Mixtures containing sulfonated tallow are used as defoamers in the paper industry. In the manufacture of paper, as the wet pulp is brought onto the suction screen or felt, unless something is sprayed on the wet pulp to kill the foam, the paper will be full of small holes called fish eyes. Water emulsions of mixtures containing sulfonated tallow are used for this purpose.

Some cutting oils for the metal working industries use sulfonated oils as emulsifiers for paraffine oil. For this purpose a highly sulfonated sperm oil is probably the most desirable. A good sulfonated sperm oil will easily mix with three parts of paraffine oil to form a clear solution. This will make a stable white emulsion with water.

The cosmetic industry uses some sulfonated oils. Bath oils are often made from sulfonated castor oil, pine oil, or other perfume oils and may contain a water softener. Permanent wave solutions often contain about 1% of sulfonated castor oil.

Large amounts of sulfonated castor oil and derivatives of or from sulfonated castor oil are used in breaking emulsions in crude oil to separate the oil and water fractions.

Castor oil which has been sulfonated and then saponified is used in the textile industry. This is what is commonly called monopole soap.

Sulfonated tallol and mixtures containing tallol are being used as substitutes for sulfonated castor oil. This cannot be used in all replacements, but must be tried out for each replacement to see if it is satisfactory. Sulfonated mixtures containing largely soybean oil are also being used as substitutes for sulfonated castor oil. None of these are replacements for sulfonated castor oil but merely stop-gaps until castor oil again becomes available.

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The Effects of Fat Upon the Rates of Digestion in the Human Stomach of Meals of High Protein Content[1,2]

JOHN A. KILLIAN and MARY G. KNAPP

Introduction

DURING the past decade our laboratory has been engaged in comprehensive experimental studies on human subjects directed to determinations of the influences of fats upon rates of digestion of meals of carbohydrates and proteins in which the fats have been incorporated by physical mixing or cooking. The first report of one phase of these investigations was made to the American Oil Chemists' Society in 1944 (1).

This second report to your Society represents an extension of the earlier studies and the application of different technics, which, however, are directed to the same objectives. The chief difference between the experimental method employed in the studies reported in 1944 and those which will be described in this report is concerned with the evaluation of the time required for complete digestion of a meal in the stomach, which is generally called the gastric evacuation time.

In the earlier experiments gastric evacuations were determined by repeatedly aspirating samples of gastric contents at regular intervals until the stomach was empty (2). This procedure was not utilized in the experiments of two later series included in the present report. In these later experiments the subjects' stomachs were evacuated completely through a stomach tube and the total gastric contents were then analyzed for remnants of the meals.

Experimental Method

The fractional method of gastric analysis (3) was utilized for determinations of gastric secretory responses to the meals.

After the swallowing of the Rehfuss gastric tube the gastric residuum was completely aspirated, and then the meal was fed with the tube in place.

Samples of gastric contents were aspirated at intervals during a period of either two or three hours, or until the stomach had completely evacuated the meal. All of these specimens were analyzed for pH, by means of a glass electrode, free hydrochloric acid (4), total acidity (5), total chlorine (6), and, in one series of experiments, peptic activity (7).

Comparative rates of evacuation of the meals from the subjects' stomachs were determined by aspirating completely the gastric contents at the end of either two or three hours after ingestion of the meals. The instructions given by Hawk and Bergeim were followed in order to assure complete emptying of the stomach (2). Volumes of these specimens were noted and analyses were made of them for total nitrogen (8) and fat (by extraction with ethyl ether).

All experiments were carried out during mornings beginning at 9 a.m. and after a fast for at least 15 hours. On the average, an interval of seven days elapsed between two consecutive experiments on any one subject.

Test Meals

The series of experiments, which are presented in this report, included comparative experimental studies of gastric secretory and motor responses to three

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[2] Presented at the 20th annual fall meeting, American Oil Chemists' Society, Oct. 30-Nov. 1, 1946, in Chicago, Ill.

