.* 1979).

During summer hot dry season the mean wind velocity inside the calf pen was recorded to be 0.80 ± 0.12, 0.88 ± 0.11 and 0.22 ± 0.05 km per hour whereas outside was 2.30 ± 0.37, 2.00 ± 0.37 and 2.08 ± 0.58 km per hour and the difference was 1.5, 1.18 and 1.86 km per hour at IF, LRS and HF farm, respectively. (Table 4.11A and Fig 26) Inside WV was observed lowest at calf pen on HF. The differences were non-significant for calf pens on IF, LRS and HF farms.

The mean wind velocity inside the calf pen during monsoon rainy wet season was recorded to be 0.13 ± 0.03, 0.16 ± 0.05 and 0.11 ± 0.02 km per hour whereas

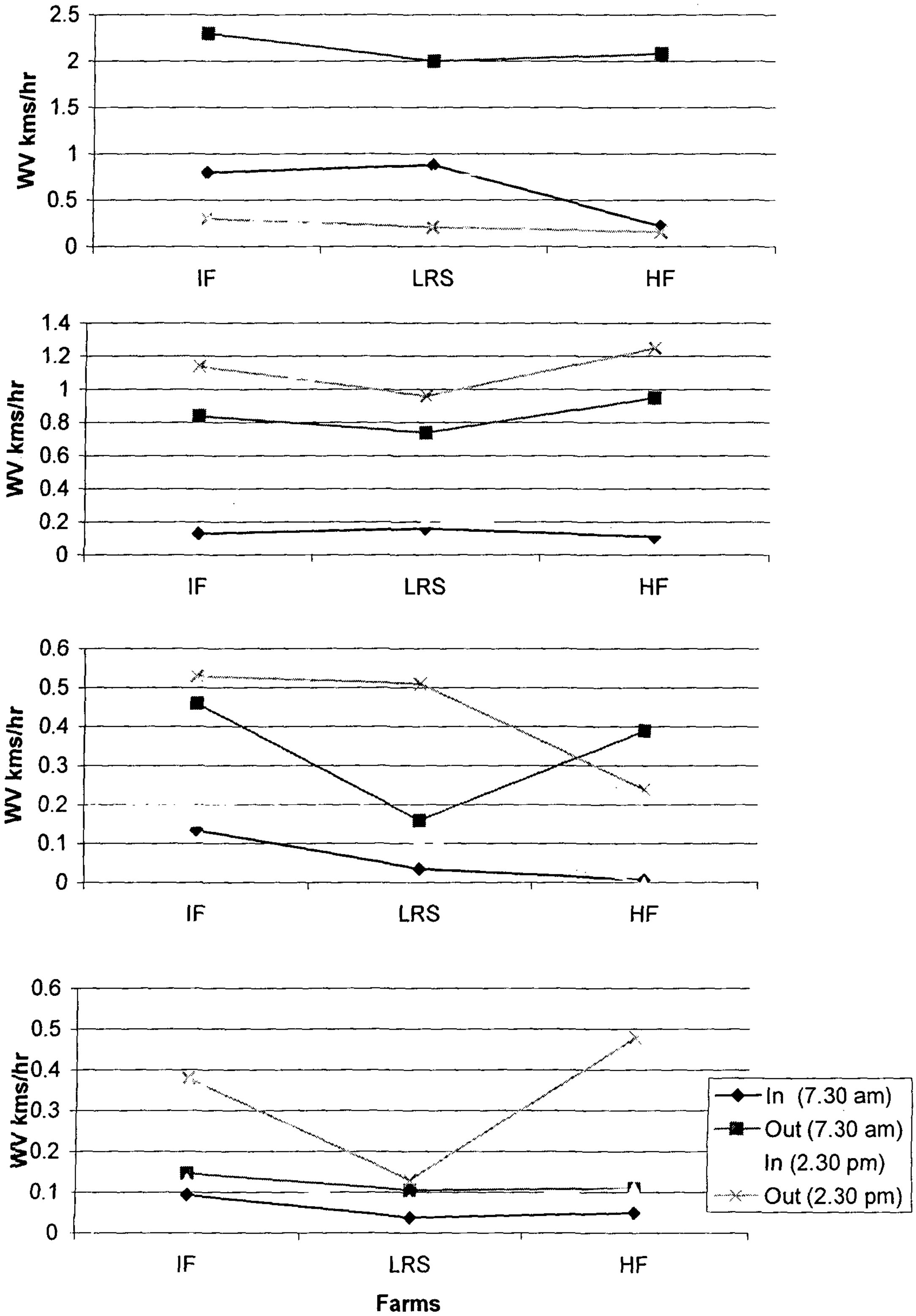
Table 4.11A Micro-macro wind velocity (kms/hr) of calf pen on different farms at 7.30 am

Season/ Farms	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
IF	0.80 ± 0.12	2.30 ± 0.37	1.5	0.13 ± 0.03	0.84 ± 0.18	0.71	0.135 ± 0.02	0.46 ± 0.08	0.325	0.094 ± 0.03	0.147 ± 0.03	0.033
LRS	0.88 ± 0.110	2.00 ± 0.37	1.18	0.16 ± 0.05	0.74 ± 0.16	0.58	0.035 ± 0.01	0.16 ± 0.04	0.125	0.038 ± 0.02	0.105 ± 0.05	0.067
HF	0.22 ± 0.056	2.08 ± 0.58	1.86	0.11 ± 0.02	0.95 ± 0.24	0.84	0.007 ± 0.01	0.39 ± 0.08	0.383	0.05 ± 0.027	0.11 ± 0.39	0.06
Avg.	0.61± 0.15	2.13 ± 0.44	1.51	0.13 ± 0.03	0.84 ± 0.19	0.71	0.059 ± 0.01	0.34 ± 0.06	0.278	0.06 ± 0.01	0.114 ± 0.02	0.054

Table 4.11B Micro-macro wind velocity (kms/hr) of calf pen on different farms at 2.30 pm

Season/ Farm	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
IF	0.67 ± 0.15	2.57 ± 0.66	1.9	0.30 ± 0.04	1.14 ± 0.18	0.84	0.16 ± 0.03	0.53 ± 0.09	0.37	0.13 ± 0.03	0.38 ± 0.08	0.25
LRS	0.77 ± 0.1	2.52 ± 0.38	1.75	0.21 ± 0.02	0.96 ± 0.12	0.75	0.11 ± 0.03	0.51 ± 0.10	0.40	0.08 ± 0.00	0.13 ± 0.03	0.05
HF	0.77 ± 0.26	2.60 ± 0.62	1.83	0.16 ± 0.02	1.25 ± 0.19	1.09	0.00 ± 0.00	0.24 ± 0.06	0.24	0.11 ± 0.03	0.48 ± 0.08	0.37
Avg.	0.74 ± 0.17	2.56 ± 0.55	1.84	0.22 ± 0.03	1.11 ± 0.16	0.89	0.09 ± 0.02	0.43 ± 0.08	0.34	0.11± 0.02	0.33 ± 0.06	0.22

Fig 26 Wind velocity in calf pen during S1, S2, S3 & S4 seasons



outside was 0.84 ± 0.18, 0.74 ± 0.16 and 0.95 ± 0.24 km per hour and the difference was 0.71, 0.58,and 0.84 at IF, LRS and HF farm, respectively. Inside WV was observed lower at calf pen on LRS. The differences were at par.

During hot humid season inside mean wind velocity of the calf pen was recorded to be 0.135 ± 0.08, 0.035 ± 0.01 and 0.007 ± 0.01 km per hour whereas outside was 0.46 ± 0.08, 0.16 ± 0.04 and 0.39 ± 0.08 km per hour and the difference was 0.32, 0.125 and 0.38 km per hour at IF, LRS and HF farm, respectively. Inside WV was lowest at calf pen on HF than IF and LRS, whereas outside WV observed lowest at calf pen on LRS and least difference also observed on LRS. However, they showed non-significant ($P < 0.05$) difference for calf pens on IF, LRS and HF farms.

The mean wind velocity during mild winter cold dry s season inside the calf pen was recorded to be 0.147 ± 0.03, 0.105 ± 0.05 and 0.11 ± 0.39 km per hour whereas outside was 0.094 ± 0.03, 0.038 ± 0.02 and 0.05 ± 0.02 km per hour and the difference (outside minus inside the calf pen) was 0.033, 0.067 and 0.06 km per hour at IF, LRS and HF farm, respectively. Inside WV was observed lowest at calf pen on LRS than on IF and HF. Analysis of variance showed non-significant ($P < 0.05$) difference among the differences (outside minus inside) mean of calf pens on IF, LRS and HF farms.

Irrespective of farms mean inside and outside wind velocity of calf pens at 2.30 pm during different seasons (Table 4.7B. and Fig 11). The mean wind velocity inside the calf pen was recorded to be 0.74 ± 0.17, 0.22 ± 0.03, 0.09 ± 0.02 and 0.11 ± 0.02 km per hour whereas outside was 2.56 ± 0.55, 1.11 ± 0.16, 0.43 ± 0.08 and 0.33 ± 0.06 km per hour and the difference was 1.84, 0.89, 0.34 and 0.22 km per hour during S_1, S_2, S_3 and S_4 season, respectively. Inside, outside and their difference WV was observed decreasing order from summer hot dry to mild winter cold dry seasons during the entire period of experiment. The analysis of variance showed significantly ($P < 0.05$) higher difference during S_1 than the other seasons. And during S_2 season difference was higher than S_3 and S_4 seasons that were at par.

During summer hot dry season the mean wind velocity inside the calf pen was recorded to be 0.67 ± 0.15, 0.77 ± 0.01 and 0.77 ± 0.26 km per hour whereas outside was 2.57 ± 0.66, 2.52 ± 0.38 and 2.60 ± 0.62 km per hour and the difference was 1.9, 1.75 and 1.83 km per hour at IF, LRS and HF farm, respectively (Table 4.11B. and Fig 26). Inside WV was observed lower at calf pen on IF than on LRS and HF, however, outside WV was lower at calf pen on HF than on IF and LRS. A non-significant ($P < 0.05$) differences were observed for calf pen on IF, LRS and HF farms. Parihar *et al.* (1992) reported wind velocity of 4.56 and 2.56 kms/hr during summer and winter, respectively. Stowell *et al.* (1998) studied the radiant heating and thermal environment of metal roofed dairy barns and observed that air and black globe temperature at two roofing exposed to both wind and solar radiation greatly influenced the outdoor black globe temperature and roof underside temperature and considerable healing of weathered metal roofing occurred when not exposed to a good breeze.

The mean wind velocity inside the calf pens during monsoon rainy wet season was recorded to be 0.30 ± 0.04, 0.21 ± 0.02 and 0.16 ± 0.02 km per hour whereas outside was 1.14 ± 0.18, 0.96 ± 0.12 and 1.25 ± 0.19 km per hour and the difference was 0.84, 0.75 and 1.09 km per hour at IF, LRS and HF farms respectively. Inside WV highest at calf pen on IF than on LRS & HF, however, outside WV at calf pen on HF was higher than calf pens on IF & LRS. Analysis the differences were at par for calf pens on IF, LRS and HF farms.

The mean wind velocity during hot humid season inside the calf pens was recorded to be 0.16 ± 0.03, 0.11 ± 0.03 and 0.00 ± 0.00 km per hour whereas outside was 0.53 ± 0.09, 0.51 ± 0.10 and 0.24 ± 0.06 km per hour and the difference was 0.37, 0.40 and 0.24 km per hour at IF, LRS and HF farm, respectively. Inside WV was lowest practically zero at calf pen on HF. Outside WV also was observed lower than on the calf pens on LRS and IF. They differed non-significantly ($P < 0.05$) from each other.

During mild cold dry season mean wind velocity inside the calf pens was recorded to be 0.13 ± 0.03, 0.08 ± 0.00 and 0.11 ± 0.03 km per hour whereas outside was 0.38 ± 0.08, 0.13 ± 0.03 and 0.48 ± 0.08 km per hour and the difference was 0.25, 0.05 and 0.37 km per hour at IF, LRS and HF farm, respectively. Inside and outside WV was observed lowest at calf pen on HF than on IF and LRS, whereas, lowest difference observed at calf pen on LRS than on HF & IF. However, they were at par. Parihar *et al.* (1992) reported wind velocity of 4.56 and 2.56 kms/hr during summer and winter, respectively.

4.2.4 Micro and macro light intensity

Irrespective of farms mean light intensity (lux) inside and outside of calf pens at 7.30 am during different seasons are presented in Table 4.7A and depicted in Fig 15. Mean light intensity inside the calf pen was recorded to be 376.94 ± 67.84, 350.79 ± 59.05, 606.9 ± 78.13 and 347.9 ± 59.57 (X1) lux whereas outside was 9233.2 ± 103.0, 5139.0 ± 92.07, 4821.0 ± 62.55 and 1405.77 ± 118.50 (X 10) lux and the difference was 8856.2, 4788.2, 4214.4 and 1057.8 (X1) lux during season, respectively. Inside LI observed lower during rainy & winter cold dry than during summer hot dry & hot humid seasons. Because of rain and cloud during monsoon rainy wet season whereas, during short day length and low intensity of light than other

Table 4.12A Micro-macro light intensity (lux) of calf pen on different farms at 7.30 am.

Season/ Farm	S_1			S_2			S_3			S_4		
	In (X1)	Out (X10)	Diff.	In (X1)	Out (X10)	Diff.	In (X1)	Out (X10)	Diff.	In (X1)	Out (X10)	Diff.
IF	621.66± 132.8	1084.16 ± 83.20	10219	423.80 ± 59.69	409.52 ± 71.01	3671.4	648.57 ± 109.40	751.42 ± 112.79	6865.6	312.77 ± 49.08	170.00 ± 10.64	1387
LRS	121.66 ± 22.59	1240.00 ± 97.83	10183	418.57 ± 87.01	630.95 ± 92.84	5890.9	829.28 ± 79.09	350.71 ± 31.33	2677.8	312.77 ± 49.8	164.44 ± 10.64	1331
H.F.	287.5 ± 48.10	445.81 ± 128.00	4170.6	210.00 ± 30.45	501.24 ± 109.38	4802.4	342.85 ± 45.92	344.28 ± 43.61	3099.9	418.33 ± 79.84	119.66 ± 44.24	1498
Avg.	376.94 ± 67.84	923.32± 103.01	8856.2	350.79 ± 59.05	513.90± 92.07	4788.2	606.9± 78.13	482.1± 62.55	4214.4	347.9± 59.57	175.37 ± 18.50	1057

Table 4.12B Micro-macro light intensity (lux) of calf pen on different farms at 2.30 pm.

Season/ Farm	S_1			S_2			S_3			S_4		
	In (X10)	Out (X100)	Diff.	In (X10)	Out (X100)	Diff.	In (X10)	Out (X100)	Diff.	In (X10)	Out (X100)	Diff.
IF	232.50 ± 39.94	613.00 ± 26.35	58975	379.52 ± 66.34	224.76 ± 22.03	18681	374.28 ± 72.04	520.00 ± 69.64	48257	168.89 ± 13.40	397.78 ± 14.43	38089
LRS	227.50 ± 56.63	585.83 ± 42.20	56308	422.30 ± 66.76	248.09 ± 28.27	29686	290.57 ± 20.70	544.28 ± 18.51	51522	148.61 ± 16.51	296.11 ± 24.47	28124
HF	158.33 ± 34.72	570.00 ± 45.62	55416	191.90 ± 22.49	281.90 ± 31.60	26.271	292.86 ± 104.64	522.14 ± 22.49	49285	211.11 ± 12.17	464.44 ± 15.91	44332
Avg.	206.11± 43.76	589.61 38.05	56899	331.24 ± 51.86	251.58 ± 27.34	21845	319.23 ± 65.79	528.80 ± 36.88	49687	176.20 ± 14.02	386.11 ± 18.27	36849

Fig 15 Light intensity (lux) in calf pen 7.30 am

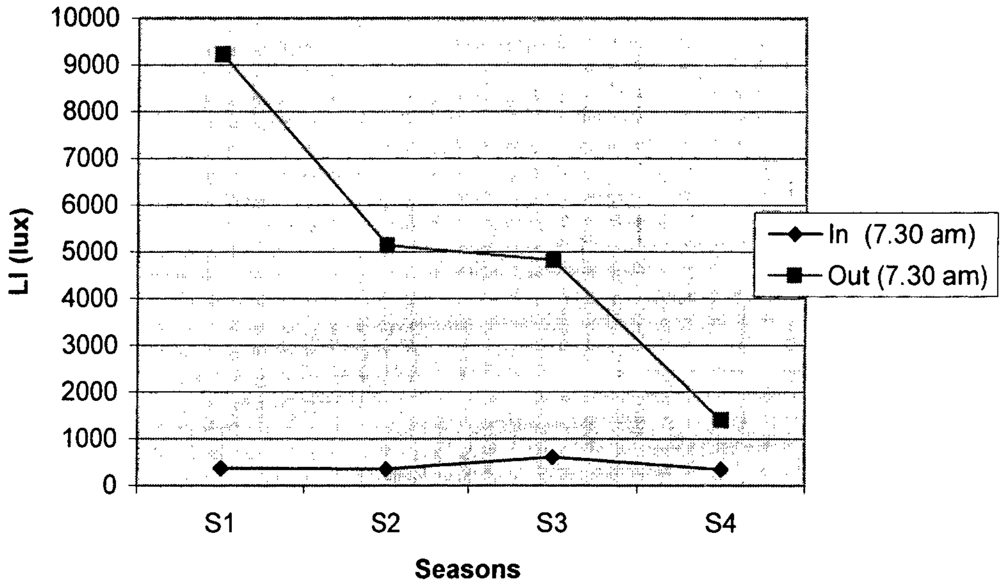
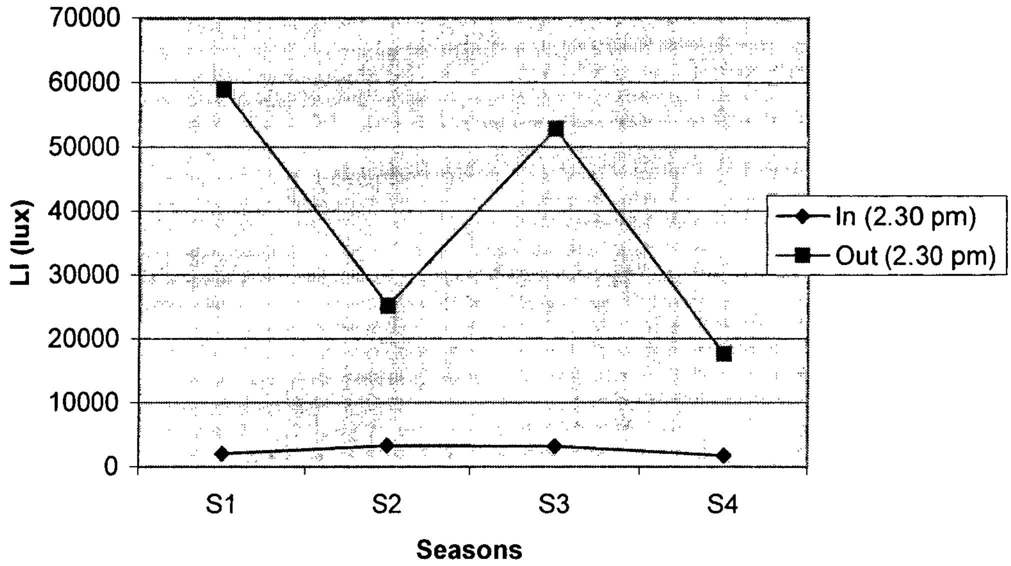


Fig 16 Light intensity (lux) in calf pen 2.30 pm



seasons. Outside LI was observed Highest during S_1 & lowest during S_4 seasons. The analysis of variance showed significant ($P < 0.05$) higher difference during than during, S_2, S_3 and S_4 seasons. S_4 differed from S_2 & S_3. S_2 & S_3 seasons were at par.

