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PHYSICAL AND THERMO-PHYSICAL PROPERTIES OF VEGETABLES DEPENDING ON THE VARIETY AND LEVEL OF RIPENESS

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The results of the study of physical and thermal indexes of vegetables of different degrees of ripeness and variety are given.

Eggplants, sweet peppers and tomatoes take an important place among vegetables. The fruit of these crops are rich in biologically active substances; they have good taste and medicinal properties. However, population of our country cannot afford themselves to consume fresh vegetables for the whole year. One solution to the problem is the storage and canning of vegetables [1, 2].

Physical properties of vegetables affect their nutritional value, the ability to transportation and storage.

Bulk mass is the weight of vegetables in the volume of 1 m^3 in the conditions of free packing including cavities between different instances of the fruit. This figure is used to calculate the capacity of containers, store houses, selection of conditions of carriage and packing of fruit in storage, estimated weight of products stored by a bulk method in bins, clamps, trenches, mounds [3, 4].

Cracks between fruit are filled with the air, make substantial bulk weight and affect the physiological processes of production significantly. Existing air moves through cracks, promotes the heat transfer by convection and the moisture transfer as steam into the environment.

Heat capacity characterizes the intensity of the temperature changes of vegetables during their cooling and heating. Specific heat is a value that indicates the amount of heat required to heat a unit of mass (kg) of vegetables per 1 ° C and depends on the content of water, organic minerals, structure and properties of tissues [3].

Thermal conductivity coefficient is the amount of heat that passes during a unit of time (c) in 1 m^2 surface of fruit and vegetables for the thickness of 1 m at the temperature difference of 1°C. Absolute coefficient of thermal conductivity of vegetables depends on the contents of their moisture, temperature, structure of tissues, porosity [3, 5].

Heat capacity is an indicator that characterizes the rate of heating or cooling of fruit. The higher the heat capacity coefficient is, the faster vegetables heat or cool down [3–6].

The purpose of the research is to establish the physical and thermal properties of vegetables depending on the particular species, variety, and degree of ripeness for later use during transportation, storage and processing.

Methodology of the research. The research was conducted during 2007–2009 in the laboratory of Department of technology of grain storage and processing at Uman National University of Horticulture. We defined the physical and thermal characteristics: bulk weight – by weighing [3]; porosity, relative (physical) and the true density, specific heat, thermal conductivity, heat capacity of fruit – by calculations of L.M. Puzik [3] and S.S. Proshkin [6].

Technically ripe fruit of eggplants of varieties Almaz and Helios, tomatoes of the variety Iskorka in consumer ripeness and sweet peppers of the variety Novohohoshary in technical and biological ripeness were used in the research. [7]

Statistical processing of data was carried out by the method described by V.O. Eshchenko and others [8].

Results of the research. Ripeness of fruits is characterized by organoleptic, internal anatomical and chemical parameters according to existing standards [9]. However, these indicators are subjective, because the fruits of different varieties have their own characteristics.

Indicators of density, porosity, bulk density, pore content and thermal properties of the fruits of eggplants of the variety Almaz and Helios, sweet peppers of the variety Novogogoshary, tomatoes of the variety Iskorka are given in tables 1–3.

Researches established varietal characteristics according to the parameters (table 1).

1. Physical and thermal properties of different varieties of eggplant fruits (average for 2007-2009)

Index	Almaz	Helios	HIP_{05}
Physical density, kg/m^3	1310,0	1130,0	*61,0*
True density, kg/ m^3	1034,9	1033,7	*51,7*
Bulk density, kg/ m^3	630,0	600,0	*29,6*
Porosity, %	52,0	47,0	*2,7*
Heat capacity, KJ/(kg•K)	3,9	3,9	*0,2*
Thermal conductivity, W/(m•K)	0,6	0,8	*0,04*
Temperature capacity, 10^8 m^2/s	11,7	18,1	*0,8*

According to the data, the bulk weight of eggplant fruit of the variety Almaz is 630,0 kg/m^3, which is for 5% more than in fruit of the variety Helios. Porosity describes the density of packing of fruit while loading the bulk. Porosity of eggplant fruit of the variety Almaz is 52% and is bigger than in the variety Helios for 5%. Obviously, higher rates of the variety by density affected the advantage of the physical parameters of fruit of eggplants of the variety Almaz. Thus, the physical and the true density of eggplant of the variety Helios was 1130,0 and 1033,7 kg/m^3, which was respectively 180 and 1,2 kg/m^3 less than the fruit of the variety Almaz.

The speed of cooling or heating depends on the thermal properties of vegetables. Characteristics of thermal properties of vegetables are used to calculate necessary amount of heat for cooling products during fruit transportation and storage.

Characteristics of the variety of eggplant for its thermal parameters were identified during the research. Thus, the thermal conductivity of the variety of eggplant Almaz is less than for the variety Helios for 25%, heat capacity – for 35% and is 0,8 W/(m•K) and 18,1 • 10^8 m^2/s. Instead, the heat of eggplants fruit regardless of the variety is 3,9 kJ/(kg•K).

Variation-statistical processing of the data in table 1 shows that the features of the variety of eggplants had a significant impact on the physical density, porosity, thermal conductivity and heat capacity of fruit.

Fruit development lasts from the formation of ovaries before the end of the growth. This stage is characterized by the synthesis and accumulation of nutrients and undergoing intensive metabolic processes. Cells become larger in size with ripening of fruit, density of fitting them to each other weakens, intercellular gaps widen, which leads to the change in the consistency of the pulp, causing decreasing of its physical density and increasing of porosity and juiciness. The physical density of the fetus depends on the fruit anatomical structure, thickness and peel.

