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THE EFFECT OF PROTECTED FAT ON MILK YIELD AND COMPOSITION, DIGESTIBILITY, AND SOME BIOCHEMICAL PARAMETERS IN LOW PRODUCING COWS

(With 7 Tables and 4 Figures)

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تأثير الدهون المحمية على إنتاج اللبن وتركيبه ومعاملات الهضم وبعض
القياسات الكيموحيوية فى الأبقار منخفضة الإنتاج

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أجريت فى هذه الدراسة خمس تجارب تغذوية متتالية مدة كل منها ٢١ يوم على على عشرة أبقار
خليط متعددة الولادات وذلك لدراسة تأثير إضافة الدهون على انتاجية اللبن ومحتـــواة مـــن
الدهن وكذلك بعض القياسات الكيميائية الحيوية. أضيفت الدهون المحميـــة (الخاملة فـــى
الكرش) فى صورة ملح كالسيومى للأحماض الدهنية إلى العليقة الأساسية الضابطة بمعـــدل
٤٠٠ جرام لكل بقرة يوميا وذلك فى المجموعتين ٢ ، ٤ مكونة بذلك العليقة المزودة بالدهون
, بينما تم تغذية الثلاث مجموعات الأخرى (١، ٣, ٥) علـــى العليقـــة الضابطـــة (١٤ %
بروتين , ٢٥,١ميجا كالورى لكل كجم مادة جافة) بدون إضافة للدهون. وقـــد أوضحـــت
النتائج أن إضافة الدهون ليس لها تأثير سلبى على معدل إستهلاك المادة الجافة وكذلك علـــى
معامل هضمها وعمليات التخمر فى الكرش عدا التجربة رقم٢ مما يعكس ضرورة زيـــــادة
مدة تهيئة الحيوان لإضافة الدهون للمرة الأولى. وقد أدت زيادة تركيز الطاقة وبالتالى زيادة
معدل استهلاكها فى العليقة المزودة بالدهون إلى تحسين إنتاجية اللبن و نسبة الدهن بالاضافـــة
الى زيادة معدل النمو إلى الضعف. كما أوضحت نتائج القياسات الكيميائية الحيوية أن هنـــاك
زيادة معنوية فى تركيز نسبة كل من الكولسترول الكلى والدهون المركبة ذات الكثافة النوعية
العالية فى المجموعتين المغذاة على علائق مزودة بالدهون وذلك لدورها فى امتصاص ونقل

الأحماض الدهنية طويلة السلسلة , كما وجد زيادة معنوية فى تركيز الجلسريدات الثلاثيـــة وذلك لزيادة إستخدامها بواسطة الضرع وبالتالى زيادة إنتاج نسبة الدهن فـــى اللبـــن. وقـــد خلصت هذه الدراسة الى أن إضافة الدهون بمعدل ٤٠٠جرام لكل حيوان يوميا لمدة ثـــلاث أسابيع بالتبادل مع فترات لا تستخدم فيها الدهون كان له أثر فعال فى زيادة معدل إنتاج اللبن وكذلك نسبة الدهن بحوالى ١٠ % , ٤,٠ % وحدة أثناء فترة إضافة الدهون مع إســـتمرار زيادة المعدل بحوالى ٣ % , ٦,٠ % وحدة (على التوالى) رغم عـــدم إستمرار إضافـــة الدهون للعلائق مما يوضح الجدوى الاقتصادية لهذه الاضافة.

SUMMARY

Five successive feeding trials, each of 21 days, were performed on ten multiparous hybrid cows, as a group, to study the effect of supplemental dietary fat on yield of milk and its fat content in addition to some biochemical parameters. Rumen-inert fat in the form of Ca salts of fatty acids was added to a basal control diet in trials 2 & 4 at the rate of 400 g per cow daily, forming the fat-supplemented diet. In the other 3 trials (1,3&5) a control diet of 14 % CP and 1.52 Mcal, NE_l/Kg DM was fed without fat addition. The results showed that fat adding had no negative effect on DM intake, digestibility and characteristics of ruminal fermentation except in trial 2 the first time of fat addition. There was a significant increase in serum total cholesterol and HDL-cholesterol in fat supplemented groups. A highly elevated level of serum triglycerides was observed, leading to increase in milk fat %. The increase in energy density and consequently its intake in fat-supplemented diets were translated in the improved milk and fat production, in addition to more than doubling the body weight gain. Conclusively, adding fat at the rate of 400 g/animal for 3 weeks alternated with periods of unsupplementation increased the milk yield and fat % by about 10 % and 0.4 fat percent unit during the fat-feeding periods and 3 % and 0.06 fat percent unit during the rest periods, respectively.

Key words: Protected fat, milk yield, milk composition, digestibility.

