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Thyroxine, Triiodothyronine and Reverse-Triiodothyronine Concentrations in Blood Plasma in Relation to Lactational Stage, Milk Yield, Energy and Dietary Protein Intake in Estonian Dairy Cows

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Tiirats, T.: Thyroxine, triiodothyronine and reverse-triiodothyronine concentrations in blood plasma in relation to lactational stage, milk yield, energy and dietary protein intake in Estonian dairy cows. Acta vet. scand. 1997, 38, 339-348. – Average levels of thyroxine (T_4), triiodothyronine (T_3) and reverse-triiodothyronine (rT_3) in blood plasma of 159 Estonian Red and Estonian Black and White cows were 55.2 nmol/L, 1.78 nmol/L and 0.25 nmol/L respectively. Animals were grouped according to stage of lactation. The T_4 level was significantly lower during the early stage of lactation (45.1 nmol/L), compared with later stages, but increased as the stage of lactation progressed (late stage of lactation – 56.7, dry cows 64.3 nmol/L). The T_3 level was significantly higher at the late stage of lactation (1.93 nmol/L) compared with the early stage of lactation (1.71 nmol/L) and level in dry cows (1.71 nmol/L). rT_3 showed a trend similar to that found for T_4 (lowest plasma concentration in early lactation, 0.19; highest in the dry period, 0.33; late lactation, 0.24 nmol/L). Levels of all thyroid hormones were negatively related to the daily milk yield ($T_4 - r = -.51$, $rT_3 - r = -.47$, calculated thyroid index as $rT_3 * T_3 * T_4 - r = -.52$, for all $p < .0001$; $T_3 - r = -.32$, $p < .01$). Plasma thyroid hormone concentrations were affected by energy and dietary protein intake. Differences were found in thyroid hormone levels between the 2 breeds and between summer and winter holding periods for Estonian Red cows, which could all be explained by differences in the feeding level and daily milk yield. It is suggested that maintaining low levels of thyroid hormones in early lactation may be one of the dairy cow's mechanisms of reducing metabolic demand.

season; cattle; hormone; breed.

Introduction

Thyroid hormones stimulate the basic metabolic rate via the metabolism of carbohydrates, lipids and proteins (*Kaneko* 1989). The function of the thyroid and its diseases are well known in companion animals but less so in livestock. Various researchers have tried to correlate levels of thyroid hormones with milk yield and stage of lactation, but the subject is still controversial (*Hart et al.* 1979, *Walsh et al.* 1980, *Akasha et al.* 1987, *Jindal & Ludry* 1991). Thyroid hormones have an important influence on growth and development of the mammary gland (*Tucker* 1988) and regulate milk production (*Magdub & Johnson* 1977).

The stage of lactation has a much greater influence on changes in serum thyroid hormones than season (*Nixon et al.* 1988). There is evidence that the serum triiodothyronine concentration is influenced by the level of feed intake (*Christopherson et al.* 1979). Metabolic events such as impending parturition, initiation of lactation and negative energy balance in early lactation may result in reductions in thyroxine and triiodothyronine levels independent of seasonal effects (*Refsal et al.* 1984). A change in energy balance can have a profound effect on nutritional status since thyroid hormones in cattle decrease in response to dietary restriction (*Kunz & Blum* 1981). Reverse-triiodothyronine (rT_3) is the most potent inhibitor of deiodination (*Visser* 1988). Therefore the inactive pathway may play a significant regulatory role, and rT_3 appears to reflect alterations of thyroid hormone metabolism in peripheral tissues. Since free and total thyroid hormones show similar patterns (*Nixon et al.* 1988), it has been suggested that the protein binding capacity of thyroid hormones in serum does not appreciably change over time in the normal dairy cow (*Gerloff et al.* 1986). Therefore levels of total hormone concentrations can be considered to reflect hormonal activity.

The emphasis of this study was placed on relating levels of thyroid hormones in Estonian Black and White (EBW) and Estonian Red (ER) cows at different stages of lactation to daily milk yield and energy-protein contents in their feed.

