RESULTS

The data obtained from the present study are divided into 2 parts. In Part I, the data presented are the effects of neonatal administration of MSG on the growth in female rats. Growth parameters consists of body weight, nasoanal length, Lee index and amount of food intake. In Part II, the results are summarized the effects of neonatal administration of MSG on reproductive capacity in female rats which were determined in terms of vaginal opening, estrous cycle, percentage of reception and pregnancy, duration of pregnancy and number and mean birth weight of pups.

Part I. Growth Parameters

Body Weight

The mean body weights of all groups of animals are shown in Table 1 and Figure 1. At 25 day of age, the mean body weights of the rats in all MSG-treated groups were less than those of the littermate control (56.5 $\pm$ 3.8 gm in control gruop, 47.5$\pm$ 4.2 gm in MSG_1 group, 50.0 $\pm$ 2.5 gm in MSG_2 group and 38.9 $\pm$ 2.3 gm in MSG_4), but only MSG_4 group was significantly different ($P < 0.005$). At 30 day of age, all experimental groups tended to have lower mean body weight than control group (77.7 $\pm$ 4.5 gm in control group, 66.5 $\pm$ 4.6 gm in MSG_1 group, 69.0 $\pm$ 3.2 gm in MSG_2 group and 62.2 $\pm$ 4.7 gm in MSG_4 group), but only MSG_4 group was significantly different ($P<0.025$). After 35 day of age, the rates of body weight gain of all MSG-treated groups were signifi-

Table 1. The body weights (gm) of control and MSG-treated rats during development (25 - 90 day of age).

Groups	Age(days)													
	25	30	35	40	45	50	55	60	65	70	75	80	85	90
control	56.5	77.7	111.0	131.0	155.5	170.0	183.5	198.0	209.0	219.5	231.0	235.5	242.0	247.0
(n=10)	±3.8	±4.5	±5.4	±6.5	±5.1	±4.0	±4.9	±4.5	±6.4	±3.7	±4.8	±5.0	±4.6	±4.7
MSG1	47.5	66.5	92.5*	104.5**	129.0**	136.0**	154.0**	171.5**	181.5**	195.5**	199.5**	209.5**	214.5**	219.5**
(n=10)	±4.2	±4.6	±4.5	±5.2	±3.6	±4.3	±3.4	±4.3	±4.7	±5.1	±5.1	±5.1	±4.7	±5.0
MSG2	50.0	69.0	95.5*	115.0*	133.0**	141.5**	152.0**	169.0**	176.5**	187.0**	193.0**	200.5**	208.0**	212.5**
(n=10)	±2.5	±3.2	±3.6	±4.3	±3.8	±3.7	±4.8	±4.4	±4.5	±5.3	±5.9	±5.8	±7.0	±6.8
MSG4	38.9**	62.2*	83.9**	103.9**	125.6**	138.9**	157.2**	171.1**	185.6*	195.0**	202.2**	212.8*	218.9*	229.4
(n=9)	±2.3	±4.7	±3.4	±3.7	±3.8	±3.8	±4.8	±5.5	±6.8	±5.5	±6.9	±7.0	±7.6	±7.7

Values are expressed as means ± SE.
* $p < 0.025$, ** $p < 0.005$

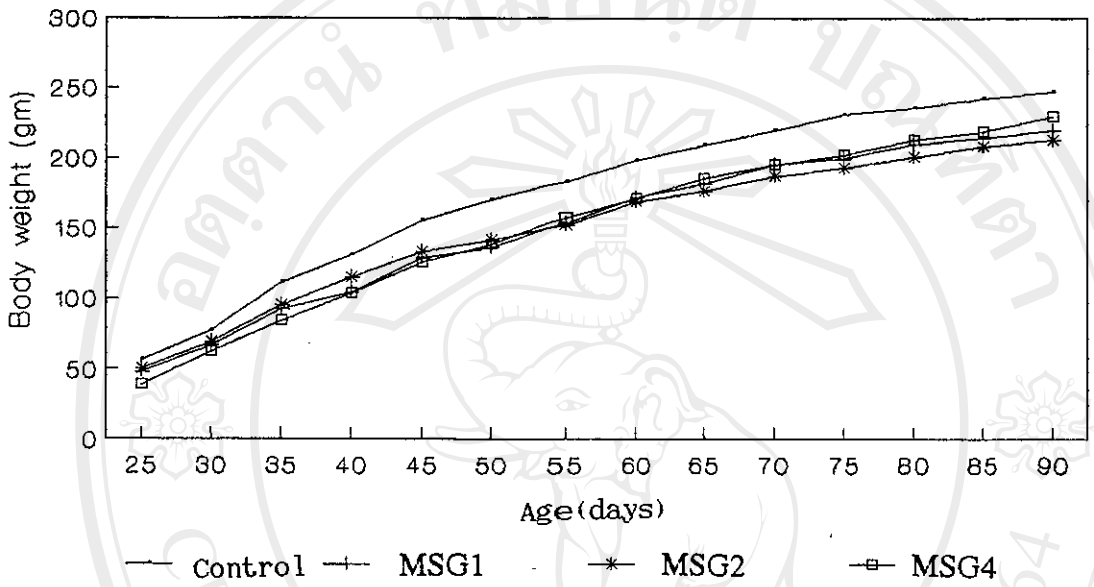

Figure 1. Comparison of mean body weights (gm) among control and MSG-treated rats during development (25 - 90 day of age).

cantly less than that of control group throughout the period of examination ($p < 0.025$) except at the end of measurement (90 day of age) at which MSG_4 group was not significantly different ($p > 0.05$)(247 $\pm$ 4.7 gm in control group, 219.5 $\pm$ 5.0 gm in MSG_1 group, 212.5 $\pm$ 6.8 gm in MSG_2 group and 229.4 $\pm$ 7.7 gm in MSG_4 group).

Nasoanal Length

Table 2 and Figure 2 show the nasoanal length of MSG-treated and control groups. Throughout the period of the examination, linear growth (nasoanal length) was significantly affected ($p < 0.025$) by MSG treatment (at 25 day of age, 13.9 $\pm$ 0.2 cm in control group, 12.8 $\pm$ 0.4 cm in MSG_1 group, 12.8 $\pm$ 0.2 cm in MSG_2 group and 12.5 $\pm$ 0.2 cm in MSG_4 group and at 90 day of age, 23.7 $\pm$ 0.2 cm in control group, 21.4 $\pm$ 0.2 cm in MSG_1 group, 20.9 $\pm$ 0.2 in MSG_2 group and 20.3 $\pm$ 0.2 cm in MSG_4 group).

Lee Index

The Lee index, a measurement of obesity, calculated from the body weight and nasoanal length, is shown in Table 3 and Figure 3. At the beginning (25 day of age) of measurement, there were no significant differences ($p > 0.05$) of Lee indexes among MSG-treated groups and control group (2.74 $\pm$ 0.05 in control group, 2.80 $\pm$ 0.03 in MSG_1 group, 2.85 $\pm$ 0.02 in MSG_2 group and 2.70 $\pm$ 0.07 in MSG_4 group), but after that all MSG-treated groups had higher Lee index values than control group. In MSG_1 group, the Lee index was significantly higher ($p < 0.05$) than that of control group, beginning at

Table 2. Nasoanal lengths (cm) of control and MSG-treated rats during development (25-90 day of age).

