CHAPTER - II

REVIEW OF LITERATURE
1. Review on Buffaloes

   1) Species Variation in Feed Utilization

   The fact that species affect the digestibility profoundly has been proved by several workers. The large variation in their ability to utilize different kinds of feeds is due to their anatomical and physiological differences. This variation, especially in the digestibility of coarse fodder, appears to be significant in ruminants compared to other farm animals. Even among ruminants, there seems to exist difference in their digestibility among the various species, with respect to certain feed stuffs which tend to disappear when high protein feeds are provided.

   The relative digestive powers of cattle and sheep on identical rations have been reported by many earlier workers and by Armsby (1917). The results of their experiments throughout consistent, show that there were no marked differences in their digestive power with regard to better grade forages and concentrates. Extensive studies have not so far been carried out in India and abroad on the comparative utilization of feed nutrients in cattle and buffalo. However, the studies carried out by various workers substantiated the belief that buffalo would be able to deal with large quantities of coarse fodders and be able to meet their requirements with a very small amount of concentrates (Smith, 1933). It has been established by Smith (1927), Howard (1927)
and Kartha (1934) that buffaloes can utilize coarse feeds as its staple diet in a better way than cow. Later studies confirmed the same findings (Dastur, 1956; Alim, 1967; Hill, 1967 and Cockriil, 1968).

Dasgupta (1940, 1945) conducted a series of trials on Haryana and Murrah breeds of animals with the object of evaluating the comparative efficiency of feeds for different physiological functions such as growth and lactation. He reported that the dry matter intake per 100 lb live weight was higher for the Haryana cattle than the Murrah buffalo, being 2.51 lb and 2.37 lb, respectively for the two species. Though the differences in their digestive power was negligible when fed on cakes and green feeds, the data showed that the buffalo possessed a slightly better digestive power for fibre and ether extract when fed on straws. However, in earlier studies, Singh (1933) could not find any significant difference in the digestibility of crude protein in cattle and buffaloes.

Entirely new findings were reported by Rao (1948) while investigating the comparative efficiency of Haryana bullocks and buffalo bulls kept on dry roughage and green fodder. He observed that buffalo bulls consumed more dry matter and took less time to adjust themselves to new rations than the cattle. He also reported that there was practically no difference in the digestibility coefficient of organic matter, nitrogen free extract and total carbohydrates in the two species. However, other authors did not observe any significant difference in the dry matter intake by buffaloes and cattle (Ichhponani and Sidhu, 1966; Whyte and Mathur, 1966 and Johnson et al., 1968). Kehar and Sahai (1949) observed that buffaloes could utilize nitrogen, calcium and phosphorus more efficiently from a high roughage ration than cattle.
Jang and Majumdar (1962) compared the digestive efficiency of goats, sheep, cattle and buffaloes under the similar experimental conditions with each animal being fed a diet of spear grass (*Andropogon contortus*) in its post flowering stage and groundnut cake. The diet was fed to each species at 8 per cent of the metabolic live weight. They found that except ether extract utilization, goat and sheep utilized the nutrients in the feed in a much better way than cattle or buffaloes. The buffaloes utilized the ether extract better than either species. Raghavan et al. (1963), studying the effects of different climatic conditions on the metabolisms of feed nutrients in cattle and buffalo bulls, found higher digestibility in buffaloes than in cattle in all the four seasons of the year. Buffalo bulls were superior to Tharparkar bulls in the utilization of ether extract, crude fibre, calcium and phosphorus (Saini, 1964).

Ayyalaswami et al. (1966) found no significant difference in the digestibility of dry matter in adult Murrah and Zebu cattle. Johnson et al. (1967) from his studies at Philippines showed that significant differences existed between water buffaloes and Holstein cattle in the digestibility of guinea grass (*Panicum maximum*) harvested during wet, early dry and late dry seasons. The buffaloes were found to have 5 to 7 per cent higher digestibility units than the Holstein cattle. In their subsequent studies, Johnson et al. (1968) did not observe any significant difference in the average dry matter intake between buffaloes and Holstein when they were kept on ad lib. guinea grass feeding. Digestion trials revealed that on poor quality roughage diet, buffaloes
had a slightly higher digestibility of crude fibre and ether extract than cattle but on better quality ration feeding, the average coefficients of digestibility for dry matter, organic matter, ether extract, crude fibre and nitrogen free extract appeared similar in both species. Apparently buffaloes can maintain themselves mainly on roughages with comparative less concentrates than cattle. Similarly, Kaduskar (1967) fed mixed grass to Sahiwal (Zebu cattle) and Murrah buffalo calves weighing about 150 kg each and found no difference in the rate of consumption and digestibility coefficients of different nutrients in two species of animals.

A number of specific studies have been reported which further suggest that the buffalo may be specially suited to a high fibrous diet. These include increased rates of cellulose digestibility in vivo (Ichhponani et al., 1962; Sidhu, 1967 and Sebastian et al., 1970), in vitro (Ichhponani et al., 1965; Mudgal, 1966 and Punj et al., 1966) and the relatively lesser effect of lignification on cellulose digestibility (Sharma and Mudgal, 1964).

Sharma and Mudgal (1964) developed regression equations for estimating cellulose digestibility at different levels of lignin content which demonstrated this relationship.

Cattle

Maize \( Y = 100.25 - 3.968 \times \)

Hybrid Napier \( Y = 103.66 - 4.850 \times \)

Jowar \( Y = 96.88 - 3.480 \times \)

Buffaloes

Maize \( Y = 100.21 - 3.525 \times \)

Hybrid Napier \( Y = 104.23 - 3.161 \times \)

Jowar \( Y = 97.31 - 3.108 \times \)
Where $Y$ is the cellulose digestibility and $X$ is the lignin content of the fodder. The lower regression coefficient for buffaloes indicate the cellulose was better digested by this species.

Contrary to above findings, El-Shazly (1966) found very little difference in fibre digestion as estimated by digestion trials on two buffalo calves and two cattle calves.

Sebastian et al. (1970) studied the comparative efficiency of utilization of feed nutrients for milk production in lactating Murrah buffaloes and Sahiwal cows and indicated the following observations:

1. Buffaloes consumed less dry matter (2.35 kg/100 kg body weight) than cows (2.54 kg/100 kg body weight).
2. Buffaloes were significantly superior to cows in digestibility of crude fibre 79.8 Vs 64.7 per cent while digestibility of other nutrients did not differ significantly.
3. Buffaloes showed better retention of N, Ca and P.

The comparative intake of DGP and TDN, estimated maintenance requirements and milk yield of buffalo and Sahiwal cows are given in Table 1.

These authors concluded that the average intakes of DGP and TDN were about 38 per cent higher for the buffaloes than for the cow but the intake per unit of milk energy expressed as SCH (Solid corrected milk) were similar for both groups.
Table 1: Average daily intakes of DCP and TDN for cows and buffaloes

<table>
<thead>
<tr>
<th>Item</th>
<th>Buffalo</th>
<th>Cow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily intake (kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DCP</td>
<td>1.31</td>
<td>0.95</td>
</tr>
<tr>
<td>TDN</td>
<td>8.90</td>
<td>6.92</td>
</tr>
<tr>
<td>Maintenance requirements (kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DCP</td>
<td>0.38</td>
<td>0.23</td>
</tr>
<tr>
<td>TDN</td>
<td>3.76</td>
<td>2.10</td>
</tr>
<tr>
<td>SQM yield/day (kg)</td>
<td>11.57</td>
<td>8.2</td>
</tr>
<tr>
<td>Intake/kg SQM produced</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DCP</td>
<td>0.080 ± 0.007</td>
<td>0.088 ± 0.005</td>
</tr>
<tr>
<td>TDN</td>
<td>0.466 ± 0.030</td>
<td>0.466 ± 0.030</td>
</tr>
</tbody>
</table>

The improved digestibility of nutrients in buffaloes is attributed mainly due to the longer retention time of ingesta in buffaloes than cattle. Ponnappa et al. (1971) studied the rate of passage of food and its relation to digestibility of nutrients in Murrah buffaloes and Haryana cattle. They indicated that buffaloes showed improved digestibility coefficients of dry matter, crude protein, ether extract and cellulose when compared to cattle.

In a recent study on growing cow and buffalo calves fed with chopped and ground straw, Chaturvedi et al. (1973) observed that there was no difference between cattle and buffalo in the utilization of ground and chopped wheat straw supplemented with concentrates.
Later Upadhayaya et al. (1973) reported higher dry matter intake and better digestibility of organic matter, total carbohydrates and NFE in buffalo calves as compared to Zebu calves, when kept on green cowpea and maize fodder. The data is summarized in Table 2.

Table 2: Digestibility coefficient of different nutrients and N balance

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Fodder cowpea</th>
<th>Fodder maize</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cow calf</td>
<td>Buff. calf</td>
</tr>
<tr>
<td>Dry matter</td>
<td>57.36 ± 1.72</td>
<td>60.13 ± 3.07</td>
</tr>
<tr>
<td>Crude protein</td>
<td>74.38 ± 1.58</td>
<td>76.21 ± 2.28</td>
</tr>
<tr>
<td>Ether extract</td>
<td>68.08 ± 1.78</td>
<td>71.04 ± 1.19</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>72.71 ± 0.98</td>
<td>70.14 ± 2.70</td>
</tr>
<tr>
<td>Nitrogen free extract</td>
<td>49.74 ± 3.11</td>
<td>55.40 ± 4.67</td>
</tr>
<tr>
<td>Organic matter</td>
<td>61.31 ± 1.11</td>
<td>63.32 ± 2.02</td>
</tr>
<tr>
<td>Nitrogen balance</td>
<td>49.26 ± 2.71g</td>
<td>48.58 ± 2.03g</td>
</tr>
</tbody>
</table>

In a recent communication, Sharma and Mudgal (1975) could not find any significant difference on digestibility of dry matter in cows and buffaloes. However, they confirmed the superiority of buffaloes in the utilization of crude fibre over the cows. No species difference was observed on the ration of nitrogen.

Some of the results available in the literature on the digestibility of feeds have been compiled and given in Table 3.

It is, therefore, apparent that considerable difference of opinion exists between different workers regarding the comparative
utilization of feeds by cattle and buffaloes. More comprehensive work in this line, therefore, seems to be necessary.

ii) Effect of Plane of Nutrition on the Utilisation of Feed Nutrients in Buffaloes

A good number of references are available regarding the effect of plane of nutrition on the utilization of feed nutrients in cattle. However, very few scientists have taken up work on this aspect in buffaloes.

Pandit and Singh (1967a) reported the effect of starch supplementation on the roughage utilization at high level of digestible crude protein (DCP) intake (0.80 kg/1000 kg body wt.) in adult male buffaloes. The intake of dry matter increased as the level of starch was increased in the diet. Dry matter and nitrogen free extract digestibilities also showed a positive trend with the incorporation of starch in the basal diet. However, crude protein and crude fibre digestibilities decreased with the increase of starch. The observations have been summarized in Table 4.

