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CHANGES IN THE QUALITY CHARACTERISTICS OF RASPBERRY FRUIT DUE TO MECHANICAL VIBRATIONS AND STORAGE CONDITIONS

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Keywords: raspberry fruits, mechanical impact, juice leakage.

Abstract

The paper presents the results of a study investigating a mechanical impact, in the form of vibrations, on the overall quality of raspberry fruits after harvest, in view of the conditions of their transport to the consumer and the processing plant. The degree of compaction of the raspberry fruit layer was determined during a test carried out under laboratory conditions, and the amount of juice leakage, resulting from the vibrations to which the raspberries were subjected, was measured. It was demonstrated that the quantity (mass) of juice leakage was considerably affected by the mechanical impact, in the form of vibrations, exerted on a layer of raspberry fruits. The leakage was smaller in cooled fruits, and significantly greater in fruits that were not subjected to cooling immediately after harvest, and were stored under ambient conditions.

Introduction

Raspberry fruits are characterized by low durability and rather loose cell/tissue structure, combined with a high water content. This results in the fact that there are many factors influencing the decrease in durability of raspberry fruits after harvest (Gołacki, Rowiński 2006, Haffner et al. 2002, Perkins-Veazie, Nonnecke 1992, Robbins, Sjulin 1986). The most important include: the fruit maturity at harvest, time, temperature and other conditions of the post-harvest storage, as well as conditions of the transport to the final consumer or processing plant. Inappropriate handling at the mentioned stages reduces the overall post-harvest quality, which is manifested by appearance of mould, fungi and other micro-organisms. Decay processes take place immediately after harvesting, when the raspberries are already in the packaging, as well as during a shorter or longer transport to the place of final use (consumer, cold store, processing plant) (Idaszewska, Bieńczak 2013, Heiberg 1988, Jakubczak, Uziak 2005, Ramsay 1983). High rating of raspberry fruits for consumption and those intended for freezing or processing depends mainly on the average size (dimensions) of the berries, which is determined in various ways, on their attractive red colour, and on mechanical properties (Dobrzański et al. 1994, Dobrzański, Rybczyński 1995, Gołacki, Rowiński 2006, Kuczyński, Rybczyński 2004, Rapcewicz, Danek 2010, Ramsay 1983). Earlier observations of the fruit at plantations show a gradual decrease in firmness as well as colour change (darkening) (Kuczyński et al. 1994, Ramsay 1983, Robbins, Sjulin, 1986, Sjulin, Robbins 1987). Raspberry fruits are among the group of most delicate soft fruits, which are sensitive to any mechanical damage associated, among other things, with changing conditions of their storage and transport. At the time of harvest and after it, various biochemical processes take place in the fruits from this group, and, additionally, changes occur in the organoleptic characteristics and intracellular structure during transport to the final consumer or processing plant. They are reflected, inter alia, in the destruction of the original shape and dimensions of the fruits, as well as an increased compaction of the layer of fruits, which, in turn, leads to juice leakage, thus lowering the overall consumption and processing value. In the context of preserving the highest possible quality of these fruits particularly their transport is one of the biggest logistical challenges. Inadequate transport conditions, viz. high temperature, too high or low humidity, extended time of transport, and unsuitable means thereof affect the overall perceived quality of the transported raspberry fruits. Changes in the shape and dimensions of both single fruits and the entire volume of the layer, reduced turgor pressure and mechanical strength, as well as compromised flavour, are among possible detriments. It can be assumed that transport of raspberries is a mobile variation of their storage, and, therefore, the same parameters that act on them during storage are responsible for the changes in the transported fruits. In the literature of the subject, be it national or international, there is relatively little information about the influence of vibrations generated during transport on the transported product, including raspberries. The data from literature concern mainly the quantitative losses estimated after the transport process, and therefore the final outcome (RYBCZYŃSKI et al. 2001, THOMPSON 2010). However, during the transport of the fruits minimal displacement of the products takes place as well as their mechanical interactions resulting from shock and vibration of a transport box. During transport raspberries might experience forced influence of mechanical phenomena and accelerated deterioration of their quality, including a reduction of the amount of certain valuable substances. Therefore, it can be assumed that the shocks and vibrations experienced during transport should be recognized as negative factors that may cause acceleration of the overall deterioration process of raspberry fruits (BARRITT et al. 1980, IDASZEWSKA et al. 2014, ROBBINS, SJULIN 1986, ROBBINS, SJULIN 1989).