Groups	Age(days)													
	25	30	35	40	45	50	55	60	65	70	75	80	85	90
control	13.9	15.2	17.0	18.5	19.8	20.7	21.3	21.7	22.0	22.4	22.8	23.4	23.4	23.7
(n=10)	±0.2	±0.2	±0.3	±0.3	±0.2	±0.2	±0.1	±0.1	±0.1	±0.1	±0.2	±0.2	±0.2	±0.2
MSG1	* 12.8	* 14.2	16.2	** 16.8	** 17.6	** 18.6	** 19.4	** 19.9	** 20.2	** 20.7	** 20.8	** 21.1	** 21.1	** 21.4
(n=10)	±0.4	±0.3	±0.3	±0.4	±0.4	±0.3	±0.2	±0.3	±0.2	±0.2	±0.2	±0.2	±0.2	±0.2
MSG2	** 12.8	* 14.3	** 15.6	** 16.7	** 18.0	** 18.5	** 19.1	** 19.7	** 19.8	** 20.0	** 20.4	** 20.7	** 20.7	** 20.9
(n=10)	±0.2	±0.2	±0.2	±0.2	±0.1	±0.2	±0.1	±0.1	±0.1	±0.1	±0.2	±0.2	±0.2	±0.2
MSG4	** 12.5	** 13.5	** 15.0	** 15.9	** 17.1	** 17.8	** 18.3	** 18.9	** 19.1	** 19.4	** 19.5	** 19.9	** 20.1	** 20.3
(n=9)	±0.2	±0.3	±0.2	±0.1	±0.2	±0.4	±0.3	±0.2	±0.2	±0.2	±0.3	±0.2	±0.3	±0.2

Values are expressed as means ± SE.
* $p < 0.025$, ** $p < 0.005$

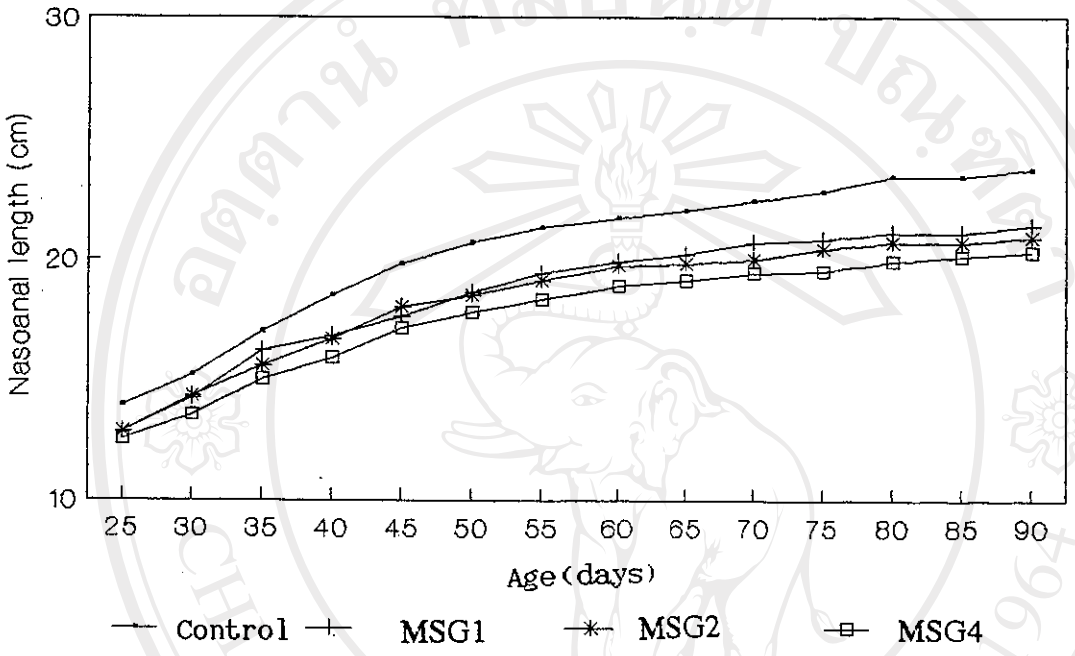

Figure 2. Comparison of mean nasoanal lengths (cm) among control and MSG-treated rats during development (25 - 90 day of age).

Table 3. Lee indexes of control and MSG-treated rats during development (25-90 day of age).

Groups	Age(days)													
	25	30	35	40	45	50	55	60	65	70	75	80	85	90
control	2.74	2.78	2.82	2.75	2.71	2.67	2.66	2.68	2.69	2.68	2.69	2.64	2.64	2.63
(n=10)	±0.05	±0.03	±0.06	±0.05	±0.03	±0.02	±0.02	±0.02	±0.03	±0.02	±0.02	±0.02	±0.03	±0.03
MSG1	2.80	2.84	2.79	2.75	2.87*	2.78*	2.76	2.79	2.81*	2.81*	2.81*	2.82*	2.83*	2.82*
(n=10)	±0.03	±0.03	±0.04	±0.04	±0.04	±0.04	±0.05	±0.05	±0.04	±0.05	±0.05	±0.05	±0.05	±0.06
MSG2	2.85	2.85	2.93	2.90*	2.83*	2.80*	2.79*	2.80*	2.83*	2.85*	2.83*	2.83*	2.85*	2.84*
(n=10)	±0.02	±0.02	±0.03	±0.02	±0.02	±0.04	±0.02	±0.02	±0.02	±0.02	±0.02	±0.03	±0.03	±0.03
MSG4	2.70	2.92*	2.90	2.94*	2.93*	2.90*	2.94*	2.93*	2.97*	2.99*	3.00*	2.99*	3.01*	3.01*
(n=9)	±0.07	±0.02	±0.04	±0.05	±0.04	±0.06	±0.04	±0.04	±0.04	±0.04	±0.05	±0.05	±0.05	±0.04

Values are expressed as means ± SE.

* $p < 0.05$

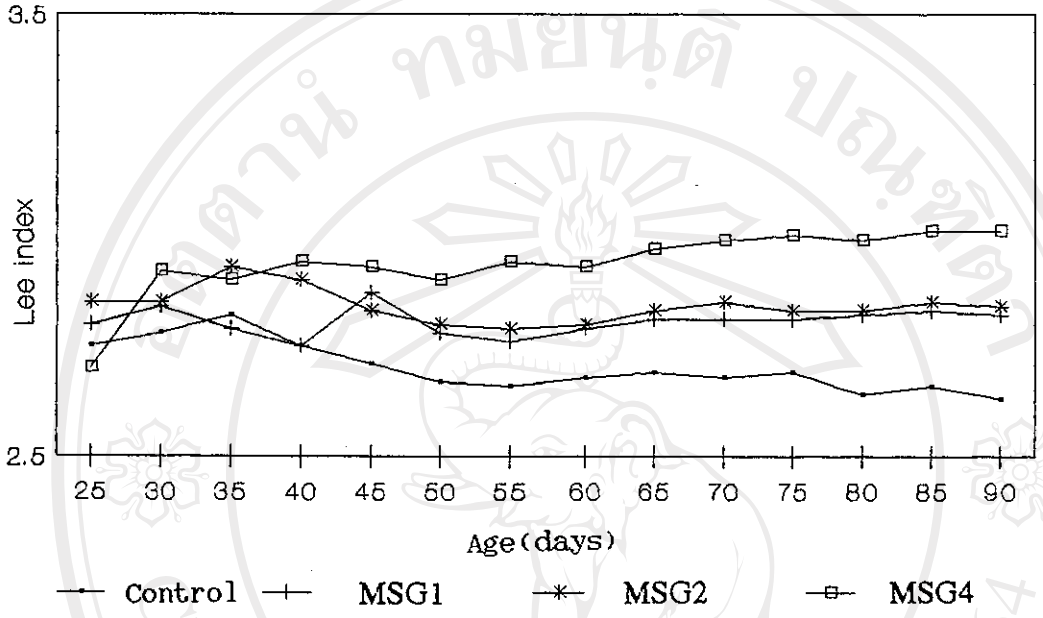

Figure 3. Comparison of Lee indexes among control and MSG-treated rats during development (25 - 90 day of age).

45 day of age, while MSG_2 and MSG_4 groups began to obese at 40 and 30 day of age, respectively.

