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PRELIMINARY TRIALS CONCERNING GROWTH AND REPRODUCTION OF RABBITS ON VARIABLE SUPPLEMENTATION OF β-CAROTENE AND VITAMIN A

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Introduction

Rabbit muscle is a source of high-quality protein, and accordingly this animal species is of growing nutritional importance. The success of intensive commercial rabbit breeding can be diminished by prolonged intervals between breeding cycles, excessive losses of does or pups, and retarded growth rates of the survivors (2). On the other hand, positive effects of vitamin A on some of these parameters are well known, particularly with regard to growth and resistance to infections. In addition it has been reported that β-carotene, a vitamin A precursor, improves reproductive performance in farm animals (1, 3). In view of these facts, and encouraged by the studies of Parigi-Bini et al. (4) we initiated some trials to study the influence of variable supplementation with β-carotene and/or vitamin A on reproduction and growth in rabbits.

Methods

A semi-synthetic diet has been formulated (see Table 1) that meets all nutritional requirements for growing rabbits except for β-carotene and vitamin A. Supplements were added to this basic diet as indicated below, then it was pelleted and analysed for β-carotene and vitamin A. Bucks utilized for insemination received a commercial rabbit chow. All animals had free access to feed and tap water.
Our tests were carried out with Swiss Hare rabbits (closed colony, outbred, Institute of Biological and Medical Research, Füllinsdorf/Switzerland). Adult animals were kept individually. Newborn pups remained with their mothers for three weeks (lactation period); they were separated from each other and used for tests when they reached a body weight of about 1 kg.

Results

Growth and reproduction (Trial 1)

Twenty female rabbits, six weeks old, were divided into a control group on the basic diet with 20,000 IUA per kg of feed and a test group on the same diet supplemented with vitamin A plus 40 mg β-carotene per kg. After 12 weeks mean body weight of the test group was 8 % higher than that of the control group (Table 2).
Comparison of these groups revealed significant differences for the final weights ($P < 0.01$, t-test) as well as for weight development throughout the experiment ($P < 0.001$, linear regression analysis).

Table 2: Influence of β-carotene supplementation on weight development. Basic diet containing 20,000 IUA per kg.

Experimental diet	Body weights in g ($\bar{x}$ ± SD) on	
	Day 0	Day 84
Control group: without β-carotene	1,100 ± 7	2,845 ± 127
Test group: 40 ppm β-carotene	1,070 ± 13	3,087 ± 83

After this experimental period of twelve weeks all rabbits were inseminated, and ten days after parturition they were inseminated again. During the whole trial they were fed the diets as outlined above, and the values in Table 3 indicate the positive influence of supplemental β-carotene on their reproductive performance.

Table 3: Influence of β-carotene on reproductive performance. Basic diet containing 20,000 IUA per kg.

Parameter (Mean values for pups)	First pregnancy		Second pregnancy	
	Control	40 ppm β-carotene	Control	40 ppm β-carotene
Animals inseminated	8	10	8	9
Animals pregnant	6	8	6	7
Pups born per litter	9.3	8.9	8.0	7.9
Pups born alive/litter	8.0	8.4	6.0	7.4
Pups surviving/litter after three weeks	6.0	7.3	3.8	6.0
Pups lost per litter after three weeks	25 %	13 %	36 %	19 %

This trial is continuing in order to evaluate the effect of β-carotene on additional breeding cycles and on pup survival during the lactation period.

Growth and vitamin A in liver (Trials 2 and 3)

These studies were conducted to test the influence of variable β-carotene supplementation on growth, feed conversion and body stores of vitamin A. Rabbits received the basic feed without vitamin A (Trial 2) or with 20,000 IUA per kg of diet (Trial 3) plus the dosages of β-carotene as indicated below.
In Trial 2, 37 weaned rabbits were kept on basic feed (with 2,000 IUA/kg) for 1-2 weeks prior to initiation of the experiment. During the next twelve weeks, groups of 4-5 animals were fed the basic diet without vitamin A but with variable β-carotene content (Table 4).

Table 4: Influence of β-carotene on growth and vitamin A levels in plasma and liver. Basic diet without vitamin A.

Parameter (Means)	β-Carotene content of diet (ppm)				
	Part A		Part B		
	4.5	9.0	20	50	100
Body weight (g)					
day 0	976	1,020	896	863	855
week 12	2,486	2,448	2,810	2,655	2,750
Weight gain (g)/day	17.8	16.8	22.8	21.3	22.6
Feed conversion	5.1	5.3	4.0	4.0	4.0
Vitamin A in plasma (IUA per litre)	2,477	2,723	3,357	2,740	3,480
Vitamin A in liver (IUA)	4,020	7,880	17,200	25,900	34,700

A control group without β-carotene was clearly vitamin A-deficient. Despite low vitamin A levels in liver (207 IUA per liver) and plasma (380 IUA per litre) all animals survived. In all groups plasma β-carotene contents were below the analytical detection limit of 20 µg per litre. Comparison of the groups on low (up to 9 ppm) and on higher β-carotene supplementation is restricted because the experiment had to be performed as two separate parts.

