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NUTRITIVE PROPERTIES OF CERTAIN ANIMAL AND VEGETABLE FATS
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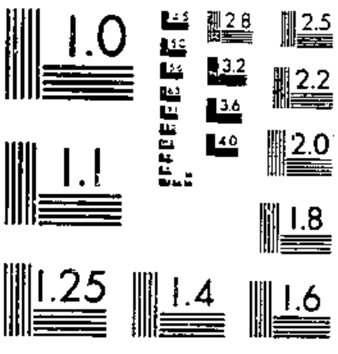

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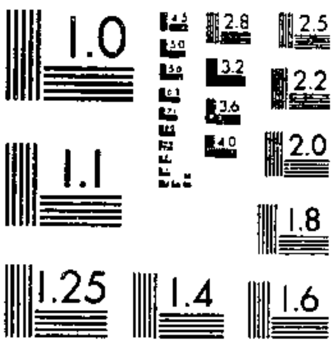

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Nutritive Properties of Certain Animal and Vegetable Fats[1]

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CONTENTS

INTRODUCTION

Until comparatively recently, the relative nutritive properties of edible fats were judged chiefly by their digestibility and to a lesser extent by their vitamin content. The discovery by Burr and Burr (*3, 4, 5*)[2] of the apparent indispensability of linoleic or a more unsaturated fat acid for normal growth and health in rats and the substantiation of these findings by Evans and coworkers (*7, 8, 9*) and by Turpeinen (*20*) have added another factor to be considered in judging the nutritive value of a fat. In view of the importance of fat in the human diet, it has seemed desirable to obtain additional information concerning the nutritive properties of a number of common food fats.

The purpose of the experiments herein reported was to determine, by means of growth and digestion experiments with young male albino rats, the relative nutritive properties of refined lard, hydrogenated lard, leaf lard, neutral lard, oleo oil, cottonseed oil, hydrogenated cottonseed oil, and peanut oil with special reference to factors affecting those properties. The vitamin content of the fats was not determined, but essential vitamins were added to the experimental diets.

PREVIOUS INVESTIGATIONS

Deuel and Holmes (*6, 11*), Holmes (*10*), and Langworthy and Holmes (*15, 16, 17*) conducted experiments with young men to determine the digestibility of a variety of fats. The digestibility of each

[1] Submitted for publication July 21, 1939.
[2] Italic numbers in parentheses refer to Literature Cited, p. 11.

fat was reported after correction for metabolic fat in the feces. Following are the coefficients of digestibility which the investigators obtained for the fats indicated: Leaf lard, 97; oleo oil, 96.8; oleo stearin, 80.1; beef-kidney fat, 93; beef-brisket fat, 97.4; cottonseed oil, 97.6; and peanut oil, 98.3 percent. Particular attention is directed to the results obtained with hydrogenated cottonseed and peanut oils (*11*). Hydrogenated cottonseed oils with melting points of 35.0°, 38.6°, and 46° C. were found to have digestive coefficients of 96.8, 95.5, and 94.9 percent, respectively. Hydrogenated peanut oils with melting points of 37°, 39°, 43°, 50°, and 52.4° had digestive coefficients of 98.1, 95.9, 96.5, 92, and 79 percent, respectively. Digestion experiments also were conducted with mixtures of cottonseed oil and completely hydrogenated cottonseed oil and with mixtures of peanut oil and completely hydrogenated peanut oil (*8*). The results were as follows: Cottonseed-oil mixtures with melting points of 41.3°, 45.8°, 47.8°, 48.1°, and 50° had digestive coefficients of 96.6, 96.4, 94.2, 94.4, and 87 percent, respectively. Peanut-oil mixtures with melting points of 43°, 44.2°, and 51.1° had digestive coefficients of 96.6, 97.4, and 92.8 percent, respectively.

McCay and Paul (*18*) determined the digestibility of cottonseed oil and of hydrogenated vegetable oil in experiments with rats. The diet consisted of dried skim milk and fat, the latter constituting approximately 20 percent of the energy value of the diet. The digestion experiments were conducted with four rats for 5-day periods. No correction was made for metabolic fat in the feces. The average apparent digestive coefficients were as follows: Cottonseed oil, 97.4; and hydrogenated vegetable oil, 94.9 percent.

Steenbock and coworkers (*19*) determined the comparative rate of absorption of a number of fats in experiments with rats. Their results indicated that, in general, lard and two commercial hydrogenated vegetable oils were absorbed at approximately the same rate. Peanut oil and cottonseed oil were absorbed at about equal rates, but oleo stock was absorbed much more slowly.

