Intra-farm transportation of easily damaged agro food products for sustainable development of agriculture

S N Borychev, I A Uspensky, I A Yukhin, A A Golikov and D I Kosorukov

Ryazan State Agrotechnological University named after P A Kostychev, 1 Kostychev Street, Ryazan, 390044, Russia

E-mail: yuival@rambler.ru

Abstract. The article presents some aspects of the issue of damage to easily damaged agricultural products during intrafarm transportation, as well as the results of a patent and license review of the scientific and technical groundwork of the authors of the article in this research area. Based on the results new scientifically grounded technical solutions of devices for increasing the safety of agricultural products during transportation are proposed, in particular containers, to reduce the damage of products during their transportation by increasing the area of contact between fruits and the container, as well as reducing the space for free movement of products.

1. Introduction
One of the main factors characterizing agricultural goods is the variability of their mechanical properties under the influence of humidity, pressure, temperature, and storage duration. As the height of the stored material increases, the risk of caking increases. Many cargoes are easily damaged. Most of all, fruits, roots and vegetables are damaged, especially when transported in bulk [1, 2].

The general structure of transportation of agricultural goods in the Russian Federation is presented as follows (Table 1).

| Mode of transportation | To the entire volume of transportation, % |
|------------------------|-------------------------------------------|
| In bulk                | 76                                        |
| Including specialized bodies | 28                                      |
| In various containers, packages, bales | 14                                     |
| Including specialized bodies | 8                                      |
| Shot lots (mass of a one-time dispatch up to 2 tons) | 4                                      |
| In tanks               | 6                                         |

At the same time, depending on the agricultural crop, transportation methods can be varied (potatoes are transported both in bulk and in containers) or individual (for example, tomatoes neatly packed in boxes). But even a rationally made choice cannot guarantee the absence of damage to the fruit during transportation.
If one considers the location of the fruit in the container (Figure 1), the likelihood of their damage will be different. The main areas here will be [3]:
- the upper layer (bruises when the upper layer of the fruit "bounces" and collisions with the underlying ones, due to the movement of the vehicle on an uneven road surface);
- the bottom layer (bruises and cracks on the fruit when interacting with the bottom of the container, due to the movement of the vehicle on an uneven road surface);
- fruits near the side walls of the container (bruises when the container is tilted sharply).

![Figure 1. Layout of agricultural cargo in a container and the likelihood of damage.](image)

In addition to the location of individual fruits in the container, the degree of damage will be influenced by a number of factors, such as the speed of the vehicle and its technical condition (which will directly affect the vibration speed of the cargo platform of the vehicle), biological properties of the fruits, their ripeness, etc. [4, 5].

2. Materials and methods
Accelerometers ADXL 320 and ADXL 103 were used to register the maximum amplitudes of the vibration velocity of the cargo platform for each of the generalized coordinates. The quality of the fruits is assessed in accordance with State Standard 34314-2017 “Fresh apples sold in retail. Technical specifications for fresh apples”. The varieties of apples “Antonovka ordinary” and “Pepin saffron” were studied.

3. Results and discussion
Studies were carried out, during which the degree of damage to fruits during intrafarm transportation was determined (fruits for transportation were loaded into a container), depending on the vibration velocity of the cargo platform of the vehicle using the example of apples [6].

For this purpose, 200 control apples, marked and clean from damage, were placed in the container. The control fruits were placed on 3 levels (bottom, middle, top), evenly distributed over the entire area. Three containers with experimental fruits were installed in the body of the vehicle, one at a time, respectively, in the front and rear of the platform and in the middle. After that, the body was fully loaded, the fruits were taken to the checkpoint and unloaded. In the process of movement, the data
necessary to determine the maximum vibration velocity of the body.

The received data were processed and on their basis the following graphical dependence was built (Figure 2).

![Figure 2](image)

**Figure 2.** The influence of the vibration velocity of the cargo platform of a vehicle on the degree of damage to agricultural products (apples) transported in a container.

Consequently, at a vibration velocity of the loading platform of a vehicle equal to 0.36 m/s, the damage to the transported agricultural products is insignificant (less than 0.35 %), and at a vibration velocity of 0.7-2.0 m/s it reaches 6.3%.

Based on this, it can be concluded that for the implementation of an effective process of intrafarm transportation of easily damaged agricultural products, a significant change in the design of the containers used is required.

To prevent damage to the top layer of fruits placed in the container for transportation (when the vehicle is driving on an uneven micro-profile of the road), there are locking devices, like the ones in Figure 3 [7].

![Figure 3](image)

**Figure 3.** The container for transportation of easily damaged agricultural products (utility model patent No. 176885): 1 - container; 2 - frame; 3 - clamps; 4 - grooves; 5 - pressure cover; 6 - clamping mechanism; 7 - splint pin; 8 - slide bar; 9 - holes for pressure adjustment; 10 - damping material; 11 - through ventilation holes.
In this technical solution, the reduction in the degree of damage to agricultural products during transportation is carried out by using a non-rigid damping material of a wave-like profile installed on the walls, bottom and lid of the container, which, together with a three-position scissor-type clamping mechanism with a locking rod, seal the fruits inside the container, which does not allow them move relative to each other during transportation. At the same time, the grooves made on the upper part of the frame make it possible to stack several such devices, excluding the interaction of fruits in filled containers.

To reduce the degree of damage to easily damaged agricultural products located at the bottom of the container, the following structure has been developed (Figure 4) [8], which includes a bottom and walls, at the bottom of which there are staggered protrusions that form a cell with the bottom plane, while the protrusions have the shape of a hemisphere, are made of a damping material, are hollow and filled with a gas.

![Figure 4](image)

*Figure 4. The container for transportation of easily damaged agricultural products (utility model patent No. 166384): 1 - the bottom of the container; 2 - container walls; 3 - hollow protrusions; 4 - cells; 5 - fruits.*

The proposed design is aimed at reducing the degree of damage to transported agricultural products (transportation is carried out in the container). This result is achieved by reducing the dynamic impact on the bottom layer of the fruit in the container.

Consider another device for reducing damage to agricultural products during transportation (the device prevents the transverse movement of cargo inside the container). It (Figure 5) [9] contains a container, including an external fence in the form of rigidly connected frames, to which the enclosing elements are attached. Vertical flexible posts are rigidly fixed on its bottom in a checkerboard pattern, at a distance from each other and from the side surfaces of the container not exceeding 20% of its width. Their height is equal to the height of the container, and the diameter does not exceed 5% of the height.
Figure 5. The container for transportation of easily damaged agricultural products (utility model patent No. 2636569): 1 - container; 2 - vertical flexible struts; 3 - fruits.

The degree of damage to agricultural products is reduced by reducing their horizontal movement on uneven roads, braking or accelerating a vehicle, as well as redistributing the load between the vertical layers of fruits located in the area of the struts and the vertical flexible struts themselves.

The technical solutions presented above make it possible to solve local problems [6, 10], and in the aggregate, reduce their number to practically zero.

4. Conclusion
The application of a scientific approach to the organization of intrafarm transportation of easily damaged agricultural products (for example, compliance with the recommended speed limit for a vehicle transporting lightly damaged agricultural products) makes it possible to achieve high efficiency indicators of this process.

The use of the above technical solutions for intrafarm transportation of easily damaged agricultural products allows to preserve its appearance, and, consequently, the cost in the consumer market.

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