Journal of Animal and Feed Sciences, 8, 1999, 483 – 495

Effect of dietary concentration of crude protein and Synovex-C on skeletal growth of dairy heifers

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(Received 25 May 1999; accepted 7 October 1999)

ABSTRACT

Eighteen prepubertal Israeli-Holstein heifers were used in an experiment to study the effects of protein supplementation and implantation of Synovex-C on body weight gain (BWG), skeletal size and age at puberty. Heifers were allocated to three treatment groups as follows: 1. heifers received a diet that was formulated according to NRC (1989; Control) recommendations. 2. heifers received the same diet fed to heifers on treatment 1 except that the diet was supplemented with 3.3% maize gluten meal (MGM) during the first 6 months and with 2.5% MGM during the next 3 months 3. heifers received the same diet fed to heifers on treatment 2 and were implanted with Synovex-C. Supplementation of MGM to the diet enhanced BWG during the first 183 d of the experiment. The implantation of Synovex-C enhanced BWG only during the first 92 d of the experiment. From d 93 to 281, BWG of heifers on treatment 3 was reduced, and, by the end of the experiment, the BW of these heifers tended to be lower than of heifers on treatment 2. Supplementation of MGM to the diet enhanced growth rates of the wither and hip during the first 281 of the experiment. However, implantation of Synovex-C eliminated the effect of supplemented MGM, and, towards the end of the experiment, withers and hip heights of heifers on treatment 3 were lower than those of heifers on treatment 1. Implantation of Synovex-C was associated with increased serum IGF-1 during the first 150 d of the experiment and with reduced age and wither height at puberty.

KEY WORDS: heifers, undegradable protein, Synovex-C, skeletal growth

INTRODUCTION

Replacement heifers contribute to a large proportion of the total cost of milk production (Heinrichs, 1993), and delay of first calving has an impact on total

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costs. However, calving at an early age may result in reduced milk production during the first lactation and increased incidence of dystocia (Foldager and Sejrsen, 1991; Sejrsen 1994; Hoffman, 1997). Body weight (BW) at first calving was found to be positively correlated with primiparous milk production (Hoffman, 1997). Although BW and wither height (WH) are closely correlated (Heinrichs and Hargrove, 1987; Heinrichs et al., 1992), the correlation between WH and primiparous milk production was higher than that observed between yield and BW (Heinrichs and Hargrove, 1987; Heinrichs et al., 1992; Markusfeld and Ezra, 1993). Compensatory growth of heifers was found to be limited (Ryan, 1990; Barash et al., 1994 a,b; Radcliff, 1997). Implantation of Synovex-C in 3-months-old beef heifers significantly enlarged their pelvic area before calving and tended to reduce calving difficulties (Deutscher et al., 1991; Rusk et al., 1992). An increase in CP concentration by 2% between the ages of 3 and 12 months resulted in an increased BW and WH of heifers (Amos, 1986; Kertz et al., 1987). Rates of BW gain (BWG) and nitrogen retention in steers treated with estrogenic growth promoters were enhanced as metabolisable energy (ME) and crude protein (CP) intake increased (Rumsey and Hammond, 1990).

The goal of the present experiment was to study the effect of an increase in dietary CP by 2% above NRC (1989) recommendations and of the implantation of Synovex-C, during the prepubertal period on BWG and skeletal size of Israeli-Holstein heifers.

MATERIAL AND METHODS

Heifers and treatments

Eighteen Israeli-Holstein heifers (87±4 d of age; 109.7±4.1 kg of BW) were allocated to three treatment groups according to their BW, age, and WH. The treatments were as follows: 1. the heifers were fed a diet formulated according to NRC (1989; Table 1) (Control), 2. the heifers were fed the same diet as treatment 1, supplemented with 3.3% maize gluten meal (MGM; 60% CP) for the first 6 months to increase the CP concentration by 2% and, with 2.5% MGM for the next 3 months to increase CP concentration by 1.5%. 3. The heifers were fed the same diet as treatment 2, and were implanted with a slow-release preparation of Synovex-C (100 mg of progesterone plus 10 mg of estradiol benzoate; Syntex, Palo Alto, CA). Implantation was carried out according to the manufacturer instructions in the right ear.