Irwin and coworkers (*12*) determined the influence of the degree of hydrogenation of fats on their rate of absorption by rats. They found that the rate of absorption of a fat decreased as the melting point increased above body temperature, but that variations in melting point below body temperature were without effect.

FATS USED IN PRESENT EXPERIMENTS

Refined lard, leaf lard, neutral lard, oleo oil, and cottonseed oil were purchased from one large meat-packing establishment, and refined lard and hydrogenated lard were obtained from another. In the case of refined lard from the first establishment, fatty tissues obtained from hogs at the time of slaughter and those obtained as a byproduct when the carcasses were cut up were rendered in a steam tank for 8 to 9 hours at 280° F. The rendered fat was drawn off, bleached by the addition of activated carbon and diatomaceous earth, filtered, and chilled by passing over a refrigerated roll. In the second establishment, similar fatty tissues were rendered in a steam tank for about 9 hours at a maximum temperature of 286° F. The clear fat was drawn off, heated to 180°, and sodium bicarbonate was added to neutralize free fat acids. Diatomaceous earth and a small quantity of caustic soda were added and the fat was filtered. The lard was then ready for hydrogenation.

The refined lard, as prepared in the second meat-packing establishment, was hydrogenated at a maximum temperature of 300° F. under a pressure of 60 pounds of hydrogen until the iodine number was reduced to approximately 60. The lard was then filtered, deodorized at 350°, and again filtered.

Fresh warm leaf fat was hashed and then rendered for 2½ hours in a steam-jacketed open kettle at a maximum temperature of 240° F. After settling, the lard was drawn into holding tanks. For grainy lard the fat was drawn into containers at 120° and allowed to cool slowly. If smooth lard was desired, the fat was run over a refrigerated roll.

In the case of neutral lard, chilled leaf fat was hashed and then rendered in an open steam-jacketed kettle at a maximum temperature of 125° F. The lard was drawn off and stored in tierces at 115°.

To obtain the oleo oil, fatty tissues taken from cattle at the time of slaughter were chilled in cold water, hashed, and rendered at 150° F. After rendering was complete, salt was added to facilitate settling. The clear fat was transferred to seeding trucks, which were held 5 days in a room at 90–92° to facilitate separation of oleo oil from oleo stearin. The mixture, commonly termed "oleo stock," was then filtered in a mechanical press at the same temperature. The fluid portion constituted oleo oil and the residual fat, oleo stearin.

The cottonseed oil, though the product of a meat-packing establishment, was not subject to provisions of the Meat Inspection Act, and details concerning its manufacture were not obtained.

The following products also were purchased:

A well-known brand of hydrogenated cottonseed oil packed in sealed tin cans was purchased on the open market.

Peanut oil was purchased from a dealer in fats who stated that the oil had been imported from the Netherlands.

Method of Storing Fats

When received at the laboratory the fats, with the exception of the hydrogenated cottonseed oil and one lot of hydrogenated lard, were transferred to glass jars, which were sealed to exclude air and stored at a temperature of about 36° F. The hydrogenated cottonseed oil in original sealed tin cans and one lot of hydrogenated lard in 1-pound cartons were stored at the same temperature as the other fats.

DIETS FED

Each of the solid fats was incorporated in an otherwise adequate diet in the proportions of 5, 30, and 55 percent, but cottonseed oil and peanut oil were added only in the proportions of 5 and 30 percent, since it was not possible to prepare uniform feed mixtures containing 55 percent of these oils. Vitamins A and D equivalent to 2 percent of high-grade medicinal cod-liver oil were added to each diet in the form of an ether extract of saponified cod-liver oil. In each diet, casein supplied approximately 19.4 percent of the total energy value of the diet, and the proportions of salts and yeast were adjusted so as to have approximately constant relations to the total energy value. The diets were made up according to the formulas in table 1.

TABLE 1.—*Formulas for diets fed to rats* [1]

Diet No.	Fat [2]	Casein	Salts	Yeast	Dextrose
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
1	0	18.6	4.0	2.9	74.5
2	5	20.6	4.3	3.0	67.1
3	30	26.6	5.8	4.2	33.4
4	55	33.0	7.0	5.0	0

[1] 100 cc. of an ether extract of saponified cod-liver oil equivalent to 20 gm. of the oil was added to 1,000 gm. of each diet. The vitamin content of the concentrate was not determined.
[2] In diets 2, 3, and 4, fat supplied 12, 53, and 78 percent, respectively, of the total energy value of the diet.