Pandit and Singh (1967b) further investigated the effect of level of molasses feeding at various levels of digestible crude protein intakes on the roughage utilization in male buffaloes. They reported that the low level of digestible crude protein and molasses caused low dry matter consumption when wheat straw formed a basal roughage. Increased level of digestible crude protein plus molasses increased the dry matter intake and improved the digestibility of dry matter. The low level (DCP 0.4 kg/1000 kg B.wt.) fed group showed significant
Table 4: Nutrient intake and digestibility coefficient

<table>
<thead>
<tr>
<th>Item</th>
<th>Basal control without starch</th>
<th>Basal + 2 lb equiv. of starch</th>
<th>Basal + 4 lb equiv. of starch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter intake kg per 100 kg body weight</td>
<td>$1.58 \pm 1.03$</td>
<td>$1.78 \pm 0.82$</td>
<td>$1.89 \pm 0.35$</td>
</tr>
<tr>
<td>Total digestible nutrient intake kg per 1000 kg body weight</td>
<td>$8.56 \pm 0.86$</td>
<td>$9.89 \pm 0.38$</td>
<td>$10.71 \pm 0.14$</td>
</tr>
<tr>
<td>Dig. Coeff.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry matter</td>
<td>$46.1 \pm 4.81$</td>
<td>$48.4 \pm 4.50$</td>
<td>$54.7 \pm 0.71$</td>
</tr>
<tr>
<td>Crude protein</td>
<td>$55.5 \pm 3.53$</td>
<td>$52.3 \pm 3.48$</td>
<td>$51.4 \pm 2.74$</td>
</tr>
<tr>
<td>Ether extract</td>
<td>$88.3$</td>
<td>$81.4$</td>
<td>$79.4$</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>$53.8 \pm 0.25$</td>
<td>$48.4 \pm 2.50$</td>
<td>$46.2 \pm 2.24$</td>
</tr>
<tr>
<td>Nitrogen free extract</td>
<td>$53.6 \pm 0.41$</td>
<td>$61.0 \pm 0.92$</td>
<td>$64.5 \pm 0.40$</td>
</tr>
<tr>
<td>Total carbohydrates</td>
<td>$53.8 \pm 0.89$</td>
<td>$57.7 \pm 3.31$</td>
<td>$58.4 \pm 0.87$</td>
</tr>
</tbody>
</table>

Impairment in fibre digestion, and when molasses was increased the impairment in fibre digestion was checked. Increased digestible crude protein and energy levels increased the digestibility of crude protein. Increase in the molasses content also showed an increase in the digestibility of nitrogen free extract and total carbohydrates. The data are summarized in Table 5.
<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Control</th>
<th>Basal + 2 lb molasses</th>
<th>Basal + 4 lb molasses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.4 kg</td>
<td>0.8 kg</td>
<td>0.4 kg</td>
</tr>
<tr>
<td></td>
<td>DCP/</td>
<td>DCP/</td>
<td>DCP/</td>
</tr>
<tr>
<td></td>
<td>1000 kg</td>
<td>1000 kg</td>
<td>1000 kg</td>
</tr>
<tr>
<td>Dry matter</td>
<td>45.4</td>
<td>51.2</td>
<td>51.6</td>
</tr>
<tr>
<td>Crude protein</td>
<td>36.2</td>
<td>55.5</td>
<td>37.6</td>
</tr>
<tr>
<td>Ether extract</td>
<td>48.1</td>
<td>88.3</td>
<td>58.9</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>53.8</td>
<td>53.8</td>
<td>54.2</td>
</tr>
<tr>
<td>Nitrogen free extract</td>
<td>50.1</td>
<td>53.6</td>
<td>60.6</td>
</tr>
<tr>
<td>Total carbohydrates</td>
<td>51.7</td>
<td>53.8</td>
<td>59.9</td>
</tr>
</tbody>
</table>

Investigating the protein requirements for maintenance in buffaloes, Bhargava (1971) found that no significant variation occurred due to increase in digestible protein in the ration on the dry matter, crude fibre, nitrogen free extract and ether extract digestibility but crude protein digestibility increased with the increase of protein in the diet. The data are summarized in Table 6.

Shukla et al. (1972) reported the studies on the milch buffaloes fed with 0.3, 0.4, 0.5 and 0.6 kg of concentrate mixture per litre of milk produced; that the digestibility of dry matter, crude protein, ether extract, and nitrogen free extract increased significantly with the increase of digestible crude protein and total digestible nutrients.
<table>
<thead>
<tr>
<th>Dig. coeff.</th>
<th>Phase I</th>
<th></th>
<th></th>
<th>Phase II</th>
<th></th>
<th></th>
<th>Phase III</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.45 kg/DCP/1000</td>
<td>0.40 kg/DCP/1000</td>
<td>0.35 kg/DCP/1000</td>
<td>0.35 kg/DCP/1000</td>
<td>0.30 kg/DCP/1000</td>
<td>0.25 kg/DCP/1000</td>
<td>0.45 kg/DCP/1000</td>
<td>0.35 kg/DCP/1000</td>
<td>0.25 kg/DCP/1000</td>
</tr>
<tr>
<td>kg B.wt.</td>
<td>kg B.wt.</td>
<td>kg B.wt.</td>
<td>kg B.wt.</td>
<td>kg B.wt.</td>
<td>kg B.wt.</td>
<td>kg B.wt.</td>
<td>kg B.wt.</td>
<td>kg B.wt.</td>
<td>kg B.wt.</td>
</tr>
<tr>
<td>Dry matter</td>
<td>45.60</td>
<td>44.15</td>
<td>43.49</td>
<td>43.02</td>
<td>42.53</td>
<td>43.09</td>
<td>48.45</td>
<td>48.57</td>
<td>49.58</td>
</tr>
<tr>
<td>Crude protein</td>
<td>31.82</td>
<td>26.89</td>
<td>27.75</td>
<td>35.10</td>
<td>35.10</td>
<td>29.71</td>
<td>40.59</td>
<td>36.42</td>
<td>30.72</td>
</tr>
<tr>
<td>Ether extract</td>
<td>66.10</td>
<td>65.93</td>
<td>72.50</td>
<td>69.28</td>
<td>67.72</td>
<td>70.12</td>
<td>65.93</td>
<td>72.50</td>
<td>-</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>51.38</td>
<td>51.00</td>
<td>51.40</td>
<td>51.16</td>
<td>49.72</td>
<td>52.38</td>
<td>65.93</td>
<td>72.50</td>
<td>-</td>
</tr>
<tr>
<td>Nitrogen free extract</td>
<td>49.75</td>
<td>51.05</td>
<td>50.20</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nitrogen balance g</td>
<td>+1.30</td>
<td>-0.59</td>
<td>-2.22</td>
<td>+2.70</td>
<td>+0.64</td>
<td>+0.04</td>
<td>+3.74</td>
<td>+0.51</td>
<td>0</td>
</tr>
</tbody>
</table>
in the diet, however, there was depression in the crude fibre digestibility in the high concentrate fed group. All the four groups showed a positive nitrogen balance.

Ludri (1973) studied the nitrogen utilization from normal protein and urea based rations in cattle and buffaloes. The four levels taken were 100, 80, 60 and 40 per cent of mid Morrison standards. The digestibilities of dry matter varied from 51.92 to 53.65 per cent in cows and the corresponding values for buffaloes were 52.61 to 55.56 per cent. The organic matter digestibility coefficients ranged from 55.85 to 57.76 per cent in cows and 56.30 to 58.99 per cent in buffaloes. However, these values were not significant statistically. The acid detergent fibre digestibility was not significantly different in two species. The same was true for cellulose digestibility which varied from 60.92 to 64.30 per cent in cows and 61.37 to 64.62 per cent in buffaloes. An interesting observation was that the apparent digestibilities of crude protein were higher in cows (53.81, 48.33, 40.80 and 38.38%) than in buffaloes (51.79, 45.08, 37.57 and 29.45%) on the four treatments. The digestibilities of ether extract on treatments I to III were higher in buffaloes but on treatment IV it was lower than in cows. Overall average digestibility was higher in buffaloes (75.26%) but it did not differ significantly from that of cows (72.21%).

While presenting data on the average intakes, excretions and balances of nitrogen on different treatments, Ludri (1973) observed that the animals of either species maintained positive nitrogen balances, except on treatment IV where the cows had negative nitrogen balances.
The values for nitrogen balances in cows were 0.044, 0.047, 0.018 and 0.036 g/kg \( w^{0.75} \) and in buffaloes the corresponding values were 0.048, 0.056, 0.045 and 0.022 g/kg \( w^{0.75} \), respectively on treatments I, II, III and IV. The balances on treatment III in cows and on treatment IV in buffaloes were lower in comparison to those on treatments I and II.

### iii) Nutrition of Adult Buffaloes

#### a) Protein and Energy Requirements for Maintenance

Lander (1949) from his own investigations suggested the following daily requirements in India.

<table>
<thead>
<tr>
<th>Maintenance</th>
<th>Body wt.</th>
<th>Dm</th>
<th>DCP</th>
<th>TDN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>400-500 kg</td>
<td>6-9 kg</td>
<td>0.367 kg</td>
<td>4.24 kg</td>
</tr>
</tbody>
</table>

He suggested that for every 50 kg increase or decrease in body weight, 0.5 kg of dry matter containing 0.03 kg DCP and 0.32 kg TDN should be added or subtracted.

Research workers at Indian Veterinary Research Institute, Izatnagar (1956-57) concluded from their studies that the buffalo bulls require about 0.40 lb of DCP per 1000 lb live weight. Singh (1965) reported that DCP requirement for buffaloes lies between 0.20 and 0.22 kg per 500 kg body weight.

In a systematic study on the metabolic behaviour of buffaloes during fasting, Gupta (1966) found protein requirements for maintenance as 0.28 kg per 154 kg body weight. In the subsequent studies, Gupta
et al. (1966), on the basis of endogenous urinary nitrogen (EUN) values, calculated minimum DCP requirements for maintenance as 0.22 to 0.24 kg for \( \frac{45}{4} \) kg body weight buffaloes.

b) Milk Production: For milk production, Lander (1949) recommended the addition of 0.030 kg DCP and 0.20 to 0.21 kg TDN for every kg of milk containing 7 per cent fat; for every 0.5 per cent below or above that fat content, 0.001 kg DCP and 0.01 kg TDN should be added or subtracted. However, Whyte and Mathur (1966) are of the opinion that the nutrient requirements worked out for cattle are suitable for buffaloes.

iv) Effect of Plane of Nutrition on the Milk Yield and Chemical Composition

Work on the 'effect of plane of nutrition on the feed nutrient utilization for milk production in buffaloes' had caught the attention of very few scientists. Only in early seventies some work has been reported. Jackson and Gupta (1971) concluded from their experiment on milch buffaloes that as the concentrate mixtures were increased in the ration, the 7 per cent fat corrected milk yield increased significantly, whereas, no effect was observed on the fat or solid-not-fat content of milk. The ration consisted of berseem ad lib., 1.5 kg sorghum straw and 1.2 kg of concentrate mixture for control group. The other three rations consisted of berseem ad lib., 1.5 kg sorghum straw and the same concentrate mixture at the rate of 0.4, 0.7 and 1.0 per kg milk yield. The data are summarized in Table 7.
Table 7: Feed consumption, milk yield and calculated nutrient intake on the four rations

<table>
<thead>
<tr>
<th>Item</th>
<th>Ration 1</th>
<th>Ration 2</th>
<th>Ration 3</th>
<th>Ration 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter consumption (%)</td>
<td>2.8</td>
<td>3.3</td>
<td>3.6</td>
<td>3.6</td>
</tr>
<tr>
<td>Milk production (kg/buffalo/day)</td>
<td>7.2</td>
<td>7.3</td>
<td>7.8</td>
<td>7.9</td>
</tr>
<tr>
<td>7.0% FCM kg/day</td>
<td>7.5</td>
<td>7.8</td>
<td>8.4</td>
<td>8.3</td>
</tr>
<tr>
<td>Total TDN intake (kg/buffalo/day)</td>
<td>8.8</td>
<td>10.4</td>
<td>11.3</td>
<td>11.2</td>
</tr>
<tr>
<td>TDN intake (kg/kg 7.0% FCM)</td>
<td>0.71</td>
<td>0.89</td>
<td>0.93</td>
<td>0.93</td>
</tr>
</tbody>
</table>

Singh et al. (1972) stated that in the ration of milch buffaloes with increase in the concentrate mixture along with sorghum forage, there was no significant increase in the milk yield and also no effect was observed on milk fat, protein and solid-not-fat content. The data for digestible protein and total digestible nutrient intake and milk yield and its composition are given in Table 8.

