The American Journal of

DIGESTIVE DISEASES

NEW SERIES VOLUME 14 • NUMBER 1 JANUARY 1969

Gastric Acid Secretory Responses to Some Purified Foods and to Additions of Sucrose or Olive Oil

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The total outputs of acid from vagally innervated pouches of 6 dogs in response to the ingestion of equicaloric meals of lean meat, purified proteins (lactalbumin, gluten, milk casein, and egg albumin), olive oil, and sucrose were determined. In comparison to the outputs to the meals of meat, equicaloric quantities of sucrose, methylcellulose (inert control meal), olive oil, and egg albumin produced the least acid; 25, 31, 40, and 42% of the meat response, respectively. The other purified proteins stimulated the production of acid equivalent to 60–92% of that obtained with meat. Except for egg albumin, the quantity of acid secreted in response to the ingestion of these foods was directly related to their buffering capacity.

An additional study, involving 4 additional dogs with innervated pouches, was made of the effect of adding 100 calories of sucrose, olive oil, or meat to a meal of 100 calories of meat. The outputs obtained were 85, 85, and 87% of those calculated by summing the separate 100-calorie outputs of the meals or multiplying the 100-calorie output to meat by 2. Provision of one-half of the calories of a 200-caloric meal by fat did not produce a greater reduction of secretion from that expected than equicaloric quantities of sugar or meat.

THIS INVESTIGATION is an extension of an earlier study of the gastric acid secretory values of some common foods.[1] The methods employed were identical to those used previously. In the prior study, foods with the greatest content of protein stimulated the greatest secretion of acid. In the present investigation we wished to determine (1) whether ingestion of a purified protein would stimulate as much production of acid as the mixture of proteins occurring in such a natural food as meat, and (2) whether a purified sugar such as sucrose would induce less secretion, on a caloric basis, than purified protein, as the results of the earlier investigation had implied. Finally, tests were done to determine the secretory effects of olive oil and of equicaloric additions of sucrose or olive oil to a meal of meat.

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Supported in part by Research Grant G-6207 from the National Science Foundation, and in part fulfilled the requirements for the degree of Master of Science in Nutrition awarded to Camilla Kotrba, Graduate School, University of Minnesota, 1960.

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The unique feature of the primary study of administering the foods in equicaloric and equivolumetric quantities was preserved.[1] Thus, calories rather than grams of food formed the basis of comparison, and the volume of all of the meals was equal in all tests. The response to the meal of meat was used as the standard for normalization of results. The meat meal was given often, and the responses of each dog to the other foods were expressed as equivalents to the mean of their responses to meat.

METHODS AND PROCEDURES

Five healthy female mongrel dogs (A, B, C, D, and E) provided with vagally innervated mucosal septal pouches of the Hollander and Jemerin[2, 3] type and weighing from 9 to 13 kg. were used for tests of purified proteins, and an additional 4 dogs (F, G, H, and I) of similar body weights and provided with the same type of pouches were used for extra tests of meals of meat. The care of the animals and the procedures employed were identical to those in the prior study.[1] The dogs were fasted for 24 hr. before each test, and the food was given by stomach tube when no free acid or less than 0.1 mEq had been secreted by the pouch in the preceding 30 min. After the meal, the juice was collected for 30-min. periods until secretion ceased or until the 30-min. collection contained less than 0.1 mEq of HCl. The volume of each sample was measured and the acidity determined by titration with 0.1 N NaOH using Töpper's reagent as an indicator. The amount of HCl in each sample was calculated from the titration and expressed in terms of milliequivalents of acid secreted in 30 min. The total amount of acid secreted in response to each test meal during the 5 hr. or more after its administration was obtained by summing the 30-min. outputs.

Lean round beefsteak was used as the standard meal. Lactalbumin, gluten, milk casein, gelatin, egg albumin, and sucrose comprised the purified foods. Olive oil was used as a source of fat, and methylcellulose, as a noncaloric substance. Meals containing 100 calories of each food were employed. The source of each food and the number of grams of each that provided 100 calories

TABLE 1. FOODS USED AS 100-CALORIE TEST MEALS

Test substances	*Gm. wt./100 calories**
Beef muscle	55.0
Lacta bumin	23.3
Gluten	21.9
Milk casein	23.5
Gelatin	25.6
Egg albumin	23.1
Olive oil	9.1
Sucrose	25.0

* Factors employed in the calculation of caloric values of proteins were coefficients of digestibility and heat of combustion of proteins and their unoxidized urinary products.[1]

are given in Table 1. In the preparation of all meals, water was added to bring the volume to 250 ml. Broiled meat was pureed in a blender; this was unnecessary with the other foods since simple stirring sufficed to bring them into solution or suspension and avoided the formation of foam. The methylcellulose was prepared by mixing a weighed amount with boiling water and then adding cold water to make a 0.6% solution.

