STUDIES ON ENERGY EXCHANGE IN CATTLE AND BUFFALOES DURING DIFFERENT SEASONS

THESIS SUBMITTED TO THE
NATIONAL DAIRY RESEARCH INSTITUTE, KARNAL
(DEEMED UNIVERSITY)
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

MASTER OF VETERINARY SCIENCE
IN
ANIMAL PHYSIOLOGY

BY
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This is to certify that the thesis entitled, **"Studies on energy exchange in cattle and buffaloes during different seasons".**submitted by DAMLE PRAVEER SHAMtowards the partial fulfilment of the award of the degree of **MASTER OF VETERINARY SCIENCE IN ANIMAL PHYSIOLOGY** of the **National Dairy Research Institute (Deemed University)**, Karnal (Haryana), India, is a bonafide research work carried out by him under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

Dated: 12th July 2013

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Dedicated To....

My beloved parents, T_2,
Guide
&
PHYSIOLOGY

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Dated: January, 2013 ***(Praveer.S.Damle)***

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% : Percentage

cm^2 : centimeter square

m^2 : meter square

@ : At the rate of

°C : Degree centigrade / Celsius

A : surface area

ad lib : Ad libitum

ATPS : Ambient temperature and pressure at saturated air.

BMR : Basal Metabolic Rate

BTPS : Body temperature and pressure, saturated

C : The exchange of energy by convection

CH_4 : Methane

CO_2 : Carbon dioxide

EE : Energy expenditure`

et al. : Co- workers

F_{ECH4} : The fraction of expired methane.

F_{ECO2} : The fraction of expired carbon dioxide.

F_{EO2} : The fraction of expired oxygen

$F_{I\ CO2}$: The fraction of inspired air carbondioxide.

F_{IO2} : The fraction of inspired oxygen

h : Hour

H : Heat production

h_c : Convection coefficient

i.e. : That is

K : kelvin

Kcal : kilo calorie

kg. : kilo gram

mm : millimeter

O_2 : oxygen

p : Statistical p-value obtained

RR : Respiration Rate

STPD : standard temperature and pressure, dry air.

t : single paired t test

T^4 : Skin surface temperature

T^a : animal surface temperature in ^{0}c

T_s : Temperature of environment in ^{0}c

V_{CO2} : The rate of carbon dioxide production.

V_{CH4} : The rate of methane production.

V_E : volume of expired air

$V_{O\,2}$: volume of oxygen

W : The body weight of the animal

ABSTRACT

The study was conducted to measure energy exchange in cattle and buffaloes during winter and summer. The experimental animals consisted of six each of Sahiwal heifers and Murrah buffaloes of 18-24 months. The expired air was collected in a Douglas bag at every half an hour or one hour interval on the day energy exchange was measured. The volume collected in Douglas bag was measured on wet test meter; CO_2, O_2 were analyzed on Del sensor Analyser and Methane was analyzed on Methane analyser (Analytical Development Co. UK, ADC). Methane emission was measured by open calorimetric system consisting of polycarbonate sheet chamber from which air was exhausted out and concentration of methane was measured. In Sahiwal cattle, the mean heat production (kcal per min) and the total heat production (kcal per day) was significantly different ($P<0.01$) during summer and winter. The heat production per unit metabolic body weight was more during summer as compared to winter but statistically there was no significant difference. The oxygen consumption was found to be significantly more in summer as compared to winter. Similarly carbon dioxide production was found to be more in summer as compared to winter but statistically there was no significant difference. Respiration rate was significantly different ($P<0.05$) during summer and winter. The energy loss as methane was more in winter as compared to summer and methane loss as energy component of total heat produced was more in winter than summer. Sensible heat loss through radiation and convection during winter was more as compared to gain in summer but statistically non-significant. In Murrah buffaloes the mean heat production (kcal) per min and the total heat production (kcal) per day were not significantly different during summer and winter. The heat production per unit metabolic body weight was less during summer compared to winter but statistically there was no significant difference. The oxygen consumption was found to be significantly more in summer as compared to winter. Similarly carbon dioxide production was found to be more in summer as compared to winter but statistically there was no significant difference. Respiration rate was significantly different ($P<0.05$) during winter and summer. The energy loss as methane was more in winter as compared to summer and methane as energy component of total heat produced was more in winter than summer. Sensible heat loss through radiation and convection was less as compared to heat gained in summer but statistically non-significant. The body weight (kg), metabolic body weight ($W^{0.75}$), surface area ($0.15\ W^{0.530}$), and basal metabolic rate kcal/kg$^{0.75}$ was significantly different ($P<0.05$) in Sahiwal and also in Murrah during summer and winter respectively.

विभिन्न मौसम के दौरान गायो और भैसों की उर्जा विनिमय पर अध्यन्न

शोधकर्ता डा0 आर.सी. उपाध्याय
प्रविर दामले पशु शरीर क्रिया विभाग

सारांश

प्रस्तुत अध्यन्न गर्मी और सर्दी के समय गाय व भैंसो द्वारा उर्जा के आदान प्रदान को ध्यान में रखकर किया गया। इस प्रयोग के लिये साहिवाल व मुर्रा नस्ल के व्यस्क पशु संख्या छः छः और जिनकी आयु 18-24 महीने के बीच थी अध्यन्न के लिये चुना गया।तथा अध्यन्न में पुशओं द्वारा निष्कासित हावा को आधे से एक घण्टे के अवधि के बीच डगलस थैले में प्रविदिन एकत्रित किया गया। इसके बाद एकत्रित की गई हवा से ऑक्सीजन व कार्बन डाईआक्साईड की मात्रा डेल सेन्सर एनेलाईजर और मीथेन की मात्राा मीथेंन एनेलाईजर (एनेलाईटिकल डिवलपमैन्ट कम्पनी ये्.के., ए.डी.सी.) उपकरण द्वारा विश्लेषण किया गया। तथा साथ ही साथ नमी परिक्षण मीटर द्वरा हवा की मात्रा का भी विश्लेषण किया गया। अध्यन्न में पशु कक्ष जोकि पोलोकार्बोनेट शीट द्वारा बना था इसके अन्दर पशु रख कर उत्सर्जित मिथेन को खुला उष्मापन प्रणाली द्वारा मापा गया और मिथेन की एकाग्रता ज्ञात की गई। निष्कर्ष में पाया गया कि साहिवाल नस्ल में उर्जा उत्पादन किलो कैलरी प्रतिमिनट और कुल उर्जा उत्पादन प्रतिदिन सर्दी व गर्मी के दौरान ($P < 0.01$) पर सार्थक रूप से भिन्न-भिन्न पाई गई। उसके साथ-साथ उर्जा उत्पादन्न प्रति ईकाई चयापचय पुश शरीर वजन गर्मी के दिनो में सर्दीयो के तुलना में अधिक थी परन्तु ससाख्यिकीय रूप में भिन्नता नही पाई गई। पशुओ में अक्सीजन की मात्रा सर्दी की तुलना गर्मी के समय सार्थक रूप से ज्यादा पाई गई। उसी प्रकार कार्बनडाईऑक्साईड सर्दी के मुकाबले गर्मी में ज्यादा थी, परन्तु सांख्किीय रूप में कोई सार्थक अन्त नहीं पाया गया। स्वसन क्रिया पर गर्मी व सर्दी के दौरान ($P<0.05$) सार्थक रूप से भिन्न पायी गई। उर्जा द्वारा मिथने के रूपे मे सर्दी के दिनो मे गर्मी के मुकबाले जायदा पाया गया और कुल ऊर्जा उत्पादन से ऊर्जा घटक ह्रास मीथेन के रूप में गर्मी के मुकाबले सर्दियों में ज्यादा थी। और महसूस की जाने वाली ऊर्जा संवहन व विकिरण द्वारा गर्मी की तुलना में सर्दी के समय ऊर्जा ह्रास अधिक पाया गया परन्तु सांख्किीय रूप में सार्थक नहीं था। उपरोक्त के साथ-साथ मुर्राह भैंसों में गर्मी और सर्दी के दौरान ऊर्जा उत्पादन किलो कैलोरी प्रति मिनट प्रतिदिन सार्थक रूप में भिन्न पाई गई। ऊर्जा उत्पादन चायपचय पशु शरीर वजनानुसार गर्मी के दौरान कम व सर्दियों में अधिक पाई गई। परन्तु सांख्किीय रूप में भिन्नता नहीं पाई गई। अध्ययन के दौरान ऑक्सीजन की खपत सर्दियों के मुकाबले गर्मी में अधिक पाई गई। इसी प्रकार कार्बनडाईऑक्साईड उत्पादन सर्दियों की तुलना में गर्मियों में अधिक था परन्तु सांख्किीय रूप में सार्थक रूप में भिन्नता नहीं पाई गई। श्वसन दर ($P<0.05$) गर्मी व सर्दी के समय सार्थक रूप में पायी गई। इसके अलावा मीथेन के रूप में उष्मा हानि सर्दियों में गर्मियों के मुकाबले अधिक पायी गई। और महसूस की जाने वाली ऊर्जा संवहन व विकिरण द्वारा प्राप्त ऊर्जा हानि गर्मी के दिनों सर्दियों की तुलना में कम थी परन्तु सांख्यिकीय रूप में सार्थक नहीं पाई गई। पशुओं का शरीर वजन कि0ग्रा0 चयपचय ($W^{0.75}$) तल क्षेत्रफल ($0.015\ W^{0.530}$) और चयपचय पशु शरीर वजन किलो कैलोरी/कि.ग्रा.$^{0.75}$ ($P<0.05$) पर साहीवाल व मुर्राह दोनों नस्लों में गर्मी व सर्दी के समय सार्थक रूप से भिन्नता पाई गई।

CHAPTER – 1

Introduction

1. INTRODUCTION

The performance of an animal is the product of interaction between the geographical environments. The productivity of livestock is adversely affected by extreme climatic conditions. Reduction in feed intake and production is the common sign of heat stressed animal. Proper understanding of how climatic factors affect the physiological responses of the animal provides a firm basis to improve their health and welfare. Over the last 30 years, considerable progress has been made in aggregating knowledge from various biological levels to understand how metabolism of whole animal is affected by its physiological state, environment, and diet. Management of energy expenditure of farm animals under controlled, confirmed conditions is one of the factors. The energy expenditure (EE) of grazing animal is related to grass land terrain, amount of time spent the grazing and muscular work associated with eating, digestion, standing and walking (Osuji, 1974; Caton & Dhuyvtter, 1997). Environmental factors can also influence the nutrient requirement and the subsequent performance of farm animals. The most important variable is the environment temperature. Below the lower critical temperature, the amount of energy required by the animal to maintain core body temperature increases.