Amount of Food Intake

Food consumption studies are shown in Table 4 and Figure 4. Throughout the period of the examination, the MSG-treated animals did not show the significant difference of amounts of food intake compared with control animal (at 3 week of age, 25.2 $\pm$ 3.3 gm/4days in control group, 20.2 $\pm$ 2.6 gm/4days in MSG_1 group, 25.0 $\pm$ 2.6 gm/4days in MSG_2 group and 27.8 $\pm$ 2.6 gm/4days in MSG_4 group, and at 12 week of age, 47.2 $\pm$ 1.6 gm/4days in control group, 47.5 $\pm$ 2.2 gm/4days in MSG_1 group, 41.0 $\pm$ 2.0 gm/4days in MSG_2 group and 44.4 $\pm$ 2.3 gm/4days in MSG_4 group)($p > 0.05$).

Part II. Reproductive Capacity

Vaginal Opening

From Table 5 and Figure 5, the days of vaginal opening of control and MSG-treated rats were 32.7 $\pm$ 0.9 days in control group, 33.9 $\pm$ 1.3 days in MSG_1 group, 34.6 $\pm$ 1.3 days in MSG_2 group and 50.5 $\pm$7.3 days in MSG_4 group. There were no significant changes ($p > 0.05$) of age at vaginal opening in MSG_1 and MSG_2 groups compared with control group. However, administration of 4 mg/gm BW MSG in neonatal period induced a significant delay of vaginal opening ($p < 0.05$).

Table 4. Amounts of food intake (gm/4days) of control and MSG-treated rats during development (3 - 12 week of age).

Groups	Age(weeks)									
	3	4	5	6	7	8	9	10	11	12
control	25.2	36.2	47.5	52.0	52.7	50.0	54.0	50.0	47.2	47.2
(n=10)	±3.3	±1.5	±1.7	±1.0	±2.1	±2.2	±3.3	±1.8	±2.0	±1.6
MSG1	20.2	32.7	43.5	46.5	47.0	52.5	53.5	47.5	45.5	47.5
(n=10)	±2.6	±1.8	±2.4	±1.2	±2.2	±2.7	±3.3	±1.9	±2.3	±2.2
MSG2	25.0	36.7	50.7	51.2	50.5	52.2	48.5	44.5	43.0	41.0
(n=10)	±2.6	±2.2	±2.9	±2.0	±3.5	±2.9	±2.7	±2.1	±2.6	±2.0
MSG4	27.8	37.2	47.2	52.2	53.9	53.3	46.7	43.3	43.3	44.4
(n=9)	±2.6	±2.1	±1.9	±2.7	±1.9	±2.3	±2.1	±2.1	±1.9	±2.3

Values are expressed as means ± SE.

($p > 0.05$)

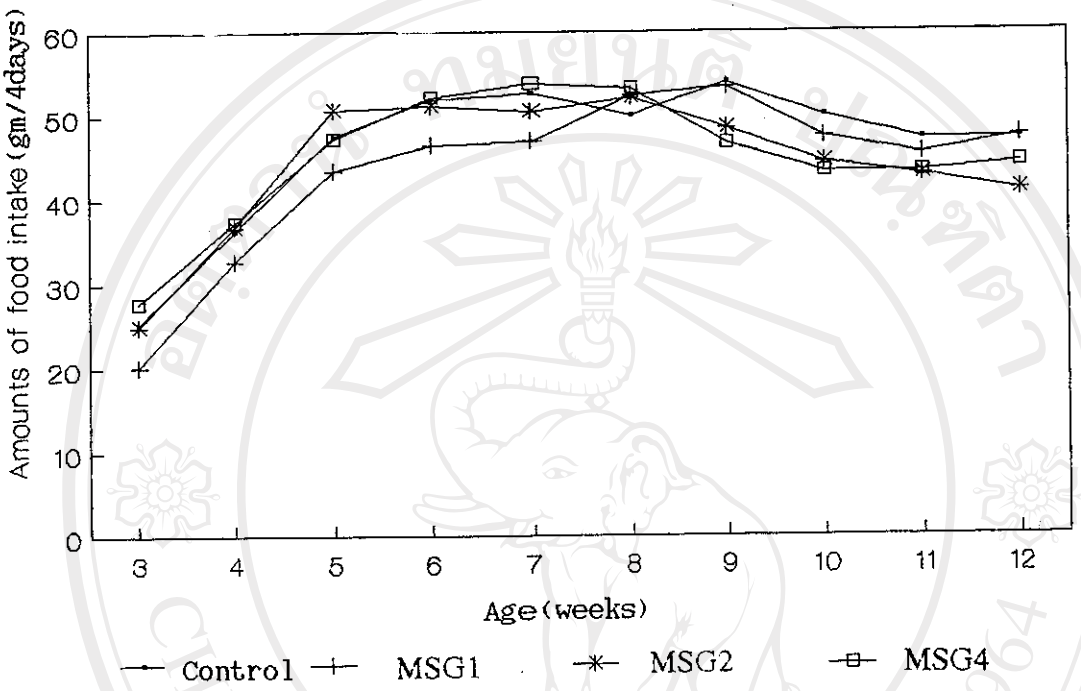

Figure 4. Comparison of amounts of food intake (gm/4days) among control and MSG-treated rats during development (3 -12 week of age).

Table 5. Age at vaginal opening in control and MSG-treated rats.

Groups	No. of rat	Age at vaginal opening (days)
Control	19	32.7 ± 0.9
MSG1	11	33.9 ± 1.3
MSG2	16	34.6 ± 1.3
MSG4	14	50.5 ± 7.3*

Values are expressed as means ± SE.
* $p < 0.05$

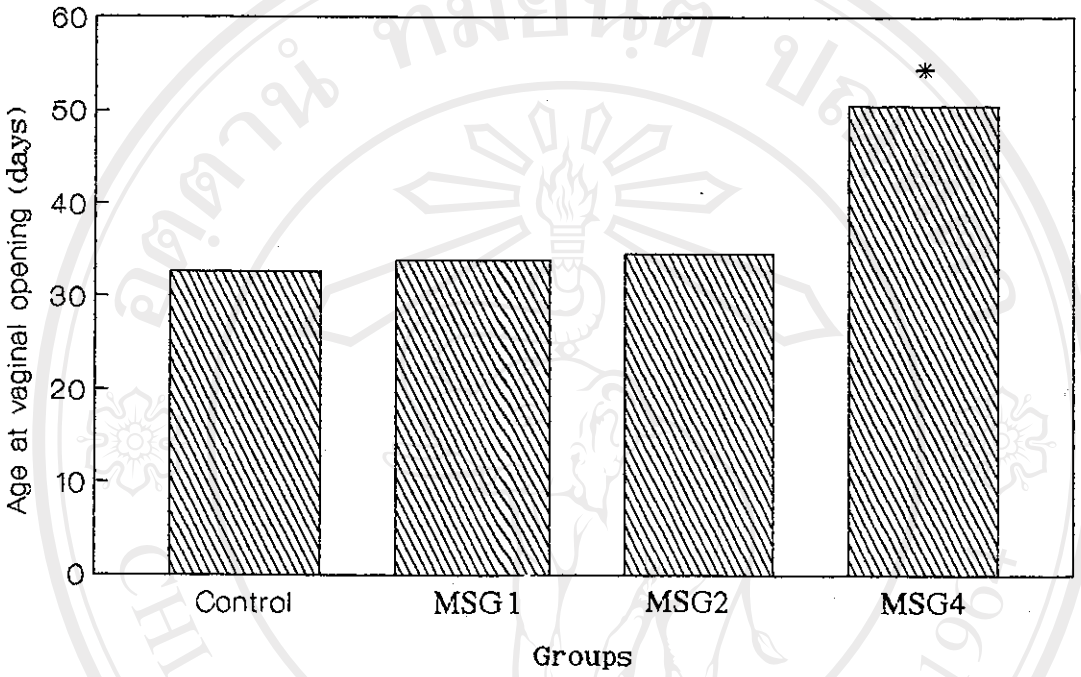

Figure 5. Comparison of age at vaginal opening among control and MSG-treated rats.
* $p < 0.05$