Materials and methods

A field study was performed in the course of one year. Fifty-nine cows of EBW breed and 100 ER cows from 2 different farms were examined. The farms are situated in central Estonia and have approximately 400 animals each. The average milk yield per year was 5000 kg on the EBW farm and 4200 kg on the ER farm (corrected to 4% fat). The mean body weight of the EBW and ER cows was 678 kg and 593 kg, respectively (measured with tape on the sampling day). The cows were in their second lactation or older. The animals were allowed to graze during May-October. Their basic diet consisted of hay, silage, mixed concentrates, white beet, potatoes, brewer's grain, straw and mineral salt, which was fed according to the milk yield and stage of lactation during the winter. Mixed concentrates comprised approx. 17% of the diets of dry cows, approx. 46% of the rations of cows in the early stage of lactation and approx. 32% of the rations of cows at the late stage of lactation, calculated on the basis of dry matter. In collaboration with the Department of Animal Nutrition at the Estonian Agricultural University, the feed samples were analysed for energy and protein content, which allowed the actual nutritional situation on the farms to be estimated and compared with the nutrient requirements recommended for dairy cattle in Estonia (*Oll* 1994). The metabolizable energy content of feedstuffs and rations was established on the basis of the data of proximal (Weende) analysis. The calorimetric coefficients and coefficients of metabolizability used in this study for calculating gross and metabolizable energy were taken from *Nehring et al.* (1972) and *Oll et al.* (1974). The crude protein content of feedstuffs was determined by analysis of nitrogen (N) (crude protein = 6.25 N) using a Kjeltec apparatus. The appropriate amount of digestible protein was calculated and used in statistical analyses. The daily milk production was based on test-milking records (kg of milk) performed at monthly intervals.

During the year, blood samples were taken 4 times from ER cows and twice from EBW cows: during the winter holding period (W) in February (30 ER cows) and April (30 ER and 30 EBW cows) and during the summer pasture period (S) in June (30 EBW and 20 ER cows) and September (20 ER cows).

Animals were grouped according to stage of lactation:

1. Nonpregnant cows in the early stage of lactation 20-60 days postpartum (ER; n = 34, EBW; n = 20).
2. Pregnant cows (5–6 months) in the late stage of lactation (ER; n = 33, EBW; n = 20).
3. Dry cows (ER; n = 33, EBW; n = 19).

The samples were taken during the morning milking from 5:00 to 7:00 a.m. To exclude the influence of the possible diurnal rhythmicity of the constituents studied, blood sampling from the ER cows during the summer grazing period was carried out at 5:00 am (before milking) and 7:00 am (after milking but before grazing).

Blood samples were collected from the jugular vein into heparinized glass tubes which were immediately sealed with airtight rubber caps and stored on ice. All samples were centrifuged (1500g for 20 min.), and the separated plasma was stored at –20 °C until analysis.

Concentrations of total thyroxine (T_4), total triiodothyronine (T_3) and reverse-triiodothyronine (rT_3) were assayed at the Department of Clinical Chemistry, Swedish University of Agricultural Sciences, Uppsala Sweden. The methods employed for T_4 and T_3 were solid-phase I^{125} radioimmunoassays (Coat-A-Count, Diagnostic Products Corporation, Los Angeles, CA, USA). For rT_3 an iodinated tracer (I^{125}) and fractional precipitation for the separation of antibody-bound hormone and free hormone (polyethylene glycol) was used (Biodata S.p.A., Serono Diagnostic, Milano, Italy). The kits were originally designed for human use. The suitability of the kits for measuring bovine plasma was previously described (T_4, T_3– *Tiirats* 1992; rT_3– *Rudas* 1980). The radioactivity of the immunocomplex precipitate was measured in a gamma counter. All values presented represent the mean of duplicate determinations. Intra-assay coefficients of variation, calculated from precision profiles, for T_4, T_3 and rT_3 were 4-6%. Inter-assay coefficients of variation were 6-9%.