Energy expenditure of the animals can be measured either by respiration chamber or Douglas bag technique. Animal calorimetry based on respiratory exchange measurement has been successfully used from the beginning of the century to obtain an estimate of energy expenditure of the animal. Calorimetry method, based on respiratory interchange, was widely used by Brody (1945) with domestic animals. Originally the method consisted of a mask or hood to fit the head of the animal and it was connected to portable respirometry equipment. This technique utilized either oxygen consumption or carbon dioxide production to estimate energy expenditure of animals. Depending on time after feeding, approximately 70 to 82 % of CO_2 emission in ruminants comes from respiration and only a small proportion originates from enteric fermentation (Hoernuicke *et al.*, 1965). The CO_2 so produced can be used to estimate EE from established equations. Energy expenditure can also be calculated from the calorific value of O_2 consumed, CO_2 and CH_4 produced or else from the calorific value of O_2 consumed alone.

Methane is a by-product of the fermentation process and it is considered as the inherent part of the energy metabolism in ruminants. Cattle and buffalo can lose about 4-9% of their dietary intake energy as methane. Methane production is also dependent on several factors including energy intake, enteric ecology, quantity and quality of feeds, body weight, age and season. Results on the effects of temperature on methane production in cattle are not consistent. *In vitro* studies carried out by Bhatta *et al*. (2006) showed that an increasded in temperature from 39 ^{o}C to 41 ^{o}C increased the total gas and methane production however values were not significant. Animal calorimetric system can be used for the measurement of methane concentration in exhaled breath from the animal. Very little information is available on the effect of energy expenditure and loss of energy as methane in Indian cattle and buffaloes during different seasons. Keeping this in view the present study was designed to measure the energy exchange (metabolic and environment) and energy loss as methane in cattle and buffaloes during summer and winter season.

Objectives of investigation:

- To measure energy exchange (metabolic and environment) in growing cattle and buffaloes during different seasons.
- To measure energy loss as methane during different seasons.

CHAPTER – 2

Review of Literature

2. REVIEW OF LITERATURE

Basic knowledge of heat production and avenue of heat exchange was described as early as time of Aristotle (Goodfield, 1960; Mendelsohn, 1964). In tropical countries like India, little information is available on the effect of different season on the energy expenditure and loss of energy as methane in cattle and buffaloes. In this review, different aspects of normal calorimeter and methane emission have been reviewed.

2.1 ANIMAL CALORIMETER AND HEAT PRODUCTION

Cathcart (1918) and Douglas and Priestley (1924) developed douglas bag with the tap open than turned to closed a bag to outside air. When animal is settled the tap is turn to collect the expired air in the douglas bag where collection is for fixed time taken.

Blaxter and Joyce (1963) have used Douglas bags to measure the energy expenditure of tracheotomised sheep. The volume of the bag allowed collection of expired air to be made for up to 30 min. The expired air volume was measured by pumping it from a bag through a gas meter, a sample of gas was collected from the outlet of the meter, dried and analyzed for oxygen, carbon dioxide and methane content.

Joyce (1964) mentioned that Douglas bag method for determining O_2 consumption gave values which agreed with those determined by hourly measurements in the chamber, the means being 16.23 lit h^{-1} for the Douglas bag method and 16.13 lit hr^{-1} for the respiration chamber method. These values were very similar to those determined over the 24-hr period in the respiration chamber 16.4lit hr^{-1}. Douglas bag determinations of CO_2, however, were 4.01 lit hr^{-1} lower for sheep Ct and 4.2 lit hr^{-1} lower for sheep Cs than the values computed from the 24-hr respiration chamber experiments.

Hall and Brody (1932) were first to publish results based on the oxygen consumption by the animal wearing a mask with the oxygen being fed to the animal by reservoir tank. The energy expenditure was estimated from the volume of oxygen consumed times the heat equivalent of oxygen. Brody's measurement of necessity was short period measures no more than 12 min and the results were extra plotted to the 24 hrs basis.

Benedict and Carpenter (1910) built a man sized calorimeter in their new laboratory at Boston which including a large group chamber capable of holding 12 individual beds.

Hill and Hill (1914) developed direct calorimeter but adiabatic chamber were built at Cambridge for work on sheep and dog and on open pig and young cattle.

McLean and Tobin (1987) reported that calorimetry is the measurement of heat and includes the measurement of heat production or energy expenditure as well as heat emission or heat loss from the body.

Regnault and Reiset *et al.* (1849) were the first to describe a closed-circuit system for measuring respiratory gases. The animal was introduced into the bell-shaped chamber through an aperture in the base; they found that the ratio of CO_2 produced to O_2 consumed varied according to the type of food eaten rather than according to the species of animal. They also reported a very small volume of nitrogen given off by most animals.

The first of a series of closed circuit respiration chamber for studies on sheep was described by Blaxter *et al.* (1954) and successive improvements on the basic design and modification to suit special experimental requirement have been reported by Wainman and Blaxter (1958) and Kelly (1977), a version large enough to accommodate an adult steer or cow was also built (Wainman and Blaxter, 1958). Turner and Thornton (1966) reported measuring the gaseous exchange (up to 1 hr) in cattle.

Blaxter (1971) reported the principle of measuring the gaseous exchange of an animal by determining the change in the composition of the air in a sealed chamber. Blaxter (1971) also reported that system (chambers) is an extension of the 'confinement' principle for the measurement of respiratory gas exchange. The chambers are large enough to accommodate an adult cattle beast, but sufficiently flexible in operation to be used with individual sheep. Blaxter *et al*. (1972) and Aulic *et al*. (1983) made the measurement nearly continuous by periodically flushing out the chamber and recharging it with fresh air.

Kleiber (1975) cited different systems of calorimeters for use with mammalians and fowls, and considered the open and closed circuit respiration chambers to be practical and suitable systems in evaluating energy metabolism. The construction and function of a medium size chamber appropriate to operate as an indirect calorimeter with small ruminants, Since the chamber has no floor, it is placed on a steel base which has a channel (5cm wide x 5cm depth) filled of water that surrounds the lower edges when the chamber is placed on the swine, dogs, and fowls, built at the Escola de Veterinária da Universidad Federal de Minas Gerais, Belo Horizonte, Brazil.

Brockway and Mc Donald (1977) mentioned that infrared analyser is perfectly suitable for the measurement of CO_2 in the 0-1% range and methane 0-0.1% which is not much greater than the highest sensitivity of analyser.

Hampton *et al*. (1982) have used a mixing box design at the Institute of Naval Medicine at Alverstokehants and found it very satisfactory.

Armitage *et al*. (1984) reported that the ventilated hood is highly successful for the measurement of energy expenditure of rats for periods of up to several months.

Agnew and Yan (2005) reported that respiration calorimetry is a usual method to determine methane and heat production in energy metabolism in farm animals. It is an indirect method, where gas exchange associated with the oxidation of energy substrates is measured and heat production (HP) is calculated from the stoichiometry of substrates oxidation. Most of them operate following the open-circuit principle, with the animal confined in a respirometric chamber.

Yeck and Stewart (1959) mentioned that there is negative linear relationship between air temperature and heat production of cattle.

Yousef (1985) defines HP as a measure of sum of total energy transformation happening per unit time.

Colovos *et al*. (1970) studied the effect of body position and interval after position change on fasting energy expenditure of the holstein steers on the basis of kilocalories of energy expenedly per kg of metabolic $W^{0.75}$ per 24 hrs. Energy expended on standing was significant ($p < 0.01$) larger than for laying posture. The animal expended 5.00 kcal/100kg wt arising and 2.72 kcal per 100 kg wt reclining or 7.7 kcal for the double change in contrast to Brody's 2.5 kcal per 100 kg wt.

Minakami and de Verdier (1976) gave a very detailed picture of the contribution of different steps in glycolysis to the heat production from erythrocytes. They were able to relate the enthalpy changes of the metabolic reactions to the heat production observed. These studies confirmed earlier observations that during normal conditions very little glucose is metabolized via the pentose shunt. This pathway can, however, easily be stimulated by adding methylene blue with a concomitant 5 to 10 fold increase in heat production.

2.1.1 METABOLIC HEAT PRODUCTION AND OXYGEN CONSUMPTION

Brody (1945) and McLean (1972) reported that the volume of oxygen consumed per unit time is termed as oxygen consumption (V_{O2}) that depends upon body weight and physiological state. During energy metabolism, the oxidation of energy substrate in the body generates heat while consuming oxygen. Therefore, measures of whole body oxygen uptake can be used to calculate heat production.

Brody (1945) observed that heat production in animals has been shown to vary with environmental temperature. However, Kibler *et al.* (1949) reported that the magnitude of response depends upon the physiological makeup of animals and extent of exposure to the stress. Also the Mean oxygen consumption in dairy cattle was found to vary between 100-150 lit/hr at a temperature of 60^{o}F.

Joyce (1964) reported that the mean O_2 consumption measured in the chamber was 0.02 lit/hr lower than that measured by the Douglas bag method and this difference was not statistically significant.

The normal mean oxygen consumption (V_{O2}) in calves has been reported to be 130 (110 to 153) lit/hr (Mullick, 1960), Ayershire oxen 0.66 lit/ min (Hales and Findlay, 1968) and adult buffaloes 94 lit/hr (Mullick, 1960).

Upadhyay (1982) reported that in adult Zebu bullocks mean V_{O2} was 3.4 (2.9-5.6) lit/ min. and in crossbred bullocks was 4-8 lit/min (Upadhyay, 1982; Praveen *et al*., 1987; Gupta and Rao, 1990).

Finch (1985) found that heat storage was positively related to environmental temperature and significant breed difference in the magnitude of increase. Also when air temperature exceeded rectal temperature there were marked increase in heat storage for Brahman x Hereford-shorthorn and shorthorn.

Chikamune (1986) reported that in adult Holstein cows the annual average oxygen consumption was 1.96 ± 0.17 lit/ min.

Dang (1990) observed the effect of exercise on oxygen consumption in she buffaloes and found mean V_{O2} increased from the resting value of 2.71 lit/min to 7.00 lit/ min after exercise.

Smith (1996) reported that metabolism or heat production ranges from a basal level (chemical sources of the metabolism) to the level that may be twenty times higher (mechanical sources of metabolism) during work *viz.* reproduction, muscular work, production and thermoregulation.

Upadhyay and Aggarwal (1997) reported oxygen consumption in Karan Fries male calves 3.7 ± 0.05 ml/kg body weight, at air temperature of $35.8\pm.89^0$C and relative humidity $62.5\pm1.6\%$.

Aggarwal and Upadhyay (1997) studied the effect of solar exposure on oxygen consumption in Sahiwal and crossbred cattle and found four hour solar exposure increased oxygen consumption from 0.55 ± 0.03 lit/min and 0.66 ± 0.55 lit/min to 1.25 ±0.05 lit/min and 1.55 ± 0.08 lit/min in Sahiwal and crossbred respectively. Consequently the metabolic heat production also increased from 677 $KJm^{-2}hr^{-1}$ and 816 $KJm^{-2}hr^{-1}$ to 1537.84 and 1880.81 $KJm^{-2}hr^{-1}$ in Sahiwal and crossbred cattle respectively.

