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Role of Dietary Fat and Protein for Lactating Cattle

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ABSTRACT

With regard to the effect of dietary fat and protein on the performance of dairy animal, this article highlights the following points: 1) the fat metabolism, 2) fat supplements and their roles for the dairy cattle, 3) effect of the dietary fat on the milk yield and composition, 4) protein metabolism, 5) effect of dietary protein during heat stress, 6) effect of the dietary protein on the production and reproduction in the lactating cattle.
KEYWORDS: fat- protein- milk- cattle

INTRODUCTION

Milk production has had a great area of active research. It is affected by such factors as diet composition, diet formulation, physiological stage of the animal, environmental conditions, breed, health, etc.In order to increase the milk yield and improve the milk quality, the scientists of nutrition must have thought to determine and control these factors as possible. The effects of the dietary protein and fat on the performance of dairy animal have been investigated. The influence of dietary protein and fat may be affected by the roughage to concentrate ratio, the level and source of dietary protein and level and source of dietary fat(19).

The milk protein content increases only about 0.02 %for each 1% increase in dietary protein. This reflects a low transfer efficiency of dietary protein to milk and points out that dietary protein could not markedly change the milk protein content. Because of that and because of the greater sensitivity of milk fat to dietary manipulating than either protein or lactose, nutritional control of milk fat content and fatty acid composition received a great deal of the attention. The discovery of conjugated linoleic acid (CLA) as an ant carcinogenic substance also led to extensive work on enhancing its concentrate in milk through nutritional manipulation.

This article highlights the major effects of the dietary fat and protein on the entire animal system and milk yield and milk composition

I- *Role of dietary fat:*

Fat content of feedstuffs

Conventional diets for lactation rarely contain than 3.5% ether extract (1). The feedstuffs vary in their contents of fatty acids. Linoleic acid (18:2) predominates in most seed lipids, whereas in forages linoleic acid (18:3) is usually highest. An important exception to this generalization is the very high (37%) (18:3) of linseed oil, soybean oil also contains significant amounts of 18:3. Fatty acids composition of feedstuffs commonly used in lactation rations (gm. /100 gm. fat) is shown in the following Table:

Fatty acids	Alfalfa hay	Grass pasture	Soybean seed	Corn grains
Myristic 14:0	0.9	1.1	--	--
Palmitic 16:0	33.9	15.9	12.4	14.3
Palmitoleic 16:1	1.2	2.5	…	.1
Stearic 18;0	3.8	2.0	3.7	1.9
Oleic 18:1	3.0	3.4	25.4	30.0
Linoleic 18:2	24.0	13.2	50.6	43.5
Linolenic 18:3	31.0	61.3	7.9	1.1

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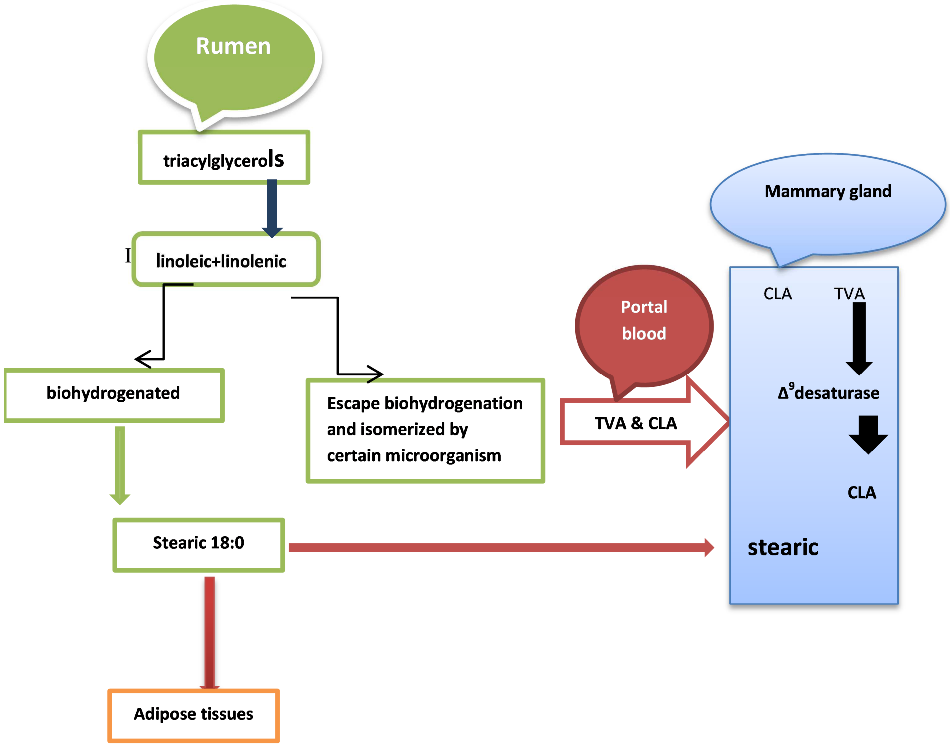
Dietary fat metabolism in ruminants



