Specific Heat Capacity of Crude Palm Oil

J. S. Alakali1, S. O. Eze2, and M. O. Ngadi3*

1Department of Food Science and Technology, University of Agriculture Makurdi, Nigeria.
2Department of Chemistry Abia State, University Uturu, Nigeria.
3*Department of Bioresource Engineering, McGill University, Montreal, Quebec. H9X 3V9. Canada.
Phone: +1 514 398-7779; Fax: +1 514 398-8387. Email: Michael.ngadi@mcgill.ca

ABSTRACT
Specific heat capacity of crude palm oils from Dura, Pisifera and Tenera varieties of palm, processed by hot and cold method and stored for 12 months as well as the fresh samples was investigated using the Differential Scanning Calorimeter technique in the temperature range of -20 to 80°C. Results show that the three factors: Variety of oil palm or source of palm oil, processing method and storage history have effect on specific heat capacity of samples. For all samples studied, the specific heat capacity increased in the temperature range of -10 to 10°C followed by a decrease to about 80°C. Maximum specific heat of samples was between 0 and 9°C, indicating that more heat was required to raise the temperature of oil samples in this temperature range. The specific heat of Dura samples highest followed by Tenera, while that of Pisifera was lowest, showing the effect of variety of oil palm on specific heat. The specific heat capacity of cold processed palm oil was generally lower, ranging from 1.29 - 5.26 J/g°C while that of hot processed samples range from 1.80 – 6.24 J/g°C, indicating that processing method had effect on specific heat capacity. The specific heat capacity of the fresh (1.63 - 6.24 J/g°C) was generally higher than the stored (1.97 – 5.47 J/g°C).

Keywords: Palm oil; heat capacity; palm varieties; thermal properties

INTRODUCTION
Heat capacity is among the basic thermophysical and thermodynamic properties of food materials. The property is directly linked with temperature derivatives of basic thermodynamic functions and therefore indispensable for the calculation of differences in these functions between different temperatures (Zábransky et al, 2002). It is used for establishing energy balances, entropy and for calculating changes in reaction enthalpies with temperature. Variations in heat capacities serve as a sensitive indicator of phase transitions and are an important tool for understanding changes in the structure of liquid solutions such as edible oils (Santos et al, 2005).

Heat capacities of edible vegetable oils are essential for a rigorous control of processes, realistic design of processes in industry (Morad et al, 1995) and setting up standards for each specific use (González et al, 2004). In order to analyse heat transfer during freezing or thawing, the specific heat capacity and heat capacity must be known (Ngadi et al, 2003). The Specific heat capacities of oils and fats are quite useful to determine their behaviour during different technological processes as it varies with chemical composition and temperature (Díegeuz et al, 2010). For example, the specific heat capacities are similar for the triglycerides in their original physical state, but can increase as a function of the unsaturation of the fatty acids. Numerical values of the specific heat capacities of liquid fats are twice larger compared to that of solid fats, and the alfa (α) form has a higher heat capacity than the (beta) β form exhibits (Santos et al, 2005). The use of thermoanalytical methods, such as Differential scanning calorimetry for the characterization of oils has distinguished role in food industry. DSC as a method for determining specific heat capacity of vegetable oils has been widely used by researchers (Timms, 1985; Santos et al, 1995; Morad et al, 2000; Abdulkarim, and Ghazali, 2007; Fasina and Colley, 2008, Narváez et al, 2008). Use of DSC to determine the specific heat capacity of triglycerides of palm oil has also been reported (Morad et al, 1995). However, no work on the application of this technique to study the heat capacity of crude palm oil as affected by variety, processing and storage has been seen in literature. However, these factors are expected to introduce variations in the chemical composition of crude palm oil and influence its specific heat capacity. In this paper the DSC is used to study the specific heat capacity of crude palm oil from three varieties of oil palm, processed by the hot and cold method with varying storage history.
MATERIALS & METHODS

Sample preparation:
Palm oil samples from three oil palm sources namely Dura, Tenera and Pisifera were collected from the Nigeria Institute for Palm Oil Research (NIFPOR) and used for the experiments. Palm fruits from three oil palm varieties were subjected to either hot or cold processes to produce the palm oil samples. The processed samples were stored in sealed plastic containers and kept for experimental use. Samples from this batch were called ‘Fresh’. A batch of samples was stored for 12 months. These samples were tagged as ‘Stored’. The resulting samples from the two batches were named: Dura, Cold Process Fresh (DCPF); Dura, Cold Process Stored (DCPS); Dura, Hot Process Fresh (DHPF); Dura, Hot Process Stored (DHPS); Tenera Cold Process Fresh (TCPF); Tenera, Cold Process Stored (TCPS); Tenera, Hot Process Fresh (THPF); Tenera, Hot Process Stored (THPS); Pisifera, Cold Process Fresh (PCPF); Pisifera, Cold Process Stored (PCPS); Pisifera, Hot Process Fresh (PHPF); Pisifera, Hot Process Stored (PHPS).