Aggarwal and Upadhyay (1998) reported that in male buffaloes, after four hours of solar exposure the mean VO_2 (0.94 lit/min) and heat production (1149.85 KJ/hr) increased to 1.68 lit/min and 2066.45 KJ/hr, respectively.

The exchange of heat between animal and environment is a major component of metabolic heat production, in addition to growth, milk production, pregnancy, and activity components. The surface area (SA) of the animal is the interphase for skin convective, radiant, and evaporative heat loss, complemented by convective and evaporative heat loss via the respiratory system (McGovern and Bruce 2000; Turnpenny 2000; Gebremedhin and Wu, 2001). Lutz (2002) noted that the mass-specific rate of oxygen consumption was smaller in larger species.

2.1.2 CARBONDIOXIDE AND METHANE PRODUCTION

Feddes *et al.* (1984) reported that Carbon dioxide can also be considered as a tracer gas. This gas is generated by animals at rates dependent on size of animal and rate of metabolism. Carbon dioxide production rates were measured in dairy, pig and broiler facilities. Results indicated that the concentration of carbon dioxide in the exhaust air from such facilities can be a convenient method of estimating ventilation rates and should be investigated further.

Kirchgessner *et al*. (1991) reported that two linear relationships of determined CO_2 as a function of animal live mass and either milk production or feed dry matter intake (DMI).

$$ECO_2 = -1.4 + 0.42 \times M_{DMI} + 0.045 \times MB\ W^{0.75}$$

Where, ECO_2 is the emission of CO_2 from animal respiration (kg CO_2 head^{-1} day^{-1}), M_{DM} is the daily intake of feed dry matter for each animal (kg DM head^{-1} day^{-1}), and MB is the animal's body mass (kg).

IPCC (2001) and Schlesinger (2000) reported that on dairy farms, CO_2 emissions result from respiration (animal, plant, and soil) and decomposition of soil organic matter (SOM) and manure 90% of on-farm CO_2 emission is due to animal respiration, followed by lower emissions from manure. IPCC (2007) also reported that carbon dioxide (CO_2) is the most important anthropogenic GHG. Its annual emissions have grown by about 80% between 1970 and 2004.

Chianese *et al*. (2009) reported that on dairy farms, animal respiration of CO_2 is a major source relative to other CO_2 emissions. In the overall farm balance, the CO_2 released largely offsets the CO_2 assimilated in the feed consumed.

2.1.3 METHANE PRODUCTION

Wainman and Blaxter (1958) reported closed circuit apparatus for cattle was built and proved successful in operation, but the cost of absorbents for water vapour and carbon dioxide in such systems are so high as to be prohibitive at the present time.

Joyce (1964) measured O_2 consumption from the pulmonary exchange which has, however, the same as that measured by confining the animal in a chamber. The experiments showed that the discrepancy between the total amount of CH_4 produced and that collected from the lungs was not constant but varied with the amount of food given and the amount of fermentation elicited. About 83 % of the CH_4 produced by tracheostomized sheep not excreted by the lungs and is lost, presumably by belching. A correction could be made to the values obtained in measurements of pulmonary excretion to take belching into account by multiplying the measured CH_4 excretion by the lungs by 6, since about one-sixth of the total CH_4 is collected.

Blaxter and Clapperton (1965) gave a mean value of methane production, i.e., 154.2 liters per day in cattle on feeding scheduled-roughages including dried gases, hays and silages, mixed diet containing some hay, and diet composed of related or milled material. Blaxster and Clapperton (1965) also gave a mean value of 29.9 L/day for methane production in sheep feeding with roughage, mixed diet and diet composed of pelleted material.

Blaxter and Clapperton (1965) defined metabolizable energy as the heat of combustion of a feed less the heat of combustion of feces, Urine and gases which are produced when it is eaten. The loss of energy in feces and urine can be determined easily by keeping the animal in metabolism cases, but to determine the loss of energy as combustible gas, i.e., as methane, involves quantative measurement of the gaseous exchange and the use of much more complex and expensive equipments. Several attempts have been made to predict the loss of energy as methane by cattle and sheep from knowledge of the amount and type of feed.

Czerkawaski (1969) reported that daily methane production ranges from 26 to 36 L on maintenance diet whereas on production diet it ranges from 45 to 55 L/day.

Bond *et al*. (1971) measured CH_4, mixing ratios in exhaled air from methane-producing individuals vary widely, from only a few ppm above ambient air ratios to more than 70 ppm, with an average of 14.8 ppm from 280 healthy individuals (Grainger *et al*., 2007) Whole-animal chambers have been used to measure total CH_4 emissions from individual cattle and paired cattle (Beauchemin *et al*., 2007).

Thorbek (1980) using a respiration calorimeter reported that methane production in calves ranged from 50to 100 L/day depending on size of animal feed composition, level of feeding and digestibility of feed. This constituted loss of 4 to11 per cent dietary gross energy.

Kirchgessener *et al*. (1991) measured the release of methane and CO_2 in relation to feeding and performance in lactating cows. The cows were given the conventional feed according to requirements based on live weights (450 to 725 kg) and milk yield (7.5 to 25.7 kg). Average methane production was 300 gm per head/day depending upon CF and EE intake. Methane production will increase with increasing milk yield. Annual methane production of 600 kg cow producing 5000 kg milk per year was estimated at 108 kg plus a further 8 and 5 kg of methane for each addition, 100 kg of live wt. and 1000 kg of additional milk annually. Ruminant livestock can produce 250 to 500 L of methane per day (Johnson and Johnson., 1995).

The amount of CH_4 produced by an animal is influenced by many factors. These include dietary factors such as type of carbohydrate in the diet, level of feed intake, level of production (e.g. annual milk production in dairy), digests passage rate, presence of ionophores, degree of saturation of lipids in the diet, environmental factors such as temperature (McAllister *et al*., 1996). In preparing the Inventory of U.S. Greenhouse Gas Emission and Sinks EPA (2002) used the spread sheet based model called Cattle Enteric Fermentation Model (CEFM), to calculate methane emissions from cattle enteric fermentation based on a ‘rolling herd’ population characterization that tracks cattle energy demand through different growth stages. These energy demands are then correlated with methane production based on diet and animal characteristics.

The major global warming potential (GWP) of livestock production worldwide comes from the natural life processes of the animals. In fact, CH_4 is considered to be the largest potential contributor to the global warming phenomenon (Johnson *et al.*, 2002 and Steinfeld *et al*., 2006).

The level of CH_4 emission is positively correlated with live weight, dry matter intake (DMI), milk yield (MY), and feeding level (Yan *et al*., 2006). Measurement of CH_4 production in animals requires complex and often expensive equipment. Some models have been developed to specifically predict CH_4 emissions from animals (Ellis *et al*., 2007).

WHO (2009) reported that emission of CH_4 is responsible for nearly as much radiative forcing as all other non-CO_2 GHG gases combined. While atmospheric concentrations of GHGs have risen by about 39% since the pre-industrial era, CH_4 concentration has more than doubled during this period.

Chianese *et al*. (2009) reported that the anthropogenic sources include fossil fuel production and exploitation, animal husbandry, including manure storage paddy rice cultivation, biomass burning, and waste management.

Madsen *et al*. (2010) developed a new method for estimating methane emissions from livestock, which is based on the use of CO_2 as a tracer gas.

Stormida and Lousie (2012) reported that the chamber method has good accuracy and precision for assessing the daily production of CH_4 from housed animals but limited capacity with regards to the number of animals. It is therefore best suited for comparison of distinct mitigation strategies in crossover or Latin square experiments. It also provides information on the daily variation in methane emission.

2.2 SURFACE AREA

Sarrus and Rameaux (1838) proposed that the surface law, which suggested that like heat loss, the heat production of different-sized species should be related to surface area rather than body mass.

Meeh (1879) published a formula to estimate BSA from body weight based on the fundamental mathematical law which states that similar solids have a surface area proportional to the 2/3 power of their volumes. He used body weight to represent volume, and derived the following equation, based on dimensional analysis:

BSA = 0.1053 weight $^{2/3}$.

The Surface area was calculated according to three equations:

1. $0.105 \times W^{0.67}$ (Meeh, 1879)
2. $0.09 \times W^{0.67}$ (Mitchell, 1928)
3. $0.14 \times W^{0.57}$ (Brody, 1945)

There are two possible methods to estimate SA in animals either by direct measurement or by a predictive equation. The relationships between body mass and SA area had been pioneered by Meeh (1879), who proposed the Euclidian theorem that for bodies of similar shape; surface area is proportional to the two-thirds power of their volume $A \times W^{0.67}$. This proposition was followed by extensive studies (Brody, 1945; Kleiber, 1961 and Mitchell, 1962).

Kelley *et al.* (1973) reported that surface area in cm^2 =734 (body weight in kg) $^{0.656}$ r = 0.99 predicts surface area of female swine of the current "meat type" more accurately than does Brody's formula on the basis of 36 observation of initial gilts and extra gilts combined.

Rotz *et al.* (1999 and 2009) reported that in IFSM, DMI is determined based upon the nutrient requirements (fiber, energy, and protein) and target milk production of a representative animal for each group within the herd and the amount and nutrient content of available feeds including pasture.

The effects of Surface Area estimates on heat exchange were calculated using a model for the thermal balance of cattle (McGovern and Bruce, 2000).

Berman (2003) by using $0.09 \times W^{0.67}$ equation (where W = weight in kilograms) used to estimate body surface area (SA) in Holstein cattle was compared with those of the equation $0.14 \times W^{0.57}$ based on weighing 41 to 617 kg. The estimate of SA produced by the first equation was 23% greater for a 650-kg cow than that obtained by the second equation.

Berman (2003**)** reported that the estimate of SA is valuable for the estimation of energy requirements in the cold as well as that of heat stress at higher ambient temperatures.

In normal dairy cattle, surface area has been found to be a direct power function of weight. The formula $SA = 1470\ W^{0.58}$ in which SA is the surface area in square centimeters, and Wt he live weight of the animal in kilograms, accurately expressed the relationship between surface area and live weight (Elting, 1926).

2.2.1 METABOLIC WEIGHT

Rubner (1883) showed that the heat production of dogs ranging in size from 3 to 31 kg were more similar when expressed relative to body surface area than if expressed per unit of body mass regarded as confirmation of the surface law of metabolism.

Keesey and Hirvonen (1997) reported that body weight, like body water and body temperature, is physiologically regulated. In the case of body weight, coordinated adjustments in both the intake and expenditure of energy serve to stabilize the weights of individuals at a specified level and to resist their displacement from this level.

NRC (2001) reported that metabolic heat production was calculated according to maintenance heat production as 0.080 Mcal/kg $BW^{0.75}$.

Cunningham (2002) reported that an increase in body temperature also increases the metabolic rate.

Energy expenditure when expressed as MJ/kg DMI was 3.48, 2.90 and 3.12; whereas as per cent of ME intake it was 50, 41 and 44 in unchopped paddy straw offered *ad lib*, Chopped paddy straw fed at restricted, level chopped paddy straw offered *ad lib* (Bhatta *et al.,* 2006).

