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NUTRITIVE PROPERTIES OF LARD AND OTHER SHORTENINGS
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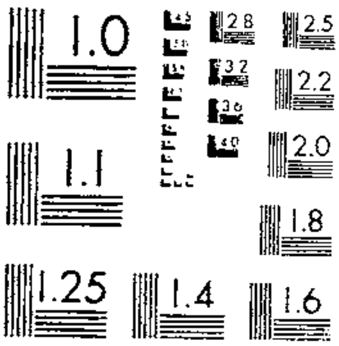

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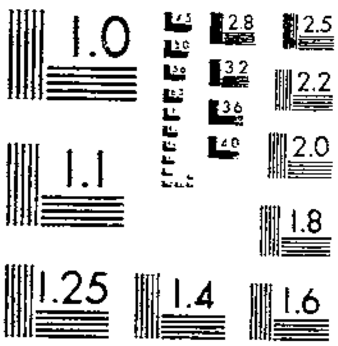

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*Technical Bulletin No. 821* • *March 1942*

UNITED STATES
DEPARTMENT OF AGRICULTURE
WASHINGTON, D.C.

# Nutritive Properties of Lard and Other Shortenings[1]

By RALPH HOAGLAND, *senior biochemist*, and GEORGE G. SNIDER, *senior scientific aide, Animal Nutrition Division, Bureau of Animal Industry*

## CONTENTS



## INTRODUCTION

Lard, together with commercial shortenings consisting wholly of vegetable fats or of mixtures of vegetable and animal fats, constitutes a considerable proportion of the fat in the diet of the people of the United States. Information regarding the nutritive properties of these products should therefore be of interest. The average annual per capita consumption of these types of shortening for the period 1931–40 was as follows:[2] Lard, 12.4 pounds; and compounds (mixtures of vegetable and animal fats) and vegetable cooking fats, 10.2 pounds. The per capita consumption of lard ranged from 9.6 pounds in 1935 to 14.6 pounds in 1940, and that of compounds and vegetable fats ranged from 7.5 pounds in 1932 to 12.4 pounds in 1936.

In a previous publication, Hoagland and Snider (*3*) reported the results of experiments with rats to determine the nutritive properties of several kinds of lard, oleo oil, cottonseed oil, hydrogenated cottonseed oil, and peanut oil. Material differences were found in the nutritive properties of certain fats when they constituted 5 and 30 percent of the diet. No consistent relationship was observed between the melting point or the chemical composition of a fat and its nutritive properties.

The writers (*4*) also compared the nutritive properties of lard and hydrogenated cottonseed oil, in experiments with rats, when the diets contained 5, 15, 30, and 54 percent of fat. Lard was found to be superior in growth-promoting properties when the diets contained 15, 30, and 54 percent of fat. The digestibility of lard was higher at all levels of intake.

[1] Submitted for publication Nov. 6, 1941.
[2] UNITED STATES BUREAU OF AGRICULTURAL ECONOMICS. THE FATS AND OILS SITUATION. U. S. Bur. Agr. Economics FOS-46, 17 pp., illus. 1940. [Processed.] (Unpublished data for 1940 were supplied by that Bureau.)

The purpose of the experiments herein reported was to determine, by the use of young male albino rats, the growth-promoting values and the digestive coefficients of well-known brands of lard, vegetable shortenings, and mixed vegetable and animal shortenings. The vitamin content of the shortenings was not determined, but adequate quantities of the essential vitamins were added to the diets. The results of these experiments supplement those previously reported by the writers (*3*, *4*) on the nutritive properties of certain animal and vegetable fats. The present experiments were conducted duirng 1939–40 at the United States Department of Agriculture, Beltsville Research Center, Beltsville, Md.