The mean light intensity were recorded at 7.30 am at calf pens on different farms during different seasons (Table 4.12A and Fig 22). The mean light intensity during summer hot dry season inside the calf pens was recorded to be 621.66 ± 132.83, 121.66 ± 22.59 and 287.5 ± 48.10 (X1) lux whereas outside was1084.14 ± 83.20, 1240.0 ± 97.83 and 445.81 ± 128.0 (X 10) lux and the differences was 10219.9, 10183.4 and 4170.6 (X1) lux at IF, LRS and HF farm respectively. Higher LI was observed inside calf pen on IF than HF and LRS. They were differed significantly from each other for differences.

The mean light intensity during monsoon rainy wet season inside the calf pen was recorded to be 423.80 ± 59.69, 418.57 ± 87.01 and 210.00 ± 30.45 (X1) lux whereas outside was 409.52 ± 71.01, 630.95 ± 92.84 and 501.24 ± 109.38 (X 10) lux and the difference was 3671.4, 5890.93 and 4802.4 (X 1) lux at IF, LRS, and HF farm, respectively. They were at par.

During hot humid season the mean light intensity inside the calf pen was 648.42 ± 109.4, 829.28 ± 79.09 and 342.85 ± 45.92 (X1) lux whereas outside was 751.42 ± 112.79, 350.71 ± 31.33 and 344.28 ± 43.6 (X 10) lux and difference was 6865.6, 2677.8 and 3099.9 (X1) lux at If, LRS and HF farm, respectively.

The mean light intensity during mild winter cold dry season inside the calf pen was recorded to be 312.77 ± 49.08, 312.77 ± 49.8 and 418.0 ± 79.84 (X10) lux whereas outside was 170.00 ± 10.64, 164.44 ± 10.64 and 119.66 ± 4.24 (X100) lux and the difference was 1387.23, 1331.63 and 1498.27 (X 1) lux at IF, LRS and HF farm, respectively. They showed non-significant ($P < 0.05$) for calf pens on IF, LRS and HF farms.

Irrespective of farms mean inside and outside light intensity at 2.30 pm during different season are presented in Table 4.7B and depicted in Fig 16. Mean light intensity inside the calf pen was recorded to be 206.11 ± 43.76, 331.24 ± 51.86, 319.23 ± 65.79 and 176.2 ± 14.02(X10) where as outside 589.61 ± 38.05, 251.58 ± 27.34, 528.8 ± 36.88 and 386.11 ± 18.27(X100) and the difference was 5600, 21846, 49688 and 36849 (X1) during S_1, S_2, S_3 and S_4 season, respectively. Lowest inside LI observed during S_4 than the other, however, outside LI was higher during S_1 and S_4 that were hot dry and hot humid season, respectively. Difference LI was observed significantly ($P < 0.05$) highest during S_1 followed S_3. S_2 and S_4 seasons were at par.

The mean light intensity during different seasons at calf pens of different farms are presented in Table 4.12B and depicted in Fig 23. The mean light intensity inside the calf pen during summer hot dry season was recorded to be 232.50 ± 39.94, 227.50 ± 56.63 and 158.33 ± 34.72 (x 10) lux whereas outside was 613.00 ± 26.35, 585.83 ± 42.20 and 570.00 ± 45.62 (X 100) lux and the difference was 58975, 56308 and 55416.7 (X 1) lux at IF, LRS and HF farm, respectively. Inside LI was lowest in calf pen on HF than on IF and LRS, however, outside LI observed higher at calf pen on IF than on LRS and HF farms. Though the differences were at par.

The mean light intensity inside the calf pen during monsoon rainy wet season was recorded to be 379.52 ± 66.34, 422.30 ± 66.76 and 191.90 ± 22.49 (X10) lux whereas outside was 224.76 ± 22.03, 248.09 ± 28.27 and 281.90 ± 31.6 (X 100) lux and the difference was 18681, 29686 and 26271 (X1) lux at IF, LRS and HF farm, respectively. Inside LI observed in calf pen on HF than IF and LR, however, higher outside LI observed at HF than IF. It might be due to different type of calf pen on HF than the others.

During hot humid season the mean light intensity inside the calf pen was recorded to be 374.28 ± 72.04, 290.57 ± 20.70 and 292.86 ± 104.64 (X10) lux and outside was 520.0 ± 69.64, 544.28 ± 18.51 and 522.14 ± 22.49 (X 100) lux and the difference was 48257, 51522.3 and 49285.4 (X1) lux at IF, LRS and HF farm, respectively. Inside LI observed higher at calf pen on IF than on LRS and HF.

The mean light intensity during mild winter cold dry season inside the calf pen was 168.89 ± 13.40, 148.61 ± 16.51 and 211.11 ± 12.17 (X10) lux whereas outside was 397.78 ± 14.43, 296.11 ± 24.47 and 464.44 ± 15.91 (X100) lux and the difference was 38089.1, 28124.9 and 44332.9 (X1) lux at IF, LRS and HF farm, respectively. The difference LI was non-significantly ($P < 0.05$) differed for the calf pens on IF, LRS and HF farms.

4.3 Status of Micro and Macro climate in Poultry Houses

4.3.1 Micro and macro temperature

Mean inside and outside temperature at 7.30 am morning during different seasons were recorded at poultry houses of Central Poultry Research Institute, A.A.U, Anand, irrespective of type of houses are presented in Table 4.13A and depicted in Fig 3. Inside the poultry houses mean temperature recorded 31.74 ± 0.19, 25.28 ± 0.25, 28.71 ± 0.42 and 22.05 ± 0.56°C whereas outside temp of the poultry houses was 33.44 ± 0.32, 24.28 ± 0.23, 28.06 ± 0.77 and 20.75 ± 0.59°C during and the mean difference (outside minus inside the poultry house) was 2.7, -0.64, -0.65 and -1.3°C during S_1, S_2, S_3 and S_4 seasons respectively. During hot dry (S_1) season inside temperature observed to be 2.7 °C lower than outside the house. While as per reported the inside temperature was higher during S_2, S_3 and S_4 seasons due to seasonal variation in temperature. The analysis of variance showed significant difference ($P < 0.05$) among the difference (outside minus inside the house) means during hot dry and winter seasons.

Inside temperature the poultry house at 7.30 am during summer hot dry season observed 31.70 ± 0.12, 31.71 ± 0.23 and 31.81 ± 0.22°C and outside 32.95 ± 0.19, 33.65 ± 0.40 and 33.71 ± 0.36°C while the difference (outside minus inside) was 1.25, 1.94 and 1.90°C at deep litter (BDLH), cage (LCH) and cage with raised platform (LCH + RP) (Table 4.14A and Fig 27). Higher temperature was inside the (LCH + RP) house than other houses. The difference was less at BDLH than CLH and CLH+RP, however, differences were non-significant.

The mean temperature during monsoon rainy wet (S_2) season recorded inside the poultry house was 25.43 ± 0.24, 25.30 ± 0.26 and 25.12 ± 0.25°C; outside 24.60 ± 0.22, 24.67 ± 0.23 and 24.64 ± 0.23°C and the difference (outside minus inside) was -

Table 4.13A Mean micro and macroclimatic variables of Poultry shed during different seasons at 7.30 a.m.

Met. Obs.	Season											
	S1			S2			S3			S4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
Temp (°C)	31.74 ± 0.19	33.44 ± 0.32	1.69	25.28 ± 0.25	24.64 ± 0.23	-0.64	28.71 ± 0.42	28.06 ± 0.77	-0.65	22.05 ± 0.50	20.75 ± 0.59	-1.3
RH (%)	63.84 ± 3.53	63.87 ± 3.75	0.03	93.97 ± 0.95	95.52 ± 0.69	1.55	71.76 ± 1.82	75.42 ± 2.23	3.66	44.49 ± 3.73	48.22 ± 3.50	3.73
WV (kms/hr)	0.50 ± 0.08	2.55 ± 0.38	2.05	0.074 ± 0.01	0.79 ± 0.09	0.72	0.152 ± 0.06	0.36 ± 0.06	0.208	0.08 ± 0.03	0.16 ± 0.04	0.076
LI (Lux)	376 ± 83	1219 ± 77	1182 1	128 ± 16	237 ± 50	2247	511 ± 91	3699 ± 26	3188	376 ± 66	1934 ± 110	1558
THI	82.90 ± 0.70	85.45 ± 0.95		76.85 ± 0.42	75.89 ± 0.40		79.64 ± 0.55	79.25 ± 1.10		67.81 ± 1.01	66.35 ± 0.98	

Table 4.13B Mean micro and macroclimatic variables of Poultry shed during different seasons at 2.30 p.m.

M. Obs.	Season											
	S1			S2			S3			S4		
	I	O	Diff.	I	O	Diff.	I	O	Diff.	I	O	Diff.
Temp (°C)	37.70 ± 0.23	42.87 ± 0.23	5.17	28.7 ± 0.40	29.78 ± 0.44	1.08	32.78 ± 0.15	37.49 ± 0.59	4.71	33.56 ± 0.33	36.98 ± 0.62	3.42
RH (%)	45.66 ± 1.19	39.91 ± 1.24	-5.74	90.29 ± 1.01	90.27 ± 1.11	-0.02	65.23 ± 0.67	61.24 ± 1.55	-3.99	38.05 ± 2.04	34.54 ± 1.95	-3.51
WV kms/hr)	0.44 ± 0.07	2.76 ± 0.39	2.32	0.21 ± 0.02	1.22 ± 0.12	1.01	0.09 ± 0.09	0.50 ± 0.02	0.41	0.07 ± 0.02	0.35 ± 0.08	0.28
LI (Lux)	257 ± 32.98	621± 31.71	5960 6	145 ± 17.13	249 ± 32.13	23516	246 ± 39.09	507 ± 26.1	48245	164.25 ± 16.35	388 ± 24.14	37208
THI	87.35 ± 0.37	92.25 ± 0.46		82.80 ± 0.63	84.09 ± 0.68		84.71 ± 0.35	90.67 ± 0.98		79.53 ± 0.60	84.17 ± 1.05	

ANOVA table of differences mean of climatic factors poultry houses at 7.30 am

Sr. No.	Source	DF	Mean Squares			
			Temp	RH	WV	LI
1.	Replication	3	1.939	2.274	0.673	3521229
2.	Season	3	4.628*	28.630*	10.599*	189173542*
3.	Treatment (houses)	2	0.953	8.786	0.230	21844093*
4.	SXH	6	1.147	6.210	0.137	23621141*
5.	Error	33	0.953	3.733	0.243	5453219

* ($P<0.05$)

Difference mean temperature (°C) of poultry houses at 7.30 am

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
1.72^b	0.58^a	1.97^b	1.16^b	*	0.814

B) Houses

BDLH	CLH	CLH+RP	Test	CD
1.7	1.59	1.11	NS	-

C) Season x Treatment (house)

	BDLH	CLH	CLH+RP	Test	CD
S_1	1.27	1.92	1.96	NS	-
S_2	0.77	0.47	0.48	NS	-
S_3	2.48	2.53	0.90	NS	-
S_4	0.95	1.445	1.10	NS	-

Difference mean relative humidity (%) of poultry houses at 7.30 am

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
2.69^a	1.61^a	5.24^c	3.69^{ab}	*	1.611

B) Treatment (houses)

BDLH	CLH	CLH+RP	Test	CD
4.146	3.08	2.71	NS	-

C) Seasons X Treatment

	BDLH	CLH	CLH+RP	Test	CD
S_1	3.90	3.65	0.99	NS	-
S_2	1.42	1.25	2.16	NS	-
S_3	7.32	4.90	3.41	NS	-
S_4	3.91	2.92	4.25	NS	-

Difference mean wind velocity of poultry houses at 7.30 am

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
2.18[c]	0.86[b]	0.25[a]	0.12[a]	*	0.411

B) Treatments (houses)

BDLH	CLH	CLH+RP	Test	CD
0.935	0.91	0.72	NS	-

C) Season X Treatment

	BDLH	CLH	CLH+RP	Test	CD
S_1	2.49	2.28	1.75	NS	-
S_2	0.88	0.94	0.76	NS	-
S_3	0.20	0.29	0.26	NS	-
S_4	0.16	0.12	0.08	NS	-

Difference mean light intensity of poultry houses at 7.30 am.

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
1028[d]	2426[b]	3384[c]	1613[a]	*	674

B) Treatments (houses)

BDLH	CLH	CLH+RP	Test	CD
3390[a]	4196[b]	5693[c]	*	583

C) Season X Treatment

	BDLH	CLH	CLH+RP	Test	CD
S_1	6157[a]	9155[b]	15534[c]	*	1167
S_2	2706	2492	2080	NS	-
S_3	3241	3222	3687	NS	-
S_4	1455	1915	1469	NS	-

ANOVA Table of differences mean of poultry houses at 2.30 pm

Sr. No.	Source	DF	Mean Squares			
			Temp	RH	WV	LI
1.	Replication	3	8.045	3.243	0.264	412752
2.	Season	3	50.078*	47.368	11.944*	278846612*
3.	Treatment (houses)	2	0.178	1.741	0.347	923411
4.	SXH	6	0.334	9.079	0.347*	483358
5.	Error	33	1.861	4.899	0.586	571795

*($P<0.05$)

Difference temperature mean of poultry houses at 2.30 pm

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
5.14^b	0.74^a	4.34^b	4.83^b	*	1.137

B) Treatments (houses)

BDLH	CLH	CLH+RP	Test	CD
3.84	3.81	3.64	NS	-

C) Seasons x Treatments

	BDLH	CLH	CLH+RP	Test	CD
S_1	5.05	4.90	5.47	NS	-
S_2	0.73	0.87	0.61	NS	-
S_3	4.59	4.41	4.02	NS	-
S_4	4.96	5.06	4.47	NS	-

Differences mean relative humidity (%) of poultry houses at 2.30 pm

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
6.06^c	1.27^a	4.44^{ab}	3.72^b	*	1.85

B) Treatments

BDLH	CLH	CLH+RP	Test	CD
3.99	4.13	3.50	NS	-

C) Season X Treatment

	BDLH	CLH	CLH+RP	Test	CD
S_1	6.91	4.58	6.67	NS	-
S_2	0.83	1.5	1.5	NS	-
S_3	5.25	6.33	1.75	NS	-
S_4	3.00	4.08	4.08	NS	-

Difference mean wind velocity of poultry houses at 2.30 pm

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
2.44^{c}	0.96^{b}	0.43^{a}	0.25^{a}	*	0.321

B) Treatments

BDLH	CLH	CLH+RP	Test	CD
1.18	0.89	1.00	NS	-

C) Season X Treatment

	BDLH	CLH	CLH+RP	Test	CD
S_1	3.18^{c}	1.78^{a}	2.39^{b}	*	0.555
S_2	1.00	1.04	0.86	NS	-
S_3	0.35	0.36	0.57	NS	-
S_4	0.19	0.37	0.19	NS	-

Difference mean light intensity of poultry houses at 2.30 pm

A) Seasons

S_1	S_2	S_3	S_4	Test	CD
6040^{d}	2419^{a}	4839^{c}	3960^{b}	*	630

B) Treatments

T_1	T_2	T_3	Test	CD
4057	4533	4352	NS	-

C) Season X Treatment

	T_1	T_2	T_3	Test	CD
S_1	6011	6144	5964	NS	-
S_2	2194	2532	2529	NS	-
S_3	4840	4804	4872	NS	-
S_4	3184	4654	4042	NS	-

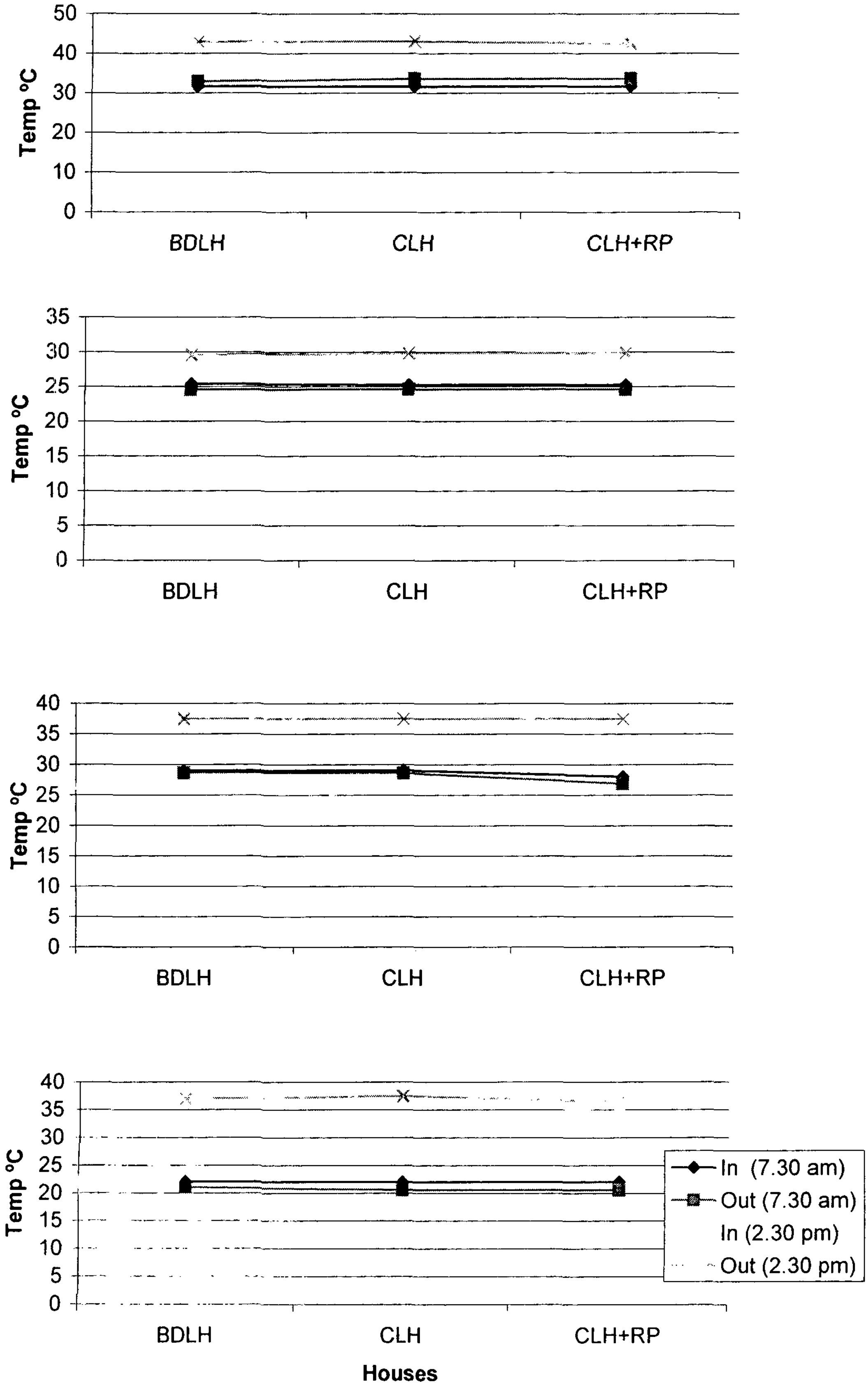
Table 4.14A Micro-macro temperature (^oC) of poultry houses at 7.30 am

