Biological Agriculture and Horticulture, 1992, Vol. 8, pp. 325–337
0144-8765/92 $10

The Influence of Biologically and Conventionally Cultivated Food on the Fertility of Rats

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ABSTRACT

Biologically and conventionally grown products of the same variety, obtained from neighbouring farms, were compared for their influence on the fertility of two groups of laboratory rats up to the third generation. Group A was fed with biologically cultivated food and group B with conventionally cultivated food. This investigation included a comprehensive analytical programme. Any nutritional deficiencies were compensated for so that, according to analytical standards, the diets were of equal nutritional quality.

The following parameters were examined: pregnancy rate, birth weight and weekly weight gain of the offspring, rearing performance, weight development of the female rats after birth and during lactation.

There was no significant difference in the pregnancy rate between the two test groups.

The average litter weight was mostly higher in group A than in group B, but not significantly so.

There were significantly fewer perinatally dead offspring in the biologically fed group.

The biologically fed females displayed a much greater capacity to compensate weight loss during and after lactation. Their weight gain was significantly higher than in the conventionally fed group.

INTRODUCTION

During recent decades a number of feeding experiments have successfully demonstrated a favourable effect of biologically cultivated products on the vital power of different test animals as indicated by fertility and health (Pfeiffer, 1969; Aehnelt & Hahn, 1973; Gottschweski, 1975; Edelmüller, 1984; Staiger, 1986; Plochberger, 1989). These authors have been instrumental in establishing feeding experiments as the standard method to test the influence of farming systems on the nutritional quality of agricultural products.

This indirect comparison of systems in which only the effects on living organisms are observed naturally involves a great number of interacting factors. It is not the aim of such experiments to investigate all influences separately, but to judge a system as a whole. Yet efforts at least to limit unpredictable side effects are desirable. The test products must be comparable with regard to variety, soil type, climate, ripeness and storage conditions but differentiated by criteria involving biological versus conventional farming methods.

The difficulty in maintaining stable experimental conditions is the weak point in this type of investigation and has given rise to criticism. At the same time we must consider the fact that we are dealing with living systems exposed to intricate and sometimes uncontrollable influences.

On the other hand it is not satisfactory to describe and judge living systems by analyzing dead matter, even if this approach removes the above-mentioned difficulties. It is well known that the nutritional quality of a product not only depends on the maximum content of a specific useful component but on the optimal distribution of all useful components and their availability to the living organism.

In order to overcome the shortcomings of both types of investigations a combination of analytical and holistic methods is proposed.

In the present feeding experiment with rats, all test foods were chemically analyzed. Based on these analytical results, minerals, trace elements and vitamins were added to the food mixture according to the nutritional needs of laboratory rats, thus avoiding excessive supply and preventing deficiencies. The results obtained from three generations of rats are presented.

MATERIALS AND METHODS

The test animals were laboratory rats (Long Evans strain). Each female was allowed to have two litters. The first mating took place at the age of 16 weeks, the second one 8 weeks later. The pups were weaned after 28 days. Rats from the first litters were chosen at random to establish the next generation. The animals were kept in Makrolon size III (2 females) and size IV cages (4 males) at 24 ± 1°C and 55–60% humidity. A day/night rhythm of 12:12 hours was simulated.

For mating each pair of rats was kept in a Makrolon cage size III for one week. Then the males were returned to their cages in groups of four, and the females stayed on in the mating cage alone for the time of pregnancy and suckling until weaning took place. The rats were divided into two groups, each consisting of 20 pairs. Group A was fed with biologically cultivated products, group B with conventionally grown ones. The products dated from the 1987 and 1988 harvests.

TABLE 1

Biological and conventional cultivation details.