## SHORTENINGS USED AND METHOD OF STORING

Four lots of lard, eight lots of vegetable shortening, and five lots of vegetable and animal shortening were used in these experiments. Each lot represented a well-known brand commonly found on the retail market. All but two lots were obtained direct from the manufacturers, and the others were purchased on the open market. Detailed information concerning the method of manufacture of each shortening was not available, but the formulas for most of the products are shown in table 1. Hydrogenated vegetable oil No. 4025, which was purchased in sealed 1-pound tin cans, was stored at room temperature in the original containers. All other lots of shortening were transferred to glass jars, which were sealed to exclude air and stored at a temperature of about 4° C. After a jar had been opened and a part of the fat removed, the air was replaced by nitrogen and the jar was sealed.

TABLE 1.—*Formulas for shortenings used in experiments with rats*

| Shortening used | Laboratory No. | Lard | Cottonseed oil | Partially hydrogenated cottonseed oil | Soybean oil | Coconut oil | Vegetable stearin | Edible tallow | Oleo stearin |
|---|---|---|---|---|---|---|---|---|---|
| | | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Refined lard | 4027 | 100 | | | | | | | |
| | 4041 | 100 | | | | | | | |
| | 4042 | 100 | | | | | | | |
| Leaf lard | 4028 | 100 | | | | | | | |
| Vegetable shortening | 4025 [1] | | | | | | | | |
| | 4026 | | 75 | 10 | | | 15 | | |
| | 4030 | | 90 | | | | 10 | | |
| | 4032 | | 74 | | | 10 | 16 | | |
| | 4033 | | 59 | | 30 | | 11 | | |
| | 4035 | | 87 | | | | 13 | | |
| | 4046 | | | 100 | | | | | |
| | 4038 | | 65 | 25 | | 5 | 5 | | |
| Vegetable and animal shortening | 4029 | | 65 | | | | | 35 | |
| | 4031 | | 39 | | | 10 | | 35 | 16 |
| | 4034 | | 50 | | 30 | | | 4 | 16 |
| | 4037 | 5 | 46 | | 5 | | | 34 | 10 |
| | 4039 | 4 | 26 | | 20 | 5 | | 25 | 20 |

[1] The label indicated that this product consisted of hydrogenated vegetable oils, but their identity was not disclosed.

## DIETS FED

Each lot of shortening was incorporated in a diet, otherwise adequate for growth, in the proportions of 5 and 15 percent by weight, corresponding to approximately 12.5 and 32.5 percent of the total energy value of the diet. Vitamins A and D, equivalent to 2 percent of cod-liver oil, were added in the form of an ether extract of saponified U. S.

P. cod-liver oil. Water-soluble vitamins were added in the form of a commercial concentrate prepared from yeast. This product was stated to contain 240 $B_1$ and 60 $B_2$ Sherman units per gram. The salt mixture was made up as previously described by the writers (3). U. S. P. dextrose containing approximately 8 percent of water was used. Commercial casein was extracted with ether for about a week until it was practically free from ether-soluble material. Each diet was made up in kilogram quantities and was stored in covered glass jars at about 4° C.

TABLE 2.—*Formulas for diets fed to rats*

| Diet No. | Fat | Casein | Salts | Yeast concentrate | Dextrose | Cod-liver-oil concentrate per kilogram of diet [1] |
|---|---|---|---|---|---|---|
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Cubic centimeters* |
| 1 | 0 | 18.6 | 4.0 | 2.0 | 75.4 | 100 |
| 2 | 5 | 20.0 | 4.3 | 2.0 | 68.7 | 100 |
| 3 | 15 | 23.0 | 5.0 | 2.5 | 54.5 | 100 |

[1] 100 cc. of concentrate corresponds to 20 gm. of cod-liver oil

In calculating the energy values of the diets, the following factors were used: Protein, 4; carbohydrate, 3.75; and fat, 9 Calories[3] per gram. The factor 3.75 was used for carbohydrate since it consisted almost entirely of dextrose. Casein, yeast concentrate, and salt mixture were added in such proportions that each bore approximately a constant relation to the total energy value of the diet, regardless of the proportion of fat present. Casein furnished approximately 20.6 percent of the energy value of the diet. The formulas for the diets, including the fat-free diet that was fed to each rat in order to determine the quantity of metabolic fat excreted, are shown in table 2.

