Tabela 11. Interna stopa rentabilnosti (U €)

<table>
<thead>
<tr>
<th>Redni broj</th>
<th>Diskonta stopa %</th>
<th>Neto sadašnja vrednost projekta</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>10</td>
<td>55.543</td>
</tr>
<tr>
<td>2.</td>
<td>20</td>
<td>-128.694</td>
</tr>
</tbody>
</table>

Interni stopa rentabilnosti projekta iznosi 13,01 %, što je više od akutnih kamatnih stopa.

**ZAKLJUČNA RAZMATRANJA**

Istraživanja u ovom radu predstavljaju su na konkretnoj studiji sljedeća analizu ocene investicije u izgradnju, odnosno proširenje kapaciteta silosa. Najveći problem pri oceni investicije u silos, ako se radi za sopstvene potrebe, jest planiranje prihoda od njegove ekспloatacije. Osnovni ekonomski efekat, prihod od investicije u silos leži u mogućnosti odložene proizvodnje koji se skladišti. Na toj razini u prodajnim cenama proizvoda, nalaze se najveći ekonomski efekti od njegove izgradnje. Ukoliko se radi o proširenju silosa u cilju eliminacije uskih grla, čekanja na prijem privremenog skladištenja, dodatni efekti proširenja silosa sadržani su u uštedama rada i manipulacije proizvodima na nezajednim susjedima i skladištem.

U konkretnom slučaju investicija u proširenje silosa je ekonomski opravdana. Uložena sredstva u investiciju vrat će se u petom mesecu pete godine. Neto sadašnja vrednost investicije (pri diskontnoj stopi od 5 % za devizna sredstva – evra) iznosi 186.667 eura. Interna stopa rentabilnosti investicije je 13,01 %, što je više od akutnih kamatnih stopa na devizna sredstva, što ukazuje na isplativost projekta.

**LITERATURA**


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Original scientific paper

**TERMOFIZIČKE OSOBINE JABUKE**

**THERMOPHYSICAL PARAMETERS OF APPLE FLESH**

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**REZUME**


**Ključne reči:** koeficijent provođenja toplotne, temperaturna provodnost, specifična toplota.

**SUMMARY**

This article deals with thermophysical properties of apples and applesauce. It is necessary to know the thermophysical characteristics of apples and applesauce for quality protection of storage process and technological process by processing to final products. Apple mass non uniform material in microscopic and macroscopic structure. There are enacted biophysical and physiological processes. Heat transfer can not be isolated by solid transfer and heat – moisture transfer. It means that specification of apple mass is difficult to determine. We used to study the relationships between thermal conductivity, thermal diffusivity, specific heat and temperature, time period of storage and quality of storage.

**Key words:** thermal conductivity, thermal diffusivity, specific heat.

**INTRODUCTION**

Great number of experimental techniques has appeared in literature so far. The methods differ in basic principles of measurement; in number of thermophysical properties they allow to estimate simultaneously; they distinguish in suitability to test different materials and under various experimental conditions. Very popular are photo thermal methods of measuring of the thermal diffusivity - the laser flash method (Parker, 1961; Vozár, 2001) and the step heating method (Bittle, 1984); electro resis-
tive heat source methods (Kubičár, Boháč, 1997) of measuring of the thermal conductivity – transient hot wire method (Davis, 1984); the hot plate (Dowding, 1996) the guarded hot – plate method. The other methods give two thermophysical parameters – the transient hot strip method (Gustafsson, 1983); the step – wise transient method and the transient plane source method (Gustafsson, 1991).

Transient methods represent a large group of techniques where measuring probes, i.e. the heat source and the thermometer, are placed inside the specimen. This experimental arrangement suppresses the sample surface influence on the measuring process which can be described as follows. The temperature of the specimen is stabilized and made uniform. Then the dynamic heat flow in the form of pulse or step-wise function is generated inside the specimen. From the temperature response to this small disturbance, the thermophysical parameters of the specimen can be calculated.

For our measurements we choose Isomet (1st method) - instrument made by firm Applied Precision, it is used for quick and exact measurement of thermophysical parameters of liquid, solid and bulk materials. Measurements by Isomet are based on Hot wire (HW) method. There were also made reference measurements by DPS-Dynamic Plane Source method (2nd method). Both methods HW and DPS are classified like transient methods. In the first series of measurements we measured relations between thermal conductivity, thermal diffusivity, specific heat to temperature in temperature range (2–24) °C and to storage period for apples by 1st method. In the second series of measurements we made reference measurements by DPS method.

MATERIALS AND METHODS

Measurement was realized for apples of variety Idared. The samples came from Slovenský vodohospodársky podnik, s. P., o.z. Hydromeliorácie Bratislava, from the locality Most near the Bratislava. Experimental measurements were realized during the apple storage from 23.2. 2002 to 27.6. 2002 approximately in the month’s intervals. The storage was provided in storage boxes at the temperature from 2°C to 3°C and 90% of the air moisture content. The measurement was realised for four variants A, B, C, K of the variety Idared. The variants differed by the method of the fertilization and irrigation (table 1). Fertilisation and irrigation was realized as dropping irrigation where the liquid contained the nutritive substances.

