The Specific Heat of Garbage

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LAWS or regulations in 45 States now require that garbage intended for animal feed be cooked to destroy pathogenic organisms. Most States require that the garbage be heated to a temperature of 212° F. and be held at this temperature for at least 30 minutes. To comply with these laws (*1*), hog feeders have built a wide variety of equipment for cooking garbage. Some of the garbage cookers show considerable ingenuity, but ingenuity alone is not enough for an efficient design. To evaluate the factors involved in the design of suitable equipment for the heat treatment of garbage, two research groups at Iowa State College have recently undertaken a project titled "Survival of Swine Disease Organisms in the Heat Treatment of Garbage." This study is being conducted by the Iowa Engineering Experiment Station and the department of veterinary medicine of Iowa State College under grant RG 3985 (C) from the National Institutes of Health.

One of the major factors to be considered in the design of a garbage cooker is the amount of heat required to destroy pathogenic organisms. The size of the burner used with direct-fired kettles and the amount of steam required for steam-injection cookers depends on the amount of heat that must be available to raise the temperature of the garbage to 212° F. The heat required to raise the temperature of the garbage without considering heat losses may be calculated by the following formula:

$$W \times \Delta T \times C_{pg} = \text{B.t.u. required}$$

when W = weight of garbage in pounds.

ΔT = 212° F. minus the temperature of garbage before cooking, degree F.

C_{pg} = specific heat of garbage in B.t.u. per pound per degree F. temperature rise.

B.t.u. = British thermal unit, the quantity of heat required to raise the temperature of 1 pound of water 1° F. at or near its point of maximum density.

Specific heat may be defined as the number of B.t.u. of heat required to raise 1 pound of a material 1° F. The specific heat of water is 1.0. The specific heat of almost all other materials, including garbage, is less than 1.0. The specific heat of garbage is not constant but will vary with the moisture content and the composition of the garbage solids. Since the moisture content of garbage will usually be between 65 percent and 85 percent (*2–4*), many engineers (*5*) have used a garbage specific heat of 1.0 for purposes of calculating heat requirements. Others, on the other hand, have based their calculations of heat requirements for garbage on specific heat values varying from 0.50 to 0.90 (*6*). No reliable bases for these assumptions have been reported in the literature.

In the study of the survival of swine disease organisms being conducted at Iowa State College, numerous types of equipment and cooking methods are being employed. Routine observa-

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tions are being made of heat losses and heat transfer coefficients obtained with each piece of equipment. A more accurate value of specific heat of garbage should be used to calculate these data with a reasonable degree of accuracy. The purpose of this paper is, therefore, to present a method for estimating the specific heat of garbage with sufficient accuracy for design purposes.

Specific Heats of Foods

Garbage fed to hogs is usually commercial garbage (*1*). Commercial garbage is obtained from restaurants, cafeterias, hospitals, hotels, and other public eating places. It is primarily waste food, and as such, the specific heat of the garbage should be very nearly the same as that of the food products that it contains.

The specific heats of many foods have been reported in the literature (*7–9*). For the most part, the specific heats vary approximately directly with the moisture content. When heated, food may be assumed to behave as a mechanical mixture of food solids and water (*10*). Some research workers have found that this assumption is in error for temperatures in the freezing zone, but the assumption will give good results for temperatures above 40° F. (*10*). The specific heat of food (and garbage) may be determined, then, by a weighted average of the specific heats of the food solids and of the water. On the basis of this assumption, specific heats, (C_p) of the solid portion of various foods were determined as follows:

EXAMPLE 1

Broccoli[1] (90 percent water, 10 percent solids)

Specific heat due to water	$0.90\times1.00=0.90$
Specific heat due to solids	$0.10\times C_p$ = ---
Specific heat of broccoli (C_f)[1]	= .93
Specific heat of food solids (C_p)	$=\dfrac{0.93-0.90}{0.10}=.30$

[1] Reference 7.