Rotz *et al*. (2009) reported that body weight was determined based upon animal breed (as specified by the model user) and age and stage of lactation.

2.2.2 BASAL METABOLIC RATE

Krogh (1916) suggested that a more empirical approach should be used to examine the relationship between metabolic rate and body size.

Forbes (1931) reported that the ideal base value from which to measure energy metabolism in cattle would be as the theoretical minimum base value of energy metabolism that is the energy requirement of an animal living entirely on its own tissues, at 100 per cent efficiency of transformation of their metabolizable energy into vital energy. The heat production representing the actual energy need; there being complete oxidation of metabolized nutrients with no waste heat of transformation, and no stimulation of heat production by metabolites the organism existing, therefore, in a manner comparable to that of an internal combustion engine operating under such hypothetical conditions that the work done would be equivalent to the potential energy of the fuel.

Lavoisier measured the minimal metabolic rate in a resting post absorptive state, which was probably the first measurement of BMR (Blaxter, 1989; Lutz, 2002).

Brody and Procter (1932) and Kleiber (1932) reported that two independent empirical studies showed that the BMRs of different-sized mammals and birds were proportional to the 0.73 power of body mass rather than the 2/3 power of body mass as suggested by the surface law.

Bond *et al*. (1971) measured CH_4, mixing ratios in exhaled air from methane-producing individuals vary widely, from only a few ppm above ambient air ratios to more than 70 ppm, with an average of 14.8 ppm from 280 healthy individuals.

In adult homeotherms, basal metabolism defines the minimum energy demand under conditions of thermo neutrality and total rest. The daily basal metabolism, expressed in megajoules (MJ), is roughly proportional to the power of the body weight

W (kg) and is given by the formula: basal metabolism = 0.293 $W^{0.75}$ with an uncertainty of about 14% (Menke and Huss, 1975).

2.3 THERMOREGULATION

Animals maintain heat balance (heat produced or gained from environment is equal to the heat loss to the environment), as per the following equation:

$M = \pm R \pm K \pm C + E$

Where, M is the metabolic heat production, R is heat exchange by radiation, K is heat exchange by conduction, C is the heat exchange by convection and E is the heat loss by evaporation from skin and pulmonary system (Robertshaw, 1985). Animal gain heat from three sources: chemical, mechanical and thermal. Chemical and mechanical heat transfer related to metabolic processes and represents the body's main heat sources.

Smith (1996) reported that the influence of the thermal environment on an animal is primarily exerted through energy exchanges involving radiation, convection, conduction and evaporation.

Sparke *et al.* (2001) reported that evaporation is referred to as insensible heat exchange because it involves latent heat and a change in the kinetic energy of molecular arrangement without a change in temperature.

Hansen (2004) reported that the rate of the heat transfer from animals to the surrounding air is dependent on the air temperature and vapor pressure gradient. Also radiation, conduction and convection are referred to as the sensible heat transfer processes due to differences in temperature of the materials with which heat exchange would take place.

2.3.1 CONVECTION

Ittner *et al*. (1957) reported increased air movement (3.7 MPH) in Hereford steers at temperature around 106°F, decreases body and skin temperature which indicates the heat is lost.

Convective heat transfer by circulation is the main mode of heat transfer to the periphery of livestock. Increasing blood flow to the skin caused by vasodilation increases the thermal gradient between the skin surface and air prompting heat loss to the surroundings (McDowell, 1972).

Convective heat transfer by circulation is the main mode of heat transfer to the periphery of livestock and increase blood flow to the skin caused by vasodilation increases the thermal gradient between the skin surface and air prompting heat loss to the surroundings (McDowell, 1972).

Ludri (1979) reported that the movement of air, aided by ceiling fan, on the body of the animals, helped in reducing the heat load by changing the microenvironment of the animals. The increase in air movement over the body surface caused disruption of the layer of air near the skin surface. This allows removing warm air and help replace by cooler air.

Robertshaw (1985) mentioned that cattle losses heat to the environment using air as the medium. Anything that resists movement will decrease the rate of convective heat transfer. Since cattle are furred animals, the fur entraps a layer of air close to the skin and tends to resist passive or natural convection.

Convection also plays a key role in respiratory heat loss. The enhanced air flow through the nasal passages and upper respiratory tract can carry a large amount of body heat. The inspired air is not only humidified, but adjusted to core body temperature by the time the air reaches the trachea (Robertshaw, 1985).

Convective heat loss from the skin is proportional to the difference between body surface and air temperatures. Maintaining a higher surface temperature benefits the animal because it enhances convective heat loss. Latent heat loss from the skin, in contrast, is practically independent of ambient temperature (Gebremedhin and Wu 2002).

Kadzere (2002) observed that when cool air comes in contact with a warm body layer, the air surrounding the surface of the body is heated and moved away from the body, carrying the heat and therefore cools the body through the process of convection. On contrary, if air temperature is greater than skin temperature, then the air movement will promote the movement of heat into the animal until air temperature equal to the skin temperature.

Dandage (2009) reported that heat loss to environment in adult sahiwal increases from 396.8±26.4 to 420.7±23.2kj/hr by convection in winter season sahiwal in natural environment condition and also reported that Heat gain in adult sahiwal varies from 292.4±11.8 to 256.7±14.8kj/hr by convection in summer.

2.3.2 RADIATION

Stewart and Brody (1954) reported that Cattle do not respond to the radiation at an ambient temperature of 21.1 and 26.7^{0}C. Jersey cows had a mean heat production rate 12-14% lower with maximum production load and on other hand, Holstein cows showed heat production decrease of 26% at 21.1^{0}C and 9% at 26.7 ^{0}C.

Brody (1954) observed that Brahman cows showed little response to radiation due to their low heat production rate; therefore, their heat dissipation requirement was not more than half of the lactating Jersey and Holsteins.

Esmay (1969) reported that the radiant heat transfer between the bodies takes place in both directions and if the bodies are at different temperature there is a net transfer from top to the cooler body.

Studies on the heat exchange in the long wave portion of the spectrum indicate that the net transfer is away from the animal (Robertshaw and Finch, 1976).

Robertshaw (1985) reported that the most part, solar radiation in cattle is a function of surface area exposed to the radiation, and the color and structure of their coat

The intensity of solar radiation that reaches the earth's surface varies, but under clear skies often reaches values of about 1000 W/m^2 on a plane perpendicular to the solar beam, of this beam roughly one-half of this energy lies in visible wavelengths, and hence is of sufficient magnitude that coat color might significantly modify an animal's heat balance (Walsberg, 1983).

Guyton and Hall (1996) reported that all the objects in proximity of an animal emit electromagnetic radiation in infrared range. Warm objects emit more energy of shorter wavelength per unit time than do cool objects. The net heat transfer in animal is from warm to cool objects, a greater quantity of heat is radiated to the body thus body gain heat.

Kadzere *et al*. (2002) reported that the amount of radiated heat exchange by an object depends not only on temperature of the object, but also on its color and texture, with dark surfaces radiating and absorbing more heat than light colored surface at same temperature.

Heat loss to environment in adult sahiwal increases from 1242.±175.0 to 1458.6±185.6 kj/hr by radiation in winter season. Heat gain in adult sahiwal varies from 1190.6±102.6 to 1158.6 ±154.8kj/hr by radiation in summer (Dandage 2009).

2.4 PHYSIOLOGICAL RESPONSES

2.4.1 RESPIRATION RATE

Increase in respiratory frequency may be used as an index of discomfort in large animals (Gaalas, 1945; Goswami and Prem Narain, 1962; Bhattacharya *et al*., 1965).

Seath and Miller (1946) reported that increased respiration rate is the first reaction when animals are exposed to environmental temperature above the thermo neutral zone.

Mullick and Kehar (1952) reported that in large animals, pulmonary system compensates for their thermoregulatory inability as sweating mechanisms limitedly contribute to heat dissipation.

Bhatnagar and Choudhary (1960) reported that the combination of relative humidity and air temperature caused variation in body temperature and respiration rate of animals, whereas the relative humidity caused variation in pulse rate.

McLean (1963) observed that the significance of increase in respiration rate under heat stress enables the animal to dissipate the excess of body heat by vaporizing more moisture in the expired air, which accounts for about 30 per cent of the total dissipation.

At higher rectal temperatures, the respiratory rate declines while tidal and minute volumes increase. The further increase in minute volume ensures that respiratory evaporation continues to increase, inspite of the fact that the increase occurs at the expense of an over-ventilation of the alveoli (Whittow, 1971).

Thomas *et al*. (1973) reported that after 8 hr of solar exposure, variation occurred in respiratory frequency from 22-45 and from 29-47 in Sahiwal and crossbreds respectively.

Chikamune and Shimizu (1983) reported that the respiration rate in swamp buffalo and Holstein showed a highly significant correlation with seasonal air temperature, when the relative humidity was kept constant. Whereas no such significant effect of relative humidity on the RR could be observed when the air temperature was kept constant.

Robertshaw (1985) reported that the increased respiratory frequency, contributes not only by increasing oxygen exchange, but also by dissipating heat through convective heat evaporation from the respiratory surfaces. Regulation of body temperature is essential by dissipating excessive heat load and involves both physiological and behavioral changes. Increased respiratory ventilation, known as panting, is associated with heat exposure.

Legates *et al*. (1991) reported a positive correlation between RR and ambient temperature (r = 0.53) in lactating dairy cows. Wind velocity affected respiration rate, heart rate and rectal temperature negatively and significantly. Mishra *et al*. (1995) reported a correlation of 0.918, 0.883 and 0.839 between respiration rate and ambient temperature in crossbred heifers, crossbred cows and purebred Jersey respectively.

Aggarwal and Upadhyay (1997) reported that the change in respiratory frequency and rectal temperature after 4 hrs of exposure was significantly higher in crossbreds (90 per min) than in Sahiwal cattle (25 per min).

Hahn *et al*. (1997) found that respiration rate showed a strong correlation with ambient temperature once it surpassed 21°C, and increased at a rate of 4.3 bpm per °C above a baseline of 60 bpm.

Hahn and Mader (1997) conducted experiments in the cyclic chamber in which air temperatures nominally cycled sinusoidally from 11 to 25ºC during thermoneutral periods and from 25 to 39 ºC during elevated temperature conditions. They found higher RR at an air temperature of 21.3ºC, with RR increasing by 4.3 bpm per degree C above a baseline RR of 60 bpm at the threshold temperature.

Aggarwal and Upadhyay (1998) reported that the change in respiratory frequency after 4 hrs of exposure was significantly higher in crossbreds (90 per min) than in Sahiwal cattle (25 per min) and also increase in rectal temperature was more in crossbred than in Sahiwal.

Hahn (1999) reported that respiratory rate increases as stressors cause an animal to maintain homoeotherm by dissipating excess heat when other avenues (i.e. conduction, convection, radiation) become inadequate.