Table 1. Fertilization dosage and methods of irrigation and fertilization for the Idared variety

<table>
<thead>
<tr>
<th>Variant</th>
<th>Fertilization dosage [kg/ha]</th>
<th>Method of irrigation and fertilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>80 80 125</td>
<td>Fertigation irrigation, liquid fertilization</td>
</tr>
<tr>
<td>B</td>
<td>120 120 125</td>
<td>Fertigation irrigation, liquid fertilization</td>
</tr>
<tr>
<td>C</td>
<td>80 80 125</td>
<td>Fertigation irrigation, solid manure</td>
</tr>
<tr>
<td>K</td>
<td>80 80 125</td>
<td>Rainfall, solid manure</td>
</tr>
</tbody>
</table>

For our measurements we choose Isomet (1st method) - instrument made by firm Applied Precision, it is used for quick and exact measurement of thermophysical parameters of liquid, solid and bulk materials. This instrument is based on the hot wire method. The simple measurement consists in measuring the temperature rise vs time evaluation of an electrically heated wire embedded in the tested material. The thermal conductivity is derived from the resulting change in temperature over known time interval.

The ideal analytical model assumes an ideal – infinitely thin and infinitely long heat source (hot wire), operating in an infinite, homogenous and isotropic material with uniform initial temperature \( T_0 \). If the hot wire is heated for the time \( t = 0 \) with constant heat flux \( q \) per unit wire length, the radial heat flow around the wire will occur. The temperature rise \( \Delta T(r,t) \) in any distance \( r \) from the wire as a function of time is described by the simplified equation (Carslaw, Jeager 1989):

\[
\Delta T(r,t) = \frac{q}{4\pi k} \ln \frac{4at}{r^2} - C
\]

where: \( k \)-the thermal conductivity, \( a \)-thermal diffusivity, \( C = \exp(\gamma) \) with \( \gamma \) the Eulers' constant. The thermal conductivity is calculated from the slope S of the temperature rise \( \Delta T(r,t) \) vs. the natural logarithm of the time In \( t \) evolution using the formula:

\[
k = \frac{q}{4\pi aS}
\]

Several corrections have been introduced to account for the heat capacity of the wire, the thermal contact resistance between the wire and the test material, the finite dimension of the sample and the finite dimension of the wire embedded in the sample. The hot wire method is in accordance with the way of measurement of the temperature increase and the place of the temperature sensor utilized in three main variations, known as the resistance technique, the standard (cross) technique and the parallel wires technique.

Fig 1. Design of devices for determination thermophysical parameters of biological materials

Sl. 1. Uređaji potrebni za definisanje termofizičkih parametara bioloških materijala

Measurements which were performed by Isomet with spike probe, which have calibration of thermal conductivity in range (0,5–0,7) W.m⁻¹.K⁻¹. Spike probe was inserted into the analyzed material. Probe is generating a heat. Time process of temperature that is related by thermophysical parameters of sample is analyzed. We measured temperature, thermal conductivity, thermal diffusivity and specific heat. We obtained relations of thermal conductivity, thermal diffusivity and specific heat to the temperature for apple flesh of variety Idared. There were measured four samples – variety A, B, C and K. Samples were stored in special cool box during 24 hours before measurement and rela-
tions of thermophysical parameters to the temperature were measured during temperature stabilization of samples. All measurements were made in laboratory settings.

RESULTS AND DISCUSSION

We obtained values of thermal conductivity, thermal diffusivity and specific heat for different samples of apple flash in temperature range (2-24)°C. Graphic relations are showed on figures 2-7.

Fig 2. Relations of thermal conductivity on applesauce temperature (variety A, B)
Sl. 2. Zavisnost koeficijenta provodenja od temperature soka od jabuke (sorta A i B)

Fig 3. Relations of thermal conductivity of applesauce temperature (variety C, K)
Sl. 3. Zavisnost koeficijenta provodenja od temperature soka od jabuke (sorta C i K)

There were also made reference measurements by DPS - Dynamic Plane Source method (2nd method) which is described in. The dynamic plane source (DPS) method is arranged for one-dimensional heat flow into a finite sample. The rear sides of the samples are in contact with heat conducting material, the temperature developed in the sample is close to adiabatic. This method appears to be useful for simultaneous determination of thermal diffusivity a and thermal conductivity λ of metals and good thermal conductivity dielectrics. Values of thermophysical parameters obtained by DPS method are in great agreement with presented values and values presented in literature.

Fig 4. Relations of thermal diffusivity of applesauce temperature (variety A, B)
Sl. 4. Zavisnost koeficijenta provodenja od temperature soka od jabuke (sorta A i B)

Fig 5. Relations of thermal diffusivity of applesauce temperature (variety C, K)
Sl. 5. Zavisnost koeficijenta provodenja od temperature soka od jabuke (sorta C i K)

Fig 6. Relations of specific heat of applesauce temperature (variety A, B)
Sl. 6. Promena specifične toplote u zavisnosti od temperature soka (sorta A i B)
showed on figures 2–7 demonstrate linear increasing relations between thermophysical parameters and temperature during temperature stabilization of samples for variety of apples A, B, C and K. Based on these reasons, it is necessary to have knowledge of the dependence of thermophysical parameters on temperature and conditions of storage if we need to protect quality of apples storage.

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