Several quotients between T_4 and T_3 and rT_3 were introduced (T_3/T_4, rT_3/T_4, rT_3/T_3) to reflect active and inactive paths of thyroid-hormone action. A thyroid index (rT_3*T_3*T_4) was constructed to reflect the changes in all circulating thyroid hormones in plasma.

The data were examined using the statistical package Statistica 4.0 (StatSoft Inc., Tulsa, OK, U.S.A.). Means are expressed as ± standard deviation (SD). P-values<0.05 were considered significant. Analyses of variance were used to test the influence of different stages of lactation on plasma thyroid hormone (T_4, T_3 and rT_3) concentrations. Differences between means were evaluated using the LSD test. Correlations between hormones and milk yield, energy and protein- intake parameters (within each stage of lactation as well) were obtained by using linear regression models in which T_4, T_3 and rT_3 were dependent variables, and energy and protein contents in diets and the daily milk yield were independent variables. In addition, in the analyses of the integrated effects of the lactational stages and diet variables (energy, protein), covariance models were investigated.

Results

The comparison of plasma hormone concentrations measured at 5:00 am with those measured at 7:00 am in the same ER cows during the S period did not reveal any change during the 2-h sampling period. However, rT_3 tended to vary more than T_4 and T_3.

Triiodothyronine. The average T_3 concentration for all samples was 1.78 ± 0.34 nmol/L. In spite of the difference in T_3 concentration between farms, differences related to stage of lactation were similar on the 2 farms. T_3 was high in late lactation (1.93 ± 0.35 nmol/L) and low in both early lactation (1.71 ± 0.34 nmol/L) and in dry cows (1.71 ± 0.32 nmol/L) (Fig. 1). The peak

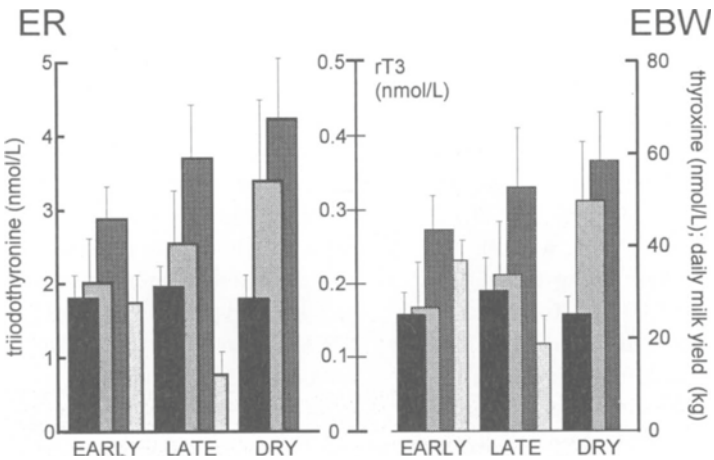

Figure 1. Concentrations (± SD) of triiodothyronine (first bar, nmol/L), reverse-triiodothyronine (rT_3, second bar, nmol/L) and thyroxine (third bar, nmol/L) in plasma of lactating dairy cows of Estonian Red (ER, n = 100) and Estonian Black and White (EBW, n = 59) breeds and their daily milk yield (fourth bar, kg) at early (EARLY) and late (LATE) stages of lactation and in the dry period (DRY).

average level of T_3 (1.92 nmol/L) in ER cows in S was found, but there was no significant difference in T_3 concentrations between the W and S periods (1.75 ± 0.34 and 1.82 ± 0.36 nmol/L).

Reverse-triiodothyronine. The average rT_3 concentration for all cows was 0.25 ± 0.09 nmol/L. Throughout lactation the trend observed in rT_3 was similar to that in T_4; i.e. rT_3 was significantly higher in late lactation (0.24 ± 0.07 nmol/L) than in early lactation (0.19 ± 0.06 nmol/L) and continued to rise significantly in dry cows (0.33 ± 0.11 nmol/L) (Fig. 1). There were significant differences in rT_3 between the W and S periods (0.28 ± 0.09 and 0.19 ± 0.08 nmol/L). Particularly high values were seen in ER cows during the W period (mean 0.29 nmol/L).

