Proceedings 5th World Rabbit Congress, 25-30 July 1992, Corvallis – USA, 1225-1234.

INTERACTIONS OF FERMENTABLE CARBOHYDRATE AND PROTEIN ON NUTRIENT DIGESTIBILITY, PERFORMANCE AND ENTERITIS IN WEANLING RABBITS

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Abstract

Six feed ingredients were analyzed for chemical components and used for computer ration formulation of four diets which contained low fermentable carbohydrate and low protein (LFC-LP), low fermentable carbohydrate and high protein (LFC-HP), high fermentable carbohydrate and low protein (HFC-LP) and high fermentable carbohydrate and high protein (HFC-HP). The low fermentable carbohydrate (LFC) diets contained no corn while the high fermentable carbohydrate (HFC) diets contained 33.4% corn. The low protein (LP) diets contained 16% crude protein (CP) while the high protein (HP) diets contained 22% CP. The diets were fed to 60 weanling New Zealand White rabbits randomly allotted to each diet with 15 rabbits per diet during a 28 day digestion and performance trial. Digestibilities of dry matter (DM), organic matter (OM) and gross energy (GE) were higher for the HFC diets than for the LFC diets irrespective of protein levels, indicating that rabbits are good digesters of starch. Between the LFC diets digestibilities of DM, OM and GE were higher for the LFC-HP diet than for the LFC-LP diet, indicating that the adverse effect of low protein on nutrient digestibility was more pronounced at LFC levels. Digestibility of fiber (ADF) was higher for the HP diets than for the LP diets, suggesting that dietary fiber utilization in rabbits could be enhanced with increased dietary protein levels. Average daily gain (ADG) was higher for the HP diets than for the LP diets and also higher for the LFC-LP diet than for the HFC-LP diet. Feed intake (FI) was higher for the LFC diets than for the HFC diets, with the highest FI observed for the LFC-HP diet and the least observed for the HFC-LP diet. These indicate that rabbits eat to meet their energy needs and that their FI is related to their dietary protein levels. The HFC-HP diet was most efficient for the rabbits. Mortality from enteritis was in the order: LFC-LP > HFC-LP = HFC-HP > LFC-HP, indicating that, although LFC diets may be protective against enteritis, they should be coupled with a HP level to be effective and that HFC diets would promote rabbit enteritis to a similar extent irrespective of dietary protein level. There was an inverse relationship between

fermentable carbohydrate level and OM and ADF intake. Growth rate was correlated with digestible energy intake and the protein/kcal ratio.

Introduction

The various dietary factors associated with incidence of enteritis in rabbits has been described by Cheeke (1987). High fiber (acid detergent fiber, ADF) diets provide bulk, stimulate motility and avoid prolonged cecal retention time, thereby having a protective effect against enteritis. Low fiber diets result in cecal-colonic hypomotility, prolonged retention time and enteritis due to dysbiosis. High fermentable carbohydrate (mainly starch) diets result in carbohydrate overload of the hindgut which may enhance the growth of pathogens such as E. coli and Clostridium species and thus promote the incidence of enteritis. Diets that are low in readily available carbohydrate are usually high in fiber, avoid carbohydrate overload and have a protective effect against the incidence of enteritis. High protein diets result in a high cecal ammonia level which increases cecal pH and may increase the growth of Clostridium species which cause enteritis. Diets that are low in protein result in low cecal ammonia level and might have a protective effect against enteritis.

The objective of this study was to evaluate the interrelationships between the levels of fermentable carbohydrate and protein fed to weanling rabbits on their performance, nutrient digestibility and the incidence of enteritis.