Shukla et al. (1972a) in a 18-week experiment on lactating Murrah buffaloes (in 3rd-5th) fed with concentrates at 0.3, 0.4, 0.5, 0.6 kg per litre of 1 per cent FCM yield with other feeds, found that
Table 6: Nutrients intake and milk yield and composition

<table>
<thead>
<tr>
<th>Item</th>
<th>Ration</th>
<th>SE of mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>DM consumption % B. wt.</td>
<td>2.6</td>
<td>2.8</td>
</tr>
<tr>
<td>DCP intake kg/day</td>
<td>0.35</td>
<td>0.56</td>
</tr>
<tr>
<td>TDN intake kg/day</td>
<td>6.2</td>
<td>7.1</td>
</tr>
<tr>
<td>Milk yield kg/day</td>
<td>5.9(5.6)</td>
<td>6.1(5.8)</td>
</tr>
<tr>
<td>Fat %</td>
<td>6.5</td>
<td>6.5</td>
</tr>
<tr>
<td>Protein %</td>
<td>4.1</td>
<td>4.1</td>
</tr>
<tr>
<td>SNF %</td>
<td>9.4</td>
<td>9.6</td>
</tr>
</tbody>
</table>

Daily milk yield increased significantly in higher groups of concentrate fed, whereas, the fat percentage was highest in the lowest concentrate fed group. The milk yield and its composition for different treatments are summarized in Table 9.

Table 9: Daily average milk yield and average composition of milk

<table>
<thead>
<tr>
<th>Item</th>
<th>Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td>Milk yield</td>
<td>6.47</td>
</tr>
<tr>
<td>Fat(%)</td>
<td>6.91</td>
</tr>
<tr>
<td>Fat corrected milk (%)</td>
<td>9.28</td>
</tr>
<tr>
<td>Total solid (%)</td>
<td>15.69</td>
</tr>
<tr>
<td>Solid-not-fat (%)</td>
<td>8.74</td>
</tr>
<tr>
<td>Concentrate fed kg</td>
<td>2.80</td>
</tr>
</tbody>
</table>
In another communication Shukla et al. (1972b), with a similar study on milch buffaloes confirmed their earlier findings. They reported an increase in the milk yield and protein percentage as the concentrate in the ration was increased. However, milkfat percentage was highest in low concentrate fed group. The data for milk yield and chemical composition for different groups are given in Table 10.

Table 10: **Average milk yield and composition**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Milk yield kg</th>
<th>Protein percentage</th>
<th>Fat percentage</th>
<th>Ash percentage</th>
<th>Energy/L of, milk MJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>6.9</td>
<td>3.67</td>
<td>7.4</td>
<td>0.75</td>
<td>4.37</td>
</tr>
<tr>
<td>II</td>
<td>5.9</td>
<td>3.83</td>
<td>6.7</td>
<td>0.81</td>
<td>4.56</td>
</tr>
<tr>
<td>III</td>
<td>8.0</td>
<td>3.89</td>
<td>6.5</td>
<td>0.85</td>
<td>4.08</td>
</tr>
<tr>
<td>IV</td>
<td>8.0</td>
<td>4.24</td>
<td>6.6</td>
<td>0.87</td>
<td>4.20</td>
</tr>
</tbody>
</table>

Mamedov (1973) studied the effect of different levels of protein on the milk yield and its composition. Water buffaloes were given 20 per cent less and 20 per cent more of protein allowance. The milk yield was found to be 1203, 1142 and 1281 kg per lactation of 271, 262 and 273 days. The milk contained 18.27, 17.97 and 18.74 per cent dry matter; 8.27, 8.05 and 8.60 per cent fat; 4.29, 4.20 and 4.42 per cent total protein and 4.95, 4.86 and 5.02 per cent lactose; 4 per cent FCM was 2487, 2296 and 2754 kg.
2. Review on Cattle

It is known that the literature available on the energy and protein requirement for dry and milch buffaloes is very limited, hence it will be desirable to record the important references available on cattle. The effort has been made to give important information in the following pages.

1) Energy Requirement

a) Energy Requirement for Maintenance

Maintenance energy requirement of an animal in terms of net energy is equal to its basal expenditure plus the net energy cost of incidental muscular activity. The basal energy metabolism is the major energy expense for maintenance costing approximately 85 per cent of the maintenance energy requirement (Brody, 1945). A linear correlation between the logarithm of fasting rate and the logarithm of body weight showed that the metabolic rate of homeotherms ranging from mice to cattle was proportional to the 3/4 power of body weight (Kleiber, 1932; 1947 and 1961). While Brody and Procter (1932) and Brody (1945) reported 0.73 power as reference base for animals ranging from mice to elephant. Kleiber's proposal that 3/4 power of body weight should be used as the standard method of expressing results of fasting metabolism for inter species comparison was adopted at the 3rd symposium of the energy metabolism held at Troon, Scotland (Kleiber, 1965).

The 2nd largest expense of maintenance is the muscular expense of movement and digestion. The expense of walking and similar muscular
excretion is proportional to body weight $W^{1.0}$ not to $W^{0.7}$ as the case for basal or resting metabolism (Brody, 1945). Hence several values of the exponent of body weight have been used to calculate the energy requirement for maintenance. The values vary from 0.6 to 1.0. Coop (1962) suggested the maintenance factor to be between 0.7 and 1.0. The values used by various workers were: Winchester and Hendericks (1953), 0.66; Armsby and Houlton (1925), 0.715; Brody (1945), 0.734 or 0.7; Kleiber (1947, 1961), 0.75; Axelsson and Erickson (1952), 0.80; Morrison (1936), 0.87 for cattle and 0.73 for horses. As there is no experimental proof for these factors the present standards i.e. NRC (1958, 1966 and 1971), Morrison (1956), Woodman (1957), ARC (1965) consider it wise to use the 3/4 power as the reference base for maintenance requirement.

**b) Present Standards**

The maintenance requirements expressed in TDN system (Morrison, 1959; NRC, 1958, 1966 and 1971) have been arrived at by feeding trials conducted by Haecker (1903 and 1914). Two values are given by Morrison: the higher being the average of Haecker (1914) and Savage (1912) i.e. 7.93 lb per 1000 lb body weight and lower being the same reduced arbitrarily by about 10 per cent i.e. 7.0 per 1000 lb body weight (Kriss, 1931). National Research Council (1966) standards recommend 3.2 kg TDN per 500 kg body weight.

The starch equivalent standards as recommended by Kellner (1926) and revised by others (Wood, 1927; Woodman, 1948, 1957 and Swans, 1960) are currently quoted in bulletins No. 42 and 48 of the Ministry of
Agriculture, Fisheries and Food, London. According to these standards, an animal weighing 1000 lb should be given 6 lb starch equivalent per day for maintenance from which allowances of animals of other weight are calculated on the basis of metabolic body size.

c) Maintenance Energy Requirements of Lactating Cows

Lactating cows normally use energy for three functions, namely, i) maintenance, ii) milk production and iii) live weight gain (or alternatively body tissue may contribute to the energy available for maintenance and milk synthesis), simultaneously. The usual approach is to apply results of maintenance and body weight gain or loss from the experiments on dry cows to determine the metabolizable energy intake used for milk synthesis. The maintenance energy requirements of lactating cows have, however, been calculated by partitioning energy intake between maintenance and productive functions using multiple regression analysis (Brody and Proctor, 1935; Brody, 1945; Wallace, 1956, 1961; Hutton, 1962; Neville and McCullough, 1969).

Brody (1945) partitioned the total digestible nutrients (TDN) consumed between its uses as for (i) milk production, (ii) maintenance and (iii) weight gain or loss. Such partitioning of the TDN consumed by 243 good lactating cows gave 3.73 kg TDN for maintaining a 454 kg lactating cow which corresponds to 135 Kcal/kg metabolic body size/24 hours (assuming 1 lb TDN equal to 1616 Kcal ME). This value is considerably higher than his estimated value of 3.07 kg TDN (111 Kcal ME/kg w^0.75/24 hour) based on the assumption that the maintenance TDN
calories is twice the basal metabolism of non-lactating mature animals of different species. The author concluded that the lactating cows should have a higher maintenance cost than the non-lactating cows.

Calculating in the same manner, Hutton (1962) found the maintenance requirement of lactating cows to be almost twice that of the dry cows with the means as 236 and 126 Kcal ME/kg metabolic body size per 24 hour (1 lb digestible organic matter = 1.01 lb TDN) respectively. Neville and McCullough (1969) found 30 per cent greater maintenance value for lactating than for non-lactating cows (178 Vs 137 Kcal ME per kg metabolic body size per 24 hour respectively).

Holmes and Jones (1964), Blaxter (1964) and Flatt and Coppock (1965) discussed the results obtained on maintenance requirement of lactating cows and suggested that the maintenance requirement of lactating cows are higher than would be estimated from the fasting metabolism or other methods on dry non-pregnant cows. For housed animals the regression estimates of maintenance requirements like those of Brody and Proctor (1935), Brody (1945), Gordon and Forbes (1970) are upto 70 per cent greater but for grazing animals (Wallace, 1956; Hutton, 1962) the maintenance requirements are greater upto 100 per cent than those of dry non-pregnant animals.