Heifers were housed in the shade, each group in a separate pen. After 8 d of adaptation, the experimental diets were offered, and Synovex-C pellets were implanted. Diets were given collectively to experimental groups and the heifers had

TABLE I

Ingredients and chemical composition of control diet[1], g/kg

Ingredients	Age, months				
	3 to 6	6 to 9	0 to12	13 to 15	16 to 22
Barley grain, cracked	28	-	-	-	280
Sorghum grain	50	-	-	-	-
Maize grain, cracked	158	-	-	-	-
Whole cottonseed	105		-	-	-
Wheat bran	-	-	-	-	87
Soyabean meal	74	88	40	-	155
Cottonseed meal	24	-	-	-	-
Rapeseed meal	24	-	-	-	-
Vetch hay	-	-	250	527	-
Wheat straw	-	-	-	-	190
Wheat hay	34	190	-	184	-
Maize silage	316	715	700	289	-
Pea silage	20	-	-	-	-
Orange peels	110	-	-	-	30
Cottonseed hulls	21	-	-	-	240
Urea	1.4	-	-	-	8
Dicalcium phosphate	4	4	4	4	4
Ground limestone	14	-	-	-	-
Salt, minerals and vitamins[2]	20	4	4	4	4
Chemical composition					
crude protein	160	119	117	118	119
acid detergent fibre	194	264	264	328	315
neutral detergent fibre	315	481	449	499	478
ME[3], Mcal/kg	2.83	2.5	2.36	2.26	2.26

[1] diet formulated according to NRC (1989)

[2] containing 16 x 10^6 IU of vitamin A, 3.2 x 10^6 IU of vitamin D, 16 x 10^6 IU of vitamin E, 48 g of Mo, 48 g of Zn, 48 g of Fe, 19.2 g of Cu, 3.4 g of I, 0.32 g of Co, and 0.48 g of Se

[3] metabolisable energy

free access to feed and water. Diets were offered every day at 08.30 h and residuals were collected every other day.

Heifers were weighed weekly during the first 9 months of the experiment and then every 2 weeks until calving. The WH, hip height (HH), and body condition score of the heifers were determined once monthly.

Blood was withdrawn from the jugular vein using heparinized vacutainers and centrifuged at 2000 g for 10 min, and the plasma was separated and stored at -20°C until analysis. For progesterone determination, blood samples were collected weekly from 4 months of age until puberty.

Blood for insulin, IGF-1, and total thyroxin analyses was sampled on d 30, 150, 280 and 430 of the experiment. The blood was taken at 08.40, 09.00, 09.20 and 09.40 h. The blood was left to coagulate at room temperature (25°C) for 30 min, cooled with ice, kept for 6 h at 5°C, and subsequently centrifuged at 2000 g for 20 min. The serum was separated and stored at -20°C until analysis.

Analyses

The chemical composition of the diets was determined according to the AOAC (1970). Radioimmunoassays were employed for the determinations of hormones using commercial kits. Progesterone was determined using Coat-A-Count® (DPC, Los Angeles, CA, USA), insulin was determined using INSIK-5® (Sorin Biomedica, Salluggia, Italy), total thyroxin was determined using Coat-A-Count®, and IGF-1 was determined using NR:53065® (INCSTAR, Stillwater, MN).

Statistical procedure

Data for BW, WH and HH were analyzed using the repeated measurement approach according to the GLM procedure of SAS (1988). Overall analyses of covariance of repeated measurements type were carried out with the measurement at t_0 as covariant. It was followed by separate analyses of covariance for each time. Differences among treatment means were tested by Student Neyman - Keuls (SNK) test. Data for the hormone concentrations in the serum and age, BW, and WH at puberty were analyzed using ANOVA (SAS, 1988). Statistical difference was determined at $P<0.10$.

RESULTS AND DISCUSSION

Body weight and skeleton measurements

The BW, WH and HH of the heifers during the experimental period are presented in Table 2 and Figure 1. BWG of heifers on treatment 2 during the first 6 months of the experiment was greater than that of heifers on treatment 1 and their BW became 31.6 kg heavier than the BW of heifers on treatment 1 ($P<0.01$). This difference persisted until the end of the experiment 10.5 months later ($P<0.07$; Figure 1a). The WHG of heifers on treatment 2 was greater than that of control heifers during the first 9 months of the experiment, and WH at d 281 was 2.9 cm more than of the control heifers ($P<0.01$; Table 2). This difference persisted until the end of the experiment 7.5 months later ($P<0.10$; Figure 1b). The pattern of increase in HH for heifers on control and treatment 2 was similar to the increase in WH noted for these heifers during the whole experimental period, although significant differences were found only during the first 9 months of the experiment (P<0.02; Table 2 and Figure 1c). The positive response of BWG and WHG of heifers in the present experiment to an elevated CP concentration is in agreement with the findings of Bagg et al. (1985) and Kertz et al. (1987). Positive effects on heifers BWG and WHG were reported also for diets containing above 16% CP of which 50% was undegradable intake protein (Amos, 1986; Tomilinson et al., 1990, 1991; Casper et al., 1994).

