

PLATE 2

1. Testis from an animal fed on the diet with 28% hydrogenated arachis oil supplemented with 1 mg linoleic acid/animal/day (group 156). Haematoxylin-eosin. $\times 96$.
2. Epididymis from the same animal. Haematoxylin-eosin. $\times 96$.
3. Ovarian interstitial tissue from an animal fed on the diet with 28% hydrogenated arachis oil (group 153). Nuclei with 'thorn-apple' appearance will be noticed. Haematoxylin-eosin. $\times 960$.
4. Ovarian interstitial tissue from a normal animal fed on the diet with 28% arachis oil (group 159). Haematoxylin-eosin. $\times 960$.

Nutrition of the cat

1. A practical stock diet supporting growth and reproduction

BY CECILIA D. DICKINSON AND PATRICIA P. SCOTT

*Department of Physiology, Royal Free Hospital School of Medicine,
London, W.C. 1*

(Received 25 April 1956)

In order to investigate problems of breeding and rearing cats in laboratory conditions, an experimental colony was established in 1950 at the Royal Free Hospital School of Medicine, where it has been in continuous existence for 6 years.

The amounts of food and the methods of feeding described in this paper have proved adequate for the maintenance in good health of thirty breeding females, their kittens, three males and about thirty other adult cats at any one time.

EXPERIMENTAL

Animal management

The methods of animal husbandry used in the maintenance of this colony have been described by Cornelius (1952) and Scott (1956), with some recent improvements detailed below. The room used for breeding and rearing was $9 \times 22 \times 8$ ft., with two wire-mesh partitions from floor to ceiling, supplied with doors dividing it into three parts. A continuous-extraction ventilation system afforded about five changes of air per hour, and the room was maintained at about 70° F. Apart from artificial lighting between 3.30 p.m. and 5 p.m. during the winter months, the colony was subjected only to seasonal changes in the length of daylight.

Usually fifteen breeding female cats (queens) with one male (tom) were maintained in both end divisions of the breeding room, and fully weaned kittens were allowed to run in the centre division until mature or removed for experiments. The males were normally allowed to run with the females except for two short periods (in the autumn and winter months of 1953 and 1955) when they were used in mating experiments. As pregnant females neared their expected delivery date (*c.* 65 days after mating) they were confined individually in specially designed cages (Scott, 1952) placed on racks or on the floor. Litters, whose individual members were identified shortly after birth, were kept together in these cages until the end of the lactation period of 7–8 weeks,

although the mothers were allowed out daily from about 4 weeks onwards for remating and exercise.

It was found that litters of three or more kittens required a supplement to their mother's milk when they were 3-4 weeks old. Some kittens learned to eat it of their own accord, but others needed a brief period of training by hand feeding. Litters of kittens that were not supplemented, or individual kittens that failed to eat, were recognizable at this stage on account of their failure to make the normal gains in weight. After a week or two on the weaning diet, the kittens began to eat the afternoon meal of stock diet (Table 1) and at 7-8 weeks old they were fully weaned on to stock diet.

Kittens were weighed three times, and adults once, each week. Any animal showing loss of weight (kittens 100 g in a week, adults 200 g), sneezing, nasal discharge or conjunctivitis was isolated and treated with antibiotics. Sulphonamides were also used alone or in conjunction with antibiotics. Care was taken to free the colony from intestinal parasites, which are abundant in ordinary domestic cats.

Sources and preparation of foodstuffs for the stock diet

The constituents of the stock diet together with their approximate proportions are shown in Table 1. All supplies were obtained as fresh as possible and stored when necessary in a refrigerator. Drinking water was available at all times, but liquid milk was not supplied on account of poor keeping quality and expense. Over the period September to November 1955, the cost of this diet was 2s. 2d./animal/week.

Morning meal. The dry ingredients and tinned cat-food shown in Table 1 were mixed with the water to a stiffish paste.