Trial 3 was similar to trial 2, the main difference was supplementation of β-carotene to the basic diet which contained also 20,000 IUA per kg (equivalent to 6 mg retinol per kg). 24 rabbits (6 animals per group) of both sexes were kept on these diets.

Table 5: Influence of β-carotene on growth and vitamin A levels in plasma and liver. Basic diet with 20,000 IUA per kg.

Parameter (Means)	β-Carotene content of diet (ppm)			
	0	25	50	100
Body weight (g)				
day 0	1,063	1,055	1,093	1,135
week 12	2,550	2,560	2,685	2,596
Weight gain (g)/day	17.7	17.9	19.0	17.3
Feed conversion	5.2	5.0	4.4	5.1
Vitamin A in plasma (IUA per litre)	2,357	2'767	2,803	2,693
Vitamin A in liver (IUA)	10,500	25,600	39,000	43,100

As in Trial 2 plasma β-carotene levels were below 20 µg per litre.

Discussion

These preliminary trials with rabbits demonstrated beneficial effects of β-carotene on growth rate and reproductive performance. This was evident despite a sufficient supply of vitamin A in the basic diet. Values of Trial 1 show that addition of 40 ppm of β-carotene decreased the losses of pups during the lactation period to about half the numbers as observed for the group without any dietary β-carotene.

Comparison of the results of trials 2 and 3 indicates that supplementation of both β-carotene and vitamin A had an additive effect on liver contents of vitamin A. Except for the unsupplemented group of Trial 2 with a low plasma content, plasma vitamin A levels always stayed within the same range. On the other hand, plasma β-carotene contents were consistently below the detection limit of 20 µg per litre. It appears that rabbits do not take up appreciable amounts of β-carotene, it is converted prior to absorption.

Trial 1 is continuing, and we hope to see positive effects of β-carotene on the third and subsequent breeding cycles. We will expand these investigations concerning reproductive performance in rabbits to confirm these preliminary results. In addition we shall also continue to study uptake and metabolism of β-carotene and/or vitamin A to gain insight into their physiological effects.

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Summary

Supplementation with 40 ppm of β-carotene to a diet containing 20,000 IUA per kg resulted in significantly higher growth rates for young female rabbits after 12 weeks. These animals were inseminated, and the group supplemented with β-carotene demonstrated a better reproductive performance as evidenced by higher percentages of pups born alive and of pups surviving the lactation period. A second breeding cycle with the same animals confirmed the results of the first one.

Separate trials showed that β-carotene may improve feed conversion. Increasing dietary β-carotene dosages increased liver stores of vitamin A, and feeding of both β-carotene and vitamin A had an additive effect. None of these feeding regimes changed plasma vitamin A levels while plasma β-carotene contents were always below the detection limit.

Résumé

Une supplémentation de 40 ppm de β-carotène à une ration de base contenant 20'000 UIA/kg augmente de façon significative le gain moyen quotidien de jeunes lapines pendant 12 semaines. Ces animaux furent inséminés, le groupe recevant du β-carotène démontra de meilleures performances reproductives et ceci par un plus grand pourcentage de lapereaux nés viables, ainsi que par le nombre de survivants durant la lactation. Le second cycle de reproduction avec les mêmes animaux confirma les résultats du précédant.

Des essais ultérieurs mettent en évidence l'amélioration de l'utilisation digestive dûe au β-carotène. L'augmentation progressive du dosage de β-carotène agrandi les dépots hépatiques en vitamine A, de même que l'administration simultanée de β-carotène et de vitamine A possède un effet cumulatif. Aucun de ces régimes alimentaires ne change le taux plasmatique de vitamine A tandis que le taux de β-carotène se situe constamment en dessous de la limite de détection.

Table 1: Composition of the β-carotene-free experimental diet for rabbits.

Ingredients	g per kg
Soy extract (90 %)	150
Barley (crushed)	150
Oat (crushed)	200
Straw (hydrolysed)	200
Glucose	150
Corn oil	30
Choline chloride	1
Minerals, micronutrients (1) with wheat middlings	100
Vitamins, amino acids (2) with wheat middlings	19
Digestible protein	15.7 %
Metabolisable energy	10.26 MJ
Crude fibre	14.1 %

Elements per kg of diet (1)

Ca 11.0 g, P 6.6 g, Na 3.0 g, Mg 2.5 g, Fe 150 mg, Mn 50 mg, Zn 22 mg, Cu 5 mg, J 0.53 mg, Mo 0.21 mg, Co 0.3 mg, Se 0.15 mg.

