Heat of Respiration of Wet, Spanish Peanuts As Affected by Initial Temperature and Moisture[1]

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ABSTRACT

The heat of respiration of high moisture Spanish peanuts was measured for seven tests during 1971 at 60°F and 30% MC and in 1972 for four tests at 70°F, 30% MC and four tests at 70°F, 40% MC. Results at 40% MC show a nearly constant rate of respiration. Including data from Suter, at 30% MC the heat of respiration is higher at temperatures of 60°F and above. In addition, variations between replicates are greater at higher initial temperatures. Differences within the same season were just as large as those between seasons.

Peanuts remain biologically active even after harvest. The respiration that continues to occur during drying until safe storage moisture can result in losses in quality. A quantative measure of the heat production of peanuts and their associated fungi is needed to better design processing equipment for handling and drying.

An initial study by Brusewitz et al. (1973) revealed the high temperatures experienced by peanuts enclosed in loads waiting to be dried. Results of that field study indicated that conditions were favorable for mold growth when a load of wet peanuts heated at a rate greater than 0.5°F per hour. Suter and Clary (1973) designed a calorimeter and measured the heat of respiration of high moisture peanuts in a controlled laboratory experiment. Results (Suter and Clary, 1973) for initial temperatures of 40, 50 and 70°F and moisture contents of 30 and 40% MC (Wet Basis) indicated significantly varied effects of those two variables. Wide differences were found at the higher temperatures and lower moisture. Thus, there was need to determine what variation could be expected during the harvest season and from year to year in the respiration of peanuts of the same initial temperature and moisture content. This variation would include differences in fungi, soil conditions, and maturity.

The objectives of this investigation were to experimentally determine the variations in heat of respiration of wet, Spanish peanuts at different initial temperatures and moisture contents. A total of seven tests were run during the 1971 harvest season at 60°F and 30% MC.* In 1972 four tests were conducted at 70°F and 30% MC and four tests at 70°F and 45% MC.

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*All moisture values reported are on a wet basis.

Materials and Methods

The peanuts were manually harvested, washed, and placed on an indoor table for drying by forced ambient air to the design moisture content. The cleaned peanuts were divided into two groups; one for the respiration test and the other for the maturity tests.

The respiration test procedure followed that developed by Suter (1972) (Suter and Clary, 1973). Briefly, it consists of using part of the peanuts for a specific heat test and part for pre-conditioning to the desired initial temperature. When the temperature of the peanuts had come to the prescribed temperature, they were placed into the one liter capacity calorimeter. The internal bulk temperature was monitored continuously for three days or until a maximum of 100°F reached, the limit of the instrumentation. Aeration continued during the test at a rate of approximately 100 milliliters per hour to prevent a CO_2 concentration over 10% which would inhibit further respiration.

Maturity measurements of the peanuts included determination of the change in oil color and kernel size distribution. Only slight increases in maturity were found (Brusewitz and Hamilton, 1972) as the harvest season progressed.

Results

Time-Temperature Response

The time-temperature response for the respiring peanuts is shown at moisture contents of 30% (Fig. 1) and 45% (Fig. 2) along with Suter's results. These results shown the differences in temperature response for different initial temper-

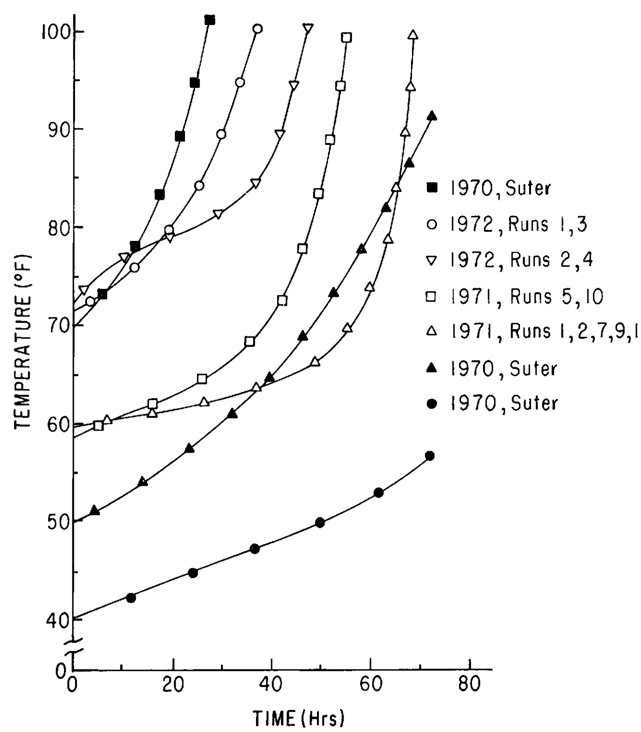

Fig. 1. Bulk temperature versus time for peanuts at 30% M.C.