Thankachan (2007) reported that there is increase in RR at the end of four hours exposure in climatic chamber at 42°C and 50% RH on Murrah buffaloes.

Dandage (2009) reported that there is an increased RR at the end of four hours exposure in climatic chamber at 40°C and 50% RH and also in the extreme seasons (winter and summer) of the year in Sahiwal, Karan Fries and Murrah buffaloes.

Extrapolating to animals weighing 500 to 700 kg produced data that overestimated tidal volume by 49% relative to the tidal volume measured in mature Holstein cattle data (Kibler, 1964; Berman, 1957).

McGovern and Bruce (2000) found that overestimation of tidal volumes led to overestimations of respiratory heat loss, as mentioned in the description of the model and the equation for maximal tidal volume estimation in the model was replaced by that based on the mean of the aforementioned studies of Holstein cows:

$Vt = 0.4 + 0.0064 \times BW$

Where Vt = tidal volume (L/breath).

2.4.2 SKIN TEMPERATURE

Brody *et al.* (1952) noted elevated skin temperature in response to increased environmental temperature and humidity in cattle.

Tanaja (1959) reported that cutaneous evaporation is more closely controlled by skin temperature than by rectal temperature.

Joshi *et al.* (1963) conducted experiments on Haryana and Gir heifers and found low evaporation rate (5.2 mg/10cm^2/5min) in winter at 18.5^{o}C.

Saravanakumar and Thiagarajan (1992) made an attempt to characterize the sweat gland and skin qualities of epidermis and total thickness and also compared the heat tolerance ability in Murrah, Surti and non-descript buffaloes. They found that Murrah was least heat tolerant (74.56) compared to Surti (76.90) and nondescript (80.97).

Omar *et al.* (1996) found that cooling by sequential sprinkling and forced ventilation during summer reduced skin temperature by 3.5 and 3.7^{o}C for white and black skinned lactating Friesian cows.

Das *et al*. (1997) mentioned that skin temperature was found to be positively correlated with rectal temperature in buffaloes. There was a significant ($P<0.05$) negative correlation of Hb with respiration rate, heart rate and rectal temperature in Murrah buffaloes during hot humid season.

Da Silva *et al*. (2003) used a spectroardiometer to evaluate the thermo-physical properties of the skin and the hair coat of cattle, water buffalo and deer (Pantanal deer, Blastocerus dichotomus) from populations in south-eastern Brazil. The results showed that short-wave radiation (300 to 850 nm) penetrates light hair coats much more than dark coats, especially in the shorter wavelengths.

Da Silva *et al*. (2003) also investigated radiative properties of the skin and hair coat of various breeds of cattle with respect to shortwave radiation. The study concluded that light hair coats exhibited much higher reflectivity than dark hair coats for wavelengths ranging from 300 to 850 nm.

The exchange of heat between the body and its environment is determined by thermal insulation and water evaporation. Thermal insulation is composed of tissue insulation (TI) and external insulation (EI). The rate of increase of metabolic heat production below the lower critical temperature (LCT) is affected by EI and the maximal value of TI. The TI represents the resistance to heat flow from body core to skin, and would therefore be expected to be proportional to body diameter (Berman, 2004).

Jiang *et al*. (2005) did a simulation study of skin temperature and sensible and latent heat losses through the fur layer and reported that increased relative humidity reduced evaporative heat loss from the skin surface because of the lower water-vapor concentration.

Infrared (IR) thermography, which allows for the measurement of the surface temperature of the animals' body that could be related to several physiological processes associated with feed efficiency (Schaefer *et al*., 2005). Moreover, several studies have applied IR thermography to determine radiant and convective heat losses IR thermography has great potential for estimating methane emissions, which is an environmental concern in large ruminant production systems (Yuri *et al*., 2007).

Thankachan (2007) reported an increase in skin temperature of Murrah buffaloes at the end of four hours exposure in climatic chamber. Similarly, Mayengbam (2008) reported in cross bred dairy cattle and Dandage (2009) in Sahiwal, Karan Fries and Murrah Buffaloes.

CHAPTER – 3

Materials and Methods

3. MATERIALS AND METHODS

3.1 GEOGRAPHICAL LOCATION OF KARNAL

Karnal is situated at an altitude of 250 meters above mean sea level and at 29º 42´ N latitude and 79º 59’ E longitudes. The highest temperature goes up to 45 º C in summer and minimum temperature 3.5 ºC to 4 ºC in winter. The average rainfall is about 700 mm. The climograph of Karnal is presented in fig 2.1.

3.2 EXPERIMENTAL ANIMALS

3.2.1 Selection of Animals

Apparently twelve healthy Sahiwal cattle and Murrah buffaloes heifers (18-24 month) were selected from the herd of National Dairy Research Institute (NDRI), Karnal and used for experiments during this study.

3.2.2 Management of Animals

The experimental animals were maintained as per the standard practices followed at the institute farm. The animals were fed as per the availability of fodders during experiments and water was available *ad libitum* round the clock.

3.2.3 Training of Animals

All the experimental animals prior to actual experimental work were trained to inspire and expire through a three way valve and putting a face mask in order to collect expired gas and analysed oxygen, corbondioxide and methane. These animals were also trained to stand quietly in a wooden travis for recording of physiological responses and collection of gases prior to actual experimentation.

3.2.4 Expired air sample collection

A three way valve and face mask was used to collect expired air from experimental animals. The total expired air for 4-5 min was collected in a Douglas bag at every half an hour or one hour interval. The volume collected in Douglas bag was measured on wet test meter and composition was analyzed. CO_2, O_2 were analyzed on (Del sensor analyzer), automatically the percentage of particular gas was displayed on LCD and memorized in the analyzer. Methane was analysed on Methane analyser (0.01 to 0.25%) (Analytical Development co.UK), ADC in expired gas. The volume of collected gas was measured on wet-test meter (precision scientific equipment U.S.A).

3.3 PHYSIOLOGICAL MEASUREMENTS

3.3.1 Respiration Rate

The respiration rate (RR) was recorded by observing the flank movement for one minute in which each inward and outward movement of the flank was counted as one complete respiration. The respiration rate was expressed as breaths per minute (bpm)

3.3.2 Skin Temperature

The observation on the peripheral skin temperature at different sites of the experimental animals, viz, forehead, ears, shoulder region (proximal scapula) and flank regions were recorded with non-contact telethermometer (Raytek, Model Raynger ST2L, M/s. Surrey Scientific, Surrey, U.K.) by keeping it 2-3 inches away from the desired surface site.

3.4 METABOLIC HEAT PRODUCTION

Metabolic heat production (H, Kcal) was determined accurately from oxygen consumption(O_2 in liters), carbon dioxide (CO_2, liters) production and methane production (CH_4, liters) The following formula was used to determine metabolic heat production (H).

$\mathbf{H=3.866\times O_2+1.200\times Co_2 - 0.518\times CH_4 - 1.431\times N}$ (Brouwer, 1964)

Where, H = heat production (H, Kcal)

O_2 = oxygen consumption (liters)

CO_2 = carbondioxide (liters)

CH_4 = Methane production (liters)

Fig. 3.1: Recording of Oxygen, Carbon Dioxide (Del sensor analyser) and Methane (Analytical Development co.UK) in the expired air collected in the Douglas bag.

3.5 RESPIRATORY GAS MEASUREMENT

The change in respiratory gases between inspired and expired breaths per unit time is the rate of gas consumption. The rate of volume of expired air was calculated from formula **:**

$$\underset{\text{(liter/min)}}{V_{E(\,ATPS)}} = \frac{\textbf{Wet test meter in liter}}{\textbf{Respiration rate}} \qquad \text{…………..(1)}$$

3.5.1 Rate of O_2 consumption

Rate of O_2 consumption is the volume of inspired O_2 minus volume of O_2 expired per unit time during respiration. Rate of O_2 consumption was calculated from formula**:**

$$\underset{\text{(liter/min)}}{V_{O\,2\,(\,ATPS\,)}} = \frac{V_E \times (F_{IO2} - F_{EO2})}{(1 - F_{EO2})} \qquad \text{…………….(2)}$$

Where,

V_{O2} = The rate of oxygen consumption,

V_E = The volume of air the subject breathes in one min (minute volume),

F_{IO2} = The fraction (percentage divided by 100) of inspired air that is oxygen i.e. 0.2094 (Since the percentage of oxygen in room air is constant at about 20.94%,)

F_{EO2} = The fraction of expired air that is oxygen (i.e., the percentage measured with the O_2 analyzer).

3.5.2 Rate of CO_2 production

The Volume of CO_2 produced per min was calculated using formula**:**

$$\underset{\text{(liter/min)}}{V_{CO2\,(\,ATPS}} = (\frac{V_E \times (F_{E\,CO2} - F_{I\,CO\,2}) - F_{I\,CO2} \times V_{O2}}{(1 - F_{I\,CO2})} \qquad \text{…………..…….(3)}$$

Where,

V_{CO2} = The rate of carbon dioxide production.

V_E = The volume of air the subject breathes in one min (minute volume),

$F_{E\,CO2}$ = The fraction of expired air that is carbon dioxide.

$F_{I\,CO\,2}$ = The fraction (percentage divided by 100) of inspired air that is carbon dioxide i.e.,$F_{I\,CO2}$ = 0.0003 (Since a little percentage (0.03%) of CO_2 in fresh air)

Fig.3.2: Recording of methane from Sahiwal animal kept in angle iron chamber fitted with polycarbonated sheet.