Vitamins per kg of diet (2)

Vitamin E	40	IU
Vitamin D_3	500	IU
Vitamin K_3	5	mg
Vitamin B_1	20	mg
Vitamin B_2	20	mg
Vitamin B_6	20	mg
Vitamin B_{12}	0.04	mg
Ca-D-pantoth.	20	mg
Folic acid	10	mg
Biotin	0.5	mg
Niacin	200	mg
L-Methionine	3	g

Analyses of pelleted diet: < 1,000 IU vitamin A per kg
< 0.1 mg β-carotene per kg

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A basic diet for growing rabbits has been formulated which meets the requirements of carbohydrates, protein, fat, fiber and all vitamins, except ß-carotene (<0.1 mg/kg) and vitamin A (<1'000 IUA/kg).
In trial 1, 20 female rabbits were fed the basic ration supplemented with 20'000 IU vitamin A/kg and divided into a control group (C) without ß-carotene and a test group (T) with 40 mg ß-carotene/kg feed. Initial weights were similar but after 12 weeks T had 8% higher body weights than C ($P<0.01$). These rabbits were then inseminated. Conception rate was 80% in group T and 75% in group C. Mean litter size at parturition was 8.9 pups (8.4 alive) for T and 9.3 pups (8.0 alive) for C. ß-carotene administration increased the survival rate of the pups born alive, during the first 3 weeks 13% of group T and 25% of group C died.
In trial 2, young rabbits of both sexes were fed the basic feed supplemented with 2'000 IUA/kg. When they reached a body weight of about 1 kg, they were divided into groups and fed diets without vitamin A but supplemented with 4.5, 9.0, 20 or 50 mg ß-carotene/kg. After 12 weeks daily growth rates ranged from 17.8 g to 22.6 g (4.5 vs 50 ppm of ß-carotene) while feed conversion improved from 5.06 to 4.0.
In trial 3, young rabbits of both sexes were given the basic ration with 20'000 IUA and 0, 25, 50 or 100 mg ß-carotene/kg. After 12 weeks, liver and plasma vitamin A were analysed. Addition of 100 ppm of ß-carotene increased vitamin A liver contents from 10'500 IU/liver to 43'000 IU/liver.

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ETUDES PRELIMINAIRES CONCERNANT LA CROISSANCE ET LA REPRODUCTION DE LAPINS EN FONCTION DE DOSAGES VARIABLES DE ß-CAROTENE ET DE VITAMINE A

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Une ration de base pour la croissance couvrant les besoins en matière protéique digestible, hydrate de carbone, matière grasse, cellulose brute et vitamines à l'exclusion du ß-carotène (<0.1 mg/kg) et de vitamine A (<1000 IU/kg) a été utilisée.

1ère Expérience: 20 lapines femelles ont reçu la ration de base complétée par 20'000 UIA/kg et ont été reparties respectivement en un groupe contrôle (C) sans ß-carotène et un groupe test (T) supplémenté par 40 mg de ß-carotène/kg. La moyenne pondérale de départ était similaire, à 12 semaines celle du groupe T était de 8% supérieure à celle du groupe C (P<0.01). Ces lapines furent inséminées, le pourcentage de conception était de 80% pour le groupe T et de 75% pour le groupe C. Le nombre de lapereaux par portée à la naissance était en moyenne de 8.9 (8.4 vivants) pour T et de 9.3 (8.0 vivants) pour C. L'apport de ß-carotène réduit les pertes en jeunes durant les 3 semaines de lactation respectivement de 25% pour le groupe C à 13% pour groupe T.

2ème Expérience: Des jeunes lapins mâles et femelles ont été repartis en groupes avec la ration de base sans vitamine A mais complétée par 4.5, 9.0, 20 ou 50 mg de ß-carotène/kg. A 12 semaines le gain moyen quotidien variait de 17.8 g à 22.6 g (4.5 vs 50 ppm de ß-carotène) tandis que le rapport fourrage ingéré/gain de poids par jour s'améliorait de 5.06 à 4.0.

3ème Expérience: La ration de base complétée par 20'000 IUA/kg et supplémentée de 0, 25, 50, 100 mg de ß-carotène/kg a été administrée à de jeunes lapins des deux sexes. Après 12 semaines le taux de vitamine A du plasma sanguin et du foie a été déterminé. L'adjonction de 100 ppm de ß-carotène accroît le taux de vitamine A du foie de 10'500 UI à 43'000 UI.