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EFFECT OF MOISTURE CONTENT AND TEMPERATURE ON THE SPECIFIC HEAT OF YAM AND COCOYAM

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ABSTRACT

The specific heat capacity of any tuber crop is an important thermal property that significantly influences the analysis of processing and storage system as well as the determination of thermal rate processes. The specific heat of yarn and cocoyam was determined at various levels of moisture content and temperature using a 5 by 5 factorial design in CRD. For both crops, the specific heat increased with increase in moisture content and temperature but the incremental rate reduced at moisture content above 30%. A regression analysis performed on the generated data gave a functional relationship between the variable for yam and cocoyam.
KEYWORDS: Moisture content, Temperature, specific heat, Yam, Cocoyam

INTRODUCTION

The knowledge of thermal properties such as thermal conductivity and specific heat of food substance is essential to researcher and designers in food engineering. Information on specific heat is required in predicting the temperature of bulk food materials under storage. Such temperature values obtained could be used in the design of temperature control systems for limiting deterioration in stored food product (Mohsenin, 1980). In tobacco industry, information on specific heat is needed to relate the mass and energy exchange in bulks of tobacco to ambient conditions, leaf moisture contents, bulk density and heat transfer problems (Mohsenin, 1980). Knowledge of the specific heat is also needed in the bakeries for predicting the temperature of dough after mixing the flour with water since the best quality bread is known to be produced by dough that set at a temperature of 80°c to 82°c(Mohsenin, 1980). Despite their importance, not much work has been done on the thermal properties of many biological products. Tuber crops are among the biomaterials that have suffered such neglect. Yarn and cocoyam are tuber crops widely known in the tropics. Wright and Porterfield (1970) acknowledged the difficulty in measuring the specific heat of biological materials which is complicated by the effect of moisture contents, heat of sorption and desorption on the specific heat.

Previous investigators have determined to a limited extent the specific heat of some biological materials (Fasina and Colley (2008). Lal, etal (1978), Surter, etal (1975) and Rakesh and Hari (2016) determined the specific heat of cow milk and Spanish peanut while Ezeike (1989) determined the specific heat of some grain crops and yarn. The existing thermal properties do not have values for wide range of temperature and moisture content.

Hence the objective of this work is to determine the specific heat of yam and cocoyam at various temperature ranges and moisture content levels and establish a functional relationship between specific heat, temperature and moisture content.

MATERIAL AND METHODS

The materials used for the experiment are copper calorimeter, fresh yam (Dioscorea Rotundata) and cocoyam (xanthosomonascococasia). The calorimeter was made up of the outer vessel, the intermediate vessel and the inner calorimeter cup which served as the sample cell. The calorimeter had a refractive surface which prevented heat loss by radiation. The spaces between the outer and intermediate vessel; the inner and intermediate vessel were heavily lagged with cotton wool to prevent heat exchange between the system and the surrounding. The intermediate vessel which was also made of copper was raised to a temperature close to the temperature of the inner vessel and it's content to bridge the temperature differential between the surrounding and the system.

The weight of the test sample, the calorimeter cup (inner vessel) and water used in the sample cell were measured with an electronic balance sensitive to 0.0 1g. The moisture content of the samples was determined by gravimetric method at a temperature of 103°C for 72 hours in accordance with the ASAE standard (1984). In order to investigate the effect of moisture content on the specific heat of the test crops (cocoyam and yarn), the samples were first sliced into chips measuring 5mm by 5mm. Some of these samples were used immediately while a portion was allowed to dry in the natural air for 24 hours. The rest were conditioned in an oven at a mild temperature of 35°C to various moisture content values of 14%, 28%, 42%, 50.4% and 70.4% for yam and 16%, 17%,. 39.8%, 48.5% and 85% for cocoyam. The experimental procedure involved introducing a known quantity of hot water raised to desired temperature into the sample cell and placing the cell in calorimeter lagging. The lagging together with the sample cell was then placed in the intermediate vessel which had been raise to a temperature close to that of the sample cell and its content. The temperature of the hot water inside the sample cell was taken and recorded as T_1 after which the test sample was weighed and introduced into the sample cell. The system temperature then drooped and gradually rose towards the initial temperature of the calorimeter. The mixture was stirred and the temperature monitored until equilibrium was attained. The experiment was conducted with a 5 by 5 factorial design in CR1). The five temperature levels used in the experiment for both yam and cocoyamare77°c, 66°c, 57°c, 47°c, and 40°c while the five levels of moisture' content for both yam and cocoyam are as earlier indicated. The specific heat of the samples was calculated using the heat balance equation (Nelkon and Parker 1979) stated below.

Ms Cs (TeTc) (Mc Cc +Mw Cw) x
(Tc —Te)………… (1)

Where Ms= mass of the sample
Mc = Mass of calorimeter
Mw = mass of water in the sample cell
Cs = Specific heat of sample
Cs = Specific heat of calorimeter
Cw = specific heat of water
Te = Equilibrium temperature of the system
Ts = Initial temperature of sample
Tc = Initial temperature of the calorimeter

While the specific heat of the calorimeter cup was calculated using pure zinc pellets, the equation was used based on the following assumptions

1. The condition is assumed to be under a steady state heat transfer
2. The heat flow through the samples is anisotropic

RESULTS AND DISCUSSION

The specific heat of calorimeter cup was found to be 0.409Jg—1 °C' using the heat equation above. The specific heat capacity of pure zinc within temperature range in which the experiment was conducted is 0.389 Ig-^{1O}C$^{-1.}$A special data sheet for the experimentally measured parameter which yielded the specific heat values of yam is shown in Table 1' while the calculated Values for specific heat of yarn and cocoyam are shown in tables 2 and 3.

