

# A COMPARISON OF THE NUTRITIVE VALUE OF THREE SORGHUM GRAINS WITH THAT OF WHEAT<sup>1</sup>

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## ABSTRACT

Diets containing equal amounts of Shallu, Waxy Kafir, Martin Maize, and wheat were fed to rats for three generations. The nutritive value of the grains was evaluated by comparing rat weights, food consumption, and reproductive capacities. The sorghum grains were nutritionally inferior to wheat. Impairment in growth of rats on the Shallu, Kafir, and Martin diets became evident in the third, second, and first generations, respectively. The sorghum grains were not as efficient as wheat in producing weight gains. This was evident for Shallu and Kafir in the second generation and for Martin in the first generation. All of the sorghum grains were inferior to wheat in producing litters in the second generation and in rearing young to weanling age in the first generation. The sorghum grain diets did not promote growth and reproduction in the second generation comparable to that produced in the first generation. Decreased efficiency in producing weight gains was noted for all the sorghum grain diets in the second generation. The results indicate that supplementation of the sorghum grains is necessary before they can be substituted for wheat in nutrition and illustrate the dangers of drawing conclusions from short-term feeding experiments on weanling rats from standard breeding stock.

Sorghum grains are the world's third most important food grain, being exceeded in volume production only by rice and wheat.<sup>5</sup> The vast group of sorghum grains has proved to be highly productive in extensive areas of the United States. The growing season of these grains is short, and yields per acre are very high. Most of the sorghum grains can be produced and harvested with machinery and require little or no cultivation (1). Production of sorghum grains has increased progressively: average annual yield during 1930-39 was 53 million bu.; during 1940-49, 119 million bu.; and during 1950-57, 227 million bu. (see footnote 5).

Sorghum grains contain approximately 12% protein, 3% fat, and 70% carbohydrate. They are not a balanced source of protein for use as a livestock ration and must be supplemented for best results. The composition of sorghum grains is similar to that of corn, but they contain more protein and less fat. Results from feeding livestock indi-

<sup>1</sup>Manuscript received July 12, 1965. Contribution from Department of Food and Nutrition, Texas Technological College and Texas Agricultural Experiment Station Substation, Lubbock, Texas.

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<sup>5</sup>Unpublished research. Report given by N. W. Kramer on sorghum hybrids for grain and forage. Third annual research conference, farm seed industry; Chicago, Ill., Jan. 27, 1958.

cate that, pound for pound, the two grains produce almost identical weight gains (1). Improvements in sorghum grains by the addition of new genetic characters are making them more acceptable for human consumption in the United States. Sorghum grains with yellow endosperm which gives them vitamin A value are being developed, and improvement in oil content and protein quality is possible (see footnote 5).

Data on the nutritive value of these grains in comparison with wheat, our staple grain, are limited. The present study was undertaken to investigate the nutritional adequacy of these grains as compared with wheat.

### Materials and Methods

Three sorghum grains were used in this study: Shallu, a pearly nonpigmented grain, easily cracked and adapted to harvest with a combine; Martin Maize, a red-pigmented, hard-kernel, combine variety; and Waxy Kafir, a large opaque white grain, characterized by waxy carbohydrate, and also adapted to combine harvest. Each of these sorghum grains, as well as the wheat, was locally produced during the same year. The threshed grains were ground into a fine meal acceptable for use in experimental diets for albino rats. The chemical analysis of these grains is given in Table I.

Nine to eleven pairs of albino rats, 4 weeks old, designated as P-1, from standard breeding stock and matched as to sex, were started on each of the three sorghum grains and on wheat in the following basic diet: one-sixth whole dried milk; five-sixth ground grain; 1% by weight of sodium chloride. The rats consumed the diet and distilled water *ad libitum*. This basic diet, when wheat is used as the grain, is Sherman's diet A and has been proved by Sherman to be adequate for successful reproduction and rearing of progeny for successive generations, though not adequate for optimum growth (2). Records of

TABLE I  
COMPOSITION OF GRAINS<sup>a</sup>

	WHEAT	SHALLU	KAFIR	MARTIN
Protein (%)	13.40	11.40	11.40	10.50
Fiber (%)	2.37	2.66	1.96	2.18
Ash (%)	1.85	1.85	1.17	1.25
Vitamin (mg./100 g.)				
Riboflavin	0.169	0.150	0.119	0.157
Niacin	4.840	4.150	2.430	2.200
Thiamine	0.247	0.226	0.266	0.220

<sup>a</sup> All of the grains were grown, harvested, ground, and chemically analyzed for this research by R. E. Karper, then agronomist in charge of sorghum grain investigation, Texas Agricultural Experiment Station Substation, Lubbock.

weight and simultaneous food consumption were kept on the rats for 8 weeks.