## EXPERIMENTAL PROCEDURE

Two series of growth experiments were conducted, one with diets containing 5 percent of fat and the other with 15 percent. Only experiments with diets containing the same percentage of fat were conducted at one time. Each diet was fed for 60 days 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 shortenings. 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 blotting paper. Rats were weighed twice weekly, and a record was kept of feed consumed.

Digestion tests were conducted with six rats on each diet, usually after the experiment had been in progress about 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 dried to a constant weight at 100° C. The quantity of fat consumed was calculated from the quantity of feed eaten and the percentage of fat added to the diet.

[3] The term "Calorie" as used in this paper denotes the kilogram-calorie.

The quantity of fat excreted was determined as follows: Approximately 2 gm. of dry feces was weighed into a 200-cc. Erlenmeyer flask, and 25 cc. of 30-percent potassium hydroxide solution was added. The mixture was heated on a steam bath until the feces were disintegrated, when 50 cc. of 95-percent ethyl alcohol was added, and heating was continued until saponification was completed. The contents of the flask 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 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 dried to constant weight at 100° C. The quantity of glycerides was calculated by multiplying the quantity of fat acids by 1.045.

Metabolic fat in the feces was determined as follows: 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 excretion of feces from the previous diet, the feces were saved for 7 days. The feces were dried to constant weight at 100° C., and the fat content was determined as previously described. The percentage of fat 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 shortening was calculated in the usual manner after making correction for the quantity of metabolic fat excreted during the digestion test. It was assumed that each rat excreted the same quantity of metabolic fat in proportion to nonfat dry matter as when it was fed the fat-free diet.

The following methods of analysis were used: 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 (*6*). A 0.1 N solution of thiocyanogen in pure acetic acid, which had been distilled over phosphoric anhydride, was used. An excess of 100 to 150 percent of the reagent was added, and absorption was conducted for 24 hours in the dark at room temperature (about 25° C.). The percentages of oleic, linoleic, and total saturated fat acids were calculated from the iodine and thiocyanogen numbers by the formulas given by Kass, Lundberg, and Burr (*5, p. 58*).

The unsaponifiable matter was determined by extraction of the saponified fat or fat acids with at least three 100-cc. portions of petroleum ether. The extraction was carried on in a 500-cc. separatory funnel. The ether extract was washed with water, transferred to a 300-cc. Erlenmeyer flask, and after evaporation of the ether the residue was dried at 100° C.

Cholesterol was determined in the unsaponifiable matter by precipitation with digitonin according to a method described by Ewert (*2*). The method was tested with pure cholesterol, and excellent results were obtained.

Statistical analyses were made for Calorie intake, gain in weight, and digestive coefficients.[4] To determine the effect of the variety of short-

[4] Acknowledgment is made to Tentle O. Johnson, formerly of the Animal Husbandry Division of the Bureau of Animal Industry, for the statistical analyses of the data.

ening independent of feed intake, a correction of variance and means for linear regression of gain as related to Calorie intake was made by the method of covariance (7). By this method the gain was corrected for correlation of gain with feed intake based on the average within-shortening variations. A relationship of gain with Calorie intake different from the average that is peculiar to a particular shortening would be kept in the data.

## EXPERIMENTAL RESULTS

### Chemical Composition of Shortenings

Data on the chemical composition of the several kinds of shortening used in the present experiments are presented in table 3. The table shows no consistent relationship between the percentage of saturated fat acids in a shortening and its melting point. For instance, the percentages of saturated fat acids ranged from 29.6 in vegetable and animal shortening No. 4034 to 55 percent in the same type of shortening No. 4031, but the melting points of the two products were similar.