The casein used in the diets was a granular commercial product. It was percolated with ethyl ether for at least a week until it was practically free from ether-soluble material. Dried brewers' yeast was extracted in the same manner. Salt mixture was made up according to the formula in the following tabulation. Each diet was prepared in kilogram quantities and was stored in tightly covered glass jars at approximately 36° F. In calculating the energy value of a diet, the following factors were used: Protein, 4; carbohydrate, 4; and fat, 9 Calories per gram. The term "Calorie" as used in this paper denotes the kilogram-calorie.

Composition of salt mixture added to diets of rats

Ingredient	*Proportion used (percent)*
$NaCl$	4.66
$MgSO_4.7H_2O$	7.17
$NaH_2PO_4.H_2O$	9.36
$CaH_4(PO_4)_2.H_2O$	14.56
K_2HPO_4	25.70
$Ca(C_3H_5O_3)_2.5H_2O$	35.05
$FeC_6H_5O_7.3H_2O$	3.14
KI	18
$MnSO_4.4H_2O$	18

EXPERIMENTAL PROCEDURE

Three series of growth experiments were conducted, one each with diets containing 5 and 30 percent of each fat, and a third series with diets containing 55 percent of each solid fat. Only experiments with diets containing the same percentage of fat were conducted at one time. Each diet was fed unrestrictedly to eight male albino rats weighing approximately 40 gm. each and not exceeding 28 days of age at the beginning of the experiment. Rats from different litters were distributed as evenly as practicable among the groups receiving the different fats. Each rat was kept in an individual cage, which was provided with a raised-screen bottom, a self-feeder, and a drinking vessel. The bottom of the cage was covered with a round sheet of blotting paper. Rats were weighed twice weekly, and a record was kept of feed consumed. Feeding tests with diets containing fat were conducted for 60 days.

Digestion tests were conducted with six rats on each diet, usually after the experiment had been in progress for 35 to 50 days. All feces from each rat were collected for 7 days, and the quantity of feed consumed during the same period was weighed. The feces were collected daily by means of forceps. The rats scattered very little feed, and the feces were not contaminated thereby. The feces were dried to a constant weight at 100° C. The quantity of fat consumed by each rat was calculated from the quantity of feed eaten and the percentage of fat added to the diet.

The quantity of fat excreted in the feces was determined as follows: Approximately 2 gm. of dry feces was weighed into a 150-cc. beaker, and 40 cc. of 30-percent potassium hydroxide solution was added. The mixture was heated on a steam bath until the feces were disintegrated, 50 cc. of 95-percent ethyl alcohol was added, and heating was continued until saponification was completed. More alcohol was added if necessary. The contents of the beaker were transferred to a 500-cc. separatory funnel, and a slight excess of concentrated hydrochloric acid was added. When cool, the contents of the funnel were extracted twice with 100-cc. portions of petroleum ether to remove free fat acids, and the ether extract was treated with water to remove hydrochloric acid. The ether extract was transferred to a tared 300-cc. Erlenmeyer flask, which was placed on a steam bath until the ether had evaporated. The flask was placed in an electric oven and the fat acids were dried in a current of nitrogen at 100°C. The quantity of glycerides was calculated by multiplying the quantity of mixed fat acids by 1.045.

Metabolic fat in the feces of the rats in the digestion tests was determined in the following manner: At the end of the 60-day experiment, each rat from which feces had been saved for analysis was changed to the fat-free diet. After a preliminary period of at least 2 days to permit the excretion of all feces from the previous diet, the feces were saved for a week. The feces were dried and the fat content was determined as previously described. The percentage of fat found in the feces of a rat while on the fat-free diet was considered to be metabolic fat, and this figure was used in correcting for the metabolic fat in the feces of the same rat in the previous digestion experiment.

The true digestibility of each fat was calculated by subtracting the quantity of metabolic fat from the total quantity of fat excreted during the test period and dividing this result by the quantity of fat consumed. In calculating the quantity of metabolic fat excreted by a rat while on a diet containing fat, it was assumed that each rat excreted the same quantity of metabolic fat in proportion to nonfatty dry matter, as when fed the fat-free diet.