Season/ Farms	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
BDL	31.70 ± 0.12	32.95 ± 0.19	1.25	25.43 ± 0.24	24.60 ± 0.22	-0.83	28.99 ± 0.46	28.64 ± 1.01	-0.35	22.08 ± 0.56	21.06 ± 0.71	-1.02
LCH	31.71 ± 0.23	33.65 ± 0.40	1.94	25.30 ± 0.26	24.67 ± 0.23	-0.63	29.07 ± 0.46	28.64 ± 1.01	-0.43	22.01 ± 0.55	20.60 ± 0.57	-1.41
LCH + RP	31.81 ± 0.22	33.71 ± 0.36	1.90	25.12 ± 0.25	24.64 ± 0.23	-0.48	28.06 ± 0.33	26.90 ± 0.29	-1.16	22.06 ± 0.58	20.60 ± 0.49	-1.46
Avg.	31.74 ± 0.19	33.44 ± 0.32	1.696	25.28 ± 0.25	24.64 ± 0.23	-0.64	28.71 ± 0.42	28.06 ± 0.77	-0.65	22.05 ± 0.56	20.75 ± 0.59	-1.3

Table 4.14B Micro-macro temperature (^oC) of poultry houses at 2.30 pm

Season/ House	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
BDL	37.88 ± 0.13	42.92 ± 0.31	5.04	28.03 ± 0.40	29.60 ± 0.49	1.57	32.55 ± 0.15	37.48 ± 0.72	4.93	32.43 ± 0.28	36.99 ± 0.53	4.56
LCH	38.16 ± 0.29	43.11 ± 0.27	4.95	29.00 ± 0.41	29.83 ± 0.45	0.83	32.66 ± 0.15	37.48 ± 0.72	4.82	32.68 ± 0.39	37.50 ± 0.61	4.82
LCH + RP	37.07 ± 0.28	42.57 ± 0.38	5.50	29.07 ± 0.41	29.92 ± 0.38	0.85	33.15 ± 15.27	37.52 ± 0.33	4.37	35.58 ± 0.32	36.45 ± 0.72	0.87
Avg.	37.70 ± 0.23	42.87 ± 0.32	5.17	28.7 ± 0.40	29.78 ± 0.44	1.08	32.78 ± 0.15	37.49 ± 0.59	4.71	33.56 ± 0.33	36.98 ± 0.62	3.42

Fig 27 Temperature (ºC) in poultry houses during S1, S2, S3 & S4 seasons



0.83, -0.73 and -0.48°C at BDLH, LCH and LCH + RP, respectively. Average inside temperature was higher in BDLH than the LCH and LCH + RP house. The difference (outside minus inside) at LCH + RP was higher due to height floor, more exposed to environment than the BDLH, LCH. Though analysis of variance showed non-significant ($P < 0.05$) differences

The mean temperature during hot humid season inside poultry house was recorded to be 28.99 ± 0.46, 29.07 ± 0.46 and 28.06 ± 0.33°C and outside the shed was 28.64 ± 0.01, 28.64 ± 1.01 and 26.90 ± 0.29°C. The difference (outside minus inside) was -0.35, -0.43 and -1.16°C at BDL, LCH and LCH + RP respectively. Inside temperature of BDLH and LCH was higher than LCH + RP. It might be a more exposure to environment due to the raised platform of LCH + RP. However, Kanga *et al.* (2002) observed lower temperature (26.06^{0}C) than afternoon (31.80±0.16^{0}C) and evening (28.27±0.21^{0}C) hours. They also observed that the layer house on raised platform had significantly ($p<0.01$) higher temperature (29.05±1.61^{0}C) than those in cage house (28.79±1.65^{0}C) and deep litter house system (28.28±1.76^{0}C).

The mean temperature during winter cold dry S_4 season at poultry complex inside the house was 22.08 ± 0.56, 22.01 ± 0.55 and 22.06 ± 0.58°C at BDL, LCH, LCH + RP. The outside temperature was 21.06 ± 0.71, 20.60 ± 0.57°C and 20.60 ± 0.49 and difference (outside minus inside) was -1.02, 1.41 and -1.46°C at BDL, LCH and LCH +RP, respectively. The inside temperature of these houses were little higher that was desirable during winter season, however, the differences were at par

Irrespective of houses means inside and outside temperature at 2.30 pm afternoon during different seasons are presented in Table 4.13B and depicted in Fig 3. The mean inside temperature of poultry house was 37.70 ± 0.23, 28.70 ± 0.40, 32.78 ± 0.15 and 33.56 ± 0.33°C whereas outside 42.87 ± 0.32, 29.78 ± 0.44, 37.49 ± 0.59

and 36.98 ± 0.62°C during S_1, S_2, S_3 and S_4 season, respectively. The difference (outside minus inside) was 5.17, 1.08, and 4.71 and 3.42°C during S_1, S_2, S_3 and S_4 season, respectively. Higher difference was observed during hot dry (S_1) and S_3 hot humid seasons than the monsoon rainy wet (S_2) and mild cold (S_4) seasons. The analysis of variance showed significant ($P < 0.05$) lower difference during S_2 than during S_1, S_3 and S_4 seasons.

The inside temperature at 2.30 pm during S_1 season was recorded to be 37.88 ± 0.13, 38.16 ± 0.29 and 37.07 ± 0.28°C whereas outside was 42.92 ± 0.31, 43.11 ± 0.27 and 42.57 ± 0.38 at BDL, LCH and LCH + RP, respectively. The differences (outside minus inside) was 5.04, 4.95, 5.50°C at BDL, LCH and LCH + RP respectively (Table 4.14B and Fig 27). A higher temperature was observed inside the cage house than deep litter & cage with raised platform. This might be due to higher temperature recorded outside the house. The analysis of variance showed non-significant ($P < 0.05$) difference among differences (outside minus inside) mean of BDL, LCH and LCH + RP type poultry houses. Murlidharan *et al.* (2001) found significantly ($P < 0.01$) lower temperature (32.93 ± 0.150°C) in the sheds with foggers than the sheds without foggers (36.14 ± 0.142°C). They recorded similar temperature (34.75 vs 34.38 °C) and lower relative humidity (44.82 ± 0.832 vs 52.46 ± 1.037 per cent) in asbestos roofed shed than those in tile roofed poultry shed.

The mean inside temperature during monsoon rainy wet (S_2) season recorded 28.03 ± 0.40, 29.00 ± 0.41 and 29.07 ± 0.41°C whereas outside was 29.60 ± 0.49, 29.83 ± 0.45 and 29.92 ± 0.38°C and the difference (outside minus inside) was 1.57, 0.83 and 0.85 in BDL, CLH, CLH + RP respectively. Though differences were at par.

During hot humid (S_3) season mean inside temperature was recorded to be 32.55 ± 0.15, 32.66 ± 0.15 and 33.15 ± 0.33 whereas outside was 37.48 ± 0.72, 37.48

± 0.72 and 37.62 ± 0.33°C and the difference (outside minus inside) was 4.93, 4.82 and 4.37°C in BDL, CLH and CLH + RP respectively. Inside temperature was observed higher in CLH + RP than BDL & CLH, however, outside temperature was similar. The differences were non-significant ($P < 0.05$). Kanga *et al.* (2002) observed higher temperature at afternoon (31.80±0.16°C) and evening (28.27±0.21°C) than the morning hours. They also observed that the layer house on raised platform had significantly ($p<0.01$) higher temperature (29.05±1.61°C), than those in cage house (28.79±1.65°C), deep litter house system (28.28±1.76°C).

The average inside temperature during mild winter (S_4) season recorded 32.43 ± 0.28, 32.68 ± 0.39 and 35.58 ± 0.32 whereas outside was 36.99 ± 0.53, 37.50 ± 0.61 and 36.45 ± 0.72°C and difference (outside minus inside) was 4.56, 4.82 and 0.87°C in BDL, CLH and CLH + RP respectively. Analysis of variance showed non-significant ($P < 0.05$) difference among differences (outside minus inside) mean above said types of poultry houses.

The differences during different seasons at CLH + RP type was lesser than the CLH & BDL type of poultry houses. It may be due to construction difference between the houses i.e. raised platform that exposed more to external environment than the houses having less height ground floor. Gill and Kansal (1993) studied the effect of rearing system of birds i.e. cage system and deep litter system on microclimate of house and reported that maximum temperature was significantly ($P < 0.01$) higher in shed with cage system than shed with deep litter system in winter October (28.83 Vs 28.97 °C), November (26.11 Vs 23.71 °C), December (24.31 Vs 17.66 °C) and January (23.43 Vs 22.16 °C)

4.3.2 Micro and macro relative humidity

Both high relative humidity and high temperature inside the poultry houses increases mortality. High temperature adversely affects the egg production in layer and reproduction in breeder birds.

Irrespective of poultry houses means daily inside and outside relative humidity percent at 7.30 am during different seasons are presented in Table 4.13A and depicted in Fig 6. The mean relative humidity inside the poultry houses was 63.84 ± 3.53, 93.97 ± 0.95, 71.76 ± 1.82 and 44.49 ± 3.73 per cent whereas outside it was 63.87 ± 3.75, 95.52 ± 0.69, 75.42 ± 2.23 and 48.22 ± 3.50 per cent and the difference was (outside minus inside) 0.03, 1.55, 3.66 and 3.73 per cent during S_1, S_2, S_3 and S_4 season, respectively. The difference was less during hot dry and more during cold dry season. Highest relative humidity as per expectation it was during monsoon to the tune of 93-95% ($P < 0.05$) Kanga *et al.* (2002) observed higher relative humidity (74.49±1.27 percent) during morning than afternoon (59.93 ±1.32 percent) and evening (67.62 ±1.84 percent) hours. They also observed that the layer house on raised platform had significantly ($p<0.01$) higher relative humidity (85.84±0.81 percent) than those in cage house (67.12±4.03 percent) and deep litter (64.94±4.03 percent).

The mean inside and outside relative humidity percent at 7.30 am during different seasons at different types of poultry houses are shown in Table 4.15A and depicted in Fig 28. The average relative humidity per cent inside the house during hot dry season was lower than 66%, to the variation of 60.30 ± 3.54, 65.15 ± 3.40 and 66.07 ± 3.66 whereas outside was 63.76 ± 4.09, 63.23 ± 3.55 and 64.61 ± 3.62 per cent and the difference (outside minus inside) was 3.46, -1.92 and -1.46 at BDL, CLH and CLH + RP type of poultry houses respectively.

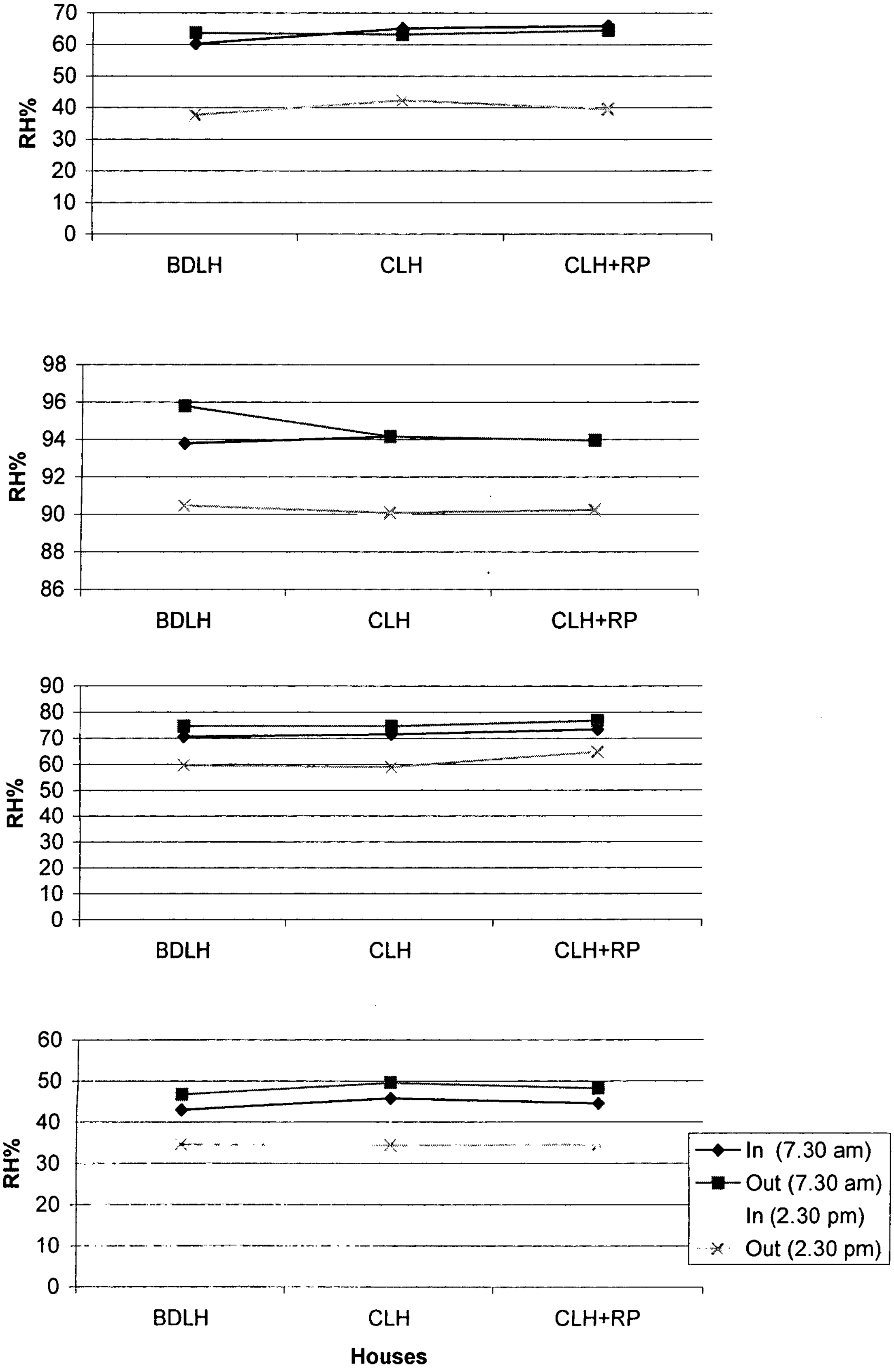
Table 4.15A Micro-macro relative humidity (%) of poultry houses at 7.30 am

Season/ House	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
BDL	60.30 ± 3.54	63.76 ± 4.09	3.46	93.80 ± 1.00	95.08 ± 0.81	1.28	70.71 ± 1.90	74.71 ± 2.64	4.5	43.05 ± 3.42	46.77 ± 3.13	3.72
LCH	65.15 ± 3.40	63.23 ± 3.55	-1.92	94.16 ± 0.95	95.84 ± 0.67	1.68	71.57 ± 2.17	74.71 ± 2.64	3.14	45.83 ± 3.80	49.61 ± 3.67	3.78
LCH + RP	66.07 ± 3.66	64.61 ± 3.62	-1.46	93.96 ± 0.90	95.64 ± 0.61	1.68	73.5 ± 1.4	76.84 ± 1.42	3.34	44.61 ± 3.96	48.27 ± 3.71	3.66
Avg.	63.84 ± 3.53	63.87 ± 3.75	0.027	93.97 ± 0.95	95.52 ± 0.69	1.55	71.76 ± 1.82	75.42 ± 2.23	3.66	44.49 ± 3.73	48.22 ± 3.50	3.73

Table 4.15B Micro-macro relative humidity (%)of poultry houses at 2.30 pm

Season/ House	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
BDL	44.46 ± 0.97	37.76 ± 0.90	-6.7	90.44 ± 1.11	90.48 ± 1.10	0.04	64.00 ± 0.65	59.78 ± 1.35	-4.22	37.44 ± 2.22	34.67 ± 2.25	-2.77
LCH	46.69 ± 1.87	42.38 ± 1.84	-4.31	89.98 ± 1.04	90.08 ± 1.19	0.28	65.07 ± 0.67	59.07 ± 1.40	-6.00	38.72 ± 1.97	34.39 ± 1.81	-4.33
LCH +RP	45.81 ± 0.75	39.61 ± 0.99	-6.23	90.64 ± 0.89	90.24 ± 1.04	-0.40	66.71 ± 1.44	64.86 ± 1.90	-1.85	38.00 ± 1.93	34.55 ± 1.89	-3.45
Avg.	45.66 ± 1.19	39.91± 1.24	-5.74	90.29 ± 1.01	90.27 ± 1.11	-0.02	65.23 ± 0.67	61.24 ± 1.55	-3.99	38.05 ± 2.04	34.54 ± 1.95	- .3.51

Fig 28 Relative humidity (%) in poultry house during S1, S2, S3 & S4 seasons



The mean relative humidity percent inside and outside the poultry house during monsoon rainy wet season was ranged 94%. They were 93.80 ± 1.00, 94.16 ± 0.95 and 93.96 ± 0.61 per cent inside the house whereas outside 95.08 ± 0.81, 95.84 ± 0.67 and 95.64 ± 0.61 per cent in BDL, CLH and CLH + RP respectively. The differences were less than 2 percent. (1.28, 1.68 and 1.68 per cent) in all houses

The mean relative humidity per cent inside the houses at 7.30 am during hot humid season was 70.71 ± 1.90, 71.57 ± 2.17 and 73.5 ± 1.4 per cent whereas outside the house was 74.71 ± 2.64, 74.71 ± 2.64 and 76.84 ± 1.42 of BDL, CLH and CLH + RP respectively. The difference (outside minus inside) was more at BDL (4.5) than CLH (3.14) and CLH + RP (3.39), however, they were at par.

The average relative humidity percent inside the poultry house during cold dry season was around 44 to 50 percent. The RH inside the house was 43.05 ± 3.42, 45.83 ± 3.80 and 44.61 ± 3.96 per cent whereas outside the poultry house was 46.77 ± 3.13, 49.61 ± 3.67 and 48.27 ± 3.71 per cent and the difference was of same magnitude of 3.72, 3.78 and 3.66 per cent in BDL, CLH and CLH + RP, respectively.

The mean inside and outside the poultry houses relative humidity percent were recorded during different seasons irrespective of type of houses are presented in Table 4.13B and depicted in Fig 6. The average relative humidity at 2.30 pm afternoon hrs percent inside the house recorded 45.66 ± 1.19, 99.29 ± 1.09, 65.23 ± 0.67 and 38.05 ± 2.04 per cent whereas outside was 39.91 ± 1.24, 90.27 ± 1.11, 61.24 ± 0.55 and 34.54 ± 1.95 per cent during S_1, S_2, S_3 and S_4 season, respectively. The difference (outside minus inside) was -5.74, -0.02, -3.99 and -3.51 percent. The RH was higher inside than outside due to output of moisture by excreta, water present inside the house. More difference (outside minus inside) observed during summer hot dry season and least difference during S_2. Highest RH observed during monsoon rainy wet season and lowest during dry mild cold dry season. RH was higher during hot humid than hot dry season that cause more stress to birds.

At 2.30 pm during different seasons the mean inside and outside the houses relative humidity percent are presented in Table 4.15B and depicted in Fig 28. The average relative humidity percent inside the houses during hot dry season was higher than the outside the house. It was 44.46 ± 0.97, 46.69 ± 1.87 and 45.81 ± 0.75 per cent inside the house whereas outside the house it was 37.76 ± 0.90, 42.38 ± 1.84 and 39.61 ± 0.99 per cent in BDL, CLH and CLH + RP, respectively. The difference was higher at CLH (-6.7) than BDL (-4.31) and LCH+RP (-6.23), but showed non-significant ($P < 0.05$) differences. Murlidharan *et al.* (2001) found relative humidity (53.66 ± 0.909%) was higher by 10% in shed with foggers than shed without foggers (43.69 ± 0.687%) and lower relative humidity (44.82 ± 0.832 vs 52.46 ± 1.037 per cent) in asbestos roofed shed than those in tile roofed poultry shed.

