RELATIONSHIP BETWEEN SOME CIRCULATING HORMONES, METABOLITES AND MILK YIELD IN LACTATING CROSSBRED COWS AND BUFFALOES

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Summary

To study the relationship between certain hormones and metabolites and between hormones and milk yield during different stage of lactation, six lactating Karan Swiss cows and six Murrah buffaloes were maintained. Growth hormone, insulin, T_3, T_4, glucose, BHBA, NEFA and milk yield were studied. Highly negative relationship of growth hormone with insulin and triiodothyronine in cows and marginally negative in buffaloes suggest that insulin and triiodothyronine aid in the process of partitioning of nutrients towards milk production through reducing the demands of nutrients by peripheral tissue. The significant and negative correlation of growth hormone with dry matter intake in both the species suggest that the availability of nutrients from the digestive tract play a role in the regulation of growth hormone secretion. Positive relationship of growth hormone with non esterified fatty acids in both the species suggest that high growth hormone levels may result in fat mobilization and thereby increase the availability of energy precursors for milk synthesis. Insulin was negatively correlated with milk yield and lactose content and positively with milk fat and protein but the degree of relationship varied. In both the species the relationship between triiodothyronine and milk yield was negative and between thyroxine and milk yield was positive. However, it was significant only in cows and not in buffaloes. Thyroxine was positively correlated with beta-hydroxybutyrate and non-esterified fatty acids with milk yield in both the species.
(**Key Words**: Cattle, Buffalo, Correlation, Milk Yield, Milk Composition, Growth Hormone, Insulin, Thyroxine, Triiodothyronine, Glucose, β-Hydroxybutyric Acid, Non-esterified Fatty Acids)

Introduction

Manipulation of the endocrine system is a potential method to improve the efficiency of milk production. It has been realized for long that certain hormones control the functioning of mammary gland but still attempts to pinpoint their specific role in milk production have been limited. Identification of the physiological basis of difference among animals for milk and meat production is being recognised as a high research priority for animal scientists (Bauman and Currie, 1980). Tucker (1981) while reviewing the significant gaps in our knowledge of lactation endocrinology stated that many of the tools of research needed to study metabolism and endocrinology are available which may provide an early pay off in development of management schemes to enhance productive efficiency of dairy animals.

Very few attempts have been made to establish relationship between hormone levels and milk yields. Most outstanding and perhaps the most comprehensive efforts to find relationship between some of the metabolic hormones and milk production were by Hart et al. (1978). There are several other studies also on the subject (Koprowski and Tucker, 1973; Smith et al. 1976; Walsh et al., 1980; Khurana and Madan, 1986; Lomax et al., 1979; Vasilatos and Wangsness, 1981; Blum et al., 1983). However, these studies left more scope for further investigations.

Materials and Methods

Materials and methods have been previously reported (Jindal and Ludri, 1990a, 1990b, 1991). At the start of experiment the animals had completed about 50 days in lactation and were yielding an average of 15.1 kg milk (cows) and 11.6 kg (buffaloes). The experiments were continued for a period of 90 days. Growth hormone, insulin, T_4, T_3, glucose, BHBA, NEFA, DMI, milk yield and milk composition were studied

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in six lactating crossbred cows and six Murrah buffaloes. The blood and milk samples were collected at fortnightly levels. In a day, four blood samplings were done during morning (08:00 a.m.), noon (14:00 p.m.), evening (20:00 p.m.) and night (02:00 a.m.) hours. To establish relationship between different parameters studied, correlation coefficients 'r' were calculated.

Results

Correlation coefficients (r)

(a) Within animals

Values of 'r' between milk yield and various hormones and metabolites, based on fortnightly average values, of individual animals of both the species have been presented in table 1. With the exception of cow no KS 3050 in all the animals of both the species, relationship of milk yield with GH was positive. In one of the cows (KS 3137) the value of 'r' was significant at 5 percent level of significance, whereas, in cow no's KS 3105 and KS 3260 these were significant at 10 percent level. In the remaining two though the relationship was positive but was not statistically significant. In four buffaloes, the relationship was significant at 5 percent level and in the remaining two these were positive but not significant.

Correlation coefficients (r) between milk yield and insulin concentration were negative in most of the animals of both the species. In five cows, the values of 'r' were negative, whereas, only in one it was positive. None of these correlations were statistically significant. In four buffaloes, the 'r' values were negative out of which in buffalo nos. 2272 and 2379 these were significant at 10 percent level and in buffalo no. 2410 it was significant at 5 percent level.

