Research Note

SPECIFIC HEAT OF PARCHMENT COFFEE[1,2]

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Knowledge of the physical and thermal properties of parchment coffee is essential when investigating heat and mass transfer phenomena in coffee drying and storage. These properties control the behavior of mechanical systems used in coffee drying and storage. They are also used to mathematically model the process and to study the effectiveness of the system.

According to classical thermodynamics, the specific heat of a substance is a thermal property that can be defined as the energy required to raise its temperature by one degree. Since the simulation models for drying grains, as well as coffee beans, are given by energy balances, this thermal property must be known before the equations of heat and mass flow can be used.

The specific heat of biological materials is usually determined by using either ice calorimetry or the method of mixture. In this study the specific heat of parchment coffee was determined by the mixture method, which has been widely used in grains such as soft white wheat (Kazarian and Hall, 1965), sorghum (Sharma and Thompsom, 1973), shelled corn (Koschatzky, 1973), rough rice (Wratten et al., 1969; Morita and Singh, 1979), wheat (Mohsenin, 1980), gram (Dutta et al., 1988), pistachios (Hsu et al., 1991) and parchment coffee (Ciro, 2000).

In the mixture method a sample is placed in water or other liquid and the temperature changes of the liquid and samples are recorded. The sample of parchment coffee was dropped directly into hot water in a calorimeter made of aluminum foil. Insulation was added between the vacuum and the calorimeter's outer metal walls. The sample of coffee beans (at a mean temperature of 8°C) was added to the hot water at 55°C. The temperature's rate of change in the water-coffee mix was measured and recorded with five "T" type thermocouples connected to a Campbell Scientific data acquisition system (multiplexer CR10X and software PC 208)[5]. The specific heat of parchment coffee was calculated by using the expression cited by Dutta et al., 1988:

$$C_p = \left[\frac{(C_c + m_h C_w)(T_h - (T_e + tr'))}{m_g((T_e + tr') - T_g)} \right] \qquad [1]$$

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Where:

C_c: Heat capacity of calorimeter, kJ/K

C_p: Specific heat of grain, kJ/kg K

C_w: Specific heat of water, kJ/kg K

m_g: Mass of grain, kg

m_h: Mass of hot water, kg

r': Rate of temperature fall of mixture after equilibrium was reached, K/s

t: Time for grain and water to come to equilibrium, s

T_e: Equilibrium temperature, K

T_g: Grain temperature, K

T_h: Temperature of hot water, K

The heat capacity of calorimeter (C_c) was obtained by using the calibrating procedure cited by Dutta et al. (1988). The term tr' accounts for the heat of hydration and the heat exchange with surroundings. The value of r' was taken as the rate of temperature drop of the mixture after equilibrium was reached. Samples of parchment coffee were conditioned from the range of 4 to 57% wet basis (wb) to provide ten different initial levels of moisture content. For each moisture content two replications were done.

This study was performed in the Agricultural and Biosystems Engineering Department at the University of Puerto Rico, Mayagüez Campus. Trials were conducted with *Coffea arabica* L., var Caturra.

Figure 1 shows the variation of the moisture level of the parchment coffee bean and the calculated specific heat. All measurements were done at 24°C room temperature. The specific heat increased linearly with moisture content. Hence parchment coffee beans with high moisture content require more energy to be dried.

The regression equation obtained for specific heat of parchment coffee as a function of moisture content, wet basis (wb), with a standard error of 0.197 was:

$$C_p = 0.0535*M_{(\%, wb)} + 1.6552 \qquad (r^2 = 0.8932) \qquad [2]$$

Where:

C_p: Specific heat of parchment coffee bean, kJ/kg K

$M_{(\%,w.b)}$: Moisture content of parchment coffee, % wet basis

This expression is valid for moisture contents from 4 to 56% wb. Expressing moisture content in dry basis (db) the equation for specific heat is:

$$C_p = 0.0228*M_{(\%, db)} + 2.0492 \qquad (r^2 = 0.8932) \qquad [3]$$

Where:

C_p: Specific heat of parchment coffee bean, kJ/kg K

$M_{(\%,db)}$: Moisture content of parchment coffee, % dry basis

This expression is valid for moisture content from 4.4 to 130.5% db.