Thyroxine. The total mean thyroxine concentration for ER and EBW cows was 55.2 ± 13.4 nmol/L. Stage of lactation influenced the concentration of thyroxine: The T_4 level was lowest during the early stage of lactation (45.1 ± 7.1 nmol/L) and increased as lactation progressed (late stage of lactation 56.7 ± 11.7, dry cows 64.3 ± 13.1 nmol/L) (Fig. 1). There were no differences in T_4 levels between the W and S periods (56.3 ± 14.9 and 53.8 ± 11.2 nmol/L). A significant difference in T4 level was found between the two breeds (ER; 57.4 ± 13.9 nmol/L, EBW; 51.5 ± 11.8 nmol/L).

Quotients and index of hormones. All mean hormone values estimated (T_4, T_3, rT_3) were significantly higher in ER cows than in EBW cows (Fig. 1). There were no significant differences between breeds in T_3/T_4, rT_3/T_4 or rT_3/T_3 ratios, but rT_3/T_3 tended to be higher in ER cows. The thyroid index (rT_3*T_3*T_4) was low during the maximum milking period and reached its highest values during the dry period (Fig. 2).

Daily milk yield and nutritional data. The average daily milk yield was 23.1 kg per day. Cows

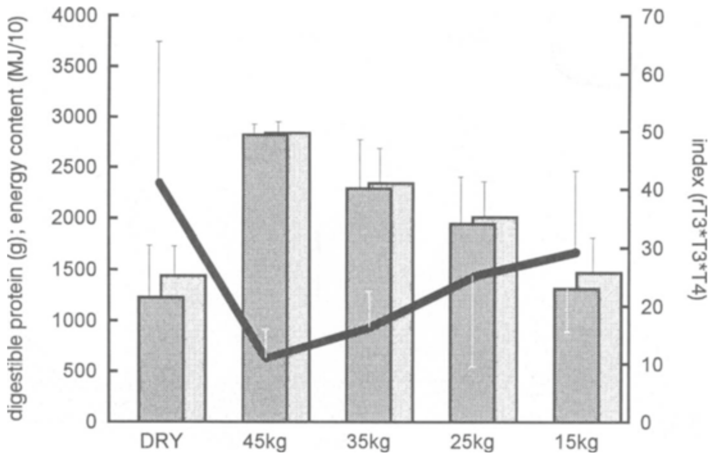

Figure 2. Mean values (± SD) of digestible protein (first bar, g) and energy content (second bar, MJ) in the diet of cows divided into groups on the basis of daily milk yield (x-axis: DRY- nonlactating cows, n = 53; up to 45 kg, n = 14; up to 35 kg, n = 33; up to 25 kg, n = 30; up to 15 kg milk per day, n = 29). The line demonstrates the calculated $rT_3*T_3*T_4$ index in these groups (arbitrary unit).

in the early stage of lactation produced 31.2 kg milk per day, and cows in late lactation 14.7 kg. EBW cows produced more milk than ER cows (average daily milk yield was 28.1 and 20.1 kg, respectively). A detailed overview of the production and nutritional data for the cows at every stage of lactation is given in Table 1. In summer there was significantly more energy and protein in the diet, but the overall milk production in the W period (23.0 kg) was similar to that in the S period (23.2 kg). Mean energy and digestible protein intakes per day were lower for ER cows (166 M, 1440 g) than for EBW cows (220 MJ; 2243 g). The ER cows were fed a more balanced diet than the EBW cows, which were significantly "overfed", receiving 113% and 125% of their daily energy and protein needs, respectively (Table 1). Changes in feeding and milk yield level greatly influenced thyroid hormone metabolism (Fig. 2).