Table 1. *Constituents of stock diet for cats*

| | Foodstuff | Parts by weight (approx.) |
|--|--|---------------------------|
| Mid-morning meal (c. 100 g/adult cat) | Full cream roller-dried milk powder fortified with vitamin D (D.M.P. Sales Ltd, Guildford) | 2½ |
| | Farex (Glaxo Laboratories Ltd) | 1 |
| | Tinned cat-food containing 50% protein (Chappie Ltd, Melton Mowbray) | 1 |
| | Water | 5½ |
| | | |
| Mid-afternoon meal (c. 200 g/adult cat) | Cooked mashed potato | 1 |
| | Dried brewer's yeast and dried-grass powder, mixed together with one of the following: | Small amount* |
| | Minced cooked liver | 1 |
| | Cooked white fish | 2 |
| | Minced cooked lights | 1 |
| | Tinned cat-food (Chappie Ltd) | 1 |

* For 3600 g cooked mashed potato 13 g of dried-grass powder and 30 g dried yeast. The diet was calculated by the method of McCance & Widdowson (1946) to provide approximately 140-150 Cal./kg cat/day.

Afternoon meal. A basis of cooked mashed potato, dried yeast and dried-grass powder was always used, but the foodstuff supplying the protein was varied as shown in Table 1 and included liver at least once weekly. Samples of the potato-fish mixture had a protein (N × 6.25) content of 67% on a dry-weight basis.

Mixture used as supplement to mother's milk at weaning. Full-cream dried milk and Farex (Glaxo Laboratories Ltd, a fortified precooked blend of cereals containing iron citrate) were mixed to a stiffish paste with water, in the same proportions as in the morning meal of the stock diet (Table 1), the tinned cat-food being omitted.

Ingredients. Potatoes were obtained by the sack and peeled mechanically before being steamed in a pressure cooker.

White fish, pieces of good quality were obtained by the cwt. (price £2. 4s. od.) direct from Grimsby (Messrs John Dory). Delivery took place once weekly (Tuesday) and 1 cwt. was sufficient to last 3-4 days. It was stored in the refrigerator and cooked under pressure as required.

Liver (10 lb. condemned (flukey) liver, price 8s.) was obtained once weekly (Friday) from a nearby slaughterhouse; it was cut up into cubes before boiling and afterwards minced.

Tinned cat-food (Chappie Ltd) was used at weekends and formed a useful standby in the event of any shortage of liver or fish.

Lights (lungs) (10 lb.) were purchased weekly from a local butcher, cut up into pieces before cooking and minced afterwards.

Dried grass was obtained from Styles Ltd, Bewdley, Worcestershire.

Dried brewer's yeast was obtained from English Grains Co., Burton-on-Trent.

RESULTS

Growth. The mean weight gained by healthy kittens, with its standard error and the weight range from birth to 24 weeks of age is shown in Table 2, the diet given being shown in the first column. In order to see whether the kittens born in the laboratory grew at about the same rate as those born under domestic conditions, some weaned kittens of known age obtained from various domestic homes were fed on the stock diet in the laboratory; since these animals did gain weight at about the same rate as those born in the laboratory figures for them have been included in Table 2.

Table 2 shows that the males were slightly heavier than the females at birth and although this difference persisted throughout, there was little apparent difference between the sexes in the growth rate for the first 12 weeks *post partum*; thereafter the males gained weight more rapidly. The variation was greater among males than among females, although there was an increase of variation among the females for the period after the 12th week. There are indications from the figures for range of some skewness at some periods in the distribution of individual weights.

It is apparent from other unpublished observations on the colony that growth is not complete in the cat by the 24th week; very few figures for males and only scattered figures for females were available after this period, owing to use of the animals for experimental purposes, and they have not been included.

