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Impact of Dietary Fat Type and Amount on Growth Performance and Serum Cholesterol in Rabbits

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Abstract: Problem statement: Literature data on the effect of dietary fat on growth performance in rabbits are inconclusive. For commercial rabbit production it is relevant to know to what extent dietary fat level and type can be manipulated. In the present study serum cholesterol was also analyzed because its relation to the amount and type of dietary fat was not known for rabbits. **Approach:** Young growing rabbits were fed diets containing one of four different levels (5.2-41.8 energy %) of either coconut fat or corn oil. Fat was added to the diets at the expense of an isoenergetic amount of corn starch and dextrose in a 1:1 ratio. The diets were in pelleted form and supplied *ad libitum*. **Results:** Increasing fat intakes in the form of either coconut fat or corn oil enhanced weight gain and improved feed efficiency. The effect of coconut fat was maximal at 20.9 energy % (9.9%, w/w) and the greatest effect of corn oil was seen at an inclusion level of 41.8 energy % (20.2%, w/w). As would be expected, replacement of dietary corn oil by coconut fat significantly decreased serum cholesterol concentrations. The cholesterol-lowering effect of corn oil versus coconut fat increased markedly with higher dietary inclusion levels of fat. **Conclusion:** The addition of fat to the diet improved growth performance. It is suggested to find out whether the present observations can be applied in the formulation of diets for fryer rabbits. The new observation for rabbits is that the hypocholesterolemic response to corn oil increased with higher intake levels.

Key words: Rabbits, coconut fat, corn oil, saturated fatty acids, polyunsaturated fatty acids, growth performance, cholesterol

INTRODUCTION

The requirement of dietary fat by rabbits has been set at 2% (w/w) of a diet containing 90% (w/w) of dry matter (National Research Council, 1977). Since plant foodstuffs form the basis of rabbit diets, the recommended amount of dietary fat will provide sufficient essential fatty acids and it is likely that the absorption of fat soluble vitamins will be adequate. Fats represent a concentrated form of energy and an increase in fat will increase energy density of the diet. If an increase in dietary level does not negatively affect feed intake, it should enhance growth performance of rabbits, but an overview of six published studies showed controversial results (Beynen, 1988a). The discrepancies between the outcome of the various studies most likely is explained by different background compositions of the experimental diets, the use of different types of fat and the addition of extra fat to the diet at the expense of an equal weight of carbohydrates rather than an isoenergetic amount (Beynen, 1988a).

The isoenergetic replacement of carbohydrates by corn oil has been found to improve growth in rabbits irrespective of whether the animals were fed restricted, isoenergetic amounts of feed (Van Manen *et al*., 1989) or had free access to feed (Beynen, 1988b). After the 1988 review (Beynen, 1988a), seven more studies on fat intake and growth performance by rabbits have been published. In four studies, only the effect of the type of fat was studied (Kelley *et al*., 1988; Abdelhamid, 1989; Fernández and Fraga, 1996; Cobos *et al*., 1993) and in three studies there were multiple dietary variables in addition to fat type and level (Santomá *et al*., 1987; Egbo *et al*., 2004; Chen and Li, 2008). Maertens (1998) stated in a literature review that the addition of fat to the diet of fryer rabbits may not alter growth rates, but may favorably influence feed efficiency. This statement is based on studies with inappropriate design (Beynen, 1988a), whereas reports showing

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enhanced growth after fat addition to the diet (Beynen, 1988b; Van Manen *et al*., 1989) were not reviewed (Maertens, 1998). For commercial rabbit production it still is relevant to address the question to what extent dietary fat level and type influence growth performance when feed is freely available. Thus, we communicate a study with young growing rabbits fed *ad libitum* on diets containing different levels of either coconut fat or corn oil and we determined growth and feed intake.

The type of fat in the diet is the major determinant of serum cholesterol concentrations in humans (Kritchevsky, 2001). Replacement of saturated by omega-6 polyunsaturated fatty acids lowers serum cholesterol and formulas have been developed to predict the quantitative effects (Mensink *et al*., 2003). In spite of the vast amount of quantitative data, the mechanism by which omega-6 polyunsaturated fatty acids lower serum cholesterol remains obscure. The rabbit is often used in studies on cholesterol metabolism and in qualitative terms, the effect of dietary fat type on serum cholesterol resembles that in humans (Beynen and Katan, 1989; Kritchevsky, 1991). However, the effect of dietary fat type and level in a dose-response fashion has not been studied so that the interactions between type and level are still poorly understood (Kritchevsky, 2001). The present study on growth performance of rabbits offered the opportunity to study the effect of dietary fat amount and type on serum cholesterol concentrations. Thus, in addition to the data on growth performance, we also report the serum and liver cholesterol concentrations found in the rabbits.