Regression analysis was performed to find the functional relationship between the specific heat (dependent variable), moisture content and temperature. A multiple regression model of the form

$Cs=a+b_1M+b_2T$ ……….. (2)

Where Cs = Specific heat capacity

M = Moisture Content

T =Temperature

a, b_1 b_2 = Constants

Was developed to explain the relationship between the variables. This model was found fit to the data for both yam and cocoyam. The results for the materials tested are as indicated in table4.

Analysis of variance performed to determine the levels of significance of the independent variables on the specific heat of yam and cocoyam at 5% probability levels are as shown in the appendix.

The variation of specific heat with moisture content at various system temperature values indicates that the specific heat increases considerably with increase in moisture contentfor both yarn and cocoyam. This trend as explained by Ezeike (1989) may be due to the fact that water absorbs heat quite readily and at high moisture content, the proportion of water compared with dry matter in the material is considerably high. It can also be seen from the figures that at each moisture content level, the specific heat is higher at a higher temperature. There was however a slight deviation from the trend for yarn at about 60% moisture content (wet basis) where the specific heat was, higher at 66°C than 72°c. It can also be observed from the slope that the rate of increase of the specific heat with moisture content reduced above 3O% (w.b) for both crops. Kazarian and Hall (1965).Lal et al. (1978), Mohesenin (1980) and Ezeike (1989) observed a similar trend in the curvature of the curves for grain crops, Cow milk, potato and melons respectively. The reasons for this trend may be associated with the observations made by Ezeike (1989) that moisture content in the neighbourhood of 65 to 70% is associated with free unbound moisture in yarn tuber. In addition, at elevated temperatures, the thermal properties of the tissue 'constituents (protein. carbohydrate, fats etc) may be affected and work by Mohsenin (1980) indicates that specific heat can be expressed in terms of weight fractions of the chemical component. Protein being hydrophilic colloids can be denatured at elevated temperature while starch is generally insoluble in cold water but can go into solution at high temperatures.

CONCLUSION

The results presented in this paper have demonstrated a relationship between moisture content, temperature and specific heat for yarn and cocoyam. The developed model can therefore be successfully used in predicting the specific heat of both crops at any given temperature and moisture content within the range covered by experiment.

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Table 1: Special data sheet for the experimentally measured parameter which yielded the specific heat values for yam

M.c, (%)	W_S(g)	W_w (g)	T_{cn} (^{0}C)	T_s (^{0}C)	T_{c1} (^{0}C)	T_{e2} (^{0}C)	T_{e3}	Te_m (^{0}C)	C(jg$^{-1 0}$C
70.4	30	50	72	25	59	58.5	58	58	3.10
70.4	30	50	60	25	54	53.5	34.5	54	3.18
70.4	30	50	57	25	47.8	47.1	47.8	87.8	3.18
70.4	30	50	47	25	41.3	41.2	40.5	41	2.88
70.4	30	50	40	25	36.0	36.5	35.5	36	2.77

M.C Moisture Content (%)
Ws Weight of Sample (Yam)
Ww = Weight of Heated water
Tc Equilibrium temperature of thesystem
Cw = Initial temperature of calorimeter and hot water (°C)
Ts = Initial temperature of sample (°C)

Table 2: Summary Table for Specific Heat of Cocoyam

Moisture Content	Temperature (^{0}C)				
%	72	66	57	47	40
85	3.49	3.37	3.24	3.15	2.99
47.5	3.14	3.02	2.65	2.61	2.49
39.8	3.06	2.80	2.50	2.58	2.28
17.8	2.16	2.11	1.81	1.62	1.42
16.0	2.08	2.04	1.73	1.54	1.38

Table 3: Summary Table for Specific Heat of Yam

Moisture	Temperature (^{0}C)				
Content %	72	66	57	47	40
70.4	3.10	3.18	3.10	2.88	2.77
50.4	2.92	2.83	2.77	2.51	2.47
42	2.83	2.74	3.40	2.40	2.30
28	2.55	2.46	2.26	2.09	1.98
14	1.93	1.78	1.58	1.50	1.37

Table 4.Regression Coefficients For yam and Cocoyam

Material	Regression Coefficients		Standard Error		
	A	B_1	B_2	R^2	
Yam	0.616	0.0235	0.0158	0.826	0.239
Coco-yam	0.397	0.188	0.2044	0.912	0.199

*** * * * MULTIPLE REGRESSION * * * ***

	Cocoyam
Multiple R	.95495
R Square.	.91193
Adjusted R	.90393
Standard Error	.19870

ANALYSIS OF VARIANCE

	DF	Sum of Squares	Mean Square
Regression	2	.8.99447	4.49724
Residual	22	0.86862	0.3948

F = 113.90353 Signif F = .000

------------------------------Variable in the Equation---------------------------

Variable	B	SE B	Beta		T Sig	T
Xl	0.21879	.0.001583	0.874351	13.819	0.0000	
X2	0.020436	0.003375	0.383094	6.055	0.0000	
(Constant)	0.396645	0.205042		1.934	0.0660	

Multiple R	Yam
R Square	0.90911
Adjust R Square	0.82648
Standard Error	0.81070
	0.23895

ANALYSIS OF VARIANCE

	DF	Sum of Square	Mean Square
Regression	2	5.98291	2.99145
Residual	22	1.25616	0.05710

F = 52.39150 Siginf F = 0.0000

-----------------------Variables in the Equation-----------------------

Variable	B	SEB	Beta	T Sig	T
Xl	0.023521	0.002483	0.841168	9.471	0.0000
X2	0.015759	0.004059	0.344836	3.883.	0.0008
(Constant)	0.616559	0.255016		2.418	0.0243