Reproduction. In the 1st year the stock was miscellaneous, but selection was practised throughout this and subsequent years in order to improve the reproduction efficiency of the females, i.e. ability to carry and rear kittens. Each year some female kittens were selected and retained for breeding and four generations are now represented in the colony. Table 3 shows that the total number of kittens produced each

Table 2. *Weights of cats from birth to 24 weeks*

| Diet | Age (weeks) | Males | | | Females | | |
|-------------------------------|----------------|-------------------|--|--------------|-------------------|--|--------------|
| | | No. of cats | Weight | | No. of cats | Weight | |
| | | | Mean value with its standard error (g) | Range (g) | | Mean value with its standard error (g) | Range (g) |
| Mother's milk | (0-24 h) | 48 | 114 ± 1.9 | 98-145 | 33 | 112 ± 2.6 | 85-145 |
| | 1 | 45 | 203 ± 3.7 | 160-258 | 32 | 199 ± 4.7 | 150-264 |
| | 2 | 43 | 277 ± 4.7 | 225-351 | 32 | 269 ± 5.2 | 222-350 |
| | 3 | 42 | 355 ± 5.7 | 292-444 | 31 | 335 ± 4.8 | 283-379 |
| Mother's milk + supplement | 4 | 43 | 415 ± 7.6 | 345-520 | 29 | 388 ± 7.1 | 320-459 |
| | 5 | 38 | 495 ± 9.8 | 411-613 | 24 | 464 ± 9.4 | 395-568 |
| | 6 | 35 | 588 ± 13.9 | 458-720 | 22 | 557 ± 13.5 | 450-695 |
| | 7 | 34 | 694 ± 17.1 | 537-905 | 22 | 647 ± 15.0 | 534-811 |
| Stock | 8 | 35 | 786 ± 15.1 | 655-1009 | 24 | 736 ± 16.8 | 623-948 |
| | 9 | 32 | 860 ± 16.3 | 715-1075 | 21 | 805 ± 16.2 | 704-979 |
| | 10 | 32 | 913 ± 18.3 | 734-1160 | 22 | 880 ± 18.4 | 710-1024 |
| | 11 | 30 | 1035 ± 24.2 | 822-1282 | 21 | 980 ± 22.0 | 800-1155 |
| | 12 | 33 | 1098 ± 24.2 | 863-1368 | 20 | 1107 ± 30.1 | 887-1347 |
| | 13 | 30 | 1227 ± 30.9 | 900-1689 | 19 | 1180 ± 24.1 | 1037-1391 |
| | 14 | 31 | 1342 ± 25.4 | 1025-1847 | 19 | 1275 ± 26.8 | 1082-1537 |
| | 15 | 36 | 1444 ± 33.6 | 1060-1900 | 18 | 1384 ± 31.0 | 1145-1715 |
| | 16 | 37 | 1546 ± 33.5 | 1210-1970 | 22 | 1472 ± 37.5 | 1200-1898 |
| | 17 | 32 | 1662 ± 35.8 | 1273-2182 | 23 | 1498 ± 34.5 | 1185-1796 |
| | 18 | 31 | 1790 ± 41.6 | 1302-2325 | 20 | 1581 ± 32.5 | 1276-1828 |
| | 19 | 24 | 1900 ± 46.7 | 1496-2636 | 19 | 1613 ± 36.3 | 1315-1892 |
| | 20 | 29 | 1997 ± 50.1 | 1543-2699 | 19 | 1669 ± 42.1 | 1393-1942 |
| | 21 | 19 | 2103 ± 64.2 | 1669-2840 | 21 | 1757 ± 43.0 | 1470-2012 |
| | 22 | 21 | 2132 ± 58.7 | 1799-2987 | 21 | 1854 ± 35.4 | 1565-2102 |
| | 23 | 16 | 2272 ± 66.7 | 1975-3047 | 18 | 1966 ± 40.7 | 1624-2253 |
| | 24 | 17 | 2419 ± 63.5 | 2118-3073 | 15 | 2115 ± 47.6 | 1844-2500 |