INTRODUCTION

Nutritional inadequacy or fault in the methods of care and management will generally manifest itself by a reduction in the yield of milk, rather than by a change in its chemical composition. In general, there is a strong tendency for a lactating animal to produce milk of

normal composition under widely varying conditions. However, certain factors have an effect on fat percentage, certain traceelements, and vitamin A or carotene content in milk. Changes in composition brought about by nutritional means occur rapidly and fat concentration in milk is the most sensitive to dietary influences (Sutton, 1989). Fat-supplementation is one of many dietary factors affecting the last. Feeding supplemented fat to lactating cows has been of interest for many years started at 1907 by Kellner.

In recent years, much of this interest has occurred because of increased milk production per cow and the need to maintain both high fiber content and high energy density especially during early lactation, in addition to increased availability of feed-grade fats (Palmquist and Jenkins, 1980 and Wu et al., 1991). Linn (2000) reported that fat can be added as whole oil-seeds and unprocessed vegetable oils primarily containing long chain polyunsaturated fatty acids; animal fats and rendered fats high in saturated fatty acids and the monounsaturated fatty acid (oleic acid), and rumen inert or protected fats. The last are generally called granular fats such as protein-coated lipids having a large proportion of polyunsaturated fatty acids; Ca soaps of fatty acids and prilled fats containing mainly the saturated fatty acids, palmitic and stearic. Free oil addition is unsuitable for milking cows as they affect rumen fermentation adversely (Storry,1981; Church,1991; and Elliott et al.,1993) and reduce fiber digestibilty (Palmquist and Jenkins, 1980; Harfoot and Hazlewood, 1988; Church,1991; and Eastridge and Frinkins, 1991) leading to an increase in propionate production at the expense of acetate and usually there was an associated reduction in the total volatile fatty acids concentration in the rumen liquor (Steele, 1985 and Elliott et al., 1993). In contrast, feeding the same vegetable oils in its natural seeds increases the yield and content of the milk fat because of partial rumen bypass of the oil in the whole seed or slow release in the rumen, allowing a complete biohydrogenation (Palmquist and Jenkins, 1980).

In order to avoid interactions between fat and ruminal digestion, different physical and/or chemical treatments have been applied on pure fats or oil seeds. The products are generally called protected lipids because their fatty acids are protected against hydrogenation by bacteria, or they offer a protection against the disturbance of ruminal digestion due to their fatty acids (Doreau et al., 1997). *Palmquist* (1976) reported

that feeding of protected lipid diets consistently increased milk fat percent due to greatly increased plasma VLDL triglyceride concentration, which increased mammary uptake of long chain fatty acid (Yang *et al.*,1978) and this exceeded the compensating reduction in de novo synthesis of short chain fatty acids, resulting in higher milk fat secretion. Also when the degree of protection was good the addition of polyunsaturated fatty acids to the diet resulted in levels of over 30 % of linoleic acid in the milk fat compared to normal values around 2% (Scott *et al.*, 1970 and 1971 and Steele,1985).

The rumen inert Ca soaps have been proposed to be used (Doreau *et al.*,1997) on the basis that Ca in the rumen is supposed to form salts with fatty acids and contribute to the reduction in the disturbances of ruminal carbohydrate digestion. The use of Ca salts has been widely developed over the last decade, first tried in 1984 by Jenkins and Palmquist, using palm oil. Disturbances of ruminal digestion were absent (Chalupa *et al.*, 1984 and 1986) and this was attributed to the low dissociation in the rumen when pH that is was between 6 and 7 (Sukhija and Palmquist,1990). Addition of the Ca salts of fatty acids to lactating cow rations increased milk yield and significantly increased the milk fat (Downer, 1987; and Schneider *et al.*, 1988) , and Morrison (1959) mentioned that experiments showed that the richness of the milk in fat may be considerably increased for a few days by adding fat or fat rich feeds to the ration but, however, tended to fall back to normal later, even though the feeding of the fat is continued.

In this study the effect of protected fat (IBEX, as Ca soaps of fatty acids derived from palm, soybean and sunflower oils) addition to the rations of especially low-producing cows, on milk yield and fat content, and serum lipid profile was tested, beside measuring rumen fermentation characteristics, and digestibility. The study was performed on 10 animals, as one self-controlled group, so that control diet and fat-supplemented one were fed on an alternative design during five feeding trials, each of 3 weeks and the control diet- stages were presumed to be the started control or the periods in which no response was anticipated even if the fat feeding is continued.

MATERIALS and METHODS

1-Animals:

Ten multiparous hybrid (Friesian X Egyptian) cows of 462 Kg

body weight on the average, varying in the phase of lactation from the first to the third and producing 13 Kg milk daily, were used in 5 successive feeding stages or trials, each of 21 days long. The animals were a part of a farm of the Faculty of Veterinary Medicine, Beni-Suef, where the experiment was performed. Cows were housed altogether in a group pen equipped with gates in order to ease the individual feeding and intake measuring. The animals were weighed at the beginning and end of each of the five trials and the body weights were recorded as an average of three weights acted on three consecutive days after the morning milkings and before feeding.

