Investigation of infrared drying of carrot chips

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Abstract. The work investigates the process of making chips from carrot root crops. Now fruit and vegetable chips are very popular due to their high concentration of nutrients which significantly increases the calorie content, biological value and assimilation of the product. The lowered moisture content provides the chips with good preservation of concentrates for a long time. Experimental studies were carried out on an experimental infrared drying plant, developed by the staff of the Department of Power Supply and Heat Power Engineering of Irkutsk State Agrarian University. Drying of carrots was carried out in an oscillating mode "heating - cooling" which allows intensifying the drying process and shortening its duration. Recording results on the change in weight and size of carrot slices along the length was carried out every ten minutes. Based on the data taken it was done graphs of the relative mass dependence from the time of infrared drying and we presented the results of studies on the shrinkage of chips.

1. Introduction
The realization of the program of the innovative development of agricultural production involves the creation of technical means and technologies that meet modern requirements [1-7].

For the manufacture of high nutritional value products, the processes of drying edible plant materials are widely used. This is due to the fact that freshly picked fruits and vegetables with a high moisture content are very unstable when stored for a long time. Removing moisture from them by heat treatment and drying to a moisture content of 10-12% will allow them to be stored for a longer time, without requiring special storage conditions.

Dried foods contain nutrients at their most concentrated form. The word "concentrate" in translation from the Latin language means concentration. Food concentrates have the following features. The lowered humidity ensures them good preservation of concentrates for a long time. A high concentration of nutrients significantly increases the calorie content, biological value and digestibility of concentrates. Freed from a significant part of moisture they have a small volume and mass which makes them transportable. Cooking of food from food concentrates is fast and simple [8]. Due to the listed properties, highly concentrated food products are now widely used in the form of fruit and fruit and vegetable chips.

A popular raw material for the production of chips is carrots. In the Irkutsk region table carrot which takes one of the first places in nutritional value among root crops are successfully cultivated and at the same time the natural and climatic conditions of the region make it possible to obtain a high yield of this crop [9].

When obtaining fruit and vegetable chips it is effective to use a combination of various methods of thermal energy which can significantly reduce the duration of the drying process, increase the intensity of moisture removal and improve the quality of the finished product. Perspectives for the development
of electrical technology show the widespread use of installations operating on the principle of using electricity converted into infrared energy for processing and drying plant materials. Recent works on the effective use of IR heating in the technology of heat treatment and drying of plant materials show that active research is being carried out in this direction [10-20].

2. Materials and methods

The aim of the work was to obtain chips from carrot root crops using infrared processing and drying. The experiments were carried out in the fall of 2019 on an infrared installation worked out at the Department of Power Supply and Heat Engineering [21]. Carrots for the experiments were purchased from the shop "Belorechenskoye" located in the village of Molodezhny, Irkutsk region.

The technological scheme for the production of chips from carrots is shown in Figure 1. Cutting of carrot root crops was carried out using a slicer into slices 3 mm thick (Figure 2). Heat treatment of carrots was carried out in an oscillating mode "heating - cooling", while the heating of the material was carried out until the maximum permissible temperature on the material surface 60 °C, cooling was implemented by forced ventilation until the temperature on the surface of the material 45 °C.

3. Results and discussion

Figure 3 shows a graph of the changes in the relative mass of carrot slices from the time of IR treatment and drying, and Figure 4 shows the average values of curves of the slices’ shrinkage along the length. The slices’ shrinkage test was carried out by measuring with a regular ruler every ten minutes. With each length measurement, five random samples of the dried raw material were taken. It was difficult to carry out the slices’ shrinkage in width as the width of individual slices when cutting carrot roots differed significantly from each other. In turn the length for all dried slices was predetermined and the same. This paper presents the results of drying of cut carrot roots with a thickness of 3.0 mm and a length of 10 cm with four replicates.

When preparing carrot roots for cutting into slices measurements of the mass of the removed skin were carried out which on average amounted to 20% of the total mass of the root crop.

![Figure 1. Cooking scheme for carrot root crops chips](image1)

![Figure 2. Slicer AIRHOT](image2)

![Figure 3. Change of relative mass of carrot slices during infrared treatment and drying](image3)
Figure 4. Shrinkage curves of carrot slices during infrared treatment and drying

The process of IR treatment and drying of carrot slices with an initial moisture content of 87.9% to a final moisture content of 12-14% took an average of 3.5 hours (figure 3).

Vegetables and fruits which are colloidal capillary-porous materials shrink significantly when dried decreasing in volume by 3-4 times. In the present experiments, the shrinkage along the length of the carrot slice occurs on average from 10 centimeters to 7-7.5 centimeters (figure 4). Almost in 2-3 times the shrinkage occurred along the width of the slices.

It should be noted that shrinkage along the length of the slice occurs evenly throughout the entire drying process. The form of the resulting carrot chips is slightly distorted from the original state, there are no breaks or cracks (figure 5). Slight curling and tucking on the sides of the slices begins after about an hour and a half of IR treatment and drying.
Figure 5. Photographs of carrot slices during infrared processing and drying: a) at $\tau = 0$ minutes; b) at $\tau = 60$ minutes; c) at $\tau = 120$ minutes; d) at $\tau = 150$ minutes; e) at $\tau = 180$ minutes; f) appearance of finished carrot chips

4. Conclusion
According to the research results, it has been found that the resulting carrot chips have a high nutritional value. Chips have no significant changes in color, odor and taste after prolonged storage in plastic wrap (figure 5, f). Preservation of valuable nutrients in carrot chips is obtained due to the observance of technological parameters using oscillating temperature regimes.

When preparing chips from carrots to obtain the optimal parameters of the IR treatment and drying process, it is necessary to continue experiments by changing the values of the thickness of the slices (2.0, 2.5, 3.5, 4.0 mm) and the heating temperature (50 and 55 ºC).

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