In all the cows, T_3 concentrations were negatively correlated with milk yield. However, the value of 'r' was statistically significant ($p < 0.05$) only in one case (cow no. KS 3260). Such trend in 'r' values was not observed with buffaloes. Out of six, in two buffaloes the 'r' values were negative, whereas, in the remaining four these were positive and very low. In buffalo no. 2383 'r' value of -0.74 was significantly correlated ($p < 0.10$) with milk production.

Correlation coefficient (r) between milk yield and T_4 concentration did not show a definite trend. In two animals of each species the values of 'r' were negative and in the remaining four these were positive. In buffaloes none of the 'r' values were significant. In cow no. KS 3105 the 'r' values was significant at 5 percent level and in KS 3257 it was significant only at 10 percent level.

Relationship with glucose was not definite. Only in cow no. KS 3050 the 'r' value (0.86) was significant ($p < 0.05$). In other animals of both the species whether the 'r' values were negative or positive, were not statistically significant.

TABLE 1. CORRELATION COEFFICIENTS (r)* BETWEEN MILK YIELD AND VARIOUS HORMONES AND METABOLITES IN INDIVIDUAL ANIMALS

Animal No.	GH	Insulin	T_3	T_4	Glucose	BHBA	NEFA
KS 3050	−0.01	−0.37	−0.50	−0.29	0.86**	−0.43	0.58
KS 3105	0.77*	0.03	0.08	0.86**	0.30	0.65	0.80*
KS 3137	0.88**	−0.37	−0.59	0.68	0.52	−0.11	0.60
KS 3163	0.59	−0.01	−0.50	−0.08	0.49	0.66	0.29
KS 3257	0.64	−0.07	−0.54	0.79*	0.12	−0.31	0.15
KS 3260	0.77*	0.56	−0.88**	0.32	−0.14	0.42	0.45
Buff 2272	0.06	−0.77*	−0.60	0.17	0.29	0.89**	0.17
Buff 2346	0.65	−0.30	0.26	−0.42	0.10	−0.22	−0.47
Buff 2379	0.90**	−0.76*	0.12	0.55	0.62	0.38	0.89**
Buff 2383	0.84**	0.09	−0.74*	0.53	0.46	0.65	0.73*
Buff 2410	0.85**	−0.83**	0.13	0.05	−0.63	0.09	0.85**
Buff 2423	0.83**	0.45	0.07	−0.04	−0.07	0.32	0.70

* Each value is based on 6 observations.

* $p < 0.10$; ** $p < 0.05$.

Concentrations of BHBA did not correlate with milk yield in a definite manner. Some of the 'r' values were negative, whereas, the others were positive. The 'r' value of 0.89 in buffalo no. 2272 was significantly correlated with milk yield ($p < 0.05$).

Concentrations of NEFA in all the cows were positively correlated with milk yield but only in cow no. KS 3105, it was significant ($p < 0.10$). Out of six buffaloes, the 'r' values were negative in one case, whereas, in other the values were positive. In two buffaloes the values of 'r' were statistically significant at 5 percent level and in one at 10 percent level.

(b) At different sampling intervals

Correlation coefficients 'r' between milk yield and growth hormone in cows and buffaloes at morning, noon, evening and night sampling intervals were positive (table 2). In cows these were significant ($p < 0.05$) only at morning sampling, whereas, in buffaloes noon and evening values were significant at 1 percent level and night values at 5 percent level. All the values of 'r' between milk yield and insulin in buffaloes were negative but in cows these were negative only at morning, noon and evening times. In both the species, the relationship in insulin and milk yield was not significant. Concentrations of T_3 were negatively correlated with milk yield in cows at all the intervals of sampling but these were highly significant ($p < 0.01$) only at morning and noon samplings. In buffaloes during morning, noon and evening samplings the relationship was negative and at night it was positive. None of the 'r' values turned out to be statistically significant. Relationship of T_4 with milk yield in cows was positive at all the sampling intervals. During night sampling the value of 'r' was highest (0.80) which was significant at 10 percent level of significance. In buffaloes 'r' values during *morning and noon were positive* but during evening and night, these were negative. At evening sampling the value of 'r' (−0.96) was statistically highly significant ($p < 0.01$). Correlation coefficient 'r' of glucose with milk yield in cows at all the sampling intervals were positive but were not statistically significant. In buffaloes, a definite trend was not observed. At noon sampling the value of 'r' was negative, though not statistically significant, whereas, at other sampling intervals, the 'r' values were positive. At night sampling, the 'r' value was significant at 10 percent level. Relationship of BHBA Concentrations with milk

TABLE 2. CORRELATION COEFFICIENTS (r)[a] BETWEEN MILK YIELD AND VARIOUS HORMONES AND METABOLITES AT DIFFERENT SAMPLING INTERVALS