The buffering capacity of each of the meals was determined by preparing a replication and measuring the amount of HCl required to reduce its pH to 2.0.

The total output of HCl in response to each of the meals was expressed as equivalent to the mean total output of the particular pouch in response to meals of 100 calories of meat. To normalize the pattern of the secretory response of each dog to the different foods, the 30-min. outputs of each were expressed as a percentage of the total amount of acid secreted when this total was expressed as a percentage of the mean total secreted with meat by that dog (total meat response equals 100).

RESULTS

Total HCl Outputs

The secretory responses to 100 calories of lean beef, lactalbumin, gluten, and casein were similar in all of the dogs (Table 2). The total outputs of acid stimulated by the purified proteins were often as much as those stimulated by the meals of beef (Table 2). Those produced in response to gelatin and egg albumin, however, were always less than those produced in response to meat. Egg albumin had the weakest action of the proteins tested, its meat equivalent value being only 42% (Table 2). The total output of acid obtained in response to olive oil was less than that produced by any of the purified proteins but more than the secretion evoked by sucrose or methylcellulose. The outputs in response to sucrose and methylcellulose were not significantly different. Their meat equivalent values were 25 and 31%, respectively.

Acid Response to Foods as Function of Buffering Capacity

Except for egg albumin, the total output of acid secreted in response to the test meals was related to their buffering capacities (Fig. 1). The correlation coefficient with egg albumin included was 0.41 and was not significant; with it excluded, the correlation was 0.95 and was highly significant ($p < 0.001$). As in the earlier study, the conclusion was reached that, except for egg albumin, the quantity of acid secreted in response to the ingestion of meals of purified foods was directly related to the capacity of the meal to neutralize acid.

The Pattern of Gastric Secretion

The meals of lactalbumin, gluten, and egg albumin produced maximal or nearly maximal secretory outputs in the second half hour, and in this respect their patterns resembled those of a meal of meat. The maximal responses to casein and gelatin were delayed until 2–2½ hr., and those to sucrose and methylcellulose occurred during the second half hour (Fig. 2).

TABLE 2. MEAN SECRETORY RESPONSES OF VAGALLY INNERVATED POUCHES OF 5 DOGS TO TEST MEALS

Test meals	*No. of tests on each of 5 dogs*	*Total mEq HCl secreted*					*Mean mEq HCl secreted*	*Mean meat equivalent values in % (meat = 100)*
		Dog A	*Dog B*	*Dog C*	*Dog D*	*Dog E*		
1. Beef	5	3.08	6.83	6.00	5.62*	3.07	4.92 ± 0.35	100
2. Lactalbumin	4	2.98	4.69	6.31	3.76	4.02*	4.35 ± 0.33	92
3. Gluten	3	2.10	7.95*	6.76	4.21	2.16	4.64 ± 0.67	89
4. Casein	3	3.88*	4.42	6.05	3.16	2.24	3.95 ± 0.43	86
5. Gelatin	4	2.48	5.50	2.45	3.37	2.50	3.26 ± 0.30	69
6. Egg albumin	3	1.52	3.84	2.39	1.81	1.07	2.12 ± 0.29	42
7. Olive oil	3	1.50	4.48	2.85	1.01	0.48	2.06 ± 0.40	40
8. Sucrose	3	0.46	3.51	2.27	0.90	0.51	1.47 ± 0.35	25
9. Methylcellulose	3	0.58	4.14	2.78	0.54	0.54	1.72 ± 0.43	31

* Values so marked are maximal mean outputs of each dog.