While studying the utilization of dietary energy for maintenance and milk production by lactating crossbred cows (Brown Swiss x Sahiwal) during their early stage of lactation, Patle and Mudgal (1976)
reported that the maintenance energy requirements of the cows as worked out from the energy balance data, was 130.66 Kcal/kg metabolic body size. When body weight change data were used instead of the energy balance data, the maintenance energy requirement for all cows was 129.53 Kcal/kg metabolic body size. The maintenance energy requirements of mature crossbred bullocks (Brown Swiss x Sahiwal) reported earlier was 103.30 Kcal/kg metabolic body size (Patle and Mudgal, 1975). These authors concluded that the maintenance energy requirements worked out on idle bullocks can not be used for lactating cows of the same breed. In earlier studies, Moe et al. (1970) also found higher maintenance requirement for lactating than the dry non-pregnant cows. Probably, the higher feed intake and more transformation of digested organic matter in intermediary metabolism by lactating than non-lactating cows is responsible for higher maintenance energy requirement for lactating cows. Leroy (1970) stated that intake, mastication and transport of food are connected with a large energy expenditure. Thus, as reported by Holmes and Jones (1965), the provision of energy for maintenance in dairy animals should be liberal. Similar results were reported by Patle and Mudgal (1977) while studying ME requirements for cross-bred cattle in mid stage of lactation. Some energy maintenance values for cattle recommended by various feeding standards and obtained by various workers are cited in Table 11.
Table 11: Maintenance values of energy recommended by various workers and feeding standards

<table>
<thead>
<tr>
<th>Animal</th>
<th>TDN kg/454 kg body weight/ day</th>
<th>ME Kcal/kg 0.75/ day</th>
<th>Method</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry cows</td>
<td>3.62</td>
<td>129.6</td>
<td>Feeding trial</td>
<td>Haecker (1914)</td>
</tr>
<tr>
<td>-do-</td>
<td>3.19</td>
<td>114.2</td>
<td>-do-</td>
<td>Morrison (1956)</td>
</tr>
<tr>
<td>-do-</td>
<td>3.59</td>
<td>128.5</td>
<td>-do-</td>
<td>NRC (1966)</td>
</tr>
<tr>
<td>-do-</td>
<td>3.20</td>
<td>118.0</td>
<td>-do-</td>
<td>Sen and Ray (1964)</td>
</tr>
<tr>
<td>-do-</td>
<td>3.77</td>
<td>132.9</td>
<td>-do-</td>
<td>Woodman (1957)</td>
</tr>
<tr>
<td>-do-</td>
<td>3.26</td>
<td>118.0</td>
<td>Energy balance</td>
<td>ARC (1965)</td>
</tr>
<tr>
<td>-do-</td>
<td>3.07</td>
<td>116.0</td>
<td>Fasting metabolism</td>
<td>Brody (1945)</td>
</tr>
<tr>
<td>-do-</td>
<td>-</td>
<td>131.0</td>
<td>Energy balance</td>
<td>Kleiber et al. (1945)</td>
</tr>
<tr>
<td>-do-</td>
<td>-</td>
<td>109.0</td>
<td>-do-</td>
<td>Van Es (1961)</td>
</tr>
<tr>
<td>-do-</td>
<td>-</td>
<td>105,112,102</td>
<td>-do-</td>
<td>Flat et al. (1965b)</td>
</tr>
<tr>
<td>-do-</td>
<td>-</td>
<td>120.7</td>
<td>-do-</td>
<td>Gopalkrishna (1971)</td>
</tr>
<tr>
<td>-do-</td>
<td>-</td>
<td>116.3</td>
<td>-do-</td>
<td>Hashizume et al. (1963)</td>
</tr>
<tr>
<td>-do-</td>
<td>-</td>
<td>96.6</td>
<td>-do-</td>
<td>-do-</td>
</tr>
<tr>
<td>Steers</td>
<td>-</td>
<td>112.0</td>
<td>Feeding trial</td>
<td>Garrett et al. (1959)</td>
</tr>
<tr>
<td>Dry cow</td>
<td>-</td>
<td>131.0</td>
<td>-do-</td>
<td>Lofgreen and Garrett (1968)</td>
</tr>
<tr>
<td>-do-</td>
<td>-</td>
<td>137.0</td>
<td>Multiple regression</td>
<td>Neville and McCullough (1969)</td>
</tr>
<tr>
<td>Lactating beef cow</td>
<td>-</td>
<td>178.0</td>
<td>-do-</td>
<td>-do-</td>
</tr>
<tr>
<td>-do-</td>
<td>-</td>
<td>154.0</td>
<td>-do-</td>
<td>Brody and Procter (1935)</td>
</tr>
</tbody>
</table>

Contd.……..
<table>
<thead>
<tr>
<th>Animal</th>
<th>TDN kg/454 kg body weight/day</th>
<th>ME Kcal/kg W⁻⁰·⁷⁵/day</th>
<th>Method</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactaging cows (grazing)</td>
<td>-</td>
<td>212.0</td>
<td>Multiple regression</td>
<td>Wallace (1956)</td>
</tr>
<tr>
<td>- do-</td>
<td>-</td>
<td>236.0</td>
<td>- do-</td>
<td>Hutton (1962)</td>
</tr>
<tr>
<td>Lactating cows (early lactation)</td>
<td>-</td>
<td>130.68</td>
<td>- do-</td>
<td>Patle and Mudgal (1976)</td>
</tr>
<tr>
<td>Lactating cows (mid lactation)</td>
<td>-</td>
<td>134.32</td>
<td>- do-</td>
<td>Patle and Mudgal (1977)</td>
</tr>
</tbody>
</table>

Conversion factors $1 \text{ kg} = 2.2 \text{ lb}$ : $1 \text{ kg}$ total digestible nutrients (TDN) $= 3580 \text{ Kcal metabolizable energy (ME)}$ (ARC, 1965). $1 \text{ kg starch equivalent (SE)} = 4.28 \text{ Kcal metabolizable energy (ME)}$ (ARC, 1965).

d) Energy Requirements for Milk Production - Present Standards

The present American feeding standard as reported by Morrison (1959) gives the allowances of 0.31 to 0.32 kg of total digestible nutrients (TDN) per kg 4 per cent fat corrected milk in addition to the allowance for maintenance, growth and pregnancy. NRC (Loosli et al., 1958) recommended the allowances of 0.32 kg TDN per kg 4 per cent fat corrected milk produced. Whereas, Woodman (1957) recommends 0.29 kg starch equivalent (0.326 kg TDN) per kg 4 per cent fat corrected milk produced.

Morrison (1959) and NRC (Loosli et al., 1958) standards are based on the work of Haeker (1903, 1914). The British standards are
quoted in bulletins No.42 and 48 of the Ministry of Agriculture, Fisheries and Food (Woodman, 1948, 1957 and Evans, 1960). The standards for maintenance have been derived from Kellner's work on bullock (Kellner, 1926) and the standards for production are based on the work of Mollgaard and Lund (1929) who found that metabolizable energy was utilized better for milk production than for fattening. Allowing for this better utilization, it can be calculated that 2.63 lb starch equivalent is required for each 10 lb of milk produced (about 2.7 lb SE/10 lb 4 per cent FCM). Mollgaard and Lund (1929) found that 840 NCF (net calories for fattening of cattle) was equivalent to 1000 calories in milk. A given amount of feed thus produced about 20 per cent more energy in milk than in body fat.

Kellner (Kris, 1931) concluded that for the production of each 10 kg of milk (3.2 per cent fat, 4.6 per cent lactose and 3.3 per cent proteins, his assumed average composition of milk) 2.0 kg of starch value (SE) are required. He also estimated that for milk of higher fat content as much as 2.7 kg may be required per 10 kg of milk. Armsby (1917) calculated 0.285 lb TDN per lb FCM whereas Mollgaard (Kris, 1931) and Hansson (Kris, 1931) suggested the requirement of 0.3 lb TDN/lb FCM. McCullough (1969) reported that the requirement ranged from 0.28 to 0.29 lb TDN. Gaines (1943) and Wallace (1959) reported 0.3 lb TDN/lb FCM produced.

e) Other Studies

Most of the earlier work on the requirement of milk production was conducted on cows of low productivity. Haecker's results were
based on cows producing 10.9 to 12.2 kg 4 per cent fat corrected milk. The results of Jenson et al. (1942) indicated that cows producing about 11000 lb fat corrected milk per year required about 0.5 lb TDN over maintenance per lb fat corrected milk.

Wagner and Loosli (1967) found the requirement of 0.413, 0.401 and 0.430 lb base line TDN per lb 4 per cent fat corrected milk for the 1st, 2nd and 3rd year of the experimental period in cows producing 16,629 lb per lactation. The actual TDN requirements per lb of FCM (corrected for actual digestion) were 0.370, 0.362 and 0.386 lb/lb FCM for the same years, respectively. The adjustment of body weight changes were made on the basis of conventional values that 3.5 lb of TDN are required per lb of body weight gained and 1 lb of body weight loss is given a value of 2.73 lb of TDN (Knott et al., 1934). Adjustment for maintenance requirements were determined on the basis of 131 Kcal ME/0.75W kg for 24 hours (Kleiber et al., 1945) with TDN being given the value of 1616 Kcal of ME/lb.

Jawetz (1956) suggested that sufficient evidence exists for a revision of the conventional recommendations for milk production, suggesting that the requirements are proportionately larger at higher levels of milk yield. Thus when the standards given are used rigidly a situation must arise where the lower yielders are over fed and higher yielders are less well fed or even underfed (Trinder, 1963). It is known that the TDN or SE values of feeds decline as intake rises mainly because there is reduction in digestibility (Blaxter, 1950, 1962; Reid, 1962; Anderson et al., 1959). The present system assumes that
energy values are constant at all levels of feeding. To obviate the errors caused by these variations, Blaxter (1959, 1962) has suggested a sliding scale of metabolizable energy needs for milk production the requirement for the first ten kg milk production being less than the second and so on. This system of feeding milch cows has been followed and recommended by the Agriculture Research Council (UK) (1965). The system has taken into consideration the fact that the availability of metabolizable energy of food varies according to the character of the food and the use to which it is put and also the fact that energy value of feeds decrease as the level of feeding increases. Different requirements are given for feeds containing metabolizable energy content from 1.8 to 3.4 Kcal ME/g DM. The diets containing 2.6 Kcal ME/g DM (ME content of diets consisting of 50 per cent roughage and 50 per cent concentrate dry matter) the values are 16.8, 23.0, 29.8, 37.2 and 45.4 Mcal ME/day for cows weighing 500 kg and producing 5, 10, 15, 20 and 25 kg milk/day, respectively. If the maintenance requirement of 500 kg cow is considered to be 12.5 Mcal ME/day (NRC, 1966) the ME requirement will be 0.86, 1.05, 1.153, 1.235 and 1.316 Mcal ME and TDN requirement will be 0.24, 0.29, 0.322, 0.344 and 0.368 kg/kg milk for the cows producing 5, 10, 15, 20 and 25 kg milk per day, respectively. NRC (1966) prescribes 10 per cent higher energy values than the earlier standards (Loosli et al., 1958) for average production and 25 per cent more for higher milk yields. The prescribed values were 0.33, 0.37 and 0.42 kg TDN per kg 4 per cent FCM for cows producing less than 20, 20 to 35 and more than 35 kg of milk per day respectively.
As described by Wagner and Loosli (1967) the present requirements for milk production listed by the NRC (Loosli et al., 1958) and Morrison (1956) are based on the assumption that (a) the ME is utilized with approximately 70 per cent efficiency for milk production; (b) that the utilization of ME remains constant regardless of the percentage of total rations consumed as concentrates or forage; (c) that the digestibility of the ration does not change with the increasing levels of intake and (d) that the maintenance requirement remains constant whether a cow is dry or lactating.

Earlier, Reid (1962) summarized the data of 59 out of 110 complete energy balance trials conducted before 1961 and concluded that 70.2 ± 4.0 per cent of the ME available for milk production was converted into milk. Most of the rations containing 40 - 60 per cent roughage with the remainder being concentrates (VanEs, 1961) or purified rations (Kleiber et al., 1945). Flatt et al. (1965a) found efficiencies of utilization of ME for milk production being 50.6 per cent for all alfalfa; 56.6 per cent for 75 per cent alfalfa and 25.0 per cent corn (ENE basis) and 58.4 per cent for ration containing 50 per cent alfalfa and 50 per cent concentrate (ENE basis). The corresponding maintenance requirements were 110.2, 109.8 and 108.6 Kcal ME/kg_0.75 kg/24 hours, respectively.