Gill and Kansal (1993) studied the effect of rearing system of birds i.e. cage system and deep litter system on microclimate of house. They recorded environmental parameters from sheds with. Maximum temperature was significantly ($P < 0.01$) higher in shed with cage system than shed with deep litter system in hot humid [July (33.41 Vs 32.46°C), August (33.02 Vs 31.71 °C), September (30.34 Vs 31.61 °C)] and winter October (28.83 Vs 28.97 °C), November (26.11 Vs 23.71 °C), December (24.31 Vs 17.66 °C) and January (23.43 Vs 22.16 °C).] The minimum temperature was significantly ($P < 0.01$) lower in asbestos roofed shed (cage system) in the months of July to January. The relative humidity (%) in sheds with cage system was significantly higher ($P < 0.01$) as compared to deep litter in hot humid months of July to November (34.79 Vs 33.25%) but was lower in December (55.59 Vs 60.89%) and January (55.44 Vs 50.40%).

The average relative humidity per cent inside the houses during monsoon rainy wet S_2 season was 90.44 ± 1.11, 89.98 ± 1.04 and 90.64 ± 0.89 whereas outside the house it was 90.48 ± 1.10, 90.08 ± 1.19 and 90.24 ± 1.04 per cent and the difference was 0.04, 0.28 and -0.40 per cent in BDL, CLH, CLH + RP house, respectively. The inside RH observed more than the outside at the CLH+RP type house. The differences were at par.

The mean relative humidity per cent during hot humid season inside the house it was 64.00 ± 0.65, 65.07 ± 0.67 and 66.71 ± 1.44 per cent whereas it was lowered to the tune of outside 59.78 ± 1.35, 59.07 ± 1.40 and 64.86 ± 1.190 per cent and showed negative difference the difference (outside minus inside) of -4.22, -6.00 and -1.85 per cent in BDL, CLH and CLH + RP, respectively. On account of higher outside the temperature during afternoon hours than the morning hours.

Kanga *et al.* (2002) observed higher relative humidity (74.49±1.27 percent) during morning than afternoon (59.93 ±1.32 percent) and evening (67.62 ±1.84 percent) hours They also observed that the layer house on raised platform had significantly ($p<0.01$) higher relative humidity (85.84±0.81 percent) than those in cage house relative humidity (67.12±4.03 percent) and deep litter house system relative humidity (64.94±4.03 percent). Gill and Kansal (1993) recorded the relative humidity (%) in sheds with cage system was significantly higher ($P < 0.01$) as compared to deep litter in hot humid months of July to November (34.79 Vs 33.25%) but was lower winter in December (55.59 Vs 60.89%) and January (55.44 Vs 50.40%).

The mean relative humidity per cent inside the poultry house during cold dry season was higher to be tune of 37.44 ± 2.22, 38.72 ± 1.97 and 38.00 ± 1.93 per cent whereas outside was 36.67 ± 2.25, 34.39 ± 1.81 and 34.55 ± 1.89 per cent and showed negative difference of -2.77, -4.33 and -3.45 per cent in BDL, CLH and CLH+RP, respectively. Both inside and outside RH at BDL were non-significantly little lower than at CLH & CLH+RP types of poultry houses. Gill and Kansal (1993) recorded the relative humidity (%) in sheds with cage system was significantly higher ($P < 0.01$) as compared to deep litter in hot humid months of July to November (34.79 Vs 33.25%) but was lower winter in December (55.59 Vs 60.89%) and January (55.44 Vs 50.40%).

4.3.3 Micro and macro THI

Heat stress condition is commonly considered as product of ambient temperature and relative humidity. The THI indicate additive effect of both temperature and humidity on body. At high ambient temperature, evaporative cooling is most important mechanism of body temperature control. The respiratory evaporative mechanism may cause a respiratory alkalosis, which is a result of hyperventilation due to panting may reduce the production of poultry.

During morning hours 7.30 am and noon hours at 2.30 pm mean THI inside and outside the poultry house irrespective of type of house during different seasons S_1, S_2, S_3 and S_4 were recorded and are presented in Table 4.13A & 4.13B and depicted in Fig 9. The THI and THIS calculated from data collected from Meteorology Laboratory are given in Table 4.24.

At 2.30 pm inside mean THI was observed 87.35 ± 0.37, 82.80 ± 0.63, 84.71 ± 0.35 & 79.53 ± 0.60 whereas outside the poultry house was 92.25 ± 0.46, 84.09 ± 0.68, 90.67 ± 0.98 & 84.17 ± 1.05 during S_1, S_2, S_3 and S_4 season, respectively. Highest THI observed during hot dry and hot humid seasons that were stressful seasons of the year. House type wise THI are presented in Table 4.16A & 4.16B. There was not much difference observed between the different types of poultry house.

Table 4.16A Micro-macro THI of poultry houses at 7.30 am

Season/ House	S_1		S_2		S_3		S_4	
	I	O	I	O	I	O	I	O
BDL	82.27 ± 0.61	84.66 ± 0.74	77.08 ± 0.40	75.79 ± 0.39	79.84 ± 0.57	79.80 ± 01.40	67.65 ± 0.93	66.62 ± 01.07
CLH	83.16 ± 0.77	85.66 ± 1.06	76.90 ± 0.43	75.98 ± 0.41	80.16 ± 0.59	79.80 ± 1.40	67.88 ± 1.04	66.30 ± 1.02
CLH+ RP	83.27 ± 0.72	86.03 ± 1.06	76.57 ± 0.43	75.91 ± 0.40	78.93 ± 0.50	78.15 ± 0.49	67.88 ± 01.07	66.13 ± 0.86
Avg.	82.90 ± 0.70	85.45 ± 0.95	76.85 ± 0.42	75.89 ± 0.40	79.64 ± 0.55	79.25 ± 1.10	67.81 ± 1.01	66.35 ± 0.98

Table 4.16B Micro-macro THI of poultry houses at 2.30 pm

Season/ House	S_1		S_2		S_3		S_4	
	I	O	I	O	I	O	I	O
BDL	87.30 ± 0.27	91.71 ± 0.39	82.80 ± 0.61	83.78 ± 0.77	84.14 ± 0.28	90.29 ± 01.06	79.23 ± 0.52	84.14 ± 1.03
CLH	88.17 ± 0.57	93.24 ± 0.57	82.68 ± 0.64	84.30 ± 0.70	84.49 ± 0.29	90.17 ± 01.13	79.82 ± 0.69	84.63 ± 0.98
CLH +RP	86.59 ± 0.27	91.80 ± 0.42	82.92 ± 0.65	84.30 ± 0.58	85.51 ± 0.49	91.55 ± 0.76	79.54 ± 0.59	83.49 ± 1.13
Avg.	87.35 ± 0.37	92.25 ± 0.46	82.80 ± 0.63	84.09 ± 0.68	84.71 ± 0.35	90.67 ± 0.98	79.53 ± 0.60	84.17 ± 1.05

4.3.4 Micro and macro wind velocity

Hot wind during summer, very low wind speed during hot humid season and high wind speed during cold dry season have a direct impact on heat dissipation by the bird. A breeze is desirable but higher wind speed is not desirable.

Mean inside and outside wind velocity (kms/hr) at 7.30 am during different seasons at poultry houses irrespective of type of houses are presented in Table 4.13A and depicted in Fig 12. Inside the poultry houses mean wind velocity was 0.50 ± 0.08, 0.074 ± 0.01, 0.152 ± 0.06 and 0.08 ± 0.03 kms per hour whereas the outside it was 2.55 ± 0.38, 0.79 ± 0.09, 0.36 ± 0.06 and 0.16 ± 0.04 kms per hour showing the difference (outside minus inside) of 2.05, 0.72, 0.20 and 0.07 kms per hour during S_1, S_2, S_3 and S_4 season, respectively. A decreasing trend in wind velocity recorded from S_1 to S_4 season throughout the experiment. Inside and outside wind velocity observed highest during S_1 and lowest during S_4 season. The analysis of variance showed significant ($P < 0.05$) differences for poultry house during S_1, S_2, S_3 and S_4 seasons.

The mean inside and outside wind velocity (kms/hr) at 7.30 am during different seasons were recorded at poultry houses of different types are presented in Table 4.17A and depicted in Fig 29. The average wind velocity inside the houses during summer hot dry season recorded 0.36 ± 0.06, 0.29 ± 0.05 and 0.86 ± 0.15 kms per hour whereas outside was 2.72 ± 0.41, 2.41 ± 0.39 and 2.51 ± 0.36 kms per hour and the difference was 2.36, 2.12 and 1.65 kms per hour in BDL, CLH and CLH + RP respectively.

During monsoon rainy wet season the mean wind velocity inside the poultry houses at 7.30 am was 0.03 ± 0.01, 0.66 ± 0.01 and 0.88 ± 0.12 kms per hour whereas outside 0.83 ± 0.15, 0.88 ± 0.12 kms per hour and the differences (outside minus

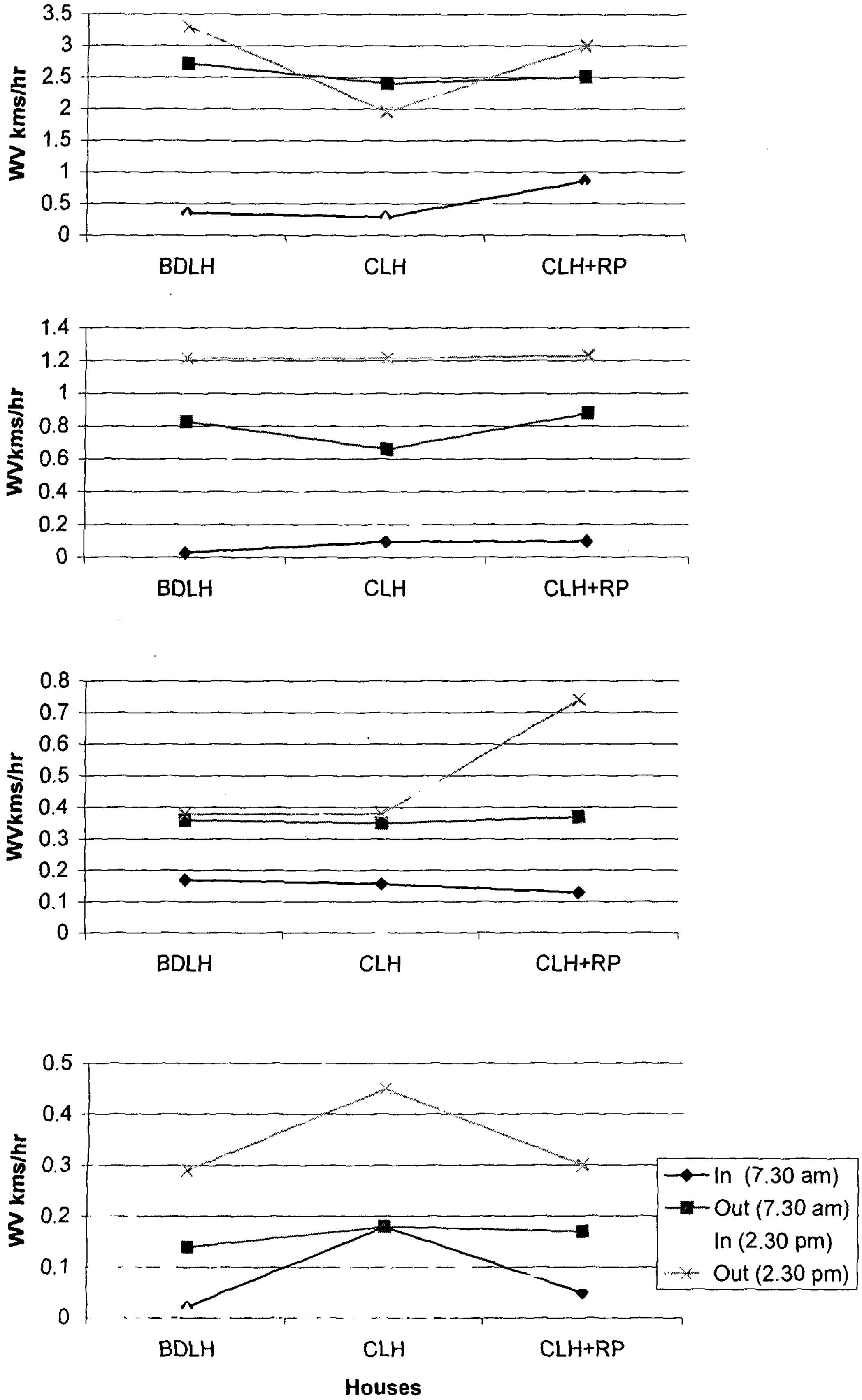
Table 4.17A Micro-macro wind velocity (kms/hr) of poultry houses at 7.30 am

Season/ House	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
BDL	0.36 ± 0.06	2.72 ± 0.41	2.36	0.03 ± 0.01	0.83 ± 0.15	0.8	0.17 ± 0.08	0.36 ± 0.07	0.19	0.022 ± 0.01	0.14 ± 0.04	0.118
LCH	0.29 ± 0.058	2.41 ± 0.39	2.12	0.096 ± 0.01	0.66 ± 0.01	0.56	0.157 ± 0.08	0.35 ± 0.078	0.19	0.18 ± 0.06	0.18 ± 0.06	0.00
LCH +RP	0.86 ± 0.15	2.51 0.36	1.65	0.096 ± 0.01	0.88 ± 0.12	0.78	0.128 ± 0.03	0.37 ± 0.53	0.24	0.05 ± 0.02	0.17 ± 0.04	0.12
Avg.	0.50 ± 0.08	2.55 ± 0.38	2.05	0.074 ± 0.01	0.79 ± 0.09	0.72	0.152 ± 0.06	0.36 ± 0.06	0.208	0.084 ± 0.01	0.16 ± 0.04	0.076

Table 4.17B Micro-macro wind velocity (kms/hr) of poultry houses at 2.30 p.m.

Season/ House	S_1			S_2			S_3			S_4		
	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.	In	Out	Diff.
BDL	0.31 ± 0.05	3.31 ± 0.53	3.00	0.072 ± 0.012	1.216 ± 0.125	1.144	0.03 ± 0.02	0.38 ± 0.09	0.35	0.02 ± 0.01	0.29 ± 0.05	0.27
LCH	0.26 ± 0.08	1.96 ± 0.23	1.70	0.168 ± 0.02	1.216 ± 0.115	1.048	0.02 ± 0.02	0.38 ± 0.09	0.36	0.12 ± 0.04	0.45 ± 0.12	0.33
LCH +RP	0.74 ± 0.09	3.0 ± 0.42	1.96	0.38 ± 0.05	1.23 ± 0.12	0.85	0.22 ± 0.04	0.74 ± 0.09	0.52	0.07 ± 0.02	0.30 ± 0.07	0.23
Avg.	0.44 ± 0.07	2.76 ± 0.39	2.32	0.21 ± 0.02	1.22 ± 0.12	1.01	0.09 ± 0.02	0.50 ± 0.09	0.41	0.07 ± 0.02	0.35 ± 0.08	0.28

Fig 29 Wind velocity in poultry during S1, S2, S3 & S4 seasons



inside the houses) were 0.8, 0.56 and 0.78 km per hour in BDL, CLH and CLH + RP respectively.

Where during hot humid season the mean wind velocity inside the poultry houses was very less to the tune of 0.17 ± 0.07, 0.157 ± 0.08 and 0.128 ± 0.03 kms per hour whereas outside was 0.36 ± 0.07, 0.35 ± 0.078 and 0.37 ± 0.053 kms per hour and the differences was 0.19, 0.19 and 0.24 kms per hour at BDL, CLH and CLH + RP, respectively. Kanga *et al.* (2002) observed higher air velocity during afternoon (0.06±0.07m/Sec.) than evening (0.34±0.07m/Sec.) and morning (0.23±0.05m/Sec) hours. They also observed that the layer house on raised platform had significantly ($p<0.01$) air velocity (0.42±0.07m/Sec) than those in cage house (0.34±0.05m/Sec)] and deep litter house system (0.206±0.04m/Sec).

The mean wind velocity inside the poultry houses at 7.30 during winter cold dry it was practically nil, i.e. 0.02 ± 0.01, 0.18 ± 0.06 and 0.05 ± 0.02 kms per hour whereas outside the houses was 0.14 ± 0.04, 0.18 ± 0.06 and 0.17 ± 0.04 kms per hour and the difference was (outside minus inside) was 0.12, 0.00 and 0.12 km per hour, respectively.

Inside poultry houses the mean wind velocity km per hour at 2.30 pm was 0.44 ± 0.07, 0.21 ± 0.02, 0.09 ± 0.02 and 0.07 ± 0.02 kms per hour whereas outside it was 2.76 ± 0.39, 1.22 ± 0.12, 0.50 ± 0.09 and 0.35 ± 0.08 kms per hour and the difference (outside minus inside) was 2.35, 1.01, 0.41 and 0.28 kms per hour during S_1, S_2, S_3 and S_4 season, respectively (Table 4.13B and Fig 12). Highest inside and outside WV observed during summer that followed by S_2, S_4 and S_3 seasons. The analysis of variance showed significant ($P < 0.05$) difference among differences (outside minus inside) means of poultry house during S_1, S_2, S_3 and S_4 seasons.

During summer hot dry season the mean daily wind velocity kms per hour inside the poultry houses was observed to be 0.31 ± 0.05, 0.26 ± 0.08 and 0.74 ± 0.09 whereas the outside was 3.31 ± 0.53, 1.96 ± 0.23 and 3.0 ± 0.42 kms per hour and the difference was higher at BDL (3.00), CLH (1.70) and CLH + RP (1.96) respectively (Table 4.17B and Fig 29). Higher WV was observed at CLH+RP that is desirable during dot dry season. In BDL house it was very less that is not also desirable. In CLH types of poultry houses comparatively lower than the CLH+RP. Murlidharan *et al.* (2001) recorded air velocity value of 0.524 ± 0.025 m/sec and 0.357 ± 0.030 m/sec were recorded in sheds with foggers and sheds without foggers, respectively.

The mean wind velocity inside the poultry houses during rainy wet season it was 0.07 ± 0.01, 0.168 ± 0.02 and 0.38 ± 0.05 kms per hour whereas outside, 1.22 ± 0.12, 1.21 ± 0.11 and 1.23 ± 0.12 kms per hour and the difference (outside minus inside the house) was 1.14, 1.04 and 0.85 kms per hour in BDL, CLH and CLH + RP, respectively. Higher WV observed inside the CLH+RP than BDL & CLH. The non-significant ($P < 0.05$) difference found for BDL, CLH and CLH + RP the type of poultry houses. However, during summer hot dry season the differences were significantly different from each other.

Practically absence of wind velocity inside the poultry houses during hot humid season. It was 0.03 ± 0.03, 0.02 ± 0.02 and 0.22 ± 0.04 kms per hour in BDL, CLH, CLH+RP, respectively whereas outside was 0.38 ± 0.09, 0.38 ± 0.09 and 0.74 ± 0.09 kms per hour and the difference was higher CLH+RP (0.52) than BDL (0.35) and CLH (0.36). Kanga *et al.* (2002) compared three different rearing systems viz. deep litter, conventional cage and raised platform to cage arrangement. Microclimatic factors (air temperature, relative humidity and air velocity) were measured and egg production in percentage was calculated. They observed higher air velocity during afternoon (0.06±0.07m/Sec.) than evening (0.34±0.07m/Sec.) and morning (0.23±0.05m/Sec) hours. They also observed that the layer house on raised platform had significantly ($p<0.01$) higher air velocity (0.42±0.07m/Sec) than those in cage house air velocity (0.34±0.05m/Sec)] and deep litter house system (0.206±0.04m/Sec)].