Attributes	Morn.	Noon	Even.	Night
		COW		
GH : MY	0.88**	0.69	0.57	0.40
Insulin : MY	−0.36	−0.24	−0.32	0.58
T_3 : MY	−0.98***	−0.94***	−0.07	−0.09
T_4 : MY	0.38	0.25	0.68	0.80*
Glucose : MY	0.30	0.53	0.37	0.50
BHBA : MY	−0.20	0.21	−0.35	0.68
NEFA : MY	0.86**	−0.45	0.67	0.61
		BUFFALO		
GH : MY	0.38	0.97***	0.92***	0.84**
Insulin : MY	−0.58	−0.20	−0.56	−0.08
T_3 : MY	−0.71	−0.37	−0.13	0.23
T_4 : MY	0.64	0.69	−0.96***	−0.04
Glucose : MY	0.39	−0.44	0.27	0.79*
BHBA : MY	0.47	−0.60	0.76*	0.18
NEFA : MY	0.91***	0.23	0.89**	0.96***

[a] Each value is based on 6 observations.

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

yield at different sampling intervals in both the species varied. In cows the value of 'r' at morning and evening samplings were negative, whereas, during noon and night these were positive. None of these 'r' values were statistically significant. In buffaloes, the 'r' value was negative at noon sampling and positive at other sampling intervals. Value of 'r' (0.76) at evening sampling was statistically significant at 10 percent level. Values of 'r' between milk yield and NEFA were positive at all the sampling intervals in buffaloes. The relationship was more pronounced ($p < 0.01$) during morning and night compared to the evening sampling ($p < 0.05$). At noon, the value of 'r' was low. In cow, at noon sampling, the relationship was negative, whereas, at other sampling intervals it was positive. The value of 'r' was significant ($p < 0.05$) only at morning sampling.

TABLE 3. CORRELATION COEFFICIENTS (r)[a] BETWEEN HORMONES, METABOLITES, MILK YIELD AND DM INTAKE IN COWS BASED ON FORTNIGHTLY VALUES OF INDIVIDUAL ANIMAL

Attributes	GH	Insulin	T_3	T_4	Glucose	BHBA	NEFA	DM	MY
GH	1.000	−0.335**	−0.390**	0.098	0.048	−0.272	-0.415**	0.422***	0.052
Insulin		*1.000*	*0.511****	*0.065*	*0.008*	0.376**	−0.125	0.114	0.088
T_3			1.000	0.158	−0.296*	0.319*	−0.175	0.137	−0.065
T_4				1.000	−0.145	0.574***	0.363**	0.161	0.202
Glucose					1.000	0.053	0.001	0.044	0.119
BHBA						1.000	−0.002	0.260	0.235
NEFA							1.000	−0.006	0.275*
DM								1.000	0.684***
MY									1.000

[a] Each value is based on 36 observations.
* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

(c) **Based on fortnightly values of individual animals**

Fortnightly values of different hormones and metabolites for individual animal were obtained by averaging the concentrations at different sampling intervals. Correlation coefficients 'r' between hormones, metabolites, milk yield and DM intake in cows have been presented in table 3. Growth hormone was negatively correlated with insulin ($r = -0.335$), T_3 ($r = -0.390$) and DM intake ($r = -0.422$) and positively with NEFA ($r = 0.415$). Correlation with BHBA was negative but could not reach the statistical significance. Value of 'r' with T_4, glucose and milk yield were positive but very low. Insulin was significantly ($p < 0.01$) correlated with T_3 and BHBA ($p < 0.05$), the respective values were 0.511 and 0.376.

Relationship of insulin with T_4 ($r = 0.065$), glucose ($r = 0.008$), NEFA ($r = -0.125$), DM intake ($r = 0.114$) and milk yield ($r = 0.088$) was low. Triiodothyronine was negatively correlated with glucose ($r = -0.296$) and positively with BHBA ($r = 0.319$) at 10 percent level of significance. Value of 'r' with T_4, NEFA, DM intake and milk yield were 0.158, −0.175, 0.137 and −0.065 respectively. Thyroxine was positively correlated with BHBA ($p < 0.01$) and NEFA ($p < 0.05$) the respective values being 0.574 and 0.363. Relationship with glucose (−0.145), DM intake (0.161) and milk yield (0.202) was not statistically significant. Relationship of glucose with BHBA, NEFA, DM intake and milk yield and of BHBA with NEFA, DM intake and milk yield were not statistically significant. Non esterified fatty acids, however, were positively correlated ($r = 0.275$) with milk yield. Dry matter intake was definitely highly ($p < 0.01$) correlated ($r = 0.684$) with milk yield.

