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Influence of fruitfly (*Bactrocera dorsalis*) infestation on thermal properties of mango fruits

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Abstract
Mango (*Mangifera Indica*) is a major fruit crop of India grown in an area of 22 Lakh ha with a production of 18.64 million tonnes in 2015-16. Although, the demand for processed mango products is continuously increasing, the existing mango processing industries which cater to the demand of these prospective markets are facing many problems and one among them is the pest attack in mango fruits. Mango fruitfly (*B. dorsalis*) is one of the major pest which causes huge economic loss in mango varieties such as Banganpalli, Alphonso and Totapuri. The engineering properties of foods invariably determine the quality of food products in terms of visual characteristics and basic functionality. One of the engineering properties of food materials which attribute the internal quality of food material is thermal properties. Therefore, specific heat and thermal conductivity of healthy and fruitfly infested Alphonso and Totapuri mango fruits were determined using the standard procedure. It was observed that specific heat and thermal conductivity of healthy mango fruit was lower compared to fruitfly infested mango fruits for both the varieties possibly due to the presence of fruitfly maggots within the infested fruits which enhanced the heating process.

Keywords: mango fruits, fruitfly, specific heat, thermal conductivity, thermal diffusivity

1. Introduction

Mango (*Mangifera Indica*) is a major fruit crop of India grown in an area of 22 lakh ha with a production of 18.64 million tonnes in 2015-16 and India is a front-runner in production of fresh mango with the share of 40% global production [1]. Mango fruits are consumed as both fresh as well as in processed form. Although, the demand for the export of processed mangoes is increasing continuously, the level of processing of mango fruits is only around 1% of the total mango production [11]. The various processed products of mango fruits are canned pulp, slices, jam, juices, RTS beverages, mango leather etc. There are hundreds of mango varieties native to India but Alphonso and Totapuri varieties are some of the prominent varieties which are commercially processed. Although, the demand for processed mango products is continuously increasing, the existing mango processing industries which meet the demand of these markets are facing many problems and one among them is the pest attack in mango fruits. Mango fruitfly (*B. dorsalis*) is one of the major pest which causes huge economic loss in mango varieties such as Banganpalli, Alphonso and Totapuri and the levels of fruitfly infestation in mango fruits vary from 5-80% [10].

The engineering properties of foods invariably determine the quality of food products in terms of visual characteristics and basic functionality. One of the engineering properties of food materials which attribute the internal quality of food material is its thermal properties. The specific heat and thermal conductivity are some of the thermal properties which are influenced by the composition, structure and processing conditions of food materials. Thermal conductivity of water, air, protein, carbohydrate and fat are 0.60, 0.026, 0.18, 0.20 and 0.13 W/mK, respectively at 20°C. The structural factors affecting thermal conductivity are porosity, pore size, shape and distribution of different phases, such as air, liquid, ice, and insoluble solids [5-9]. Many studies have been conducted over the years to evaluate the thermal properties of mango fruit pulp but meagre information is available on the comparative study of thermal properties of healthy and fruitfly infested mango fruits. Therefore, the present study was undertaken to investigate the influence of fruitfly infestation on thermal properties of healthy and fruitfly infested mango fruits.

2. Materials and Methods

The matured mango fruits of Alphonso and Totapuri varieties without any visible infections were collected in the early morning from the research farm of UAHS, Shivamogga, Karnataka, India. The harvested fruits were artificially ripened before conducting the experiments. The ripe mango fruits of Alphonso and Totapuri varieties were further artificially infested for fruitfly under laboratory conditions.

2.1 Thermal properties of mango fruits

The thermal properties such as specific heat and thermal conductivity were determined for healthy and fruitfly infested Alphonso and Totapuri mango fruits as per the procedure discussed hereunder.

2.1.1 Specific Heat

The Specific heat is defined as the amount of heat required to raise the temperature of any material by one degree centigrade and expressed in kJ/kg°C. The measurement of specific heat (C_p) was based on the method of mixtures [4]. This method involved heating a known volume of water in a beaker and immersing the test sample at a lower temperature. The specific heat of sample was then computed from a heat balance equation between the heat lost by the water and calorimeter and that gained by the sample and capsule. The following equation was used to determine specific heat 'C_p' (J/kg°C) of infested and healthy mango fruits.

$$C_s = \frac{CwW_w\,(T_{wi}-T_{wc}-T_R)+CwW_c(T_{ci}-T_{wc}-T_R)-C_{cap}\,W_{cap}\,(T_{ws}-T_{capi}+T_R)}{W_s(T_{ws}-T_{si}+T_R)} \quad \ldots\ldots\ldots 1$$