The aim of the study was to determine the amount of raspberry juice leakage depending on storage conditions after harvest and the intensity of mechanical vibrations. The research was conducted in terms of changes in qualitative and technological features that may occur in the conditions of fruit transport to the consumer and processing plant. The degree of shaking of the raspberry layer was determined in laboratory conditions, determined in various ranges of mechanical vibrations.

Material and methods

Studies were carried out on the fruits of an autumn variety of raspberries, i.e. Polka, collected at a private plantation in the area of Ostrów Lubelski. Raspberries harvest took place in the second half of August. Immediately after harvest, fresh raspberry fruits were placed in a container into layer with the thickness

Fig. 1. The view of a laboratory vibrating shaker

of a = 50 mm, and then subject to a shake for the time of t_w = 15 min, using a laboratory vibratory shaker (Fig. 1). Vibratory shaker ANALYSETTE (AS 400 Retsch GmbH) is equipped with an optical amplitude control with an amplitude value label allowing to read amplitude value. Two vibration amplitudes 1 and 2 mm were used in relation to the gravitational acceleration at a vibration frequency of 50 Hz.

The scope of the experiment included the use of various parameters of the process of mechanical vibration impact on the raspberry fruit layer. The total vibration time was 15 minutes, with varying vibration intervals (t_{id} = 20, 40, 60, 80), conducted at 3-second intervals. Two groups of fruits were used in the study, viz. raspberries stored for 24 hours at the temperature of 25°C and those stored for the same period of time in cold store condition at T = 5°C. In the particular stages of research the degree of compaction u (decrease in the thickness of the raw material layer before and after shaking) in mm was determined and quantity (mass) of the juice leakage m_s in g was measured (Fig. 2).

A statistical analysis of the obtained results was carried out in order to obtain a mathematical representation of the change in the thickness of the material layer and juice leakage as a result of the vibrations used.

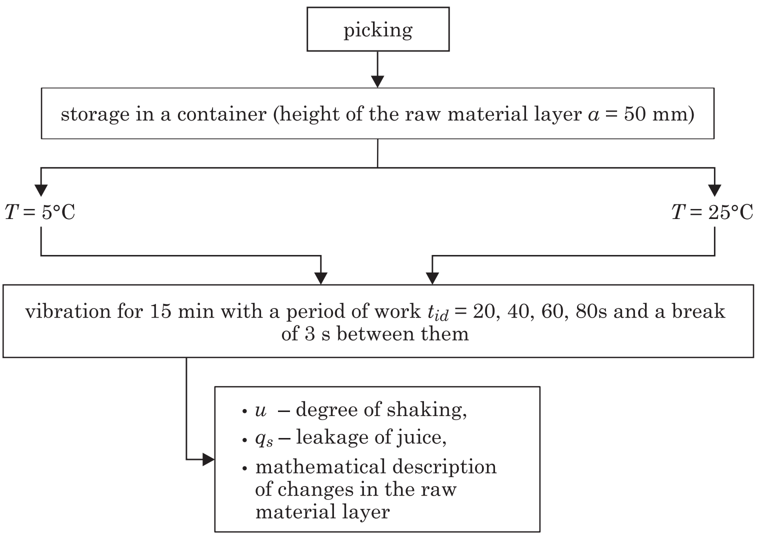

Fig. 2. Research scheme

Research results and their analysis

On the basis of the results obtained, it can be concluded that in the case of raspberry fruits temperature and the remaining environmental conditions in which the raspberries are stored immediately after harvesting are very important factors affecting the overall consumer-processing quality. This is confirmed by the data on the degree of compaction of the two layers of raspberries, i.e. fruits stored after harvesting at the temperature of 25°C and fruits stored in a cold store (Figs. 3, 4).