Blaxter (1962a) and McDonald et al. (1969) have reviewed the data and concluded that the efficiency of utilization of ME for lactation varies depending upon the relative proportions of volatile fatty acids in the rumen. Ration composition has been shown to influence the fermentation by-products formed in the rumen with the molar proportion
of acetic acid being higher when roughages were consumed than when the concentrate rations were fed. When there was a normal rumen fermentation the proportion of acetic acid was the main volatile fatty acids remained in the range of 50–60 per cent and the efficiency of utilization of ME for lactation was maximal approximately 70 per cent. It would seem that when the proportion of acetic acid remains below 50 per cent the cow is unable to synthesize sufficient of the lower and medium chain fatty acids which form a large part of milk fat; when there is more than 65 per cent of acetic acid the efficiency is low in other form of production.

The efficiency of metabolizable energy is also influenced by the level of protein in the diet. Where protein content is inadequate body tissues are katabolized (or catabolized) to make good the deficiency, a process which is wasteful of energy; where protein content is high excess amino acids are used as a source of energy. Since protein is used relatively inefficiently as a source of energy for the animal such a process reduces the overall efficiency of utilization of ME (McDonald et al., 1969).

Mitchell (1962) postulated that the net availability of the ME of all perfectly balanced rations is maximal.

Coppock (1964) calculated the efficiency of utilization of ME available for milk production assuming that the maintenance requirements were 131 Kcal ME/kg W. Tissues gained or lost was corrected to zero balance using the factor 1.61 for gains and 1.43 for losses. The
efficiency of conversion of ME into milk was 75.5 ± 15.9 per cent. Linear regression analysis of the same data using ME available for milk yield and maintenance Vs milk energy resulted in an estimate of 61 per cent efficiency with the maintenance requirement, being 112.7 Kcal ME/kg $w^{0.75}$ kg/day. Flatt (1966) recomputed the data of energy balance studies and found that when 116.3 Kcal ME/kg $w^{0.75}/24$ hour was considered the average efficiency for production was 63.9 per cent. Whereas when 131 Kcal ME/kg $w^{0.75}/24$ hour was considered as the maintenance requirement the efficiency with which ME was utilized for milk production was 72 per cent.

Armstrong and Blaxter (1965) while working with a lactating goat and Graham (1964) while working with lactating ewes indicated that lipogenesis which occurs simultaneously with milk secretion was quite different than when tissue was being deposited in the non-lactating animal. Energy retention in milk secretion proceeded with almost equal efficiency in lactating goats (69.1 per cent) but the efficiency of lipogenesis in the non-lactating goats was lower (50.3, 52.3 and 44.4 per cent respectively for each of the three rations); whereas Neville and McCullough (1969) observed that lactating cows require more energy per unit of gain than non-lactating cows.

Stallcup and Rakes (1970) estimated the net energy requirement for maintenance plus milk production. The values for Jersey, Holstein-Friesian were 0.512 and 0.526 therm/lb lb per cent FCM respectively. The gross efficiency of conversion of feed energy to milk energy in high producing cows averaged 35.0 per cent for 13 Holstein-Friesian and
34.7 per cent for 9 Jersey cows. Higher efficiencies were observed in all cows in early lactation.

Patle and Mudgal (1977) reported that the efficiency of ME for milk production was 68.52, 65.48 and 66.12 per cent respectively for cows at mid stage of lactation. The energy required per kg of FCM was 4.580, 4.791 and 4.746 MJ ME for the respective groups of cows. The efficiency of utilization of ME for tissue gain was 67.67 and 64.86 per cent for cows on positive balance and for all the cows respectively. In the earlier communication (Patle and Mudgal, 1976a) during early lactation of crossbred cows the efficiency of ME for milk production was 64.4 per cent. The ME required for the production of 1 kg FCM in early lactation was found to be 4.877 MJ.

The energy requirements for milk production by various standards, 4 per cent fat corrected milk, are given in Table 12.

ii) Protein Requirement

a) Protein Requirement for Maintenance

The quantity of nitrogen or protein required for maintenance is that which balances the endogenous urinary and metabolic faecal nitrogen (plus the small dermal losses occurring in hair, sweat, etc.). Unlike that of energy there is no activity increment of protein since the moderate muscular activity does not increase the expenditure of nitrogen nor does it induce an acceleration of the endogenous erosion of the nitrogenous components of the tissues (Mitchell, 1962).
Table 12: Energy requirement for milk production at different levels of production recommended by various standards.

<table>
<thead>
<tr>
<th>4 per cent fat corrected milk yield (kg per day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
</tr>
<tr>
<td>kg/TDN per day for milk production in addition to maintenance requirement</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARC (1965)¹</td>
<td>1.2</td>
<td>2.9</td>
<td>4.83</td>
<td>6.88</td>
<td>9.20</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NRC (1966)</td>
<td>1.65</td>
<td>3.3</td>
<td>4.95</td>
<td>7.40</td>
<td>9.25</td>
<td>11.10</td>
<td>14.70</td>
</tr>
<tr>
<td>Evans (1960)²</td>
<td>1.55</td>
<td>3.11</td>
<td>4.66</td>
<td>6.21</td>
<td>6.76</td>
<td>9.21</td>
<td>10.76</td>
</tr>
<tr>
<td>McDonald et al. (1969)³</td>
<td>1.72</td>
<td>3.45</td>
<td>5.17</td>
<td>6.89</td>
<td>8.61</td>
<td>10.33</td>
<td>12.05</td>
</tr>
<tr>
<td>NRC (1958)⁴</td>
<td>1.60</td>
<td>3.20</td>
<td>4.80</td>
<td>6.40</td>
<td>8.00</td>
<td>9.60</td>
<td>11.20</td>
</tr>
<tr>
<td>Morrison (1959)⁵</td>
<td>1.55</td>
<td>3.10</td>
<td>4.65</td>
<td>6.20</td>
<td>7.75</td>
<td>9.20</td>
<td>10.75</td>
</tr>
<tr>
<td>Morrison (1959) lower value</td>
<td>1.55</td>
<td>3.10</td>
<td>4.65</td>
<td>6.20</td>
<td>7.75</td>
<td>9.20</td>
<td>10.75</td>
</tr>
<tr>
<td>Sen and Ray (1964)⁶</td>
<td>1.58</td>
<td>3.16</td>
<td>4.74</td>
<td>6.32</td>
<td>7.90</td>
<td>9.48</td>
<td>11.06</td>
</tr>
</tbody>
</table>

1. The values given are for rations containing 2.6 Kcal ME/g dry matter. Maintenance requirement 12.5 Kcal ME/500kg body weight (NRC, 1965) was substracted and the production values were converted into TDN assuming 3.58 Kcal ME equal to 1 kg TDN.

2. The standard is 0.26 kg SE/kg 4 per cent FCM converted to TDN assuming 1 kg TDN equal to 3.575 Kcal ME (Reid, 1961b) and 1 kg SE = 4.26 Mcal ME (ARC, 1965).

3. The standard is 0.29 kg SE/kg 4 per cent FCM values for TDN and SE were taken as in 2.

4. The standards are 0.32 kg TDN/kg 4 per cent FCM.

5. - do - 0.31 - do -

6. - do - 0.316 - do -
The endogenous urinary nitrogen excretion is related to the metabolic body size similar to that of basal energy metabolism and varies with the \(\frac{3}{4}\) power of body weight (Brody et al., 1934; Brody, 1945; Kleiber, 1961), whereas, the metabolic faecal nitrogen is not related to the metabolic body size but is related to the food intake or faecal dry matter (Blaxter and Mitchell, 1948; Mukerjee and Kehar, 1949; Kehar and Mukherjee, 1949; ARC, 1965; McDonald et al., 1969).

However, the present feeding standards (NRC, 1966; Morrison, 1959; Woodman, 1957) use \(\frac{3}{4}\) power of body weight to calculate maintenance protein requirements of animals of different weights.

b) Present Standards

Morrison (1959) recommended 0.27 to 0.29 kg digestible crude protein per \(\frac{1}{2}\) kg body weight. National Research Council (US) (1966) recommended 300 g digestible crude protein per 500 kg body weight, whereas, Woodman (1957) recommended 0.28 kg digestible crude protein per \(\frac{1}{2}\) kg body weight. Perkins (Halman, 1929) found that the maintenance protein requirements of the 1000 lb cows are less than the generally accepted standard of 0.6 lb. The results of the studies of Bailey and Broster (1957) suggested that the level of protein recommended by some authorities may be extensive though the need for safety margin in practice may have been encouraged. For heavier animals disagreement is wide among authorities both in the amount of protein required at given live weight and in the trend in the requirement with change in live weight. Studies of Bailey and Broster (1957), Broster et al. (1963) studied the response of growing short-horn and
Friesian heifers to variations in the intake of protein and energy. They showed that the daily maintenance requirement for dietary crude protein as 255 g DCP/500 kg body weight considering 50 per cent digestibility of dietary protein.

Hashizume et al. (1965) estimated digestible crude protein requirement for maintenance of 453.6 kg Holstein cow as 220 to 245 g. However, they observed that when large amount of rice straw was given the requirement was greater.

Blaxter (1959) reviewed the available literature on protein requirement and concluded that protein requirement varies with the dry matter intake. For every 5 lb dry matter protein requirement increases by about 0.06 lb digestible crude protein. ARC (1965) has given one general assumption that all diets for ruminants should contain at least the equivalent of 9 per cent crude protein in dry matter even if this exceeds the factorial estimates of minimum requirement. Low protein estimates are likely to be insufficient to promote optimum fermentative activity of the rumen microorganisms.

c) Protein Requirement Studies in India

In India some work has been carried out on endogenous urinary nitrogen. One important finding has been that the endogenous urinary nitrogen secretion of an adult non-producing Indian cattle is only 90.4 mg/kg W⁰.⁷⁵ (Kehar and Mukherjee, 1943) as contrast to 120 mg/kg W⁰.⁷⁵ reported for cattle (ARC, 1965). This shows that Indian non-producing cattle can be maintained on a daily digestible crude protein
intake of 0.4 lb/1000 lb body weight, while the recommended standards
by Western workers (Morrison, 1959) being at least 0.6 lb/1000 lb body
weight. Long term feeding trials carried out by Kehar and Mukherjee
(1949) have corroborated the fact that Indian cattle can be maintained
on 0.4 lb DCP/1000 lb body weight.

Gupta et al. (1966) reported 0.194 g EUN per kg body weight in
male buffaloes. The minimum protein requirement which can replace the
wear and tear of the tissue was found to be 0.0558 kg per 454 kg body
weight. They further reported that minimum protein requirement for
maintenance derived by Crampton's technique worked out to be 0.223 and
0.235 kg per 454 kg body weight. These workers also found the MPN as
0.341 g per 100 g dry matter intake.