TABLE 2

Body weight (kg), and wither and hip heights (WH and HH) (cm) of heifers during the experimental period

Days on experiment	Treatment[1] 1	2	3	SEM	P > F
Body weight, kg					
initial	111.0	111.2	110.3		
92	192.5[b]	202.8[ab]	210.2[a]	13.4	0.08
183	261.7[b]	293.3[a]	296.5[a]	15.7	<0.01
281	331.8	365.7	350.0	41.2	NS[d]
393	409.2	439.3	429.3	28.3	NS
503	482.8[b]	521.5[a]	504.7[ab]	26.0	0.07
Wither height, cm					
initial	88.6	88.5	89.0		
92	102.3	104.0	101.7	2.02	NS
183	111.5[b]	114.3[a]	110.8[b]	1.85	0.02
281	118.4[b]	121.3[a]	116.6[c]	1.29	<0.01
393	123.5[b]	126.4[a]	122.1[b]	2.87	0.08
503	128.5[ab]	131.2[a]	126.7[b]	3.18	0.10
Hip height, cm					
initial	92.5	94.5	93.0		NS
92	107.6	109.3	106.6	1.47	NS
183	117.3[b]	120.7[a]	117.0[b]	1.74	0.04
281	122.0[b]	127.8[a]	123.3[b]	2.40	0.02
393	128.1	131.2	128.9	2.85	NS
503	132.6	135.3	131.8	3.26	NS

[a,b,c] – means within a row without a common super script differ according to P value given d – P>0.1

[1] the heifers were fed a diet formulated according to NRC (1989). 2, The heifers were fed the same diet as treatment 1, supplemented with 3.3% CGM for the first 6 months and, with 2.5% CGM for the next 3 months 3. The heifers were fed the same diet as treatment 2, and were implanted with a slow-release preparation of Synovex-C