Materials and Methods

Six feed ingredients (alfalfa meal, wheat mill run, soybean meal, yellow dent corn, almond hulls and annual ryegrass straw) were ground through a Wiley mill (20-mesh screen) and analyzed for dry matter (DM), crude protein (CP) and ash as described by the Association of Official Agricultural Chemists (AOAC) (1975). ADF was determined by the method of Van Soest (1963) as described in the modified micro-procedure of Waldern (1971). Cell wall constituents and cell contents (CC) were determined by the method described by Van Soest and Marcus (1964). Organic matter (OM) was determined by correcting for ash content. Chemical components of the various ingredients (Table 1) were programmed into the computer and used for computer ration formulation of four diets which contained (a) low fermentable carbohydrate and low protein (LFC-LP), (b) low fermentable carbohydrate and high protein (LFC-HP), (c) high fermentable carbohydrate and low protein (HFC-LP) and (d) high fermentable carbohydrate and high protein (HFC-HP). The low fermentable carbohydrate diets were formulated with no corn while the high fermentable carbohydrate diets contained 33.4% corn. The low protein diets were formulated to contain 16% crude protein while the high protein diets were formulated to contain 22% crude protein.

Table 1. Chemical composition of the major ingredients used in computer ration formulation of the various experimental diets.

	Ingredient					
Ryegrass Item	Alfalfa Meal	Wheat Mill Run	Soybean Meal	Corn (Yellow Dent)	Almond Hulls	Annual Straw
Dry matter (DM, %)	92.2	90.7	90.1	90.1	91.7	93.6
Organic matter (OM, %)	83.1	85.0	83.0	88.8	82.7	87.8
Analysis, % of DM:						
Crude protein (CP)	18.7	18.8	53.7	9.5	6.3	3.6
Acid detergent fiber (ADF)	34.1	13.4	7.0	3.2	37.2	51.3
Cell content (CC)	55.7	58.1	91.8	85.0	56.2	21.8
Ash	9.1	5.7	7.1	1.3	9.0	5.8

Table 2. Ingredient composition of the experimental diets.

	Diet (% DM Basis)			
Item	Low Fermentable Carbohydrate-Low Protein (LFC-LP)	Low Fermentable Carbohydrate-High Protein (LFC-HP)	High Fermentable Carbohydrate-Low Protein (HFC-LP)	High Fermentable Carbohydrate-High Protein (HFC-HP)
Alfalfa meal	9.9	9.9	9.9	9.9
Wheat mill run	68.3	56.7	21.7	3.1
Ryegrass straw	1.0	1.6	9.8	10.3
Almond hulls	9.8	5.0	5.0	5.0
Cane molasses	6.0	6.0	6.0	6.0
Corn	-	-	33.4	33.4
Soybean meal	-	15.7	8.8	26.4
Vegetable oil	2.9	3.1	3.4	3.9
Limestone	1.5	1.4	-	-
Dicalcium phosphate	-	-	1.4	1.4
Vitamins	.3	.3	.3	.3
Trace minerals	.3	.3	.3	.3

The experimental diets were pelleted and fed ad libitum to 60 weanling New Zealand White rabbits (5 weeks old, average weight 1046.7 g) allotted at random to 4 treatments with 15 rabbits per treatment during the 28 day experimental period. The ingredient and chemical composition of the experimental diets are shown in Tables 2 and 3, respectively. The experimental animals were kept in individual cages equipped with automatic waterers. Live weight of each animal was recorded on days 1, 21 and 28, respectively. Mortality records were kept. All dead animals were kept at 5° C and taken to the Oregon State University Veterinary Diagnostic Laboratory for necropsy within 24 h of death. Fecal collection screens were attached to the bottom of each cage during the fourth week and total daily feces voided by each animal during this period were kept in labelled plastic bags at 5° C. Grab samples (about 100 g) of each experimental feed were collected during each feeding and kept in air-tight polythene bags. Sub-samples of each experimental diet were mixed together, ground in a Wiley mill (20-mesh screen) and kept in covered plastic containers for further analysis. Cumulative fecal samples of each experimental animal were dried in an oven at 60° C for 48 h, ground and kept in similar manner as the feed samples. The experimental feeds and feces were analyzed for DM, CP, ash, ADF, CC and OM as described previously. Gross energy (GE) was determined using a Parr adiabatic oxygen bomb calorimeter. Digestion coefficients for components of each diet were determined by methods described by Schnelder and Flatt (1975). Data for the digestion and performance trial were analyzed using the general linear models procedure and means were compared by the Student-Newman-Keul's test as outlined by Steel and Torrie (1980).