The research reports available from tropical and subtropical
countries show that the protein requirement of cattle in these areas
is less as compared to those stated in the present feeding standards.
The results of Elliot and Topps (1963a,b) showed that Africander and
Mashona breeds of cattle require 40 per cent less protein than that
recommended by Brody (1945). The investigations carried out in India
(Kehar and Mukherjee, 1943; Mudgal and Ray, 1965; Gupta et al., 1966;
Gopal Krishna, 1971; Patle and Mudgal, 1975) also showed that Indian
pure bred cattle, crossbred cattle and buffaloes require less protein
than that stated in foreign feeding standards. However, large breed
differences in the protein requirement of cattle have been reported by
Elliot et al. (1964).
Gopal Krishna (1971) found the DGP requirement of Tharparkar and Sahiwal cows to be 177 g per 400 kg for maintenance i.e. about 60 per cent less than that of NRC (1966). Patle and Mudgal (1975) studied the protein requirement for maintenance of crossbred cattle. They observed that EUN as measured using regression of urinary nitrogen over nitrogen intake was $0.1648 \, g/\, W^{0.75} \, kg$ and MFN as estimated by plotting nitrogen intake against faecal nitrogen both expressed on the basis of per cent dry matter intake was $0.5036 \, g/100 \, g \, dry \, matter \, intake$. The DGP requirement as estimated from endogenous urinary nitrogen, MFN, average biological value and average dry matter intake was $2.01 \, g/\, W^{0.75} \, kg/day$. The NRC (1966) stated the DGP requirement as $2.837 \, g$; Sen and Ray (1971) as 2.862 g and Woodman (1957) as $2.903 \, g/\, W^{0.75} \, kg/day$ respectively. Thus the maintenance requirements of DCP obtained by Patle and Mudgal (1975) was lower by 18.5 per cent than NRC (1966) and Morrison (1959) standards. However, these values were higher than those of 1.238 g DCP/kg $W^{0.75}/day$ for steers and 1.637 g DCP/kg $W^{0.75}/day$ for Holstein cow reported by Elliot and Topps (1963) and Hashizume et al. (1963) respectively.

The maintenance values of digestible crude protein recommended by various workers and feeding standards are given in Table 13.

d) Digestible Crude Protein Requirement for Milk Production

Morrison (1959) recommended 0.041 to 0.049 lb DCP per lb 4 per cent FCM considering 0.6 to 0.65 lb digestible crude protein per 1000 lb body weight for maintenance. Based on a maintenance requirement of
Table 13: Maintenance values of protein recommended by various workers and feeding standards

<table>
<thead>
<tr>
<th>Animal</th>
<th>DCP g/454 kg body weight</th>
<th>g DCP/kg w.75/day</th>
<th>Method</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry cow</td>
<td>237</td>
<td>2.304</td>
<td>Feeding trial</td>
<td>Wolf (Halnan, 1929)</td>
</tr>
<tr>
<td>-do-</td>
<td>318</td>
<td>3.228</td>
<td>-do-</td>
<td>Haecker (1903,1911)</td>
</tr>
<tr>
<td>-do-</td>
<td>272</td>
<td>2.761</td>
<td>-do-</td>
<td>Hills et al. (1922)</td>
</tr>
<tr>
<td>-do-</td>
<td>282</td>
<td>2.862</td>
<td>-do-</td>
<td>Sen and Ray (1964)</td>
</tr>
<tr>
<td>-do-</td>
<td>272</td>
<td>2.761</td>
<td>Nitrogen balance</td>
<td>Amsby (1917)</td>
</tr>
<tr>
<td>-do-</td>
<td>263</td>
<td>2.670</td>
<td>-do-</td>
<td>Mollgaard (1929)</td>
</tr>
<tr>
<td>-do-</td>
<td>286</td>
<td>2.903</td>
<td>-do-</td>
<td>Woodman (1957)</td>
</tr>
<tr>
<td>-do-</td>
<td>341</td>
<td>3.461</td>
<td>Factorial method</td>
<td>Brody (1945)</td>
</tr>
<tr>
<td>-do-</td>
<td>250</td>
<td>2.538</td>
<td>-do-</td>
<td>Reid (1961b)</td>
</tr>
<tr>
<td>-do-</td>
<td>174,176</td>
<td>1.663</td>
<td>Nitrogen balance</td>
<td>Hashisume et al. (1963)</td>
</tr>
<tr>
<td>Steers</td>
<td>122</td>
<td>1.238</td>
<td>-do-</td>
<td>Elliot and Topps (1963)</td>
</tr>
<tr>
<td>Zebu cattle</td>
<td>-</td>
<td>1.978</td>
<td>-do-</td>
<td>Gopal Krishna (1971)</td>
</tr>
<tr>
<td>Lactating cows</td>
<td>-</td>
<td>2.850</td>
<td>-do-</td>
<td>Tyrrell et al. (1970)</td>
</tr>
<tr>
<td>Bullock</td>
<td>-</td>
<td>2.100</td>
<td>-do-</td>
<td>Patle and Mudgal (1975)</td>
</tr>
<tr>
<td>Cows (in early lactation)</td>
<td>-</td>
<td>2.246</td>
<td>-do-</td>
<td>Patle and Mudgal (1976)</td>
</tr>
<tr>
<td>Cows (in mid lactation)</td>
<td>-</td>
<td>2.227</td>
<td>-do-</td>
<td>-do-</td>
</tr>
</tbody>
</table>
0.3 kg of digestible protein daily for a 500 kg dairy cow with requirements for other weights calculated on the basis of 3/4 power, the NRC (1966) furnishes 135 to 145 per cent of the protein in the milk in addition to the maintenance requirement. The additional amounts required increase as the fat content of the milk increases. Woodman (1957) recommended 0.60 lb DCP per gallon milk containing 3.5 to 3.8 per cent fat. Blaxter (1959) stated that protein requirements per gallon tend to increase at higher yields when margin of safety is included.

e) Other Studies

Fries et al. (1924) conducted nitrogen balance trials on two lactating cows and found that allowing 0.6 lb digestible crude protein per 1000 lb live weight for maintenance an intake of DCP equal to 1.25 times the milk protein or an intake of 1.03 times true protein was sufficient. Increasing the intake of protein diminished its percentage utilization for milk production. While, Forbes and Swift (1925) found that the average utilization of feed for milk production was 38 per cent only.

Later Drori and Folman (1970) concluded that in a high energy high concentrate feeding regime like that practised in general, a protein allowance for lactation which supplies 1.25 times as much DCP as milk contains, does not limit production and can be safely supplied throughout the lactation by a concentrate mixture containing 11.5 per cent crude protein.
Reid (1961b) indicated that the requirement of the digestible protein should be within the range of 0.05 to 0.07 lb/lb FCM produced, depending upon the level of milk production. Jumah et al. (1965) found the average requirement of digestible protein above maintenance to be 0.052 ± 0.04 lb. All cows showed higher protein efficiency at early stages of lactation than later in the lactation. A significant correlation (r = 0.73) was found between protein requirement and the level of production. There was considerable variation among cows in energetic and protein efficiencies.

Reid et al. (1966) reported that as the milk yield increased, the level of feed intake also increased. Accordingly, the percentage of protein apparently digested also decreased. As a consequence at a large feed intake (or high milk yield) more dietary protein was needed per pound of milk. The authors estimated that the minimum DF (g) requirement per lb of FCM for 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 lb as 25.3, 25.7, 26.1, 26.5, 27.0, 27.5, 28.0, 28.6, 29.6 and 30.0 g/lb per day respectively.

Masaokametaka (1968) stated that 48.5 g of DCP was enough for 1 kg FCM production. Morimoto et al. (1965) concluded from feeding trials with cows producing on an average of 26.8 lb of 4 per cent FCM/day and from nitrogen balance trials that the requirement for DF was 154 per cent of the milk produced.

Elaxter (1959) stated that when DM intake was 30 lb daily the theoretical requirement on an average was 0.55 lb DCP for maintenance of 1000 lb cow and 0.47 lb DCP for each gallon of milk produced.
Patle and Mudgal (1976) found the maintenance requirement of digestible crude protein for crossbred cows in early lactation and cows in mid lactation and all cows as 2.246, 2.227 and 2.314 g/kg W^{0.75} day. The digestible N required per 100 g nitrogen secreted in milk was 151.1, 150.0 and 149.7 g for cows in early lactation, cows in mid lactation and all cows, respectively.

Some data on protein requirements for milk production recommended by the current feeding standards are cited in Table 14.

Table 14: Some currently recommended protein allowances for milk production

<table>
<thead>
<tr>
<th>g/kg</th>
<th>Per cent FCM</th>
<th>Per cent of protein in milk</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>175</td>
<td>Haecker (1914)</td>
<td></td>
</tr>
<tr>
<td>41-49</td>
<td>129-163</td>
<td>Morrison (1959)</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>135-145</td>
<td>NRC (1966) for cows</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>producing less than 20 kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>milk.</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>180</td>
<td>Woodman (1948)</td>
<td></td>
</tr>
<tr>
<td>53.9</td>
<td>154</td>
<td>Morimoto et al. (1965)</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>160</td>
<td>Tyrrell et al. (1970)</td>
<td></td>
</tr>
</tbody>
</table>
iii) Digestibility and Energy Losses

a) Effect of Intake and Digestibility

The largest and most variable loss of dietary energy and protein is represented by the faeces. In general, ruminants lose about 30 to 50 per cent of energy in faeces, 3 to 5 per cent in urine, 6 to 13 per cent in methane and 30 to 50 per cent as heat. Similarly, 35 to 70 per cent of nitrogen is lost in faeces depending on the digestibility and dry matter intake (Reid, 1961b, Greenhalgh, 1969).

It has been reported by many workers that increased level of feeding decreases the digestibility (Anderson et al., 1959; Blaxter, 1956, 1962; Blaxter and Graham, 1955, 1956; Blaxter and Wainman, 1961; Wagner and Loosli, 1967; Leever et al., 1969; Reid et al., 1966) and decrease in digestibility with increasing level of feeding has been one of the main cause for the diminished output of milk per unit of feed (Reid, 1961a; Blaxter, 1962; ARC, 1965; Reid et al., 1966; Wagner and Loosli, 1967).

However, there is also evidence that increased level of feeding increases the digestibility (Lassiter et al., 1957, 1958; Elliot and Loosli, 1959; Bines and Dave, 1970) or level of feeding has no effect on digestibility (Anderson et al., 1959; Wiktorsson, 1971).

Blaxter (1950) reported that increased level of feeding causes a decline in digestibility in some rations while no effect in others. Blaxter and Graham (1955) and Blaxter et al. (1956) stated that the
extent to which digestibility was depressed appeared to be related to the fineness of the forage; finer the material lesser the digestibility.

The results of most of the experiments on effect of level of feeding on digestibility of mixed rations show that digestibility decreases with increased consumption of a ration. Moe et al. (1965), Reid et al. (1966) and Tyrrell et al. (1966) reported that the average rate of depression in the TDN values was 4.0 per cent (range 3.11 to 6.22), per increment of intake equivalent to the maintenance requirement of TDN. The results of the studies of Tyrrell et al. (1966), Wagner and Loosli (1967) and Leaver et al. (1969) showed that the digestibility depression becomes larger as the fraction of concentrates in the total diet increases.

On the other hand, no change in digestibility of mixed diets has been reported by other workers (Graham, 1964) or even higher digestibility has been reported by others (Lassiter et al., 1957; 1958; Robinson and Forbes, 1970).