	Biological	Conventional
First year		
Fertilization	700 kg rock-powder compost and biodynamic compost and preparations green manure	540 kg P-K (15:30) 720 kg N-P-K (6:12:24) 50 kg P 100 kg K_2O 38% chloride 550 kg P-K (15:30) 200 kg N-$CaCO_3$ (28:26)
Weed control	Mechanical (hoeing and hand hoeing) crop rotation spraying with silicate	2 l 2.4D 4 l dinoseb acetate 5 l alachlor + antracine 0.75 l metribuzin 3 l bentazone acetate 2 kg linuron
Fungicides and insecticides	none	1 l dinocap
		Ha-Te 4c against game damage
Second year		
Fertilization	10 tons horse-pig-dung green manure compost	N-P-K (60kg:48kg:48kg) N-P-K (80kg:56kg:56kg) P-K (50kg:100kg) 400 kg P-K (15:30) 350 kg N-B (26:4)
Weed control	Mechanical (hoeing and hand hoeing) crop rotation	3 l 2.4 dichlorprop 1.5 l cyanazine 1.5 l MCPB-acetate 300 kg pirimicarb 50% 5 l alachlor 0.75 l metribuzin 3 l bentazone 480g/l 4 kg chloridazon 80%
Fungicides and insecticides	none	none

All amounts are given /ha

The cultivation details are given in Table 1.

The test foods consisted of the following components:

Oats (*Avena sativa* L.)	11.2%
Barley (*Hordeum vulgare* L.)	25.9%
Soya beans (*Glycine max.* L.)	22.2%
Field peas (*Pisum avense* L.)	25.9%
Carrots (*Daucus carota* L.)	7.4%
Common beets (*Beta vulgaris* L.var. crassa)	7.4%

TABLE 2

Chemical analyses of the food mixture (dry components)

	1987 (biol.)	1987 (conv.)	1988 (biol.)	1988 (conv.)
raw protein (%FW)	17.6	19.9	19.2	18.1
crude fibre (%FW)	6.4	5.9	6.3	6.4
raw oil (%FW)	6.7	6.5	5.9	5.7
raw ash (%FW)	3.5	3.3	3.5	3.6
N-free extractive substance (%FW)	56.7	55.7	65.1	66.2
water content (%FW)	9.1	8.8	8.2	8.2
dry matter (%)	90.9	91.2	91.8	91.8
P ($mgPO_4$/100g)	1628	1644	1443	1513
Na (mg/100g)	3.6	4	18.9	19.4
K (mg/100g)	1079	1091	1112	1220
Ca (mg/100g)	61.6	61.4	98.3	108
Mg (mg/100g)	160	160	168.5	187.9
Mn (mg/100g)	4	3.8	2	2.4
Fe (mg/100g)	13.3	11.2	7.6	8.6
Zn (mg/kg)	32	31	34.3	44.5
Cu (mg/kg)	7.2	5.9	17.5	19.9
Pb (mg/kg)	0.3	0.3	0.3	0.3
Cd (mg/kg)	0.04	0.04	0.5	0.6
Ni (mg/kg)	—	—	3.1	4.5
Cr (mg/kg)	—	—	1.3	1.8
vitamins (content/kg)				
Biotin μg	169	150	181	157
Thiamine-HCl mg	8.21	8.43	13.8	13.1
Riboflavin mg	3.75	3.7	2.99	2.31
Pyridoxol-HCl mg	1.3	1.3	0.86	0.93
Niacin mg	28.8	32	29.2	39.5
Folic acid mg	0.64	0.59	0.45	0.52
Pantothenic acid mg	10.7	10.1	10.4	9.41
Vitamin D2 IE	3980	smaller than 1000—not traceable		
Choline mg	1930	2000	1700	1210
Vitamin E-complex mg: alpha-Tocopherol-acetate	13.7	16	7.2	10
alpha-Tocopherol	12.4	14.5	6.6	9.16
Vitamin K1 μg	199	193	20.9	29.7
Chlorinated hydrocarbons (mg/kg)				
Hexachlorbenzol		less than 0.001		
alpha-Hexachlorcyclohexane		less than 0.001		
beta-Hexachlorcyclohexane		less than 0.001		
Lindane	0.004	0.003	0.002	0.003
Heptachlor/Heptachlorepoxide		less than 0.001		
Aldrin/Dieldrin		less than 0.002		
Endrin		less than 0.003		
DDT + DDD + DDE + isomeres		less than 0.003		

biol.: biologically cultivated; conv.: conventionally cultivated.
FW—fresh weight.

TABLE 3

Chemical analyses of the fresh products.