Subsequent records of weight and food consumption were kept for a minimum of 10 pairs of young from each of two breedings of the original P-1 females on each grain diet. This group of progeny, designated as F-1, represents the second generation. Weight records were also kept for 3 weeks on the young from two breedings of the F-1 females. This group of progeny, designated as F-2, represents the third generation.

Reproduction records were kept for the P-1 and F-1 generations producing F-1 and F-2 generations respectively. Not less than 10 of the P-1 females on each grain diet were randomly selected for the reproductive studies. Each female was allowed to breed twice, to produce two litters of young. From each of the two litters produced by P-1 females, 10 F-1 females were randomly selected and allowed to breed twice, to produce two litters of third-generation, F-2 young. The males used for breeding were litter mates of the females, that is, they were also on the same grain diets.

Statistical analysis consisted of a multiple range test (3) on the growth data, a chi-square test on the breeding data, and an analysis of variance on the total young born and survival of young.

## Results

*Growth.* The experimental growth periods were different for the first and second generations. Comparisons on growth of P-1 and first- and second-litter F-1 rats are based on statistical analysis of growth data through the 8th week of age.

The average growth, based on weight gain, of P-1 rats on each of the four grain diets is shown in Fig. 1. Differences in weight gain among the groups of rats on Shallu, Kafir, and wheat diets were not significant ( $P > 0.05$ ), but each of these grain diets produced significantly greater ( $P < 0.05$ ) weight gains than did the Martin diet.

Weight gain of first-litter F-1 rats on each of the four grain diets is shown in Fig. 2. Rats on the Shallu diet had significantly greater ( $P < 0.05$ ) weight gain than did those on any of the other diets. Differences in weight gain among groups of rats on the Martin, Kafir, and wheat diets were not significant ( $P > 0.05$ ). Weight gain of second-litter F-1 rats on each of the four grain diets is shown in Fig. 3. Weight gain of rats on Shallu and wheat diets was comparable and significantly greater ( $P < 0.05$ ) than weight gain on either Kafir or Martin diet. Rats on the Martin diet had significantly greater ( $P < 0.05$ ) weight gain than did those on the Kafir diet.

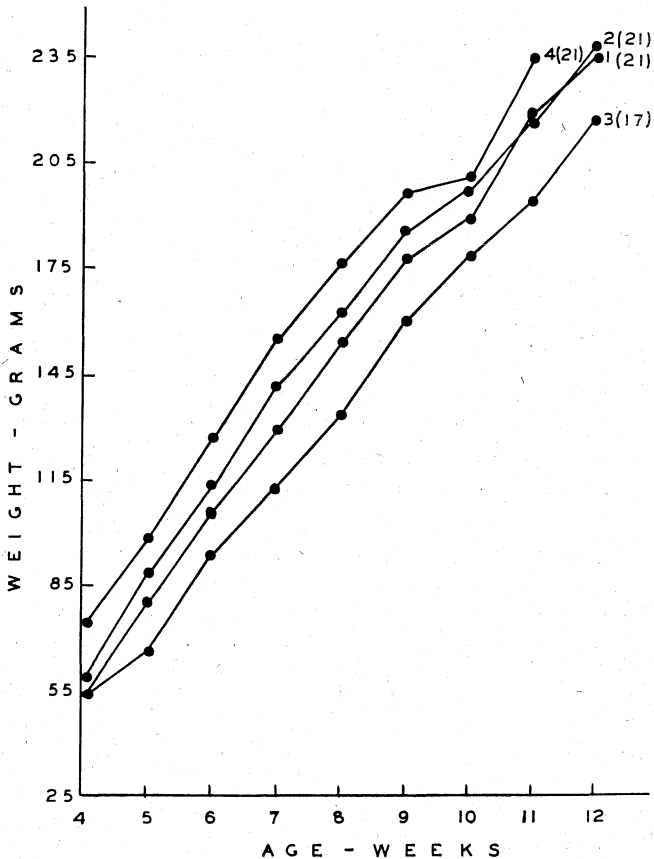


Fig. 1. Average growth of P-1 rats. Numbers 1, 2, 3, and 4 refer to the wheat, Shallu, Martin, and Kafir diets respectively. Figures in parentheses represent the number of rats on which the curve is based.