Fatty acids out in the milk usually exceeds daily intake of fatty acids that is because acetic acid which is a precursor for de novo fatty acids in mammary gland results from fiber digestion in the rumen.

So fat content in milk is affected by the ratio of roughage to concentrate in the ration of the dairy animal.

Dietary fat and ruminal fiber digestion:

Dietary fat may exert a negative effect on the ruminal digestion of dietary fiber by:

a- Physical coating of the fiber by fat, protecting the fiber from the microbial attack in the rumen
b- A modification of the rumen microbial population due to toxic effects of fat on certain microbes
c- Reducing cations availability from formation of insoluble complexes with LCFA

These inhibitory effects may be reversed by increasing the level of dietary fiber or by using calcium cation forms insoluble complexes(17)

Fat supplements

Fat supplements are: 1) whole, extruded, or exploded oilseeds, 2) calcium salts of long – chain fatty acids, 3) pelleted fats containing triacylglycerol and starch, 4) animal and vegetable blended fat, 5) yellow grease, 6) formaldehyde - treated oil and protein supplement.

Why fat is supplemented

There are two main reasons: a) to increase the diet energy density, b) to modify the milk fat composition. Each reason can be illustrated as follows:

a- to increase the diet energy density

a) 1- during the transition period

Transition period for high- yielding dairy cows, defined as 3 wk. pre calving to 3 wk. post calving, is the most critical phase of the lactation cycle. During this period, cows often go off feed which leads to mobilization of adipose tissue and development of fatty liver. Supplemental Dietary fat sources are commonly used as an attempt to provide extra energy for cows during this transition period (2).

Feeding prepartum diets supplemented by tallow at 2.2% of dry matter intake, has led to reductions in plasma non esterified fatty acids (NEFA) concentration and lipid infiltration of the liver but did not improve lactation performance. However, increasing the protein content of the pre partum diet did not appear to confer any advantages to cow production (3).

It has been found that hydrogenated palm oil triglyceride provide a better energy supply for high-yielding dairy cows in negative energy balance than calcium soaps of palm oil fatty acids around calving(4).

a-2- during the heat stress

It is well known that dairy animal reduces its feed intake as a thermoregulation effort to prevent an excessive increase in body temperature. Studies have been conducted to evaluate the response of hot-stressed lactating animals to fat supplementation. It was found that less heat must be dissipated per unit of net energy intake from dietary fat than dietary concentrate or forage. The added long chain fatty acids (LCFA) to the diets of dairy cows, resulted in decreasing the diet density energy, and in decreasing the methane production. So, the diet metabolizable energy increased for the milk secretion(5).

b- to modify the milk fat composition

There is considerable interest in modifying the fatty acid composition of milk with the overall aim to improve the long- term health of consumers. Several human intervention trials were performed investigating the potential health benefits of a butter-fat modified through manipulations by the cows' diets to increase the un-saturated: saturated fatty acid ratio (6,7,8). The un-saturated: saturated ratio could be increased when highly un-saturated oils are directed added to the diet, or when full- fat seeds or meals containing polyunsaturated fatty acids are supplemented. These sources must be protected by heat or chemical methods to reduce or eliminate rumen bio hydrogenation and hydrolysis of un-saturated fatty acids. This procedure increases the extent of incorporation of these un-saturated fatty acids into the milk fat (10).

b-1- increase the conjugated linoleic acid (CLA)

What is the CLA?