2-Diets:

A basal diet was formulated and composed of a concentrate mixture and the roughage wheat straw (Table1). The animals were offered each's quota of concentrate and roughage mixed altogether making a ration of 14 % CP and 1.52 Mcal NE_l/Kg DM and satisfying the recommendations of NRC (1988) for the animals having the same weight range and average production. IBEX protected fat, a mixture of long chain fatty acid–calcium salts (CaSFA), where acids derived from palm, soybean and sunflower oils, were mixed with the diet in the trials number 2&4 at the rate of 400 g per cow daily, as recommended by the responsible company (IBEX), given in two portions forming the fat-supplemented diet. To adapt the animals for the product and according to the company advice, the fat was added gradually to the ration in its respective stage on a five day period starting with 80 g and ending with the prescribed amount. For each animal an amount of the stage diet was assigned according to the cow size and level of milk production, and offered in two equal post-milking meals at 8 a.m. and 5 p.m. Food consumed was daily recorded and refusals considered.

3- Experimental design:

Five successive feeding trials each of 21 days were performed on the ten animals as a group, and the CaSFA was added, at the aforementioned rate,during the second and fourth stages. In the other three stages (1,3 &5) the basal control diet was fed without fat addition. As a digestibility indicator, chromic oxide was given at the rate of 10 g per animal, 5 g at each meal and introduced directly into the mouth from day 11th to day 21st of each period.

4-Sampling:

4-1. Milk:

Milk yield was recorded daily and averaged every three days. Milk samples were obtained from the two daily milkings at the rate of 3% of the yield, and samples of each three successive days were mixed and a pooled sample (about 500 ml) preserved with the addition of potassium dichromate and stored at 4 °C until analysis.

4-2. Blood:

Blood was sampled by jugular vein-puncturing 6 h after the morning meal, on the 21st days of each of the feeding trials. Serum was separated and stored at $-20°C$ until analysis.

4-3. Ruminal fluid:

On the 21st days of each of the feeding trials, samples of ruminal fluid were taken using a stomach tube 6 h after the a.m. feeding for determining the hydrogen ion and volatile fatty acid concentrations. At each time about 500 ml – size ruminal sample was taken, filtered through two layers of cheesecloth, where pH was immediately determined. Each sample was divided into 10 portions of fifties, acidified to pH 2.0 using 10 ml of HCl and 5 ml orthophosphoric acid , and centrifuged at 3000 r.p.m. for 10 min. The supernatant fluids were frozen and kept for further analysis.

4-4. Fecal matter:

The fecal samples were collected for the last five days of each feeding period. Fecal matter was sampled as grabs twice daily after milking and kept frozen for analysis. At the time of analysis the samples were thawed, dried at 55 °C in a forced – air oven and ground. At the end of each collection period, samples for each cow were mixed thoroughly and subsampled for further analysis.

5- Estimations:

5-1. Milk fat and Milk protein:

Milk fat was determined using the Gerber method, while milk protein was estimated by Kjeldahl procedure (Association of Official Analytical Chemists, 1984).

5-2. Blood lipids and glucose:

Blood serum was analyzed by enzymatic colorimetric assays for total lipids (Frings and Dum 1970), triglycerides (Eggstein and Kuhlmann, 1974), total cholesterol (Flegg, 1972), HDL-Cholesterol

(Lopez- Virella, 1977) and glucose (Trinder, 1969).

5-3. Ruminal acidity and total volatile fatty acids:

As soon as the ruminal fluid samples were obtained, the hydrogen ion concentration was estimated using pH meter. For the analysis of the total volatile fatty acids (TVFAs), the steam distillation procedure described by Abou- Akkada and El-Shazly (1964) was followed.

5-4. Nutrient digestibility:

The amounts of dry matter and nutrient consumed by each animal were estimated by sampling the whole mixed ration offered and the food refused, each of the left and blowed wheat straw or concentrates, during the 5 day – collection periods, where composited for each cow, dried and ground. The diet and refused samples and feces were analyzed for dry matter, crude protein and crude fiber following *AOAC(1984)*, and for chromic oxide according to Kimura and Miller method (1957).

The DM or nutrient digestibility was calculated using the following equations:

$$\text{Digestibility of DM} = 100 - \left(100 \text{ X} \; \frac{\% \text{ indicator in feed}}{\% \text{ indicator in feces}} \right)$$

$$\text{Digest. of a nutrient} = 100 - \left(100 \text{ X} \; \frac{\% \text{ indicator in feed}}{\% \text{ indicator in feces}} \text{ X } \frac{\% \text{ nutrient in feces}}{\% \text{ of nutrient in feed}} \right)$$

6- Statistical analysis:

Statistical significance was measured by analysis of variance using PC-State program (1985).