2. Physical and thermal properties of sweet pepper of the variety Novogogoshary (average for 2007-2009)

Index	Level of ripeness		HIP_{05}
	technical	biological	
Physical density, kg/m^3	1030,0	970,0	*49,2*
True density, kg/ m^3	1030,5	1034,1	*52,0*
Bulk density, kg/ m^3	440,0	400,0	*21,0*
Interparticle, %	57,0	59,0	*2,9*
Porosity, %	0,05	6,2	*1,5*
Heat capacity, KJ/(kg•K)	4,0	3,9	*0,2*
Thermal conductivity, W/(m•K)	0,5	0,4	*0,02*
Temperature capacity, 10^8 m^2/s	12,1	10,6	*0,6*

All these parameters significantly affect the quality of the products (table 2). Thus, the physical density of the technically ripe sweet pepper is 1030,0 kg/m³, which is almost 6% more than in biologically ripe fruit. With decreasing of physical densities during fruit ripening, an increase in their porosity from 0,05% (technical level of ripeness) to 6,2% (biological level of ripeness) was observed.

The value of volume (bulk) mass depends on the density, size, and shape of products. According to the data, the bulk density of pepper fruits decreases from 440,0 kg/m^3 in a technically mature fruit to 400,0 kg/m^3 in biologically ripe fruit, that is 9%. For larger values of mass density air, the volume between species of smaller fruits (interparticle) and bulk density are higher, and vice versa.

The value of interparticle depends on the same factors as the size of bulk weight. Thus, the interparticle of pepper fruit, with the change in the degree of ripeness (technical and biological) increases from 57 to 59%, which is more than three percent.

The true density depends on the content of dry matter in vegetables, water and air in the tissues. The more moisture in the fruit, the less their true density is. This physical parameter of the biologically ripe sweet pepper is 1034,1 kg/m³, more than technically ripe fruit that is only 3,6 kg/m³.

Sweet pepper of the variety Novogogoshary of the technical degree of ripeness has excellent thermal performance compared to fetus that is biologically ripe. Thus, heat content of technically ripe peppers is higher for 2,5%, the thermal conductivity – for 20%, heat capacity – for 12,4% of the biologically ripe and are respectively 4,0 kJ/(kg•K), 0,5 W/(m•K) and 12,1•10^8 m^2/s.

Variation-statistical analysis shows that the ripeness degree of sweet pepper of the variety Novogogoshary had a significant impact on physical density, porosity, volumetric mass, thermal conductivity and heat capacity of fruits.

The physical and thermal characteristics of different years of tomato yield are presented in table 3.

3. Physical and thermal properties of tomato growing of the variety Iskorka

Index	Year			HIP_{05}	Average
	2007	2008	2009		
Physical density, kg/m^3	890,0	880,0	880,0	*44,0*	883,3
True density, kg/ m^3	1029,7	1028,1	1028,5	*51,2*	1028,8
Bulk density, kg/ m^3	660,0	650,0	650,0	*32,7*	653,3
Interparticle, %	26,0	26,0	26,0	*1,3*	26,0
Porosity, %	13,6	14,1	14,4	*0,7*	14,0
Heat capacity, KJ/(kg•K)	4,0	4,0	4,0	*0,2*	4,0
Thermal conductivity, W/(m•K)	0,4	0,4	0,4	*0,02*	0,4
Temperature capacity, 10^8 m^2/s	11,2	11,4	11,4	*0,5*	11,3

We found that the tomatoes of the variety Iskorka had an average physical density of fruit – 883,3 kg/m^3, the true density – 1028,8 kg/m^3, porosity – 14,0%, interparticle – 26,0%, volume weight – 653,3 kh/m^3, heat capacity – 4,0 kJ/(kg•K), thermal conductivity – 0,4 W/(m•K) and temperature capacity – 11,3•10^8 m^2/s. Larger values of physical and true density were observed in fruits of tomatoes in 2007, however, fruit of that year of growing were inferior in terms of porosity and diffusivity.

Variation-statistical analysis of data of the table 3 showed that the characteristics of the weather conditions of tomato growing of the variety Iskorka had no effect on their physical characteristics.

Conclusion. Physical and thermal indexes determine the suitability of vegetables to preserving and canning.

The ripeness degree of sweet pepper determines their physical parameters including density (R) and porosity (P). Physical density of the technically ripe sweet pepper is almost 6% higher than of the bio-ripe fruit. With decreasing of the physical density during fruit ripening, an increase in their porosity from 0,05% (technical ripeness) to 6,2% (biological ripeness) was observed. Thus, the higher the ripeness degree of sweet pepper was, the higher porosity was, and the more gas was formed inside the tissue, which was reflected in their physical density. With increasing of porosity the tissue breathability increases and physical density reduces.

Bulk weight of vegetables depends on the type and size of the fruit. Variety of eggplant of a round shape (Almaz) is characterized by higher bulk weight and interparticle, which is almost 5% more than in the fruit variety Helios.

Thermal properties of fruits of eggplant, sweet pepper and tomato largely determine the outcome storage. The thermal conductivity of the variety of eggplant Almaz is smaller than the variety Helios for 25%, heat capacity – for 35%. Heat capacity of technically ripe peppers is higher for 2,5%, the thermal conductivity – for 20%, temperature capacity – for 12,4% of the biologically mature fruit. Fruits of tomatoes of the variety Iskorka had an average heat capacity – 4,0 kJ/(kg•K), thermal conductivity – 0,4 W/(m•K) and temperature capacity – 11,3•108 m^2/s.

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