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Thermo-physical properties of avocado from Southeast Asia

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The article studies the effect of temperature on the thermo-physical properties (TPP) of avocado form Southeast Asia. The specific heat of food plays an important role in the design of storage and transport systems. A large number of methods are known that are used to determine the TPP of food products. The article concerns the most popular one — DSC 204 F1. Specific heat of avocado was determined by the DSC method under refrigerating conditions and in the temperature range of from –25 to 25 ºC. The DSC method for determining the specific heat capacity of food products included four stages: such as setting the temperature program, correction, calibration, and measurement. As a result, it was shown that the specific heat of the avocado depends on temperature. The results of the research are of immediate use in designing refrigerating and storage systems in food industry.

Keywords: thermo-physical properties, avocado, Southeast Asia, differential scanning calorimetry, temperature.

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Исследование теплофизических характеристик авокадо Юго-Восточной Азии

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Проведено исследование теплофизических характеристик авокадо, в зависимости от температуры. Удельная теплоемкость пищевых продуктов играет важную роль при проектировании систем хранения и транспортировки. Известно большое количество методов, которые используются для определения ТФХ пищевых продуктов. Наиболее распространенным является метод ДСК. В работе применен метод ДСК (DSC 204 F1), с помощью которого определялась зависимость удельной теплоемкости авокадо в условиях замораживания и размораживания, в диапазоне температур от –25 до 25 ºC. Метод ДСК для определения удельной теплоемкости пищевых продуктов включал четыре этапа: задание температурной программы, коррекция, калибровка и измерение. В результате исследования показано, что удельная теплоемкость авокадо зависит от температуры. Полученные результаты могут быть непосредственно использованы при проектировании систем хранения и охлаждения пищевых продуктов в пищевой промышленности.

Ключевые слова: теплофизические характеристики, авокадо, Юго-Восточная Азия, дифференциальный сканирующий калориметр, температура.

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Introduction

Avocado is considered to be a unique tropical fruit due to the content of fat-soluble vitamins, which are not so abundant in other fruits, as well as due to the high content of protein, potassium, and unsaturated fatty acids [1]. Avocado has high nutritional value and is of great use for human body growth and development [2, 3]. In Myanmar avocado is considered to be the main fruit being harvested from August till December. It is widely used not only for food, but also in medicine and cosmetology [1, 2, 5].

Export of tropical fruits is limited due to such factors as product shelf life and some difficulties in preserving the quality of the product in tropic climate and with poorly developed after-harvesting technologies in Southeast Asia [4]. A newer technology of after-harvesting avocado handling should then be implemented to enlarge export and increasing storage time for fresh fruits. However, due to its season character the storage systems of out-of-season availability are necessary, allowing to decrease production losses. Most fruits and vegetables stay «live» after harvesting; their biological processes are going on. The processes can be controlled by low temperature storage to a certain extent. For tropic fruits the storage time is greatly dependent on their properties, environmental conditions, after-harvesting handling, and microbial contamination.

Therefore, one should pay much attention to the thermo-physical properties (TPP) of food, namely heat conductivity, thermal conductivity, and specific heat capacity [6, 7]. Specific heat capacity of food is of great importance in designing storage systems and also is one of the main technological parameters of food, used when dealing with the issues of heat equilibrium and heat exchange. TPP data are necessary in calculating heat-and-mass-transfer equipment and developing storage technologies. The data on specific heat capacity of food can be taken form reference literature, as well as by experimental and analytic methods. Thermo-physical properties of food can be measured by a number of methods such as the method of mixtures, the method of steady regime, and differential scanning calorimetry [7, 8, 9].