Table 3. *Production of kittens*

| Year | No. of mothers | No. of litters | Total no. of kittens born | Mean no. of kittens per litter (value with its standard error) |
|------|-------------------|-------------------|---------------------------------|--|
| 1951 | 16 | 17 | 56 | 3.3 ± 0.24 |
| 1952 | 13 | 21 | 92 | 4.4 ± 0.31 |
| 1953 | 24 | 42 | 154 | 3.7 ± 0.23 |
| 1954 | 26 | 46 | 201 | 4.0 ± 0.22 |
| 1955 | 30 | 54 | 224 | 4.1 ± 0.21 |

year has risen steadily, although the number of litters per mother and the average number of kittens per litter have not altered appreciably during the later years, the improvement after the 1st year being due to better management and feeding. Fig. 1 shows the numbers of kittens born in each month for 4 years; though the greatest numbers were born in March and April with very small numbers in May, there was a second littering period during the summer months and small numbers of kittens were born in the autumn. Productivity tended to be low in November, December, January and February.

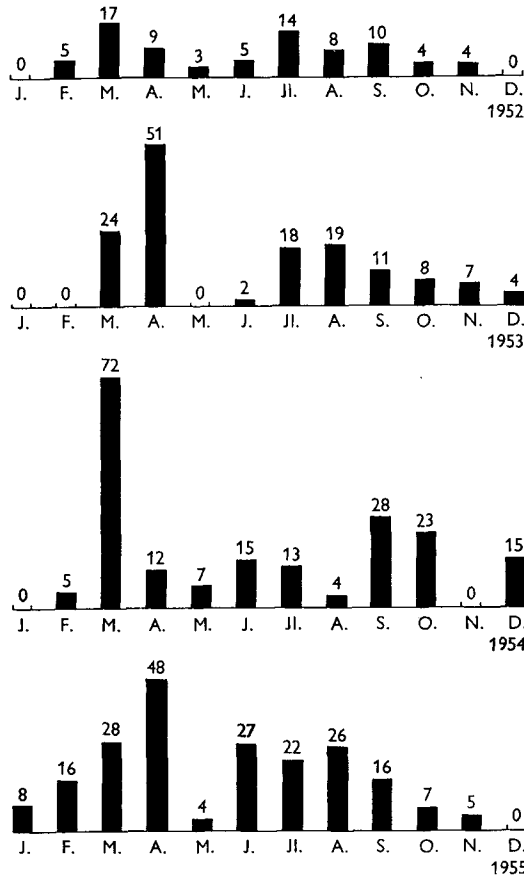


Fig. 1. Numbers of kittens born in each month from 1952 to 1955. Numbers above the columns indicate the number of kittens.

DISCUSSION

In designing the stock diet described in this paper attention was given to the availability, cost and ease of preparing of the foodstuffs chosen, as well as to their nutritive value. Cooked potatoes formed a cheap and easily obtained carbohydrate basis, providing in addition some protein and mineral salts. Previously, potatoes had been successfully used by Dawson (1950) and Carvalho da Silva (1950*a*), the alternative, stale white bread, being suspect on account of possible toxic effects of 'improvers'. Meat was excluded from the stock diet because it cost between three and four times as much as fish, which formed the principal source of protein. Liver, yeast and grass powder were included as sources of vitamins and other (unknown) factors of importance to the cat. In this connexion it was observed that the unavoidable omission of liver, over a period of weeks, resulted in a marked deterioration in the health of the colony. Cod-liver oil, on the other hand, was omitted, since the fish and liver diet was unlikely to be deficient in vitamin A and the addition of excess cod-liver oil has been known to lead to deficiency of vitamin E.

In one of the most extensive investigations of the feeding habits of feral cats in the U.S.A., Eberhard (1954) found that rodents, table food and garbage occurred more frequently than other foods in stomach contents and faeces. It is interesting to note that grass was present in a large proportion of these animals' stomachs. Rodents (live mice), table scraps and milk formed the weaning diet used by Latimer & Ibsen (1932). They studied small numbers of kittens (six ♂, six ♀) and these gained weight at a rate much similar to that of the kittens maintained on the stock diet in our laboratory. These observations confirm the value to the cat of a mixed diet, containing a proportion of offal, especially liver.

