



EXPERIMENTAL STUDY ON MICROWAVE-VACUUM DRYING OF ALFALFA

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ABSTRACT

The experimental study on microwave-vacuum drying of green alfalfa in the drying apparatus of the continuous operation were a research objective. Carotene retention in microwave-vacuum drying process was the main object of this research. Carotene retention during the period of storage of the dried alfalfa was investigated. It is set that microwave-vacuum drying ensures good carotene retention in the drying process of green alfalfa and during storage of the dried alfalfa. Low level of carotene destruction in microwave-vacuum drying process is interpreted by the fact that use of vacuum allows to realize drying at lower temperature. Low level of carotene destruction during storage of the dried alfalfa hypothetically is interpreted by the isomerization of carotene reducing its oxidation. The method of microwave-vacuum drying is perspective for the organization of industrial drying of forage and officinal herbs.

Keywords: microwave-vacuum drying, moisture elimination, carotene retention, alfalfa.

INTRODUCTION

Alfalfa (*Medicago sativa* L.) is one of the most important forage herbs. Alfalfa contains a large amount of valuable nutrient carotene [1].

To Alfalfa dry to moisture content 10-15 % for saving during the winter period [2]. In the past alfalfa was dried in the field after harvest under the influence of solar radiation [3, 4]. But now application of this method decreases because of the long duration of drying and possible significant nutrient loss [5]. The most widespread method of industrial drying of an alfalfa is hot air convective drying [5, 6]. But destruction of the considerable part of carotene under the influence of high temperature is a lack of this method [7]. Various methods on drying of plant materials, inclusive of alfalfa, were suggested [8].

The microwave drying is the most effective method of dehydration as in the course of drying plant tissue does not heat up [5, 9]. Only the water which is contained in plant tissue heats up during a microwave drying [9, 10]. The microwave drying ensures good retention of carotene and other nutrients because of the short duration of heating [9, 11]. Increasing pressure occur in particles of plant materials during their warming of a microwave radiation. Increasing pressure leads to intensive deleting water and water vapor through capillars and pores of plants [12]. Therefore process of a microwave drying can be effective only in case of timely deleting water vapor, and native ventilation does not provide execution of this condition [12, 13]. Effective evacuation of water vapor can be provided with method of vacuumization of the drying camera [14, 15].

It is set that microwave-vacuum drying is effective for evacuation of moisture from plant materials [16]. But the experimental studies on microwave-vacuum drying of alfalfa were not performed. Combined influence of a microwave radiation and vacuum is perspective for drying of alfalfa. The boiling temperature of the water which is contained in plant materials decreases in case of

the low pressure of the atmosphere [17]. Therefore it is possible to realize drying at lower temperature. It hypothetically will ensure greater carotene retention in alfalfa. But the topic of carotene destruction during of a microwave drying of green plants is a deficient investigated.

Content of carotene is an important quality level of the dried-up alfalfa [20]. Carotene retention during the winter storage period is other important quality level of the dried-up alfalfa [21]. But the topic of carotene retention in the alfalfa which is dried by a microwave drying in case of its long storage is insufficiently investigated.

Lack of the modern apparatuses for a microwave drying is drying of plant material in the portions. The portion of material loaded in the drying apparatus, dries in it, then is unloaded from the apparatus [5, 8]. Then the cycle of drying is repeated. Scaling of results of laboratory researches on a microwave drying for the industry is problem [12]. The drying apparatus of the continuous action needs to be developed for an industrial microwave drying.

The experimental study of process on microwave-vacuum drying of green alfalfa in the drying apparatus of the continuous action were a research objective. Carotene retention in the course of drying was the main object of research. Carotene retention during the period of storage of the dried alfalfa was also investigated.

MATERIALS AND METHODS

Alfalfa was harvested from farm in the Rostov region, Russia at the beginning of September, 2017 (the third harvest). Alfalfa had an initial moisture content of 75-80 % wet basis. Carotene content in alfalfa before drying made 113 mg/kg. Alfalfa was chopped with a mechanical cutter before drying to the size of particles of 10-20 mm.

The test apparatus for microwave-vacuum drying of plant materials is shown in Figure-1.