In this regard the aim of the research is to determine the heat capacity of avocado by differential scanning calorimeter (DSC). DSC method is based on the measurement of the heat flow difference between sample and reference [10, 11]. Differential scanning calorimeter representing heat flow as a function of temperature is an adequate tool for measuring temperature-dependent specific heat and phase transfers [9]. The method is widely used in the research in various branches of science both in Russia and all over the world to determine TPP of different materials. The advantage of DSC method is that only a small amount of sample under investigation is necessary, which minimizes thermal lag in a system [9, 12,]. A number of researches used differential scanning calorimetry to determine specific heat capacity of such kinds of food as borage seeds (Yang et al, 2002) [13], papaya (Rosario et al, 2010) [14], edible-wild mushrooms (Soraya et al, 2017) [15], and refined sunflower oil (Fedorov et al, 2019) [16]. DSC is the most accurate and quick method of determining specific heat capacity among the available techniques. The measurement error is within 3% [17, 18].

Taking everything into consideration, the aim of the paper is to investigate the dependency of specific heat capacity of avocado (of Southeast Asia origin) on the temperature by differential scanning calorimetry with the use of DSC 204 F1 (Phoenix by NETZSCH).

Methods

Currently a great number of methods for measuring specific heat capacity of the materials are available. The main methods are DSC method and the method of steady regime, DSC being the most frequent used in thermal analysis. Its main advantages are quick analysis, high relevance for the tasks of quality research and control, and the simplicity of measuring device, which is sure to contribute to its universal character. The values being measured are absolute temperature of the sample and temperature difference between sample and reference proportional to the difference of heat flow between them [11].

The measurement was carried out by DSC method according to the following equation [16, 19]:

$$\frac{DSC_{sample} - DSC_{base}}{DSC_{ref} - DSC_{base}} = \frac{c_{P,\,sample} \cdot m_{sample}}{c_{P,ref} \cdot m_{ref}} \tag{1}$$

$$c_P = \frac{DSC_{sample} - DSC_{base}}{DSC_{ref} - DSC_{base}} \cdot \frac{m_{ref}}{m_{sample}} c_{P,ref} \tag{2}$$

The operating temperature range of DSC 204 F1 is from – 180 to 700 °C, its heating/ cooling rate is from 0.001 to 200 K/min, sensitivity: τ-sensor — 3.2 mkV/mW and μ-sensor — 70 mkV/mW. The instrument response time is: for τ-sensor — < 0.6 sec and for μ-sensor — < 3 sec [16, 20].

The experiment was carried out according the following procedure described by DSC method for determining specific heat capacity. To determine specific heat capacity all three measurements should be made with the same crucible and under the same conditions [21]. There were for stages in determining specific heat capacity of avocado samples:

- Setting temperature program;
- Correcting;
- Calibrating;
- Measuring.

In setting temperature program the measurement of specific heat capacity were made in the temperature range of from –25 to 25 ºC at heating/cooling rate of 2 K/min and with gaseous nitrogen with flow rate of 20 ml/min and 50 ml/min. In the method the initial thermal scanning was made with an empty crucible to obtain a base line (correcting). Than a sapphire of 50.1 mg was used as a calibration reference and thermal scanning was carried out again. During the last measurements the sample was weighted and placed back into the crucible in calorimeter and the same scanning was repeated.

During the experiment avocado samples (Myanmar origin) were placed in a specialized aluminum crucible (Netzsch NGB810419) with aluminum lid (Netzsch NGB810420). The weight of samples were measured by AND HR-200 analytical weighing apparatus of the first accuracy class. Crucible mass was 38 mg, lid mass — 25 mg. From 26 to 31 mg of the samples were used in the experiments. Sample weight was measured with an accuracy of ±0.1 mg. Every experiment was repeated three times.