Table 1 lists average values and ranges of values of percentage of moisture and specific heats for representative types of food products calculated from data reported by others (*7–9*).

The specific heats of most food solids vary from 0.15 to 0.45, with an average value of about 0.33. This rather wide variance in values can be explained by the high moisture content of food and the low specific heat of the food solids. On the average, the moisture content of food is about four times as great as the food solids content, and the specific heat of this water portion is about three times as great as the specific heat of the solids. Therefore, a relatively small variance in the determination of the moisture content of the food can produce a rather large variance in the determination of the specific heat of the food solids.

Table 1. Specific heats of foods

Food	Average values			Range of values		
	Percent moisture	C_f[1]	C_p[2]	Percent moisture	C_f	C_p
Meat	60.1	0.717	0.343	20 –90	0.48–0.93	0.150–0.408
Fish and seafoods	71.0	.783	.288	60 –80	.72– .90	.200– .486
Fowl	57.2	.750	.420	52 –65	.70– .80	.375– .500
Vegetables:						
Green leafy	87.6	.930	.302	65 –97	.76– .98	.125– .500
Squash, and so on	92.6	.932	.295	83.7–97	.72– .974	.227– .333
Beans and peas	51.3	.676	.367	12 –92	.85– .91	.182– .677
Potatoes, carrots, and so on	85.4	.888	.306	75 –95.8	.79– .972	.167– .400
Fruit:						
Berries	79.1	.861	.348	78 –94	.53– .92	.118– .800
Apples, pears, and so on	82.5	.891	.366	65 –90	.80– .96	.167– .743
Oranges, lemons, and so on	88.6	.917	.267	81 –92.5	.89– .945	.154– .580
Dairy products:						
Milk products	58.3	.777	.441	10 –87	.64– .92	.267– .683
Eggs	68.5	.783	.310	48 –87	.67– .92	.111– .385
Bread	46.0	.67	.388	44 –48.5	.65– .68	.375– .418

[1] C_f—specific heat of the food. [2] C_p—specific heat of the food solids.

EXAMPLE 2

Specific heat of broccoli, C^1=0.93

Percent moisture	*Specific heat of food solids* (C_s)
91	0.22
90 [1]	.30
89	.36

[1] Reference 7.

Conversely, values of the specific heat of food solids that are considerably in error may be used without introducing an appreciable error in the value computed for the specific heat of the food. Table 2 lists nine foods and their respective specific heats. The specific heats of the foods in this table, as computed by using an average value of specific heat of 0.33 for the food solids, are compared with the specific heats that were reported by others (*7–9*). Two conclusions may be drawn from table 2. First, the variance in the calculated value of specific heat for a food is small when the average value (0.33) is used for the specific heat of the food solids. Second, the variances are smallest if the water content of the food is high.

Table 2. Variations in specific heats of foods

Food	Percent moisture	Specific heat of food	Computed specific heat of food	Percent variance
Beef, boiled [1]	57	0.73	0.71	2.7
Butter [1]	14	.49	.42	4.3
Ice cream [2]	67	.80	.78	2.5
Milk [2]	87	.92	.92	.0
Parsnips [2]	79	.86	.86	.0
Peas, green [2]	74	.85	.83	2.4
Potatoes, boiled [1]	80	.87	.87	.0
Strawberries [2]	90	.92	.93	1.1
White bread [1]	44	.65	.62	4.6

[1] Reference 8. [2] Reference 7.

Specific Heat of Garbage

The water content of garbage ordinarily varies from 65 percent to 85 percent (*2–4*). Since garbage solids are food solids, the specific heat of garbage solids may be expected to approximate 0.33, the average specific heat of food solids. It is proposed, therefore, that the average specific heat of garbage be calculated as shown in example 1, using a specific heat for the water of 1.0 and a specific heat for the solids of 0.33. Table 3 shows the relationship that exists between the percent of moisture in the garbage and the specific heat of the garbage if this assumption is made. The variances resulting from using the average value of specific heat for the food solids in the garbage should be rather small. The chart illustrates the variances resulting from using this average value for estimating the specific heat of a garbage for moisture contents of 65 percent and 85 percent. It also shows the variance in moisture content that will produce the same variance in the specific heat of the garbage.