It is an octadecadienoic acid (linoleic acid) having two conjugated double bonds not having methylene group between them. It is a positional and geometric isomer of linoleic acid (cis-9, trans-12 18:2). It is trivial name rumenic acid is proposed on the basis of its ruminal origin.

Formation of milk CLA

It originates from two sources. A portion comes from CLA that is absorbed after escaping complete bio hydrogenation in the rumen. However, the major source is endogenous synthesis of CLA in the mammary gland. The enzyme catalyzing endogenous synthesis is Δ^9 -desaturase and the substrate is trans-11 18:1(vaccenic acid), another intermediate that escapes complete ruminal bio hyrogenation of polyunsaturated fatty acids (9).

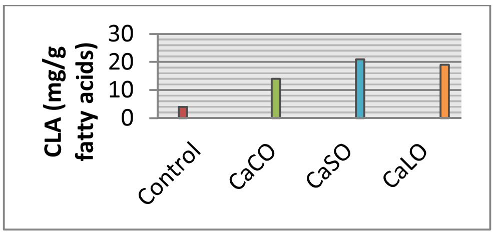
Influencing factors on the milk CLA

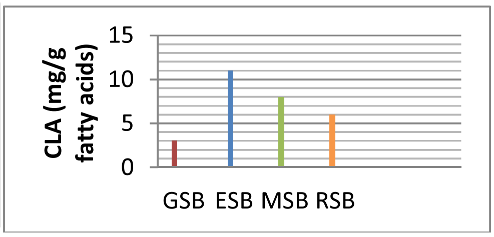
The concentration of milk CLA is affected by animal breed, animal feeding, lactation parity, and lactation stage. But the most important one is the animal feeding such roughage to concentrate ratio, forage type, and source and amount of the dietary fatty acids (10).

Evaluation of dietary fat supplements added to increase milk CLA

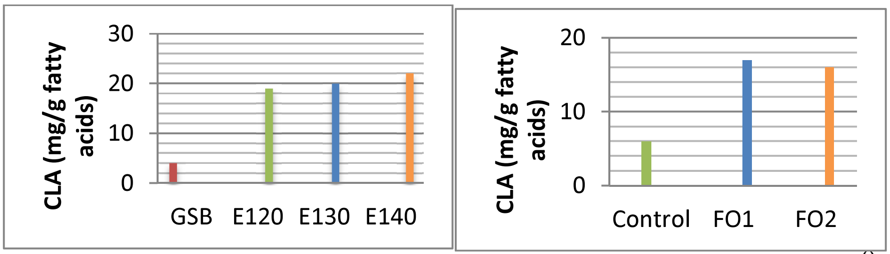
1-calcium salts of CLA dramatically decrease de novo synthesis of short chain fatty acids in the mammary gland.
2-plant oils cause inhibitory effects on the ruminal microorganisms
3-tallow and yellow grease have no content of polyunsaturated fatty acids
4-fish oil of fish meal yields trans-11 18:1 not CLA in the rumen
5-both whole oil seeds and fish meal (as a mixture) yield CLA and trans-11 18:1

Moreover, six trials have been conducted to determine the effect of different dietary fat supplements and processing methods on the cow milk CLA (11). The results of these trials are simplified in the following figures:

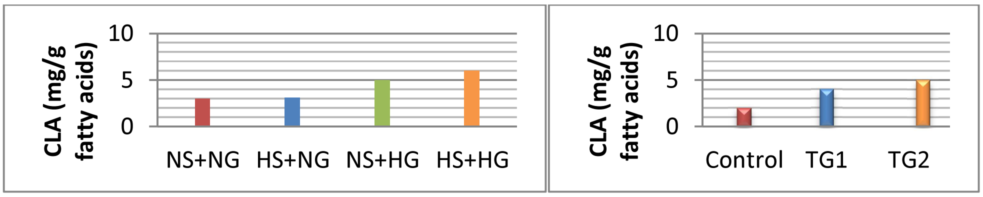




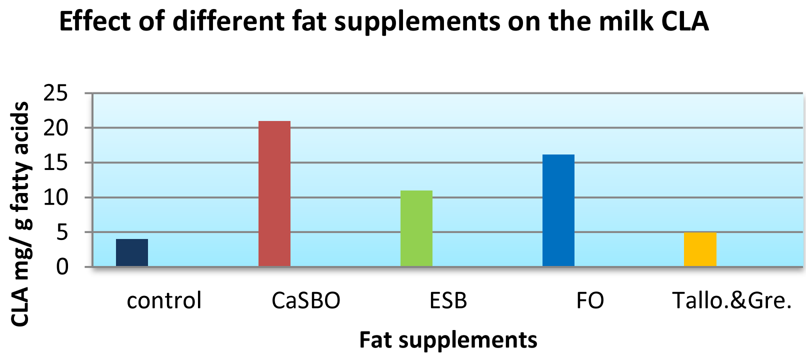
Trial 1 compares Ca salts of fatty acids from canola oil(CaCO),soybean oil (CaSO),and linseed oil (CaLO)., Trial 2 compares processing methods of full fat soybeans for control (ground; GSB), extrusion (ESB), micronizing (MSB), and roasting (RSB).



Trial 3 compares ground soybeans (GSB) with full fat soybeans extruded at 120°C (E120), 130°C (E130) and 140°C (E140).,Trial 4 compares two levels of fish oil, 200 ml/d (FO1)and 400 ml/d (FO2).



Trial 5 compares diets containing grain (G) and silage (S) from normal (N)and high oil (H) corn hybrids., Trial 6 compares two levels of animal fat byproducts, 1.9% tallow + 0.3% yellow grease (TG1) and 3.9% tallow and 0.5% yellow grease (TG2).



Effect of the dietary fat on milk fat content

The dietary fat has caused milk fat content to decline via inhibiting de novo synthesis of short chain fatty acids(6:0 to 14:0) in the mammary tissue. This occurred mostly with unprotected unsaturated fatty acids and in studies where fiber digestion was decreased. This inhibition may originate from: a) a low supply of acetate, b) high propionate produced in the rumen causes a glucogenic response which increases insulin level, the insulin inhibits the pituitary fat mobilization factor, and adipose tissue then competes with the mammary gland for lipogenic substances.

In general, the effects of fat supplementation on the milk fat composition and content are influenced by the type and amount of fat and its degree of inertness or protection in the rumen (1, 10, 11, 13).

Effect of the dietary fat on milk protein content

Inclusion of fat supplements in the diet of lactating ruminants generally reduces the protein content of milk. The physiological or metabolic basis for this negative relationship between dietary fat intake and milk protein content has not been established. It may be related to the adverse effects of fat on dry matter intake, carbohydrates fermentation, or efficiency of microbial protein synthesis (13, 14, 15).

Effect of the dietary fat on milk yield

When crossbred cows in mild lactation were fed diet supplemented with by -pass prill fat at 75 gm. /d., milk yield was 13.44±1.10 and 14.18±0.78 kg. /d for the control and fat group respectively. It was concluded that rill fat supplementation can be used to increase milk production during mild lactation in crossed cows (16). This result was attributed to the extra energy provided to cows in fat group. Prill fat is a non- hydrogenated vegetable oil containing more than 85% palmitic acid with high melting point. It does not melt at low pH, by-pass rumen degradation and is digested in small intestine.

The response in milk yield appears to vary with source and level of fat and with stage of lactation. When dry intake is not lowered by dietary fat, milk production tends to increase. The workers have demonstrated the existence of a curvilinear response in milk yield by increased dietary fat level below an intake 35 gm. fat / kg DM/ day. Increases in response are much less pronounced above 40 gm. / kg DM/ day. The response in milk yield is greater in early lactation and with higher yielding cows(1, 11, 12)

It is of interest to report that the combination of basal and these supplemental fats should not exceed 5-6% of feed dry matter. If more than 6% fat is needed in the diet, a quality rumen-inert fat should be used in order to maintain normal rumen function (10).