The following methods were used in the analysis of the fats: The iodine number was determined by the Hanus method and the melting point by the capillary-tube method *(1)*. The thiocyanogen number was determined by the method of Kaufmann *(14)*, and the percentages of various fat-acid glycerides were calculated from the iodine and thiocyanogen numbers by the formulas given by Jamieson *(13, p. 346)*. It was assumed that none of the fats contained any fat acid more unsaturated than linoleic acid. The saturated fat-acid glycerides include unsaponifiable matter. The percentage of iodine absorbed by the undigested fat acids from a rat was calculated from the iodine numbers of the total fat acids and of the metabolic fat acids, and from the quantity of each kind of fat acids excreted during the digestion experiment.

EXPERIMENTAL RESULTS

The composition of the fats that were used in the experiments is shown in table 2. The significance of these data as related to the nutritive value of the fats is discussed later.

TABLE 2.—*Composition of fats used in experiments with rats*

Fat used	Laboratory No.	Melting point	Iodine number	Thiocyanogen number	Saturated fat acid glycerides	Unsaturated fat acid glycerides	Oleic acid glyceride	Linoleic acid glyceride
		° C.	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Refined lard	3382	42.5	68.8	56.7	34.2	65.8	51.8	14.0
Do	4001	43.0	62.4	57.7	33.0	67.0	61.6	5.4
Do	4008	43.0	65.1	59.4	31.0	69.0	62.4	6.6
Hydrogenated lard	3375	46.0	58.7	56.3	34.6	65.4	[1] 62.6	2.8
Do	4009	48.0	58.8	57.6	33.1	66.9	[1] 65.5	1.4
Leaf lard	3383	47.0	58.8	49.0	43.1	56.9	45.6	11.3
Do	4002	48.0	55.7	52.0	39.6	60.4	56.1	4.3
Neutral lard	3385	41.5	59.6	51.3	40.4	59.6	50.0	9.6
Do	4004	48.0	54.8	50.7	41.2	58.8	54.1	4.7
Oleo oil	3384	33.0	46.7	44.2	48.6	51.4	48.5	2.9
Do	4003	36.5	46.2	43.5	49.5	50.5	47.4	3.1
Cottonseed oil	3381		109.1	65.4	24.4	75.6	25.2	50.4
Hydrogenated cottonseed oil	3377	46.5	73.7	61.0	29.2	70.8	[1] 56.1	14.7
Do	4007	45.0	74.3	63.1	26.8	73.2	[1] 60.3	12.9
Peanut oil	3378		100.1	70.9	17.8	82.2	48.5	33.7

[1] Includes isooleic acid glycerides.

GROWTH-PROMOTING VALUES OF FATS

The growth-promoting values of the fats are shown in table 3. Only the average data for each group of rats are shown and data not considered essential for the interpretation of the results are omitted. The average age of the several groups of rats used in these experiments ranged from 20 to 24 days, and their average weight at the beginning of the experiments ranged from 39 to 41 gm.

TABLE 3.—*Average growth-promoting properties of diets containing 5, 30, and 55 percent each of different fats when fed to rats for 60 days*

Fat used	Laboratory number of fat [1]	Gain in weight on diet containing—					
		5 percent of fat		30 percent of fat		55 percent of fat	
		Per rat	Per 100 Calories	Per rat	Per 100 Calories	Per rat	Per 100 Calories
		Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
Refined lard	3382, 4001	225	8.81	200	7.85	265	7.91
Do	4008					263	7.83
Hydrogenated lard	3375, 4009	198	8.21	239	6.88	242	6.92
Leaf lard	3383, 4002	225	8.12	277	7.53	287	7.62
Neutral lard	3385, 4004	220	7.99	263	7.31	271	7.82
Oleo oil	3384, 4003	200	7.72	241	6.98	264	7.05
Cottonseed oil	3381	234	8.91	221	7.29		
Hydrogenated cottonseed oil	3377, 4007	221	8.71	238	7.28	228	7.20
Peanut oil	3378	235	8.58	264	7.48		

[1] When 2 lots of a fat were used, the lot with the lower number was used in diets containing 5 or 30 percent of fat, and both lots were used in the diet containing 55 percent of fat.

When the diets contained 5 percent of fat, peanut oil and cottonseed oil induced the largest gains in weight per rat, and hydrogenated lard and oleo oil the smallest gains. However, gain in weight in relation to the energy value of the feed consumed is a more satisfactory basis for comparison. When judged by the latter standard, cottonseed oil, refined lard, and hydrogenated cottonseed oil had the highest growth-promoting values, whereas oleo oil had the lowest value.