Lassiter et al. (1957) studied the effect of level of intake on digestibility using hay : grain rations 80:20, 50:50 and 20:80 on dry matter basis. Coefficient of digestibility of dry matter, crude fibre and protein increased significantly as feeding level increased from 70 to 130 per cent dry matter intake. The same authors in 1958 also found similar trend although the results were not significant. Robinson and Forbes (1970) offered a high or low level of ME and a constant level of DCP to ewes. A significant higher digestibility of dry matter on higher energy intake was found.
However, under normal feeding conditions the cows are fed roughage at a constant levels i.e. for maintenance and first few kg of milk and the increased requirements for milk production are met by feeding concentrates. This increase in level of concentrate, according to the production changes, the roughage concentrate ratio, results in an increase in the overall digestibility of the ration (Bloom et al., 1957; Putnam, 1958; Anderson et al., 1959; Elliot and Loosli, 1959; Putnam and Loosli, 1959; Broster et al., 1969; Bines and Dave, 1970).

Wikström (1971) fed to each cow 7 kg hay, 1 kg beet pulp and a concentrate mixture ranging from 3.0 to 13.5 kg in experiment I and 0 to 15.7 kg in experiment II, and found that cows digested the concentrate to the same extent regardless of the quantity consumed. The authors concluded that there seems no reason to assume a lower digestibility at high feed consumption as long as the animals are adopted to a normal feeding ration with long hay and crushed concentrates.

b) Losses of Energy as Methane

The microbial activity in the rumen produces mainly carbon dioxide and methane. Some quantity of hydrogen, hydrogen sulphide and carbon monoxide (Brody, 1945) and methane (Blaxter, 1962a) are also produced, but the analytical work has shown that the combustible gases produced by ruminants on normal rations consist almost entirely of methane (Blaxter, 1962a; McDonald et al., 1969). Methane is formed in the rumen by reduction of carbon dioxide by methogenic bacteria (Barker...
et al., 1960; Carrol and Hungate, 1955; Hungate et al., 1959; Blaxter, 1962 and Bryant, 1965). Formic acid is the most likely source of hydrogen for methane synthesis (Blaxter, 1962a). A 500 g steer produces about 300 ml methane per day (Brody, 1945; Blaxter and Czerkawski, 1966). Assuming that the energy equivalent for methane is 9.45 Kcal/litres (Brouwer, 1965) the energy loss in methane is 2835 Kcal/day.

Bratzler and Forbes (1940) and Swift et al. (1968) found that the relationship between methane produced and carbohydrates digested was most significant and accordingly the authors developed formula for calculating methane production on the basis of digestible carbohydrates for cattle in 1960 and for sheep in 1968. Around 4.8 g of methane is produced per 100 g of carbohydrates digested (Armsby and Fries, 1915; Kleiber, 1961).

At maintenance level loss of energy as methane is less (6.2 Kcal) when feeds of low digestibility and high (10.8 Kcal) when feeds of high digestibility is fed (Blaxter and Clapperton, 1965). Blaxter and Wainman (1964) stated that methane losses per 100 Kcal intake, increased with increasing proportion of flaked maize in the diet until the diet containing 60 to 80 per cent flaked maize was given, when it declined markedly.

As the amount of food given to a ruminant is increased, methane production also increases but the production per unit feed intake decreases (Blaxter, 1962a; Armstrong, 1964; Blaxter and Clapperton, 1965; ARC, 1965; Graham, 1967).
c) **Losses of Energy in Urine**

The energy containing substances excreted in urine are urea, hippuric acid, creatinine and allantoin and also such nitrogenous compounds as glucuronates and citric acid. About 3 to 5 per cent of dietary energy is excreted in the urine (Brody, 1945; Reid, 1961a; Haynard and Loosli, 1969). Loss of energy as urea depends upon the nitrogen intake (Brody, 1945) and the quality of protein (McDonald et al., 1969). Each gram of nitrogen excreted as urea represents the loss of 5.45 Kcal (Blaxter, 1962a).

Losses of energy in urine usually vary less with nutritional level than do methane losses (ARC, 1965); however, the loss of energy in urine is significantly less with increased intake (Blaxter, 1962a; Armstrong, 1964; Reid, 1961a; Greenhalgh, 1969). Blaxter and Wainman (1964) found that energy per g N in the urine was over 30 Kcal when rations of hay were given and declined to 12 Kcal when flaked maize was the sole food.

iv) **Utilization of Metabolizable Energy**

a) **Utilization of ME for Maintenance**

The efficiency of utilization of ME for maintenance has been reported to be more than that for fat production. Blaxter and Wainman (1964) found the efficiency of utilization of ME for maintenance to be between 71 to 79 per cent and for fattening from 29 to 61 per cent depending upon the type of ration. Graham (1969) found that the net
availability of ME was 84 per cent between fasting and half maintenance, 69 per cent between fasting and maintenance and 54 per cent above maintenance.

b) Utilization of ME for Milk Production

Kriss (1943) found that on an average ME of food given in excess of maintenance needs was converted to milk energy with an efficiency of 70 per cent, when the same foods were given to fattening animals the average efficiency with which these were converted to body fat was 58 per cent. Blaxter (1962a) stated that milk secretion is energetically a more efficient process than the deposition of fat. One reason is that amino acids are incorporated in the milk proteins and thus less energy is lost as heat of combustion of the urea formed from the unused amino acids. A further reason is that the fatty acids of the milk have an average shorter carbon chains than those of depot fat.

Although Reid (1961a) states that there is a progressively less efficient utilization of absorbed matter for milk production as the level of intakes is increased, Hashizume et al. (1965a) and Flatt (1966) found that the relationship between ME input (at body energy equilibrium) and the milk energy output appears to be linear.

c) Effect of Stage of Lactation on ME Utilization for Milk Production

Wallace (1956, 1959) found that the digestible organic matter was more efficiently utilized during early stage of lactation. Blaxter
(1966) reported that a fall in yield of one gallon of milk in early lactation resulted in a gain in weight of 1.8 lb, whereas, at advanced lactation a fall in yield of a gallon was associated with smaller gains of 1.3 falling to 1.1 lb. The reason for more efficient utilization of ME during early stage of lactation may be that considerable amount of body tissues are catabolized and used for milk production during peak yield (Flatt et al., 1965c). The efficiency of utilization of body tissue for milk production was 82 to 84 per cent and that of feed nutrients was 60 to 70 per cent. The actual efficiency of utilization of energy depended upon the proportion of these two sources of energy utilized for milk production (Nye et al., 1971).

v) Milk Yield and Composition

a) Effect of Level of Feeding on Milk Yield in Cows

Nevens (1927) found no significant increase in the milk yield when cows consumed up to 60 per cent more energy than that recommended in standards. Rumsey and Plum (1963) also could not find any increase in milk production when the lactating Holstein cows were fed 50 per cent more grain. However, the cows eating extra grain mixture gained 70 lb more than those in the control group.

On the other hand, Jensen et al. (1942) obtained substantial increase in milk production by feeding over the Haecker's standards, and that each successive increment in food intake produced a smaller response. Yates et al. (1942) also concluded that the law of diminishing returns applied to milk production. Larsen and Eskedal (1952) found
that there was an increase of 20 to 40 per cent in milk yield after heavy feeding. Reid (1956a, 1961a) concluded that an intake of TDN about 25 per cent in excess of the allowances of the commonly used standards increase milk production by about 15 to 20 per cent. In addition, the production response to increased amounts of feed is less at high levels of intake than at low levels.

Castle et al. (1959) found a significant increase in milk production and SNF content of milk, when milch cows were fed two concentrate rations containing SE 63 and 79 per cent, each given at the rate of 4.6 and 2.6 lb per gallon milk in addition to the basal ration of hay, dried grass, grass silage and fodder beet. Rook and Line (1961) provided 2.5 lb less and 5 lb more SE than the Woodman's standards and compared with a normal ration. In another experiment the rations were more extremes and ranged from 35 per cent to 25 per cent more or less of the theoretical requirements for maintenance and production. In both experiments raising the plane of energy nutrition gave an increase in the yield of milk and its SNF content.

Dijkstra and Frens (1965) fed to 13 dairy cows rations supplying 103, 114 and 124 per cent of the standards. From the results, it was concluded that the feeding of 1 kg extra SE resulted in increased milk yield by 1.35 kg on the fat corrected milk basis. Petkow (1968) working with German Black Pied cows found that increasing or decreasing the energy content by 30 per cent of the Polish standards increased or decreased the average daily milk yield by 0.5 kg and also the contents of fat and crude protein. The live weight of animals did not vary
significantly. Smith and Boyd (1968) concluded that the high energy fed cows consistently produced more milk, with higher SNF and protein content. Wilson et al. (1969) fed to two groups of 24 Angus-Holstein crossbred cows 38,640 and 28,650 Kcal ME per head per day (115 and 85 per cent of NRC, 1966 standards). Protein intake was kept the same in both the groups. Energy levels significantly (P < 0.01) influenced cow weight loss, cow and calf condition and FCM yield. Although the cows receiving the 85 per cent energy level lost on an average of 54.4 kg, the 115 per cent group maintained their initial weight. Dijkstra (1970) fed cows in 3rd-4th months of lactation at 11.8 per cent below the feeding standards of the Central Bureau of Livestock Feeding (Dutch SE standard or SES) for 56 days. Control group received 4.2 per cent above SES. The results showed that feeding one kg SE below standard caused an average daily loss in milk yield per cow by 1.23 kg or 4 per cent FCM. Compared with milk from controls, milk from experimental cows contained more fat (0.02 per cent), less SNF (0.11 per cent) and less protein (0.06 per cent). Experimental group showed a slight relative loss in condition.

Mudgal and Lal (1970) reported that factors such as nutrition, systems of feeding, type of housing and seasonal changes affect the yield and composition of milk. They observed highly significant (P < 0.01) differences in milk yield due to level of TDN feeding. The high energy group averaged 6.068 kg 4 per cent FCM per day and medium and low energy fed groups yielded 5.787 and 5.848 kg milk respectively. The high DCP fed cows produced 6.130 kg 4 per cent FCM per day and the medium and low fed group produced 5.075 and 4.842 kg
respectively ($P < 0.01$). In later communication, Lai and Mudgal (1972) observed highly significant ($P < 0.01$) differences on solid-not-fat (SNF) contents due to feeding in all the seasons studied. It was also observed that the energy content of the ration was a decisive factor for the richness of milk, rather than the protein. In the winter feeding trial, the SNF of medium and low level fed groups fell below the prescribed legal standard. These workers concluded that high level of energy feeding (TDN) specially in the winter season will be highly desirable to maintain the richness of the milk.

Earlier, Blaxter (1959) concluded, "in general it appears that the response of cows to different levels of feeding obeys the law of diminishing returns. As the level of feeding increases above that prescribed by the standards, milk yield is increased at an ever diminishing rate and when feed intake is decreased below the standards, the milk yield falls at an ever increasing rate. Simultaneously, upward or downward adjustments of body weight occur." Similar conclusions were drawn by Reid (1956b), Burt (1957b) and others.

b) Effect of Level of Feeding During Early Lactation

Burt (1957a) reviewed the work of Dijkstra (1942) and Kajanoja (1944) and concluded that the milk yields were markedly affected by the energy intakes during the early stage of lactation. Bailey et al. (1956) could not observe any difference in milk yield during the first three weeks, but yields were significantly higher at the higher level of feeding during the remainder of the experimental period.
Burt (1957b) conducted a series of experiments on Ayrshire, Dairy Shorthorn and Friesian cows during the early and mid lactation. Mean milk yields rose progressively with increasing level of feeding and the milk yield response to additional food declined as the lactation progressed. Wallace (1959) also drew similar conclusion.