EXAMPLE 3

The average value of specific heat of food solids, 0.33, is used to calculate the specific heat of a garbage whose actual moisture content is 85 percent. The calculated specific heat of the garbage would be 0.90. If the actual specific heat of the food solids is 0.218, the specific heat of the garbage would be 0.883.

Variance in specific heat of food solids, 51 percent.

Variance resulting in specific heat of garbage, 1.9 percent.

Variance in moisture content which would cause an equivalent variance in specific heat of the garbage, 3.0 percent.

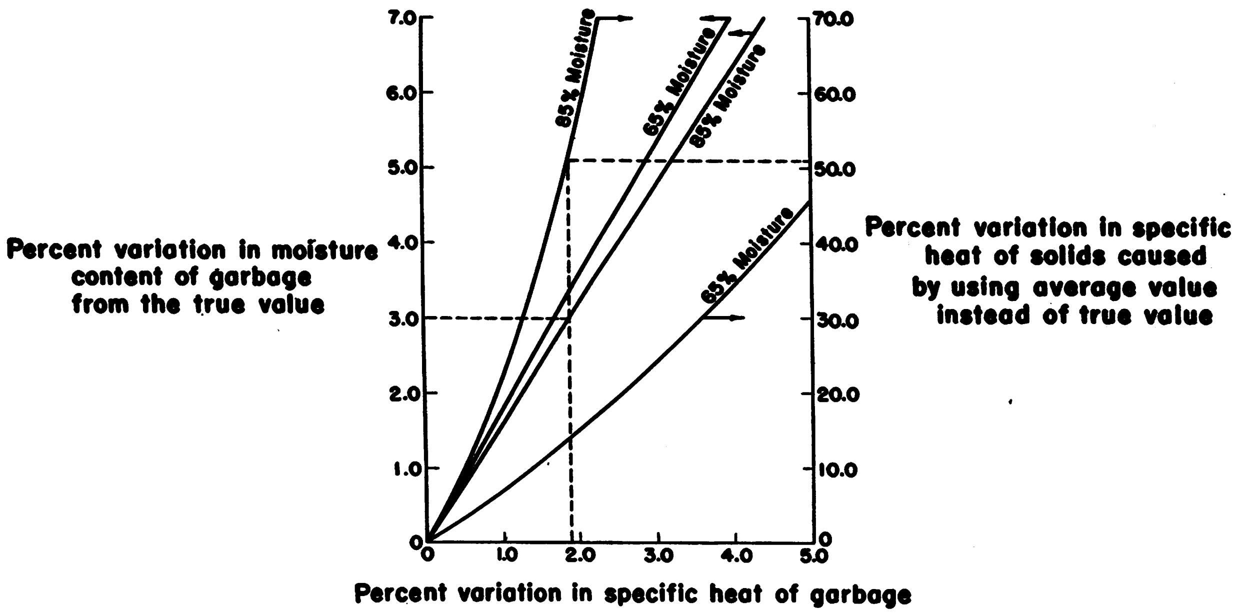
(This would result if a moisture content of 82.4 percent were used instead of the actual value of 85 percent.)

In most estimates of specific heat, the use of an average value of specific heat for the food solids should be sufficiently accurate. However,

Table 3. Relationship between moisture content and specific heat of garbage [1]

Percent moisture	Specific heat of garbage	Percent moisture	Specific heat of garbage
100	1.000	74	0.826
95	.97	73	.82
90	.93	72	.81
85	.90	71	.806
84	.89	70	.80
83	.886	69	.79
82	.88	68	.786
81	.87	67	.78
80	.866	66	.77
79	.86	65	.766
78	.85	60	.73
77	.846	55	.70
76	.84	50	.665
75	.83		

[1] Specific heat of water, 1.0; specific heat of garbage solids, 0.33.



if the makeup of the garbage is known, additional accuracy might be attained by computing a specific heat of solids for that particular garbage. Values of the specific heat of food solids can be used for computing this value if the approximate solids composition and moisture content of the garbage are known.