3.5.3 Rate of CH_4 production

The volume of CH_4 produced per min was calculated:

$$\mathbf{V_{CH4\,(ATPS)} = V_E \times F_{E\,CH4}} \qquad \text{(liter/min)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where,

V_{CH4} = The rate of methane production

V_E = The volume of air the subject breathes in one min (minute volume)

$F_{E\,CH4}$ = The fraction of expired air that is methane

3.5.4 Volume of standard temperature and pressure, dry air

The V_E, V_{O2}, V_{CO2}, V_{CH4} for STPD (standard temperature and pressure, dry air) obtained from respective V_E, V_{O2}, V_{CO2}, V_{CH4} for ATPS (ambient temperature and pressure, saturated) by using following formula**:**

$$\mathbf{V_E\,(STPD)}\text{(liter/min)} = \mathbf{V_E\,(ATPS) \times 0.825} \qquad \ldots\ldots\ldots\ldots(5)$$

$$\mathbf{V_{O2}\,(STPD)}\text{ (liter/min)} = \mathbf{V_E\,(STPD)\,(F_{IO2} - F_{EO2})} \qquad \ldots\ldots\ldots\ldots(6)$$

$$\mathbf{V_{CO2}\,(STPD)}\text{(liter/min)} = \mathbf{V_E\,(STPD)\,(F_E\,CO2 - F_{I\,CO2})} \qquad \ldots\ldots\ldots\ldots(7)$$

$$\mathbf{V_{CH4}\,(STPD)}\text{ (liter/min)} = \mathbf{V_E\,(STPD) \times (F_E\,CH_4)} \qquad \ldots\ldots\ldots\ldots(8)$$

Where,

V_{O2} = The rate of oxygen consumption

V_E = The volume of air the subject breathes in one min (minute volume)

F_{IO2} = The fraction (percentage divided by 100) of inspired air that is oxygen i.e. 0.2094 (Since the percentage of oxygen in room air is constant at about 20.94%)

F_{EO2} = The fraction of expired air that is oxygen (i.e., the percentage measured with the O_2 analyzer)

V_{CO2} = The rate of carbon dioxide production

$F_{E\ CO2}$ = The fraction of expired air that is carbon dioxide

$F_{I\ CO\ 2}$ = The fraction (percentage divided by 100) of inspired air that is carbon dioxide i.e.,

$F_{I\ CO2}$ = 0.0003 (Since a little percentage (0.03%) of CO_2 in fresh air)

V_{CH4} = The rate of methane production

$F_{E\ CH4}$ = The fraction of expired air that is methane

STPD = standard temperature and pressure, dry air

ATPS = ambient temperature and pressure, saturated

3.6 SURFACE AREA

The surface area was calculated using formula:

$$\text{Surface area } (m^2) = 0.15\mathbf{w}^{0.56} \qquad \textbf{…………..(9)}$$

3.6.1 Basal metabolic rate

The body weight, like body water and body temperature, is physiologically regulated and remain almost static in physiological limits. In the case of body weight, coordinated adjustments in both the intake and expenditure of energy serve to stabilize the weights of individuals at a specified level and to resist their displacement from this level (Keesey and Hirvonen, 1997).

Heat production in the animal body is due to the oxidation processes within the body, and hence is an accurate measure of the rate of metabolism. In order to utilize this standard in research, it becomes necessary to devise a satisfactory method for comparing the heat production of animals of different sizes. The basal metabolic rate of the animal was calculated from body weight using formula

$$\mathbf{BMR = 70.5W^{0.734}} \qquad \textbf{……………………(10)}$$

Where,

BMR = The basal metabolic rate (kcal/day)

W= The body weight of the animal in kg.

3.7 SENSIBLE HEAT

$$\mathbf{Q_i = h_i\ A_D\ (T_s - T_o)} \quad \text{..(11)}$$

Where,

Q_i=amount of heat exchange

h_i =Heat exchange coefficient 2.3 for free convection,3.8 for radiation during winter and 5 during summer

T_s = Average body surface temperature

T_o = Environment temperature

3.8 STATISTICAL ANALYSIS

The data obtained during different experiments on cattle and buffalo were analyzed statistically for mean; standard error, single paired t-test two sample assuming equal variances models.

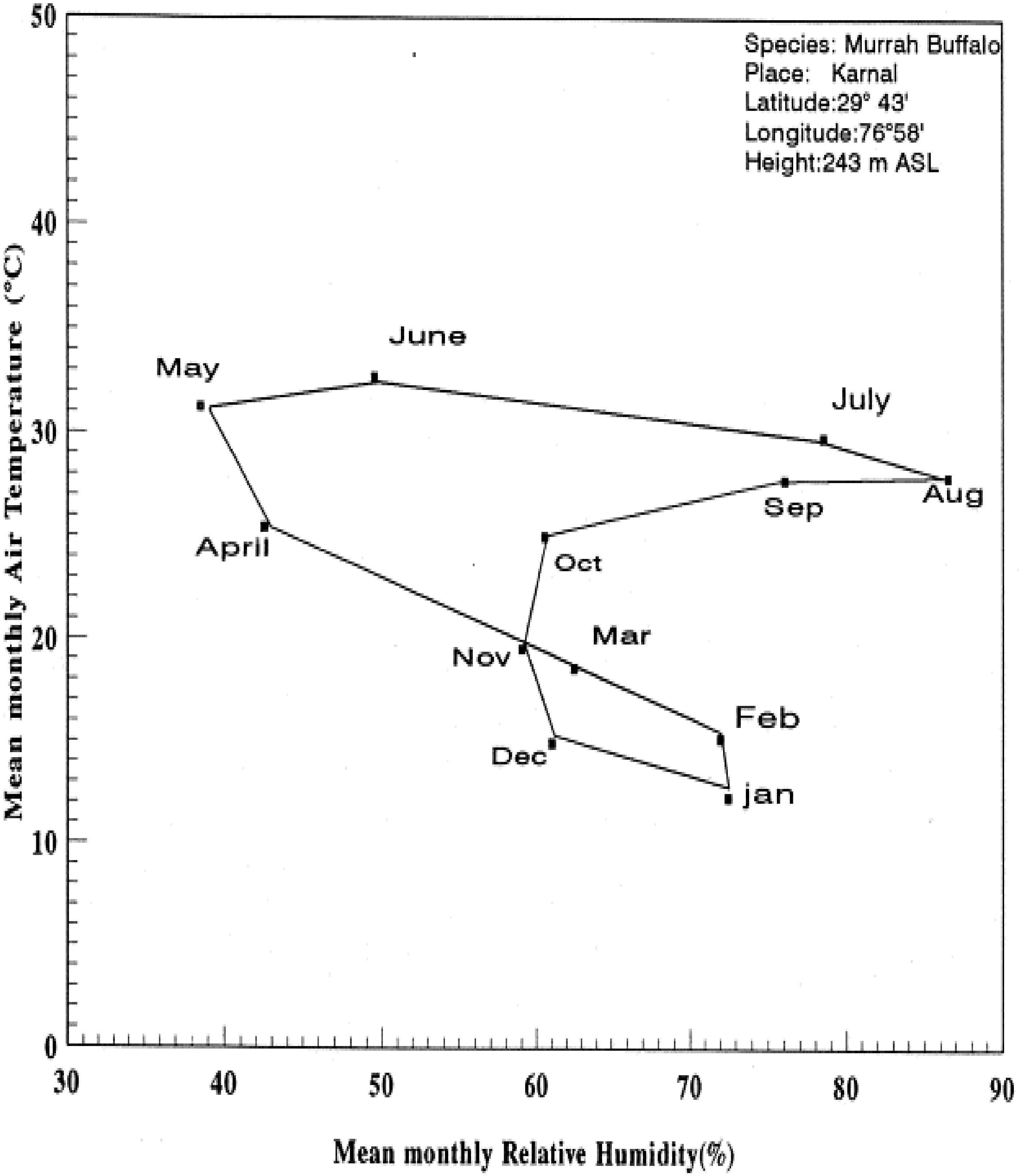

Figure 3.1. The Climograph of Karnal

CHAPTER – 4

Results and Discussion

4. RESULTS AND DISCUSSION

The results and statistical analysis for the present study carried on Sahiwal cattle and Murrah buffalo heifers have been presented in table 4.1 to 4.2.

Experiment was conducted during winter from February to March and summer in the month of April. The average minimum and maximum environment temperature value of dry bulb in the month of February was 10.6^{o}C and 19.9^{o}C, respectively. The minimum and maximum average value of dry bulb in the month of March was 15.1^{o}C and 27.1^{o}C respectively. The average minimum and maximum environment temperature value in the month of April was 21.1^{o}C and 35.0^{o}C, respectively.

The mean body weight of growing Sahiwal cattle during winter was 275.9±18.541 kg and metabolic body weight ($W^{0.75}$) was 67.536±3.339 kg. The surface area of Sahiwal cattle was 3.474±0.127 m^2 (0.15 $W^{0.530}$). The energy expanded by the animal, was calculated from the oxygen consumption and CO_2 production. Experimental animals at the time of gas collection during winter were observed to be breathing at a mean rate of 13.71±0.714 per min and tidal volume was 2.897±0.204 lit. The mean ventilation rate was 32.375±1.769 lit/min during winter.

The O_2 content in expired air of Sahiwal cattle ranged from 0.9 to 1.64 % and CO_2 from 0.41 to 1.06%.The mean oxygen uptake was 1.222±0.119 lit/min CO_2 exhaled was 0.722±0.090 lit/min. The values of normal mean oxygen consumption in calves have been reported by Mullick (1960) and Hales *et al.* (1968) who reported the similar type of results in cattle. The methane content in expired air of cattle ranged from 0.005 to 0.075% lit/min. The mean CH_4 production was 0.031±0.009 lit/min during winter season. The mean values of methane production in cattle were similar to Blaxter and Clapperton reported in 1965. The heat production ranged from 3.399 to 7.56 kcal/min and per day ranged from 4894.73 to 10866.63 kcal/day. The mean value of heat production was 5.558±0.554 kcal/minute during winter whereas total heat production was 8050.1±798.6 kcal per day. The heat production per unit surface area kcal/m^2 in Sahiwal cattle ranged from 1.08 to 2.15 kcal/m^2. The mean heat production per/m^2

surface area was 1.612±0.161 kcal/m^2 during winter. Heat production per kg metabolic body weight in cattle ranged from 82.661 to 159.260 kcal and the mean heat production per kg metabolic body weight was 119.945±11.407 kcal during winter. The growing cattle lost heat from the body surface to the environment in winter season through radiation and it ranged from 34.47 to 86.93 w/m^2k. The values are in agreement with Aggarwal and Upadhyay (1998) who reported the increased metabolic heat production with increased oxygen consumption in Sahiwal. The mean radiation heat exchange was 58.36±13.05 w/m^2k.The heat loss through free convection ranged from 20.87to 52.61 w/m^2k and the mean free convection was 35.33±7.89 w/m^2k. The results were according to Dandge *et al.* (2009) who reported that heat gain in adult sahiwal varies in summer.

The mean body weight of growing Sahiwal cattle during summer was 388.7±29.606 kg and metabolic body weight ($W^{0.75}$) was 87.305±5.204 kg. Rotz *et al.* (2009) reported that body weight was determined based upon animal breed and age and stage of lactation. The surface area of cattle was 4.256±0.146m^2. Experimental animals at the time of gas collection were observed to be breathing at a mean rate of 17.714±1.340 per min during summer and tidal volume was 2.723±0.149 lit. The mean ventilation rate was 40.301 ± 4.326 lit/min during summer.

The O_2 content in expired air of sahiwal ranged from 1.29-2.73 % and CO_2 content ranged from 0.53 to 1.14%.The mean oxygen uptake was 1.882±0.203 lit/min and CO_2 exhaled was 0.761±0.09 lit/min. The methane content in expired air of cattle during summer ranged from 0.006 to 0.078%. The mean CH_4 production was 0.0279±0.010 lit/min during winter season. The heat production per min ranged from 5.62 to 11.92 kcal/min and per day was 8105.67 to 17171.41 kcal/day. The mean heat production per minute was 8.19±0.886 kcal/minute during summer whereas; heat production per day was 11798.7±1276.3 kcal .The heat production per m^2 surface area in cattle ranged from 1.28 to 2.53 kcal/m^2 and the mean heat production was 1.900±0.1751 kcal/m^2during summer. Heat production per kg metabolic body weight in sahiwal cattle ranged from 88.092 to168.880 kcal and the mean heat production was 135.915±11.273 kcal/$^{0.75}$kg during summer. The growing Sahiwal cattle gained heat from the surroundings in summer through radiation from 27.59 to 119.24 w/m^2k and the mean radiation heat exchange was 64.4±12.63 w/m^{2}k.The heat gained through free convection ranged from 12.57 to 60.39 w/m^{2}k and the mean free convection rate was 29.63±3.86 w/m^{2}k.