Hall & Pierce (1934) measured the growth of seventy kittens during the period of lactation. The mean weights were less than those obtained in this laboratory; at birth the difference was about 6 g, and at the 7th week their kittens were about 70 g lighter. Hall & Pierce did not distinguish between the sexes, but the gains made by small numbers of weaned male and female kittens were measured by Carvalho da Silva (1950*b*). On his stock diets, which consisted, approximately, of one part by weight of cooked potatoes or cooked compressed oats, added to either two parts of fish and meat or two parts of a liver-milk-casein mixture, the mean weights of the males between the 9th and 16th weeks were slightly lower than in our laboratory, but thereafter the weights agreed more closely. However, the mean weights given by Carvalho da Silva for female kittens were less at all ages. The small sex differences between the live-weight gains of the male and female kittens in our series between birth and the 12th week agree with the observations of Olsson (1952) for horses from birth to 17 months of age, but contrast with those for cattle and sheep, in which the males were markedly heavier than females at birth, a difference persisting throughout life.

A study of the literature suggests that it is rather more difficult to formulate a diet supporting reproduction than one satisfactory for growth in the cat. Dawson (1950) found a mixed diet containing cooked potatoes, fish, meat, liver and other offal, supplemented by milk, satisfactory for his breeding colony. No figures were given for the yield of kittens on this diet, presumably because Dawson used his pregnant cats before term. Hall & Pierce (1934) gave a diet of milk and raw beef, with the occasional substitution of liver, at the same caloric level as our stock diet, to their breeding females, which also received 5 ml. cod-liver oil once weekly. On this diet they obtained a mean litter size of 3.88 kittens. Amoroso (1952) gave 3.68 ± 0.102 as the mean of a series of observations on litter size, but did not indicate how the cats were maintained. Except in the 1st year, the mean litter size of 4.05 on the stock diet described here was slightly higher than those quoted above. This increase may have been brought about to some extent by selection of the mothers, since a litter of four formed a convenient experimental group and was well supported by the mother during lactation. Litters of more than five tended to make relatively poorer weight gains during the lactation period.

Using diets composed largely of meat and milk with the addition of 'liberal' amounts of cod-liver oil, Pottenger & Simonsen (1939) and Robinson (1947) found that raw meat gave 'satisfactory' reproduction, although no precise details of output are given. But when the meat was cooked, or canned, reproduction was seriously affected,

many kittens being stillborn. With cats fed on canned food any live kittens died within a few days, and on the cooked meat the viable kittens showed subnormal growth. According to Pottenger & Simonsen (1939) the ovaries of the cats fed on the cooked diet showed few developing follicles or primordial ova, whereas those of the cats on the raw meat showed many more actively developing follicles. Our diet was cooked to render it more easily digestible and to destroy parasites, but heat was applied for short periods only and usually under pressure. Evidence is available that a meat diet may be particularly susceptible to heat injury (Harms & Scott, 1956), but fresh fish, on the other hand, has been shown to produce thiamine deficiency in cats (Smith & Prout, 1944) due to the presence of an antithiamine which is destroyed by cooking.

SUMMARY

1. The stock diet described in this paper has been used to feed a colony of cats, many of which have been bred and reared in the laboratory, and it has proved adequate for growth and reproduction.

2. The diet was given as two meals. The main afternoon meal consisted of pressure-cooked potatoes with either cooked fish, liver or lights, or tinned cat-food and small amounts of dried grass and brewer's yeast. A secondary meal consisting of milk powder, Farex (fortified, precooked blend of cereals) and tinned cat-food was fed in the morning. Water was given to drink.

3. At the 4th week of lactation a supplement to the mother's milk was found necessary and a paste of milk powder and Farex with water was used. Some kittens needed hand feeding before they would take the supplement.

4. The mean weight of the male kittens was 114 g at birth and of the female 112 g, reaching 2419 and 2115 g, respectively, at 24 weeks of age. There was no sex difference in the growth rate until the 12th week, after which males gained more rapidly than females.

5. The total numbers of kittens born, their distribution throughout the year, and the mean litter size, were recorded for each year. In 1955, thirty adult females gave birth to 224 kittens, the maximum numbers of births occurring in March and April, and the mean litter size was 4.1 ± 0.21 .