EXAMPLE 4

For a garbage known to contain:

Food	*Amount*	C_p[1]
White bread	0.30×0.375=	0.11
Potatoes	.30× .350=	.11
Parsnips	.15× .333=	.05
Peas	.10× .423=	.04
Beef	.05× .372=	.02
Milk	.05× .360=	.01
Ice cream	.03× .394=	.01
Butter	.02× .407=	.01
	Average C_p=	.37

[1] C_p=Specific heat of food solids.

For a moisture content of 75 percent:

Specific heat due to water_____(0.75×1.00)=0.75
Specific heat due to solids_____(0.25×0.37)= .09

Specific heat of garbage= .84
Calculated specific heat of the garbage= .83

Because the makeup of different lots of garbage from the same source will vary considerably, the use of an average specific heat of food solids in calculating the specific heat of garbage will probably give results as good as any that might be computed for it on the basis of its assumed makeup.

Laboratory Studies

To verify the accuracy of the calculated value of the specific heat of garbage, some experiments were run in the laboratory to determine the specific heat of several samples of garbage. In these tests, garbage samples were homogenized in a blender and tested in a homemade calorimeter. The laboratory tests were found to give a value of garbage specific heat within about 3 percent of the specific heat calculated on the basis of the proposed method. The proposed method should be checked, however, using a food calorimeter of the type in operation at the University of Texas (*10*).

Conclusions

1. The specific heat of garbage may be calculated with reasonable accuracy when the water fraction of the garbage is assumed to have a specific heat of 1.0 and the solids fraction is assumed to have a specific heat of 0.33.

2. The specific heat of garbage will normally range between 0.77 and 0.90 for moisture contents of 65 percent and 85 percent, respectively.

3. For determining the amount of heat re-

quired for cooking garbage, the specific heat should be assumed to be 1.0 if heat losses are not considered and 0.9 if heat losses are considered.

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Tabulated values of moisture contents and specific heats for various foods may be obtained from the authors on request.

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To Develop Cancer Drugs

A national voluntary program of cooperative research and development to find and produce effective drugs for the treatment of cancer has been launched under sponsorship of the American Cancer Society, Atomic Energy Commission, Damon Runyon Memorial Fund for Cancer Research, the Veterans Administration, the Food and Drug Administration, and the Public Health Service National Cancer Institute.

General guidance of the program will come from the Cancer Chemotherapy National Committee, established May 14, 1955, as the top policymaking body. The committee will define the scope of the program, develop general policies, assist in obtaining financial support for the work, coordinate the activities of the sponsoring organizations, and observe the rate of progress of the entire effort.

The committee will be headed by Dr. Sidney Farber, scientific director of the Children's Cancer Research Foundation in Boston and also chairman of the Chemotherapy Committee of the National Advisory Cancer Council, Public Health Service.

Dr. Kenneth M. Endicott, National Cancer Institute, is executive secretary of the committee and in charge of the small full-time staff provided by the sponsoring agencies to administer the program, organize an information exchange, and give needed assistance to research scientists. Staff headquarters will be at the Cancer Chemotherapy National Service Center, National Institutes of Health, Public Health Service, Bethesda 14, Md.

Members of the committee are: Dr. Charles L. Dunham, Atomic Energy Commission; Mrs. Albert D. Lasker, National Advisory Cancer Council and American Cancer Society; Dr. Theodore S. Moise, Veterans Administration; Dr. C. P. Rhoads, Memorial Center for Cancer and Allied Diseases; Robert S. Roe, Food and Drug Administration; Dr. Antonio Rottino, Damon Runyon Memorial Fund; Mefford R. Runyon, American Cancer Society; and Dr. Leon A. Sweet, Parke, Davis and Company.