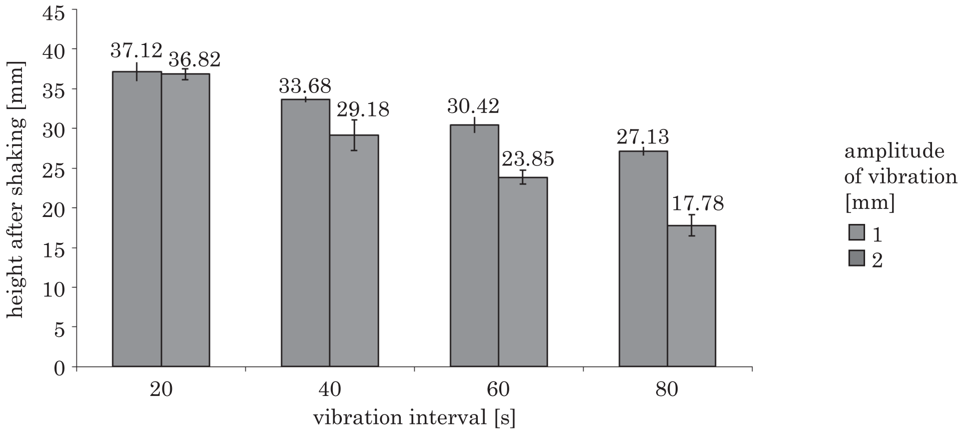

Fig. 3. Data set concerning the degree of compaction of the fresh raspberry fruits stored at the temperature $T = 25°C$ along with statistical deviation. The initial thickness of the fruit layer $a = 50$ mm (±1 mm)

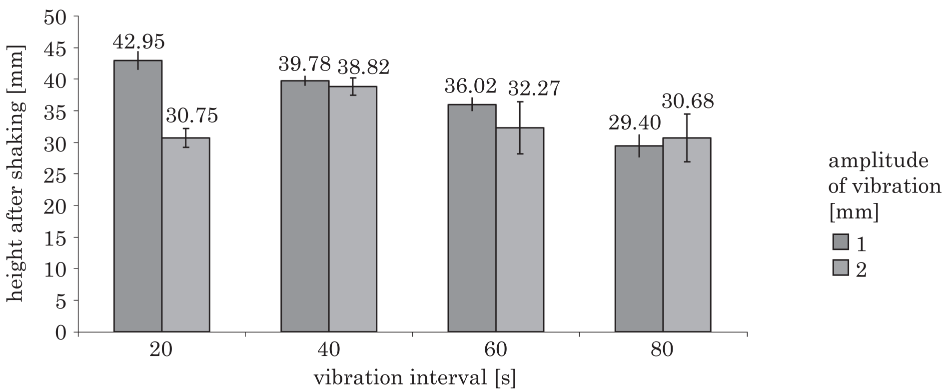

Fig. 4. Research results illustrating the degree of compaction of the layer of raspberry fruits cooled immediately after harvesting and stored at the temperature $T = 5°C$ along with statistical deviation. The initial thickness of the fruit layer $a = 50$ mm (±1 mm)

The tests carried out in the laboratory are an approximate representation of the vibrations that occur in various forms during the final transport of raspberries to the recipient. The analysis of the research results showed that rapid cooling of raspberries after harvesting determine their increased resistance to mechanical stress in the form of multi-planar shocks, vibrations, and mini displacements.

By comparing the degree of compaction (compression) of the layer of cooled raspberry fruits and that of stored at ambient temperature the differences of the height, when compared with the original height of a = 50 mm, ranged from 25.76% to 64.44% (for T = 25°C) and from 14.4% to 41.2% in the case of cooled fruits (T = 5°C). The average difference of the value of this parameter between the two test groups of the fruits ranged from 11.3% to 25.9%. With regard to the parameters of vibration to which the test samples were subjected to, the greatest degree of compaction of the layer of fruits was recorded for the longest intervals t_{id} equal to 60 and 80 s, regardless of the vibration amplitude. The data obtained confirm susceptibility of raspberry fruits to mechanical influence, with fruits stored immediately after harvesting at ambient temperature being particularly sensitive in this regard.

Figures 5 and 6 summarize the results of studies concerning the increase of juice leakage from the layer consisting of two respective groups of raspberries, viz. cooled ones and stored at the temperature T = 5°C and those stored at the temperature T = 25°C, both groups for the period of 24 hours.

The analysis of the obtained data clearly demonstrate that mechanical stress in the form of vibration exerted on raspberry fruits has a large impact on the amount of juice leakage. This effect is smaller in the case of cooled fruits, and much larger in the case of fruits not cooled immediately after harvesting and stored at ambient conditions. The average values of juice leakage, regardless of the parameters of vibration process, oscillate approximately between 1.7 and 4.3%. From the point of view of processing usefulness these are big losses that significantly decrease the desired value and technological quality of raspberries.

With respect to the quality and value of raspberries intended for direct consumption such scale of losses which may arise due to inappropriate storage conditions immediately after harvesting and during transport is not acceptable.