Table 3.—*Composition of shortenings used in experiments with rats*

| Shortening used | Laboratory No.[1] | Melting point | Iodine number | Thiocyanogen number | Saturated fat acids[2] | Oleic acid[2] | Linoleic acid[2] |
|---|---|---|---|---|---|---|---|
| | | ° *C.* | | | *Percent* | *Percent* | *Percent* |
| Lard | 4027 | 46 | 61.6 | 52.5 | 42.0 | 47.7 | [3] 10.3 |
| | 4041 | 40 | 60.2 | 58.2 | 35.6 | 51.9 | [3] 12.5 |
| | 4042 | 44 | 65.1 | 54.9 | 39.3 | 49.1 | [3] 11.6 |
| | 4028 | 50 | 56.2 | 47.0 | 48.1 | 41.5 | [3] 10.4 |
| Vegetable shortening | 4025 | 48 | 63.7 | 55.0 | 39.1 | 51.0 | 9.9 |
| | 4026 | 47 | 90.7 | 60.3 | 34.1 | 31.4 | 34.5 |
| | 4030 | 53 | 81.3 | 57.1 | 37.4 | 35.1 | 27.5 |
| | 4032 | 55 | 78.5 | 48.9 | 46.7 | 10.7 | 32.6 |
| | 4033 | 52 | 100.2 | 66.4 | 37.4 | 24.2 | [4] 38.4 |
| | 4035 | 56 | 92.9 | 57.5 | 37.4 | 22.4 | 40.2 |
| | 4036 | 30 | 71.1 | 56.6 | 37.5 | 46.0 | 16.5 |
| | 4038 | 46 | 89.2 | 57.8 | 36.9 | 27.5 | 35.6 |
| Vegetable and animal shortening | 4029 | 43 | 75.4 | 55.8 | 38.7 | 30.1 | 22.2 |
| | 4031 | 47 | 58.1 | 40.9 | 55.0 | 27.7 | 17.3 |
| | 4034 | 45 | 97.1 | 64.4 | 29.6 | 33.3 | [4] 37.1 |
| | 4037 | 50 | 84.2 | 58.6 | 35.7 | 35.2 | 29.1 |
| | 4039 | 45 | 71.3 | 54.7 | 39.8 | 41.4 | [4] 18.8 |

[1] The formula for each of the shortenings is given in table 1.
[2] Expressed as percentage of total fat acids.
[3] May include a small proportion of arachidonic acid.
[4] May include a small proportion of linolenic acid.

With the exception of partially hydrogenated cottonseed oil No. 4025, the vegetable shortenings and the vegetable and animal shortenings contained much higher percentages of linoleic acid than any of the samples of lard.

The relationship of the composition of the shortenings to growth-promoting values is discussed later.

### Growth-Promoting Values of Shortenings

The growth-promoting values of the shortenings are shown in table 4. There were considerable differences between the average unadjusted gains made by the rats fed certain lots of each type of shortening at each level of fat intake. However, these data alone do not provide an accurate measure of the relative growth-promoting values of the different lots of shortening, because the rate of growth is affected by the feed intake. For example, among the rats fed the diets containing 5 percent of lard, the largest unadjusted gain was made by those receiving lard No. 4041, and the smallest by those fed lard No. 4027, the difference being 33 gm. The relative feed consumption of the two groups of rats was in the same order. However, when the gains were adjusted to a common feed intake, the difference in gain was only 8 gm., which is not significant. Other similar examples may be found among the unadjusted gains. For these reasons, only the adjusted gains were used in comparing the relative growth-promoting values of the different lots of shortening. When fat constituted either 5 or 15 percent of the diet, a difference of 15 gm. between the average adjusted gains is highly significant, and in order to simplify the discussions, only such differences are considered.

TABLE 4.—*Average growth-promoting values of diets containing 5 and 15 percent each of different shortenings when fed to male rats for 60 days*