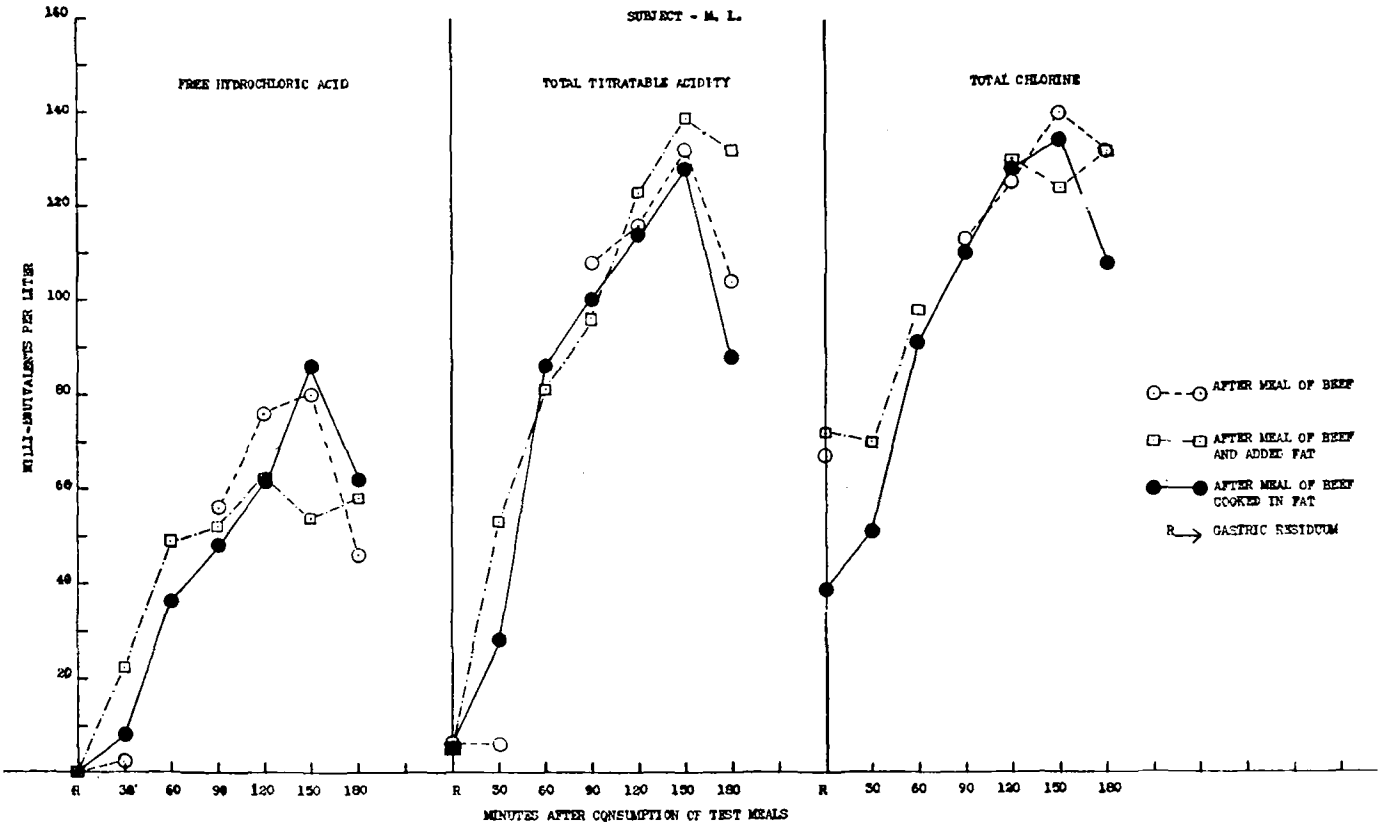

CHART II. Comparative gastric secretory responses to meals of beef alone or of beef and fat.

types of meals: a) broiled lean beef, b) broiled lean beef to which was added hydrogenated vegetable oil, and c) lean beef fried in hydrogenated vegetable oil.