The juice leakage increased in direct proportion to the vibration intervals set up for the experiment. Its greatest value of 370.88 g (as referred to 1 kg of fruits) was obtained for the layer of fruits stored at 25°C and shook with the amplitude of vibration equal to 1 mm. In the case of cooled raspberries (5°C) the value of the leakage was equal to 345.42 g. The difference in respect of these data was 6.86% (Figs. 5, 6). The analysis of data shows that regardless of the test parameters the difference in the amount of leakage from the layer of raspberries cooled after harvesting and those not cooled ranges from 4.92% to 10.05%. A similar trend was noted in relation to the degree of compaction.

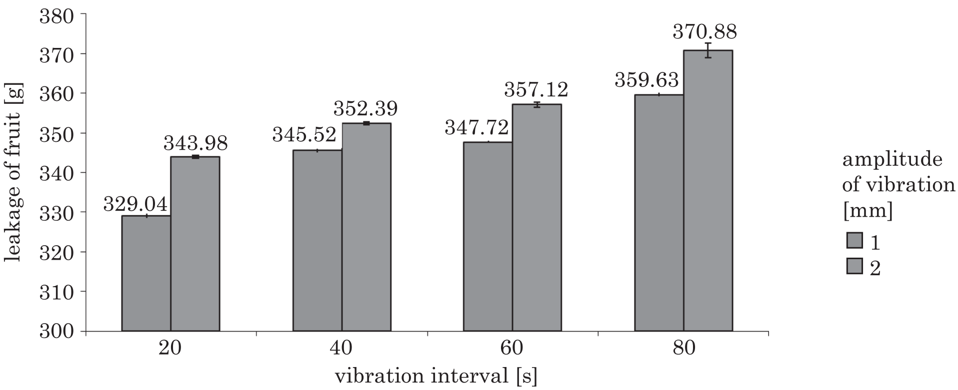

Fig. 5. Research results of the intensity of juice leakage from the layer of raspberry fruits stored at $T = 25°C$ along with statistical deviation

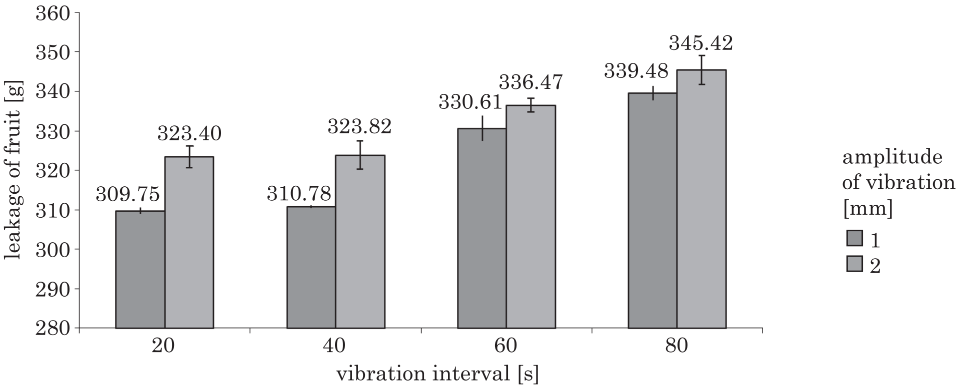

Fig. 6. Research results showing the intensity of juice leakage from the layer of raspberry fruits stored at $T = 5°C$ along with statistical deviation

The layer of cooled raspberry fruits was compacted to a lesser extent, regardless of the applied vibration, i.e. the frequency and amplitude.

On the basis of the results obtained, mathematical models describing the loss of the thickness of the raw material layer and juice leakage during simulated transport were developed (Tab. 1, 2).

In view of the delicacy of the structure and susceptibility of raspberry fruits to shocks, which were confirmed in the research, several practical principles should be recommended that are necessary to maintain high consumer and processing quality of the fruits. It is therefore recommended to:

– cool fruits as soon as possible after harvesting and deliver them fast to the final consumer, cold store, or another processing establishment;

– adjust the means of transport to suit demands of the soft fruit group, including raspberries;

– make technical improvements to the means of transport through the use of suspended chassis, transport boxes with limited capacity, and minimize the distance over which fruits are transported;

– use partitioned fruit crates, which allow to reduce the thickness of the fruit layer in the box (Fig. 7 – Utility model W.126925) (appropriate patent pending).