Values of 'r' in buffaloes have been presented in table 4. Relationship of GH with NEFA was positive ($r = 0.443$) and highly significant ($p < 0.01$). Similarly, as in cows, the value of 'r' of GH with DM intake was negative (−0.489) and highly significant ($p < 0.01$). Values of 'r' with other hormones and metabolites were not statistically significant. Unlike cows insulin concentrations were negative ($r = 0.593$) and highly correlated with milk yield. There was no significant relationship between T_3 and other hormones and metabolites, and glucose and other hormones and metabolites. Thyroxine was positively ($r = 0.465$) and significantly ($p < 0.01$) correlated with BHBA. The relationship of BHBA with milk yield ($r = 0.275$) was significant ($p < 0.10$). The values of 'r' between NEFA and milk yield ($r = 0.372$) were significant at 5 percent level, whereas, 'r' between DM intake and milk yield (0.275) was significant only at 10 percent level.

TABLE 4. CORRELATION COEFFICIENTS (r)[a] BETWEEN HORMONES, METABOLITES, MILK YIELD AND DM INTAKE IN BUFFALOES, BASED ON FORTNIGHTLY VALUES OF INDIVIDUAL ANIMALS

Attributes	GH	Insulin	T_3	T_4	Glucose	BHBA	NEFA	DM	MY
GH	1.000	−0.230	−0.019	0.202	0.046	0.110	0.443***	−0.489***	0.222
Insulin		1.000	−0.196	−0.028	0.114	0.020	−0.153	−0.165	−0.593***
T_3			1.000	−0.145	−0.258	−0.112	−0.207	−0.136	0.027
T_4				1.000	0.039	0.465***	0.091	0.195	0.199
Glucose					1.000	0.065	−0.100	−0.040	−0.031
BHBA						1.000	−0.055	−0.061	0.275*
NEFA							1.000	−0.208	0.372**
DM								1.000	0.275*
MY									1.000

[a] Each value is based on 36 observations.
* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

(d) **Overall correlation coefficients** (r)

For the calculation of overall 'r' values between different hormones, metabolites and milk yield in cows and buffaloes, the fortnightly values of individual animals were pooled. As given in table 5, relationship of GH with milk yield was *positive and significant in* both the species. The 'r' values were higher in buffaloes (0.94) compared to cows (0.74). In both the species the relationship between T_3 and milk yield was negative. However, it was significant ($p < 0.10$) only in cows and not in buffaloes. In cows concentrations of T_4 and NEFA were significantly correlated ($p < 0.10$) with milk yield but the values of 'r' in buffaloes for these parameters were low. Relationship of BHBA with milk yield in buffaloes was significant ($p < 0.05$) but in cows, it was not so. Values of 'r' between glucose and milk yield were positive in both the species but were not significant. Relationship of insulin with milk yield in both the species was negative. The respctive values for cows and buffaloes were −0.23 and −0.70, which were statistically non-significant. However, in buffaloes the values compared to cows were higher.

TABLE 5. OVERALL CORRELATION COEFFICIENTS (r)[a] BETWEEN MILK YIELD AND VARIOUS HORMONES AND METABOLITES BASED ON AVERAGE FORTNIGHTLY VALUES

Attributes	Values of 'r'	
	Cow	Buffalo
GH : Milk yield	0.74*	0.94***
Insulin : Milk yield	−0.23	−0.70
T_3 : Milk yield	−0.75*	−0.30
T_4 : Milk yield	0.74*	0.51
Glucose : Milk yield	0.65	0.49
BHBA : Milk yield	0.40	0.88**
NEFA : Milk yield	0.76*	0.45

[a] Each value is based on 6 observations.
* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

(e) **Between concentrations of hormones and percent milk constituents**

Values of 'r' between overall average values of individual animals for various hormones and percent fat, protein and lactose in milk have been presented in table 6. Relationship of GH with fat and protein content of milk in both the species was negative. In buffaloes the values of 'r' for both the constituents of milk were highly significant ($p < 0.01$) but in cows the values of 'r' between GH and protein was significant only at 5 percent level and remained non-significant with fat. Relationship of growth hormone with lactose was negative in cows and positive in buffaloes but none of these were statistically significant. In both the species the value of 'r' between insulin and fat were positive and significant at 10 percent level but with protein these were not significant. Relationship of insulin with lactose in cows and buffaloes was negative but the values were significant ($p < 0.10$) only in cows. Concentrations of T_3 were positively correlated with fat and protein in both the species but only the value of 'r' between T_3 and protein was significant ($p < 0.10$) in cows. Relationship of T_3 with lactose was negative in cows and positive in buffaloes, but none of them was statistically significant. Negative relationship of T_4 with milk fat in cows was significant ($p < 0.10$) but not in buffaloes. The negative values of 'r' between T_4 and protein in both the species were low. Thyroxine to lactose relationships were positive in cows and negative in buffaloes which were not statistically significant.