Experimental Subjects

Three women and one man whose ages varied from 42 to 63 years were utilized as experimental subjects.

TABLE I

Gastric Secretory and Motor Responses of Subjects to Alcohol Test Meals

Subject	Sex	Age, years	Time of appearance of maximum gastric acidity, minutes	Maximum values		Gastric evacuation time, minutes
				Acidity as pH	Total chlorine milli-equivalents per liter	
L. H.	F	42	60	1.61	104	90
M. L.	F	44	60	1.57	101	75
C. K.	F	63	60	1.70	95	135
C. M.	M	55	75	1.43	117	165

Table I presents a summary of gastric secretory responses of the subjects to a test meal of dilute ethanol. In these tests all subjects exhibited maximum gastric acidities within the normal range. Two subjects, L. H. and M. L., who evacuated the test meal from their stomachs in less than two hours, may be considered representative of "fast" stomachs. For the other two subjects, gastric evacuation times were 135 and 165 minutes. These latter subjects may be classified as typifying relatively "slow" stomachs. However, the responses of the four subjects to the alcohol test meal were within normal ranges both in respect to acidity and to gastric emptying times.

Owing to the fact that the quantities of the three meals fed to the subjects varied and, also, the experimental procedures differed in minor details in some of the experiments, the experiments have been grouped in two series. In each series all experimental conditions were uniform.

First Series of Experiments

In the first series of experiments the portions of lean broiled beef which were fed to the subjects were 100 gm. and supplied 26.9 gm. of protein and from 2.0 to 4.1 with an average of 3.4% of fat.

Portions of the meal of broiled lean beef to which fat was added after cooking were 125 gm. Protein contents of the samples of this meal fed to the subjects varied from 28.8 to 31.9 with an average of 30.0 gm. Quantities of fat in these samples ranged from 26.2 to 27.6 with an average of 27.0 gm.

Portions of the lean beef fried in fat were also 125 gm. containing from 31.3 to 33.8 with an average of 32.2 gm. of protein and from 21.0 to 23.3 with an average of 22.1 gm. of fat. These meals were fed with 200 c.c. of water to the subjects with their gastric tubes in situ.

Two subjects, C. K. and M. L., were employed in this first series of experiments.

Samples of gastric contents were aspirated for analyses at intervals of 30 minutes during a period of three hours after ingestion of the meals. At the end of this period the total contents of the subjects' stomachs were removed for determinations of protein and fat.

Results of the First Series of Experiments

Two experiments with each test meal were carried out on Subject C. K., but the other Subject, M. L., participated in only one experiment with each meal.

Chart I summarizes, in graphic form, changes in pH, free hydrochloric acid, total acidity, and total

chlorine of gastric contents of C. K. as averages for the two experiments with each meal.

In the interpretation of the significance of these curves particular attention should be given to the types or conformations of curves, i.e., the rate of rise, the maximum values, and the time of appearance of these maximum values. For any one criterion of acidity included in the chart the three curves show strikingly similar conformations. However, the average curves for both hydrogen ion concentration and free hydrochloric acid of gastric contents rise uniformly more rapidly during the first two hours after the meal of beef cooked in fat than they do within the same period following the meal of beef alone, and these average results reflect the differences observed in both experiments on this subject with these two meals.

Chart II summarizes data for changes in free hydrochloric acid, total acidity, and total chlorine of the gastric contents of Subject M. L. before and after each of the three test meals. Since five, out of a total of 18 aspirations of gastric contents after these meals, yielded insufficient quantities for determination of pH, curves for hydrogen ion concentrations of gastric contents have been omitted from Chart II.

Here again, the comparative curves in each of the three categories of gastric acidity follow approximately parallel courses after ingestion of the meals. Differences among the curves at any interval of 30 minutes during the three hours of digestion are insignificant.