6. The results are compared with the information obtained by other authors who have used similar diets for cats. Where meat diets were employed growth and reproduction were unsatisfactory if the meat was cooked or canned, but the cooked fish and liver in the stock diet we have described gave adequate growth and reproduction.

The authors would like to express their grateful thanks to Professor E. M. Killick for her continued interest and encouragement. Grants were received between 1951 and 1955 from the Senate and the Central Research Fund of the University of London, the Royal Society and the Medical Research Council, whose support enabled this work to be carried out. Valuable technical assistance was given by Miss O. Cornelius and Miss A. Elkins.

REFERENCES

- Amoroso, E. C. (1952). In *Marshall's Physiology of Reproduction*, 3rd ed., vol. 2, p. 212. [A. S. Parkes, editor.] London: Longmans, Green and Co.
- Carvalho da Silva, A. (1950a). *Acta physiol. Lat.-Amer.* **1**, 20.
- Carvalho da Silva, A. (1950b). *Acta physiol. Lat.-Amer.* **1**, 26.
- Cornelius, P. (1952). *J. Anim. Tech. Ass.* **3**, 41.
- Dawson, A. B. (1950). In *The Care and Breeding of Laboratory Animals*, p. 206. [E. J. Farris, editor.] New York: John Wiley and Sons, Inc.
- Eberhard, T. (1954). *J. Wildlife Mgmt.* **18**, 284.
- Hall, V. E. & Pierce, G. N. (1934). *Anat. Rec.* **60**, 111.
- Harms, A. J. & Scott, P. P. (1956). *J. Sci. Fd Agric.* **7**, 477.
- Latimer, H. B. & Ibsen, H. L. (1932). *Anat. Rec.* **52**, 1.
- McCance, R. A. & Widdowson, E. M. (1946). *Spec. Rep. Ser. med. Res. Coun., Lond.*, no. 235, 2nd ed.
- Olsson, N. (1952). *Medd. LantbrHögsk. HusdjursFörsAnst.* no. 49. Quoted by Pomeroy, R. W. (1955). In *Progress in the Physiology of Farm Animals*, vol. 2, p. 412. [J. Hammond, editor.] London: Butterworth.
- Pottenger, F. M. & Simonsen, D. G. (1939). *J. Lab. clin. Med.* **25**, 238.
- Robinson, H. E. (1947). In *Appraisal of Human Diets by Animal Experiment*, p. 41. [R. R. Williams, editor.] New York: Williams Waterman Fund.
- Scott, P. P. (1952). *J. Physiol.* **118**, 35 P.
- Scott, P. P. (1956). In *The UFAW Handbook on the Care and Management of Laboratory Animals*, 2nd ed. [A. N. Worden and W. Lane-Petter, editors.] London: Baillière, Tindall and Cox. (In the Press.)
- Smith, D. C. & Prout, L. M. (1944). *Proc. Soc. exp. Biol., N. Y.*, **56**, 1.

Nutrition of the cat

2. Protein requirements for growth of weanling kittens and young cats maintained on a mixed diet

BY CECILIA D. DICKINSON AND PATRICIA P. SCOTT

Department of Physiology, Royal Free Hospital School of Medicine, London, W.C. 1

(Received 25 April 1956)

After designing a practical stock diet that would support growth and reproduction of cats maintained under laboratory conditions, the next step was to ascertain the minimal level of protein necessary for normal growth on a mixed diet, since protein sources formed the most expensive of the ingredients used (Dickinson & Scott, 1956). The experiments briefly reported earlier (Dickinson & Scott, 1955) indicated that, with the type of mixed diet used, growth was satisfactory only when the protein fraction exceeded 30% of the dry weight of the diet.

EXPERIMENTAL

General. The origin, selection and management of the kittens were similar to those described in a previous paper (Dickinson & Scott, 1954); most were born and reared in the laboratory and the rest were obtained at weaning from domestic sources. Each kitten was weighed three times a week and its general condition noted.