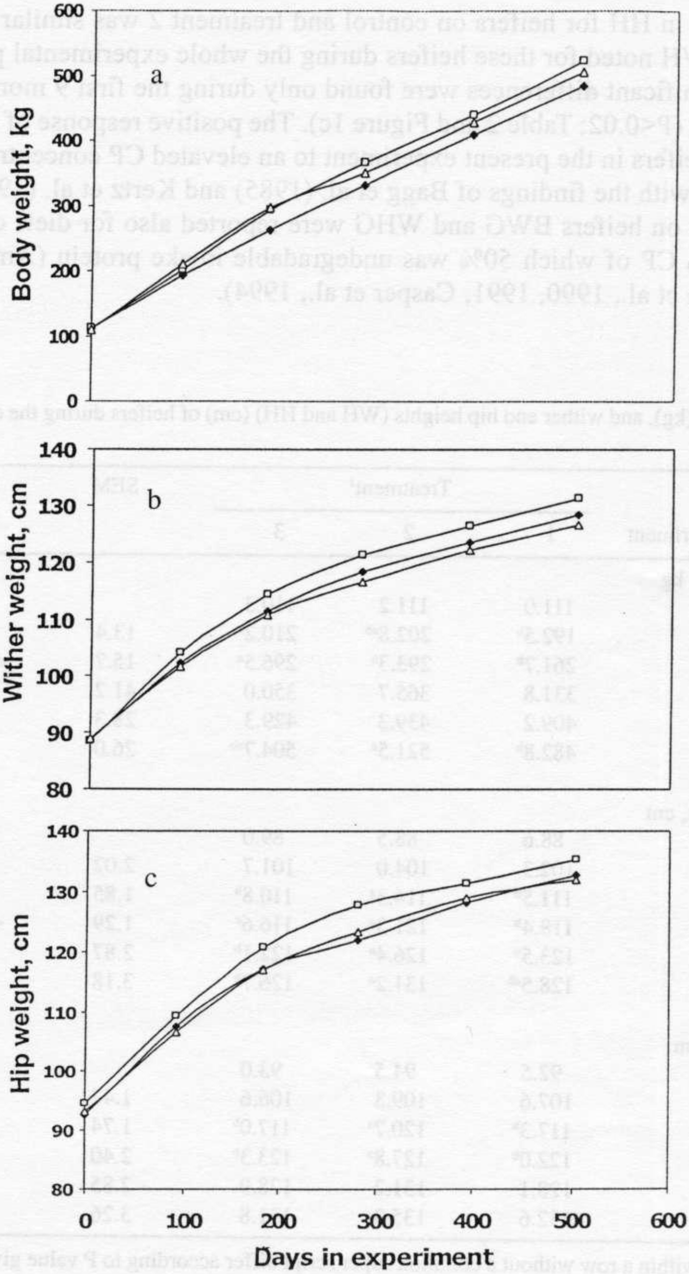

Figure 1. The effect on body weight (a), wither height (b) and hip height (c) of heifers fed a control diet (♦) or the control diet supplemented with protein (□) or heifers fed the control diet supplemented with protein and implanted with Synovex-C (Δ), during experimental period

Heifers on treatment 3 had a different pattern of BWG, WHG, and HH gain (HHG) than did heifers on treatments 1 and 2 (Table 2 and Figure 1). During the first 3 months of the experiment they gained 99.9 kg, whereas heifers on treatments 1 and 2 gained 81.5 kg and 91.6 kg, respectively ($P<0.08$; Table 2). From this time until the end of the experiment, the BWG of heifers on treatment 3 slowed down in comparison with that of heifers on treatment 1 and 2, and heifers on treatments 1, 2, and 3 gained 221.2, 228.2, and 208.2 kg, respectively (Table 2 and Figure 1a). At the end of the experiment the BW of heifers on treatment 3 was lower than that of heifers on treatment 2 ($P<0.1$). The WH of heifers on treatment 3 was significantly lower than that of heifers on treatment 2 and tended to be lower even than that of control heifers (Table 2 and Figure 1b). During the 16.5 months of the experiment, WHG for heifers on treatment 1, 2, and 3 was 39.9, 42.7, and 37.7 cm, respectively ($P<0.10$; Table 2). The pattern of HHG for heifers on treatment 3 was similar to their pattern of WHG. HH of heifers on treatment 3 were significantly lower than that of heifers on treatment 2 only on day 183 and 281 of the experiment (Table 2) but tended to be so during the whole experimental period (Figure 1c). Accordingly, at the end of the experiment, the HHG for heifers on treatment 1, 2, and 3 were 40.1, 40.8, and 38.8 cm, respectively.

The positive effect of Synovex-C on the BWG of heifers during the first 92 d of the experiment is in agreement with previous findings (Roch and Quirke, 1986; Madar et al., 1992). The repression of BWG starting 92 to 183 d after the implantation of Synovex-C is consistent with results from our previous study in which the withdrawal of the growth promoter Cimaterol was followed by a repression in BWG (Barash et al., 1994b). The inhibitory effect of Synovex-C on the WHG and HHG observed in the present experiment is in agreement with the report of Russel et al. (1995), regarding a dose-dependent inhibition of estrogen implantation on longitudinal growth of ovariectomized rats and mice. The inhibitory effect is also consistent with additional studies (Russel et al., 1995) that have shown that estrogen administration during early postnatal and prepubertal periods resulted in the shortening of the limbs of rats. When Synovexc-C was implanted to Charolais and Salers steers and heifers, the length of the metacarpus of the implanted steers was shorter and that of the heifers was similar as compared with the control ones (Hardt et al., 1995).

It can be concluded that supplementation of growing heifer diet with undegradable protein above NRC (1989) recommendations, enhances their skeletal growth rate. Likewise, the pattern of BWG and skeletal growth of heifers treated with Synovexc-C is different than that of heifers on treatment 2 that were fed with supplemental CP only. This indicates that nutritional and hormonal treatments can affect differently BWG and skeletal growth, and the rate of BWG does not mean always a similar skeletal growth rate.