The test of significance was used for finding out differences during both the seasons by using t-test. The statistical analysis of results indicated that respiration rate and oxygen consumed were significantly different during both seasons. The difference in observed values during winter and summer was due to seasonal changes and body weight difference in groups during winter and summer. Heat production per m^2 surface area was almost similar in both the seasons and heat production per unit metabolic body weight was low during summer even though animals were of high body weight 388.7 ±29.606 kg with large surface area and metabolic body weight than during winter. Sahiwal of large body weight try to have low expenditure and loose less heat per unit body size. Sahiwal on an average weighed 275 kg during winter, spent 119.945±11.407 kcal/kg$^{0.75}$ and 1.612±0.1617 kcal per m^2 as compared to Sahiwal weighed 388 kg during summer, spent 135.91±11.273 kcal/kg$^{0.75}$ and 1.990±0.1751 kcal/m^2 during summer. These results though do not differ significantly during both the seasons but indicate that during summer heat production were more in sahiwal per unit metabolic body weight than that of winter season. The energy loss as CH_4 in expired air was 0.053 ±0.027 lit/min during winter and 0.028±0.008 lit/min during summer respectively. The methane as an energy component of total heat produced was 4.43±1.78% during winter and 2.99±0.76% during summer. There were variations in energy loss as methane in different animals and ranged from 0.67% to 13.39% during winter and 0.96% to 6.58% during summer. There were no significant differences between two seasons in heat production per kg body weight of surface area.

The mean body weight of growing Murrah buffalo heifers during winter was 248.4± 13.147 kg and metabolic body weight ($W^{0.75}$) was 62.48±2.475 kg. The surface area of buffaloes ($0.15W^{0.530}$) was 3.285±0.097m^2. Sarrus and Rameaux (1838) proposed the surface law, which suggested that the heat loss, heat production of different-sized species should be related to surface area rather than body mass. The energy expanded by the animal, was calculated from the oxygen consumption and CO_2 production. Experimental animals at the time of gas collection were observed to be breathing at a mean rate of 12.833±1.077 per min during winter and tidal volume was 2.923±0.376 lit. The mean ventilation rate was 29.581±2.063 lit/min during winter.

The analysis of expired air collected in Douglas bag was carried out for O_2, CO_2 on Del sensor (Denmark) and CH_4 on Methane analyser (Analytical development co, UK). The O_2 content in expired air of buffaloes during winter ranged from 0.60 to 1.64 % and CO_2 from 0.38 to 1.09 %.The mean oxygen uptake was 0.981±0.146 lit/min and CO_2 exhaled was 0.600±0.015 lit/min. Hales and Findlay in 1960 reported the value of normal mean oxygen consumption in buffalo and similar type of results have been reported. The methane content in expired air of buffaloes ranged from 0.01to 0.08%. The mean CH_4 production was 0.045±0.015 lit/min during winter season. The results were similar to Thorbek (1980) who reported the methane production in calves using respiration calorimeter. The heat production ranged from 2.79 to 7.65 kcal/min and from 4010.54 to 11018.80kcal/day. The mean heat production per minute was 4.492±0.688 kcal/min during winter and heat production 6469.1±991.8 kcal per day .The heat production per unit surface area kcal/m^2 in buffaloes ranged from 0.86 to 2.20 kcal/m^2. The mean heat production was 1.357±0.185 kcal/m^2 during winter. These results correlate with those of Shibu *et al.*, (2008) and Yasotha (2007). The heat production per kg metabolic body weight in buffaloes ranged from 65.15 to163.88 kcal and the mean heat production per kg metabolic body weight was 102.736±12.411 kcal/kg $^{0.75}$during winter. The growing buffaloes lost heat from the body surface to the environment in winter season and radiation ranged from 44.72 to 97.46 w/m^{2}k. The mean radiation heat exchange was 73.65±4.08 w/m^{2}k.The heat losses through free convection ranged from 44.72 to 97.46 w/m^{2}k. The mean value of free convection was 46.07±1.77 w/m^{2}k.

The mean body weight of growing murrah buffalo during summer was 393.5±14.240 kg and metabolic body weight ($W^{0.75}$) was 88.293±2.389 kg. The surface area of buffalo was 4.254±0.085 m^2. Animal at the time of gas collection were observed to be breathing at a mean rate of 17.66±1.358 breath per min during summer and tidal volume was 2.450±0.142 lit. The mean ventilation rate was 35.285 ± 2.352 lit/min during summer. Chikamune *et al.* (1983) reported that the respiration rate in swamp buffalo showed a highly significant correlation with seasonal air temperature.

The O_2 content in expired air of buffaloes ranged from 1.03-1.73 % and CO_2 from 0.48 to 0.66 %.The mean oxygen uptake was 1.416±0.100 lit/minand CO_2 exhaled was 0.589±0.048 lit/min. The methane content in expired air of buffaloes during summer ranged from 0.01to 0.1%. The mean CH_4 production was 0.0503±0.013 lit/min during summer season. The results are in accordance with according to Aggarwal and Upadhyay (1998) who reported that increase in mean Vo_2 and heat production due to solar exposure. The heat production per min ranged from 4.55 to 7.47 kcal/min and per day was 6550.09 to 10755.25 kcal/day. The mean heat production was 6.154±0.435 kcal/minute; whereas, total heat production was 8863.1±626.4 kcal per day during summer.The heat production per m^2 surface area in buffaloes ranged from 1.08 to 1.78 kcal/m^2 and mean heat production was 1.446±0.097 kcal/m^2 during summer. The heat production per Kg metabolic body weight in buffaloes ranged from 75.58 to125.70 kcal/$kg^{0.75}$. The mean heat production in buffalo was 100.451±6.268 kcal/kg $^{0.75}$during summer .The growing buffaloes gained heat from surroundings in summer through radiation from 66.11 to 193.25 w/m^2k and the mean radiation heat exchanged was 123.87±8.35 w/m^2k. The heat loss through free convection ranged from to 30.41 to 85.57 w/m^2k and the mean free convection rate was 56.98±3.84 w/m^2k.

Finch (1985) and Hensen (2004) reported that heat exchange through radiation and convection depends upon surface area per unit body weight.

The test of significance was applied for find out difference during both the seasons by using t-test. The statistical analysis of results indicated that respiration rate and oxygen consumed were significantly different during both the seasons. The difference in observed values during winter and summer was due to seasonal changes and body weight difference in groups during winter and summer. Heat production per m^2 surface area was almost similar in both the seasons and heat production per unit metabolic body weight was low during summer even though animals were having 393.5 ±14.240 kg and with large surface area and metabolic body weight than during winter. Buffaloes of large body weight reduced energy expenditure and per unit body size lose less heat. Buffalo on an average weighed 248 kg during winter and spent 102.736±12.411 kcal/kg $^{0.75}$ and 1.357±0.185 kcal per m^2 as compared to buffalo on an average weighing 393 kg per day during summer and spent 100.45±6.268 kcal /kg $^{0.75}$

and 1.446±0.097 kcal/m^2 during summer. The results though do not differ significantly during both the seasons but indicate that during summer heat production was less per unit metabolic body weight than that of winter season. The energy loss as CH_4 was 0.044±0.015% during winter in exhaled air decreases to 0.032±0.011% during summer. The methane as an energy component of total heat produced was 8.935±2.67%during winter and 4.92±1.42%during summer. There were variations in energy loss in different animals and ranged from 2.14% to18.91% during winter and1.12% to 10.84% during summer.

In order to validate results on methane emission, angle iron chamber fitted with polycarbonate sheet (8ˈˈ× 8ˈˈ× 8ˈˈ) was fabricated. The chamber had electromagnetic door lock and feed manger with front door to facilitate animalfeeding. A provision of fans (8ˈˈsize) was made for mixing air inside the chamber Air was exhausted by a pump at a precise rate of 897.8 lit/min. A sample of mixed air was taken from exhaust duct 1.0 lit/min and CH_4 was analysed by Methane analyser. (Analytical Development Co. UK). The methane produced was calculated from average concentration of methane in expired air, rate of flow of pump and time of measurement. The results for CH_4 have been presented in table 4.3.

The sahiwal cattle of weighing 348.9 kg emitted methane at an average rate of 0.0118 %, a mean rate of CH_4 emitted per day was 125 lit and energy loss as methane wt / rate of CH_4 was 1187 cal/day. The methane emission varied from 61 to 175 lit/day in sahiwal. The emission of CH_4 from Sahiwal cattle is in agreement with Blaxter and Clapperton (1965) and Thorbek (1980).

Table 4.1 Metabolic and Energy exchange in Sahiwal

Parameters	Winter	Summer	t value
Body weight(kg)	275.9±18.541	388.7±29.606	3.23**
Metabolic body weight(kg)	67.536±3.339	87.305±5.204	3.2**
Surface Area (m)^2	3.474±0.127	4.256±0.146	4.03**
Basal metabolic rate(kg)	4351.7±210.3	6324.8±462.8	3.88**
Period in calculating time (min)	4.62±0.248	4.105±0.420	1.05
Respiration rate(bpm)	13.71±0.714	17.714±1.340	2.63*
Volume in Douglas bag(liter)	176.6±4.669	184.2±1.202	1.57
V_E(ATPS)(liter/min)	39.29±2.169	48.85±5.246	1.68
Tidal volume(liter)	2.897±0.204	2.7239±0.149	0.68
V_{O2}(ATPS)(liter/min)	1.222±0.119	1.882±0.203	2.8*
V_{CO2}(ATPS)(liter/min)	0.722±0.090	0.761±0.09	0.31
V_{CH4}(ATPS)(liter/min)	0.031±0.009	0.027±0.010	0.23
V_E(STPD)(liter/min)	32.375±1.769	40.301±4.326	1.7
V_{O2}(STPD)(liter/min)	0.824±0.081	1.2749±0.137	2.81*
V_{CO2}(STPD)(liter/min)	0.591±0.073	0.557±0.111	0.3
V_{CH4}(STPD)(liter/min)	0.053±0.027	0.028±0.008	0.89
HP/min(kcal)	5.588±0.554	8.19±0.886	2.49*
HP/day(kcal)	8050.1±798.6	11798.7±1276.3	2.49*
CH_4*9.45(kcal)	0.216±0.082	0.265±0.082	0.42
HP/surface Area (kcal/m^2)	1.612±0.161	1.900±0.175	1.21
HP/metabolic body weight kcal/kg$^{0.75}$	119.945±11.407	135.915±11.273	2.17
CH_4*9.45(kcal)/hp(kcal/min)	4.43%±1.78%	2.99%±0.76%	2.17
Radiation (w/m^{2}k)	58.36±13.05	64.4±12.63	0.56
free Convection (w/m^{2}k)	35.33±7.89	29.63±3.86	0.12