Brown _et al._ (1962) fed to three groups of lactating cows from 36 days post partum to the end of lactation. The levels of feeding were 1 lb grain per 3.5 lb milk, 1 lb grain per 2.5 lb milk and _ad lib._ grain feeding. The cows fed on two higher levels of grain produced considerably more milk than expected from the first part of lactation, whereas cows fed on low level of grain produced slightly less milk than expected.

The experiments of Flux and Patchell (1954, 1957) and Broster (1970) showed that a genuine level of feeding in the first four weeks of lactation improved milk yield both currently and later in lactation. The effect over the lactation equalled 3-4 times the immediate effect. Under feeding in early lactation depressed milk yield and SNF and fat percentage both currently and over the lactation.

Broster _et al._ (1958) gave cows 2.0 or 3.20 kg SE per 10 kg milk during the first 12 weeks of lactation. Those given the higher allowance gave 2 per cent more FGM during that period. Subsequently, all the cows were fed on similar plane of nutrition over the whole lactation, but those fed at the higher level initially gave 5 per cent more FGM. Broster _et al._ (1969) and Broster (1970) confirmed the above findings.

Broster (1970) studied two fixed levels of intake _H = 35 and L = 28 Mcal ME_ daily in early and in mid lactation (weeks 1-9 and weeks
10-18 of lactation) in 80 British Friesian cows. The extra food in ration in early lactation increased milk yield by 3.14 kg per day, SNF by 0.25 per cent and reduced live weight losses by 0.26 kg per day. In mid lactation it increased milk yield by 2.64 kg per day, SNF by 0.20 per cent and live weight gain by 0.32 kg per day. The response in milk production declined and in live weight increased as lactation proceeded and this trend continued in later lactation. There was a residual effect in mid lactation from earlier feeding.

Blaxter (1959) stated that the higher the lactation yield of the cow when fed according to standard the greater will be her response to additional feed expressed in terms of lb of milk per lb of SE. This was true also within lactations, i.e. when high yields in early lactation were compared with lower yields later on. The response appeared to be one of the direct proportion.

Patle and Mudgal (1976) fed 90, 110 and 130 per cent energy levels and 90, 110 per cent protein levels of NRC (1966) standards to crossbred (Brownswiss x Sahiwal) cows. The milk yield, 4 per cent fat corrected milk (FCM), solid-not-fat (SNF) and fat yield were significantly (P ≤ 0.01) affected due to level of feeding. Body weight gain increased significantly (P ≤ 0.01) as energy level increased. The increase in milk and FCM yield was significantly (P ≤ 0.01) higher on each increment of energy intake. However, the response per kg TDN was lower when the energy was increased above ME when compared with low energy level. These workers further observed that the response to increased level of energy was curvilinear and followed the law of diminishing returns.
The other information available in the literature showed that the effect of level of feeding on milk yield were variable. Rumery and Plum (1963) and Owen et al. (1970) could not find any increase in milk production due to high level of feeding.

c) Effect of Level of Protein Feeding on Milk Yield in Cows

Variable results have been reported on the effect of level of protein feeding on milk yield. Holmes et al. (1956), Solodatenkov et al. (1960), Rook and Line (1962), Mathur and Rao (1964), Silva et al. (1968), Petkov (1968), Herold and Mankaesi (1968) and Patel et al. (1970) did not find any significant difference in milk production or in milk composition due to the variation in protein level in the ration.

On the other hand, Zorin (1956), Lassiter et al. (1957), Paveta and Dardzhonov (1970), Vilela (1971), Gordon and Forbes (1970), Lal (1970) reported an increase in milk production when the protein level was increased above the normal feeding standards. Logan et al. (1959) fed 100 and 150 per cent protein requirements and the mean milk yields of high and low protein rations were 32.4 and 31.0 lb. The difference was significant.

Paveta and Darzhonov (1970) found that reduction of protein level by about 23 per cent in comparison with the USSR standard to a level said to be that of upper limit of Morrison standard reduced milk yield by 8.5 per cent in first lactation, 15 per cent in the next and 20 per cent in the 3rd. In the 2nd experiment, protein intake was reduced by about 15 per cent and milk yield fell about 12 per cent. Lal (1970) studied the effects of three levels of protein i.e. 125, 100 and 75
per cent of Sen and Ray (1964) standards on milk yield and composition and found the high level protein caused significant increase in milk yield.

Breirem (1949a,b) and Rook and Line (1962) reported that reduction of the protein level from 80 to 60 per cent of the recommended allowance caused considerable decrease in milk yield. Breirem (1949a,b) found that reduction in dietary protein of the diet to about 60 per cent for a period of ten weeks caused a fall in milk protein by 0.25 per cent and also a loss of milk yield of about 2 lb per day in an average yield of 25 lb per cow.

Vilela (1971) fed to cows concentrate mixture containing 14, 16, 18, 20 or 22 per cent protein and 70 per cent TDN at the rate of 0.1 kg per kg milk produced. Daily yield was 11.77, 11.98, 12.20, 12.41 and 12.62 kg for the supplements with increasing protein contents. When protein was increased the efficiency in utilization of TDN for milk production increased but that of crude protein decreased.

In a recent communication, Patle and Mudgal (1976a) while working on the effect of feeding during early lactation on milk yield and milk composition of crossbred cows, reported that the increase in protein level significantly (P < 0.01) increased the 4 per cent fat corrected milk yield as the level of DCP intake increased from 87.88 to 100.47 per cent of NRC standard. The results further indicated that as the level of protein decreased below normal standards (from 100.47 to 87.88 per cent), there was a reduction in the milk yield.
d) **Effect of Level of Feeding on Cow Milk Composition**

Blaxter (1950), Burt (1957a), King (1960), Rook and Line (1961), Trinder (1963), Huber and Boman (1966), Kirchgessner et al. (1967), Madam Kazdal-Savoie (1970) and Lal (1970) have extensively reviewed the literature on effect of level of feeding on milk composition.

**e) Effect of Plane of Energy on Fat Percentage of Cow Milk**

Prolonged under feeding has been reported to lower down the production of milk and its fat content (Mollgaard and Lund, 1929; Breier, 1949; Isaachsen and Ulvesli, 1949). However, Riddet et al. (1941), Logan et al. (1929) and Hotchkiss et al. (1960) noted little or no change in the milk fat content when under feeding was practised. While, Flux and Patchell (1951), Leffel and Shaw (1957), Robertson et al. (1960) and Smith and Boyd (1968) reported an increase in fat content, especially where there was a short term sudden reduction in feed intake. This was accompanied by a fall in milk and also a drop in live weight. Blaxter (1950) concluded that the percentage of fat declines only when under nutrition is prolonged. Short periods of under-nutrition in which yield falls rapidly are associated with increase in fat percentage.

Higher energy intake than the standards did not cause any increase but in some cases even a decrease in fat percentage was observed (Bailey, 1952a; Holmes et al., 1956, 1960; Larsen and Larsen, 1956; Castle et al., 1959; Logan et al., 1959).

Trinder (1963) concluded that use of excessive amounts of flaked maize (energy) leads to a depression of the butter fat content of milk.
because of reduced acetic acid and more propionic acid production in the rumen.

Burt (1957a) and Kirchgessner et al. (1967) reported that the changes in energy intake usually had little or no effect on fat content of milk.

Patle and Mudgal (1976a), reporting results on crossbred cows, could not find any significant effect on milk fat percentage due to energy or protein levels on the ration. Kirchgessner et al. (1967), after reviewing various studies, also concluded that the change in level of energy intake usually had little or no effect on the fat content of milk. However, Lal and Mudgal (1973) reported a significant \( P < 0.01 \) effect of feeding high level of TDN (125 per cent of Sen and Ray, 1964) in fat content of milk of Tharparkar cows. Similar observations were made for high protein feeding.

f) Effect of Plane of Energy on Solid-not-fat and Protein Percentage of Milk

The studies of Riddet et al. (1941), Rowland (1946), Breirem (1949a,b), Holmes and Arnold (1956), Bailey (1952), Rook (1953), Holmes et al. (1956, 1960), Rook and Rowland (1959), Castle et al. (1959), Rook and Line (1962), Huber and Boman (1966), Lal (1970) and Gordon and Forbes (1970) showed that increase in dietary energy, also increased the SNF and protein content of the milk. Armstrong (1968) concluded that the protein content of the milk increases as energy level was raised, the changes being more marked at low level of energy than at high level.
Patle and Mudgal (1976a) reported that milk protein percentage increased as the level of energy and protein increased, but the effect was not significant in both early and late lactation in crossbred cows. The SNF percentage increased significantly (P < 0.01) as the level of energy in the diet increased but the protein level did not affect the SNF percentage. Yousef et al. (1970) also reported increased SNF and protein content of milk due to higher energy intake. They stated that the increase in SNF content of milk was largely due to increased protein content.

g) Effect of Plane of Protein on Milk Fat Percentage

Variable results have been reported on the effect of level of protein feeding on the milk fat content. Decrease in fat content of milk due to protein deficient rations has been reported by Breirem (1946) and Ekern (1960). Dyers et al. (1949) and Ryzokova (1951) reported an increase in fat content of milk due to higher protein feeding than the requirements, whereas, Balch et al. (1954), Zorin (1956), Logan et al. (1959) and Rook and Line (1962) did not find any change in fat percentage due to increased level of protein feeding.

h) Effect of Plane of Protein on Milk SNF and Protein Percentage

Varying quantities of protein in the ration can likewise alter the content of milk protein but the alteration here is less obvious than in the case of energy (Kirchgessner et al., 1967). Studies of Steenberg (1947), Breirem (1949a,b), Waite (1956), Rook and Line (1962) have shown that where the rations were obviously deficient in protein, the milk protein percentage was reduced. While Frens and
Dijkstra (1959) in a comparison of rations providing approximately 105, 95 and 85 per cent of the Woodman standards found no effect on either the fat or SNF content of the milk. Experiments of Rook (1953), Holmes et al. (1956), Zorin (1956), Frens and Dijkstra (1959), Politick and Sybrandy (1962) showed that protein levels only slightly above or below the protein requirements have little influence on the SNF or protein content of milk.

When level of protein feeding was raised above the requirements, the total protein content of milk generally rose but the increase was particularly in the NPN content of the milk (Stein, 1957; Rook and Line, 1961, 1962; Orth, 1962; Orth and Kaufmann, 1964; Yousef et al., 1970).

Patle and Mudgal (1976a) carried out their experiment on 18 lactating crossbred cows (Brownswiss x Sahiwal) to study the effect of level of feeding on milk yield and milk composition. These were distributed in 6 groups with 6 treatments consisting of factorial arrangements of three levels of energy (90, 110 and 130 per cent) and two levels of protein (90 and 100 per cent) of NRC (1966) standards. It was concluded that the level of protein in the ration did not affect either fat, protein or SNF percentage of milk.