Results and Discussion

The % digestibilities for components of the experimental diets are shown in Table 4. Digestibilities of DM, OM and GE were higher (P<.05) for the high fermentable carbohydrate diets than for the low fermentable carbohydrate diets irrespective of protein levels, indicating that rabbits are good digesters of starch. There were no differences (P>.05) in the digestibilities of DM, OM and GE between the HFC-LP and the HFC-HP diets. However, DM, OM and GE digestibilities were higher (P<.05) for the LFC-HP diet than for the LFC-LP diet, indicating that the adverse effect of low protein on nutrient digestibility was more pronounced at a low dietary starch level. The % CP digestibility was lower (P<.05) for the LFC-LP diet than for the other diets with no differences (P>.05) among the other diets. The % digestibility of ADF was generally higher (P<.05) for the high protein diets than for the low protein diets, irrespective of starch levels. This suggests that dietary fiber utilization in rabbits could be enhanced with increased dietary protein levels. However, the low fiber levels of the various diets (<16% ADF) and the low % ADF digestibilities (<27%) make these results less meaningful. Low fiber digestibility is typical in rabbits (Cheeke, 1987). The % cell content digestibility was higher (P<.05) for the high fermentable carbohydrate diets than for the low fermentable carbohydrate diets, irrespective of protein levels, which further indicated that rabbits are good digesters of starch. The % digestibility of ash was generally higher (P<.05) for the high fermentable carbohydrate diets than for the low fermentable carbohydrate diets. Between the low fermentable carbohydrate diets, the % ash digestibility was higher (P<.05) for the LFC-HP diet than for the LFC-LP diet.

Performance data are shown in Table 5. Average final live weight of the animals was lower (P<.05) for the HFC-LP diet than for the other diets with no differences (P>.05) among the other diets. Average daily gain (ADG) was higher (P<.05) for the high protein diets than for the low protein diets, indicating that dietary protein level plays a major role in the growth rate of rabbits. ADG was also higher (P<.05) for the LFC-LP diet than for the HFC-LP diet. Feed intake (FI) of the experimental animals was generally higher (P<.05) for the low fermentable carbohydrate diets than for the high fermentable carbohydrate diets. The highest FI was observed for animals on the LFC-HP diet while those on the HFC-LP diet consumed the least. These indicate that rabbits eat to meet their energy needs and that their feed consumption is affected by dietary protein levels. Feed conversion (FC) was higher (P<.05) for animals on low protein diets than for those on high protein diets, irrespective of fermentable carbohydrate levels, with no difference (P>.05) between those on the LFC-LP and HFC-LP diets. Between the high protein diets, FC was higher (P<.05) for animals on LFC-HP diet than for those on HFC-HP diet. The lowest FC value was obtained from animals on HFC-HP diets, indicating that it was the most efficient for weanling rabbits among the experimental diets. The % mortality of the experimental animals was in the order: LFC-LP > HFC-LP = HFC-HP > LFC-HP. All dead animals died within the first 14 days of the experiment. Necropsy findings showed that the animals died of enteritis. The highest mortality (43.8%) was recorded for animals on the LFC-LP diet, while the lowest mortality (18.8%) was recorded for animals on the LFC-HP diet. The results indicate that although low level of fermentable carbohydrate may have a protective effect against rabbit enteritis, it should be coupled with high dietary protein level to be effective and that high level of fermentable carbohydrate in rabbit diets would promote enteritis to a similar extent, irrespective of the dietary protein level.