MATERIALS AND METHODS

Random-bred, male rabbits of the New Zealand strain were used. The rabbits were housed individually as described earlier (Beynen *et al*., 1986, Beynen, 1988b). Food and water were provided *ad libitum*.

On arrival in the animal house, the rabbits, which were aged about 6 weeks, were maintained on commercial rabbit pellets for two weeks. Subsequently, on the basis of their body weights, the rabbits were allocated to the experimental diets given in Table 1. Each dietary group consisted of 8 animals. The diets contained four levels of either coconut fat or corn oil as fat source. Extra fat was added to the low-fat diet at the expense of an isoenergetic amount of corn starch and dextrose in a 1:1 ratio. The diets were in pelleted form.

The experimental period lasted 56 days. Body weights and feed intake were measured. One week before the beginning and at the end of the experiment, blood samples were taken from the lateral ear vein for cholesterol determination. At the end of the experiment, the rabbits were killed by cervical dislocation and cutting the carotid arteries and jugular veins. Livers were removed and weighed. Serum and liver cholesterol were analyzed as described (Yuangklang *et al*., 2005).

Table 1: Composition of the experimental diets

	Energy percentage of dietary fat[1]			
	5.2	10.5	20.9	41.8
Ingredient	**g**			
Corn oil	10	10	10	10
Coconut fat/corn oil	10/10	30/30	70/70	150/150
Corn starch	255.85	233.35	188.35	98.35
Dextrose	255.85	233.35	188.35	98.35
Constant components[2]	468.3	468.3	468.3	468.3
Total	1000	975	925	825
	kJ metabolisable energy g^{-1}			
Energy density[3]	13.7	14.0	14.8	16.6
Chemical analysis	**g/100 g**			
Crude fat	3.0	5.3	9.9	20.2
Crude protein	15.2	15.5	16.5	18.3

[1]: Percentage of metabolisable energy from fat as calculated on the basis of the ingredient composition. The following energy values for metabolisable energy were used (kJ g^{-1}): Protein, 16.5; fat, 35.8; fiber, 4.1; carbohydrates, 15.9; [2]: The constant components consisted of (g): casein, 160; molasses, 100; cellulose, 150, dicalcium phosphate, 6.1; calcium carbonate, 6.2; magnesium carbonate, 0.7; magnesium oxide, 0.3; potassium carbonate, 18.0; sodium chloride, 5.0; vitamin premix, 12.0; mineral premix, 10.0. The composition of the vitamin and mineral premix has been described earlier (Beynen *et al*., 1986); [3]: Calculated on the basis of the ingredient composition

The data were subjected to two-way ANOVA to identify statistically significant effects of fat type, fat level and the interaction between type and level. The level of statistical significance was pre-set at $p<0.05$.

RESULTS

Table 2 summarizes the observations on growth performance. Final body weights were systematically lower in the rabbits fed the diets containing coconut fat than in their counterparts fed the diets with corn oil. Increasing the level of corn oil in the diet produced a dose-dependent increase in final body weight. Between 5.2 and 20.9 energy % coconut fat in the diet, an increase in coconut fat intake raised final body weight, but there was a fall with the highest level.

The diet effects on final body weight were paralleled by those on feed intake. Increasing levels of corn oil or coconut fat in the diet raised feed intake, but only for coconut fat the highest inclusion level reduced feed intake substantially. The addition of increasing amounts of corn oil or coconut fat to the diet generally improved feed conversion, except for the highest level of coconut fat which lowered feed efficiency to a value similar to those seen on the diets with lowest fat content. The energy intake per unit of weight gain was increased for the diet with the highest level of coconut fat, but for the other three diets containing coconut fat it was similar.