| Shortening used | Laboratory No.[1] | Intake of diet containing— | | Gain in weight— Unadjusted, on diet containing— | | Gain in weight— Adjusted[2] on diet containing— | | |
|---|---|---|---|---|---|---|---|---|
| | | 5 percent of fat | 15 percent of fat | 5 percent of fat | 15 percent of fat | 5 percent of fat | 15 percent of fat | Average of 5 and 15 percent of fat |
| | | *Calories* | *Calories* | *Grams* | *Grams* | *Grams* | *Grams* | *Grams* |
| Lard | 4027 | 2,917 | 3,361 | 220 | 280 | 245 | 254 | 250 |
| | 4041 | 3,177 | 2,948 | 202 | 254 | 253 | 260 | 257 |
| | 4042 | 2,985 | 3,231 | 231 | 264 | 241 | 251 | 246 |
| | 4028 | 3,050 | 3,101 | 234 | 245 | 238 | 244 | 241 |
| Average | | 3,032 | 3,160 | 239 | 261 | 244 | 252 | 249 |
| Vegetable shortening | 4025 | 2,802 | 3,280 | 210 | 251 | 237 | 233 | 235 |
| | 4026 | 2,833 | 3,262 | 221 | 258 | 245 | 242 | 244 |
| | 4030 | 3,007 | 3,380 | 234 | 268 | 242 | 241 | 242 |
| | 4032 | 3,007 | 3,011 | 245 | 241 | 247 | 248 | 248 |
| | 4033 | 3,137 | 3,161 | 246 | 266 | 241 | 259 | 250 |
| | 4035 | 3,107 | 3,182 | 250 | 267 | 243 | 258 | 254 |
| | 4036 | 2,957 | 3,314 | 228 | 271 | 240 | 250 | 245 |
| | 4038 | 3,021 | 3,002 | 245 | 251 | 252 | 259 | 256 |
| Average | | 2,992 | 3,200 | 235 | 259 | 244 | 249 | 247 |
| Vegetable and animal shortening | 4029 | 2,828 | 3,322 | 212 | 257 | 237 | 235 | 236 |
| | 4031 | 3,055 | 3,118 | 240 | 250 | 244 | 247 | 246 |
| | 4034 | 3,114 | 3,039 | 239 | 261 | 237 | 266 | 252 |
| | 4037 | 2,947 | 3,165 | 235 | 264 | 248 | 257 | 253 |
| | 4039 | 3,130 | 3,083 | 252 | 253 | 248 | 254 | 251 |
| Average | | 3,016 | 3,145 | 236 | 257 | 243 | 252 | 248 |
| Minimum significant difference (odds 19-1) | | 240 | 249 | 26 | 26 | 11 | 11 | 8 |
| Minimum highly significant difference (odds 99-1) | | 328 | 328 | 34 | 34 | 15 | 15 | 11 |

[1] The formula for each of the shortenings is given in table 1.
[2] Adjusted for Calorie intake.

When the diets contained 5 percent of fat, only one lot of refined lard, No. 4041, produced significantly higher gains than leaf lard No. 4028, which produced the lowest gains. Among the vegetable shortenings, only sample No. 4038 was definitely superior to any other shortening of this type. The vegetable and animal shortenings did not differ materially in growth-promoting values.

When fat constituted 15 percent of the diet, refined lard No. 4041 again was definitely superior in growth-promoting value to leaf lard

No. 4028. Vegetable shortenings 4033, 4035, and 4038 were superior to samples 4025, 4026, and 4030. Vegetable and animal shortenings 4034, 4037, and 4039 had significantly higher growth-promoting values than sample 4029. Therefore, with only a few exceptions, there was no material difference between the growth-promoting properties of a shortening at the two levels of fat intake.

A comparison of the average adjusted gains for both the 5- and 15-percent levels shows that refined lard No. 4041 was definitely superior to leaf lard No. 4028. Vegetable shortenings 4035 and 4038 had significantly higher growth-promoting values than samples 4025 and 4030. Vegetable and animal shortenings 4034, 4037, and 4039 were definitely superior to sample 4029.

At both the 5- and 15-percent levels of intake, lard, vegetable shortening, and vegetable and animal shortening had practically the same average growth-promoting values.

## Digestibility of Shortenings

The results of the digestion experiments are presented in table 5. Only differences in digestibility that are statistically highly significant are considered. The average digestive coefficients for the four lots of lard for both the 5-percent and the 15-percent levels of intake indicate that the refined lards 4027 and 4041 were superior to leaf lard 4028.