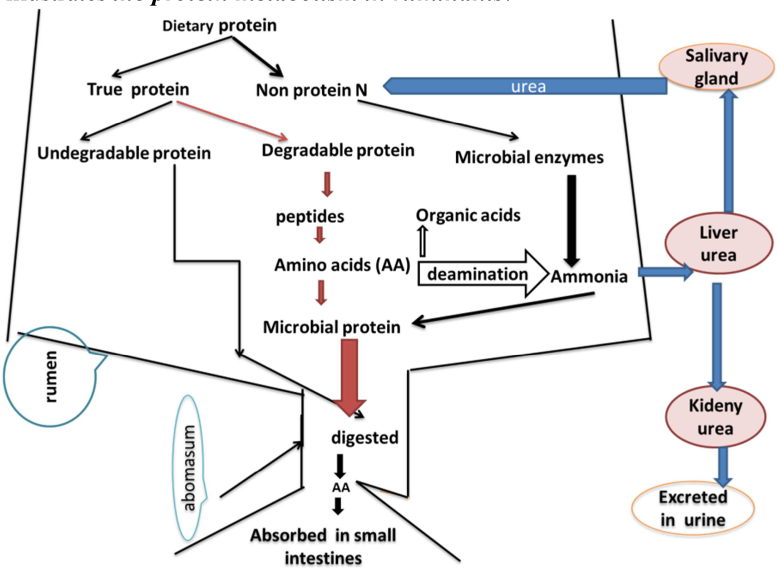
Moreover, not all oil seed could be used as a good supplement. When, protected oil of *Sterculiafoetida* seed (rich in cyclopropene fatty acids), was fed to lactating cows. The increase in C18:0 and the reduction in C18:1 content of milk fat was most probably to the cyclopropene- inhibition of Δ^9 – desaturase enzyme in the mammary gland (17). Also the endogenous synthesis of CLA(cis-9, trans-11 18:2) was inhibited by sterculic acid in dairy sheep (18). Thus oil seeds rich in cyclopropene fatty acids are not good and not appreciate supplements.

II- Role of dietary protein

Frist of all, it is of interest to refer to ***certain definitions*** that are commonly used in dairy ration formulation:

Ruminal microbial protein, it is the protein fraction synthesized by microbes in the rumen. About 60 to 80 % of the dairy cow protein requirements are provided by ruminal microbial protein. It is highly digestible by the animal (80% digestibility). Metabolizable protein (MP), it is defined as the net quantity of true protein or amino acids absorbed in the small intestine. It is the summation of digested protein and microbial protein minus nucleic acids. Ruminal degradable protein (RDP), it is degraded by the rumen microbes**.** Ruminal un degradable protein (RUP), it is resistant to microbial attack in the rumen and becomes available for enzymatic digestion in the small intestine, it can be of plant or animal origin, meat and bone meal, fish meal and feather meal are the main animal RUP sources. Ruminal by pass protein, the proportion of dietary protein that evades microbial attack by passes the rumen without thoroughly mixing with ruminal contents (19).

The following figure illustrates ***the protein metabolism in ruminants***:



Crude protein in feedstuffs

The dietary ingredients contain different levels of crude protein, and their proteins may be degraded or undegraded in the rumen. Legume forages contain higher levels of crude protein (≥14% on DM basis) than grass forages (≤5% on DM basis). Supplements of protein such as soybean meal, blood meal contain ≥30% CP on DM basis

Protein content and ruminal degradable (RDP) and undegradable (RUP) protein content of some protein sources are shown in this Table:

Item	CP%	RDP(%CP)	RUP(%CP)
Alfafa hay	19	73	38
Grain corn	10	40	60
Soybean meal	55	65	35
Canola meal	42	72	28
Sunflower meal	26	74	26
Fish meal	67	40	60
Feather meal	89	29	71
Blood meal	92	18	82

Dietary protein during different stages of lactation

The dietary protein requirements vary by the different stages of the lactation season in the high yielding cows (≥20 kg. / d) as follows:

Item	Early lactation	Mid lactation	Late lactation
CP % on DM basis	15-17	14-16	13-15
RDP (% CP)	65-60	70-65	75
RUP (% CP)	35-40	30-35	25

Effect of dietary protein levelson milk yield

Producers often feed high CP diets to ensure a sufficient supply of the MP required for maximal milk production of dairy cows. But to what extent the dietary CP level can be increased. The following paragraph may be the answer:

Several studies have evaluated the effects of varying dietary protein levels on the performance of lactating animals. They found that a linear increase in dry matter intake (DMI) when dietary CP was increased from 15.1 to 16.7 and 18.3%, however, milk yield increased from 33.0 to 34.1 kg. /d only with the first CP increment, with no further change at 18.3 %, resulting in lower feed efficiency (milk yield / DMI) at the highest CP. In milk of these cows, yields of fat and protein improved when the dietary CP increased from 15.1 to 16.7% but with no further increase at 18.3% CP. Moreover, other workers noticed that N secreted in milk decreased from 36.5 to 25.4 % as dietary protein increased from 13.5 to 19.4 %. And they observed that the linear increase in urinary N excretion resulted from a sharp decline in N efficiency as dietary CP content increased to 19.4% (20, 21, 22).

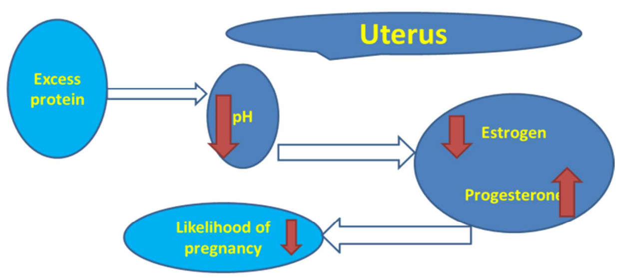
Effect of dietary protein quality on milk yield

In high yielding cows, the milk production has become so high that microbial protein alone is not sufficient to fulfill the protein requirements. Therefore, diets of these cows should be supplemented with the RUP supplements. The amino acids (AA) pattern of RUD should be complementary to that of microbial protein AA (22, 23, 24).

It was found that increased amounts of RUP (6.2, and 7.3 % of dry matter intake) in diets (16.5% CP) of cows tended to increase milk yield (34.0 vs. 36.5 kg/d). It was attributed to improve protein status, improve metabolizable energy, or both (22)

Association between dietary protein and reproduction

Several studies have shown that cows- feeding excess amounts of protein may be detrimental to the fertility of cows. Some workers have studied the effects of decreasing both the dietary CP level and dietary RUP(the Lys: Met (3:1)) in diets of dairy cows in early lactation. The CP content was 18, 16.4 and 15.6%, RUD was 6.2, 5.4, and 4.6 % for the control, treatment 1, and treatment 2, respectively. The results indicated that the concentration of both plasma urea N and milk urea N was decreased. The milk urea N was 17.3, 15.2, and 15.1mg./dl for the control, treatments 1&2, respectively. No negative effects on milk production or composition were observed (25,26). The following figure illustrates the effect of the excess protein on the sexual hormones of the ovary in the uterus of dairy cattle.

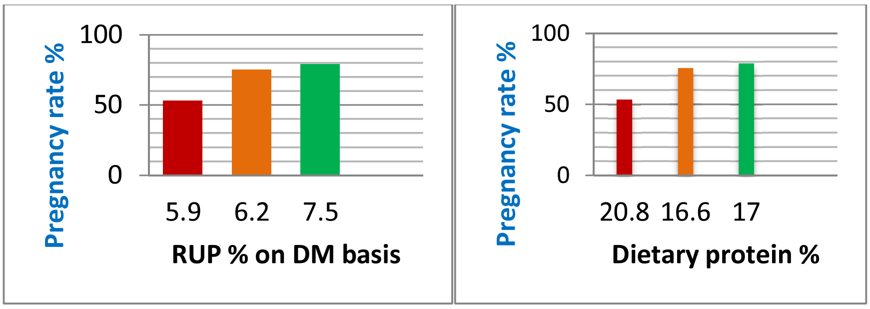


Moreover, excess dietary protein is degraded to NH3 by ruminal microbes, absorbed into the portal blood and rapidly converted into urea by the liver. The concentrations of plasma urea nitrogen (PUN) above 19 mg. / dl, have associated with lowered pregnancy rates in dairy cows (26). The following Table and figure illustrate this association:

Item	HPMRUP[1]	MPMRUP[2]	MPHRUP[3]
Dietary CP%(on DMbasis)	20.8	16.6	17.0
RUP % (on DM basis)	5.9	6.2	7.5
RDP % (on DM basis)	15.1	11.4	11.0
Plasma-urea-N mg./dl	25.0	20.1	18.5
Days to first breeding	89.8	80.5	79.4
Pregnancy rate %	53.4	75.4	79.0

[1]HPMRUP=high protein moderate RUP, [2]MPMRUP= moderate protein moderate RUP, [3]MPHRUP= moderate protein high RUP

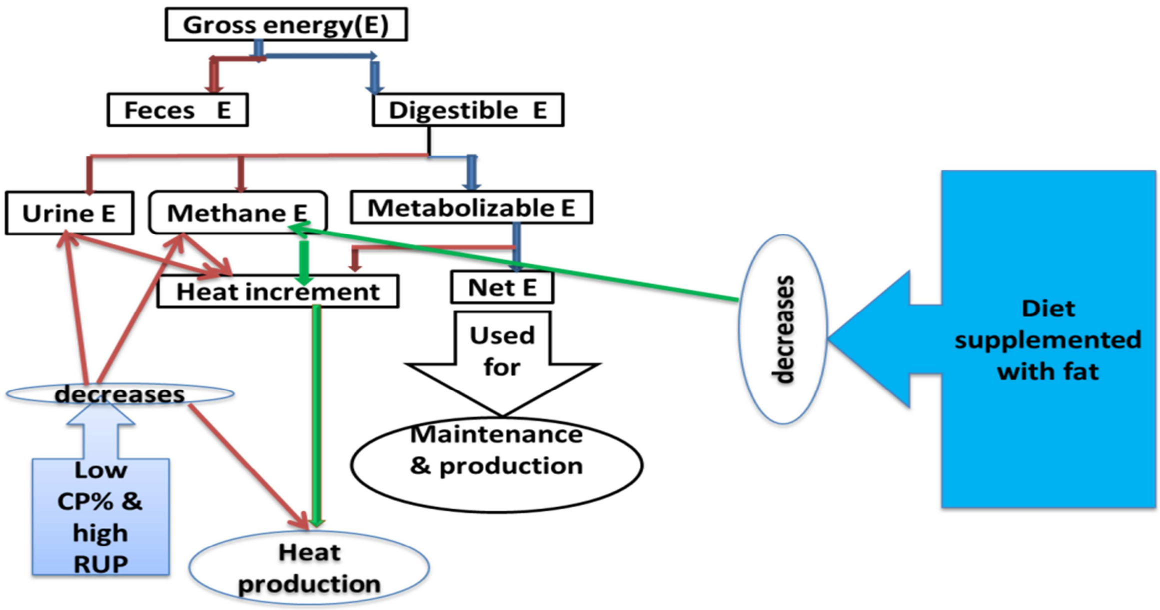
Uterine pH normally increases from about 6.8 at estrus up to 7.1 on d 7 of the estrous cycle(luteal phase), but this increase failed to occur in both heifers and lactating cows fed excess RDP or RUP (high PUN). , uterine pH and PUN concentrations were inversely related



Effect of dietary protein during heat stress

With regard to dietary N during heat stress, it could be reported that the protein in excess of dairy cows requirements is excreted in the urine as urea. The energy cost association with synthesizing and excreting urea is accounted for the reduced milk. Furthermore, high dietary protein can increase the water needed for urinary disposal of urea. So, the diet should contain low level of CP or high level of RUD under heat stress, (27).

The following figure illustrates that manipulating dietary protein (low level& high RUP) is better than adding fat during heat stress



Conclusion

The dietary fat and protein have great effects on the performance of dairy animal. Fat could be supplemented to the high lactating animal during transition period. Mixture of fish oil and soybean oil could be a good tool to increase the concentration of the functional fatty acid in milk(CLA). Diets with high ruminal undegradable protein had positive effects on the milk yield during heat stress. Diets with low protein could improve the fertility in dairy animal.

The future trends

In my opinion, manipulating the diets low in CP and high in RUD for cattle having high ruminal urease activity may be a tool to improve their fertility. Also, isolating the bacterium responsible for the formation of CLA and vaccenic acids in the rumen may be used as a probiotic.

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