Barowsky, Upham, Dotti, and Kleiner (9) have stated that, in response to the stimulus of an alcohol test meal, normal individuals usually show a peptic activity of gastric contents between 1,000 and 2,000 units per c.c. and rarely over 2,000 units. However, after consumption of a meal containing cooked lean beef, Barowsky, Tauber, and Kleiner (7) have reported peptic activity as high as 2,400 units per c.c. of gastric contents. These latter authors have stated also that peptic activity of gastric contents appears to run parallel with the concentration of free hydrochloric acid except in cases of achylia gastrica, who may show activity of pepsinogen or of pepsin despite the fact that their gastric contents contain no free hydrochloric acid.

Subject C. K. exhibited not less than 2,500 units of pepsin per c.c. in all but one of the 35 specimens of gastric contents analyzed. In one instance, the peptic activity was found to be 1,700 units per c.c. This value, however, is well within the normal range (References 7 and 9). Peptic activities of the 12 specimens of gastric contents aspirated in the two experiments after the meal of lean beef cooked in fat and of the 12 specimens obtained in the two experiments after the meal of cooked beef and added fat are equivalent to activities of the 12 specimens collected from this subject in the two experiments after the meal of cooked lean beef.

In the experiments on M. L., comparisons of peptic activities were limited to the last two hours of the period of gastric digestion of these meals. A total of 12 specimens of gastric contents obtained from M. L. were analyzed for pepsin. This total comprised four specimens after each of the three meals. All of these specimens showed uniformly 2,500 units of pepsin per c.c.

The capacity of the stomach to digest protein is a function of the concentrations of both free hydrochloric acid and pepsin in the gastric contents. These two factors are accepted generally as the most important criteria of a gastric secretory response to a