TABLE 6. OVERALL CORRELATION COEFFICIENTS (r)# BETWEEN THE CONCENTRATIONS OF VARIOUS HORMONES AND PERCENT MILK CONSTITUENTS

Attributes	Value of 'r'	
	Cow	Buffalo
GH : Fat	−0.34	−0.93***
GH : Protein	−0.86**	−0.92***
GH : Lactose	0.43	0.17
Insulin : Fat	0.80*	0.76*
Insulin : Protein	0.59	0.35
Insulin : Lactose	−0.75*	−0.07
T_3 : Fat	0.46	0.15
T_3 : Protein	0.76*	0.09
T_3 : Lactose	−0.65	0.71
T_4 : Fat	−0.79*	−0.25
T_4 : Protein	−0.65	−0.31
T_4 : Lactose	0.35	−0.57

Each value is based on 6 observations.

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Discussion

Growth hormone was significantly and negatively correlated with DM intake in both the species. Correlations between GH and amount of organic matter digested have been reported in sheep fed a variety of diets (Bassett et al., 1971). Smith et al. (1976) reported a significant, negative correlation in early lactating Holstein cows between plasma GH concentrations and nutrient intake expressed either on estimated net energy intake basis or on MD intake basis. The significant and negative correlation between GH and DM intake indicated that availability of nutrients from the digestive tract play a role in the regulation of GH secretion. Less intake or availability of nutrients from the digestive tract may stimulate the hypothalamus to release more of growth hormone either directly or indirectly through the levels of blood metabolites, gastro-intestinal hormones and somatomedin C (Ronge et al., 1988). Hove and Blom (1973) found that underfed cows had about twice the level of GH as compared to the adequately fed and that growth hormone levels in underfed cows decreased subsequent to feeding. Findings of Emery et al. (1986) that reduced feed intake in lactating dairy cows was associated with an increase in concentrations of serum GH also support the metabolite based regulation of GH secretion. Ronge et al. (1988) also reported that GH is inversely related to energy intake.

The positive correlation between GH and NEFA in both the species suggest that high GH may result in fat mobilization and thereby increase the availability of milk precursors. A high positive relationship between GH and NEFA has been reported earlier by Hart et al. (1979) and by Ronge and Blum (1988). This suggests that GH secretion may be sensitive to the animals metabolic status in addition to neural control from the hypothalamus. Williams et al. (1963) and Peel et al. (1983) reported elevated plasma concentrations of NEFA after growth hormone administration. Furthermore, during the administration of GH to lactating cows, effects of epinephrine on NEFA become enhanced (McCutcheon and Bauman, 1986). The evidence suggests that increased lipolysis of adipose reserves could be providing at least a portion of the additional milk energy during lactation.

Growth hormone was negatively correlated with insulin but the 'r' values were high in cows (tables 3 and 4). Such a negative association in lactating dairy cows has been reported earlier also (Koprowski and Tucker, 1973; Smith et al., 1976). It is, however, doubtful that the elevated

GH directly results in the depression of plasma insulin since injection of GH did not affect peripheral insulin concentrations in ruminants (Head et al., 1970; Manns and Boda, 1965; Peel et al., 1983). The negative correlation between GH and insulin suggest that these hormones are involved in the partitioning of nutrients towards milk production. A low insulin and high GH favours the movement of energy substrates away from the adipose tissues stores. Since insulin exerts an anti-lipolytic effect on bovine adipose tissue (Yang and Baldwin, 1973) and a lipogenic effect in bovine adipocytes (Etherton and Evock, 1986) and GH elevates NEFA levels, it seems reasonable that the elevated plasma GH and depressed plasma insulin represent part of the mechanism permitting mobilization of energy stores during lactation.

Significant negative correlation between GH and T_3 in cows but not in buffaloes, has not been reported by any of the earlier workers. Since early lactation is characterised by high GH, a depressed T_3 in plasma further aids in the process of nutrient partitioning towards milk production by depressing metabolic demands of peripheral tissues. Recently Ronge et al. (1988) has also reported lower circulating levels of T_3 during early lactation and suggested their role in the partitioning of nutrients. The suggested role of T_3 in the partitioning of nutrients also draws support from studies which report that during early lactation glucose utilization in organs other than the mammary gland is reduced (Bennick et al., 1972; Remesy et al., 1986; Chilliard, 1987).