	1987 (biol.)	1987 (conv.)	1988 (biol.)	1988 (conv.)
Carrots				
Crude protein (%DW)	7.4	9.2	8.1	7.1
Crude fibre (%DW)	7.9	8.6	9	8
Raw oil (%DW)	0.7	1.4		
Raw ash (%DW)	8.6	10.2	10	7.5
N-free extractive substance (%DW)	75.4	70.6		
H_2O-content (%DW)	89.6	88.3	90.5	89.8
Dry matter (%) (%DW)	10.4	11.7	9.5	10.2
Na (mg/100g)	261.4	717.7	169	295
K (mg/100g)	2472	2095	3020	2540
Ca (mg/100g)	264	301.5	280	296
Mg (mg/100g)	122.5	141.5	117.5	99
Mn (mg/100g)	2.5	3	1.03	0.82
Fe (mg/100g)	6.3	3.6	3.9	3.8
P ($mgPO_4$/100g)	980	1010	974	791
Zn (mg/kg)	—	—	18.9	15.25
Cu (mg/kg)	—	—	10.25	8.85
Cd (mg/kg)	—	—	0.5	0.5
Ni (mg/kg)	—	—	1.25	1.85
Cr (mg/kg)	—	—	1.1	1.4
Glucose (mg/gDM)	219.45	144.64	148	68
Fructose (mg/gDM)	182.74	117.01	128	80
ß-Carotin mg/kg FW	170	225	—	—
Common beets				
Crude protein (%FW)	9.5	3.4	11	12.2
Crude fibre (%FW)	6.2	5.8	9.7	8.8
Raw oil (%FW)	0.3	0.2		
Raw ash (%FW)	5.9	5.2	14.7	14
N-free extractive substance (%FW)	78.1	85.4		
H_2O-content (%FW)	85.9	84	92.6	91.9
Dry matter (%) (%FW)	14.1	16	7.4	8.1
Na (mg/100g)	377.1	219.5	393	335
K (mg/100g)	2070	1438	2660	3360
Ca (mg/100g)	136.5	100	107.5	125
Mg (mg/100g)	228	144	119	151
Mn (mg/100g)	8.3	2.6	2.3	3.5
Fe (mg/100g)	7.6	4.2	7.2	8.7
P ($mgPO_4$/100g)	480	370	683	662
Zn (mg/kg)	—	—	32.4	34.3
Cu (mg/kg)	—	—	14.5	13.9
Cd (mg/kg)	—	—	0.5	0.6
Ni (mg/kg)	—	—	1	1.15
Cr (mg/kg)	—	—	1.25	1.2
Glucose (mg/gDM)	33.06	8.41	90	74
Fructose (mg/gDM)	16.57	2.79	16	15

biol.: biologically cultivated; conv.: conventionally cultivated.
DW—dry weight; FW—fresh weight; DM—dry matter.

To inactivate the trypsin inhibitor, the soya beans were toasted before pelleting. After chemical analyses of all products, vitamins, minerals and trace elements were added if needed, according to Meyer *et al.* (1977), Köhler *et al.* (1978) and Baker *et al.* (1979). Tables 2 and 3 show the results of the chemical analyses; Table 4 lists the additions to the food mixtures. The dry ingredients were ground, mixed and pressed into pellets. Pellets and water were offered *ad libitum*; raw carrots and common beets were apportioned daily.

Methods of Investigation:

The following data were obtained from three generations (F1, F2, F3) comprising two litters each:

1—pregnancy rate;
2—birth weight and weekly weight gain of the offspring;
3—rearing proportion;
4—weight gain or loss of the females during and after lactation.

RESULTS

The consumption of pellets was measured, but no difference was found between the groups (female rats consumed about 120 g, males about 130 g weekly). The fresh products, raw carrots and common beets were offered in specific amounts (180 g carrots and 130 g common beets weekly per animal).

TABLE 4

Additions to the food mixtures

Food mixture 1987	
Vitamin B12 (0.1%)	14 g each
NaCl (cattle salt) iodated (40% Na)	1.8 kg each
$CaCO_3$ (lime) (36% Ca)	6.65 kg each
Manganese oxide (62%Mn)	12 g each
Vitamin D (500,000 IE/g)	3g to the conventional food only
Food mixture 1988	
Vitamin D	0.5 g each
Vitamin B12	7.2 g each
NaCl (cattle salt) iodated (40% Na)	0.9 kg each
$CaCO_3$ (lime (36% Ca)	3.3 kg each
Manganese oxide	6 g each

1. Pregnancy rate

There was no significant difference between the two test groups. The pregnancy rate was 85.3% for group A and 84% for group B.