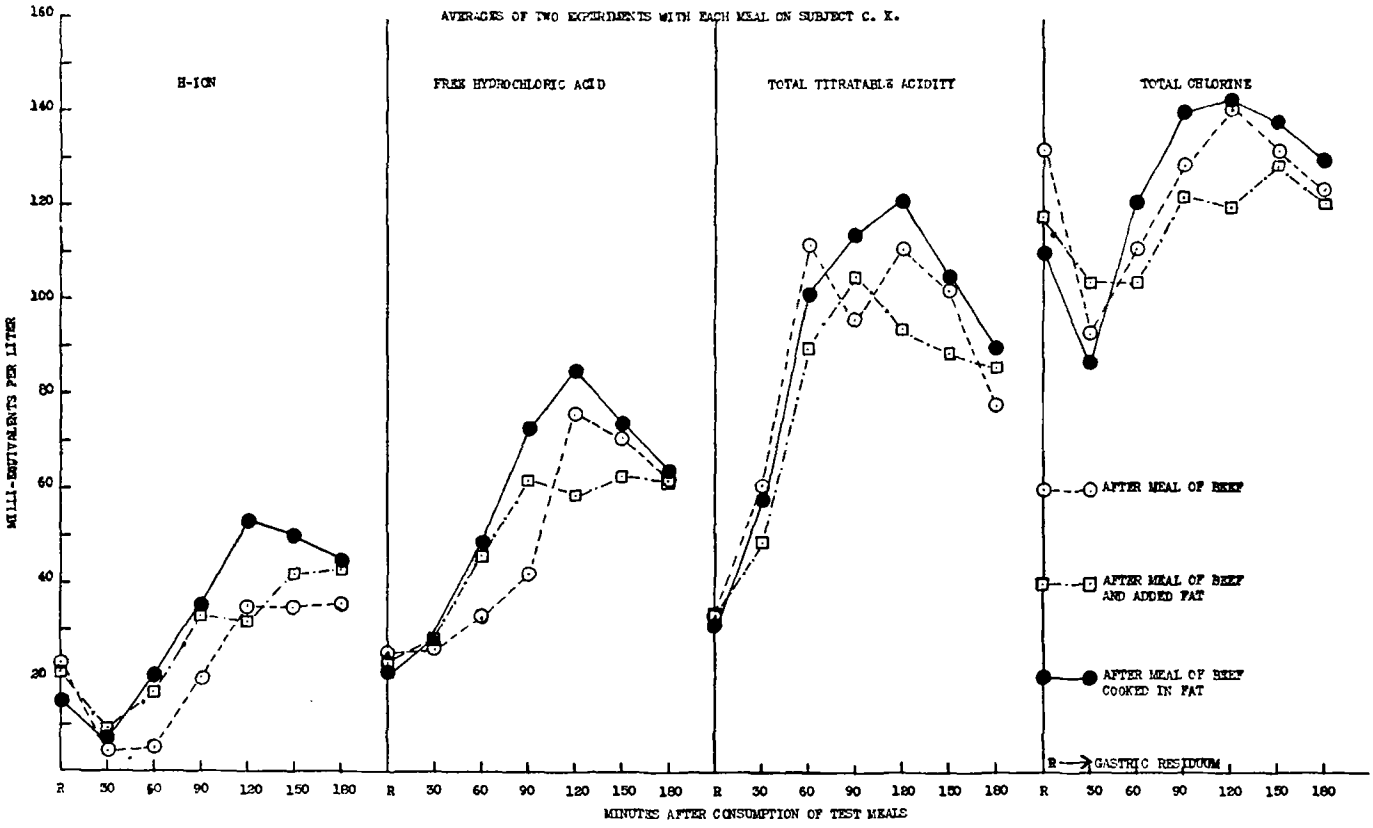

CHART I. Comparative gastric secretory responses to meals of beef alone or of beef and fat.

meal. Data for gastric acidity, summarized in Charts I and II, and data for peptic activities of the gastric contents present conclusive evidence that the incorporation of fat in a meal of lean beef either in the process of frying or physical mixing with the cooked lean beef does not affect the capacity of the stomach to digest protein.

TABLE II

Comparative Amounts of Protein and Fat Recovered From Subjects' Stomachs Three Hours After Ingestion of Meals

Test meal	Subject	Volume of gastric contents c.c.	Amount of food remaining in stomach as per cent of quantity fed	
			Protein	Fat
Lean beef	C. K.	30	0.74	0
		20	0.37	7.32
	M. L.	12	1.12	2.44
Averages		21	0.74+0.25	3.25+2.71
Lean beef and added fat	C. K.	12	1.25	0.74
		22	1.04	7.25
	M. L.	15	2.04	2.17
Averages		16	1.44+0.40	3.39+2.58
Lean beef cooked in fat	C. K.	20	0.89	0.86
		27	0.96	10.96
	M. L.	22	1.91	7.14
Averages		23	1.25+0.44	6.32+3.64

Table II summarizes the analytical data for percentage fractions of protein and fat of the meals recovered in the gastric contents at the time of evacuation of the stomachs.

Concentrations of protein have been calculated from figures for total nitrogen by multiplying the total nitrogen by the factor 6.25. This calculation is based on the assumption that all of the total nitrogen found in the gastric contents represents remnants in the stomach of protein as lean beef. Obviously, this assumption ignores the fact that gastric juice, uncontaminated with food, contains some nitrogen. An approximation of the nitrogen content of stomach contents, the source of which is gastric juice, may be obtained from analyses of gastric contents after ingestion of an alcohol test meal.

In experiments on four subjects (summarized in Table I) exhibiting normal gastric secretory responses to the alcohol test meal (200 c.c. of 7% ethanol), the last specimens of gastric contents were obtained at intervals of either 75 or 165 minutes after the meal. Volumes of these specimens varied from 3 to 15 with an average of 7 c.c. The range of concentrations of total nitrogen was from 0.032 to 0.062 with an average of 0.045%. Recalculated as protein, these values corresponded to 0.20 to 0.39 with an average of 0.28%.

All of the figures for concentration of protein in samples of gastric contents reported in Table II are significantly greater than the protein concentrations of gastric contents found in the four cases cited above at the time of emptying of the stomach after an alcohol test meal. These comparisons indicate that a large part, if not all of the values reported for protein in gastric contents, represent residues of protein of the meals remaining in the subjects' stomachs three hours after consumption of these meals.