RESULTS and DISCUSSION

1- Dry matter intake, digestibility and body weight gain:

1-1. Dry matter intake:

Feeding each of the ten lactating animals in trials 2 & 4 on 400 g fat increased the NE_l density in the whole ration to 1.65 NE_l/Kg DM, and in spite of this, the DM intake did not decrease when compared with that of the control diet in trial 1 (table 2). The increase in energy density in fat-supplemented diets resulted in an intake reaching to 18.350 and 19.005 Mcal NE_l / day in trials 2 & 4 respectively but only 16.822 in trial

1. Also no effect was found, on DM intake , with the addition of tallow and protected one (Smith *et al.*,1978; Wrenn *et al.*,1978; Palmquist and Conrad, 1980; Schauff *et al.*, 1992), or with partially hydrogenated tallow (Drackley and Elliott, 1993). On the contrary, lack of palatability was a problem with the feeding of some inert fat sources (Coppock and Wilks, 1991; and Grummer *et al.*, 1990), 5 % yellow grease (Jenkins and Jenny,1989), or high corn-oil and 5% tallow (Elliott *et al.*,1993). It was found by Pantoja *et al.* (1994) that increased addition of unsaturated fat decreased DM by 14 % and the decrease was probably due to gut fill, if ruminal fiber digestion was inhibited, or by postruminal effects.

1-2. Digestibility of dry matter:

The addition of inert fat had no negative effect on digestibility, as it was expected, but only in trial 2 in which the animals first tried the added fat the length of 21 days seems to be too short to adapt the rumen microbes to the added fat. At the same time the 21 days were sufficient in length for the microbes to start modification and for the animals to store this potential, to the degree that the inert fat had no effect on digestion when fed 21 days later in trial 4 (Table 3).

1-2.1. Digestibility of crude protein:

The protein digestibility did not differ due to the addition of fat (Table 3).This result does not support the increased N digestion distal to abomasum as found by Hogan *et al.* *(1972)*, and bacterial protein synthesis found by Pantoja *et al.*(1994), or ruminal protein synthesis by Doreau and Ferlay (1995).

1-2.2. Crude fiber digestibility:

Regarding the crude fiber digestion, the addition of fat in the second trial did have an effect on the digestion of the DM which seems to be mainly due to reduced fiber digestion. Factorially, it is 2.76 percent units decrease in fiber digestibility, approaching the same percentage of decrease recorded in DM digestibility (3.05). The period of trial 2 appears to be expended in microbial modification in the rumen and adaptation to the new diet ingredient introduced. Fat addition in trial 4 failed to practice its lowering effect (Table 3). The reduction of ruminal fiber digestion was reported with protected tallow by Bines *et al.* (1978), yellow fat by Eastridge and Firkins (1991), while a higher decrease caused by unsaturated fats was observed by Ikwuegbu and Sutton (1982); Zinn (1989) and Pantoja *et al.* (1994). In contrast, digestion of fiber components were found not to be affected by vegetable

oils (Doreau *et al.*, 1991, with rapeseed oil*)*; unprotected animal fats (Palmquist and Conrad, 1980 and DePeters *et al., 1989)* partially hyrogenated tallow (Drackley and Elliott, 1993) or inert fats (Schauff and Clark,1989 and Palmquist, 1991).

1-3. Body weight gain:

The increase in energy intake was translated in the improved milk and fat production, in addition to more than doubling the body weight gain. The animals gained on the average 2 Kg in trial 1 and more than double this amount (5 Kg) in trials 2 and 4 (Table 2). This coincides with that found by Palmquist (1978) that high –fat diets reduced weight loss of cows in the first 7 weeks of lactation. On the other hand, feeding 4 % Ca salts of palm oil by Schneider *et al.*(1988) and 5 % added fat from saturated tallow, tallow, or animal–vegetable fat by Pantoja *et al.* (1994)

2- Ruminal pH and total volatile fatty acid concentration:

In the fat-diet trials 2&4, the ruminal pH was above 6 (table 4) resulting in low dissociation of fat in the rumen (Sukhija and Palmquist,1990). On the other hand , ruminal pH was not affected by the addition of cod liver oil (Beitz and Davis, 1964), prilled fatty acids and Ca salts of fat (Schauff and Clark, 1989), and saturated tallow, tallow, or animal-vegetable fat (Pantoja *et al.,* 1994).

Characteristics of ruminal fermentation reflected by the total concentration of volatile fatty acids were not significantly different among treatments. The highest decrease in TVFA was in trial 2 as a result of the passive effect of fat on fiber digestion reflects the need for a longer period for the ruminal microbes to adapt (Table 4). The decrease in VFA may be also due to less fermentable organic matter in the fat-diets (Pantoja *et al.* 1994). Others stated that total concentration of VFAs were not affected by fat supplementation (Grummer,1988; Schauff and Clark, 1989; Ohajuruka *et al.*1991; Palmquist, 1991; Darckley and Elliott, 1993 and Palmquist, *et al.* 1993).

