CV. THE NUTRITIVE VALUE OF WHEATEN PRODUCTS

By N. PALMER

From the Research Laboratory, Hovis Ltd., London, S.W. 1

(Received 23 March 1939)

WHEATEN products used as flour and bread are generally held to be of low nutritive value apart from their capacity to supply energy. It is certainly true that rats cannot be kept in good health or even alive for any length of time on a diet of bread alone. If the bread is made of white patent flour there is no growth at all and the animals die after 2 months. When the bread is made of 3 parts of white flour and 1 part of germ, constituting a foodstuff rich in the vitamin B complex, growth occurs for a time, but ceases after about 2 months and after another 2 months the animal dies (Fig. 1). This nutritive failure is attributed mainly to the low biological value of the proteins of wheat. We found, however, that rats could live and grow for many months in apparently good health on a diet composed almost entirely of wheaten products, namely, white flour to which sufficient wheat germ had been added to give an adequate supply of the vitamin B complex (3 parts of flour and 1 part of germ) and in which the abnormal Ca/P ratio of 1 : 9 had been corrected by the addition of 3 % calcium lactate, to produce a Ca/P ratio of 1 : 0.45.

The average mineral content of a germ-flour mixture is as follows:

	% in moist flour
CaO	0.04
P ₂ O ₅	0.65
MgO	0.16
K ₂ O	0.28
NaCl	1.53
Fe	0.002

The remarkable improvement in the nutritive value of a germ-white flour mixture brought about by correcting the unfavourable Ca/P ratio by the addition of calcium lactate does not take place when calcium lactate is added to white flour alone. On this latter diet the rats show only a slight initial growth and die after about 2 months with deficiency symptoms just as they do on a diet of white flour alone. This difference is illustrated in Figs. 2 and 3, which represent typical growth curves of individual animals.

The following experiments were carried out in order to study in some detail the nutritive value of a diet composed entirely of wheaten products with a corrected Ca/P ratio. The plan of these experiments was to test the length of survival of male and female rats kept on a germ-white flour-calcium lactate diet and to determine whether it interfered with breeding and with the rearing of the young. In this way it seemed possible to obtain some direct evidence of the nutritive value or defects of the proteins of wheat and of wheaten cereals as a whole.

White Wistar rats bred in the laboratory were selected for these experiments as they were found to give good indications of rickets and grew well on the usual rachitic diet. Coloured rats of unknown origin, which, when fed on the same

rachitic diet did not grow well and in some cases died after 3-4 weeks, did not give equally consistent results. The food mixture was mixed with tap water. In each experiment one male and two female rats were kept together in one cage. Many of the females became pregnant and littered. Of the newly born rats many died; the survivors, after having been weaned, were at once put on the flour germ-calcium lactate diet. When they had reached sexual maturity they were again divided into groups of one male and two females for each box, in

Fig. 1. Germ bread and white bread.
●—● Germ bread. ×—× White bread.

Fig. 3. White flour + NaCl + 3% calcium lactate. ♂ ●—●. ♀ ×—×

Fig. 2. Germ flour + 3% calcium lactate. ♂ ●—●; ♀ ○—○; ♀ ×—×

order to see whether breeding from them could be continued on this diet. This was successful in a number of experiments. Thus, in Exp. 512 (Table I) two litters were obtained, of which 10 rats survived weaning and lived for 9 months or more on the cereal diet. A similar result was obtained in Exps. 549, 560 and 561 in which 17 young rats survived weaning. Of these rats, 1 lived for 8 months and 4 for 12 months on the cereal diet. The maximal weights of these 4 rats were 235 and 170 g. for two males, 220 and 160 g. for two females. They lost in weight eventually and were killed. One of the female rats (no. 1819) had 3 litters of 7, 7 and 8 young respectively, all of which, however, died or were eaten by the mother; the other rat (no. 1820) had one litter, all the members of which were eaten by the mother.

The results of the breeding experiments are collected in Table I. It is evident from the experiments that a diet composed entirely of wheaten products, in which the Ca/P ratio is corrected, is of a sufficiently high nutritive value to enable the animals not only to live and to grow, but also to reach sexual maturity,

Table I. *Breeding records*

Exp. no.	Rat no.	No. of young in litter			Remarks
		1	2	3	
374	1204	7	—	—	None survived
380	1228	2	—	—	"
512	1625	5	—	—	5 survived
	1626	7	—	—	5 survived
					Survivors grouped to form Exps. 550, 551. No young obtained
549	1731	9	—	—	9 survived
	1732	3	—	—	2 survived
560	1758	4	—	—	None survived
	1759	5	—	—	4 survived
					Survivors grouped to form Exp. 580
561	1761	2	—	—	2 survived
	1762	5	—	—	None survived
580	1819	7	7	8	Third generation, none survived
	1820	?	—	—	None survived
653	2043	5	4	—	"
654	2046	7	—	—	"

Table II. *Survival periods of 21 rats*

Months	...	4	5	6	7	8	9	10	11	12	13	24
No. of rats surviving after period shown (all lived at least 4 months)		18	16	15	14	11	8	8	7	2	1	0

to breed and, in some cases, to suckle the young. This second generation can then again be reared on the diet and can breed, but so far we have not succeeded in rearing a third generation on this cereal diet.