Effect on Total HCl Output of Additions of Fat or Sucrose to Meat Meal

Two contrasting meals of 200 calories each were used to answer the question whether the addition of fat to a meal of meat reduces the expected total output of HCl. One meal consisted of 100 calories of meat and 100 calories of olive oil and the other meal, 100 calories of meat mixed with 100 calories of sucrose. The volume of all meals was maintained at 250 ml. The separate total outputs of acid from the pouches in response to 100 calories of meat and to 100 calories

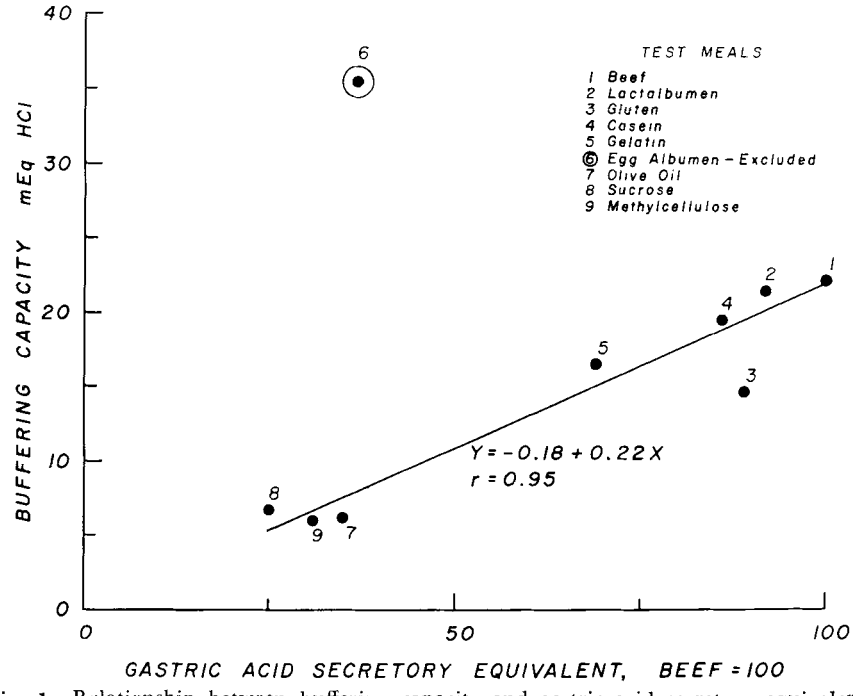

Fig. 1. Relationship between buffering capacity and gastric acid secretory equivalent of some purified substances and lean beef. Because methylcellulose has no caloric equivalent, the amount used in testing its buffering capacity was that given to the dogs as a noncaloric meal (250 ml. of a 0.6% solution). The result obtained with egg albumin (*Food 6*) is clearly outside the family of data represented by the remainder of the substances. It was therefore not included in the calculation of the linear regression and correlation coefficient.

of either sucrose or olive oil were summed to give the calculated or theoretically expected total output in response in the 200-calorie meals. These theoretic values were compared with the observed secretory outputs (Table 3). In 4 of the 5 dogs the responses to both of the mixed meals were less than the calculated or theoretically expected totals derived from the sum of the responses to the two components. But the differences between the responses to the two combined test meals, one of meat and sucrose and the other of meat and fat, were not significantly different. Thus, the addition of fat produced no greater

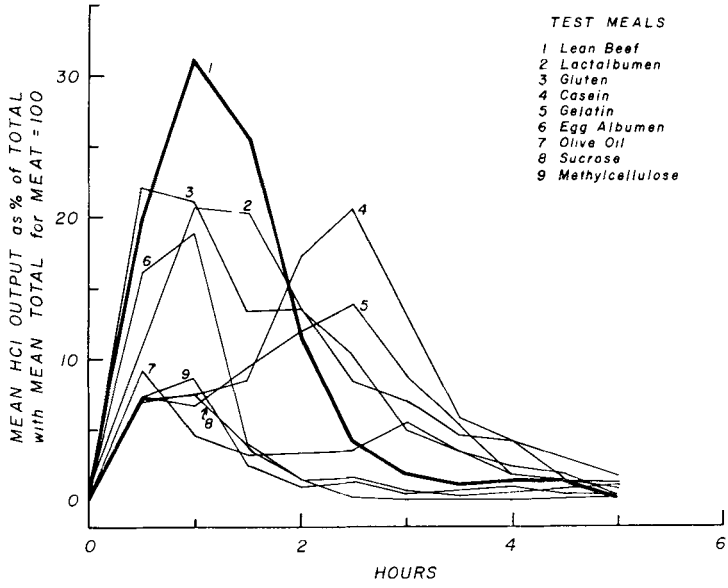

Fig. 2. Mean gastric acid secretory pattern of vagally innervated pouches of 5 dogs fed 9 different test meals.