Table 1

The regression equations illustrating the nature of changes in the height of raspberry fruit layer resulting from varied intervals of the vibration

Fruit temperature $T = 25°C$		
Amplitude of vibration [mm · g-1]	equation	R^2 (coefficient of determination)
1	$a = -0.166 \cdot t_{id} + 40.395$	0.999
2	$a = -0.312 \cdot t_{id} + 42.517$	0.995
Fruit temperature $T = 5°C$		
Amplitude of vibration [mm · g-1]	equation	R^2 (coefficient of determination)
1	$a = 0.427 \cdot t_{id} + 334.74$	0.960
2	$a = 0.469 \cdot t_{id} + 321.99$	0.928

a – height of the fruit layer [mm],
t_{id} – vibration interval [s].

Table 2

The regression equations illustrating the nature of changes in the amount of raspberry fruits juice leakage resulting from varying vibration intervals

Fruit temperature $T = 25°C$		
Amplitude of vibration [mm · g-1]	equation	R^2 (coefficient of determination)
1	$m_s = -0.222 \cdot t_{id} + 48.138$	0.968
2	$m_s = -0.337 \cdot t_{id} + 34.817$	0.661
Fruit temperature $T = 5°C$		
Amplitude of vibration [mm · g-1]	equation	R^2 (coefficient of determination)
1	$m_s = 0.5451 \cdot t_{id} + 295.4$	0.989
2	$m_s = 0.3936 \cdot t_{id} + 312.6$	0.909

m_s – amount (mass) of juice [g],
t_{id} – vibration intervals [s].

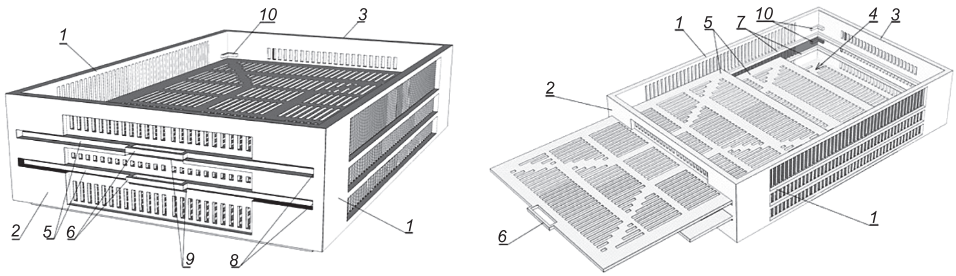

Fig. 7. Proposed partitioned box for harvesting, storage and transport of soft fruits, including raspberries; *1*, *2*, *3* – box walls, *4* – box bottom, *5* – pull-out partitions, *6* – protruding partition handles, *7* – slat supports, *8* – partition mounting slots, *9* – recesses for handles, *10* – limiters

Conclusions

On the basis of the conducted research it can be concluded that:

1. In the case of raspberry fruits very important factors determining the overall consumer-processing quality thereof are the temperature (5 and 25°C) and other environmental conditions (vibration amplitudes 1 and 2 mm, vibration frequency of 50 Hz) in which they are stored immediately after harvesting.

2. When comparing the degree of compaction (compression) u of the layer of raspberry fruits cooled after harvesting and those stored at ambient temperature the differences in the height of fruit layer with respect to the initial height a ranged from 25.76% to 64.44% (for $T = 25°C$) and from 14.4% to 41.2% in the case of the cooled fruits ($T = 5°C$).

3. With regard to the parameters of the vibration used, the greatest degree of compaction of the fruit layer, regardless of the amplitude of vibration (vibration amplitudes 1 and 2 mm, vibration frequency of 50 Hz), was observed for the longest intervals t_{id} equal to 60 and 80 seconds respectively.

4. Mechanical impact on the fruits in the form of vibration has a significant impact on the quantity (mass) of the juice leakage. This effect is smaller in the case of cooled fruits, while in the case of the fruits not cooled after harvesting and stored at ambient conditions the impact is much larger.

5. The average values of juice leakage (recognized as loss), regardless of the parameters of the shaking process, range from 30 to 35%.

6. The test results confirmed that from the point of view of the general quality and technological value of raspberry fruit, it is advisable to cool them as soon as possible after harvesting and storage in a thin (less than 5 cm) layer, which is possible of the proposed box structure. In addition, it is recommended to use flexible and cushioned chassis means of transport, guaranteeing the greatest possible reduction of mechanical vibration when transporting fruit to the consumer or processing plant.

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