In the experiments with the diets containing 30 percent of fat, refined lard induced a larger gain in weight per rat than any other fat, followed by leaf lard, whereas cottonseed oil induced the smallest gain. When comparisons are made on the basis of gain in weight for each 100 Calories consumed, refined lard again resulted in the largest gain, whereas hydrogenated lard and oleo oil resulted in the smallest gains.

When the diets contained 55 percent of fat, leaf lard induced the largest gain in weight per rat and hydrogenated cottonseed oil induced the smallest. On the basis of gain in weight for each 100 Calories consumed, oleo oil induced the largest gain, closely followed by refined lard, whereas hydrogenated lard induced the smallest gain. Particular attention is directed to the fact that in this series of experiments oleo oil had the highest growth-promoting value, as related to energy consumption; whereas in the experiments with diets containing 5 or 30 percent of fat, oleo oil had either the lowest or next to the lowest value.

Since the three series of experiments were not conducted at the same time, the results are not strictly comparable owing to the possible influence of season on growth. However, with the possible exception of cottonseed and peanut oils, 5 percent of none of the fats was adequate for normal growth of rats. All fats except oleo oil were utilized most efficiently for growth when the diets contained 5 percent of fat, but oleo oil was used most efficiently when the diet contained 55 percent of fat. All solid fats were utilized as efficiently, or more so, when the diets contained 55 percent of fat as when they contained 30 percent of fat. Since the diets containing 55 percent of fat were free from carbohydrates, these results indicated that preformed carbohydrates were not essential for the efficient utilization of fat by the rats.

Digestibility of Fats

The results of the digestion experiments are shown in table 4. Only the average results are presented, the experimental data used in calculating the final results being omitted.

When the rats were fed a diet containing 5 percent of fat, corresponding to 12 percent of the energy value of the diet, table 4 shows that there were rather wide differences between the digestive coefficients of certain fats. Refined lard and cottonseed oil had the highest digestive coefficients, whereas hydrogenated lard, hydrogenated cottonseed oil, and oleo oil had much lower values. Particular attention is directed to the differences in digestibility between refined lard and hydrogenated lard, and between cottonseed oil and hydrogenated cottonseed oil. In each case the hydrogenated fat had a much lower digestive coefficient than the untreated fat. Attention is called also to the lower digestibility of peanut oil than of cottonseed oil.

When the diets contained 30 percent of fat, corresponding to 53 percent of the energy value of the diet, the digestive coefficients of some of the fats differed considerably, but not so greatly as when the diets contained 5 percent of fat. Cottonseed oil, refined lard, and peanut oil had the highest, and oleo oil the lowest, digestive coefficients. As in the experiments with diets containing 5 percent of fat, refined lard had a considerably higher digestive coefficient than hydrogenated lard, and cottonseed oil a higher value than hydrogenated cottonseed oil. Cottonseed oil again had a higher digestive coefficient than peanut oil.

TABLE 4.—*Average true digestibility of fats in 7-day tests with rats when each fat constituted 5, 30, or 55 percent of the diet*

Fat used	Laboratory number of fat [1]	Digestibility of fats constituting indicated proportion of diet						
		5 percent [2]	30 percent—			55 percent—		
		Digestive coefficient	Digestive coefficient	Iodine absorbed by— Undigested fat acids	Iodine absorbed by— Metabolic fat acids	Digestive coefficient	Iodine absorbed by— Undigested fat acids	Iodine absorbed by— Metabolic fat acids
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Refined lard	3382, 4001	97.6	96.5	17.2	54.8	95.1	15.4	51.9
Do	4008					95.9	14.4	52.2
Hydrogenated lard	3375, 4009	89.0	92.4	20.2	55.6	94.0	22.3	58.4
Leaf lard	3383, 4002	93.4	93.0	10.4	63.8	94.5	11.4	52.9
Neutral lard	3355, 4004	95.2	93.7	10.3	61.7	92.5	10.1	54.4
Oleo oil	3384, 4003	86.2	89.8	10.2	62.0	92.3	12.0	56.8
Cottonseed oil	3381	96.6	97.2	50.1	59.6			
Hydrogenated cottonseed oil	3377, 4007	88.2	92.2	25.7	51.2	93.7	22.1	53.8
Peanut oil	3378	93.1	95.7	24.3	58.7			

[1] When 2 lots of fat were used in the digestion tests, the lot with the lower number was used in the diets containing 5 or 30 percent of fat, and both lots were used in the diet containing 55 percent of fat. In each case both lots of fat were obtained from the same source.
[2] The iodine numbers of the fat acids excreted by the rats fed the diets containing 5 percent of fat were not determined.