Data in this table show that, in all nine experiments of the first series, 98% or more of the protein had left the subjects' stomachs at the end of the third hour of gastric digestion. Protein of meals containing either 22 or 27% fat was evacuated from the stomachs as completely as the protein of meals supplying only from 2 to 4% of fat.

As in the case of protein, it has been assumed that the meals are the sources of all of the fat found in the samples of gastric contents.

Six of the nine experiments show that more of the fat than of the protein of the meal was recovered in the gastric contents. In other words, the fat leaves the stomach slightly less rapidly than the protein. This was found to be true of the meal of low fat content, i.e., lean beef, as well as of the meals containing relatively large amounts of fat. In reference to the comparative rates of evacuation of fat from the subjects' stomachs, there are evident no significant differences among the three test meals.

In the series of six experiments with meals containing from 21.0 to 27.6 gm. of fat, from 89 to 99 with an average of 95% of the fat had been evacuated from the stomach at the end of three hours of gastric digestion.

Second Series of Experiments

In this series of experiments two modifications of the experimental procedure, as described for the first series, were adopted.

1) Although the test meals were prepared by the methods previously described, greater quantities of fat were added to the beef by mixing or frying and larger portions of all meals were fed to the subjects.

The portions of broiled lean beef fed were 188 gm. supplying from 53.1 to 56.3 with an average of 54.7 gm. of protein and from 8.1 to 16.2 with an average of 12.1 gm. of fat.

The portions of cooked beef to which fat was added were 288 gm., containing 54.7 gm. of protein and 106.6 gm. of fat.

The portions of beef fried in fat were 288 gm. of which 63.9 gm. were protein and 99.9 gm. were fat.

In the latter two meals the quantities of fat consumed by the subjects were approximately four times the amounts of fat in the corresponding meals fed to subjects in the first series of experiments and the ratios of fat to protein were about two to one whereas in the experiments of the first series, these ratios were less than one to one.

2) Whereas in the first series of experiments samples of gastric contents were aspirated at intervals of 30 minutes and the stomachs were evacuated completely three hours after consumption of the meals, in the second series the subjects' stomachs were emptied through Rehfuss tubes at the end of the second hour of gastric digestion of the meals. Also, during this interval of 2 hours no samples of gastric contents were removed for analyses. Hence, in this second series of experiments, data for acidities and chlorine contents of gastric contents are available for only the total contents of the subjects' stomachs withdrawn at the end of two hours after consumption of the meals.

Results of the Second Series of Experiments

All of the four subjects whose gastric secretory responses to the alcohol test meal were reported in the first table participated in the experiments of the second series.

All of the subjects consumed the meal of broiled lean beef. However, only two subjects, C. K. and C. M., were fed the meals of broiled lean beef to which fat was added and the remaining two subjects L. H. and M. L., received meals of lean beef fried in fat.

TABLE III

Comparative Concentrations of Acid and of Total Chlorine in Gastric Contents Aspirated From Subjects Two Hours After Ingestion of Meals

Test meal	Subject	Gastric pH	Milli-equivalents per liter of gastric contents	
			Acidity free HCl	Total chlorine
Broiled beef	C. K.	2.31	27	132
	C. M.	2.35	34	147
	L. H.	2.77	34	97
	M. L.	2.73	25	101
Averages		2.48	30	119
Broiled beef and fat	C. K.	2.38	28	150
	C. M.	2.07	26	137
	L. H.	3.66	25	84
	M. L.	3.29	31	120
Averages		2.48	28	123

Table III presents data for pH, free hydrochloric acid, and total chlorine in gastric contents removed from each of the four subjects at intervals of two hours after consumption of the meals of either broiled lean beef, or of lean beef and fat. Since no significant difference was observed between the meal of cooked beef to which fat was added and the meal of beef fried in fat, in respect to the subjects' gastric secretory responses to them, data for these two meals have been combined in the calculation of the averages for meals of cooked beef and fat.