TABLE 3. SECRETORY RESPONSES OF VAGALLY INNERVATED POUCHES OF 5 DOGS TO 200-CALORIE TEST MEALS

*Test meals**	*Dog*	*mEq HCl output*		*Percentage ratio of observed to calculated output*
		Calculated†	*Observed‡*	
Beef and sucrose	A	3.24	2.27	70
	B	10.35	9.61	93
	C	8.26	8.71	105
	D	6.52	4.41	68
	E	3.58	3.07	86
$\bar{X}$				84
Beef and olive oil	A	4.59	3.10	68
	B	11.31	9.67	85
	C	8.84	8.87	100
	D	6.63	6.03	91
	E	3.55	2.92	82
$\bar{X}$				85

* Each food contained 100 calories in 250 ml.

† Sum of mean outputs of each dog to 100-calorie mea's of each food.

‡ Each of the mixed meals of beef and sucrose or beef and olive oil was fed three times to each dog, and these are the mean of the responses.

TABLE 4. SECRETORY RESPONSES OF VAGALLY INNERVATED POUCHES OF 4 DOGS TO 100- AND 200-CALORIE MEALS OF LEAN MEAT

	*mEq HCl output**			
		200-calorie meal		*Percentage ratio of observed to calculated output*
Dog	*100-calorie meal*	*Calculated†*	*Observed*	
F	16.8	33.6	23.7	70
G	15.3	30.6	30.0	98
H	4.8	9.6	6.8	71
I	10.5	21.0	22.9	109
$\bar{X}$				87

* All values for measured outputs are means of at least three tests on each dog.
† The values for 100-calorie meal were multiplied by 2.

reduction from the expected output than did the addition of sucrose (Table 3).

Unfortunately, when the analysis of these data had been completed, Dogs A, B, C, D, and E were no longer available; we would like to have determined in them whether the response to 200 calories of meat was more or less than that calculated by simply doubling their outputs in response to 100 calories of meat. These tests were then done on 4 additional dogs (F, G, H, and I). Their pouches were similar in character, but larger in the case of Dogs F, G, and I than those in dogs of the earlier series. The results with the 200-calorie meals of meat in this series of animals were similar to those obtained with the prior group of dogs fed 200-calorie meals composed of 100 calories of meat plus 100 calories of either fat or sugar. The meals of 200 calories of meat gave outputs which were on the average 87% of those of the 100-calorie meal multiplied by two (Table 4). The meals of 100 calories of meat plus 100 calories of sucrose or olive oil gave meal outputs that were 85% of calculated values (Tables 3 and 4). Clearly, in terms of total output, the addition of fat on a caloric basis was no more effective in reducing expected acid output than was the addition of sucrose or more meat.

DISCUSSION

The results confirm and extend earlier investigations.[1] In prior tests the degree of stimulation of gastric secretion by a group of common foods was proportional to their buffering capacity. This relationship was identified again in our experiments with purified proteins and sucrose. The only exception was egg albumin. Why this protein stimulated the production of so little acid in the stomach when its buffering capacity in a beaker was so great has not been answered by our results. A number of factors besides buffering capacity are involved—for example, gastric emptying and the effects of acid-peptic digestion. If, for any reason, a test meal passes so quickly into the duodenum that some is lost from the stomach before the pH of the contents is lowered, the usual correlation between secretory stimulation and buffering capacity will be lost. Likewise, if a food was particularly vulnerable to diges-

tion, and this reduced its buffering capacity, then less acid would be required to lower the pH in the stomach than in a beaker. Our data, however, do not define whether these factors were involved.

A special secretory factor in meat has been proposed.[4] Because the amounts of acid secreted in response to 100 calories of meat were similar to those produced by lactalbumin, gluten, and casein and because such differences as were found in the secretory stimulating capacity of all the foods tested, except egg albumin, were accountable as differences between their buffering capacities, our results do not support the suggestion that meat contains a special gastric acid secretory factor.

The failure of fat to produce a more significant reduction in the total output of acid, when combined with a meal of meat, than an equicaloric addition of sucrose or meat itself prescribes that ultimately the acid produced by the stomach is regulated more by the amount required to bring the contents to a given pH than the nature of the food ingested. The effect of fat and of sucrose was more in the regulation of the timing of the secretory output than in the total amount of acid produced. The results confirm those of Brooks and associates,[5, 6] who found that fat in the stomach delayed as well as reduced the secretory response of dogs with vagally innervated pouches to the ingestion of meals of meat.

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