In the experiments with the diets containing 55 percent of fat, corresponding to 78 percent of the energy value of the diet, there were comparatively small differences between the digestive coefficients of the fats. Refined lard and leaf lard had relatively high, and hydrogenated cottonseed oil, neutral lard, and oleo oil somewhat lower digestive coefficients.

On comparing the digestive coefficients of the same fat when it constituted different proportions of the diet, it appears that the values obtained for most of the fats differed only slightly, but those of hydrogenated lard, hydrogenated cottonseed oil, and oleo oil increased considerably as the percentage of fat in the diet was increased.

Comparison of the iodine numbers of the undigested fat acids shows that those from cottonseed oil had much the highest number, and those from leaf lard, neutral lard, and oleo oil low numbers. The iodine numbers in each case were similar whether the diet contained 30 or 55 percent of fat. In general, the relatively low iodine number of the undigested fat acids as compared with the iodine number of the fat consumed by the rats (table 2) indicates a pronounced selective absorption of unsaturated fat acids. The much lower iodine number of the undigested fat acids from peanut oil, as compared with cottonseed oil, is probably due to arachidic and lignoceric acids (*2*) in the undigested fat acids from peanut oil.

The iodine numbers of the metabolic fat acids excreted by the rats (table 4) seem to bear no relationship to the iodine numbers of the fats previously fed (table 2). In general, the iodine numbers of the metabolic fat acids from rats fed different fats do not differ very widely, most of the values ranging from 50 to 60 percent. It is surprising that in most instances, cottonseed oil excepted, the iodine number of the metabolic fat acids was so much higher than that of the undigested fat acids. Just why the rat should excrete fat acids with an iodine number between 50 and 60 when fed a fat-free diet is not clear. Apparently unsaturated fat acids are a normal excretory product of the albino rat.

Comparison Between Growth Values and Digestive Coefficients of Fats

In a comparison of the nutritive properties of fats, apart from their vitamin content, it is important to know the relationship between the growth value (as measured in terms of gain in weight of rats per 100 Calories consumed) and the digestibility of a fat. It is essential, of course, that comparisons be made between the two values obtained for a fat when it constituted the same proportion of the diet.

When fat constituted 5 percent of the diet, a comparison of the growth values of the fats in table 3 with their digestive coefficients in table 4 indicates a fairly close parallelism between the two values for some fats, but a rather wide divergence between the values for other fats. For example, cottonseed oil and refined lard had the highest growth values and likewise the highest digestive coefficients, and oleo oil had the lowest growth value and likewise the lowest digestive coefficient. On the other hand, hydrogenated cottonseed oil had only a slightly lower growth value than refined lard but a much lower digestive coefficient. Also, neutral lard had a comparatively low growth value, but it ranked third in digestibility.

When fat constituted 30 percent of the diet, there was a fairly close parallelism between the growth values and digestive coefficients of all the fats except cottonseed oil and leaf lard. Cottonseed oil had the highest digestive coefficient but ranked fifth in growth value, and leaf lard ranked fifth in digestibility but second in growth value.

When fat constituted 55 percent of the diet there was a fairly close parallelism between the growth values and the digestive coefficients for refined lard, leaf lard, neutral lard, and hydrogenated cottonseed oil. On the other hand, oleo oil had the highest growth value but the lowest digestive coefficient, and hydrogenated lard had the lowest growth value but ranked fourth in digestibility.

Comparison Between Composition and Nutritive Properties of Fats

On account of the indispensability of linoleic acid, or of a more unsaturated fat acid, for growth and health in rats, the possible relationship between the linoleic acid content of a fat and its nutritive properties is a matter of interest. Table 2 shows that hydrogenated lard and oleo oil contained the smallest proportions of linoleic acid, and table 3 shows that the same fats, when they constituted 5 percent of the diet, induced the smallest gains in weight per rat. However, when the comparison is made between the linoleic acid content of a fat and the gain in weight per 100 Calories consumed, oleo oil again had the lowest growth value but hydrogenated lard had a slightly higher value than either leaf lard or neutral lard, each of which contained more linoleic acid. In general, it appears that the small proportion of linoleic acid in oleo oil and hydrogenated lard was a limiting factor affecting the growth of rats when the diets contained 5 percent of fat.