3- Blood glucose and lipid profile:

3-1. Glucose:

Differences among treatments in concentration of serum glucose were not significant (Table 5). Our results seem to be supported by Bines *et al.*(1978), Palmquist and Conrad (1978), and DePeters *et*

al.(1989). Darckley and Elliott (1993) reported that if partially hydrogenated tallow (PHT) increased availability of glucose, the glucose probably was used for lactose synthesis, because milk production was higher with increased PHT, and concentration of glucose in plasma was unchanged. The glucose level tended to be greater for cows fed supplemental fat probably because of its sparing effect on glucose from oxidation in the mammary gland (Grummer and Carroll, 1991). Also Smith *et al.*(1978) suggested that higher fat feeding might alter glucose metabolism, and Moser (1978) observed a 25 % reduction in plasma insulin concentration when protected lipid diet was fed to lactating cows. Moreover, Lavau *et al.* (1979) suggested that long chain acyl CoA inhibits acetyl CoA carboxylase activity, reduction of NADPH utilization and decrease of glucose oxidation throughout pentose phosphate pathway, effectively decreased glucose uptake in rats. Also this result was supported by Jenkins and Jenny (1989) with yellow grease and Elliott *et al.* (1993) with diets containing high corn oil and/or tallow.

3-2. Blood lipid profile
In this study, the total lipid concentration of serum was increased by ($P<0.01$) the addition of fat in trial 4 (table 5). This agrees with what is reported by Yang *et al.* (1978), Selner and Schultz (1980), and Gaynor *et al.*(1994). With the addition of IBEX protected fat in trial 2 and 4, the concentration of serum triglycerides was highly increased ($P<0.01$) as compared with the first one (table 5). This was found to increase the mammary uptake of long chain fatty acids (Yang *et al.*, 1978) , exceeding the compensating reduction in short chain fatty acids, and resulting in higher milk fat secretion. On the other hand Schneider *et al.* (1988) reported no effect for Ca SFAs on triglycerides.

Serum cholesterol was increased in trials 2 and 4 . The lactating cow was unique in its ability to maintain a high concentration of cholesterol in plasma with no determintal effect (Kaneko, 1989). When fat (protected tallow or fat) was fed by Sharma *et al.*(1978), and Jenkins and Jenny (1989) there was a significant increase in plasma total cholesterol as it is required for absorption and transport of dietary long-chain fatty acids. On the contrary, no change in cholesterol concentration with CaSFAs was observed by Schneider *et al.*(1988).

The level of HDL-cholesterol was highly increased with fat supplementation in trials 2 & 4. The uniquely high level of HDL, the

cholesterol carrying lipoprotein, in the ruminant may help to protect this species from any detrimintal effects of hypercholesteremia which normally developed during lactation (Puppione,1978). This increase indicates the capacity of the mammary gland to form milk fat (Kaneko, 1989) a fact which was reflected in the increased milk fat in both trials (2&4).

4- Percentage of milk fat:

During feeding the control diet, the concentration of fat in milk ranged from 3.28% to 3.51% with an average of 3.36 %. Adding the protected fat to the diet increased the fat in milk to 3.61% in trial 2 and 3.53% in trial 4 in the first 3 d-periods and the effect is continued to reach a maximum of 4.21% in trial 2 and 4.13 % in trial 4 at the third d-period (table 6, figure 2). At the fourth 3 d -period the fat started to decrease reaching 3.45% at the end in trial 2 & 3.51 % in trial 4, levels still higher than that of trial 1. Increased milk fat due to the addittion of CaSF was also recorded by Schneider *et al.*(1988). Generally, the protected-fat diets increased milk fat content with little effect on other milk components (Mattos and Palmquist, 1974; and Sharma *et al.*, 1978). On the other side, addition of 2.5 % unprotected tallow (Wrenn *et al.* 1978) or 5 or 7 % yellow grease (Jenkins and Jenny, 1989 and DePeters *et al.* 1987) showed a decrease of 0.4 to 0.7 percentage units.

The effect of fat addition did not stand at the time of feeding but also extended along the rest periods (trials 3 & 5). The effect extended to 15 days in trial 3 and allover the 21 days in trial 5. Fat adding, on the average, increased milk fat % by 0.38 – 0.4 percentage unit in the feeding periods and by 0.05 – 0.07 percentage unit in the inbetween rest periods.

5- Milk protein content:

In spite of the positive relationship between milk fat and milk protein, the increase in fat % as a result of fat addition in trials 2 & 4 or as a result of its continued effect in trials 3 & 5 meets a decrease in protein percent. It appears that the abnormal increase in fat does not have a positive relationship with normally synthesized milk proteins. The negative effect on percent of milk protein in diets containing fat was also observed by Doreau and Chilliard(1992), Elliott *et al.*(1993), and Wu and Huber (1994). In spite of the decrease in the yield of protein

increased by about 10 % in trials 2 & 4 and remained constant in trials 3 & 5. This due to the increase in milk yield at different rate in the four directly or indirectly affected periods. Steele *et al.* (1971) on feeding soybean oil as a supplement observed an increase in milk protein yield while Banks *et al.* (1976) noted a decrease.