Feed intake and efficiency

The efficiencies of dietary metabolisable energy (ME) and of CP for BWG are presented in Table 3. No statistical analysis was carried out because feed intake was determined for groups and not individually. During the first 6 months of the experiment additional CP and Synovex-C implantation tended to improve the efficiency of dietary ME utilisation for BWG. During the next 3 months of the experiment Synovex-C implantation tended to reduce the efficiency of dietary ME and of dietary CP utilisation for BWG, as compared to treatments 1 and 2. Positive effects of increased dietary protein concentration and degradability and of carbohydrate structure on feed efficiency for BWG of Holstein and Jersey heifers, have already been reported (Amos, 1986; Tomilinson et al., 1990, 1991). This combination of carbohydrates and proteins from a diversity of sources is probably an important factor of the effect of dietary protein on the growth of heifers as presented by Hoffman (1997). The high efficiency of dietary ME and CP conversion to BWG by heifers implanted with Synovex-C is in agreement with the results obtained for steers and heifers implanted with estrogenic growth promoters (Rumsey and Hammond, 1990; Rusk et al., 1992). Interestingly the synchronization between the transient severe retardation in BWG and the reduction in the efficiency of ME and of CP intake for BWG occurred between d 184 and 281 of the experiment. In a previous study, Barash et al. (1994b) reported on a transient severe retardation in BWG and feed efficiency for BWG after the β-agonist Cimaterol was withdrawn from the diets of growing heifers. The combination of retardation in BWG after Cimaterol withdrawal, without change in normal feed consumption was found to create a fattening situation (Hanrahan et al., 1988; Williams, 1988).

TABLE 3

Dry matter intake (DMI) and efficiency of metabolisable energy (ME) and crude protein (CP) intakes for body weight gain (BWG) during the experimental periods

		Treatment[1]		
Days on experiment		control	high CP	high CP + S
0 to 92	DMI, kg/d	4.7	4.7	4.8
	ME intake/BWG	15.0	13.3	12.5
	CP intake/BWG	0.85	0.85	0.79
93 to 183	DMI, kg/d	5.7	5.9	6.1
	ME intake/BWG	18.8	14.8	15.8
	CP intake/BWG	0.89	0.82	0.88
184 to 281	DMI, kg/d	6.5	6.5	6.5
	ME intake/BWG	21.4	20.8	28.1
	CP intake/BWG	1.06	1.23	1.67

[1] see footnote in Table 2

Puberty attainment

Results of age, BW and WH at puberty attainment are presented in Table 4. Heifers on treatment 2 attained puberty 15.1 d earlier than did control heifers with no significant difference in WH (Table 4). Similar results were obtained by Radcliff et al. (1997), as high-CP, high-energy diet increased BWG and decreased age at puberty but had no effect on WH at puberty. The implantation of Synovex-C to heifers on treatment 3 induced earlier puberty by 38.1 d as compared with the control heifers ($P<0.08$), and their WH was shorter by 4.5 cm ($P<0.08$). In previous studies it was shown that age and BW at puberty attainment could fluctuate and that the determinant factor for puberty initiation is probably the rate of fattening (Peri et al., 1993; Barash et al., 1994 a,b). The earlier puberty attainment of treatment 3 was probably a result, of a combination of retardation in BWG with normal feed consumption which induced a fattening situation (Hanrahan et al., 1988; Williams, 1988), enough for puberty initiation. Earlier attainment of puberty at the age of 3 months was reported also for Angus calves implanted with Synovex-C (Rusk et al., 1992). A retardation in the rate of gain of wither and hip heights after pubertal attainment is shown in Figure 1b and c. It supports the idea that enhanced skeletal growth could be better induced before pubertal attainment.

Implantation of Synovex-C was accompanied by a transient enlargement of the udder. To quantify this effect, the distance between the right rear teat and the udder base of the heifers on d 115 of the experiment was determined. The mean teat length of heifers on treatments 1, 2, and 3 was $2.3^{B}\pm0.28$, $2.8^{B}\pm0.40$ and $5.0^{A}\pm0.43$, respectively ($P<0.01$). This difference in teat and udder size disappeared during the next 6 months.

Serum hormones

Concentrations of insulin, IGF-1 and total thyroxin in the serum of heifers at d 30, 150, 230 and 430 are presented in Table 5. Insulin concentration of heifers on treatment 2 was higher than that of control heifers only on d 430 ($P<0.08$). Maize gluten meal supplied to heifers on treatment 2 tended to increase serum IGF-1 concentration during d 150 and 180, as compared with control heifers (Table 4). The advantage in WH gained during this period was maintained until the end of the experiment, at the age of 19.5 months. A positive effect of dietary CP concentration on plasma concentration of IGF-1 in steers was reported (Elsasser et al., 1988). Serum IGF-1 concentration of heifers on treatment 3 was significantly higher than of control heifers on d 30 and 150 of the experiment. This result is in agreement with the positive effect of estradiol-17β on the IGF-1 concentration in steers (Breier et al., 1987). An increase in plasma estradiol-

17β concentration as a consequence of Synovex-C implantation in calves was found by Castree et al. (1988). No significant effect of the treatments on the total serum T_4 concentration was noted (Table 4).