When the diets contained 30 percent of fat, hydrogenated lard and oleo oil, which contained the smallest proportions of linoleic acid, also induced the smallest gains in weight per 100 Calories consumed.

When the diets contained 55 percent of fat, hydrogenated lard again had the lowest growth value per rat for each 100 Calories consumed, but oleo oil had a slightly higher value than any other fat. The reason for the increased growth value of oleo oil when it constituted 55 percent of the diet is not apparent.

A comparison of the linoleic acid content of the fats (table 2) with their digestive coefficients (table 4) indicates no consistent relationship between the two values. For example, when the diets contained 5 percent of fat, hydrogenated lard and oleo oil, which contained the smallest proportions of linoleic acid, also had relatively low digestive coefficients; but hydrogenated cottonseed oil likewise had a low digestive coefficient although it contained a relatively high proportion of linoleic acid.

In general, there seemed to be no definite relationship between the percentage of saturated fat acids in a fat and either its growth value or digestibility. For example, oleo oil contained the highest percentage of saturated fat acids and had both low growth values and digestive coefficients when it constituted either 5 or 30 percent of the diets. On the other hand, hydrogenated lard contained a much lower percentage of saturated fat acids, yet it also had relatively low growth values and digestive coefficients. Refined lard and hydrogenated lard contained approximately the same proportions of saturated fat acids, but their growth values and digestive coefficients differed widely.

SUMMARY

The comparative nutritive properties of refined lard, hydrogenated lard, leaf lard, neutral lard, oleo oil, cottonseed oil, hydrogenated cottonseed oil, and peanut oil were determined by growth and digestion experiments with young male albino rats.

When fat constituted 5 percent by weight, or 12 percent of the total energy value of the diet, the growth-promoting values of the diets, expressed as gain in weight per 100 Calories consumed, were as follows: Cottonseed oil, 8.91; refined lard, 8.81; hydrogenated cottonseed oil, 8.71; peanut oil, 8.58; hydrogenated lard, 8.21; leaf lard, 8.12; neutral lard, 7.99; and oleo oil, 7.72 gm.

The digestive coefficients of the fats when each constituted 5 percent of the diet were as follows: Refined lard, 97.6; cottonseed oil, 96.6; neutral lard, 95.2; leaf lard, 93.4; peanut oil, 93.1; hydrogenated lard, 89.0; hydrogenated cottonseed oil, 88.2; and oleo oil, 86.2 percent.

When fat constituted 30 percent by weight, or 53 percent of the total energy value of the diet, the growth-promoting values of the diets were as follows: Refined lard, 7.85; leaf lard, 7.53; peanut oil, 7.48;

neutral lard, 7.31; cottonseed oil, 7.29; hydrogenated cottonseed oil, 7.28; oleo oil, 6.98; and hydrogenated lard, 6.88 gm.

The digestive coefficients of the fats when each constituted 30 percent of the diet were as follows: Cottonseed oil, 97.2; refined lard, 96.5; peanut oil, 95.7; neutral lard, 93.7; leaf lard, 93.0; hydrogenated lard, 92.4; hydrogenated cottonseed oil, 92.2; and oleo oil, 89.8 percent.

When fat constituted 55 percent by weight, or 78 percent of the total energy value of the diet, the growth-promoting values of the diets were as follows: Oleo oil, 7.95; refined lard, 7.87; leaf lard, 7.82; neutral lard, 7.82; hydrogenated cottonseed oil, 7.29; and hydrogenated lard, 6.92 gm.

The digestive coefficients of the fats when each constituted 55 percent of the diet were as follows: Refined lard, 95.5; leaf lard, 94.5; hydrogenated lard, 94.0; hydrogenated cottonseed oil, 93.7; neutral lard, 92.5; and oleo oil, 92.3 percent.

The growth-promoting value of a fat did not show a consistent relationship to its digestive coefficient.

There was no consistent relationship between the chemical composition of a fat or its melting point and the nutritive value of the fat. In a few cases linoleic acid appeared to be a limiting factor.

The iodine numbers of the undigested fat acids indicated a pronounced selective absorption of the unsaturated fat acids. The iodine numbers of the metabolic fat acids indicated that unsaturated fat acids are a normal excretory product of the albino rat.

LITERATURE CITED

(1) Association of Official Agricultural Chemists.
1935. Official and tentative methods of analysis of the Association of Official Agricultural Chemists. Ed. 4, 710 pp., illus. Washington, D. C.