6- Milk yield:

The animals used in the experiment were low-producing and yield about 13.2 Kg milk per day on the average when fed on a diet containing 1.52 Mcal/Kg and 14 % CP (the control diet). Adding inert fat to the diet at the rate of 400 g/ animal increased the energy density by about 1.65 % and increased the yield of milk with a starting response during the first 3 day-period of feeding in both trials 2 & 4. The increasing effect reached to a maximum after about 12 day of feeding and continued in its high level for the rest of the period (9 days). In the whole feeding period the yield reached 14.52 Kg/d on the average in trial 2 and 14.64 in trial 4 by an increase of 10 % and 11%, respectively when compared with that of trial 1 (table 7). The increase in milk yield was observed by Mattos and Palmquist (1974) with feeding full-fat soybean; Downer (1987) with Ca salts of palm oil; Jenkins and Jenny (1989) with 5% hydrogenated yellow grease and Wonsil and Herbein (1991) with 3% partially hydrogenated tallow. This may be due to the direct utilization of dietary fat by the mammary gland (Schneider *et al.*,1988) or due to the improvement of energetic efficiency (Coppock and Wilks, 1991). In contrast, Selner and Schultz (1980) , Darckley and Elliott (1993) , and Pantoja *et al.* (1994) observed no or little production response to dietary fat. This may be due to the slow initial response to supplemental dietary fat which makes production responses difficult to be detected in short-term experiments with few replications (Clapperton and Steele, 1983 and Jenkins and Jenny, 1989). The benificial effect of adding inert fat extended beyond the feeding periods although the fat addition was discontinued. The extended increasing effect continued along the whole control diet- periods starting with an increase of 13.6 % & 5.7 % (in trials 3&5) at the first 3-day periods and ending with an increase of only 3.3 % & 3.0 % at the last 3 d-periods. The continued effect of the added fat was so effective that on the average the yields were significantly different from that of the control one (trial 1). Conclusively we can say that adding fat at the rate of 400 g / animal for

3 weeks alternated with unsupplemented periods increases the yield by about 10 % during the fat-feeding period and 3 % during the rest periods.

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Table (1): Composition of the basal diet

Composition	Percent
Physical composition	
<u>Concentrate mixture</u>	
Ground shelled corn	37.33
Soybean meal (SBM)	17.46
Dicalcium phosphate	1.00
Limestone, ground	0.50
Sodium chloride	0.50
Trace-mineral mix.[#]	+
VitaminAD$_3$E premix[@]	+
Subtotal	56.79
<u>Dry roughage</u>	
Wheat straw	43.21
Total	100.00
Chemical composition*	
Crude protein (%)	14.00
NE$_1$ (Mcal/Kg)	1.52
Ether extract (%)	2.35
Calcium (%)	0.65
Phosphorus (%)	0.38

Eurovet mineral mixture added at the rate of 2 Kg/ton of diet.
@ *Agri-Vet vitamin AD$_3$E premix added at the rate of 3 Kg/ton of diet.*
**Calculated using the NRC (1988) composition tables ,on DM basis .*

Table (2):Dry matter intake (mean±SE) in cows fed, alternatively, control and fat–supplemented diets

	Trial No. & diets#				
	1 CD	2 FD	3 CD	4 FD	5 CD
Dry matter intake(Kg/d)	11.14 ± 0.46	11.09 ± 0.38	11.07 ± 0.34	11.52 ± 0.42	11.57 ± 0.39
Body weight, (Kg)	462 ± 15.90	464 ± 14.5	469 ± 14.2	472 ± 14.2	477 ± 13.5[@]
Weight gain (Kg)	2.30±0.37	5.40±0.31**	3.20±0.33	5.20±0.29**	3.00±0.37
DM % of BWt	2.41	2.39	2.36	2.43	2.43

#CD = *Control diet* , FD = *Fat-supplemented diet.* ** *Significant at P<0.01*
@ *Reached to 480 Kg at the end of the fifth trial gaining 3 Kg throughout this trial.*

Table (3): Digestibility of control and fat – supplemented diets in cows

	Trial No. & diets				
	1 CD	2 FD	3 CD	4 FD	5 CD
DM	66.57 ± 0.63	63.52 ± 1.28*	65.53 ± 0.56	65.18 ± 1.22	66.00 ± 1.10
CP	76.54 ± 0.81	67.78 ± 1.24	66.55 ± 0.47	68.09 ± 1.10	67.04 ± 0.73
CF	46.22 ± 0.91	43.46 ± 1.00*	44.64 ± 0.40	44.06 ± 0.45	45.00 ± 1.26

* Significant at P<0.05

Table (4): Ruminal pH and total volatile fatty acids (TVFA) in animals during the five feeding trials

	Trial No. & diets				
	1 CD	2 FD	3 CD	4 FD	5 CD
pH	5.95 ± 0.03	6.02 ± 0.04	5.97 ± 0.03	6.07 ± 0.04*	6.00 ± 0.02
TVFA, mM/L	110.0 ± 2.28	104.7 ± 3.82	108.3 ± 1.83	107.5 ± 3.35	111.2 ± 2.91

* Significant at P<0.05

Table (5): Effect of dietary fat addition on serum glucose level and lipid profile in cows