2. Birth weight and weekly weight gain of the offspring

There was no significant difference between the two test groups. In the 1st generation (F1) both litters of the conventionally fed rats (group B) weighed slightly more than those fed biologically (group A). In the first litter of the 2nd. generation (F2) this trend was reversed in favour of group A. Between the first and second litters of F2, the change in food from the 1987 to the 1988 mixture took place. Initially the new diet had a beneficial effect on the weight development of group B, whereas in the third generation (F3) both litters of group A showed a tendency to a better weight gain than group B (Table 5; Figures. 1 and 2).

3. Rearing proportion

Offspring born dead

The first litters of the biologically fed group (A) had significantly fewer offspring born dead than the conventionally fed ones (B). The second litters did not show this difference (Table 6).

TABLE 5

Average litter weight (in g) of all three generations (6 litters) from birth until weaning at the age of four weeks. The average litter weight (ALW) was calculated including average litter size (ALS) and average pup weight (APW) (ALW = ALS × APW).
A = biologically fed group; B = conventionally fed group

		birth		1st week		2nd week		3rd week		4th week	
generations		A	B	A	B	A	B	A	B	A	B
F1	1st litter	61	61	112	132	194	214	340	385	577	592
	2nd litter	57	60	108	106	187	196	289	308	516	535
F2	1st litter	55	52	107	97	184	173	285	267	497	462
	2nd litter	56	61	105	120	215	214	337	367	557	609
F3	1st litter	57	54	115	105	220	201	320	308	532	492
	2nd litter	63	59	115	109	213	193	326	289	584	506