(2) Barbour, A. D.
1934. The effect of the saturated fatty acid content of the diet on the composition of the body fat. Jour. Biol. Chem. 106: 281–288.

(3) Burr, George O., and Burr, Mildred M.
1929. A new deficiency disease produced by the rigid exclusion of fat from the diet. Jour. Biol. Chem. 82: 345–367, illus.

(4) ——— and Burr, Mildred M.
1930. On the nature and rôle of the fatty acids essential in nutrition. Jour. Biol. Chem. 86: 587–621, illus.

(5) ——— Burr, Mildred M., and Miller, Elmer S.
1932. On the fatty acids essential in nutrition. III. Jour. Biol. Chem. 97: 1–9, illus.

(6) Deuel, Harry J., Jr. and Holmes, Arthur D.
1922. Digestibility of cod-liver, java-almond, tea-seed, and watermelon-seed oils, deer fat, and some blended hydrogenated fats. U. S. Dept. Agr. Bul. 1033, 15 pp.

(7) Evans, Herbert M., and Lepkovsky, Samuel.
1932. Vital need of the body for certain unsaturated fatty acids. I. Experiments with fat-free diets in which sucrose furnishes the sole source of energy. Jour. Biol. Chem. 96: 143–156, illus.

(8) ——— and Lepkovsky, Samuel.
1933. Vital need of the body for certain unsaturated fatty acids. III. Inability of the rat organism to synthesize the essential unsaturated fatty acids. Jour. Biol. Chem. 99: 231–234, illus.

(9) ——— Lepkovsky, Samuel, and Murphy, Elizabeth A.
1934. Vital need of the body for certain unsaturated fatty acids. IV. Reproduction and lactation upon fat-free diets. Jour. Biol. Chem. 106: 431–440, illus.

(10) HOLMES, ARTHUR D.
1919. DIGESTIBILITY OF CERTAIN MISCELLANEOUS ANIMAL FATS. U. S. Dept. Agr. Bul. 613, 27 pp.

(11) ——— and DEUEL, HARRY J., JR.
1921. DIGESTIBILITY OF SOME HYDROGENATED OILS. Amer. Jour. Physiol. 54: 479–488.

(12) IRWIN, MARGARET HOUSE; WEBER, JANET; STEENBOCK, H.; and GODFREY, T. M.
1938. THE INFLUENCE OF HYDROGENATION AND OXIDATION OF FATS UPON THEIR RATE OF ABSORPTION. Amer. Jour. Physiol. 124: 800–803.

(13) JAMIESON, GEORGE S.
1932. VEGETABLE FATS AND OILS; THE CHEMISTRY, PRODUCTION AND UTILIZATION OF VEGETABLE FATS AND OILS FOR EDIBLE, MEDICINAL AND TECHNICAL PURPOSES. 444 pp., illus. New York.

(14) KAUFMANN, H. P.
1926. DIE RHODANOMETRIE VON FETTEN UND FETTGEMISCHEN. Ztschr. f. Untersuch der Nahr. u. Genussmtl. 51: 15–27.

(15) LANGWORTHY, C. F., and HOLMES, A. D.
1915. DIGESTIBILITY OF SOME ANIMAL FATS. U. S. Dept. Agr. Bul. 310, 23 pp.

(16) ——— and HOLMES, A. D.
1917. DIGESTIBILITY OF SOME VEGETABLE FATS. U. S. Dept. Agr. Bul. 505, 20 pp.

(17) ——— and HOLMES, A. D.
1917. STUDIES ON THE DIGESTIBILITY OF SOME ANIMAL FATS. U. S. Dept. Agr. Bul. 507, 20 pp.

(18) McCAY, C. M., and PAUL, HENRY.
1938. THE EFFECT OF MELTING POINT OF FAT UPON ITS UTILIZATION BY GUINEA PIGS. Jour. Nutrition 15: 377–382.

(19) STEENBOCK, H.; IRWIN, MARGARET HOUSE; and WEBER, JANET.
1936. THE COMPARATIVE RATE OF ABSORPTION OF DIFFERENT FATS. Jour. Nutrition 12: 103–111.

(20) TURPEINEN, OSMO.
1938. FURTHER STUDIES ON THE UNSATURATED FATTY ACIDS ESSENTIAL IN NUTRITION. Jour. Nutrition 15: 351–366, illus.

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