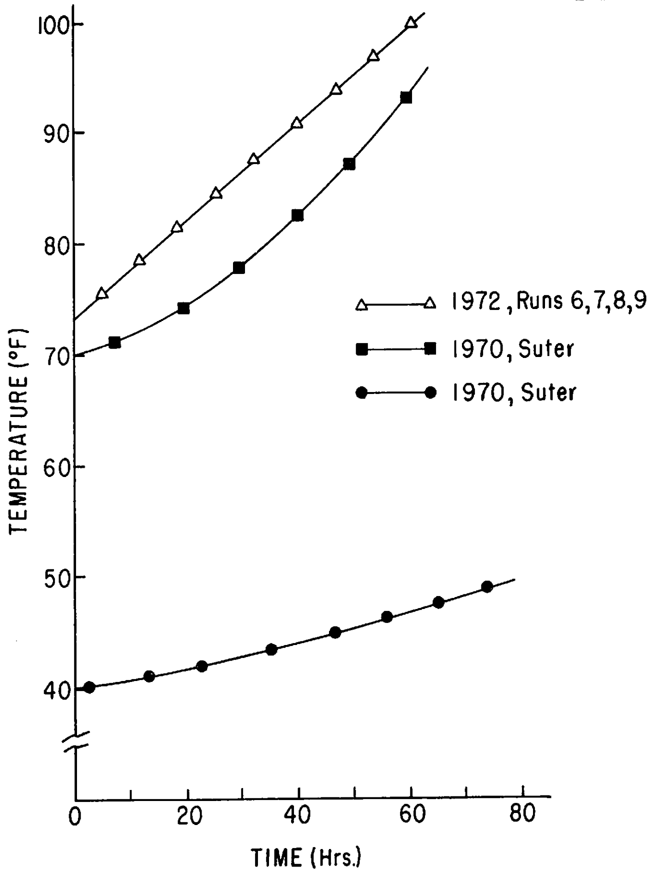

Fig. 2. Bulk temperature versus time for peanuts at 45% M.C.

atures and also the variability at the same temperature. It was found that higher initial temperatures produce greater variability between replicates. The 60 and 70°F initial temperature curves show that once the temperature begins to increase, it develops rapidly. The final rates of increase for 60° and 70°F were similar. Suter's data for 50°F initial temperature does not display such a large slope when the high temperatures are finally reached. Figure 1 shows a type of curve having three distinct portions. The first portion of the time-temperature curve shows a low, constant rate of temperature rise, followed by a rapidly increasing rate, which is followed by high constant rate. This type of behavior is typical for respiring biological materials.

At the higher moisture (Fig. 2) the temperature-time data is linear at both 40° and 70°. These results show that the abundance of moisture inhibits the rapid development of temperature increases and fungi growth. The data of measured temperature versus time was fit to a fourth degree polynomial as suggested by Suter (1972). Although this was not always necessary for all replications it was used for consistancy. The resulting time-temperature equation regression coefficients are shown in Table 1.

RESPIRATION

The heat of respiration was computed using the energy balance equation from Suter (1972). The heat generated is the algebraic sum of energy stored in peanuts, air and flask.