Where,
C_s = specific heat of sample, kJ/kg °C
C_w = specific heat of water, kJ/kg°C
W_w = weight of water, kg
T_{wi} = initial temperature of water, °C
T_{wc} = equilibrium water temperature, °C
T_R = heat gain or loss factor and can be calculated as $[(T_2-T_1)/(t_2-t_1)]t_1$, °C
C_c = specific heat of calorimeter (copper container), kJ/kg °C
W_c = weight of calorimeter, kg
T_{ci} = initial temperature of calorimeter, °C
C_{cap} = specific heat of capsule, kJ/kg °C
W_{cap} = weight of capsule, kg
T_{ws} = equilibrium temperature of sample, °C
T_{capi} = initial temperature of capsule, °C
W_s = weight of sample, kg
T_{si} = initial temperature of sample, °C

2.1.2 Thermal conductivity Measurement

The thermal conductivity of mango fruits was determined by line heat source method [8]. Whole fruit was used for thermal conductivity measurement in an insulated cylinder. A calibrated heating wire made of Constantan with an outer diameter of 0.3 cm and a length of 8 cm was used as a heating probe. The ambient temperature of the sample was observed and when the sample reached a uniform ambient temperature, power was supplied to the probe. Temperature rise was measured using K-type thermocouple. The following equation was used to determine thermal conductivity (W/m°C) of infested and healthy mango fruits.

$$k = \frac{Q}{4\pi(T_2-T_1)} * \ln\frac{t_2}{t_1} \quad \ldots\ldots\ldots\ldots 2$$

Where,
Q' is heat produced per unit length of probe (W/m)
t_1 and t_2 are the initial and final times (s)
T_1 and T_2 are the initial and final temperatures (°C).

2.2 Statistical Analysis

The statistical analysis was performed for ANOVA in Systat.

3. Results and Discussion

The results of the thermal properties of healthy and fruitfly infested mango fruits is given in Table 1 and Table 2 respectively.

3.1 Specific heat of healthy and fruitfly infested mango fruits

It was observed from the Table 1 and Table 2 that the specific heat of healthy Alphonso mango fruit was 3.62 kJ/kg °C and infested Alphonso fruit was 4.25 kJ/kg °C. Also, the specific heat of healthy Totapuri variety was 3.87 kJ/kg °C and infested Totapuri variety was 4.57kJ/kg °C. The specific heat of healthy Alphonso and Totapuri mango fruit was lower compared to fruitfly infested Alphonso and Totapuri mango fruits respectively. The specific heat of healthy samples was lower than infested mangoes possibly due to the presence of the fruitfly maggots within the infested fruits which conducted more heat to raise the temperature of infested fruits. Statistical analysis showed a significant difference ($P < 0.05$) in specific heat between fruitfly infested mango fruits and healthy mango fruits for both the varieties.

3.2 Thermal conductivity of healthy and fruitfly infested mango fruits

It was observed from the Table 1 and Table 2 that thermal conductivity of healthy Alphonso mango fruit was 0.103 W/m °C and infested Alphonso mango fruit was 0.1828 W/m °C. Also, the thermal conductivity of healthy Totapuri variety was 0.1142 W/m°C and infested Totapuri variety was 0.2034 W/m°C. Thermal conductivity of healthy mango fruits was found lower than infested mango fruits for both the varieties even though the difference in moisture content between the healthy and infested fruits was negligible. The difference in thermal conductivity between healthy and fruitfly infested mango fruits was due to differential heating of the healthy and fruitfly infested mango fruits. The statistical analysis showed a significant difference ($P < 0.05$) in thermal conductivity between infested and healthy mangoes for both the varieties.

Table 1: Thermo-chemical properties of healthy mango fruits

Variety	Moisture content (%, wb)		Specific heat (kJ/kg°C)		Thermal Conductivity (W/m°C)	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Alphonso	47.10	0.73	3.62	0.02	0.103	0.002
Totapuri	43.00	1.581	3.87	0.03	0.1142	0.0031

Table 2: Thermo-chemical properties of fruitfly infested mango fruits

Variety	Moisture content (%, wb)		Specific heat (kJ/kg°C)		Thermal Conductivity (W/m°C)	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Alphonso	48.20	0.580	4.25	0.06	0.1828	0.0037
Totapuri	44.30	1.369	4.57	0.05	0.2034	0.0020

4. Conclusion

Mango is a major horticultural crop in India. The external and internal quality of mango fruit is determined based on its engineering properties. The thermal properties of mango fruits such as specific heat and thermal conductivity define the internal quality of mango fruits for pest attack. It was observed from this study that there existed a statistically significant difference ($P < 0.05$) between the thermal properties of fruitfly infested mango fruits and healthy mango fruits. The specific heat and thermal conductivity of healthy mango fruit was lower compared to fruitfly infested mango fruits for both the varieties possibly due to the presence of fruitfly maggots and higher moisture in fruitfly infested mango fruits. The differences in thermal properties of healthy and fruitfly infested mango fruits can be exploited in the sorting of infested mango fruits during the mango processing operations.

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