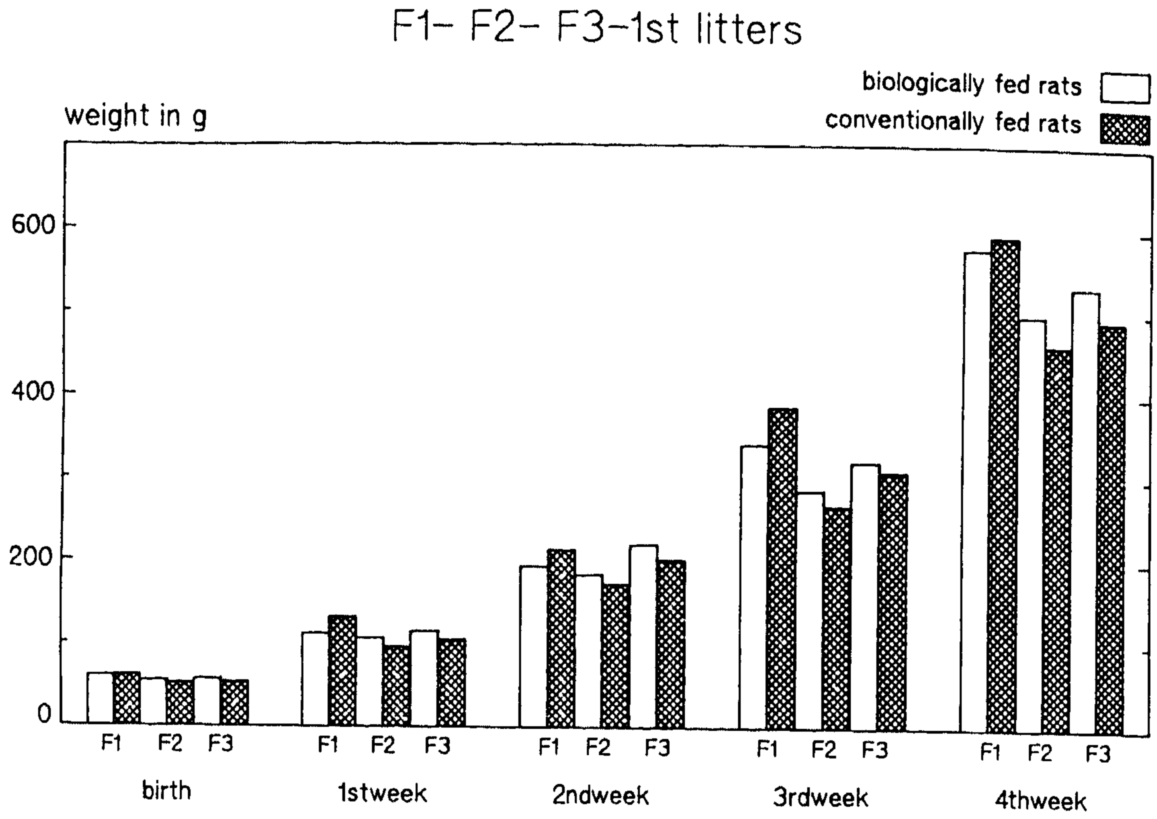

FIGURE 1 Average litter weight of the first litters of three generations (F1, F2, F3).

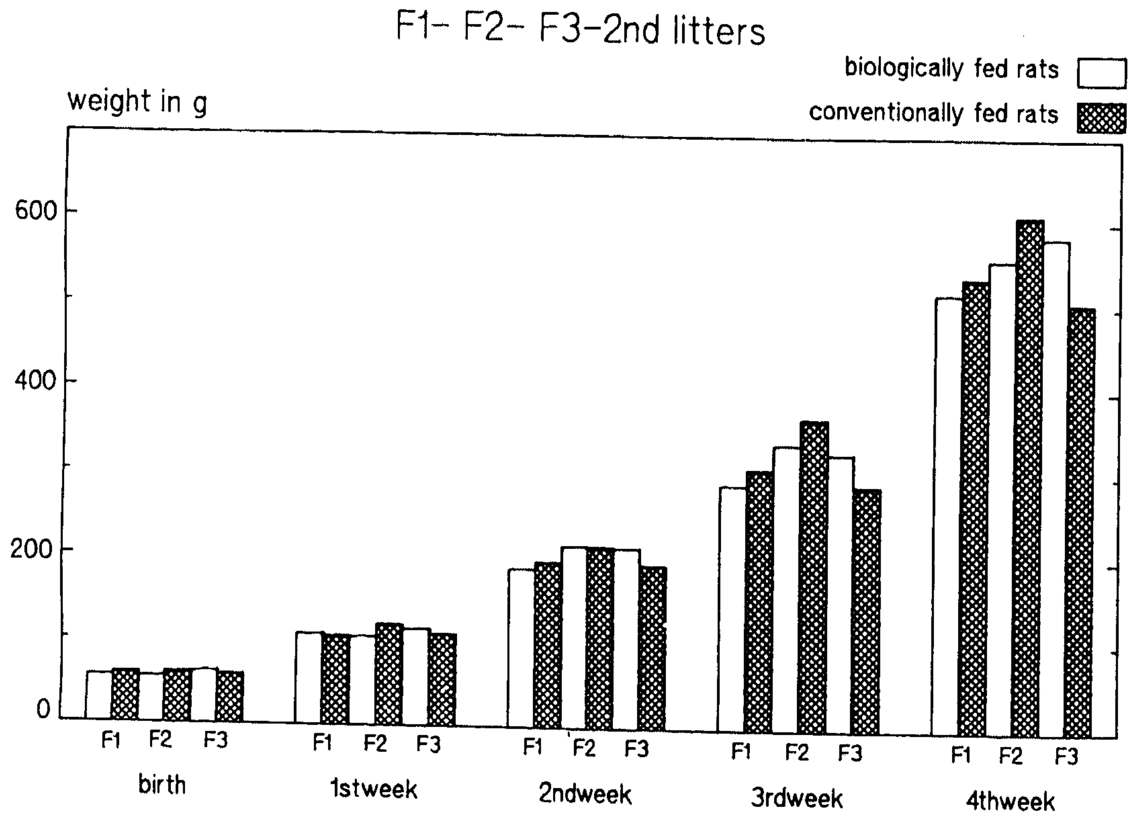

FIGURE 2 Average litter weight of the second litters of three generations (F1, F2, F3).