A comparison of Figs. 1, 2, and 3 will show weight gain across generations and across successive litters of the second generation for rats fed each of the grain diets. Weight gains of P-1, first-litter F-1, and second-litter F-1 rats on the wheat diet were not significantly different ( $P > 0.05$ ). The Shallu and Martin diets produced weight gain in the first-litter F-1 rats comparable to that produced in P-1 rats; however, the weight gain of the second-litter F-1 rats was significantly less ( $P < 0.05$ ) than that of the first litter. P-1 rats on the Kafir diet had significantly greater ( $P < 0.05$ ) weight gains than did either first- or second-litter F-1 rats; weight gain of first-litter F-1 rats was significantly greater ( $P < 0.05$ ) than that of second-litter F-1 rats.

The weekly average weight of both litters of F-1 and F-2 rats up

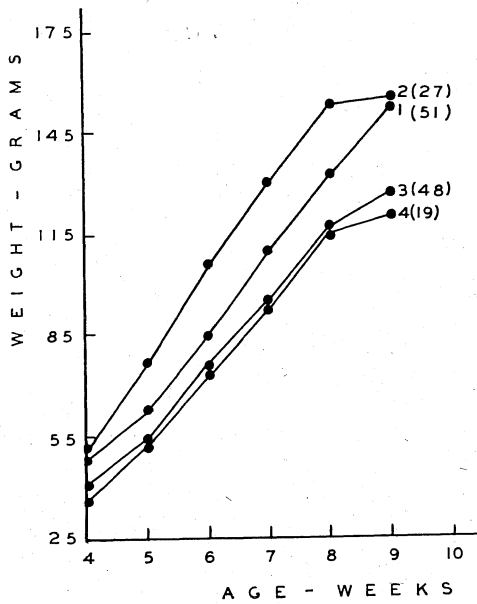


Fig. 2. Average growth of first-litter, F-1 rats. See Fig. 1 for explanation of numbers.

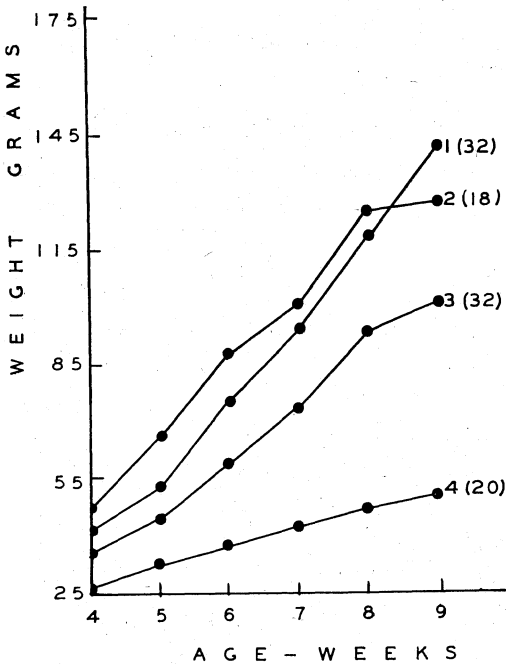


Fig. 3. Average growth of second-litter, F-1 rats. See Fig. 1 for explanation of numbers.

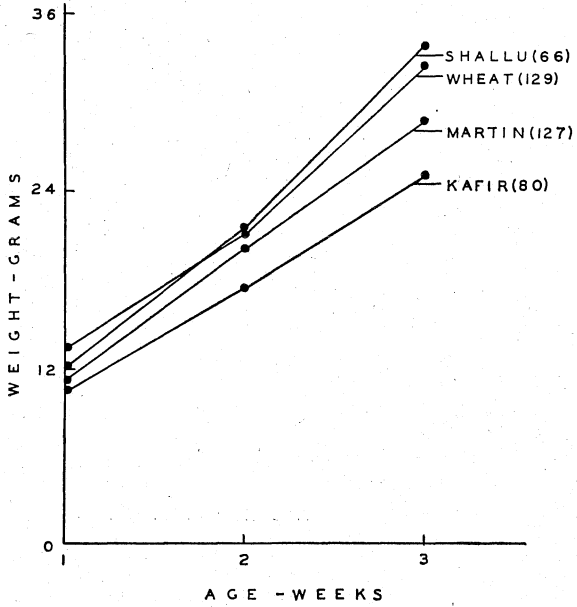


Fig. 4. Average growth of F-1 rats, both litters, up to weaning age. Figures in parentheses: number of rats on which curve is based.