Estrous Cycle

Table 6 shows the results of studying estrous cycle of control and MSG-treated animals. On carry out for 30 days examination of estrous cycle (starting from around 60-90 day of age), percentage of normal estrous cycle (a cycle of 4 to 5 days length with regular changes) was determined. There were 100%, 80%, 57.1% and 0% in control, MSG_1, MSG_2, and MSG_4 groups of animals, respectively (Figure 6.). In control group, the number of day of each period of the cycle calculated against total period examined were 14.9 $\pm$ 0.5 days for diestrus, 6.2 $\pm$ 0.4 days for proestrus, 7.1 $\pm$ 0.2 days for estrus and 1.7 $\pm$ 0.2 days for metestrus in control group. These were not significantly different ($p > 0.05$) from those in MSG_1 group (13.5 $\pm$ 0.9 days for diestrus, 6.2 $\pm$ 0.8 days for proestrus, 8.3 $\pm$ 1.4 days for estrus and 2.3 $\pm$ 0.5 days for metestrus). However, in MSG_2 and MSG_4 groups, it was shown significantly prolonged estrus period (10.2 $\pm$ 1.0 days in MSG_2 and 13.2 $\pm$ 1.3 days in MSG_4 groups, ($p < 0.005$)) and shortened proestrus period (4.8 $\pm$ 0.4 days in MSG_2 and 4.6 $\pm$ 0.3 days in MSG_4 groups,($p < 0.05$)). In addition, shortened diestrus period was found in MSG_4 group (10.2 $\pm$ 1.0 days)(Figure 7.). The histograms in Figure 8 present the patterns of estrous cycle in representative control and MSG-treated rats at 60-70 day of age. It shows the regular changes in control and MSG_1 groups and irregular changes in MSG_2 and MSG_4 groups.

Table 6. Estrous cycles of control and MSG-treated rats at 60-90 day of age.

Groups	Period examined (day) (60-90 day)	% normal cycle	Number of days against total period examined			
			diestrus	proestrus	estrus	metestrus
Control (n=15)	30	100.0	14.9 ±0.5	6.2 ±0.4	7.1 ±0.2	1.7 ±0.2
MSG1 (n=10)	30	80.0	13.5 ±0.9	6.2 ±0.8	8.3 ±1.4	2.3 ±0.5
MSG2 (n=14)	30	57.1	13.0 ±1.0	4.8* ±0.4	10.2** ±1.0	1.8 ±0.3
MSG4 (n=9)	30	0.0	10.2** ±1.0	4.6* ±0.3	13.2** ±1.3	1.8 ±0.3

Values are expressed as means ± SE.
* $p < 0.05$, ** $p < 0.005$

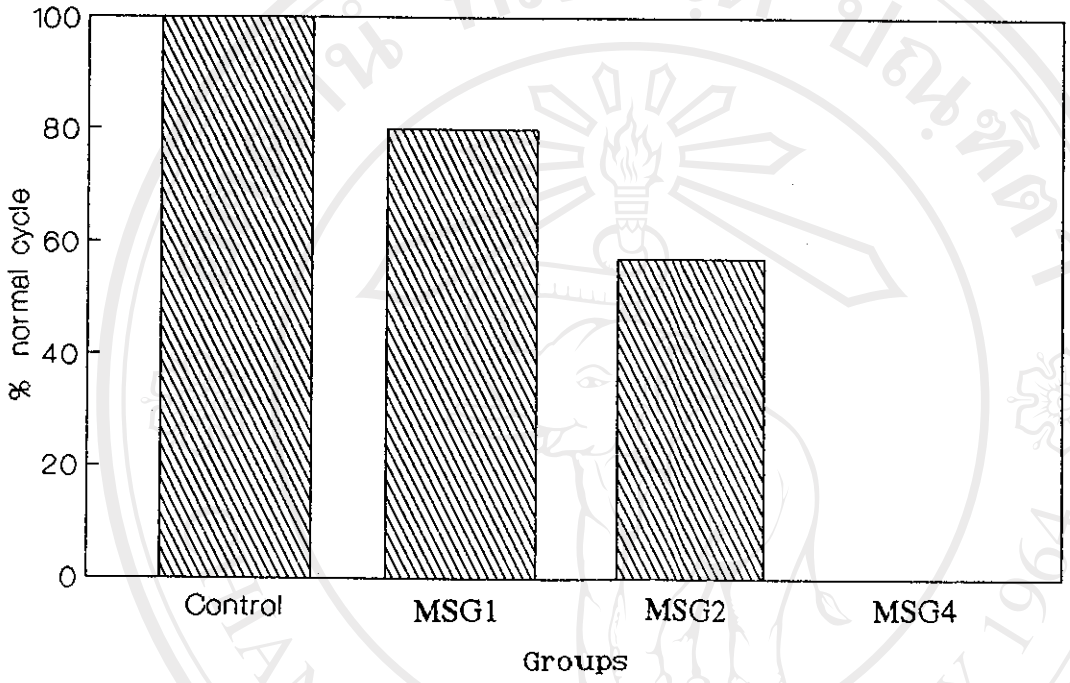

Figure 6. Comparison of percentage of normal estrous cycle among control and MSG-treated rats.