Rearing performance

This part of the investigation involves the percentage of surviving offspring from birth until weaning. The biologically fed group had significantly fewer perinatal deaths than the conventionally fed one (Figure 3).

Rearing performance was always more successful in the biologically fed group (A), except for the second litter of the 2nd. generation. As mentioned above the change from the 1987 to the 1988 food mixture took place between the first and second litters of the 2nd. generation (F2). Initially this new diet also had a favourable effect on the rearing performance of group B.

4. Weight loss or gain of the females during and after lactation

The biologically fed females (group A) displayed a much greater capacity to compensate weight loss during and after lactation than the conventionally fed

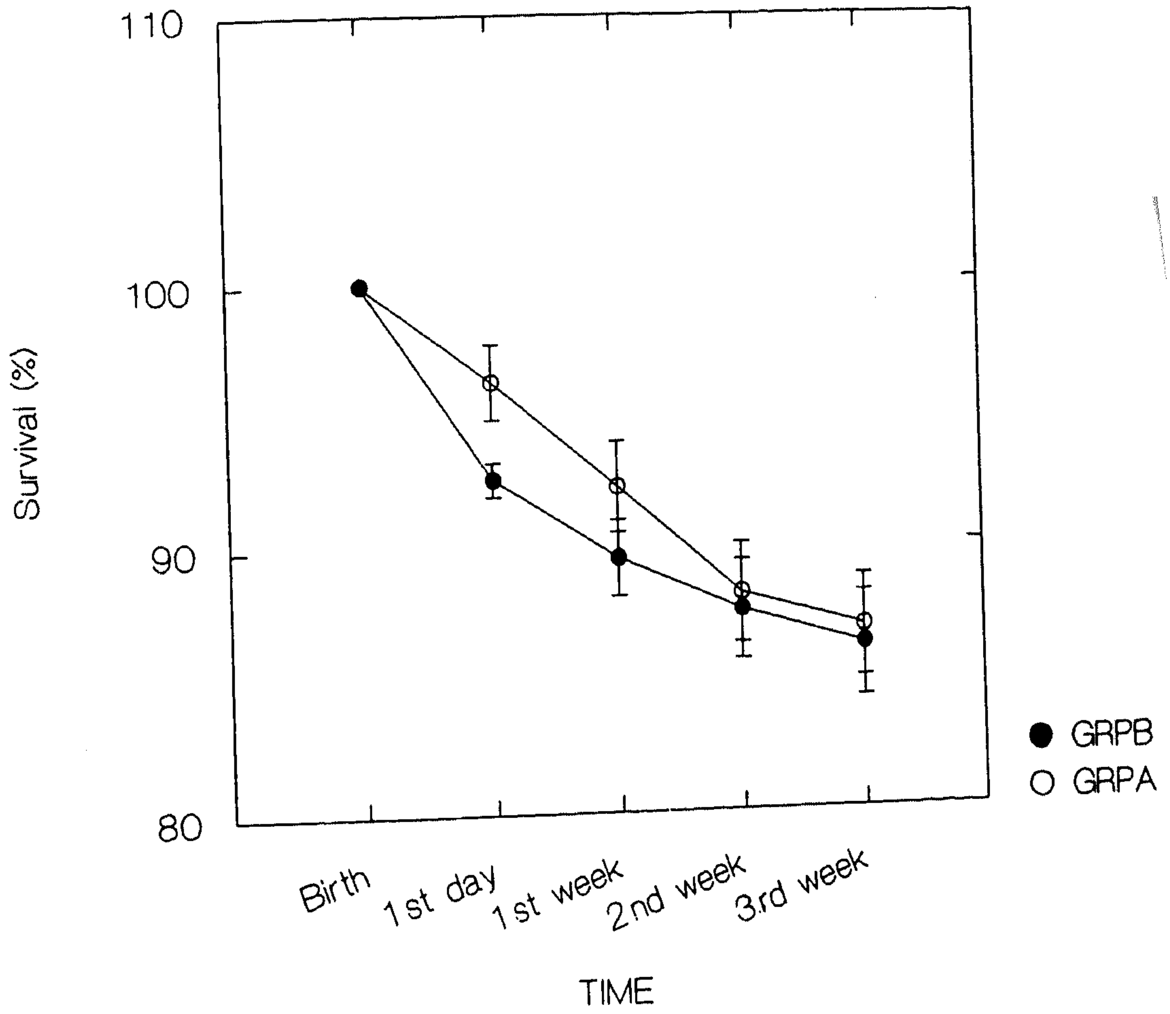

FIGURE 3 Rearing proportion. There were significantly fewer perinatally dead offspring in the biologically fed group (group A).