Table 1. Temperature vs. time regression coefficents*

Year	Run**	Moisture Content (WB)	Initial Temp. (°F)	B_0	B_1 x 10	B_2 x 10^2	B_3 x 10^3	B_4 x 10^6	Std. Dev.
1971	1	30	59	59.4	-4.1	5.2	-1.47	13.3	0.7705
1971	2	30	60	60.3	-2.9	4.2	-1.28	11.9	0.8169
1971	5	30	60	59.8	0.5	2.0	-0.99	15.8	0.3394
1971	7	30	60	59.8	1.9	-0.9	0.13	0.6	0.8413
1971	9	30	61	60.5	1.6	-0.3	-0.05	1.8	0.6242
1971	10	30	60	59.6	5.9	-3.3	0.82	-3.4	0.5988
1971	11	30	59	59.2	0.8	0.0	0.07	1.9	2.8742
1972	1	29	73	72.5	7.5	-4.9	2.04	-20.3	0.3267
1972	2	29	73	72.7	2.6	1.7	-1.22	19.6	1.5453
1972	3	28	71	71.3	4.6	-3.5	1.79	-17.8	0.4305
1972	4	28	73	73.4	3.2	1.4	-1.21	21.4	0.4290
1972	6	48	70	70.4	1.9	2.6	-0.67	5.2	0.4627
1972	7	49	72	71.7	7.9	-2.1	0.51	- 4.1	0.4126
1972	8	43	70	70.4	5.8	1.4	-0.57	7.2	0.4050
1972	9	47	72	71.5	5.9	-0.2	0.00	0.2	0.2432

* $T = B_0 + B_1\,\theta + B_2\,\theta^2 + B_3\,\theta^3 + B_4\,\theta^4$

where θ is in hours and T is °F

** Run Nos. show order of harvest time

$$\dot{q} = \frac{[(C_p\,W)_p + (\rho C_p V)a + H_f]\,[T_2 - T_1]}{[\theta 2 - \theta 1]}$$

where $\dot{q}$ = rate of energy generated, Ca 1/hr

Cp = specific heat at constant pressure, cal/gm - °C

W = weight of peanuts, gm

ρ = density, gm/cm³

V = volume, cm³

Hf = heat capacity constant for flask, cal/°C

T_2-T_1 = temperature difference, °C

θ_2-θ_1 = time interval, hr

The energy changes due to aeration were omitted due to its small size compared to the other terms. The heat of respiration was computed on a dry matter basis at one-half hour increments using points from the fourth degree polynomial time versus temperature curve. Specific heat values used were those measured in the laboratory for each particular run. The resulting curve for respiration was fit to a fourth degree polynomial and the resulting regression coefficients are shown in Table 2. Resulting curves are shown in Figures 3 and 4 along with Suter's data. The results at 30% moisture content show a rather high rate of heat respiration at temperatures of 60 and 70°F. The slope of the respiration versus time curve is commonly 0.1 calories/gram-hour per hour of test. It was found that the 60°F slope was very close to that of 70°F except for a slight time delay. The respiration rate at 60°F was considerably higher than that measured by Suter at 50°F.

At higher moisture contents the respiration curves were found to be nearly linear in all cases. At the higher temperature the rate is approximately 0.57 calories/gram-hour which compares favorably with Suter's results. At lower temperatures the rate is also constant but at a lower level.

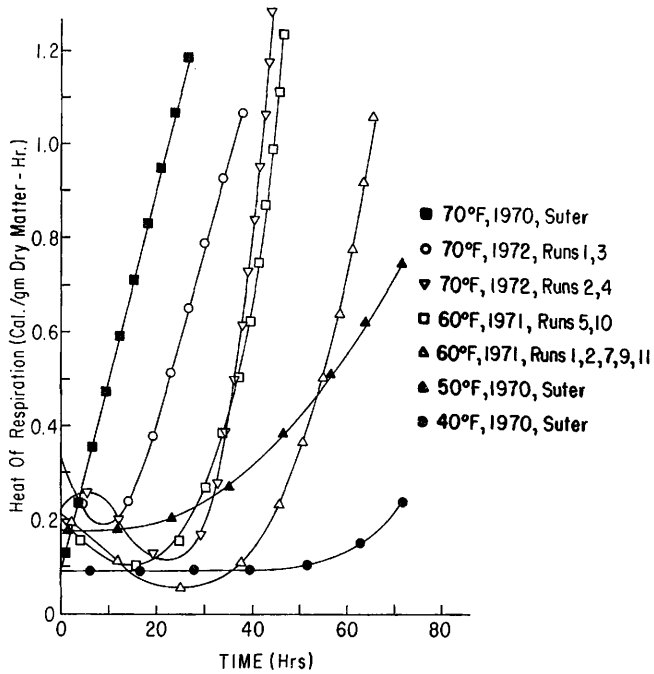

Fig. 3. Heat of respiration versus time for peanuts at 30% M.C.