In conformity with the earlier reports (Smith et al., 1976; Hove and Blom, 1973; Hart et al., 1979). GH was not found to be correlated with blood glucose in both the species. Negative correlations (table 6) between GH and milk fat and proteins were expected, since with advancing stage of lactation GH and milk yield decrease and the milk fat and protein increase. The correlations obtained with milk lactose in both cows and buffaloes are due to the fact that lactose concentrations in milk change little with the stage of lactation. However, administration of pituitary or recombinantly derived bGH to animals did not result in a change in fat and protein composition of milk (Baumann et al., 1985; Ludri et al., 1988).

With reference to Bines et al. (1983) in cows insulin was negatively correlated with milk yield. In buffaloes though the 'r' values of some animals were higher, all animals did not have the same sign. When the relationship of insulin with milk yield during different sampling intervals was considered then it was found to be negative in both the species, but the degree of relationship varied and did not achieve statistical significance in either of the species. When the overall correlation coefficients based on average fortnightly values were considered, the relationship was again negative in both the species. However, when 'r' values based on fortnightly values of individual animals were considered these were marginally positive in cows ($r = 0.088$) and significantly ($p < 0.01$) negative in buffaloes. This difference was attributed to the significant fortnight × sampling interval interaction in cows. It appears that though insulin levels in an animal are negatively correlated with milk yield, but the relationship is not strong. A negative correlation between insulin levels and milk yield has been reported earlier by Koprowski and Tucker (1973) and Walsh et al. (1980). Milk yields are reduced in response to insulin administration (Kronfeld et al., 1963; Schmidt, 1966). The lack of correlation between blood glucose values may be because glucose levels are a poor reflection of its rate of utilization in lactating cattle (Hart et al., 1979).

Correlation coefficients of insulin with NEFA, though not significant, were negative in both the species. Negative correlations between serum insulin and free fatty acids have been reported earlier (Schwalm and Schultz, 1976; Bines et al., 1983) also. A negative relationship is probably a reflection of increased fat mobilization during insulin insufficiency.

Insulin was significantly correlated with BHBA in cows only. Similar association was also obtained by Bines et al. (1983). A positive correlation between insulin and milk fat concentration has been reported earlier by Flach et al. (1984). It is surprising that insulin being lipogenic was positively correlated with body water and negatively with body fat, though the relationship with body fat was not significant (Jindal and Ludri, 1993).

Levels of T_3 were generally negatively correlated (table 1) with milk yield in cows but not in buffaloes. Concentration of T_3 were negatively correlated with milk yield in cows at all the intervals of sampling but these were highly significant only at morning and noon samplings. In buffaloes during morning, noon and evening samplings the relationship was negative and at night it was positive. When 'r' values based on fortnightly values of individual animals were considered, the values were not significant in both the species. Overall correlation coefficients between T_3 and milk yield were negative but significant only in cows. A negative but non significant correlation has been reported earlier (Walsh et al., 1980) also.

Triiodothyronine was positively correlated with body water and body protein and negatively with body fat but the correlations were not high. In buffalo the values of 'r' were still lower than the cows. For comparisons the information on the effect of T_3 levels on body composition is not available. The results obtained in both the species clearly indicate that some relationship between body composition changes and T_3 levles definitely stand where T_3 is negatively correlated with body fat and positively with body water and body protein(Jindal and Ludri, 1993). More research efforts in this direction are needed.

Highly positive correlations of T_4 with BHBA concentrations in both the species were obtained which were due to the similar pattern in change of concentrations of both the variables at different fortnights. Such a correlation has been reported by Bines et al. (1983) also. The pattern of T_4 at different fortnights was inversely related with T_3 in cows and not in buffaloes but the relationship was not strong. The negative relationship of T_4 of T_3 in cows may be suggestive of an active and rapid transformation of T_4 to T_3. The increase in the rate of this transformation is very likely in lactating animals since plasma T_4 has to be transformed to T_3 in tissues before it becomes biologically active (Boonnamsiri et al., 1979).

In both the species, glucose concentrations in blood were similar and were negatively correlated with T_3 but the 'r' values were not high. Since T_3 is the metabolically active form of thyroid hormone which exerts its metabolic effect through increased oxygen consumption. thereby, increased rate of glucose utilization, therefore, the relationship between glucose and T_3 appears to be negative. Due to the high rate of gluconeogenesis in the lactating cow this relationship could not be exhibited more significantly. The relationship between milk yield and glucose was not high. Blum et al. (1983) also failed to obtain a significant relationship between blood glucose levels and milk yield.