Figure 2 shows the specific heat of parchment coffee from the range of 5 to 40% wb compared with specific heat for shelled corn (Koschatzky, 1973), wheat (Mohsenin,1980) and pistachios (Hsu, 1991). The specific heat of parchment coffee is higher than that of shelled corn, wheat and pistachios. The specific heats of these grains are highly dependent upon their moisture content. Moreover, in the range of 5 to 20% wb (not shown in Figure 2) the specific heat of parchment coffee is higher than that of soybeans (Alam and Shove, 1972), sorghum (Sharma and Thompsom, 1973) and rough rice (Morita and Singh, 1979). Hence parchment coffee needs more energy for drying than the previously cited grains.
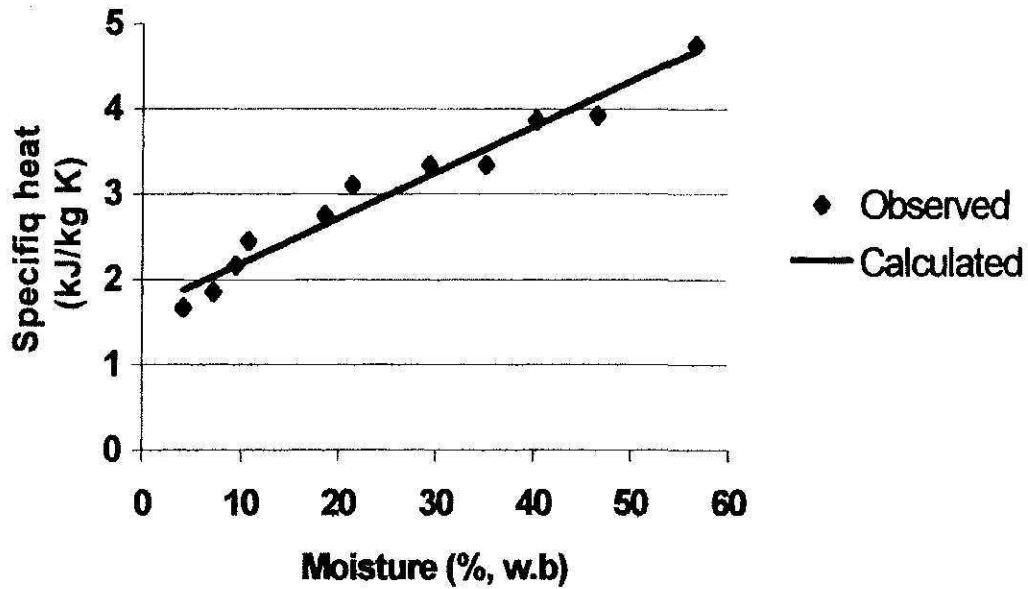
Figure 1. Specific heat as a function of moisture content of parchment coffee bean.

From this study we can conclude that the specific heat of parchment coffee beans, regardless of the bean temperature, has a linear relationship with its moisture content, where the specific heat increases with moisture content. In comparison with the above mentioned grains, the parchment coffee bean has higher energy requirements.
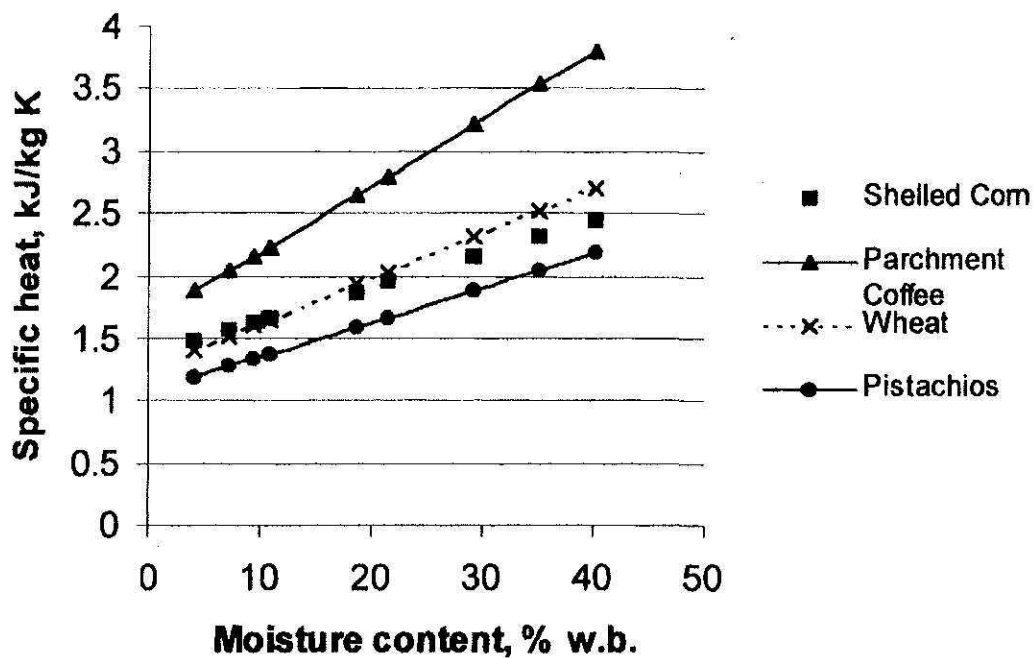

Figure 2. Comparison of specific heat for parchment coffee, wheat and shelled corn. The figure was generated from the equations available in the literature as indicated in the manuscript.

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