TABLE 5.—*Average true digestibility of shortenings in 7-day tests with male rats when fat constituted 5 and 15 percent of the diet*

| Shortening used | Laboratory No.[1] | Digestive coefficient of shortening when diet contained— | | |
|---|---|---|---|---|
| | | 5 percent of fat | 15 percent of fat | Average of 5 and 15 percent of fat |
| | | *Percent* | *Percent* | *Percent* |
| Lard | 4027 | 95.3 | 94.8 | 95.1 |
| | 4041 | 95.7 | 95.1 | 95.4 |
| | 4042 | 93.4 | 95.0 | 94.2 |
| | 4028 | 90.7 | 91.7 | 91.2 |
| Average | | 93.8 | 94.2 | 94.0 |
| Vegetable shortening | 4025 | 86.6 | 87.9 | 87.3 |
| | 4026 | 91.9 | 91.1 | 91.5 |
| | 4030 | 86.9 | 88.1 | 87.5 |
| | 4032 | 85.9 | 90.0 | 87.9 |
| | 4033 | 89.0 | 87.0 | 88.3 |
| | 4035 | 86.4 | 82.7 | 84.6 |
| | 4036 | 85.9 | 83.4 | 84.6 |
| | 4038 | 89.4 | 87.0 | 88.2 |
| Average | | 87.8 | 87.1 | 87.5 |
| Vegetable and animal shortening | 4029 | 84.6 | 86.4 | 85.5 |
| | 4031 | 84.2 | 86.4 | 85.3 |
| | 4034 | 87.5 | 86.5 | 87.0 |
| | 4037 | 83.2 | 83.9 | 83.5 |
| | 4039 | 87.0 | 86.0 | 86.5 |
| Average | | 85.3 | 85.8 | 85.6 |
| Minimum significant difference (odds 19-1) | | 4.1 | 4.1 | 2.9 |
| Minimum highly significant difference (odds 99-1) | | 5.4 | 5.4 | 3.8 |

[1] The formula for each of the shortenings is given in table 1.

The data for vegetable shortenings indicate that sample 4026 was definitely superior in digestibility to samples 4032, 4035, and 4036 when the diets contained 5 percent of fat, and superior to samples 4035 and 4036 when the diets contained 15 percent of fat. Sample 4032 also was superior in digestibility to samples 4035 and 4036 at the 15-percent level of intake. The average digestive coefficients for both levels of fat intake indicate that sample 4026 had a significantly higher value than samples 4025, 4030, 4035, and 4036.

The four lots of vegetable and animal shortenings did not differ significantly in digestibility at either level of fat intake.

There was a comparatively small difference in the digestibility of a shortening whether the diet contained 5 or 15 percent of fat.

The average data for each type of shortening show that lard was definitely superior in digestibility both to the vegetable and to the vegetable and animal shortenings at each level of intake. The average digestive coefficients for the vegetable shortenings did not differ significantly from those for the vegetable and animal shortenings

## Composition of Feces of Experimental Rats

In the determination of the digestibility of a fat by the procedure followed in the experiments herein reported, it was found that the crude fat acids extracted from the feces contained a considerable quantity of unsaponifiable matter. Analyses were made, therefore, to determine the proportion and character of the unsaponifiable matter in the crude fat acids from the rats that had been fed the diets containing 15 percent of fat and also from the same rats when fed the fat-free diet. The results are shown in table 6.

TABLE 6.—*Average composition of feces of rats fed diets containing 15 percent of fat and of the same rats fed a fat-free diet*