Correlation analyses. T_4 was significantly correlated with T_3 in early-lactating (r = .46) and dry cows (r = .42), but not in late-lactating cows. The correlation between T_4 and rT_3 was significant (r = .45, r = .62 respectively) in late-lactating and dry cows, but not in early-lactating cows. All thyroid hormones were negatively correlated with the daily milk yield (r = –.51, p<.0001 for T_4; r = –.32, p<.01 for T_3; r = –.47, p<.0001 for rT_3) and energy intake (r = –.48, r = –.24, r = –.48) during lactation (early and late lactating cows together), but in early-lactating cows the only significant negative correlation was between rT_3 and milk yield. In lactating cows significant negative relationships were found between digestible protein content and rT_3 (r = –.49) as well as T_4 (r = –.44). In the dry period there were no significant correlations between feeding parameters and studied hormones.

The body weight of the cows tended to have a negative influence on plasma levels of all thyroid hormones in lactating cows (r = –.25, p<.01) but not in dry cows.

Table 1. Mean values (± SD) of daily milk production (kg), diet energy content (metabolizable MJ) and digestible protein (g) both compared with requirements recommended (%), and protein/energy ratio (g/MJ) in diets.

	n	Daily milk yield	Energy		Digestible		Protein/ energy ratio
			content in diet	require-ment	protein in diet	require-ment	
		kg	MJ	%	g	%	g/MJ
All	159	23.1 ± 10.4	186 ± 56	108	1738 ± 708	110	9.0 ± 1.7
Summer	70	23.2 ± 10.9	199 ± 47	116	1952 ± 445	128	9.8 ± 0.5
Winter	89	23.0 ± 10.1	176 ± 60	102	1569 ± 824	95	8.4 ± 2.0
EBW	59	28.1 ± 10.4	220 ± 54	113	2243 ± 526	125	10.2 ± 0.4
ER	100	20.1 ± 9.2	166 ± 47	105	1440 ± 630	100	8.3 ± 1.8
Early lact.	54	31.2 ± 6.6	245 ± 36	104	2393 ± 497	108	9.6 ± 0.8
Late lact.	53	14.7 ± 6.1	169 ± 41	110	1593 ± 538	124	9.2 ± 1.1
Dry cows	52		143 ± 27	109	1205 ± 486	97	8.2 ± 2.4
EBW							
Early lact.	20	36.9 ± 3.9	285 ± 5	109	2248 ± 84	111	9.9 ± 0.5
Late lact.	20	18.8 ± 6.0	217 ± 4	124	2221 ± 9	149	10.3 ± 0.2
Dry cows	19		156 ± 23	107	1630 ± 283	117	10.4 ± 0.3
ER							
Early lact.	34	27.8 ± 5.4	222 ± 25	102	2125 ± 441	106	9.5 ± 0.9
Late lact.	33	12.3 ± 4.8	139 ± 22	103	1213 ± 276	109	8.6 ± 1.1
Dry cows	33		136 ± 28	111	961± 405	86	6.9 ± 2.1

Discussion

Diurnal variations in blood concentrations of thyroid hormones in lactating cattle are not well described (*Bines et al.* 1983, *Jindal & Ludri* 1991). *Bitman et al.* (1994) described the existence of ultradian rhythms of T_4 and T_3 with a 90-min period. To our knowledge, there are no available data describing the daily rhythmicity of rT_3 in bovine plasma. Our results suggest non-existence of any significant influences that a diurnal rhythm could have had during the 2-h sampling period. The higher rT_3 variation could be explained by a more independent peripheral metabolism of rT_3 (95% of the rT_3 is derived from the conversion of T_4 in peripheral tissue; *Hennemann* 1986) which is more rapidly influenced by events such as feed intake.

Due to differences in milk yield and body weight between EBW and ER cows, the energy and protein contents of the diets vary as well; i.e. due to the lower milk yield and lower body weight of ER cows their energy intake was also lower. Diets varied much more in ER cows, in which seasonal differences in T_3 and rT_3 concentrations were reported as well. Therefore differences in plasma thyroid hormones between ER and EBW cows could be explained by differences in feeding levels and daily milk yield between the 2 farms. The seasonal difference between the summer and winter holding periods could be explained in the same way. The high-yielding cows (EBW) had lower plasma T_4 levels compared with the low yielders (ER). Similar findings have been reported by others (*Walsh et al.* 1980, *Blum et al.* 1983, *Hassan et al.* 1985, *El-Nouty et al.* 1989).