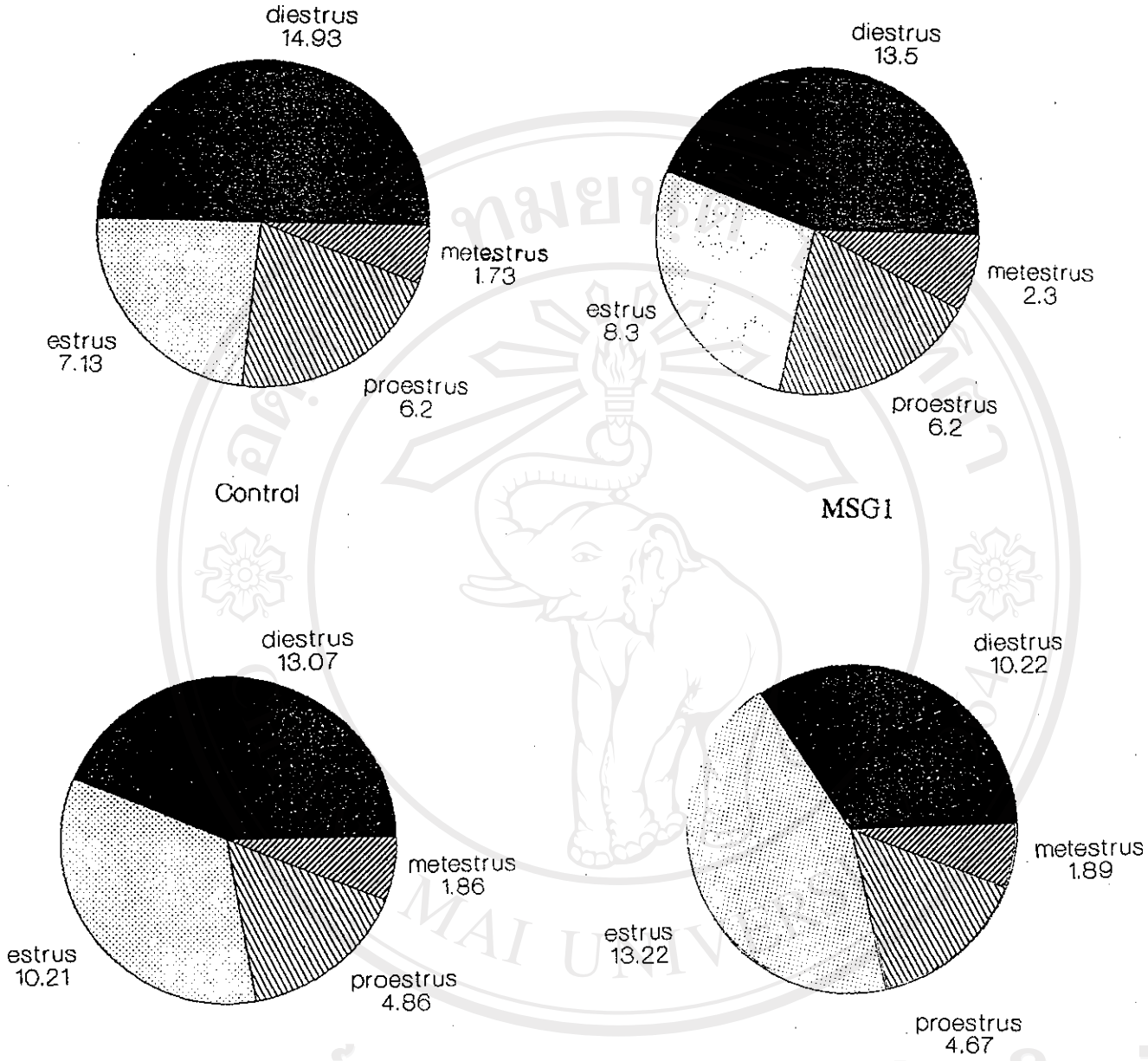

Figure 7. Comparison of number of days against total period examined among control and MSG-treated rats.

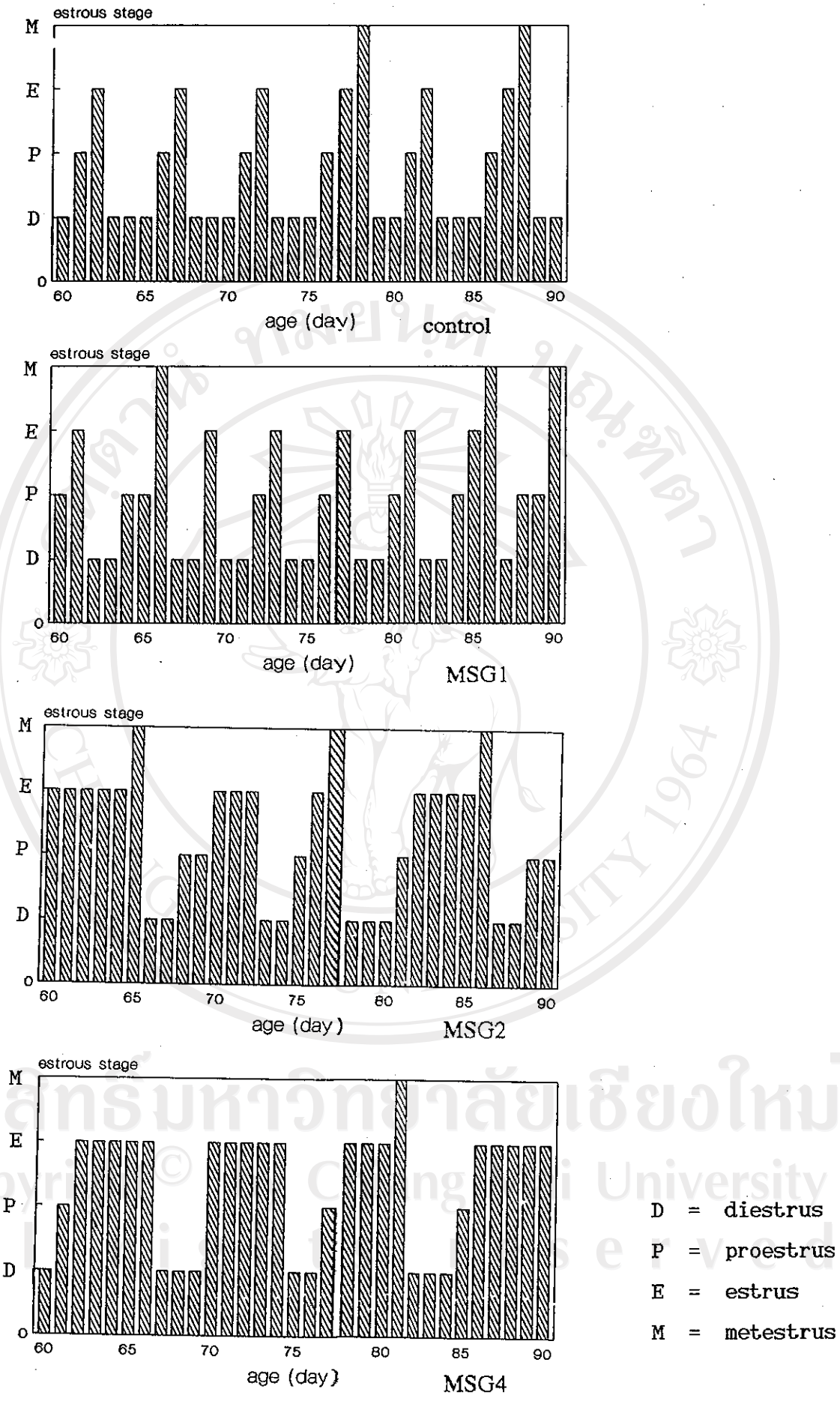

Figure 8. Patterns of estrous cycles of representative control and MSG-treated rats at 60 - 90 day of age.

Fertility and Offspring of Rat Treated with MSG as Neonates

In matings of MSG-treated and control females with a normal male for 30 days, the major findings are shown in Table 7. Percentage of reception in MSG-treated rats were reduced with increase in dosage of MSG administration. There were 100.0%, 100.0%, 83.3% and 54.5% reception in control, MSG_1, MSG_2 and MSG_4 groups of animals, respectively (Figure 9.). Moreover, the percentages of pregnancy (percentage of receptive rats which turned to be pregnant) were also reduced in MSG-treated rats with increase in MSG dosage (100.0% in control, 88.8% in MSG_1, 80.0% in MSG_2 and 33.3% in MSG_4 groups)(Figure 10.). The durations of pregnancy were recorded, however, no significnat differences ($p > 0.05$) between MSG-treated and control rats were found (21.4 ± 0.1 days in control group, 22.1 ± 0.2 days in MSG_1 group, 22.7 ± 0.3 days in MSG_2 group and 22.5 ± 0.5 days in MSG_4 group)(Figure 11.). When pregnancy terminated, the MSG-treated females gave significantly smaller litter size ($p < 0.01$). Control group gave 10.1 ± 0.1 pups/litter whereas there were only 7.2 ± 0.9, 6.8 ± 0.1 and 4.5 ± 0.2 pups/litter in MSG_1, MSG_2 and MSG_4 groups, respectively (Figure 12.). The average birth weights of pups in MSG_1, MSG_2 and MSG_4 groups were 5.5 ± 0.1, 5.7 ± 0.1, 5.6 ± 0.1 gm, respectively, which shown no significant difference ($p > 0.05$) when compared with those of control group (5.7 ± 0.1 gm)(Figure 13.).

The Organ Weights

Table 8 shows in details the effect of MSG on some organs. By autopsy, at around 120 day of age, the absolute and relative

Table 7. Fertility and offspring of control and MSG-treated rats.