| Shortening used | Laboratory No. | Feces of rats fed a fat diet: Fat acids, Crude | Feces of rats fed a fat diet: Fat acids, Pure | Feces of rats fed a fat diet: Unsaponifiable matter in crude fat acids | Feces of rats fed a fat diet: Cholesterol in crude fat acids[1] | Feces of rats fed a fat diet: Cholesterol in unsaponifiable matter | Feces of rats fed a fat-free diet: Fat acids, Crude | Feces of rats fed a fat-free diet: Fat acids, Pure | Feces of rats fed a fat-free diet: Unsaponifiable matter in crude fat acids | Feces of rats fed a fat-free diet: Cholesterol in crude fat acids[1] | Feces of rats fed a fat-free diet: Cholesterol in unsaponifiable matter |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Lard | 4027 | 27.61 | 25.40 | 7.67 | 4.77 | 62.14 | 6.33 | 4.46 | 29.52 | 16.25 | 55.05 |
| | 4041 | 17.79 | 16.59 | 5.04 | | | 4.34 | 3.01 | 30.56 | | |
| | 4042 | 26.97 | 24.94 | 5.06 | 2.70 | 53.38 | 5.67 | 4.03 | 29.01 | 19.42 | 66.94 |
| | 4028 | 36.05 | 35.35 | 3.55 | 1.80 | 53.21 | 5.84 | 4.13 | 29.31 | 17.90 | 61.07 |
| Average | | 27.08 | 25.67 | 5.33 | 3.12 | 56.24 | 5.55 | 3.91 | 29.60 | 17.86 | 61.02 |
| Vegetable shortening | 4025 | 46.18 | 43.21 | 6.39 | 4.05 | 63.34 | 5.92 | 4.11 | 30.64 | 18.69 | 60.00 |
| | 4026 | 36.11 | 33.00 | 6.71 | 4.53 | 67.47 | 6.08 | 4.23 | 30.22 | 19.62 | 64.94 |
| | 4030 | 45.63 | 43.85 | 3.89 | 2.22 | 57.10 | 6.47 | 4.53 | 29.91 | 18.61 | 62.23 |
| | 4032 | 40.43 | 38.47 | 4.85 | 2.89 | 59.60 | 6.06 | 4.12 | 32.07 | 19.49 | 60.78 |
| | 4033 | 35.79 | 35.09 | 1.95 | | | 5.59 | 4.33 | 22.53 | | |
| | 4035 | 42.57 | 41.11 | 3.44 | | | 5.02 | 3.75 | 25.23 | | |
| | 4036 | 40.00 | 38.18 | 4.54 | | | 4.63 | 3.05 | 34.14 | | |
| | 4038 | 35.60 | 33.60 | 6.15 | | | 4.38 | 2.89 | 33.95 | | |
| Average | | 40.30 | 38.39 | 4.74 | 3.42 | 61.88 | 5.52 | 3.88 | 29.84 | 19.10 | 62.24 |
| Vegetable and animal shortening | 4029 | 51.05 | 48.30 | 5.38 | 3.74 | 60.48 | 6.52 | 4.41 | 32.41 | 19.64 | 60.59 |
| | 4031 | 48.35 | 46.80 | 3.01 | 1.50 | 49.70 | 5.93 | 3.85 | 35.06 | 21.75 | 62.05 |
| | 4034 | 36.73 | 35.30 | 3.89 | | | 5.15 | 3.78 | 26.68 | | |
| | 4037 | 39.00 | 37.77 | 4.61 | | | 4.44 | 3.29 | 25.92 | | |
| | 4039 | 38.77 | 36.60 | 5.45 | | | 4.30 | 3.09 | 28.71 | | |
| Average | | 42.90 | 40.98 | 4.47 | 2.62 | 59.04 | 5.27 | 3.68 | 29.76 | 20.70 | 61.32 |

[1] Data for cholesterol are incomplete on account of insufficient supply of digitonin.

The percentages of fat acids in the feces of the rats that had been fed different lots and kinds of shortening differed rather widely. In general, the proportion of fat acids was related to the digestibility of the shortening consumed but the relationship was not uniform, as may be seen from a comparison of the data in tables 5 and 6.

The percentages of unsaponifiable matter in the crude fecal fat acids from the rats fed 15 percent of each of the different lots of shortening varied considerably, but the average values for the three types of shortening differed only slightly. The unsaponifiable matter was found to consist largely of cholesterol.

The feces of the rats fed the fat-free diet contained relatively small proportions of crude fat acids and even smaller percentages of pure fat acids. These proportions of fat acids were not related to the proportions previously found in the feces from the same groups of rats when fed diets containing 15 percent of shortening.