Data included in this table show concentrations of both titratable free hydrochloric acid and total chlorine in gastric contents after the meal of beef and fat approximately equivalent to those found under like conditions after meals of broiled beef. These findings indicate that, under the conditions of these experiments, the gastric secretory responses to beef and fat were as effective as those to lean beef for the maintenance of conditions in the stomach essential for digestion of protein.

TABLE IV

Comparative Amounts of Protein and Fat Recovered From Subjects' Stomachs Two Hours After Ingestion of Meals

Test meal	Subject	Volume of gastric contents, c.c.	Total solids of gastric contents, per cent of volume	*Amount of food remaining in stomach as per cent of quantity fed*	
				Protein	Fat
Broiled beef	C. K.	48	5.1	3.40	1.23
	C. M.	8	6.4	0.71	0.49
	L. H.	32	5.0	1.95	1.23
	M. L.	10	3.7	0.44	0.30
Averages		25	5.1	1.63±1.05	0.81±0.42
Cooked beef and fat	C. K.	6	4.3	0.35	0.01
	C. M.	13	7.1	0.91	0.21
	L. H.	32	7.0	2.49	0.66
	M. L.	11	4.6	0.73	0.10
Averages		16	5.8	1.12±0.68	0.25±0.21

In two instances, viz., L. H. and M. L., the higher values for pH of gastric contents after meals of beef and fat suggest that these meals in the stomach more effectively buffered gastric acidity than did the meal of beef alone. However, since this result was not observed in the experiments on either C. K. or C. M., it is probably not dependent entirely upon the combination of beef and fat.

Table IV presents data for volumes and total solids of gastric contents and also their contents of protein and fat expressed as percentages of the respective quantities of these foodstuffs consumed in the meals.

It is of interest to note that both the volumes and the total solids of the contents of the subjects' stomachs after meals of beef and fat are not greater than the volumes and total solids of the gastric contents obtained, under similar conditions, after meals of broiled beef.

Gastric contents removed from the four subjects two hours after the meals of broiled beef contained amounts of protein varying from 0.44 to 3.40 with an average of 1.63% of the protein fed in the meal. Quantities of protein found in the subjects' stomach contents, aspirated at a similar interval after meals of beef and fat, ranged from 0.35 to 2.49 with an average of 1.12% of the protein fed in the meals. There is no significant difference between these two average results. Hence, it is evident that even relatively large quantities of protein fed in meals along with large amounts of fat as a hydrogenated vegetable oil leave the stomach as rapidly as do similar quantities of protein consumed with small amounts of fat in the form of lean beef. In other words, the portions of fat fed in this series of experiments did not prolong the time required for digestion of the protein in the subjects' stomachs.

The meals of broiled lean beef supplied from 8.1 gm. to 16.2 gm. of fat. Amounts of fat found in contents of the subjects' stomachs which were evacuated two hours after the feeding of these meals varied from 0.30 to 1.23 with an average of 0.81% of the fat fed in the meal.

Meals of beef and fat supplied from 99.9 to 106.6 gm. of fat which were from 6 to 12 times the amounts of fat given as lean beef. At an interval of two hours after consumption of meals of beef and fat, the subjects' gastric contents contained quantities of fat which ranged from 0.01 to 0.66 with an average of 0.25% of the portions of fat fed with the meal. These results indicate that, in all experiments, at the end of two hours of gastric digestion of the meals of beef and fat, more than 99% of the amounts of fat contained in the meals had left the stomach.

Summary

Results of the two series of experiments on four human subjects who were representative of normal gastric secretory and motor functions have shown that, under the experimental conditions, neither moderate nor large amounts of fat, added to lean beef either by physical mixing or by cooking, affect the gastric secretory response to the meals.

In other words, the addition to lean beef of fat as a hydrogenated vegetable oil did not diminish the capacity of the gastric juice to digest protein.

Also, the addition of moderate or large amounts of fat to the lean beef did not retard the evacuation from the stomach of either the protein or the fat of the meal.

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