Average daily intakes of individual chemical components of the experimental diets (dry basis) are shown in Table 6. Daily intakes of OM, ADF and ash by the animals on the various diets generally ranged in the order: LFC-HP = LFC-LP > HFC-HP = HFC-LP (P<.05), indicating an inverse relationship between the level of fermentable carbohydrate in the diet and consumption of these components. Daily intake of CP was higher (P<.05) for the high protein diets than for the low protein diets. Between the high protein diets, daily CP consumption was higher (P<.05) for the LFC-HP diet than for the HFC-HP diet. Daily CP consumption was also higher (P<.05) for the LFC-LP diet than for the HFC-LP diet. Thus, daily intake of CP by the experimental animals was a reflection of a combination of factors which include (a) dietary CP level, (b) feed consumption and (c) dietary fermentable carbohydrate level. Daily intake of CC was lower (P<.05) for animals on the HFC-LP diet than for those on the other diets with no difference (P>.05) among the other diets. The lower value observed for animals on the HFC-LP diet was a reflection of the unusually low DM consumption of animals on this diet (Table 5). Thus, the CC represents the most uniformly consumed chemical component. This indicates that rabbits eat to meet their CC needs. The fact that the CC level of the various diets (Table 3) varies between 61.9% (LFC-LP) and 71.1% (HFC-HP) makes the inference more meaningful. Daily intake of GE was generally higher (P<.05) for the low fermentable carbohydrate diets than for the high fermentable carbohydrate diets with no difference (P>.05) between the low fermentable carbohydrate diets. Between the high fermentable carbohydrate diets, GE intake was higher (P<.05) for the HFC-HP diet than for the HFC-LP diet. It should be pointed out that daily

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Table 3. Chemical composition of the experimental diets.

	Diet			
Item	Low Fermentable Carbohydrate-Low Protein (LFC-LP)	Low Fermentable Carbohydrate-High Protein (LFC-HP)	High Fermentable Carbohydrate-Low Protein (HFC-LP)	High Fermentable Carbohydrate-High Protein (HFC-HP)
Dry matter (DM, %)	89.5	89.6	89.5	89.5
Organic matter (OM, %)	81.0	81.1	82.9	82.7
Gross energy (GE, kcal/g)	4.5	4.6	4.6	4.6
Analyses, % of DM:				
Crude protein (CP)	16.4	22.0	15.7	21.6
Acid detergent fiber (ADF)	15.5	13.7	13.5	12.9
Cell contents (CC)	61.9	65.2	67.4	71.1
Ash	8.5	8.5	6.6	6.8

Table 4. Digestibility (%) of individual components of each diet by the experimental animals.

	Diet			
Component	Low Fermentable Carbohydrate-Low Protein (LFC-LP)	Low Fermentable Carbohydrate-High Protein (LFC-HP)	High Fermentable Carbohydrate-Low Protein (HFC-LP)	High Fermentable Carbohydrate-High Protein (HFC-HP)
Dry matter (DM)	64.0^{a}	67.3^{b}	73.2^{c}	74.4^{c}
Organic matter (OM)	64.1^{a}	67.2^{b}	73.6^{c}	74.8^{c}
Crude protein (CP)	69.2^{a}	75.5^{b}	76.0^{b}	77.9^{b}
Acid detergent fiber (ADF)	20.0^{a}	26.8^{b}	19.1^{a}	22.9^{a,b}
Cell content (CC)	84.8^{a}	84.6^{a}	88.5^{b}	87.3^{b}
Ash	60.3^{a}	64.8a^{b}	66.3^{b,c}	67.7^{c}
Gross energy (GE)	64.5^{a}	68.6^{b}	74.0^{c}	75.4^{c}

^{a,b,c} Means in the same row with different superscripts differ ($P < .05$).

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Table 5. Selected data on performance characteristics of experimental animals.