Serum (g/L or mg/dl)	Trial No. & diets				
	1 CD	2 FD	3 CD	4 FD	5 CD
Glucose	50.95 ± 2.65	55.46 ± 3.25	48.38 ± 2.61	53.35 ± 2.82	49.98 ± 2.47
Total lipids,g/L	2.67 ± 0.20	3.21 ± 0.23	2.95 ± 0.26	3.59± 0.23**	2.81 ± 0.19
Triglycerides	19.31 ± 1.07	29.49± 2.28**	20.80 ± 0.84	26.46±1.03**	22.06 ± 0.96
Total cholesterol	116.14 ± 5.60	128.61 ± 5.76	111.35 ± 4.55	130.69±4.39*	109.97 ± 4.48
HDL cholesterol	36.64 ± 1.85	52.86±4.08**	41.04 ± 2.11	50.62±3.19**	38.03 ± 2.38
LDL- cholesterol	75.63±3.51	69.85±3.67	66.15±4.01	74.78±2.91	67.52±3.00

* Significant at p<0.05   *** Significant at P< 0.01*

Table (6):Effect of protected fat – supplementation on the milk fat and protein content

Component	Trial No. & diets				
Fat % 3d-periods	1 CD	2 FD	3 CD	4 FD	5 CD
1	3.30±0.06	3.61±0.04**	3.55±0.49	3.53±0.05**	3.52±0.07
2	3.42±0.06	3.92±0.48**	3.36±0.05	3.85±0.05**	3.44±0.06
3	3.51±0.06	4.21±0.06**	3.42±0.05	4.13±0.07**	3.36±0.07
4	3.33±0.05	3.85±0.04**	3.38±0.05	3.93±0.04**	3.40±0.07
5	3.37±0.05	3.64±0.07	3.50±0.11	3.76±0.09	3.43±0.04
6	3.28±0.05	3.51±0.08	3.33±0.05	3.60±0.08	3.41±0.05
7	3.34±0.04	3.45±0.06	3.31±0.03	3.51±0.05*	3.42±0.06
Average (kg/d)	3.36±0.03	3.74±0.10**	3.41±0.03	3.76±0.09**	3.43±0.02*
Fat yield (kg/d)	0.444±0.005	0.544±0.010**	0.474±0.012*	0.549±0.009**	0.471±0.004*
Protein (%)#	3.09±0.04	2.97±0.05	2.99±0.05	2.92±0.06	3.03±0.04
Protein yield (kg/d)#	0.405±0.016	0.450±0.015	0.406±0.014	0.449±0.017	0.410±0.02

*# Average protein percentage and yield for composited milk sample of the last three days of each trial. * Significant at $p<0.05$ ** Significant at $P< 0.01$*

Table (7): Effect of protected fat – supplementation on milk yield in the five alternative feeding trials

3 day- periods	Trial No. & diets				
	1 CD	2 FD	3 CD	4 FD	5 CD
1	13.25 ± 0.49	14.25±0.54	15.05 ± 0.58	14.45 ±0.66	14.00 ±0.73
2	13.21 ± 0.48	14.50 ± 0.56	14.32 ± 0.49	14.73 ±0.55	13.89 ±0.60
3	13.33 ± 0.47	14.00 ± 0.58	13.93 ± 0.44	14.23 ±0.49	13.85 ±0.66
4	13.23 ± 0.46	13.67 ± 0.55	13.75 ± 0.44	13.71 ±0.60	13.76 ±0.61
5	13.17 ± 0.45	14.85 ± 0.55	13.50 ± 0.50	14.93 ±0.54*	13.64 ±0.73
6	13.05 ± 0.46	15.22 ± 0.56**	13.13 ± 0.43	15.02 ±0.47*	13.54 ±0.64
7	13.15 ± 0.46	15.14 ± 0.54*	13.58 ± 0.55	15.38 ±0.61**	13.54 ±0.57
Average (kg/d)	13.20 ± 0.03	14.52 ± 0.22**	13.89 ± 0.24**	14.64 ±0.14**	13.75±0.07*