Results and Discussion

The results of investigation of avocado specific heat capacity in the temperature range of from –24 to 18 ºC are

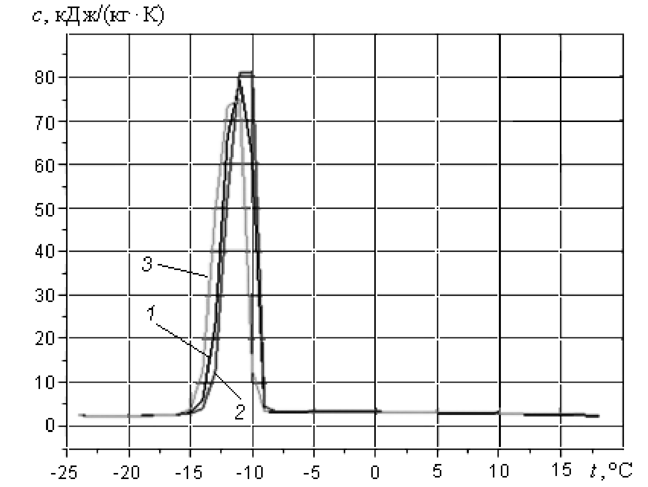

Рис. 1. Температурная зависимость удельной теплоемкости авокадо для каждого образца

Fig. 1. Temperature dependence of avocado specific heat capacity for each sample

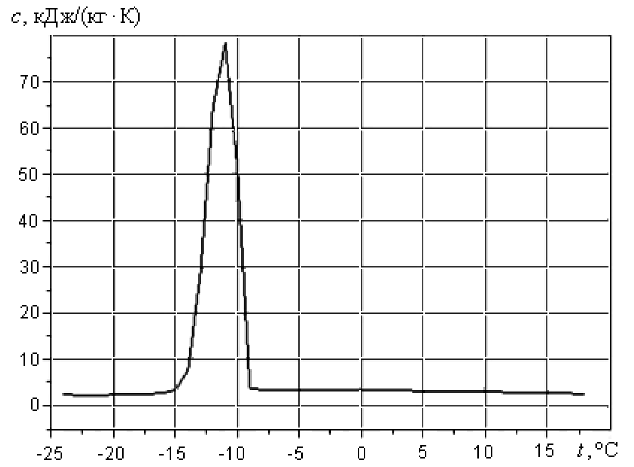

Рис. 2. Температурная зависимость средней арифметической удельной теплоемкости авокадо

Fig. 2. Temperature dependence of the arithmetic mean for specific heat capacity of avocado

shown in Fig. 1. As it can be seen from the figure, in the temperature dependencies for all avocado samples under conditions of freezing and defrosting specific heat capacity increased with the temperature increase of from –24 to –15 ºC, increased sharply with the temperature increase of from –15 to –13 ºC, then decreased sharply with the temperature increase of from –13 to –8 ºC, and slightly decreased with the temperature increase of from –10 to –8 ºC, respectively.

Temperature dependency for the arithmetic mean of specific heat capacity for all avocado samples is shown is Fig. 2. The data from [22, 23] show that in the range of в positive temperature avocado specific heat capacity is 3.67 kJ/(kg·K) and 3.02 kJ/ (kg·K). According to the experimental data average avocado specific heat capacity at the temperature of 5 ºC is 3.147 kJ/ (kg·K).

There were several scientific reports on experiments concerning determining specific heat capacity of food and crop materials. However, the data depend on the origin (variety), composition, processing conditions, and the structure of food. According to [9, 24, 25] specific heat capacity of food depend on its composition, structure, and temperature. Avocado specific heat capacity was discovered to depend on temperature. Specific heat capacity of unfrozen product is slightly decreased with the temperature increase of 0 to 20 °C [22]. As a result is has been demonstrated that avocado specific heat capacity decreased with the temperature increase of from 0 to 18 °C.

Conclusion

In the article the dependence of specific heat capacity of avocado from Southeast Asia on the temperature have been investigated by DSC method (DSC 204 F1). The results have demonstrated that the thermo-physical characteristics of avocado depend on the temperature, the origin, and the composition of raw materials and are of immediate use in designing food storage and refrigerating systems in food industry, engineering calculations for engineering constructions and in other fields of application.

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