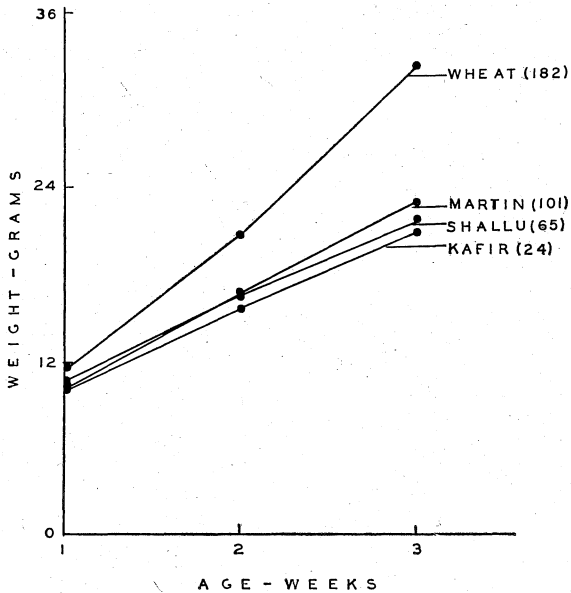


Fig. 5. Average growth of F-2 rats, both litters, up to weaning age. Figures in parentheses: number of rats on which curve is based.

to weanling age is shown in Figs. 4 and 5 respectively. The gain in weight of F-1 young up to 3 weeks of age was greater on the wheat and Shallu diets than on either Martin or Kafir. The weight gain of F-2 rats on the sorghum grain diets was reduced to almost half that achieved on the wheat diet. A comparison between second- and third-generation rats on the same grain diet shows that F-2 rats on the wheat diet had weight gains comparable to gains of F-1 rats; F-2 rats on the sorghum grain diets failed to achieve the increments in weight noted for F-1 rats.

The rats on the Martin diet were the only ones to show outward signs of physical abnormality. Severe alopecia developed in the P-1 females after their first litter of young and in their progeny.

*Food Utilization.* The average of food consumed, g. per g. of total weight and per g. gain for P-1 and both litters of F-1 rats, is shown in Table II. P-1 rats on the Shallu diet had the lowest food consump-

TABLE II  
FOOD CONSUMPTION

GENERATION	GRAIN	NUMBER OF RATS	FOOD CONSUMED	
			g./g. total wt.	g./g. gain
P-1	Wheat	21	0.71	4.54
	Shallu	21	0.59	4.22
	Martin	17	0.75	4.93
	Kafir	21	0.72	4.32
F-1	Wheat	83	0.92	4.22
	Shallu	45	1.06	4.93
	Martin	80	1.10	6.23
	Kafir	39	1.07	4.56

tion per g. total weight and per g. gain; those on Kafir and wheat diets consumed almost equal amounts; and those on Martin diet had the highest food intake per g. of total weight and per g. gain. In second-generation rats (F-1), wheat was superior to the sorghum grains in producing weight gain, Martin again showing the least weight gain per g. of diet consumed.

A comparison between generations shows that P-1 rats on the sorghum grain diets consumed less food per g. of total weight and per g. gain than did F-1 rats. Although not shown in the table, first-litter F-1 rats on the sorghum grain diets consumed less food per g. gain and per g. of total weight than did second-litter F-1 rats.

*Reproduction.* A summary of reproduction results is given in Table III. Two litters were produced by 95% of P-1 females on the wheat diet, 90% of P-1 females on each of the Shallu and Martin diets, and 73% of P-1 females on the Kafir diet. These differences among