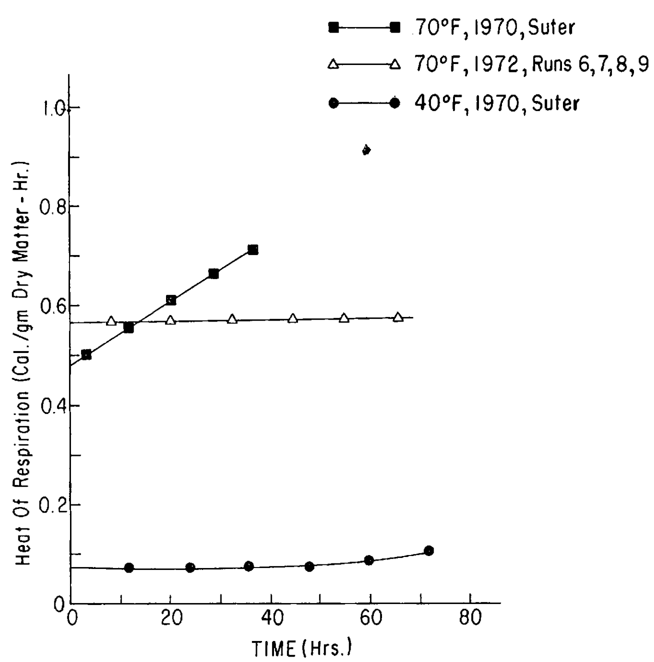

Fig. 4. Heat of respiration versus time for peanuts at 45% M.C.

Table 2. Heat of respiration vs. time regression coefficients*

Year	Run	Moisture Content (WB)	Initial Temp. (°F)	B_0	B_1	$B_2 \times 10^3$	$B_3 \times 10^6$	$B_4 \times 10^8$	Std. Dev.
1971	1	30	59	-0.201	0.048	-1.57	3.21	24	0.02418
1971	2	30	60	-0.134	0.038	-1.30	1.74	23	0.02071
1971	5	30	60	0.044	0.016	-0.78	-2.48	51	0.01210
1971	7	30	60	0.106	-0.010	0.27	0.94	3	0.00999
1971	9	30	61	0.098	-0.005	0.13	-2.29	6	0.01037
1971	10	30	60	0.305	-0.027	0.74	6.03	-6	0.03300
1971	11	30	59	0.046	-0.002	0.03	-0.46	6	0.00539
1972	1	29	73	0.490	-0.061	3.53	-37.37	-14	0.0010
1972	2	29	73	0.172	0.018	-1.72	23.78	35	0.0051
1972	3	28	71	0.302	-0.045	3.31	-41.09	4	0.0004
1972	4	28	73	0.208	0.014	-1.57	23.56	44	0.0043
1972	6	48	70	0.180	0.052	-1.65	9.13	11	0.0003
1972	7	49	72	0.828	-0.040	1.33	-8.07	-9	0.0001
1972	8	43	70	0.496	0.028	-1.28	14.41	16	0.00008
1972	9	47	72	0.579	-0.002	-0.95	0.56	0	0.00006

* $\dot{q} = B_0 + B_1\,\theta + B_2\,\theta^2 + B_3\,\theta^3 + B_4\,\theta^4$

where θ is in hours and $\dot{q}$ is in cal/gm per hour

Some question arose regarding that portion of the lower moisture curves displaying a decrease in heat of respiration at early times. This is not expected to be a natural occurrence and is thought to be an experimental error. It is suggested that the decrease in rate of respiration, which was actually a temporary leveling off of temperature rise, may have been due to improper preliminary preconditioning of the peanuts to the designed temperature. Either the time was too short or the peanuts had not reached equilibrium with the new environment. One should also be cautioned with regard to the fourth degree polynomial equations. It must be remembered that these equations fit the data and may not be accurate when extrapolating to higher temperatures or longer times.

Summary and Conclusions

The results of these tests indicate variations in the heat of respiration are greater at higher initial temperatures. At 30% moisture content the heat of respiration is very high at temperatures of 60°F and higher. At 45% moisture content the heat of respiration is nearly constant at a level depending on the initial temperature.

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