Groups	%reception	%pregnancy	duration of pregnancy (day)	pups/litter	Average birth weight of pups (gm)
Control (n=11)	100.0	100.0	21.4 ± 0.1	10.1 ± 0.1	5.7 ± 0.1
MSG1 (n=9)	100.0	88.8	22.1 ± 0.2	7.2 ± 0.9 *	5.5 ± 0.1
MSG2 (n=9)	83.3	80.0	22.7 ± 0.3	6.8 ± 0.1 **	5.7 ± 0.1
MSG4 (n=11)	54.5	33.3	22.5 ± 0.1	4.5 ± 0.2 **	5.6 ± 0.1

%reception = Percentage of female rats in each groups inwhich sperms were detected in their vaginal smear.
%pregnancy = Percentage of receptive female rats in each groups that turned to be pregnant.
Values are expressed as means ± SE.
* $p < 0.01$, ** $p < 0.005$

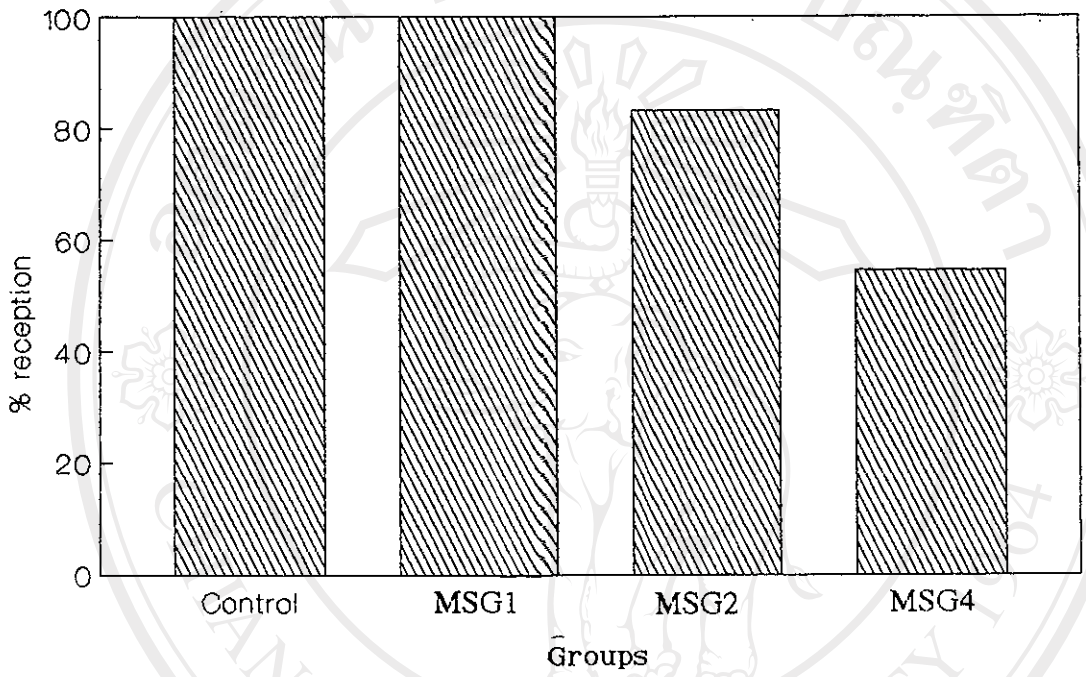

Figure 9. Comparison of percentage of reception among control and MSG-treated rats.

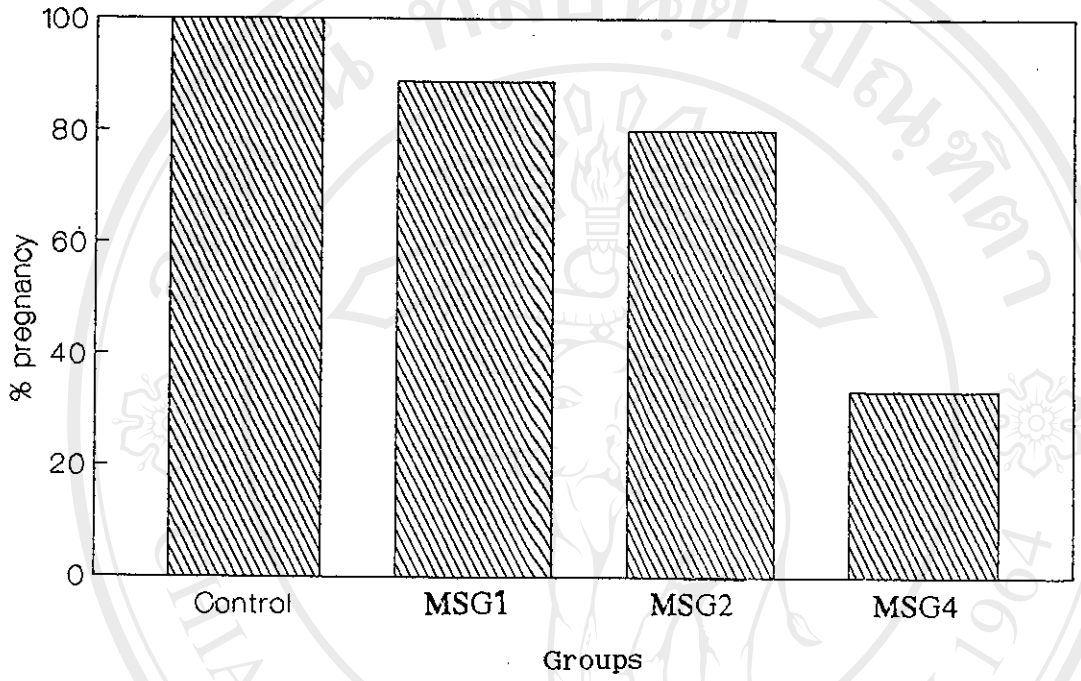

Figure 10. Comparison of percentage of pregnancy among control and MSG-treated rats.

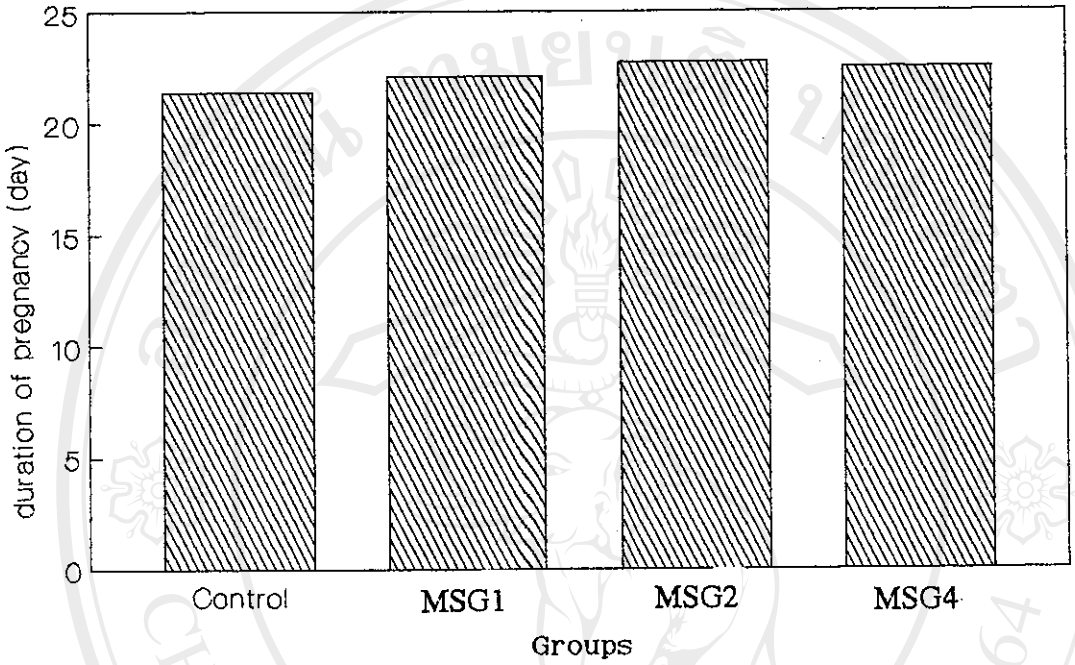

Figure 11. Comparison of duration of pregnancy among control and MSG-treated rats.
$p > 0.05$