TABLE III  
SUMMARY OF REPRODUCTION

	GRAIN DIETS							
	Wheat		Shallu		Martin		Kafir	
Generation of female bred	P-1	F-1	P-1	F-1	P-1	F-1	P-1	F-1
Generation of offspring	F-1	F-2	F-1	F-2	F-1	F-2	F-1	F-2
Number of females	10	20	10	20	10	20	13	20
Total number of litters from two breedings	19	32	18	20	18	23	19	8
Number of litters with survival	14	23	9	9	17	17	12	4
Total young born	199	310	175	173	169	208	179	65
Total young dead	70	128	109	108	42	107	99	41
Young dead in complete litter loss	56	88	89	88	15	52	70	31
Total young surviving at 3 weeks	129	182	66	65	127	101	80	24
Average young born per litter	10.5	9.7	9.7	8.7	9.4	9.1	9.4	8.1
Average size of surviving litters	10.2	9.7	9.6	9.5	9.1	9.2	9.1	8.5

the grain diets were not significant ( $P > 0.05$ ). When litters produced by second-generation (F-1) females were compared, significant differences were found among the different grain diets. F-1 females on the wheat diet had more litters from two breedings than did those on the Kafir ( $P < 0.01$ ), Shallu ( $P < 0.01$ ), and Martin ( $P > 0.05$ ) diets. Rats on the Kafir diet also produced significantly fewer ( $P < 0.01$ ) litters than did those on Shallu and Martin diets.

The difference in litters produced by P-1 and F-1 rats on the wheat diet was not significant ( $P > 0.05$ ). F-1 females on the Shallu, Martin, and Kafir diets produced significantly fewer ( $P < 0.01$ ,  $< 0.05$ ,  $< 0.01$  respectively) litters than did P-1 females.

The average litter size varied slightly among the grain diets and between generations. None of these differences were significant ( $P > 0.05$ ). Complete litter loss immediately after birth was greatest on the Shallu diet and least on the Martin diet. The differences in average size of surviving litters between generations and among grain diets were not significant ( $P > 0.05$ ). Therefore the differences in survival of progeny up to 3 weeks of age are not attributable to differences in litter size.

P-1 females on the wheat diet had significantly more progeny surviving at 3 weeks than did those on each of the Kafir, Shallu, and Martin diets ( $P < 0.05$ ). Survival of progeny from P-1 females on the Martin diet was significantly greater ( $P < 0.01$ ) than that from P-1 females on the Shallu diet. The only significant difference in survival of progeny from F-1 females was noted between the wheat and Shallu



diets ( $P < 0.01$ ), the wheat diet being superior. Comparisons between generations show that only F-1 rats on the Martin diet failed to rear their progeny to weanling age as successfully as did P-1 rats ( $P < 0.05$ ).

### Discussion

*Growth.* The Shallu diet was comparable to wheat in producing weight gain in rats over two generations and two successive breedings of the second generation. Results with the Martin diet indicate that this grain is inferior to wheat in producing weight gain in first-generation rats. Although first-litter F-1 rats on the Martin diet showed weight gains comparable to those on the wheat diet, in second-litter F-1 rats Martin was inferior to wheat. The Kafir diet was comparable to wheat in producing weight gain in rats of the first generation and the first litter of the second generation, but it was greatly inferior to wheat in producing weight gain in the second litter of the second generation. The sorghum grain diets were all inferior to wheat in producing weight gain in third-generation rats up to weanling age.

The wheat diet produced weight gain in second- and third-generation rats comparable to that produced in the first generation. None of the sorghum grain diets was adequate for growth in successive generations. The inadequacy of the Shallu and Martin diets was not evident until the second litter of the second generation; the inadequacy of the Kafir diet was evident in the first litter of the second generation.

*Food Utilization.* The efficiency of the Shallu and Kafir diets in producing weight gain was comparable to that of wheat in first-generation rats but was slightly inferior to the efficiency of wheat in second-generation rats. The Martin diet was inferior to wheat in producing weight gain in both generations. Decreased efficiency in growth-promoting properties was noted for all the sorghum grain diets when they were fed to rats for successive generations and for successive breedings of the second generation.

*Reproduction.* First-generation rats on the sorghum grain diets were as successful in producing litters as were those on the wheat diet. In second-generation rats, the Kafir diet was greatly inferior to the other diets. The wheat diet was superior to the Shallu and Martin diets. The sorghum grain diets were all inferior to the wheat diet in producing litters in second-generation rats comparable to those produced in first-generation rats.

The consistency noted in litter size suggests that successful breeding occurred only in those females which had full reproductive capacity. The more complete loss of litters by females on the Shallu diet than by those on the other diets is difficult to evaluate, because

no definitive observations were made on congenital malformations. Surviving litter size was comparable for all grain diets and for the two generations on the same grain diet. The superiority of females on the wheat diet in nourishing their young to weanling age is therefore not a reflection of litter size but rather of lactation.

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