**(P<0.01)Significant at 1% level * (P<0.05)Significant at 5% level

Table 4.2 Metabolic and Energy exchange in Murrah

Parameters	**winter**	**summer**	**t value**
Body weight(kg)	248.4±13.147	393.5±14.240	7.49**
Metabolic body weight(kg)	62.489±2.475	88.293±2.389	7.5**
Surface Area (m)^2	3.285±0.097	4.254±0.085	7.5**
Basal metabolic rate(kg)	4033.2±156.4	5657.1±149.8	7.5**
Period in calculating time (min)	4.883±0.276	4.388±0.278	1.26
Respiration rate(bpm)	12.833±1.077	17.666±1.358	2.79*
Volume in Douglas bag(liter)	172.6±5.717	184.1±2.831	1.8
V_E(ATPS)(liter/min)	35.856±2.501	42.770±2.851	1.82
Tidal volume(liter)	2.923±0.376	2.450±0.142	1.17
V_{O2}(ATPS)(liter/min)	0.981±0.146	1.416±0.100	2.45*
V_{Co2}(ATPS)(liter/min)	0.600±0.104	0.589±0.048	0.1
V_{CH4}(ATPS)(liter/min)	0.045±0.015	0.0503±0.013	0.24
V_E(STPD)(liter/min)	29.581±2.063	35.285±2.352	1.82
V_{o2}(STPD)(liter/min)	0.659±0.099	0.954±0.068	2.44*
V_{co2}(STPD)(liter/min)	0.495±0.086	0.486±0.04	0.1
V_{CH4}(STPD)(liter/min)	0.044±0.015	0.032±0.011	0.61
HP/min(kcal)	4.492±0.688	6.154±0.435	2.04
HP/day(kcal)	6469.1±991.8	8863.1±626.4	2.04
CH_4*9.45(kcal)	0.423±0.148	0.311±0.109	0.61
HP/surface Area (kcal/m^2)	1.357±0.185	1.4462±0.097	0.42
HP/metabolic body weightkcal/kg$^{0.75}$	102.736±12.411	100.451±6.268	2.22
CH_4*9.45(kcal)/hp(kcal/min)	8.935%±2.67%	4.925%±1.42%	2.22
Radiation (w/m^{2}k)	73.65±4.08	123.87±8.35	5.2
Convection (w/m^{2}k)	46.07±1.77	56.98±3.84	2.47

**(P<0.01)Significant at 1% level   *(P<0.05)Significant at 5% level

Table 4.3 Methane Emission in Sahiwal Cattles

Animal	Tag no	Body weight	Mean% CH4	lit/ min (BTPS)	lit/min CH4 STPD	CH4 lit/day	Energy loss as CH4/day	BMR 70.5W0.73
Sahiwal-1	1688	407	0.0058	0.0519	0.0428	61.625	582.3562	5664.9103
Sahiwal-2	2167	300.2	0.005	0.0449	0.037	53.3293	503.9621	4536.2702
Sahiwal-3	1927	430	0.0122	0.1098	0.0906	130.4517	1232.7688	5896.8637
Sahiwal-4	2014	300	0.0109	0.0981	0.0809	116.5041	1100.9633	4534.0639
Sahiwal-5	1855	382	0.0165	0.1478	0.1219	175.5765	1659.1982	5408.7309
Sahiwal-6	1930	376.23	0.0152	0.1368	0.1129	162.5275	1535.8844	5348.9694
Sahiwal-7	2002	306.4	0.0145	0.1305	0.1076	155.0106	1464.8498	4604.4728
Sahiwal-8	2014	290	0.0141	0.1264	0.1043	150.1425	1418.8471	4423.2314
Mean		**348.97**	**0.0118**	**0.1058**	**0.0873**	**125.6459**	**1187.3537**	**5052.1891**

CHAPTER – 5

Summary and Conclusions

5. SUMMARY AND CONCLUSIONS

The study was conducted to quantify the energy expenditure, oxygen consumption, carbon dioxide production, metabolic heat loss, sensible heat exchange through radiation and convection. The experiments consisted of six each of Sahiwal heifers and Buffaloes. The experimental animals were fed *ad libitum* as per the standard practices followed at NDRI Karnal and fresh water was made available for drinking throughout the day. All the experimental animals prior to actual experimental work were trained to wear a face mask, and then inspire and expire through three way valve. The expired air was collected and analyzed for oxygen, carbon dioxide and methane. These animals were also trained to stand quietly in a wooden travis for recording of physiological responses and collection of gases prior to actual experimentation. All experimental animals were maintained to natural ambient conditions during winter and summer seasons for similar durations as in climatic chamber.

In sahiwal, the mean respiration rate was 13.71±0.714 bpm and 17.714±1.340 bpm, oxygen consumed was 1.222±0.119 lit/min and 1.882±0.203 lit/min during winter and summer respectively. These values were significantly different ($P<0.05$) during winter and summer. The differences in observed values during winter and summer were due to seasonal changes and body weight differences in groups, during summer and winter. The average Heat production per m^2 surface area was 1.612±0.161 kcal/$m^2$and 1.900±0.175 kcal/m^2 during winter and summer respectively and heat production per unit metabolic body weight was low i.e.119.945±11.407 kcal/$kg^{0.75}$ and 135.91±11.27 kcal/$kg^{0.75}$. During summer even though animals were weighing 388.7±29 kg, with large surface area and metabolic body weight than during winter which was 275.9±18.541 kg. Sahiwal on an average weighing 275 kg during winter, spent 119.945±11.40 kcal/$kg^{0.75}$ and 1.612±0.16 kcal per m^2 as compared to Sahiwal weighing 388 kg per day during summer and spent 135.915 kcal/$kg^{0.75}$ and 1.900±0.1751 kcal/m^2 during summer. The results indicated that during summer heat production was less per unit metabolic body weight than that of winter season.

The energy loss as CH_4 was 0.053±0.027 lit/min during winter and 0.028±0.008 lit/min during summer. Methane as an energy component of total heat produced was 4.43±1.78% during winter and 2.99±0.76% during summer.

In Murrah buffalo, the mean respiration rate was 12.833±1.077 bpm and 17.66±1.358 bpm, oxygen consumed was 0.981±0.146lit/min and 1.416±0.100 lit/min and there was significant difference ($p<0.05$) during winter and summer. The difference in observed value during winter and summer are due to seasonal changes and body weight difference in groups during winter and summer. Heat production per m^2 surface area was almost similar i.e. 1.375±0.185 kcal/m^2 and 1.4462±0.097 kcal/m^2 in both the seasons. Heat production per unit metabolic body weight was low i.e.102.736±12.411 kcal /$kg^{0.75}$ and 100.45±6.268 kcal /$kg^{0.75}$during winter and summer. Murrah buffalo on an average weighed 248 kg during winter and spent 102.736±12.411 kcal/$kg^{0.75}$ and 1.357±0.185 kcal per m^2 as compared to Murrah buffalo weighing 393 kg per day during summer and spent 100.451±6.26 kcal/$kg^{0.75}$ and 1.4462±0.097 kcal/m^2. During summer heat production was less per unit metabolic body weight than that of winter season. The energy loss as CH_4 was 0.044±0.015 lit/min during winter and 0.032±0.011 lit/min during summer, respectively.

The growing cattle lost heat from the body surface to the environment in winter season through radiation and it ranged from 34.47 to 86.93. The mean radiation heat exchange was 58.36±13.05 w/m^2k. The heat loss through convection ranged from 20.87 to 52.61 w/m^2k. The mean convection was 35.33±7.89 w/m^2k. There was no significant difference in radiation and convection. The growing Sahiwal cattle gained heat from the surroundings in summer through radiation from 27.59 to 119.24 w/m^2k and the mean radiation heat exchange was 64.4±12.63 w/m^2k. The heat gained through convection ranged from 12.57 to 60.39 w/m^2k and the mean convection rate was 29.63±3.86 w/m^2k. There was no significant difference during winter and summer.

The growing buffaloes lost heat from the body surface to the environment in winter season through radiation that ranged from 35.89 to 60.52 w/m^2k. The mean radiation heat exchange was 73.65±4.08 w/m^2k. The heat loss through convection ranged from heat 35.89 to 60.52 w/m^2k. The mean value of convection was 46.07±1.77 w/m^2k. The mean heat production of buffalo was 100.451±6.268 kcal/$kg^{0.75}$during summer. There is no significance during winter and summer. The growing buffaloes gained heat from surroundings in summer through radiation from 66.11 to 193.25 w/m^{2}k and the mean radiation heat exchanged was 123.87±8.35 w/m^{2}k. The heat loss through convection ranged from 30.41 to 85.57 w/m^{2}k and the mean convection rate was 56.98±3.84 w/m^{2}k. There is no significance difference.

From the present study it can be concluded that;

- The oxygen consumption was found to be significantly ($p<0.05$) more in Sahiwal during summer as compared to winter. Similarly carbon dioxide production was found to be more in Sahiwal during summer as compared to winter but statistically there was no significant difference. Whereas, the oxygen consumption was found to be significantly ($p<0.05$) more in Murrah during summer as compared to winter. Similarly carbon dioxide production was found to be more in summer as compared to winter but statistically there was no significant difference.
- The heat production (kcal) per min and total heat production (kcal) per day was significantly different ($P<0.01$) in Sahiwal during winter and summer. The heat production (kcal) per min and Heat production (kcal) per day was not significantly different in Murrah during winter and summer.
- The heat production per unit metabolic body weight was more in Sahiwal during summer as compared to winter but statistically there was no significant difference. The heat production per unit metabolic body weight was less in Murrah during summer compared to winter but statistically there was no significant difference.
- The energy loss as methane was more in winter as compared to summer and methane as energy component of total heat produced was more in winter than in summer in both Sahiwal and Murrah but statistically no significant difference was observed.
- In sahiwal, sensible heat loss through radiation and convection during winter was more as compared to gain in summer. In murrah, sensible heat loss through radiation and convection was less as compared to heat gained in summer.
- Respiration rate was significantly different ($P<0.05$) during winter and summer in both Sahiwal and Murrah. Tidal volume is more in winter than in summer but there was no significant difference in both Sahiwal and Murrah during winter and summer.

- The body weight (kg), metabolic body weight ($W^{0.75}$), surface area, ($0.15\ W^{0.530}$) and basal metabolic body rate kcal/ $kg^{0.75}$ was significantly different ($P<0.05$) in Sahiwal and Murrah during summer and winter respectively. The results though do not differ significantly during both the seasons but indicated that during summer heat production was less per unit metabolic body weight than that of winter season.

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