Early lactation. Blood levels of T_3 and T_4 were lower in early lactation than in late lactation. In dry cows T_3 dropped slightly to levels similar to those measured in early lactation, but T_4 continued to rise. The diminished mean serum T_4 concentrations in early lactation in this study suggest that the peripheral metabolism of T_4 is markedly increased in this period. This assumption is supported by the comparison of the calculated plasma-concentration ratios of T_3/T_4, rT_3/T_4 and rT_3/T_3: The high T_3/T_4 ratio and low ratios of rT_3/T_4 and rT_3/T_3 in early- lactating cows suggest that the peripheral conversion of T_4 to T_3 is given priority. But plasma concentrations of both T_3 and rT_3 were low in this period, possibly owing to increased metabolic clearance of thyroid hormones in peripheral tissues and/or to the suppressed secretion of thyroid during the period of maximum milking.

In this study no significant relationship was observed between T_4 levels and the milk yield or the energy or protein contents of the feed at the early stage of lactation. Milk yield has previously been reported to be negatively correlated with levels of T_4 and T_3 by *Hart et al.* (1979) and *Walsh et al.* (1980), in general accordance with our results. Thyroid hormone concentrations were not significantly correlated with daily milk yield with the exception of rT_3 which was negatively correlated with the milk yield during early lactation. The non-significant correlation between T_4 and rT_3 probably reflects the importance of an active deiodination pathway in early lactation. Dairy cows enter a period of negative energy balance during early lactation, despite being offered high-energy diets *ad libitum* (*Coppock* 1985). This change is due to the fact that feed intake cannot meet the nutritional demands of milk production which are very high during this heavy milk-producing period. In later stages of lactation a positive energy balance returns as milk production decreases. It is possible that changes in T_4 secretion are associated with homeostatic adaptations to changes in the energy supply during early lactation, when the energy balance is negative and the milk yield is at its maximum.

The reduction in T_3 and T_4 should be associated with reduced metabolic activity by peripheral tissues, but energy is used more efficiently by lactating cows than by non-lactating ones (*Moe et al.* 1970) which may be related to the decreased thyroid-hormone concentration and more efficient peripheral tissue metabolism during lactation (*Gerloff et al.* 1986).

The secretion of thyroid hormones, iodine and iodinated compounds into milk has been suggested as a cause for the apparent "hypothyroid" state of lactating animals (*Facuda et al.* 1980). Results from *Thompson-Ball & Anderson* (1980), *Akasha & Anderson* (1984), *Slebodzinski* (1986) and *Akasha et al.* (1987) indicate that thyroid hormones are present in milk, but in low concentrations. Therefore we can exclude the possibility that large amounts of plasma thyroid hormones are lost in connection with their secretion into milk.

El-Nouty et al. (1989) reported that a high milk yield was related to an elevated thyroid function, and *Anderson* (1971) found a non-significant, but consistently positive, correlation between milk production and the T_4 secretion rate of lactating cows. This contradicts our findings which indicate that low concentrations of T_4 and T_3 are associated with high milk yield. *Johnson & Van Jonack* (1976) suggested that low T_4 was associated with high lactational performance, possibly owing to the greater utilisation of T_4 in high-producing cows.

Marked endocrine changes occur that are considered responsible for the shift from an anabolic metabolic state during late pregnancy towards a primarily catabolic one in early lactation (*Collier et al.* 1984, *Kunz et al.* 1985). The changes in T_4 and T_3 during the lactation cycle seem to be primarily associated with a shift in energy metabolism (*Ronge et al.* 1988). *Blum et al.* (1983) proposed that low T_4 and T_3 concentrations in early lactation could help to conserve muscle mass. Therefore, reduced thyroid secretion during early lactation (*Tveit et al.* 1990) could explain the low thyroid hormone levels seen at this stage of lactation in dairy cows.