The mean wind velocity inside the poultry house during winter cold dry season was also practically absence. It was 0.02 ± 0.01, 0.12 ± 0.04 and 0.07 ± 0.02 kms per hour whereas outside was 0.29 ± 0.05, 0.45 ± 0.12 and 0.30 ± 0.07 kms per hour and the difference 0.27, 0.33 and 0.23 kms per hour at BDL, CLH and CLH + RP, respectively. WV observed higher at CLH than LCH+RP and BDL, it might be due to change in the direction of wind. Analysis of variance showed non-significant ($P < 0.05$) differences.

4.2.5 Micro and macro light intensity

Light is most important climatic factor in poultry. It regulates the hormonal complex as well as the feed computation, digestion of nutrients in turn.

Irrespective of types of houses Mean inside and outside light intensity at 7.30 am during different seasons at poultry houses are presented in Table 4.13A and depicted in Fig 17. Inside the poultry houses mean light intensity was 376 ± 83.28, 128 ± 16.82, 511 ± 91.91 and 376 ± 66.74 (X1) lux whereas outside was 1219.7 ± 77.30, 237.5 ± 50.48, 369.9 ± 26.25 and 193.4 ± 11.76 (X10) lux and the differences was 11821, 2247, 3188 and 1558 (X1) lux during S_1, S_2, S_3 and S_4 season, respectively. Highest inside LI observed during hot humid than the other type houses, however, outside LI was highest during hot dry than the other types of poultry houses. The analysis of variance showed significant ($P < 0.05$) differences for poultry houses during S_1, S_2, S_3 and S_4 seasons.

Table 4.18A Micro-macro light intensity (lux) of poultry houses at 7.30 am.

Season/ House	S_1			S_2			S_3			S_4		
	In (X1)	Out (X10)	Diff.	In (X1)	Out (X10)	Diff.	In (X1)	Out (X10)	Diff.	In (X1)	Out (X10)	Diff.
BDL	443.07 ± 73.81	940.00 ± 64.62	8956	95.40 ± 18.81	231.2 ± 48.80	2216	436.42 ± 84.42	340.00 ± 17.69	2963	276.11 ± 48.70	169.72 ± 12.48	1420.8
LCH	286.92 ± 99.71	1155.38 ± 89.64	11525	139.6 ± 15.09	250.40 ± 54.40	2364	447.14 ± 84.27	359.28 ± 27.28	3145	266.66 ± 35.80	206.11 ± 11.11	1794.4
LCH +RP	399.23 ± 76.33	1563.85 ± 77.64	15238	148.8 ± 16.56	230.8 ± 48.24	2159	650.71 ± 104.90	410.71 ± 33.78	3456	575.00 ± 115.74	204.44 ± 11.69	1469
Avg.	376.40 ±83.28	1219.74 ±77.3	11820	127.93 ± 16.82	237.47 ± 50.48	2246	511.42 ± 91.19	369.99 ± 26.25	3188	375.59 ± 66.74	193.42 ± 11.76	1558.6

Table 4.18B Micro-macro light intensity (lux) of poultry houses at 2.30 pm.

Season/ House	S_1			S_2			S_3			S_4		
	In (X10)	Out (X100)	Diff.	In (X10)	Out (X100)	Diff.	In (X10)	Out (X100)	Diff.	In (X10)	Out (X100)	Diff.
BDL	137.69 ± 16.33	604.61 ± 33.44	59084	141.20 ± 14.57	209.2 ± 24.00	19508	183.57 ± 33.49	497.86 ± 21.61	4795 0	143.33 ± 14.75	330.55 ± 29.43	31621
LCH	245.38 ± 61.30	629.29 ± 39.08	60475	148.4 ± 19.85	282.00 ± 47.92	26716	182.14 ± 33.47	494.28 ± 22.74	4760 6	158.33 ± 15.32	453.89 ± 17.09	43180
LCH + RP	389.23 ± 21.33	631.53 ± 22.61	59260	145.60 ± 16.97	260.8 ± 26.19	24624	375.00 ± 50.31	529.28 ± 33.96	4917 8	119.11 ± 18.97	381.11 ± 25.91	36199
Avg.	257.43 ± 32.98	621.83 ± 31.13	59606	145.06 ± 17.13	249.67 ± 32.70	23516	246.90 ± 39.09	507.14 ± 26.1	4824 5	164.25 ± 16.35	388.5 ± 24.14	37207

Fig 30 Light intensity in poultry houses during S1, S2, S3 & S4 seasons

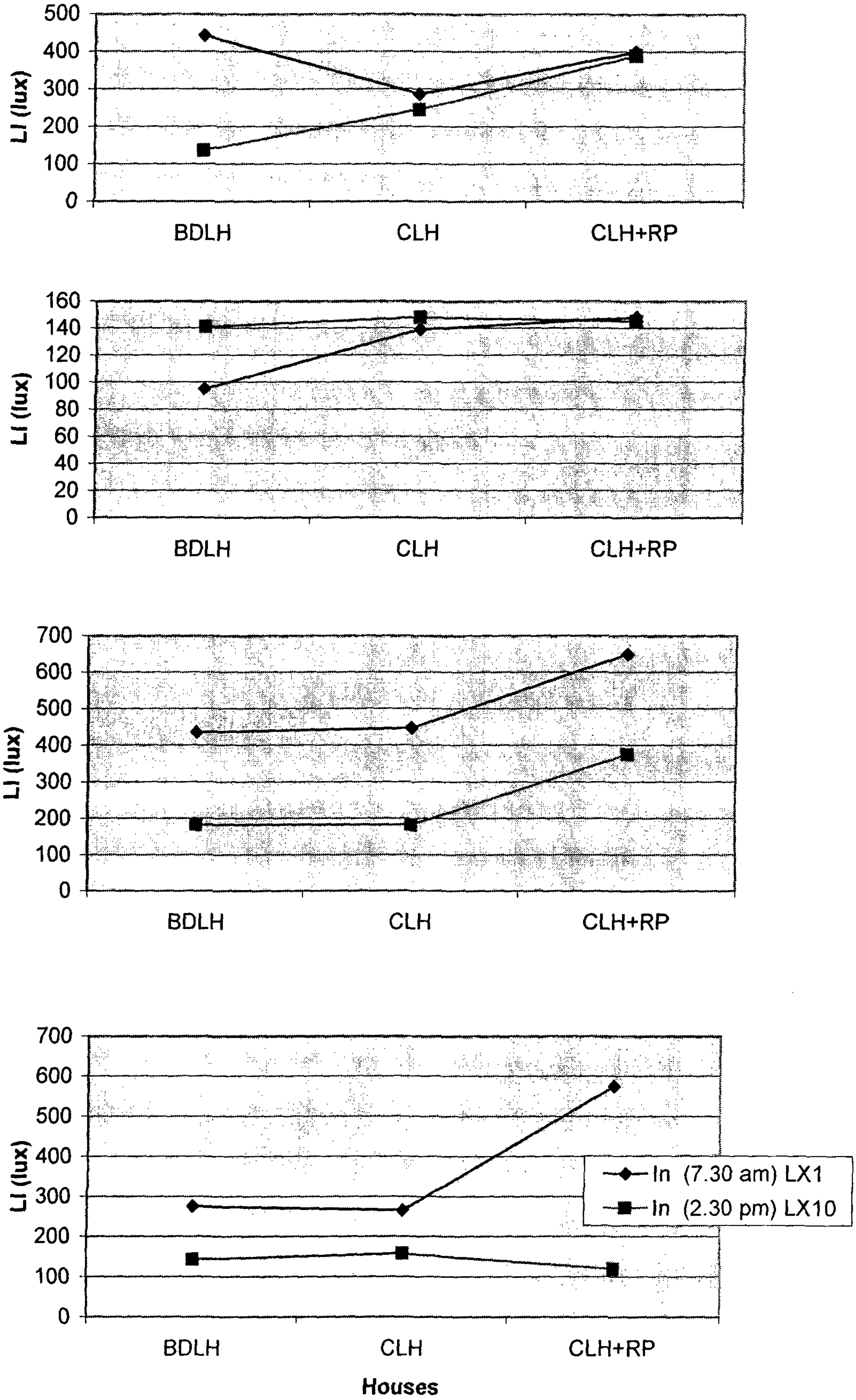


Fig 17 Light intensity (lux) in poultry house 7.30 am

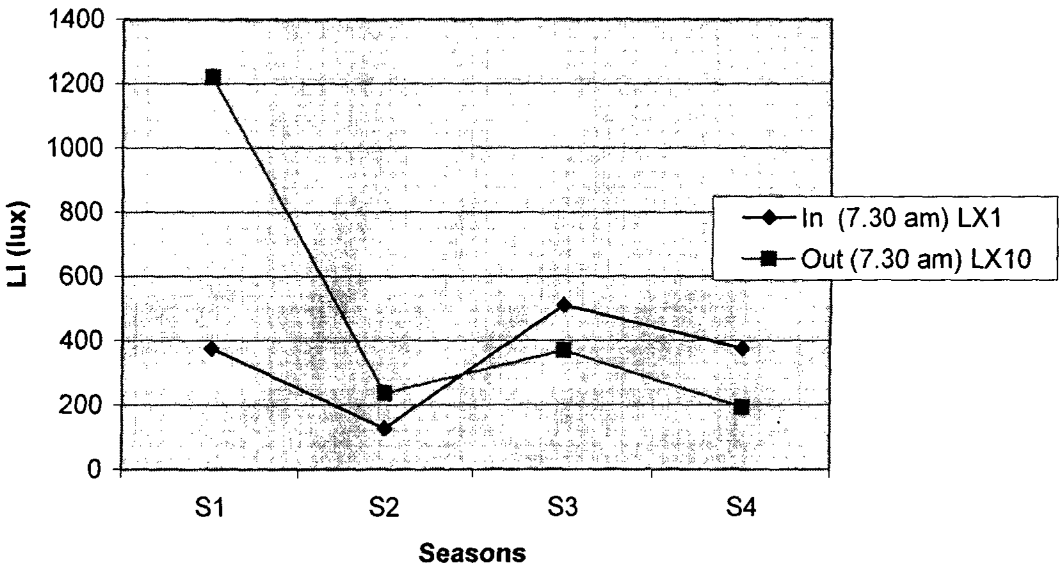
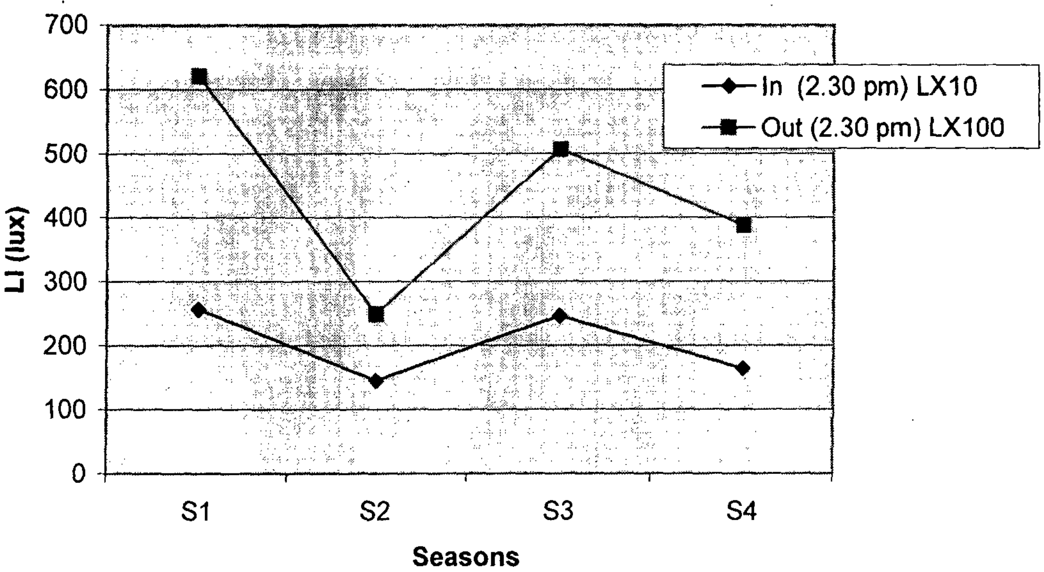


Fig 18 Light intensity (lux) in poultry house 2.30 pm



The average inside light intensity during hot dry season was 443.07 ± 73.81, 286.92 ± 99.71 and 399.23 ± 76.33 (X1) lux whereas outside 940.00 ± 64.62, 1155.38 ± 89.64 and 1563.85 ± 77.64 (X10) lux difference was 8956, 11525 and 15238.7 (X1) lux at BDL, CLH and CLH + RP, respectively (Table 4.18A and Fig 30) Analysis of variance showed non-significant ($P < 0.05$) difference among differences (outside minus inside) means of BDL, CLH and CLH + RP the type of poultry houses.

The mean inside light intensity during monsoon rainy wet season was 95.40 ± 18.81, 139.6 ± 15.09 and 148.8 ± 16.56 (X1) lux whereas outside was 231.0 ± 48.80, 250.40 ± 54.40 and 230.8 ± 48.24 (X10) lux and the difference (outside minus inside light intensity) was 2216.6, 2364.4, 2159.2 (X1) at BDL, CLH and CLH + RP, respectively. Higher inside LI observed at CLH+RP than at CLH & BDL type of poultry house, it might be due to raised plat farm that leads to more expose to the external environment.

The mean inside light intensity during hot humid season was 436.42 ± 84.42, 447.14 ± 84.27 and 650.71 ± 104.90 (X1) lux whereas outside was 340.00 ± 17.69, 359.28 ± 27.28 and 410.71 ± 33.78 (X10) lux and the difference (outside minus inside) was 2963.5, 3145.6 and 3456.3 (X1) lux at BDL, CLH and CLH + RP, respectively. Higher inside LI observed at CLH+RP than at CLH & BDL type of poultry house.

The mean inside light intensity during winter cold dry season was 276.11 ± 48.70, 266.66 ± 35.80 and 575.00 ± 115.74 (X1) lux whereas outside was 169.72 ± 12.48, 206.11 ± 11.11 and 204.44 ± 11.69 (X10) lux and the difference (outside minus inside) was 1420.80, 1794.4 and 1469 (X1) lux at BDL, CLH and CLH + RP, respectively. Higher LI observed at CLH+RP than at CLH & BDL type of poultry house.

Irrespective of houses the means inside and outside light intensity at 2.30 pm afternoon hours during different seasons in poultry houses are presented in Table 4.13B and depicted in Fig 18. Inside the poultry houses mean light intensity was 2574.3, 1450.6, 2469 and 1642.5 (X1) lux whereas outside was 62181, 24967, 50714 and 38850 (X1) lux and the differences (outside minus inside the houses) was 59606.7, 23516.0, 48245 and 37208.5 (X1) lux during S_1, S_2 S_3 and S_4 season, respectively. Higher LI observed during hot dry and hot humid than the remaining monsoon rainy wet and winter cold dry seasons. The analysis of variance showed significant ($P < 0.05$) difference for poultry house during S_1, S_2, S_3 and S_4 seasons.

The inside light intensity during hot dry season at 7.30 am was 137.69 ± 16.33, 245.38 ± 61.30 and 389.23 ± 21.33 (X10) lux whereas outside was 604.61 ± 33.44, 629.29 ± 39.08 and 631.53 ± 22.61 (X100) lux and the difference (outside was inside the poultry houses) was 59084, 60475.2 and 59260.7 (X1) lux at BDL, CLH and CLH +RP, respectively (Table 4.18B Fig 30).

The mean inside light intensity during monsoon rainy wet season was 141.20 ± 14.57, 148.4 ± 19.85 and 145.60 ± 16.97 (X 10) lux whereas outside was 209.2 ± 24.00, 282.00 ± 47.92 and 260.8 ± 26.1 (X100) lux and the difference was 19508, 26716 and 24624 (X1) lux at BDL, CLH, CLH + RP, respectively. Inside LI observed at BDL higher than at CLH & CLH+RP type of poultry house.

The average inside light intensity during hot humid season was 183.57 ± 33.49, 182.14 ± 33.47 and 375.00 ± 50.31 (X 10) lux whereas outside the poultry houses was 497.86 ± 21.61, 494.28 ± 22.74 and 529.28 ± 33.96 (X100) lux and the difference was 47950.3, 47606 and 49178 (X1) lux at BDL, CLH, CLH + RP, respectively. Inside LI was observed higher at CLH+RP than at CLH & BDL type of poultry house. The differences were non-significant for BDL, CLH and CLH + RP the type of poultry houses.

The mean inside light intensity during winter cold dry season was 143.33 ± 14.74, 158.33 ± 15.32 and 119.11 ± 18.97 (X10) lux whereas outside, 330.55 ± 29.43, 453.89 ± 17.09 and 381.11 ± 25.91 (X100) lux and the difference (outside was inside) was 31621.7, 43180.5 and 37207.5 (X1) lux at BDL, CLH and CLH + RP, respectively. Inside LI observed higher at CLH+RP than at CLH & BDL type of poultry house. A non-significant ($P < 0.05$) difference observed between the difference (outside minus inside) mean of BDL, CLH and CLH + RP the type of poultry houses.

4.3 Dust Concentration

The average dust concentration during hot dry and hot humid seasons in cowshed on different farms are presented in Table 4.19a and depicted in Fig 31. The average dust concentration during hot dry and hot humid monsoon season was 70 and 21.1 mg/3 hrs /shed, respectively. It was 231.75 percent more during hot dry than hot humid season. During hot dry season wind velocity during was more than the hot humid it might more increasing concentration of dust particles in the air than the other components like dust like feed, fodder, dung etc.

During hot dry season average dust concentration in cowshed was in order of 97.1, 73, 40 and 26.6 mg/3 hrs /shed on LRS, IF, HF and FAS farm, whereas, during hot humid season they were 40, 23, 19.4 and 21 mg/3 hrs /shed at FAS, LRS, IF and HF, respectively. It was 331 percent higher during hot dry in all cow shed on different farms than the hot humid season.

The average dust concentration in calf pens during hot dry and hot humid seasons (Table 4.19b and Fig 32) was 39 and 24 mg/3 hrs /shed, respectively. The average dust concentration during hot dry season was 59, 22 and 38 mg/3 hrs /shed on IF, LRS and HF, respectively and the corresponding values for hot humid season were 32, 19 and 21. During hot dry season 162.5 percent higher dust concentration was than the hot humid season in calf pen on different farm also.

The overall (cow shed + calf pen) concentration during hot dry season (Table 4.19c) was 65.5, 59.1 and 38.9 mg/3 hrs /shed on IF, LRS and HF, respectively. The corresponding values for hot humid season were 27.3, 19.4 and 20.91 mg/3 hrs /shed. The range of dust concentration during hot dry season was 21.37 to 97.1 mg/3 hrs /shed (LRS cowshed) where as during hot humid 19.4 to 31.5 mg/3 hrs /shed (IF calf pen).

Table 4.19a. Average dust concentration (mg/3 hrs/shed) during hot-dry and hot humid seasons in cowshed of different farms.

Farm / Season	IF	LRS	HF	Org. Farm Avg.	FAS
Hot-dry	73.0	97.1	40.0	70.0	26.6
Hot-humid	23.0	19.4	21.0	21.1	15.0
Avg.	48.0	58.0	30.5	45.0	20.8

Table 4.19b. Average dust concentration (mg/3 hrs/pens) during hot-dry and hot humid seasons in calf pens on different farms.

Farm / Season	IF	LRS	HF	Avg.
Hot-dry	59.0	22.0	38.0	39.0
Hot-humid	32.0	19.0	21.0	24.0
Avg.	45.0	20.4	29.4	31.59

Table 4.19c. Average dust concentration (mg/3 hrs /shed) on different farms (cowshed + calf pen) during different seasons.

Farm / Season	IF	LRS	HF	Avg.
Hot-dry	65.5	59.1	38.9	54.5
Hot-humid	27.3	19.4	20.91	22.53
Avg.	46.39	39.25	29.92	38.52

Table 4.20. Average dust concentration (mg/ 3 hrs/shed) in different types of poultry houses during different seasons.