Table 2: Body weights, feed intake and feed conversion in rabbits fed the experimental diets

	Energy percentage of dietary fat				
Type of fat	5.2	10.5	20.9	41.8	Significance[1]
Body weight, kg					
Day 0					
Coconut	1.69±0.05	1.66±0.05	1.72±0.05	1.69±0.04	
Corn	1.68±0.06	1.68±0.05	1.71±0.05	1.71±0.05	
Day 56					
Coconut	2.92±0.11	3.15±0.10	3.28±0.09	2.73±0.16	A, T, AxT
Corn	3.01±0.12	3.27±0.11	3.36±0.13	3.85±0.12	
Feed intake, g day^{-1}					
Coconut	85.1±4.9	99.4±4.4	100.0±3.7	72.5±4.0	A, T, AxT
Corn	94.6±5.6	103.6±5.5	107.5±6.1	116.1±4.3	
Feed conversion, g feed g^{-1} gain					
Coconut	3.88±0.08	3.73±0.07	3.59±0.06	3.92±0.13	A, AxT
Corn	3.99±0.11	3.65±0.14	3.68±0.18	3.06±0.12	
Energy conversion, kJ g^{-1} gain					
Coconut	53.2±1.10	52.2±0.98	53.2±0.89	65.1±2.16	T, AxT
Corn	54.7±1.51	60.0±1.96	54.0±2.66	50.0±1.99	

Results are expressed as means±SE for 8 rabbits per dietary group, except for the rabbits fed the 20.9 energy percentage corn-oil diet, which consisted of 7 animals. [1]: Significance was calculated by analysis of variance. A: Effect of amount of fat; T: Effect of type of fat; AxT: Effect of interaction; NS: No Significant effect of amount and type of fat

Table 3: Serum and liver cholesterol concentrations in rabbits fed the experimental diets

	Energy percentage of dietary fat				
Type of fat	5.2	10.5	20.9	41.8	Significance[1]
Serum cholesterol, mmol L^{-1}					
Day-7					
Coconut	1.54±0.10	1.51±0.08	1.57±0.10	1.52±0.11	
Corn	1.49±0.11	1.44±0.09	1.43±0.14	1.53±0.17	
Day 56					
Coconut	6.85±1.16	6.50±1.20	8.54±1.29	12.34±2.67	T, AxT
Corn	5.74±1.29	5.37±0.74	3.48±0.54	2.75±0.45	
Liver weight g					
Coconut	100.5±4.7	119.7±5.7	121.5±5.2	80.1± 10.4	AxT
Corn	118.3±9.2	116.2±9.1	86.9±4.5	114.5±11.4	
Liver cholesterol, µmol g^{-1}					
Coconut	10.01±0.59	9.27±0.90	9.06±0.77	10.79±1.48	NS
Corn	7.79±0.64	8.93±0.91	8.37±0.77	9.41±1.35	

Results are expressed as means±SE for 8 rabbits per dietary group, except for the rabbits fed the 20.9 energy percentage corn-oil diet, which consisted of 7 animals. [1]: Significance was calculated by analysis of variance. A: Effect of amount of fat; T: Effect of type of fat; AxT: Effect of interaction; NS: No Significant effect of amount and type of fat

For the diets with corn oil, energy conversion was most favorable at the highest inclusion level.

There were clear effects of dietary fat type and amount on serum cholesterol concentrations (Table 3). The feeding of corn oil instead of coconut fat at identical inclusion levels consistently reduced cholesterol concentrations. Increasing dietary levels of coconut fat raised cholesterol concentrations, whereas increasing levels of corn oil caused a dose-dependent decrease. Liver cholesterol concentrations were not affected by dietary fat type and amount.

DISCUSSION

In an earlier study, rabbits were fed different dietary levels of corn oil in diets with identical composition as those used in the present study, but they were fed restricted amounts of feed to equalize energy intake (Van Manen *et al*., 1989). In that study it was found that increased corn oil intake raised weight gain in a dose-dependent fashion up to 20.9 energy % in the diet. Because the rabbits were fed isoenergetic amounts of feed, it would appear that growth is more efficient with dietary energy in the form of fat than carbohydrates. Alternatively, it could be suggested that high fat intakes change carcass composition towards a higher protein content and thus higher water content so that body weight becomes increased. However, there is no evidence for an effect of increased fat intake on carcass composition (Beynen *et al*., 1989; Cobos *et al*., 1993; Fernández and Fraga, 1996). The present study, which was carried out under *ad libitum* conditions, also shows that increasing dietary corn oil level up to 20.9 energy % in the diet increases final body weight, but even up to 41.8 energy % weight gain was raised. Moreover, feed intake was increased in a dose-dependent fashion, but feed conversion became more favorable. Thus, high corn oil intakes most likely had promoted the efficiency of feed utilization. This effect might be related to the recent observation that a high fat intake by rabbits stimulates insulin secretion (Zhao *et al*., 2008).