TABLE 4

Age, body weight and wither height (WH) of the heifers at puberty

	Treatment[1]				
	control	high CP	high CP + S	SEM	P > F
Age, d	249.6 [a]	234.5 [ab]	211.7[b]	10.7	0.08
BW, kg	266.8	255.5	241.8	11.1	NS[c]
Withers height, cm	109.6 [a]	110.2[a]	105.1[b]	1.5	0.08

[a,b] – means within a row without a common super script differ according to P value given c – P>0.1
[1] see footnote in Table 2

TABLE 5

Blood insulin, IGF-1, and total thyroxin concentrations (±SE) of the experimental heifers

	Treatment[1]			SEM	P > F
Days on experiment	1	2	3		
Insulin, μU/ml					
30	7.75	8.68	7.81	0.619	NS[c]
150	11.77	12.60	10.37	1.246	NS
280	18.25	18.41	18.88	2.243	NS
430	14.77[b]	19.43[a]	16.49[ab]	1.409	0.08
IGF-1, nmol/l					
30	15.56[b]	15.78[b]	19.43[a]	0.866	0.03
150	13.91[b]	15.80[ab]	17.27[a]	0.892	0.05
280	14.02	16.98	16.13	0.984	NS
430	14.49	15.00	15.11	0.874	NS
Total thyroxin, μg /100ml					
30	5.92	5.82	5.27	0.368	NS
150	5.96	7.06	6.59	0.368	NS
280	6.07	6.42	6.24	0.298	NS
430	5.19	5.80	5.78	0.321	NS

[a,b] – means within a row without a common super script differ according to P value given c – P > 0.1
[1] see footnote in Table 2

CONCLUSIONS

The present data suggest that increasing dietary CP:energy ratio above NRC (1989) recommendations in diets for replacement heifers during the period from 3 to 9 months of age, enhanced BWG and skeletal growth rate without affecting the age of puberty attainment. Implantation of the growth promoter Synovex-C to 3-months-old heifers enhanced BWG but reduced skeletal growth rate. Likewise, it induced an earlier puberty attainment. The use of Synovex-C for replacement heifers might be reconsidered. It is assumed that enhanced skeletal growth could be better induced before pubertal attainment.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the technical assistance of Channa Lehrer and Moshe Nikbachat.

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STRESZCZENIE

Wpływ poziomu białka ogólnego w dawce i dodatku Synovexu-C na rozwój szkieletu u jałówek rasy mlecznej

W doświadczeniu przeprowadzonym na 18 jałówkach izraelskich holsztynów, nie dojrzałych płciowo, badano wpływ dodatku białka i implantu Synovex-C na przyrostu masy ciała (BWG), rozwój szkieletu i wiek osiągnięcia dojrzałości płciowej. Jałówki podzielono na 3 grupy i żywiono następująco: 1. dawka ułożona wg norm NRC (1989; kontrolna); 2. taka sama dawka, jak w grupie 1, lecz z dodatkiem 3,3% mączki z glutenu kukurydzianego (MGM), podawana w ciągu pierwszych 6-ciu miesięcy i z dodatkiem 2,5% MGM, przez następne 3 miesiące; 3. dawka jak w grupie 2, lecz z implantowanym preparatem Synovex-C.

Dodatek MGM do dawki zwiększał BWG w ciągu pierwszych 183 dni doświadczenia. Implantacja Synovexu-C zwiększała BWG tylko w ciągu pierwszych 92 dni doświadczenia. Przyrosty masy ciala jałówek grupy 3 od 93 do 281 dnia były niższe, podobnie jak i przy końcu doświadczenia; stwierdzono przy tym tendencję do mniejszej masy ciała w porównaniu z jałówkami grupy 2. Dodatek MGM do dawki zwiększał tempo wzrostu mierzonego w kłębie i biodrach w ciągu pierwszych 281 dni doświadczenia, a implantacja preparatu Synovex-C eliminowała ten wpływ tak, że w końcu doświadczenia wysokość w kłębie i biodrach jałówek grupy 3 była mniejsza niż jałówek grupy 1. Implantacja Synovex-C powodowała zwiększenie poziomu IGF-1 w surowicy krwi w pierwszych 150 dniach doświadczenia oraz obniżenie wieku i wysokości w kłębie przy osiągnięciu dojrzałości płciowej.