The BHBA was significantly correlated with milk yield in buffaloes but not in cows (table 5). When correlations based on fortnightly values of individual animals were considered (tables 3 and 4), the 'r' values were again significant in buffaloes but not in cows. The positive relationship indicates that BHBA play an important role in the supply of precursors for milk synthesis.

The concentrations of NEFA were positively correlated with milk yield in both the species. The relationship was strong during morning and night in buffaloes and at morning sampling only in cows. Hart et al. (1979) also reported a relationship between blood NEFA and milk yield which was significant at 10 percent level. These observations are in conformity with the known role of NEFA as supplier of precursors for milk synthesis during lactation.

Since the relationship between certain hormones, metabolites and milk composition in the two species is not much different, therefore, it is supposed that the control of milk production process in the two species is similar and if there are minor differences they are at the fine tuning level. The present study is too limited to permit definite conclusions but there are indications that the increase or decrease in the levels of some hormones and metabolites during different stages of lactation support the exacerbated demands of nutrients for milk synthesis. More research efforts in this direction are still needed.

Literature Cited

Bassett, J. M., R. H. Weston and J. P. Hogan. 1971. Dietary regulation of plasma insulin and growth hormone concentration in sheep. Aust. J. Bio. Sci. 24:321-330.

Bauman, D. E. and W. B. Currie. 1980. Partitioning of nutrients during pregnancy and lactation: a review of machanisms involving homeostasis and homeorhesis. J. Dairy Sci. 63:1514-1529.

Bauman, D. E., F. J. Eppard, M. J. DeGeeter and G. M. Lanza. 1985. Responses of high producing dairy cows to long term treatment with pituitary somatotropin and recombinant somatotropin. J. Dairy Sci. 68:1352-1362.

Bennink, M. A., R. W. Mellenberger, R. A. Frobish and D. E. Bauman. 1972. Glucose oxidation and entry rate as affected by the initiation of lactation. J. Dairy Sci. 55:712 (Abstr).

Bines, J. A., I. C. Hart and S. V. Morant. 1983. Endocrine control of energy metabolism in the cow: diurnal variations in the concentrations of hormones and metabolites in the blood plasma of beef and dairy cow. Hormone and metabolic Res. 15:330-334.

Blum, J. W., P. Kunz, H. Leuenberger, K. Gautschi and M. Keller. 1983. Thyroid hormones, blood plasma metabolites and heamatological parameters in relation to milk yield in dairy cows. Anim. Prod. 36:93-104.

Boonnamsiri, V., J. C. Kermode and B. D. Thompson. 1979. Prolonged intravenous infusion of labelled iodocompounds in the rat: [125]I thyroxine and ([125]I) triiodothyronine metabolosm and extrathyroidel conversion of thyroxine to triiodothyronine. J. Endocrinol. 82:235-243.

Chilliard, Y. 1987. Literature survey: body composition and lipid metabolism in adipose tissues and liver during pregnancy and lactation. 2. In the ewe and the cow. Reprod. Nutr. Dev. 27:327-398.

Emery, R. S., J. Luoma, J. Liesman, J. W. Thomas, H. A. Tucker and L. T. Chapin. 1986. Effect of serum magnesium and feed intake on serum growth hormone concentrations. J. Dairy Sci. 69:114 8- 1150.

Etherton, T. D. and C. N. Evock. 1986. Stimulation of lipogenesis in bovine adipose tissue by insulin and insulin like growth factor. J. Anim. Sci. 62: 357-362.

Flach, D., V. Dzapo and R. Wassmuth. 1984. Metabolic parameters and performance in cattle. 1. Correlations between thyroid hormone, insulin, creatine kinase, glutamate dehyrogenese and glutathione reductase and dairy performance traits. Zeitschrift fur tierzucht and zuchtungbiol. 101:188-195 (DSA 47:4510).

Hart, I. C., J. A. Bines, S. V. Morant and J. L. Ridley. 1978. Endocrine control of energy metabolism in the cow: comparison of the levels of hormones (prolactin, growth hormone, insulin and thyroxine) and metabolites in the plasma of high and low yielding cattle at various stages of lactation. J. Endocrinol. 77:333-345.

Hart, I. C., J. A. Bines and S. V. Morant. 1979. Endocrine control of energy metabolism in the cow: correlations of hormone and metabolites in high and low yielding cows for stages of lactation. J. Dairy Sci. 62:270-277.

Head, H. H., M. Ventura, D. W. Webb and C. J. Wilcox. 1970. Effect of growth hormone on glucose, non esterified fatty acids and insulin levels and on glucose utilization in dairy calves. J. Dairy Sci. 53:1496-1501.