Measurement of specific heat
The heat capacity was measured using the DSC (Model V4.7A DSC 2000, TA Instruments, New Castle, DE, USA). Crude palm oil samples of approximately 5.30 mg were placed in the aluminum sample vessel. The sample vessel was then placed on the sample platform while an empty aluminum vessel was placed on the reference platform. To determine the specific heat capacity, the instrument was operated at temperatures ranging from -20 to 80°C, and scan rate of 10°C/min, with delay and dwell times of 2 and 1 min, respectively. Nitrogen was passed through the heating chamber at atmospheric pressure and a flow of 13.3 mL/min measured at the bypass outlet. The low-temperature-head assembly (Perkin-Elmer) filled with liquid nitrogen was used to cool the samples and detector. Prior to measurements, the DSC was calibrated for temperature and energy sensitivities as specified in the manual. The DSC was fully computer controlled with rapid energy compensation and equipped with automatic data analysis software to calculate heat capacity from the heat flow data. Linear and nonlinear regression models were fitted to experimental data.

RESULTS & DISCUSSION

Specific heat capacities of the oil samples were in the range from 1.27 to 6.24 J/g°C for temperatures from -10 to 80°C. Typical variations in specific heat capacities with respect to temperature are shown in Figure 1. Specific heat capacity of palm oil generally increased from -10°C to about 10°C followed by a sharp decrease to about 60°C and it subsequently remained fairly constant up to 80°C. Thus, more heat was required to raise the temperature of oil samples at the lower temperature range (-10 to 10°C) than at the higher temperature range (10 to 80°C). The increase can be attributed to phase change and expansion of the materials in the temperature range (Fasina and Colley, 2010). The peak specific heat capacity values for the different samples were significantly different (p ≤ 0.05). Crystallization temperatures of palm oils and some of its derivatives have been reported to fall in the temperature range of 0 to 8°C, although it may also vary between 0 – 35°C depending on composition and cooling rate (Mihara et al. 2007; Ng and Oh 1994). In the crystalline state, palm oil require more heat to break intermolecular forces for melting. This energy demand decreases with temperature, higher or lower than the crystallization point (Mihara et al, 2007). The value of specific heat capacity obtained for the different oils in the range from 60 to 80°C are within the range reported by others authors for vegetable oils (Santos et al, 2005).

Oils from different palm varieties presented different peak values of specific heat capacity. The specific heat capacity of Dura samples hit the highest peak compared to the other varieties. This indicates variation in composition of samples based on variety of oil palm. According to Tan and Cheman (2002) and Vuillequez et al (2010), crystallization of palm oil depend on the fractions of its constituents (Olein and Stearin) as well as the polymorph (α, β', β) of its triglycerides. Samples with more Stearin and β polymorph fractions are more stable and have higher crystallization temperature (Vuillequez et al, 2010). This implies therefore that sample from Dura variety are likely to have higher Stearin and β fractions. Also, Palm oil from Dura stock may have higher saturated fatty acids, making it more stable and accounting for the higher thermograms peaks. Tan and Cheman (2002) also reported that specific heat capacity are higher for larger molecules of triglycerides and decrease with the degree of unsaturation. This further explains variations in specific heat of the palm oil samples based on varieties.
Results of different processing methods revealed that for a given variety and storage history, the specific heat capacity of cold processed was lower (1.29–5.26 J/g°C) than the hot processed samples (1.80–6.24 J/g°C). Exception to this trend was observed in the stored samples of Dura stock. This shows that in general, less heat was required to raise the temperature of unit mass of cold processed palm oil samples. Similarly, specific heat capacity of stored samples tended to be higher that fresh samples of the same variety. Chemical changes occur in the oil during extraction. These changes influence the overall physical and chemical properties of the extracted oil. Normally, the degree of saturation of the fatty acids influences specific heat capacity values (Santos et al, 2005). Specific heat capacities tend to increase as a function of the unsaturation of fatty acids in the liquid and also in the solid state. Considering, thermal degradation that may have occurred during hot processing, it was expected that specific heat capacity would be higher for hot processed than cold processed oils. This appears contrary to the results obtained in this study. Eze et al (2010) observed that cold processed palm oils showed higher viscosity than hot processed palm oils. The mobility of oil and fat molecules in different states may have affected their values of specific heat capacity. Thus, the results suggest that hot processed palm oil may require more energy to heat than cold processed oil. Effect of storage history on the specific heat capacity of crude palm oil samples showed that the specific heat capacity of the fresh samples were generally higher (1.629–6.243 J/g°C) than the stored samples (1.966–5.400 J/g°C), except for the cold processed samples from Dura and Tenera stock. The result shows that in general, more heat will be required to raise the temperature of the fresh than the stored samples. This result was in agreement with earlier study reported by Eze at al (2010), which indicated that the fresh samples were more stable than the stored. This gives an indication that palm oil stored for a period of 12 months, as considered in this work, undergoes quality degradation resulting to lowering of its properties such as, specific heat. During storage, palm oil is likely to undergo oxidation and per-oxidation leading to the breaking down of longer chain fatty acids to shorter chains (Rodenbush et al, 1999, Geller and Goodrum 2000), and resulting to reduction in stability and specific heat.
CONCLUSION

The specific heat capacity of crude palm oil is affected by variety of oil palm, processing method and specific heat capacity. The specific heat of Dura samples was higher followed by Tenera while Pisifera had the lowest. Cold processed oil samples had higher specific heat than the hot processed. The specific heat of fresh samples was higher than stored samples.

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