Item	Diet			
	Low Fermentable Carbohydrate-Low Protein (LFC-LP)	Low Fermentable Carbohydrate-High Protein (LFC-HP)	High Fermentable Carbohydrate-Low Protein (HFC-LP)	High Fermentable Carbohydrate-High Protein (HFC-HP)
Avg. initial live wt., g	1092.2	1027.4	1069.3	997.9
Avg. final live wt., g	1954.4[b]	2121.5[b]	1721.1[a]	2037.7[b]
Avg. live daily gain, g	30.8[b]	39.1[c]	23.3[a]	37.1[c]
Avg. daily feed intake, g (dry wt. basis)	97.8[b,c]	105.9[c]	73.2[a]	87.9[a,b]
Avg. feed conversion, g feed/g gain (dry wt. basis)	3.6[c]	3.0[b]	3.5[c]	2.7[a]
Mortality (%)	43.8	18.8	31.3	31.3

[a,b,c] Means in the same row with different superscripts differ ($P<.05$).

intake of GE among the experimental diets was less uniform than daily intake of CC despite the fact that the GE content of the diets (Table 3) was more uniform than the CC content. These indicate that feed consumption in rabbits reflects the need to meet their CC requirements more than the need to meet their GE requirements.

Selected data on protein and energy values of the experimental diets are shown in Table 7. The digestible crude protein (DCP) content of the diets was higher ($P<.05$) for the high protein diets than for the low protein diets with no difference ($P>.05$) associated with dietary fermentable carbohydrate level. The digestible energy content (DE) of the diets was higher ($P<.05$) for the high fermentable carbohydrate diets than for the low fermentable carbohydrate diets with no difference ($P>.05$) between the HFC-LP and HFC-HP diets. Between the low fermentable carbohydrate diets, DE content was higher ($P<.05$) for the LFC-HP diet than for the LFC-LP diet. Average daily digestible crude protein intake (DCPI) and the protein:energy ratio (P:E) for the animals ranged in the order: LFC-HP > HFC-HP > LFC-LP > HFC-LP ($P<.05$). The average daily digestible energy intake (DEI) was higher ($P<.05$) for animals on the LFC-HP diet than for those on HFC-LP diet. Between the low fermentable carbohydrate diets, DEI was higher ($P<.05$) for animals on the LFC-HP diet than for those on the LFC-LP diet. DEI was also higher ($P<.05$) for animals on the LFC-HP diet than for those on the LFC-LP diet. DEI was also higher ($P<.05$) for animals on the HFC-HP diet than for those on the HFC-LP diet.

Table 6. Daily consumption of individual chemical components of each diet by the experimental animals (g dry basis).

	Diet			
Chemical Component	Low Fermentable Carbohydrate-Low Protein (LFC-LP)	Low Fermentable Carbohydrate-High Protein (LFC-HP)	High Fermentable Carbohydrate-Low Protein (HFC-LP)	High Fermentable Carbohydrate-High Protein (HFC-HP)
Organic matter (OM)	79.2^{b}	85.9^{b}	60.7^{a}	$72.7^{a,b}$
Crude protein (CP)	16.0^{b}	23.3^{d}	11.5^{a}	19.0^{c}
Acid detergent fiber (ADF)	15.2^{b}	14.5^{b}	9.9^{a}	11.3^{a}
Cell content (CC)	60.5^{b}	69.1^{b}	49.4^{a}	62.6^{b}
Ash	8.3^{b}	9.0^{b}	4.8^{a}	6.0^{a}
Gross energy (GE, kcal)	$440.7^{b,c}$	491.0^{c}	336.5^{a}	405.5^{b}

^{a,b,c} Means in the same row with different superscripts differ ($P < .05$).

Table 7. Selected data on protein and energy values of the experimental diets.