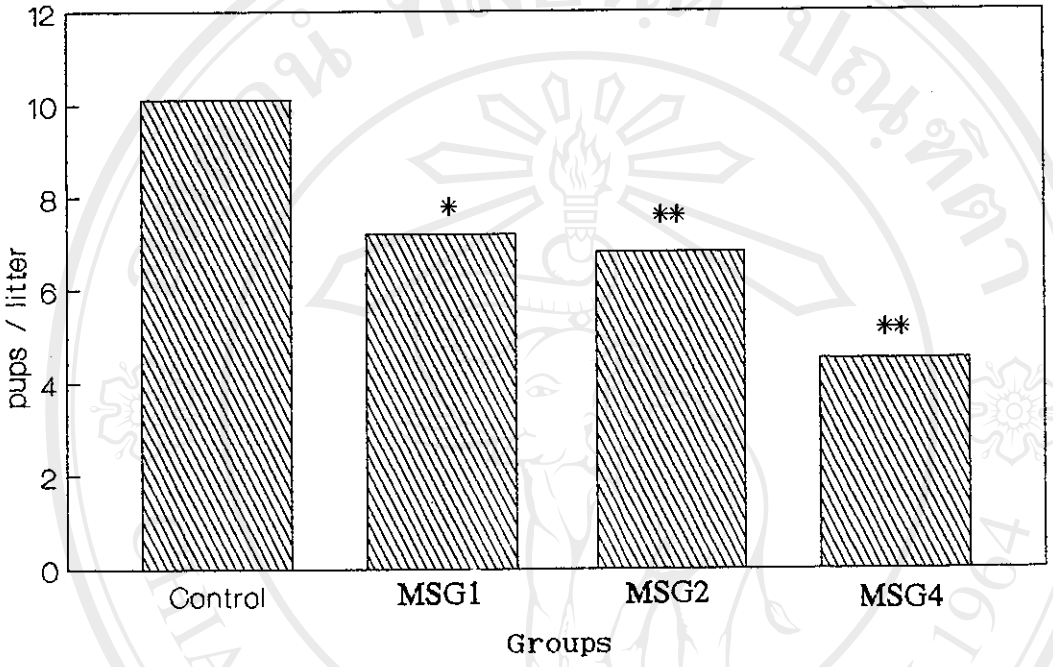

Figure 12. Comparison of number of pups per litter among control and MSG-treated female rats mated with normal adult male.
* $p < 0.01$, ** $p < 0.005$

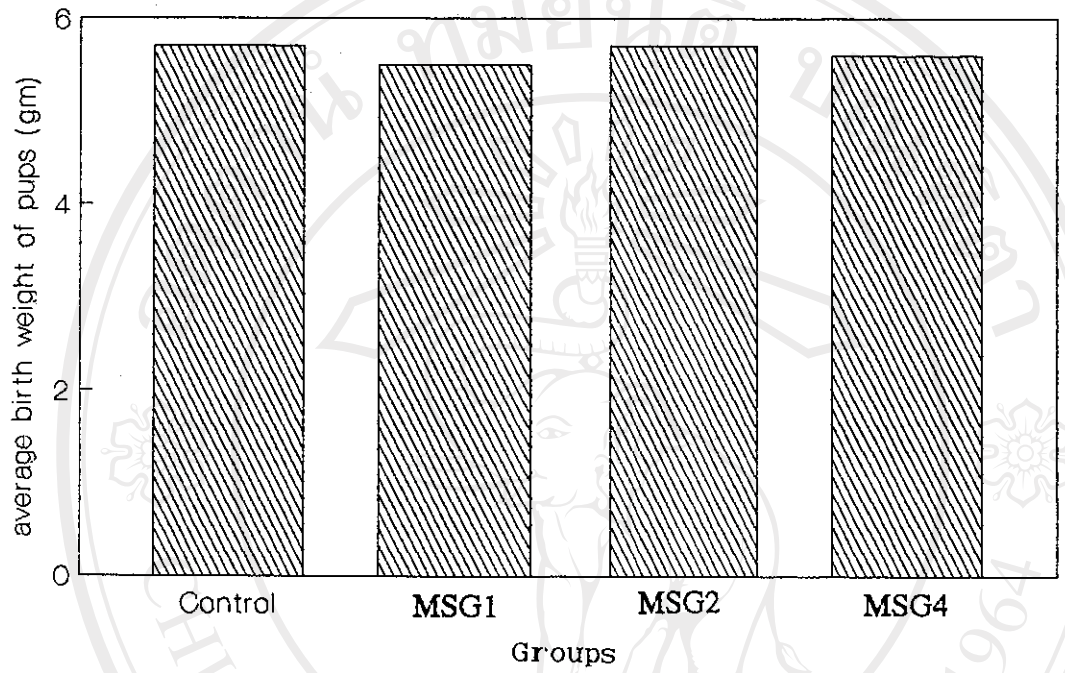

Figure 13. Comparison of average birth weight of pups (gm) among control and MSG-treated rats mated with normal adult male.
$p > 0.05$

Table 8. Some organ weights of control and MSG-treated rats at around 120 day of age.

Groups	uterine weight		ovarian weight		pituitary weight	
	mg	mg/100gmBW	mg	mg/100gmBW	mg	mg/100gmBW
Control (n=10)	264.5 ±20.4	123.7 ±7.7	78.3 ±4.4	36.6 ±1.3	8.8 ±0.4	4.1 ±0.1
MSG1 (n=13)	265.1 ±14.4	125.5 ±7.6	68.9 ±4.3	32.2 ±1.6	7.5 ±0.5	3.8* ±0.1
MSG2 (n=9)	271.0 ±26.1	135.5 ±10.5	69.7 ±5.8	34.7 ±2.3	6.3** ±0.4	3.1** ±0.2
MSG4 (n=10)	219.3 ±24.2	115.1 ±16.0	26.8** ±4.0	13.3** ±1.7	4.2** ±0.2	2.1** ±0.1

Values are expressed as means ± SE.
* $p < 0.01$, ** $p < 0.005$

weights of uteruses of all MSG-treated groups were not significantly affected by MSG treatment ($p > 0.05$)(264.5 ± 20.4 mg and 123.7 ± 7.7 mg/100gm BW in control group; 265.1 ± 14.4 mg and 125.5 ± 7.6 mg/100gm BW in MSG_1 group; 271.0 ± 26.1 mg and 135.5 ± 10.5 mg/100gm BW in MSG_2; and 219.3 ± 24.2 mg and 115.1 ± 16.0 mg/100gm BW in MSG_4). The relative weights of uteruses in control and MSG-treated rats are graphically compared and illustrated in Figure 14. Though ovarian weights of MSG-treated rats tended to decrease and the ovaries apparently atrophied, only those values in MSG_4 group were significantly less than those in control, either in absolute or relative values (78.3 ± 4.4 mg and 36.6 ± 1.3 mg/100 gm BW in control group; 68.9 ± 4.3 mg and 32.2 ± 1.6 mg/100 gm BW in MSG_1 group; 69.7 ± 5.8 mg and 34.7 ± 2.3 mg/100 gm BW in MSG_2 group; and 26.8 ± 4.0 mg and 13.3 ± 1.7 mg/100 gm BW in MSG_4 group)($p < 0.005$). The histograms in Figure 15 present the comparison of the relative weights of ovaries among control and MSG-treated groups. The pituitary weights in MSG-treated rats were strikingly different ($p < 0.005$) from those in control rats. The mean pituitary weights (absolute value) of control, MSG_1, MSG_2 and MSG_4 groups were 8.8 ± 0.4, 7.5 ± 0.5, 6.3 ± 0.4 and 4.2 ± 0.2 mg, respectively. Although the value in MSG_1 group was not significantly ($p > 0.05$) affected by MSG treatment, the relative weight of pituitary was significantly affected ($p < 0.01$) (4.1 ± 0.1 mg/100 gm BW in control group and 3.8 ± 0.1 mg/100 gm BW in MSG_1 group). The relative weights of pituitary glands in all MSG-treated groups were significantly different ($p < 0.005$) from control group (4.1 ± 0.1 mg/100 gm BW in control group, 3.8 ± 0.1