This study shows a clear effect of the type of fat on growth performance. Dietary coconut fat raised final body weight up to an inclusion level of 20.9 energy %, but at the 41.8 energy % level weight gain had fallen. Feed intake showed the same pattern. Increasing intakes of coconut fat improved feed efficiency, but at the highest level feed efficiency worsened. Possibly, the high amount of coconut fat had a negative impact on palatability. The lower feed intake had increased the dietary fraction of energy used for maintenance so that the feed efficiency became less favorable. Previous studies have also shown an effect of the type of fat on growth performance. Abdelhamid (1989) found that beef tallow enhanced feed intake and growth when compared with cotton seed oil or hydrogenated palm oil. Lard versus soybean oil has been reported to lower feed intake and improve feed efficiency (Chen and Li, 2008). Likewise, butter instead of groundnut oil lowered feed intake and improved feed efficiency (Egbo *et al*., 2004). Kelley *et al.* (1988) observed greater weight gain on diets containing either safflower oil or linseed oil when compared with hydrogenated soybean oil or menhaden oil. In other studies there was no effect of fat type on growth performance (Fernández and Fraga, 1996; Santomá *et al*., 1987). Thus, taken all data together the issue of dietary fat type and growth performance in rabbits does not yet form a clear picture.

Feeding of the low-fat, experimental diets was associated with a marked increase in serum cholesterol (Table 3). This increase is explained by the hypercholesterolemic activity of the casein component in the experimental diets (Beynen *et al*., 1983). Coconut fat is rich in saturated fatty acids, lauric, myristic and palmitic acid together comprising about 70% of total fatty acids. Corn oil, on the other hand, is rich in the polyunsaturated omega-6 fatty acid, linoleic acid, the amount being about 53% of total fatty acids. The levels of palmitic and oleic acid in corn oil are about 10 and 25%. It is well-known that oils rich in linoleic acid lower serum cholesterol concentrations in rabbits, when compared with saturated fatty acids (Kritchevsky, 1991). The present data confirm that replacement of dietary corn oil by coconut fat significantly decreases serum cholesterol concentrations (Beynen and West, 1981). The new observation for rabbits is that the cholesterol-lowering effect of corn oil versus coconut fat is greater at higher dietary inclusion levels. In other words, there is a dose-response relationship between dietary fat level and serum cholesterol. Extra coconut fat above 10.5 energy percentage in the diet raised serum cholesterol, whereas extra corn oil had a lowering effect. In an extensive meta-analysis of studies in humans, Mensink *et al*. (2003) computed that serum total cholesterol will increase by 0.036 mmol L^{-1} when carbohydrates constituting 1% of dietary energy are replaced by saturated fatty acids, whereas with replacement by monounsaturated or polyunsaturated fatty acids there is a decrease by 0.006 and 0.021 mmol L^{-1}, respectively. In the rabbits, an increase in coconut fat and corn oil from 5.2-41.8 energy % increased and decreased serum cholesterol by 5.49 and 2.99 mmol L^{-1}, respectively. When assuming that coconut fat and corn oil contain 50% of saturated or polyunsaturated fatty acids as the only cholesterol-determining fatty acids, the application of the formula of Mensink *et al*. (2003) would predict an increase by 0.65 mmol L^{-1} after feeding coconut fat and a decrease by 0.38 mmol L^{-1} after feeding corn oil. At the fixed fat level of 41.8 energy %, there is a replacement of saturated by polyunsaturated fatty acids which caused a fall in serum cholesterol by 9.59 mmol L^{-1}. The predicted lowering in humans would be 1.03 mmol L^{-1}. Thus, it appears that rabbits are extremely sensitive to the cholesterolemic effect of dietary fat type. In a qualitative sense, the rabbit may be a model to study effects of dietary fats on serum cholesterol metabolism, but in quantitative terms it is not.

CONCLUSION

In conclusion, this study, in which rabbits had free access to feed, has demonstrated that increasing fat intakes in the form of either coconut fat or corn oil enhanced weight gain and improved feed efficiency. The positive effect of corn oil has also been seen earlier under conditions of restricted, isoenergetic feeding (Van Manen *et al*., 1989). The effect of coconut fat was maximal at 20.9 energy % and the maximum effect of corn oil was seen at an inclusion level of 41.8 energy %. In this study, semipurified diets were used. It would be important to see whether the present observations can be applied in practical diet formulation for fryer rabbits.

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