** Significant at $p<0.05$ ** Significant at $P< 0.01$*
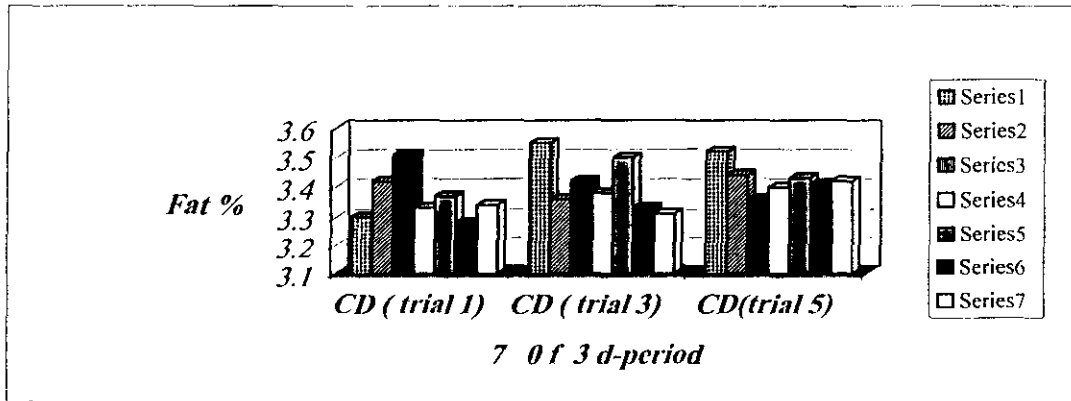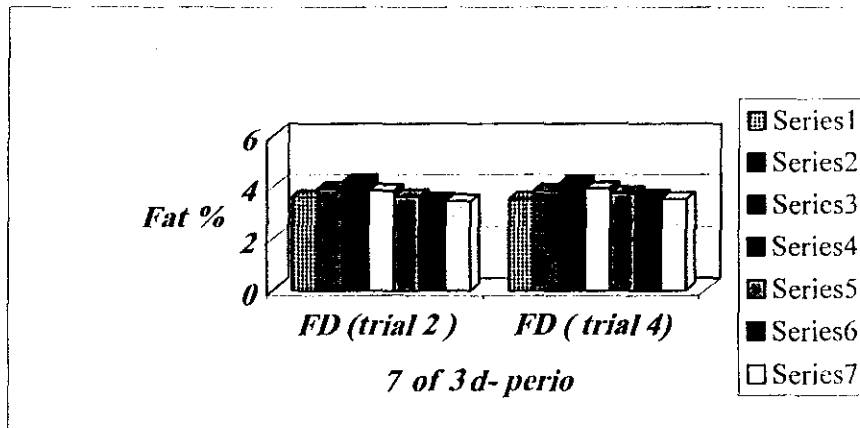
Figure (1): Fat percent of milk from cows fed on control diets during trials 3&5 preceded by fat-supplemented diets

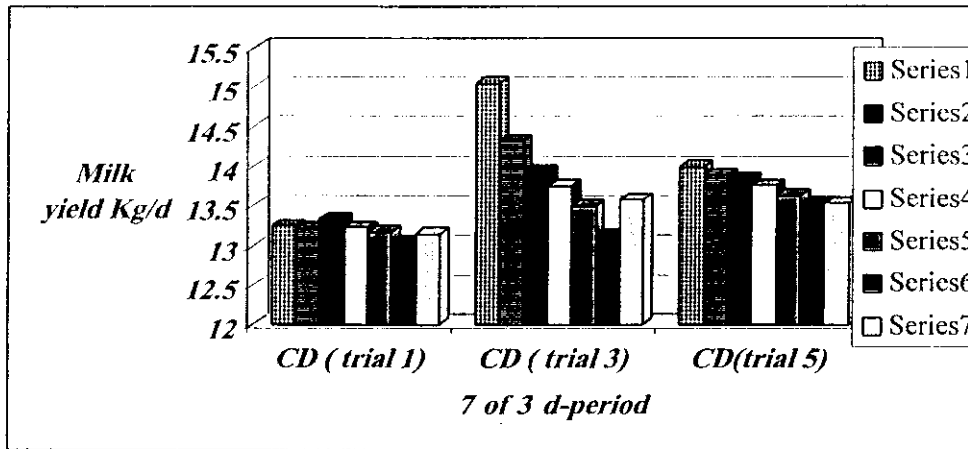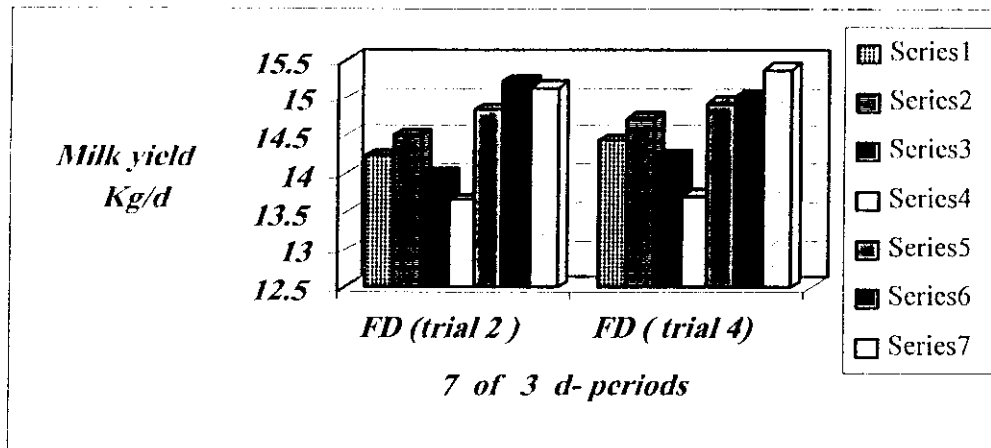*Figure(2): Fat percent from cows fed on fat-supplemented diets*

*Figure (3): Milk yield from cows fed on control diets in trials 3&5
preceded by fat-supplemented diets*

Figure(4): Milk yield from cows fed on fat-supplemented diets