Farms / Season	BDLH	CLH	CLH+RP	Org. Farm Avg.
Hot-dry	23.0	26.0	20.0	23.0
Hot-humid	45.0	37.0	46.0	42.43
Avg.	33.8	31.0	33.0	32.67

Fig 31 Dust concentration in cow shed during hot dry & hot humid seasons

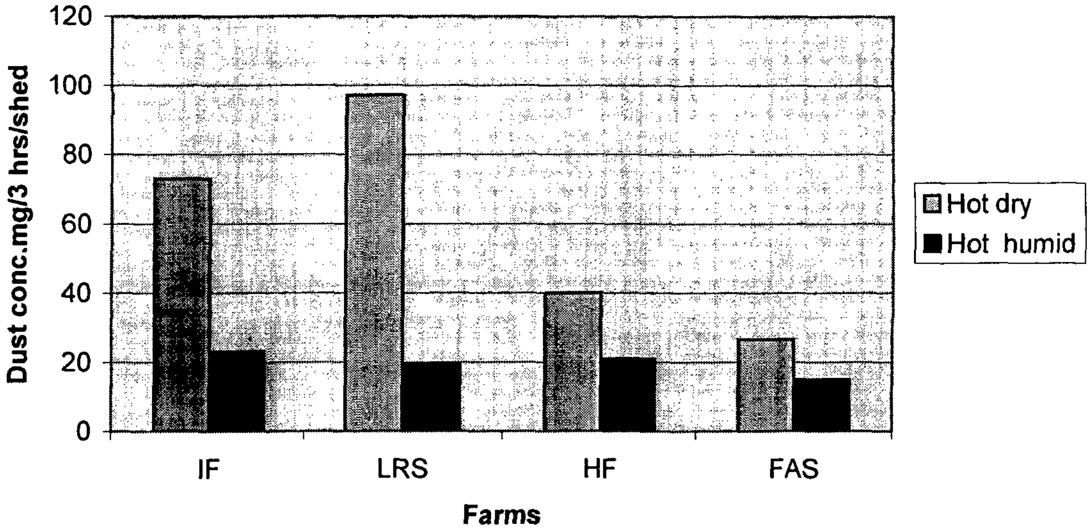


Fig 32 Dust concentration in calf pen during hot dry & hot humid seasons

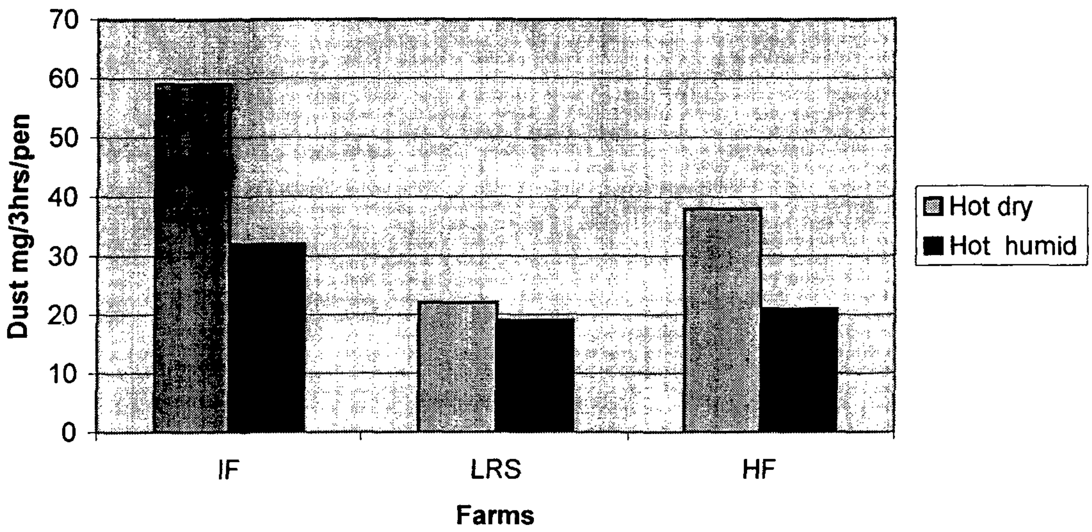


Fig 33 Dust concentration in poultry house during hot dry & hot humid seasons

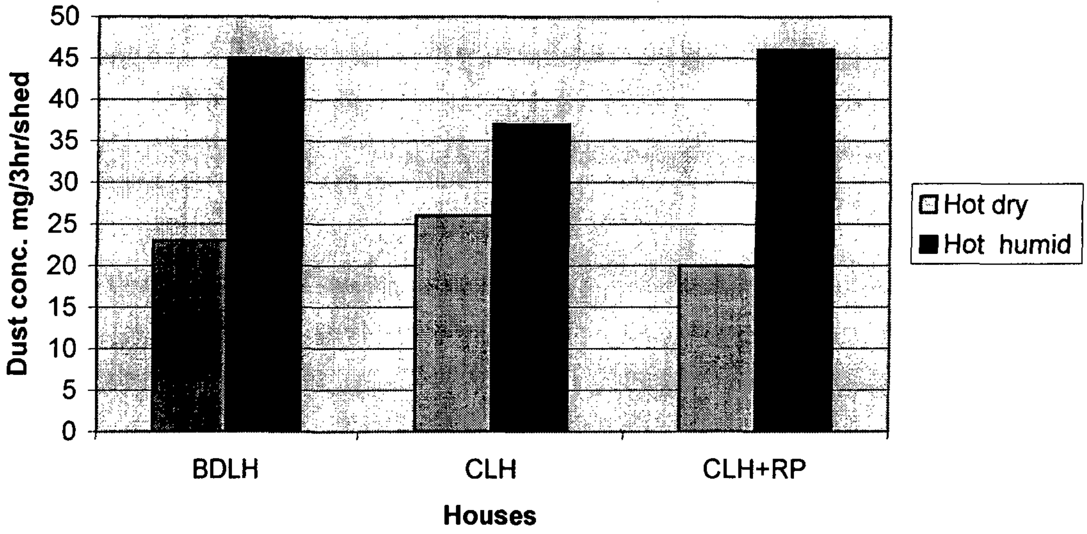


Fig 34 Microbial colony count in cow shed during hot dry & hot humid seasons

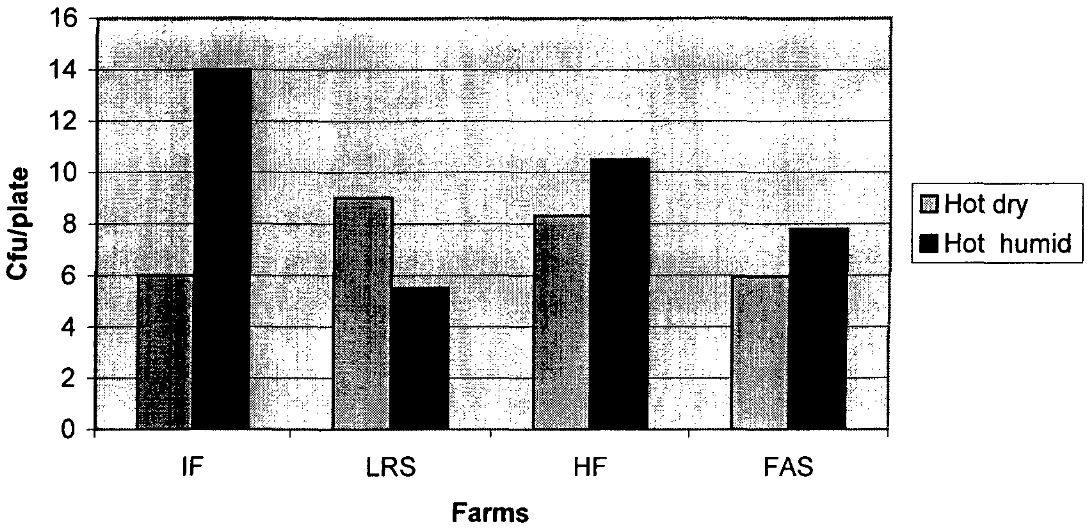


Table 4.21 Average dust concentration at animal and poultry sheds (mg/3 hrs/shed) during different seasons.

Season / Shed	Hot dry	Not humid	Org. Farm Avg.
Cowshed	70.0	21.0	
Calf pen	39.0	24.0	
Animal houses			38.5
BDLH	23.0	43.0	
CLH	26.0	37.0	
CLH+RP	20.0	46.0	
Poultry houses			32.8

Table 4.22a Average microbial colony count (cfu/plate) in cowsheds of various farms during hot-dry and hot humid seasons

Farm / Season	IF	LRS	HF	Org. Farm Avg.	FAS
Hot dry	6.0 (2-8)	9.0 (6-12)	8.3 (8-9)	7.77	5.95 (3.0-16.7)
Hot humid	14.0 (13-19)	5.5 (2-9)	10.5 (9-12)	10.00	7.8 (2-21)
Avg.	10.0	7.25	9.4	8.88	6.87

Table 4.22b Average microbial colony count (cfu/plate) at calf pens of various farms during hot-dry and hot-humid seasons

Farms / Seasons	IF	LRS	HF	Avg.
Hot dry	6.7 (5-8)	11.0 (9-12)	18.5 (14-23)	12.05
Hot humid	4.5 (4-5)	5.0 (3-7)	9.0 (8-11)	6.17
Avg.	5.58	8.00	9.17	7.58

Table 4.22c Average microbial colony count (cfu/plate) at various poultry sheds during hot-dry and hot-humid seasons.

Farm / Season	BDLH	CLH	CLH+RP	Avg.
Hot dry	189	81	142	137.33
Hot humid	146	125	158	146.6
Ave.	167	103.00	150	140.00

Table 4.23 Average microbial colony count (cfu/plate) at animal sheds and poultry sheds during hot-dry and hot-humid seasons

Shed	Hot-dry	Hot humid	Avg.
Cowshed	7.77	10.00	
Calf pen	12.05	6.17	
Animal houses			9.00
BDLH	189	146	
CLH	81	125	
CLH + RP	142	158	
Poultry houses			140.00

At LRS cowsheds are nearby and in a compact sequence whereas IF, teaching unit, other animal sheds like sheep, goat, horse, poultry might have increased the concentration. At HF farms shed are little far apart, more height of roof and more wind velocity may have lower the concentration of dust.

The average dust concentration in different types of poultry house during two seasons are presented in Table 4.20 and depicted in Fig 33. The average dust concentration was 23 and 42.43 mg/3 hrs /shed during hot dry and hot humid season, respectively. Higher dust concentration 185 percent observed during hot humid season than hot dry season.

The average dust concentration during hot dry season was 23, 26 and 20 mg/3 hrs /shed in deep litter house for breeder, cage layer house and cage layer house with raised platform, respectively. The range during hot dry season was 20 to 26 mg/3 hrs /shed where as during hot humid 37 to 46 mg/3 hrs /shed. As per expectation, higher dust concentration was observed deep litter system 11.5 percent more in than in cage layer with raised platform and 13 percent than in cage layer house.

Irrespective of seasons the average dust concentration in animal houses and poultry houses was 38.5 and 32.8 mg/3 hrs /shed (Table 4.21). Dust concentration was 11.74 percent more in animal houses than poultry houses.

Zeiter (1987) observed highest dust concentration 2.4 mg/ m^3 of air in horse stable. Sevi (2003) measured 0.78 mg / m^3 in control house and 0.36, 0.49 and 0.32 mg/ m^3 in The treatment viz. (1) fortnightly application of 0.5 Kg granular bentonite per $m^2$of litter (BENT), (2) Litter renewal after first 4 weeks of the trial, without bentonite treatment (REN), (3) fortnightly treatment with bentonite + litter renewal (BENT+ REN). Yasotha *et al.* (2002) observed higher concentration of dust 1.20 mg / m^3 in mud floor than 0.72 mg/ m^3 in slatted floor of sheep pens.

4.4 Microbial Colony Count

The average microbial colony count during hot dry and hot humid seasons in cowshed on different farms are presented in Table 4.22a and depicted in Fig 34. The average microbial colony count was 7.77 and 10.00 cfu/ plate during hot dry and hot humid season, respectively. Twenty-eight percent more colony count was observed during hot humid than the hot dry season. It might be due to higher relative humidity coupled with high temperature which favored the environment for the growth of microbes, Kanga *et al.* (2002).

Fig 35 Microbial colony count in calf pen during hot dry & hot humid seasons

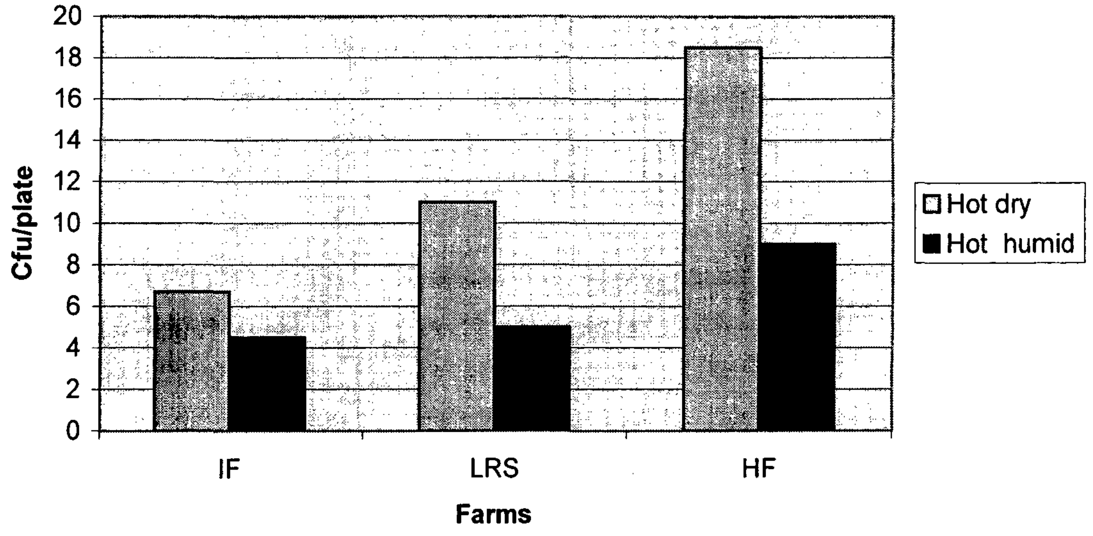
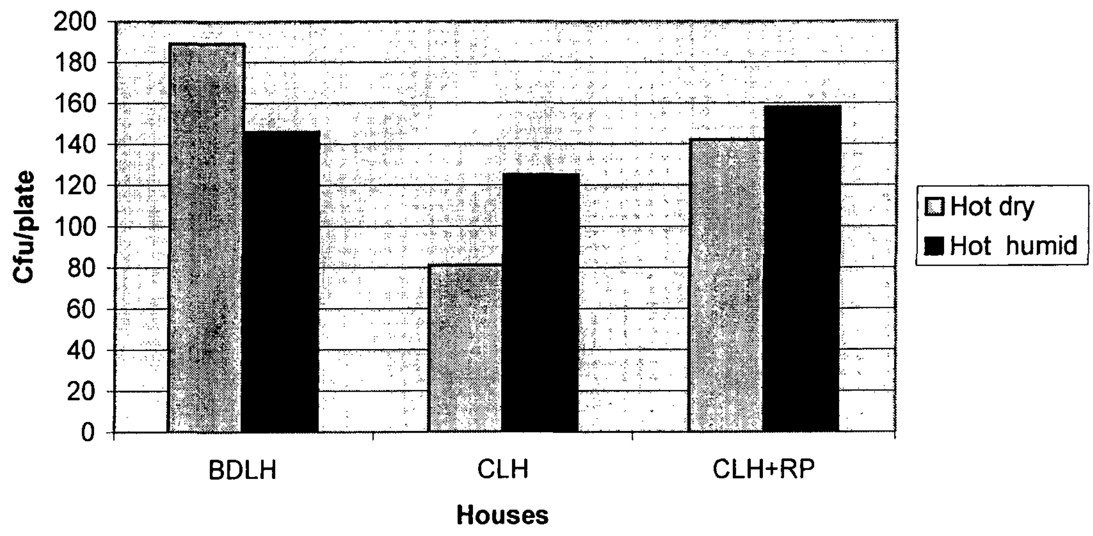


Fig 36 Microbial colony count in poultry house during hot dry & hot humid seasons



4.4.1 Microbial colony count in cowshed

During hot dry season average microbial colony count was 6.0, 9.0 and 8.3 of cfu/ plate in cowshed at IF, LRS and HF farm, respectively. They were practically at same level.

4.4.2 Microbial colony counts in calf pen

The average microbial colony count at calf pen of different farms during hot dry and hot humid season is presented in Table 4.22b and depicted in Fig 35. The average microbial colony count was 12.05 and 6.17 cfu/ plate during hot dry and hot humid season, respectively.

During hot dry season microbial colony count in calf pen was 6.7, 11.0 and 18.5 cfu/ plate on IF, LRS and HF farm, respectively. Higher microbial colony count (176 percent) was observed in calf pen at HF being a complete closed barn than at IF and 68 percent higher than in calf pen at LRS.

During hot humid season also highest microbial colony counts (cfu/plate) in calf pen was observed at HF (9.0) than the calf pen at IF (4.5) and LRS (5.0). It might be due to the more closed type of calf pen at the HF farm. More stagnation of airflow and humidity are favorable factors for microbial growth. Similar results were also obtained by Yasotha *et al.* (2002) who compared air pollution level in sheep pens with slatted floor and mud floor. Total bacterial count was recorded to be 42.86 cfu/ 30 litre of air Vs 23.83 cfu/ 30 litre of air (mold count 22.84 cfu/ 30 litre of air Vs 15.0883 cfu/ 30 litre of air) higher in mud floor than the slatted floor. This might be due to less dust concentration and freer environment in slatted floor than the mud floor. Zeitler (1987) observed higher concentration of bacteria and fungi @ 352 ± 53 cfu/ litter of air during activity of horse and human in the stable.

4.4.3 Microbial colony count in poultry house

Average microbial colony count (cfu/ plate) at different type of poultry houses during hot dry and hot humid seasons were recorded are presented in Table 4.22c and depicted in Fig 36.

The average microbial colony count was 137.33 and 146.6 cfu/ plate during hot dry and hot humid season, respectively. During hot humid season 6.7 percent higher microbial colony count was observed than during hot dry season. It might be due to high temperature coupled with high humidity in hot humid season than in hot dry season. Similar results were obtained by Kanga *et al.* (2002).

During hot dry season average microbial colony count was 189, 81 and 142 cfu/ plate, whereas during hot humid, it was 146, 125 and 158 cfu/ plate in BDLH, CLH and CLH+RP, respectively. During hot humid season, 33 percent higher microbial colony count was observed in BDLH than the CLH and 33 percent more than the CLH+RP. Similarly during hot humid season 16.8 percent higher microbial colony count was observed in BDLH than the CLH. In deep litter system, the movement of bird in groups on droppings with litter material enhance the microbial load in the air.

Similar results were reported by Kanga *et al.* (2002). They found significantly ($P < 0.01$) higher total bacterial count (337.58 ± 4.48/ 30 litter/ minute) coliform count (225.48 ± 28.64 30 litter/ min) and mold count (29.97 ± 2.45 30 litter/ min) in deep litter poultry house than the conventional as well as cage house with raised platform.

The average microbial colony count was only 9.00-cfu/plate in animal houses whereas it was 15 times more in poultry house i.e.140 cfu/ plate (Table 4.23). It might be due to the more closed types of housing which favored higher relative humidity and presence of mash feed and litter and excreta in the poultry house than the animal house.