Late lactation. Pregnancy markedly increases maternal metabolic rate and energy consumption. *Melnik et al.* (1989) suggested that activated thyroid hormone secretion in the pregnant cow could explain the high plasma concentrations of T_4 in late pregnancy. It has been hypothesised (*Ekins* 1985) that maternal T_4 plays a vital role in foetal neurogenesis. This could explain the high T_4 and T_3 concentrations in our study during late lactation (5-6 months of pregnancy), when the daily milk yield is low, but the maternal metabolism places priority on growth of the foetus. Energy and protein intakes are lower in this period compared with during the period of maximum milk production. Despite this, the T_3/T_4 ratio was high while the rT_3/T_4 and rT_3/T_3 ratios remained stable. This may reflect an active deiodination of T_4, resulting in the formation of T_3, needed to meet the metabolic demands of the foetus when foetal growth is accelerated in late lactation.

Dry cows. The T_4 concentration continued to be high in dry cows (8.2 months of pregnancy in this study). The presence of high levels of T_4 in maternal blood during this period suggests that T_4 rather than T_3 may exert a specific hormonal role during late fetal development. Maternal T_4 has limited access to the fetal circulation (-*Strbak & Tomsik* 1988), but seems to ensure an adequate placental supply during the last trimester of foetal life. To compensate for elevated thyroid secretion the interactive deiodination pathway from T_4 to rT_3 in peripheral tissues takes place. This statement is supported by the observed high rT_3 concentration and low T_3/T_4, high rT_3/T_4 and rT_3/T_3 ratios in the plasma of dry cows.

Conclusion

This study suggests that stage of lactation, pregnancy and feeding strongly influence the dynamics of plasma thyroid hormone concentrations in dairy cows. Pathways of T_4 degradation, either to T_3 or rT_3, may have great importance as regulatory mechanism to conserve energy. The increased metabolic demand and suppressed thyroid secretion led to low levels of thyroid hormones at peak lactation. One could speculate that low levels of thyroid hormones at this stage could be one of the dairy cow's mechanisms for reducing metabolic demand in a situation where catabolic functions are high.

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Sammanfattning

Koncentrationer i blodplasma av tyroxin, trijodtyronin och reverse-trijodtyronin hos estniska mjölkkor i relation till laktationsstadium, mjölkproduktion och energi/proteinintag.

Koncentrationerna av tyroxin (T_4), trijodtyronin (T_3) och reverse-trijodtyronin (rT_3) hos 159 estniska mjölkkor av två raser (estnisk röd och estnisk svart och vit) var 55.2 nmol/L, 1.78 nmol/L och 0.25 nmol/L. När djuren grupperades beroende på i vilket laktationsstadium de befann sig visade det sig att nivån av T_4 var signifikant lägre under tidig laktation (45.1 nmol/L) jämfört med andra stadier, men plasmakoncentrationen ökade allt eftersom laktatione framskred (sen laktation; 56.7 nmol/L, sinkor; 64.3 nmol/L). Koncentrationen av T_3 var signifikant högre under sen laktation (1.93 nmol/L) än under tidig laktation (1.71 nmol/L) och under sinperioden (1.71 nmol/L). Koncentrationen av rT_3 visade samma mönster som T_4 (tidig laktation; 0.19 nmol/L, sen laktation; 0.24 nmol/L, sinperioden; 0.33 nmol/L). Koncentrationerna av skjöldkörtelhormoner var negativt korrelerade till mjölkproduktionen (T_4- $r = -0.51$, rT_3- $r = -0.47$, beräknat tyroidaindex $rT_3{*}T_3{*}T_4$- $r = -0.52$, hos samtliga var $p<0.0001$; T_3- $r = -0.32$, $p< 0.01$). Koncentrationerna av samtliga hormoner påverkades av energi- och proteinintaget. Koncentrationsskillnader kunde också observeras mellan de två raserna och mellan sommar och vinter vilket kunde förklaras med skillnader i utfodring och mjölkproduktion. Resultaten från undersökningen tyder på att de låga nivåer av skjöldkörtelhormon som kunde uppmätas under tidig lakatation kan vara ett sätt för mjölkkor att minska kroppens ämnesomsättnig för att klara av en hög mjölkproduktion.

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