TABLE 6

Comparison of the percentage of still-born offspring of the two groups (t-tests). The biologically fed group was characterised by significantly fewer still-born offspring in the first litters. A = biologically fed group; B = conventionally fed group

	1st litters		*2nd litters*	
	A	*B*	*A*	*B*
number of litters	54	53	54	53
Min.	0.000	0.000	0.000	0.000
Max.	18.180	80.000	20.000	71.430
mean value	1.044	3.669	3.482	3.596
standard deviation	3.467	11.920	5.692	10.888
significance	a = 0.009*		a = 0.975	

ones (group B) (Figure 4). The difference in weight gain was highly significant in the third and fifth week, and significant in the second and fourth week in favour of group A. The significance was calculated by means of T-tests and variance analysis, and included litter size and average weight of the off-spring (Table 7).

DISCUSSION

Despite the efforts of various authors it has not yet been firmly established whether farming methods have any influence on the pregnancy rate of

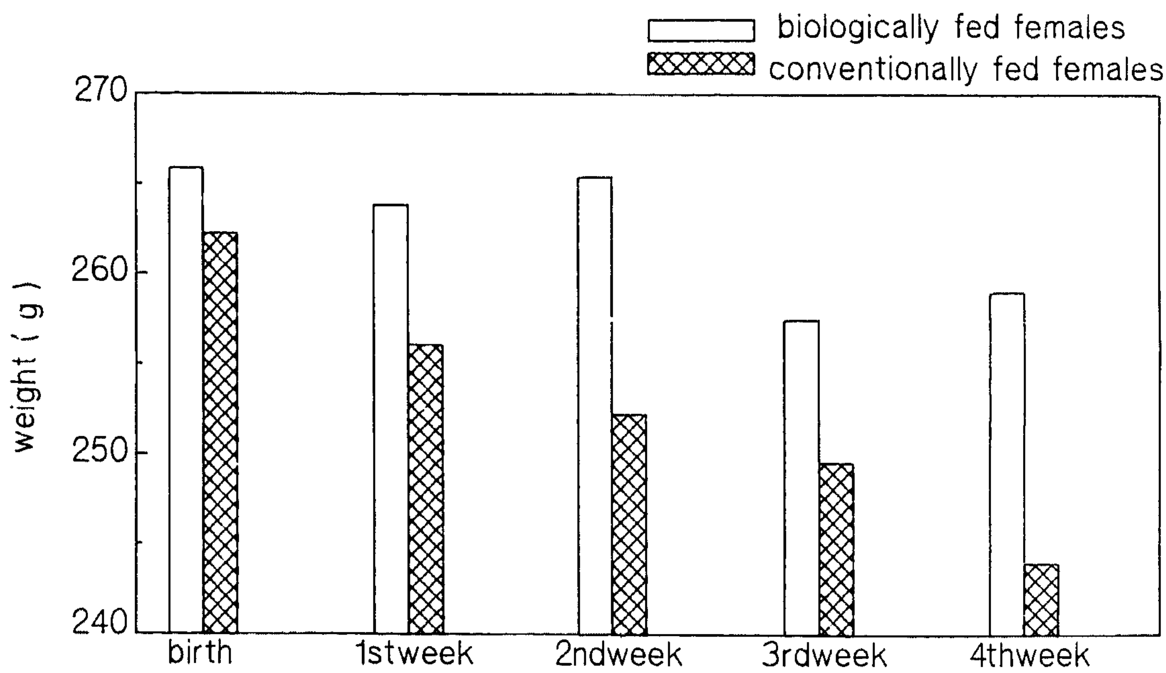

FIGURE 4 Average weight of female rats during the first 4 weeks after birth.