4.5 Housing Index of Animal and Poultry Houses

The houses provide the comfort and protection from inclement weather to animals and poultry and these have direct bearing on health and production of animals and birds. The housing index reflects the level of comfort and protection provided to animals.

(1) Housing index on twenty-eight point scale

Sr. No.	Housing Index	Category
1.	22 and above	Excellent
2.	19-21	Very good
3.	16-18	Good
4.	13-15	Average
5.	12 and below	Poor

Table 4.25 Housing index at various farms on 28-scale point.

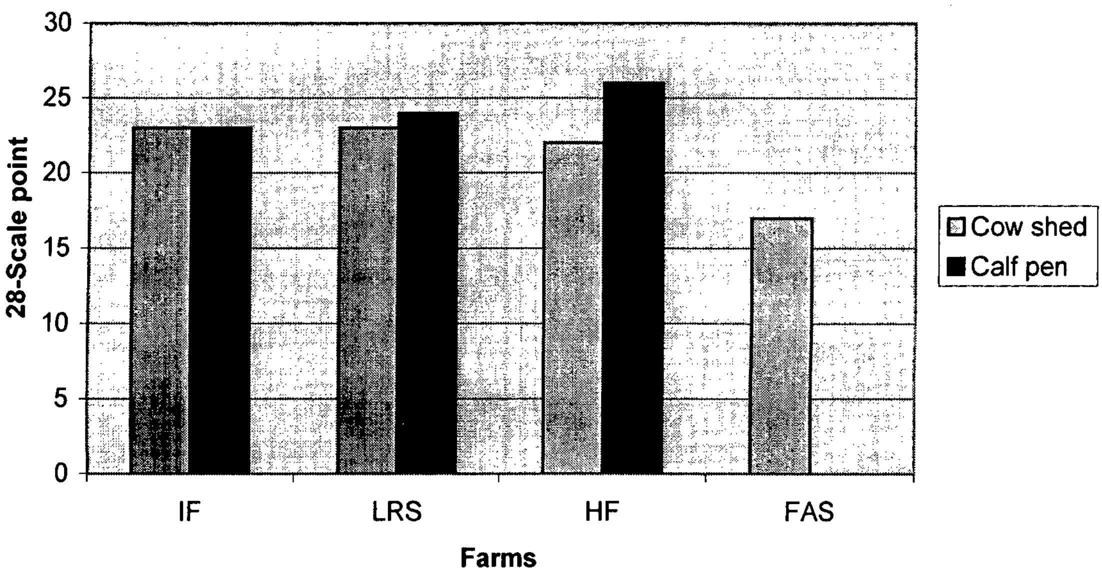
Farm	Cowshed	Calf pen
IF	23	23
LRS	23	24
HF	22	26
Avg.	22.7	24.3
FAH	17	--

Poultry houses

BDLH	CLH	CLH + RP
26	26	24

The housing index (HI) during most stressful hot-humid season i.e. July, August 2004 was observed on the 28-scale point for the organized farmhouses of Anand Agricultural University and rural farmers animal houses. It was observed that the housing index for cowsheds at organized farms was 22.7 points i. e. excellent whereas at farmer's animal houses, 17.0 points i. e. average catagary. Similarly, the HI for

Fig 37 Housing Index



BDLH, CLH and CLH + RP poultry houses were 26, 26 and 24 points which falls under the excellent category (Fig 37). The average Cattle Housing Index of 14.38 i. e. average was observed at farmers' animal houses by Patel *et al.* (2003) during project for NATP on Sugarcane Based Production System- Village Resource Map.

SUMMARY & CONCLUSIONS

CHAPTER V

SUMMARY & CONCLUTIONS

A study was carried out to find out the status of micro and macro climate of cattle and poultry houses on organized farms during (a) Summer: Hot dry (May and June 2003), (b) Monsoon season: rainy-wet (August 2003), (c) Hot humid (September 2003) and (d) Mild Winter season: Cold dry (November 2003).

For the purpose of study, following cattle and poultry farms of Anand Agricultural University, Anand; (i) Two sheds, cowshed and calf pen were selected from Instructional Farm, Department of Livestock production and Management, College of Veterinary and Animal Husbandry, Anand (ii) cowshed at Livestock Research Station and (iii) cowshed at Holstein Friesian Bull Mother Farm and (iv) Central Poultry Research Station, three types of poultry houses namely (a) deep litter (b) cage house and (c) cage house with raised platform were selected.

Meteorological observations were recorded at 7.30 am and 14.30 hrs both inside and outside of cowshed, calf pen and poultry house by (a) Digital thermo-hygrometer (J411TH) for temperature & relative humidity (Plate XI), (b) digital anemometer (Lutron-AM4201) for wind velocity, (c) digital lux meter (Masteck-ms6610) for light intensity and (d) Yash High Volume Air Sampler (Yash Engineering, Vadodara) for dust concentration in the air of houses.

Dust concentration (suspended particles in the air) was estimated by Yash High Volume Air Sampler. The VHVAS was placed in the center of animal and poultry houses and run for 3 hrs for 10.00 to 13.00 hrs. The average volume of air passed through YHVAS was calculated.

The filter papers used were Glass Microfibre Filters GF/A Cat No. 1820 866 Whatman International Ltd., England. Sterilized filter papers were opened only at the site where it was directly placed in position in YHVAS machine with the help of sterilized forceps. The YHVAS run for three hours in animal and poultry sheds from10:00 hours to 13:00 hours. The filter paper were removed after 3 hours and filled in the same polypropylene bags and weighed on microbalance. The difference between final and initial weights was taken as dust concentration. After being weighed for dust concentration these filter papers were then transferred into microbiology laboratory for microbial colony count (*cfu*/plate).

The housing index was calculated for rural farmers' animal houses and for organized farms on 28-scale point.

To study the status of micro and macroclimate of cattle and poultry houses on organized farms,

there were following objectives:-

1. To study the status of macro and microclimate viz. temperature, relative humidity, air velocity and light intensity in the animal and poultry houses of A.A.U. farms.
2. To study the level of dust (suspended particles) in the air of animal and poultry houses.
3. To compute the major microbial colony count in the air of animal and poultry houses and
4. To study the housing index of animal and poultry houses.

The mean inside cowshed temperature (°C) irrespective of farms at 7.30 am during different seasons (S_1 – Summer-hot dry, S_2 – Monsoon-rainy wet, S_3– Hot-humid and S_4– Winter cold-dry) was 30.70 ± 0.26, 25.27 ± 0.25, 27.01 ± 0.24 and 21.81 ± 0.59°C whereas the outside mean temperatures was 30.04 ± 0.31, 25.95 ± 0.27, 27.01 ± 0.20 and 20.47 ± 0.58°C during S_1, S_2, S_3 and S_4 season, respectively.

The mean difference (outside minus inside the cowshed) was 1.44, -0.32, -0.68 and -1.34°C during S_1, S_2, S_3 and S_4 season, respectively. The outside temperature was more than inside during S_1 season; however, inside temperature was more than outside during S_2, S_3 and S_4 seasons. Analysis of variance showed significant ($P < 0.05$) difference among the difference mean (outside minus inside the shed) during S_1, S_2, S_3 and S_4 seasons.

Mean inside cow shed temperature during hottest period of the day i.e at 2.30 pm during different seasons irrespective of farms was 38.92 ± 0.26, 28.76 ± 0.42, 33.27 ± 0.18 and 32.23 ± 0.34 °C whereas outside the cow shed was 42.49 ± 0.40, 29.76 ± 0.47, 37.28 ± 0.39 and 36.76 ± 0.68 °C during S_1, S_2, S_3 and S_4 season, respectively. The mean difference (outside minus inside the cowshed) was 3.57, 0.75, 4.01 and 4.55°C during S_1, S_2, S_3 and S_4 season, respectively. Highest and lowest temperatures were recorded during hot dry and rainy wet season, respectively. Less difference (outside minus inside the cowshed) was observed during S_2. It may be due to rain and high humidity during this season, while, more difference was recorded during S_1, S_3 and S_4 seasons. Season conflict was significant, it is bound to be. During hot dry season the inside temperature was lower by 3.57 °C than the outside intense temperature of 42.49 °C, however, inside temperature of 38.92 °C was also higher and uncomfortable to cows. They should add cooling system on shed like ceiling fans, showering of water or plantation of trees.

The average temperature during summer hot dry (S_1) season inside the cowshed was recorded to be 38.44 ± 0.42, 38.73 ± 0.16, 39.26 ± 0.28 and 39.25 ± 0.25°C whereas the outside 41.55 ± 0.48, 42.90 ± 0.27, 43.10 ± 0.21 and 42.44 ± 0.23 °C at FAS, IF, LRS & HF farm, respectively. The temperature difference (outside minus inside) was 3.11, 4.7, 3.84 and 5.19 at FAS, IF, LRS and HF farm, respectively. Average inside shed temperature was recorded higher at LRS and HF than FAS and IF farm. In spite of higher difference of 5.19 °C, inside shed temperature of 39.25 °C was observed at HF farm, was comfortable cow sand forced them to come out under trees. It is suggested to establish a cooling system either ceiling fans or showering or plantation of trees around the cowshed. The higher temperature adversely affects the feed consumption and digestibility in turn milk production and reproduction of animals. The mean temperatures (outside minus inside) of cowsheds on IF, LRS and HF farms were at par.

The mean temperature inside the cowshed during hot humid S_3 season was 32.94 ± 0.19, 33.00 ± 0.16 and 33.56 ± 0.21°C whereas outside the shed was 36.44 ± 0.40, 37.92 ± 0.36 and 37.97 ± 0.41°C on IF, LRS and HF farm, respectively. The temperature difference (outside minus inside the shed) was 3.50, 4.62 and 3.91°C IF, LRS and HF farms, respectively. Thus three sheds had provided more comfort during hot humid season. However, the analysis of variance showed non-significant ($P < 0.05$) difference for IF, LRS and HF farms.

The mean relative humidity inside cowshed on different farms at 2.30 pm during different seasons was 41.30 ± 1.60, 45.61 ± 2.07, 41.23 ± 1.99 and 41.00 ± 0.86 per cent whereas outside the cowshed was 37.76 ± 1.72, 39.69 ± 2.07, 41.00 ± 1.64 and 36.38 ± 0.74 per cent and the difference (outside minus inside) was -3.54, -5.92, -0.23 and -4.62 per cent on FAS, IF, LRS and HF farm, respectively. The more RH observed inside more than outside during this season at all farms. Lowest difference was observed at cow shed on LRS, while the highest, difference (outside minus inside) at cowshed on IF farm. The differences were non-significant ($P < 0.05$).

The mean relative humidity inside the cowshed during hot humid (S_3) season at 2.30 pm was recorded to be 68.50 ± 1.11, 66.64 ± 1.11 and 68.50 ± 1.61 per cent whereas outside, 68.07 ± 0.91, 62.28 ± 1.79 and 64.28 ± 1.65 per cent and the differences was -0.43, -4.36 and -4.22 per cent at cowshed on IF, LRS and HF farm, respectively.

Inside mean THI at 2.30 pm was estimated to be 88.16 ± 0.42, 82.48 ± 0.63, 85.83 ± 0.34 &77.20± 0.52 whereas outside the cowshed was 91.40 ± 0.68, 83.92 ± 0.76, 91.15 ± 0.69 & 81.45± 0 during S_1, S_2, S_3 and S_4 season, respectively. Highest THI was observed during hot dry and hot humid seasons being stressful seasons of the year. There was not much difference between the cowsheds at FAS, IF, LRS & HF farms.

The mean wind velocity inside cowshed at 2.30 pm during different seasons irrespective of farms was 1.09 ± 0.33, 0.45 ± 0.05, 0.12 ± 0.02 and 0.22 ± 0.05 km per hour whereas outside, 2.22 ± 0.47, 1.23 ± 0.15, 0.61 ± 0.08 and 0.46 ± 0.08 km per hour and the difference (outside minus inside the cowshed) was 1.13, 0.78, 0.49 and 0.24 km per hour during S_1, S_2, S_3 and S_4 season, respectively. Highest and lowest wind velocity both inside & outside observed during S_1 & S_4 season, respectively. Decreasing trend was observed from hot dry S_1 to cold dry S_4 season throughout the experiment. Significant ($P < 0.05$) differences were observed for the difference (outside minus inside) mean during S_1, S_2, S_3 and S_4 seasons.

The average wind velocity inside the cowshed during hot dry (S_1) season was 0.024 ± 0.06, 0.68 ± 0.12, 1.04 ± 0.18 and 2.41 ± 0.98 km per hour whereas outside it was 0.62 ± 0.12, 1.80 ± 0.29, 2.67 ± 0.43 and 3.78 ± 1.06 km per hour and the difference was 0.38, 1.12, 1.63 and 1.37 km per hour at farmers, IF, LRS and HF farm, respectively. Surprisingly the highest inside wind velocity was observed at cowshed on HF, and higher inside temperature of 39.25 °C and RH 41%. Higher difference was at cow shed on LRS followed by HF, IF and FAS. The analysis of variance showed non-significant ($P < 0.05$) difference for difference mean.

The mean wind velocity inside the cowshed during hot humid (S_3) season was recorded to be 0.18 ± 0.02, 0.05 ± 0.02 and 0.13 ± 0.02 km per hour whereas outside, it was 0.66 ± 0.09, 0.60 ± 0.94 and 0.56 ± 0.88 km per hour and the difference was 0.48, 0.55 and 0.43 km per hour IF, LRS and HF farm, respectively. Highest and lowest inside wind velocity were observed at cowshed on IF and LRS farm, respectively. Lowest difference was observed at cow shed on HF than the on LRS & IF farms. However, the analysis of variance showed non-significant ($P < 0.05$) difference among the difference (outside minus inside) mean of cow shed on IF, LRS and HF farms.

During afternoon hours irrespective of farms mean inside light intensity of cowshed at 2.30 pm during different seasons was 4428 ± 60.78, 5600 ± 59.74, 3907 ± 63.12, and 2390 ± 18.92 (X1) lux whereas outside was 60518 ± 38.94, 33800 ± 70.24, 49809 ± 21.94, 42759 ± 18.67 (X1) lux and the difference was 56089, 28200, 45901 and 40367 (X1) lux during S_1, S_2, S_3 and S_4 season, respectively. Highest inside LI and highest outside LI were observed during S_1& S_2 season, respectively. However, during winter cold dry, being short day length it was lowest. It differed significantly ($p<0.05$) from other seasons.

Mean temperature inside calf pen irrespective of farms at hottest period of day 2.30 pm during different seasons was recorded to be 38.72 ± 0.26, 28.82 ± 0.47, 33.13 ± 0.15 and 32.02 ± 0.35°C whereas outside was 42.79 ± 0.30, 29.38 ± 0.54, 37.57 ± 0.38 and 36.67 ± 0.64 °C during S_1, S_2, S_3 and S_4 season, respectively. Mean difference (outside minus inside) was 4.07, 0.56, 4.44 and 4.65°C during S_1, S_2, S_3 and S_4 season, respectively. Inside & outside temperature observed highest during hot dry and lowest during monsoon rainy wet seasons. Season conflict was significant and it is bond too. During hot dry season the inside temperature was lower by 4.07 °C than the outside intense temperature of 42.79 °C, however, inside temperature of 38.72 °C was also higher and uncomfortable to calves. The analysis of variance showed significantly ($P < 0.05$) lowest difference during S_2 than during S_1, S_3 and S_4 seasons, which being at par.

The average temperature inside the calf-pen during hot dry season was recorded to be 38.80 ± 0.16, 39.07 ± 0.34 and 38.28 0.29 whereas outside was 43.15 ± 0.36, 42.65 ± 0.31 and 42.58 ± 0.24°C and the average difference (outside minus inside the calf-pen) was 4.35, 3.58, 4.30°C calf pen on IF, LRS and HF, respectively. The inside temperature was lower at calf-pen on HF than the on IF and LRS. High outside temperature at calf-pen on IF which might be due to the cement concrete floor (open paddock). The differences were non-significant ($P < 0.05$) for calf-pen on IF, LRS and HF farms.

The mean temperature inside the calf-pen during hot humid season was 32.89 ± 0.18, 33.14 ± 0.14 and 33.36 ± 0.14 whereas outside the calf-pen was 36.46 ± 0.41, 37.82 ± 0.36 and 38.44 ± 0.39°C and the difference (outside minus inside) was 3.57, 4.68 and 5.08°C at IF, LRS and HF farm, respectively. Inside temperature of the calf pen on HF was higher than IF & IRS and difference was also observed higher at calf pen on HF. It might be due to more closed house than calf pen on other farms. This is not desirable during hot humid season, as it imposes more stress on the calf due combined effect of high inside temperature coupled with high humidity and very low speed of wind movement prevailed in the house. The differences were non-significant for calf-pen on IF, LRS and HF farms.

During noon hours at 2.30 pm mean inside relative humidity of calf pen irrespective of farms during different was recorded to be 42.77 ± 1.44, 91.47 ± 1.26, 66.87 ± 1.14 and 37.49 ± 1.60 per cent whereas outside was 39.53 ± 1.04, 92.24 ± 1.20, 64.93 ± 1.40 and 34.68 ± 1.88 per cent and the difference was -3.24, 0.77, -1.94 and -2.81 percent at IF, LRS and HF farm, respectively. Inside RH was higher than outside during all seasons except monsoon rainy wet that was rainy-wet season. As usual the highest RH was observed during monsoon rainy wet whereas, lowest RH was observed during mild cold dry season. The analysis of variance showed significant ($P < 0.05$) lower RH difference during monsoon rainy wet (S_2) than the others. The RH difference during S_1, S_3 and S_4 were at par.

The mean relative humidity during hot humid season inside the calf pen was 68.78 ± 1.18, 64.78 ± 1.03 and 67.07 per cent whereas outside was 68.36 ± 1.15, 63.85 ± 1.40 and 62.57 ± 1.66 per cent and the difference was -0.42, -0.93 and -4.50 per cent on IF, LRS and HF farm, respectively. Inside RH was higher than outside. Least difference was observed at calf pen on IF than LRS. Higher difference was observed at calf pen on HF. However, they differed non-significantly ($P < 0.05$). for calf pens on IF, LRS and HF farms.

During morning hours 7.30 am and noon hours at 2.30 pm mean THI inside calf pen irrespective of farms during different seasons S_1, S_2, S_3 and S_4 was recorded to be 83.18 ± 0.73, 77.19 ± 0.49, 78.53 ± 0.33 & 65.98 ± 0.97 whereas outside was 84.51 ± 0.96, 75.98 ± 0.50, 77.85 ± 0.33 & 68.03 ± 0.96 during S_1, S_2, S_3 and S_4 season, respectively. During hottest period of the day at 2.30 pm the average THI in side the calf pen was 87.94 ± 0.42, 82.59 ± 0.72, 85.51 ± 0.32 & 79.11 ± 0.61 whereas outside was 92.04 ± 0.39, 83.67 ± 0.87, 91.58 ± 0.65 & 83.74 ± 1.03. Highest THI was observed during hot dry and hot humid seasons being stressful seasons of the year.

Irrespective of farms mean inside wind velocity of calf pens at 2.30 pm during different seasons was 0.74 ± 0.17, 0.22 ± 0.03, 0.09 ± 0.02 and 0.11 ± 0.02 km per hour whereas outside was 2.56 ± 0.55, 1.11 ± 0.16, 0.43 ± 0.08 and 0.33 ± 0.06 km per hour and the difference was 1.84, 0.89, 0.34 and 0.22 km per hour during S_1, S_2, S_3 and S_4 season, respectively. Inside, outside and their difference WV was observed decreasing order from summer hot dry to mild winter cold dry seasons during the entire period of experiment. The analysis of variance showed significantly ($P < 0.05$) higher difference during S_1 than the other seasons. And during S_2 season difference was higher than S_3 and S_4 seasons that were at par.