Hove, K. and A. K. Blom. 1973. Plasma insulin and growth hormone in dairy cows: diurnal variation and relation to food intake and plasma sugar and acetoacetate levels. Acta Endocrinol. 73:289-303.

Jindal, S. K. and R. S. Ludri. 1990a. Growth hormone concentration in lactating crossbred cows and buffaloes. AJAS. 3:319-322.

Jindal, S. K. and R. S. Ludri. 1990b. Insulin concentrations in lactating crossbred cows and buffaloes. Int. J. Anim. Sci. 5:249-252.

Jindal, S. K. and R. S. Ludri. 1991. Circulating thyroxine (T_4) and triiodothyronine (T_3) levels in lactating crossbred cows and buffaloes as affected by stage of lactation and time of sampling. Int. J. Anim. Sci. 6:122-127.

Jindal, S. K. and R. S. Ludri. 1993. Body composition changes in crossbred cows and Murrah buffaloes during lactation. AJAS 6:577-580.

Khurana, M. L. and M. L. Madan. 1986. Thyroidal hormones relation to stage of lactation and milk yield in cattle and buffaloes Indian J. Anim. Sci. 56(3):324-327.

Koprowski, J. A. and H. A. Tucker. 1973. Bovine serum growth hormone, corticoids and insulin during lactation. Endocrinology 93:645-653.

Kronfeld, D. S., G. P. Mayer, J. M. Robertson and F. Raggi. 1963. Depression of milk secretion during insulin administration. J. Dairy Sci. 46:559-563.

Lomax, M. A., G. O. Baird, C. G. Mallinson and H. W. Symonds. 1979. Differences between lactating and non lactating dairy cows in concentrations and secretion rate of insulin. Biochem. J. 180:281-289.

Ludri, R. S. and Mahendra, Singh. 1988. Growth hormone T_3 and T_4 release in buffaloes milked with and without oxytocin IV. Annual Conference of Society of Animal Physiologists of India, 24th to 26th Sept. 1988, CIRG, Makhdoom.

Manns, J. G. and J. M. Boda. 1965. Effects of ovine growth hormone and prolactin on blood glucose, serum insulin, plasma nonesterified fatty acids and amino nitrogen in sheep. Endocrinology 93:1109-1114.

McCutheon, S. N. and D. E. Bauman. 1986. Effect of chronic growth hormone treatment on responses to epinephrine and thyrotropin releasing hormone in lactating cows. J. Dairy Sci. 69:44-51.

Peel, C. J., T. J. Fronk, D. E. Bauman and R. C. Gorewit. 1983. Effect of exogenous growth hormone in early and late lactation on lactational performance of dairy cows. J. Dairy Sci. 66:776-782.

Remesy, C., Y. Chilliard, Y. Rayssiguier, A. Mazur and C. Demigne. 1986. Reprod. Nutr. Dev. 26: 205-226.

Ronge, H. and J. W. Blum. 1988. Somatomedine C and other hormones in dairy cows around parturition in new born calves and in milk. J. Anim. Physiol. a. Anim. Nutr. 60:168-176.

Ronge, H., H. Blum, C. Clement, F. Jans, H. Leuenberger and H. Binder. 1988. Somatotropin C in dairy cows related to energy and protein supply and to milk production. Anim. Prod. 47:165-183.

Schmidt, G. H. 1966. Effect of insulin on yield and composition of dairy cows. J. Dairy Sci. 49:381-385.

Schwalm, J. W. and L. H. Schultz. 1976. Relationship of insulin concentrations to blood metabolites in the dairy cows. J. Dairy Sci. 59:255-261.

Smith, R. D., W. Hansel and C. E. Coppock. 1976. Plasma growth hormone and insulin during early lactation in cows fed silage based diets. J. Dairy Sci. 59:248-254.

Tucker, H. A. 1981. Physiological control of mammary growth, lactogenesis and lactation. J. Dairy Sci. 64:1403-1421.

Vasilatos, R. and P. J. Wangsness. 1981. Diurnal variation in plasma insulin and growth hormone associated with two stages of lactation in high producing dairy cows. Endocrinology 108:300-304.

Walsh, D. S., J. J. Vasely and S. Mahadevan. 1980. Relationship between milk production and circulating hormones in dairy cows. J. Dairy Sci. 63:290-294.

Williams, W. F., S. D. Lee, H. H. Head and J. Lynch. 1963. Growth hormone effects on bovine blood plasma fatty acid concentration and metabolism. J. Dairy Sci. 46:1405-1408.

Yang, Y. T. and R. L. Baldwin. 1973. Lipolysis in isolated cow adipose cells. J. Dairy Sci. 56:366-374.