Another method for testing the nutritive value of this diet was to determine the period of survival of rats kept on the diet. The results are given in Table II. The maximum age of the albino rat is, according to Donaldson, 3 years. There are apparently no observations on record concerning the mortality of rats on different diets composed of single natural foodstuffs, so that a comparison is not possible. Table II shows that the diet, while not an optimum one, enables all the animals to reach sexual maturity and about 30% to live for a year or longer. The bones were well formed, as the following analyses show: bone ash in dry, fat-extracted bone, 60.7%. The bone ash from the bones of a similar rat fed on a normal mixed diet was found to be 56.3%. None of the rats observed in our experiments developed rickets, xerophthalmia or septic glands. The lungs were normal except that in some of the animals kept on the diet for a year or more, there was a moderate degree of the septic bronchiectasis characteristic of a deficiency of vitamin A. Nor could the cause of death in this series be identified with any specific lesion which could be referred to an inadequacy of the protein or to any other defect of the diet. The causes of death appeared to be various intercurrent diseases. These diseases affected the body-weights, which declined during the last few weeks before death.

In order to search for the presence of any specific lesion which might be obscured by the diseases which killed the animals in the preceding series, a large number of rats were placed on the diet and killed at intervals while apparently still well. Table III contains data concerning the sex, age and increase in weight of the rats observed in this series. No specific lesion was found in these animals. A further experiment to test the survival was carried out with 6 young rats. Of

Table III. *Records of rats killed after varying periods on diet*

Months ...	2	3	4	5	6	7	8	9	10	11	12	13	24
Maximal weights, g.	130	110	190	190	190	210	—	285	200	185	235	255	280
	120	100	145	—	240	240	—	195	150	—	170	205	—
	125	120	165	—	160	210	—	175	—	—	210	205	—
	120	—	130	—	130	—	—	—	—	—	160	—	—
	—	—	160	—	—	—	—	—	—	—	—	—	—
Sex and no.	F 4	F 3	M 1	F 1	M 2	M 3	—	M 1	M 1	M 1	M 2	M 1	M 1
	—	—	F 4	—	F 2	—	—	F 2	F 1	—	F 2	F 2	—

Fig. 4. Raw steak. ♂ ●—●; ♀ ×—×; ♀ ○—○.

Fig. 5. Raw steak + 5.5% calcium lactate Ca:P::1:0.5. ♂ ●—●; ♀ ×—×; ♀ ○—○.

Fig. 6. White bread + 30% raw steak. ♂ ●—●; ♀ ×—×; ♀ ○—○.

Fig. 7. Germ bread + 30% raw steak. ♂ ●—●; ♀ ×—×; ♀ ○—○.

Fig. 8. Germ bread + 30% cheese. ♂ ●—●; ♀ ×—×; ♀ ○—○.

Fig. 9. White bread + 30% cheese. ♂ ●—●; ♀ ×—×; ♀ ○—○.

these, 1 died after 4 months, 1 after 5 months, 1 after 10 months, while 2 rats were alive after 11 months.

For comparison, similar experiments were carried out with another important foodstuff, namely meat, the proteins of which are supposed to have a higher biological value than the proteins of wheat. The growth charts show the following results.

Meat alone was unable to maintain growth or even life for more than 5 weeks (Fig. 4). When the Ca/P ratio of meat, which is even below that of bread, having the value 1/20, was corrected by the addition of 5.5% calcium lactate to bring the Ca/P ratio to the value of 1/0.5, there was a temporary period of growth which ceased after 10 weeks. The animals continued to live for 6 months, but lost in weight, looked ill and emaciated and were then killed (Fig. 5). The nutritive value of meat alone, as tested by this method, is therefore inferior to that of the wheaten cereal mixture. On a diet of 2 parts of white bread and 1 part of meat, the animals did almost as badly as on white bread alone (Fig. 6), while the diet of germ bread and meat prolonged life, without, however, allowing of a survival as long as the diet of germ flour and calcium lactate. Growth soon became stationary, the animals declined in weight and their condition deteriorated, so that they had to be killed after 23 weeks (Fig. 7). It should be noted that the Ca/P ratio 1/12 of this diet is below that of bread alone and, therefore, more unfavourable.

On the other hand, a diet of bread and milk, or bread and cheese gave excellent results, even when white bread was used. The rats grew rapidly and produced several litters (Figs. 8 and 9) and after 12 months the animals are still alive and in excellent condition.

SUMMARY

On a diet composed entirely of wheat cereals, namely white flour and germ, a vigorous strain of rats will grow progressively, reach sexual maturity, remain in good health for many months and will breed, provided that the unfavourably low Ca/P ratio of this diet has been corrected by the addition of calcium lactate in such an amount as to produce a Ca/P ratio of 1 : 0.5. On such a diet some rats have been kept alive for a year or more. If the Ca/P ratio is not corrected, growth proceeds for a month only and then ceases and all the animals die within 3-4 months.

The addition of calcium chloride or of calcium carbonate does not give such good results, whilst calcium citrate is as effective as calcium lactate.

These results show that the nutritive value of the wheaten cereal mixture used in these experiments is very high. The proteins of wheaten cereals have, therefore, a much higher biological value than has been attributed to them hitherto. The cereal mixture contains a potential supply of vitamin A in the form of carotene, but the amount is not sufficient to afford complete protection when the diet is given over long periods. This is confirmed by figures given by Copping [1939]. Using rats as test objects, the main defect of cereals is the low amount of calcium and probably also of iodine. When this is corrected the mineral content is adequate.

In a diet composed of natural foodstuffs, the main nutritional defects of cereals are corrected by the addition of milk and its products, butter and cheese. Milk and cheese are among the few foodstuffs rich in calcium. They are also rich in vitamin A, and so is butter. Milk and its products represent, therefore, the rational dietetic complement to cereals, while the combination of meat with

cereals is of doubtful nutritive value, since it aggravates the disproportion of calcium and phosphorus. For the human dietary, which requires an extraneous supply of vitamin C, the inclusion of foodstuffs rich in vitamin C—vegetables and fruits—is required.

The experiments were carried out at the suggestion and under the supervision of Dr W. Cramer.

REFERENCE

Copping (1939). *Nutrit. Abstr. Rev.* 3, 563.