Irrespective of farms mean inside light intensity at 2.30 pm during different seasons was recorded to be 206.11 ± 43.76, 331.24 ± 51.86, 319.23 ± 65.79 and 176.2 ± 14.02(X10) where as outside 589.61 ± 38.05, 251.58 ± 27.34, 528.8 ± 36.88 and 386.11 ± 18.27(X100) and the difference was 5600, 21846, 49688 and 36849 (X1) during S_1, S_2, S_3 and S_4 season, respectively. Lowest inside LI observed during S_4 than the other, however, outside LI was higher during S_1 and S_4 that were hot dry and hot humid season, respectively. Difference LI was observed significantly ($P < 0.05$) highest during S_1 followed S_3. S_2 and S_4 seasons were at par.

Irrespective of houses, mean inside temperature of poultry house at 2.30 pm afternoon during different seasons was 37.70 ± 0.23, 28.70 ± 0.40, 32.78 ± 0.15 and 33.56 ± 0.33°C whereas outside 42.87 ± 0.32, 29.78 ± 0.44, 37.49 ± 0.59 and 36.98 ± 0.62°C during S_1, S_2, S_3 and S_4 season, respectively. The difference (outside minus inside) was 5.17, 1.08, and 4.71 and 3.42°C during S_1, S_2, S_3 and S_4 season, respectively. Higher difference was observed during hot dry (S_1) and S_3 hot humid seasons than the monsoon rainy wet (S_2) and mild cold (S_4) seasons. The analysis of variance showed significant ($P < 0.05$) lower difference during S_2 than during S_1, S_3 and S_4 seasons.

The mean inside poultry houses relative humidity percent was recorded to be 45.66 ± 1.19, 99.29 ± 1.09, 65.23 ± 0.67 and 38.05 ± 2.04 per cent whereas outside was 39.91 ± 1.24, 90.27 ± 1.11, 61.24 ± 0.55 and 34.54 ± 1.95 per cent during S_1, S_2, S_3 and S_4 season, respectively. The difference (outside minus inside) was -5.74, -0.02, -3.99 and -3.51 percent. The RH was higher in inside the shed than outside due to output of moisture by excreta and waterer present inside the house. More difference (outside minus inside) was observed during summer hot dry season and least difference during S_2. Highest RH was observed during monsoon rainy wet season and lowest during dry mild cold dry season. RH was higher during hot humid than hot dry season that cause more stress to birds.

At 2.30 pm inside mean THI was 87.35 ± 0.37, 82.80 ± 0.63, 84.71 ± 0.35 & 79.53 ± 0.60 whereas outside the poultry house was 92.25 ± 0.46, 84.09 ± 0.68, 90.67 ± 0.98 & 84.17 ± 1.05 during S_1, S_2, S_3 and S_4 season, respectively. Highest THI was observed during hot dry and hot humid seasons that were stressful seasons of the year. Practically very less differences were observed between the different types of poultry house.

Inside poultry houses the mean wind velocity km per hour at 2.30 pm was 0.44 ± 0.07, 0.21 ± 0.02, 0.09 ± 0.02 and 0.07 ± 0.02 kms per hour whereas outside it was 2.76 ± 0.39, 1.22 ± 0.12, 0.50 ± 0.09 and 0.35 ± 0.08 kms per hour and the difference (outside minus inside) was 2.35, 1.01, 0.41 and 0.28 kms per hour during S_1, S_2, S_3 and S_4 season, respectively. Highest inside and outside WV was observed during summer followed by S_2, S_4 and S_3 seasons. The analysis of variance showed significant ($P < 0.05$) difference among difference (outside minus inside) means of poultry house during S_1, S_2, S_3 and S_4 seasons.

Irrespective of houses the mean inside light intensity at 2.30 pm afternoon hours during different seasons in poultry houses was 2574.3, 1450.6, 2469 and 1642.5 (X1) lux whereas outside was 62181, 24967, 50714 and 38850 (X1) lux and the differences (outside minus inside the houses) was 59606.7, 23516.0, 48245 and 37208.5 (X1) lux during S_1, S_2 S_3 and S_4 season, respectively. Higher LI was observed during hot dry and hot humid than the remaining monsoon rainy wet and winter cold dry seasons. The analysis of variance showed significant ($P < 0.05$) difference for poultry house during S_1, S_2, S_3 and S_4 seasons.

The average dust concentration in cow shed during hot dry and hot humid monsoon season was 70 and 21.1 mg/3 hrs /shed, respectively. It was 231.75 percent more during hot dry than hot humid season. Higher wind velocity during hot dry season might have increased concentration the dust particles in the air than the other components like dust like feed, fodder, dung etc.

The average dust concentration in calf pens during hot dry and hot humid seasons (Table 4.19b) was 39 and 24 mg/3 hrs /shed, respectively. The average dust concentration during hot dry season was 59, 22 and 38 mg/3 hrs /shed on IF, LRS and HF, respectively and the corresponding values for hot humid season were 32, 19 and 21. During hot dry season 162.5 percent higher dust concentration was recorded than the hot humid season in calf pen on different farms also.

Irrespective of seasons the average dust concentration in animal houses and poultry houses was 38.5 and 32.8 mg/3 hrs /shed and showed 11.74 percent more in animal houses.

The average microbial colony count in cowshed was 7.77 and 10.00 cfu/ plate during hot dry and hot humid season, respectively. Twenty-eight percent more colony count was observed during hot humid than the hot dry season. It might be due to higher relative humidity coupled with high temperature, which favored the environment for the growth of microbes.

During hot dry season microbial colony count in calf pen was 6.7, 11.0 and 18.5 cfu/ plate on IF, LRS and HF farm, respectively. Higher microbial colony counts observed in calf pen on HF being a complete closed barn (176 percent) than on IF and 68 percent higher than in calf pen on LRS.

The average microbial colony count during hot dry season in poultry house was 137.33 and 146.6 cfu/ plate during hot dry and hot humid season, respectively. During hot humid season 6.7 percent higher microbial colony count was observed than during hot dry season.

The average microbial colony count was only 9.00-cfu/ plate in animal houses whereas it was 15 times more in poultry house i.e.140 cfu/ plate (Table 4.23). It might be due to the more closed types of housing which has favored higher relative humidity in presence of mash feed and litter and excreta in the poultry house than the animal house.

It was observed that the housing index for cowsheds at organized farms was 22.7 points i. e. excellent whereas at farmer's animal houses 17.0 points i. e. average. Similarly the HI for BDLH, CLH and CLH + RP poultry houses was 26, 26 and 24 points which falls under the excellent category.

CONCLUTIONS

1. During hot dry season, inside temperature at 7.30 am was lower than outside the house. While the inside temperature was higher during S_2, S_3 and S_4 seasons due to seasonal variation in temperature. During hot dry season at 2.30 pm though, the inside temperature was lower by 3.57 °C than the outside intense temperature of 42.49 °C, At HF farm., inside temperature of 38.92 °C was also higher and or uncomfortable to cows. They should add cooling system on shed like ceiling fans, showering of water or plantation of trees around the cow shed to reduce the micro and macroclimate difference as well as to stop the hot air waves during afternoon hours and cold air during winter season and alternative shed for HF cows during resting period. In general, during hot humid season where high wind velocity is required in loose house with paddock on both side proved better because of cross ventilation than the loose house with one side paddock.
2. At IF & LRS farms micro and macro climatic difference were marginal an account of canopy of trees around the shed. However, wind velocity during the hot humid season was lower at IF& LRS than HF farm. There is need to increase the cross ventilation by reducing the height of wall by half and changing the orientation of tree plantation.
3. There were differences in cowshed temperature and relative humidity at IF, LRS, HF & FAS farms but did not result into higher in THI values. Modification in farmers' animal houses to reduce the micro and microclimate difference to obtain favorable microclimate of animal houses.

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2. At IF & LRS farms micro and macro climatic difference were marginal an account of canopy of trees around the shed. However, wind velocity during the hot humid season was lower at IF& LRS than HF farm. There is need to increase the cross ventilation by reducing the height of wall by half and changing the orientation of tree plantation.
3. There were differences in cowshed temperature and relative humidity at IF, LRS, HF & FAS farms but did not result into higher in THI values. Modification in farmers' animal houses to reduce the micro and microclimate difference to obtain favorable microclimate of animal houses.

4. All three cowsheds on organized farms has provided sufficient light intensity because all are loose housing systems with sufficient height of shed.

5. Calf pen on IF showed high inside temperature & less difference between inside and outside temperature during hot dry and hot humid season because of cement concrete floor, Whereas, Neem tree in front of open paddock at LRS calf pen reduces inside temperature as well as difference between inside and outside the calf pen. Calf pen on HF showed more difference between inside and outside temperature, relative humidity, THI, wind velocity and light intensity because of more closed type calf pen. This is preferred in winter season only, however, there is need to increase the ventilation during hot humid season and provide cooling system during hot dry season to reduce the incidence of heat stroke in calves.

6. Higher differences (outside minus inside) for the temperature observed during hot dry and hot humid seasons than the monsoon rainy wet and mild cold seasons. A higher temperature was observed inside the cage house than deep litter and cage with raised platform. The differences during different seasons at CLH + RP type were lesser than the CLH & BDL type of poultry houses. It might be due to construction difference between the houses i.e. raised platform that exposed more to external environment than the houses having less height from ground floor. The raised platform house proved better arrangement than deep litter and conventional cage on ground floor during hot humid, monsoon wet and mild winter season. However, during hot dry season, the ambient temperature was more than the conventional cage system and one has to take measures to reduce heat stress.

7. During hot dry season wind velocity was more than the hot humid might increased concentration of dust particles in the air than the other components like dust like feed, fodder, dung etc. however, at poultry houses higher dust concentration was observed during hot humid season than hot dry season might be due to excreta removal from the shed increased the dust concentration. Twenty-eight percent more colony count was observed during hot humid than the hot dry season. It might be due to higher relative humidity coupled with high temperature, which favored the environment for the growth of microbes. More microbial colony counts in poultry houses than the animal houses were observed. It might be due to the more closed type of house favored higher relative humidity and tighter with presence of mash feed and litter and excreta in the poultry house than the animal house.

8. It was observed that the housing index for cowsheds at organized farms was 22.7 points i. e. excellent whereas at farmer's animal houses, 17.0 points i. e. average. Similarly the HI for BDLH, CLH and CLH + RP poultry houses were 26, 26 and 24 points, respectively, which falls under the excellent category. Farmers have to improve the housing condition by providing adequate space, ventilation, and modification of house to combat stress during hot dry and hot humid seasons.

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APPENDIX-I.

DATE	ET	EP	BSS	RF	WS	DT1	WT1	DT2	WT2	MAXT	MINT	VP1	RH1	VP2	RH2
1	2.51	3.40	9.83	0.00	4.54	11.86	9.70	25.76	16.63	26.63	10.67	7.76	74.36	8.75	34.70
2	1.99	3.10	9.73	0.00	4.00	11.91	10.33	26.34	17.66	27.16	10.99	8.49	81.46	9.89	38.38
3	1.61	3.57	9.56	0.00	3.67	12.49	10.61	27.70	18.44	28.87	12.20	8.48	79.45	10.32	36.98
4	1.34	3.44	10.13	0.00	4.10	13.26	11.53	28.01	18.71	29.03	11.99	9.21	81.02	10.57	37.20
5	1.14	4.31	10.19	0.00	3.79	13.66	10.86	30.51	18.43	31.13	12.43	8.08	69.15	8.57	26.29
6	0.90	3.70	9.64	0.00	2.76	11.00	10.11	28.89	18.44	30.56	9.87	8.81	89.29	9.64	32.46
7	0.86	4.47	10.54	0.00	3.49	10.51	7.26	30.49	16.37	31.07	8.80	5.72	60.25	5.43	16.92
8	0.71	4.83	10.61	0.00	3.96	12.40	9.91	31.11	16.69	31.84	11.04	7.76	71.29	5.53	16.70
9	0.90	5.61	10.54	0.00	3.96	16.74	13.14	34.44	19.43	35.73	14.19	9.31	64.84	7.81	19.52
10		5.04	10.53	0.00	3.11	16.51	13.37	37.14	19.60	37.81	14.87	9.63	69.41	6.42	13.77
11		7.71	10.46	0.00	3.49	18.80	14.57	37.54	19.37	38.90	15.91	9.98	62.09	5.80	12.00
12		6.06	8.96	0.00	3.39	18.31	15.69	35.83	19.00	37.69	16.73	11.96	74.61	6.30	14.15
13		6.26	8.11	0.00	4.24	24.20	19.34	36.64	22.26	37.96	22.81	13.93	61.64	11.39	24.69
14		7.14	10.20	0.00	4.90	23.49	19.57	35.83	22.09	37.36	21.70	14.70	68.45	11.58	26.42
15		7.17	10.69	0.00	5.41	22.73	19.17	36.06	20.37	37.61	19.90	14.60	69.94	8.49	19.01
16		8.86	10.43	0.00	5.44	24.09	18.26	37.51	21.07	38.56	20.70	12.21	55.03	8.69	18.07
17		8.79	10.99	0.00	5.00	25.03	21.43	38.79	22.56	40.04	21.83	17.02	71.42	10.60	20.55
18		8.80	10.56	0.00	7.23	24.47	21.20	36.81	22.83	38.67	22.07	17.02	73.25	12.32	26.98
19		9.40	11.03	0.00	5.80	27.83	23.71	39.59	24.26	41.14	25.74	19.53	69.76	13.32	24.74
20		9.69	11.59	0.00	5.96	28.31	24.20	40.67	23.94	42.46	25.53	20.25	70.62	12.08	21.31
21		8.91	11.04	0.00	9.37	28.44	25.66	37.83	27.20	39.97	27.10	23.00	79.04	20.52	41.78
22		9.51	10.11	2.80	10.03	29.06	25.94	36.20	26.66	37.66	26.51	23.22	77.10	20.33	45.32
23		8.86	10.51	0.00	10.56	28.91	25.51	37.20	25.91	38.77	27.21	22.41	74.98	18.16	38.20
24		10.11	9.64	0.00	10.69	28.80	25.57	37.29	27.54	38.71	27.54	22.60	76.16	21.68	45.29
25		9.50	9.34	0.00	10.89	28.74	26.04	36.49	28.83	38.14	27.26	23.62	79.85	25.01	54.73
26		8.61	6.55	0.00	11.97	28.60	25.03	35.49	26.13	37.51	27.97	21.61	73.67	19.71	45.47
27	6.90	7.67	6.36	0.00	10.59	27.89	24.94	34.89	25.43	36.37	26.91	21.87	77.68	18.56	44.33
28	2.94	6.20	3.95	15.80	11.33	27.34	24.71	33.34	25.54	35.23	26.54	21.74	79.98	19.74	52.17
29	3.96	4.23	3.40	70.50	7.13	25.61	24.83	29.23	25.50	31.99	24.87	23.04	93.54	22.20	73.96
30	3.88	3.27	2.97	115.60	6.50	25.91	24.86	29.89	26.00	32.26	25.37	22.91	91.46	22.84	73.47
31	3.70	2.69	2.12	71.80	8.11	25.46	24.80	28.63	26.29	30.26	24.89	23.08	94.54	24.22	82.86
32	2.49	3.21	1.85	40.00	6.21	25.37	24.51	29.66	26.14	30.46	25.06	22.56	92.84	23.27	74.85
33	6.00	4.67	4.44	4.40	5.74	25.71	24.46	31.14	25.57	32.33	25.33	22.23	89.68	21.16	62.56
34	5.80	5.80	4.67	5.80	6.67	25.34	24.26	31.37	24.97	32.53	24.70	22.06	90.98	19.79	57.63
35	6.84	4.70	6.06	8.80	6.01	25.06	23.83	31.71	24.89	33.26	24.24	21.40	89.80	19.40	55.68
36	7.21	5.06	8.07	0.00	6.91	25.07	23.67	32.09	25.50	33.56	24.36	21.09	88.39	20.44	57.15
37	10.94	5.59	8.96	0.00	6.07	25.19	23.51	32.77	25.20	34.03	24.21	20.72	86.22	19.39	52.06
38	9.43	5.80	8.86	0.00	6.80	25.74	23.69	33.43	25.83	34.66	24.91	20.70	83.35	20.29	52.47
39	10.93	5.50	9.17	0.00	5.04	25.91	23.57	35.29	25.09	35.91	24.90	20.39	81.41	17.61	41.54
40	8.17	4.89	6.87	34.80	3.76	25.74	23.26	34.29	24.50	37.47	24.53	19.95	80.36	17.08	46.70
41	7.40	2.80	8.15	204.20	3.83	21.91	21.31	30.51	23.14	30.43	20.44	18.73	94.55	16.84	53.47
42	8.41	4.17	9.74	0.00	2.99	22.17	20.74	33.31	22.23	34.39	19.66	17.56	87.61	13.39	35.34
43	7.03	4.16	10.69	0.00	1.83	18.51	16.23	33.30	19.63	34.79	16.16	12.46	78.21	8.81	22.96
44	3.93	3.86	10.57	0.00	1.69	17.23	15.86	33.91	20.30	35.00	15.81	12.69	86.11	9.56	24.07
45	2.06	3.21	10.26	0.00	1.71	17.77	15.49	33.40	20.73	34.83	15.67	11.82	77.73	10.63	27.60
46	1.14	3.17	10.17	0.00	1.91	16.91	14.37	32.00	19.60	33.71	14.79	10.79	74.87	9.57	26.77
47	0.70	2.84	10.04	0.00	1.53	15.74	14.34	30.69	19.77	31.96	13.97	11.44	85.27	10.65	32.35
48	0.54	2.50	9.73	0.00	1.70	15.57	13.89	31.04	19.49	32.39	14.69	10.91	82.29	10.01	29.62
49	1.39	3.13	9.79	0.00	2.49	13.86	11.86	30.01	18.61	31.60	12.63	9.24	77.90	9.18	28.86
50	0.94	2.44	8.43	0.00	2.27	15.39	13.94	28.81	19.51	29.09	14.60	11.29	84.10	11.61	37.93
51	0.30	2.96	9.69	0.00	2.64	15.37	13.60	30.06	19.31	31.13	14.56	10.83	80.62	10.38	32.37
52	0.26	2.44	9.26	0.00	2.51	13.49	12.83	28.08	18.14	29.45	12.39	10.91	94.09	9.63	33.90

APPENDIX-II

Sr. No.	Housing component	Score
1	Floor area of the stall available per animal	Can be measured quantitatively
2	Height of the stall	Can be measured quantitatively
3	Flooring of the stall	Pucca-2; tiled-1 and kutcha-0
4	Level of the floor	Sloopy-2; levelled-1 & uneven-0
5	Height of the wails	Half wall-2; full wall-1 & no wall-0
6	Type of walls	Pucca-3; kutcha-0 & improvised-1
7	Type of roof	Pucca-2; thatched or asbestos-1 & tin-0
8	Ventilation	Good-2, fair-1 & poor-0
9	Type of drain	Clean-1 & not clean-0
10	Cleanliness of floor	Clean-1 & not clean-0
11	Cleanliness of the stall as a whole including walls	Clean-1 & not clean-0
12	Sanitary conditions of surrounding area	Yes-1 & no-0
13	Care taken to keep floor dry	Yes-1 & no-0
14	Stall site at a level higher than surrounding area	With same species-1 with other animals-0
15	Housing with animals	Yes-1 & no-0
16	Arrangement made against hot or cold winds	Yes-1 & no-0
17	Shade provided against sun of rain	Yes-1 & no-0
18	Cooling arrangement in summer and warming in winter	Yes-1 & no-0
19	Arrangements made against stagnation of extra winter	Yes-1 & no-0
20	Provision of straw bedding	Yes-1 & no-0