TABLE 7

The average weights (in g) of female rats after birth and during lactation.
A = biologically fed females; B = conventionally fed females.

	birth	1st week	2nd week	3rd week	4th week
A	266	264	265	258	259
B	262	256	252	249	244
a	0.203	0.033*	0.001*	0.051*	<0.001*

(The significance was calculated including litter size and average weight of the offspring)

animals. Scott *et al.* (1960) described a reduced pregnancy rate in mice when fed with minerally fertilized feed as compared to biologically fertilized feed, but McSheehy (1977) did not observe this influence when biologically and conventionally grown feed was ingested by mice. Aehnelt and Hahn (1973) found that minerally fertilized products had a negative effect on the fertility of rabbits, although Alter (1978) could not confirm these results. The alternative diet consisted of biologically fertilized products. In a feeding trial with rabbits, Staiger (1986) observed that does fed with biodynamically grown feed had considerably more embryos than those fed with conventionally grown feed; Gottschewski (1975), however, was not able to detect any differences between the differently fed animals in this respect. In the present investigation the two diets also had no significant influence on the pregnancy rate of rats.

The weight development of the offspring showed a tendency to be more favourable in biologically fed animals. Bram (1974) also described a better weight development in rabbits fed with biodynamically grown products.

The weight gain of female rats in connection with litter size and pup weight during and after lactation was significantly higher in the biologically fed group and thus demonstrated a better ability to recover from natural stress. Staiger (1986) and Plochberger (1989) observed that biologically fed animals had a shorter time of convalescence after falling ill with coccidiosis. These observations indicate that biologically produced feed enhances the capability to cope with stress whether it be "healthy" or caused by illness.

Scott *et al.* (1960), Edelmüller (1984) and Staiger (1986) also described the positive influence of biologically grown products on offspring number. The conventionally fed groups were similarly characterised by more animals born dead (Gottschewski, 1975; Edelmüller, 1984).

The results of the present investigation confirm these findings, showing significantly fewer offspring born dead in the first litters of the biologically fed group. The lower number of stillbirths was not significant in the second litters.

The percentage of perinatally dead offspring was significantly higher in the conventionally fed group (a = 0.021). The survival rate until weaning time was slightly more successful in group A but not significantly so (Figure 4).

Weight development as well as rearing performance showed a reverse tendency—in favour of the conventionally fed group—when the change from the 1987 to the 1988 food mixture took place (between the first and second litters of the 2nd generation). The chemical analyses offer no explanations for this phenomenon. After adaptation to the new diet, which was new only with respect to the year of harvest and site but not as far as the components or farming methods were concerned, the biologically fed group again displayed better results than the conventionally fed one. Although the weight differences are not statistically significant, the authors do not consider them to be due to biological variability, since the same tendency can be seen in the rearing performance.

It is possible that animals do not derive a decided benefit from biologically grown products under all circumstances and at all times; this could not only explain the surprising findings in this feeding trial, but also the contradictory results of the above-mentioned investigations. As indicated above we are dealing with intricate systems, and unforeseen events or still unrecognized interactions must be taken into account. Further feeding experiments would best be conducted under the condition that only products from field trials be used. This would provide a more accurate and detailed knowledge of the marginal conditions and the terms of cultivation.

CONCLUSIONS

—The aim of this feeding experiment was to investigate the influence of biologically and conventionally cultivated products on the fertility of laboratory rats.

—The pregnancy rate did not reveal any influence of the different diets.

—There was a tendency towards higher average litter weights in the biologically fed group but not significantly so.

—The first litters of the biologically fed group had significantly fewer offspring born dead than the conventionally fed ones.

—The rearing performance was more successful in the biologically fed group, showing significantly fewer perinatally dead offspring.

—The weight of the biologically fed females during and after lactation was significantly higher in connection with litter size and pup weight.

—The change from the 1986 food mixture to that of 1988, which took place between the first and second litters of the 2nd. generation, led to better results for the conventionally fed group during the second litter of the 2nd. generation. Both litters of the 3rd generation, however, developed in favour of the biologically grown feed.

ACKNOWLEDGEMENTS

This work was supported by the Fonds zur Förderung der Wissenschaftlichen Forschung, Vienna, Austria.

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(Received 3rd June, 1991; accepted 12th December, 1991)