The fecal fat from the rats on the fat-free diet contained a much larger proportion of unsaponifiable matter than was present when the diet contained 15 percent of fat. Percentages of cholesterol in the unsaponifiable matter were somewhat greater than those of the rats when receiving 15 percent of fat in their diets.

The presence of a considerable proportion of unsaponifiable matter in the crude fecal fat from rats fed a diet containing fat and of a larger proportion in the crude fecal fat from rats fed a fat-free diet, raised the question as to the effect of this constituent in the determination of the true digestibility of a fat. In order to answer this question, the digestive coefficients for all the shortenings, when they constituted 15 percent of the diet, were calculated by two methods: (1) The presence of unsaponifiable matter in the fat fed to the rats, in the fecal fat when the diet contained 15 percent of fat, and in the fecal fat when the diet contained no fat, was disregarded. Correction was made for the crude metabolic fat excreted when the rats were fed the fat-free diet. The digestive coefficients calculated by this method are shown in table 5. (2) Correction was made for the unsaponifiable matter in the fat fed and in the fecal fats mentioned above. The digestive coefficients were then calculated and found to agree closely with those previously determined. These results indicate that in the determination of the digestibility of a fat which contains a relatively small proportion of unsaponifiable matter, the presence of this constituent in the fat consumed, as well as in the crude fat excreted, may be disregarded, provided that correction is made for the crude metabolic fat excreted when the experimental animal is fed a fat-free diet.

## DISCUSSION OF RESULTS

Although certain lots of shortening differed materially in growth-promoting values, these differences did not seem to be definitely related to the chemical composition of the products. For example, the four lots of lard contained from 10.3 to 12.5 percent of linoleic acid, yet they had as high growth-promoting values as samples of vegetable and vegetable and animal shortenings, which contained much higher proportions of this fat acid. Vegetable shortening No. 4025 contained only 9.9 percent of linoleic acid as compared with 22.2 percent in vegetable and animal shortening No. 4029, yet both products had practically the same growth-promoting value. Linoleic acid did not seem to be a limiting factor as related to the growth-promoting values of any of the shortenings tested.

Likewise, there seemed to be no definite relationship between the digestibility of a shortening and its growth-promoting value, as may be seen from the data in tables 4 and 5. For example, the average digestibility of the four lots of lard was definitely higher than the average values for the vegetable shortenings and for the vegetable and animal shortenings, yet the average growth-promoting values of the three types of shortening were very similar.

The melting point of a shortening did not show a consistent relationship to its digestibility, as may be seen from the data in tables 3 and 5. For example, vegetable shortenings Nos. 4035 and 4036 had melting points of 56° and 39° C., respectively, yet the two products had practically the same digestive coefficient. Again, lard No. 4041 and vegetable shortening No. 4036 had practically the same melting point, but the lard had a much higher digestive coefficient.

The percentage of total saturated fat acids in a shortening showed no relationship to its digestibility.

## SUMMARY

The comparative nutritive properties of 17 lots of commercial shortenings, each representing a well-known brand, were determined by means of growth and digestion experiments with young male albino rats. The shortenings included 3 lots of steam-rendered and 1 lot of leaf lard, 8 lots of vegetable shortening, and 5 lots of vegetable and animal shortening. The experiments were conducted in 1939–40 at the United States Department of Agriculture, Beltsville Research Center, Beltsville, Md.

The growth-promoting values of certain lots of each type of shortening were found to differ materially, but the average values for lard, for vegetable shortening, and for vegetable and animal shortening were very similar. There was no apparent relationship between the growth-promoting value of a shortening and its content of linoleic acid.

The digestibility of lard was superior to that of the other types of shortening. The digestive coefficients for lard ranged from 91.2 for leaf lard to 95.4 for a steam-rendered lard, with an average of 94 percent. The digestive coefficients for vegetable shortening ranged from 84.6 to 91.5, with an average of 87.5 percent. The digestive coefficients for vegetable and animal shortening ranged from 83.5 to 87.0 with an average of 85.6 percent. There was no consistent relationship between the percentage of saturated fat acids in a shortening or its melting point and the digestive coefficient.

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