	Diet			
Item	Low Fermentable Carbohydrate-Low Protein (LFC-LP)	Low Fermentable Carbohydrate-High Protein (LFC-HP)	High Fermentable Carbohydrate-Low Protein (HFC-LP)	High Fermentable Carbohydrate-High Protein (HFC-HP)
Digestible crude protein content of diet (g/kg)	113.5^{a}	166.1^{b}	119.2^{a}	168.1^{b}
Digestible energy content of diet (kcal/kg)	2905^{a}	3181^{b}	3400^{c}	3478^{c}
Avg. daily digestible crude protein intake (g)	11.0^{b}	17.5^{d}	8.7^{a}	14.6^{c}
Avg. daily digestible energy intake (kcal)	$282.9^{a,b}$	336.0^{c}	247.9^{a}	$303.6^{b,c}$
Protein:energy ratio (mg digestible crude protein/ kcal digestible energy)	39.1^{b}	52.2^{d}	35.0^{a}	48.3^{c}

^{a,b,c,d} Means in the same row with different superscripts differ ($P < .05$).

Growth rate was correlated with energy intake (Fig. 1) and with the protein/kcal ratio (Fig. 2). The protein/kcal ratio in the HFC-LP diet was too low to support normal growth; the optimal ratio is about 50 mg CP/kcal DE (de Blas et al., 1981; Cheeke, 1987). With the HFC-LP diet, energy intake was limited by the protein deficiency, accounting for the lower DE intake of this group (Table 7).

Conclusions

This study provided useful information about the interrelationships between levels of fermentable carbohydrate and protein in rabbit diets on performance and incidence of enteritis. Although rabbits eat to meet their energy requirement, this requirement is in part determined by protein intake. When protein is deficient, energy is not consumed in excess of that required for protein synthesis. Low dietary protein in rabbits reduces performance and nutrient digestibility which is more pronounced at a low fermentable carbohydrate level. These results show that although low levels of fermentable carbohydrate may have a protective effect against rabbit enteritis, it should be coupled with high dietary protein to be effective and that high levels of fermentable carbohydrate in rabbit diets would promote enteritis to a similar extent, irrespective of dietary protein level.

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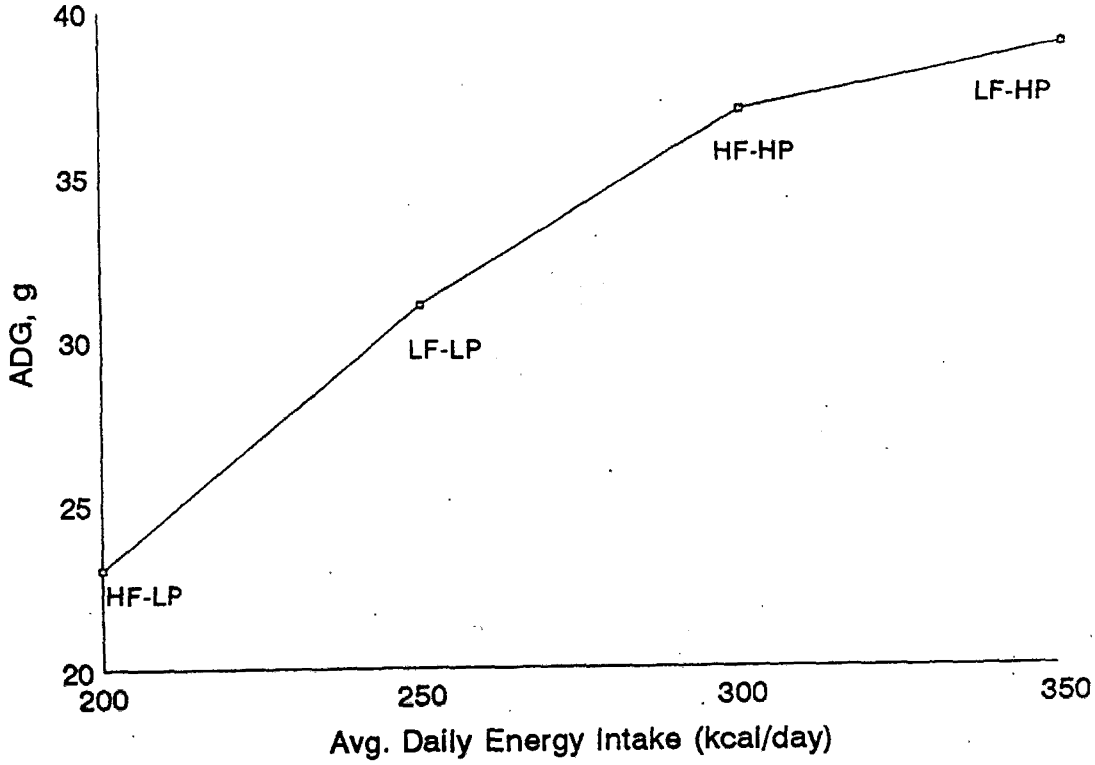