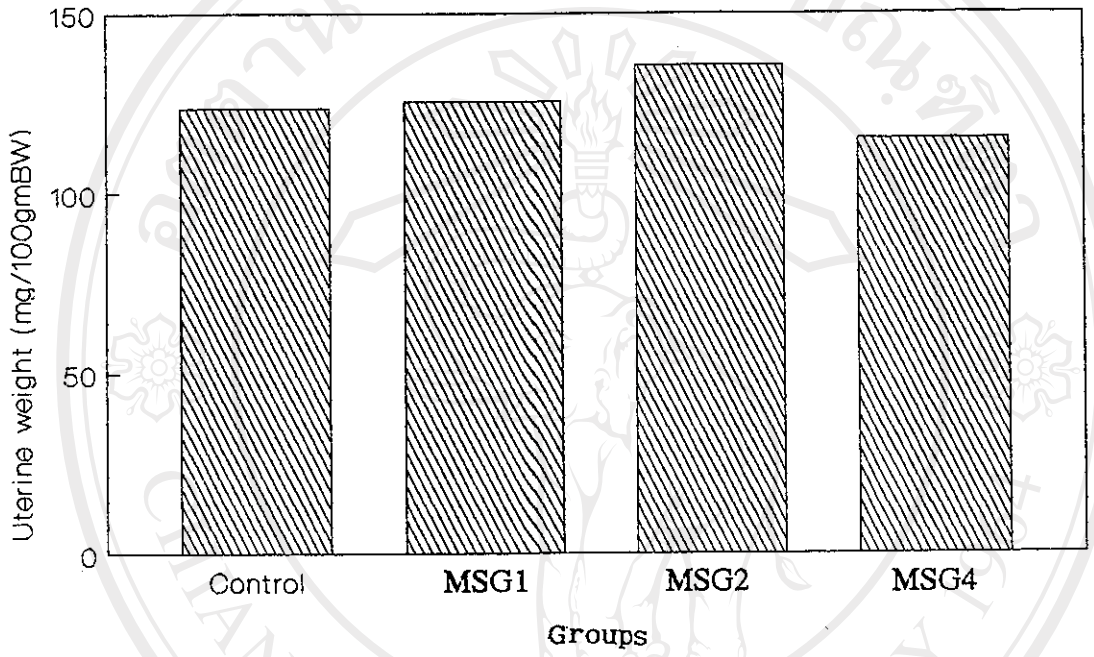

Figure 14. Comparison of relative uterine weights (mg/100gmBW) among control and MSG-treated rats.
$p > 0.05$

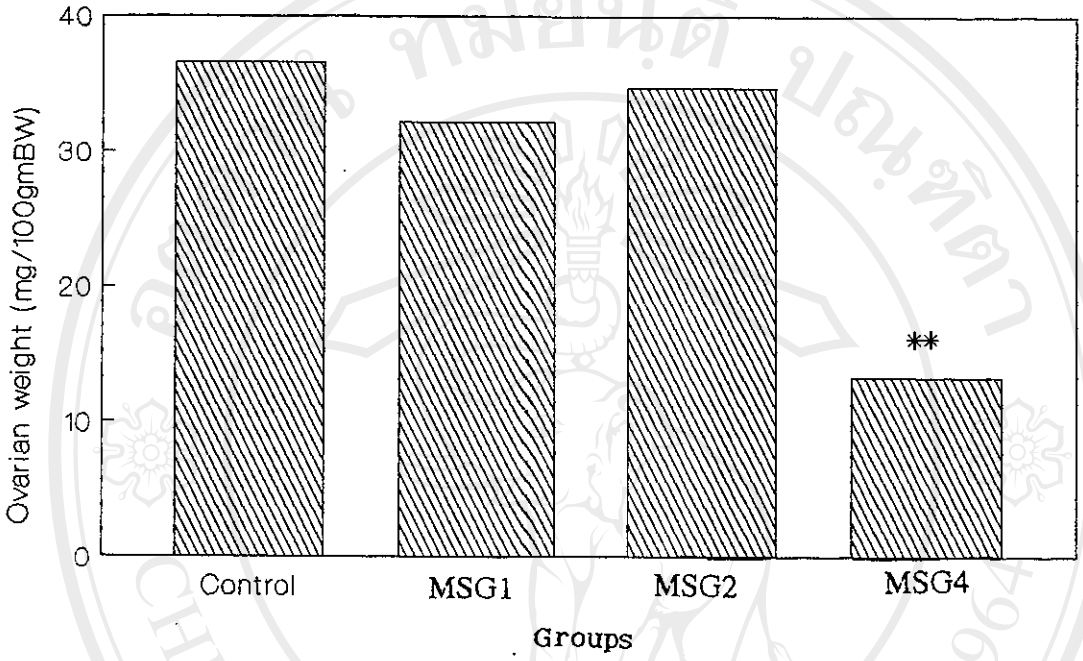

Figure 15. Comparison of relative ovarian weights (mg/100gmBW) among control and MSG-treated rats.

** $p < 0.005$

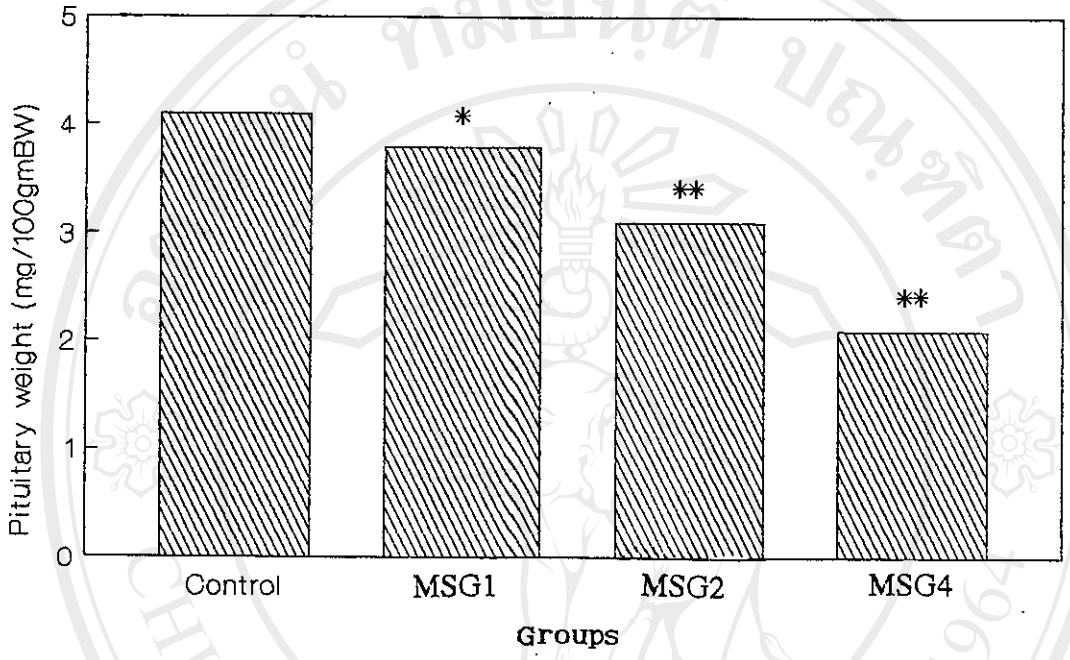

Figure 16. Comparison of relative pituitary weights (mg/100gmBW) among control and MSG-treated rats.

* $p < 0.01$, ** $p < 0.005$

mg/100 gm BW in MSG_1 group, 3.1 ± 0.2 mg/100 gm BW in MSG_2 group and 2.1 ± 0.1 mg/100 gm BW in MSG_4 group)(Figure 16.).