Fig. 1. Growth rate by energy intake.

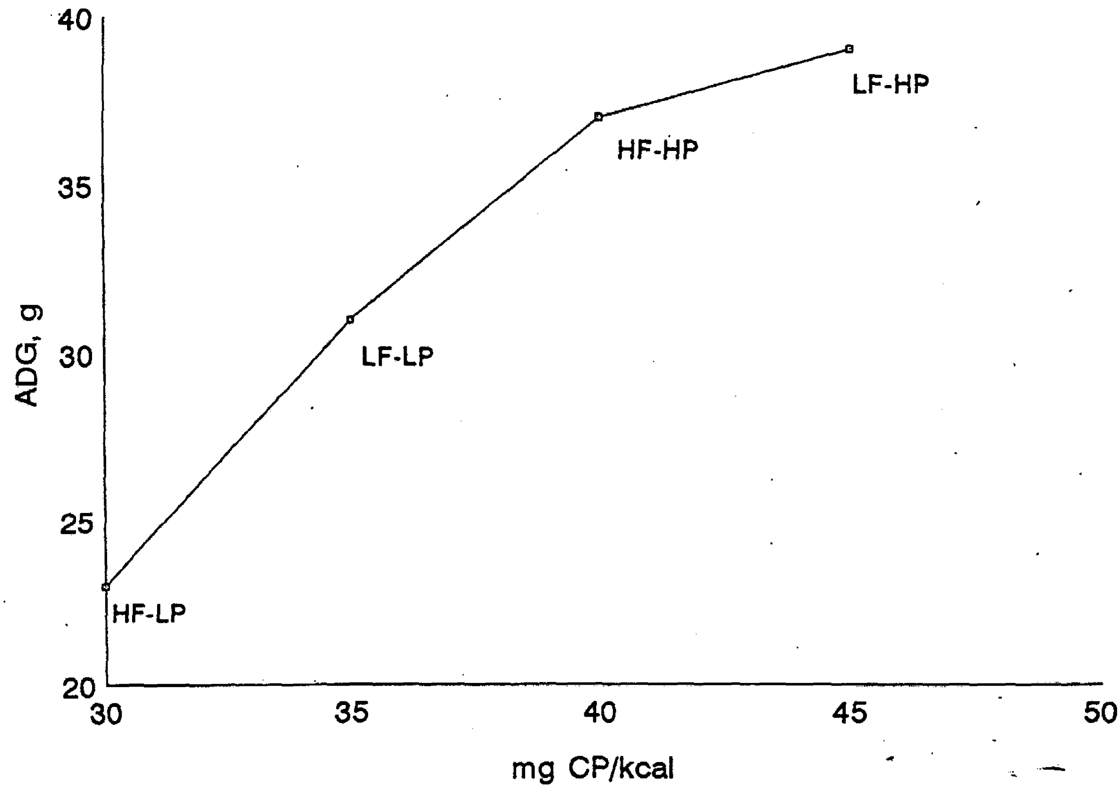

Fig. 2. Growth rate by protein/kcal ratio.