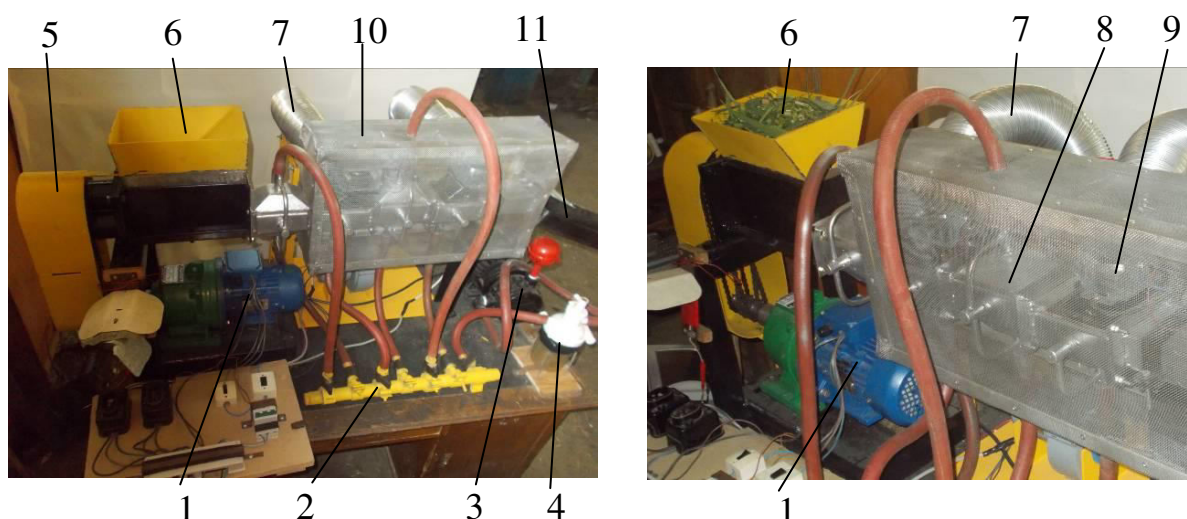


Figure-1. Test apparatus for microwave-vacuum drying of plant materials:

- 1 - electric motor; 2 - vacuum collector; 3 - vacuum pump; 4 - filter; 5 - power mechanism; 6 - load bunker; 7 - device for cooling of magnetrons; 8 - drying camera; 9 - magnetrons; 10 - barrier to protection of a staff against a microwave radiation; 11 - unloading tray

Construction of the apparatus was patented [18]. The apparatus is capable to execute drying of plant materials in the continuous operation.

The apparatus consists of the load bunker with screws, the electric drive and the drying camera. The drying camera consists of connected sections, in each of which the magnetron with a waveguide are set which are connected by a hose to the vacuum pump. A particle of alfalfa during drying move on the drying camera under the influence of the backup pressure created by screws of the load bunker. Backup pressure is regulated by relocation of the damper. Particles of alfalfa are affected by a microwave radiation in case of movement on the drying camera. Evaporable moisture is removed from the camera with air under the influence of the vacuum pump.

Drying of the grinded alfalfa was carried out at the constant power consumption of a microwave generator of 800 W and frequency of 2450 MHz. The heating temperature of alfalfa changed at the range from 120 to 185 °C. Moisture content of the dried alfalfa made of 14-15 %. The low atmospheric pressure of 80 kPa was created in the drying camera. Density of a alfalfa in the drying camera was a constant of 220 kg/m³.

Efficiency of the drying apparatus changed by method of frequency change of rotation of screws on the load bunker under the influence of the frequency converter. The residence time of alfalfa in drying camera and drying temperature in case of increase in efficiency of the apparatus decreased properly.

The heating temperature of particles of alfalfa in the course of a microwave drying was measured by an

optic pyrometer on output of the drying camera of the apparatus.

Moisture content of alfalfa before and after drying was determined by a drying method in a drying oven at a temperature of 105 °C until stabilization of the mass (almost 24 h). Moisture content was measured as the specific content of water in alfalfa expressed as a percentage.

Drying rate was measured as change of moisture content of alfalfa during its moving through one section of the drying camera.

Carotene content in alfalfa was determined by a high performance liquid chromatography (HPLC) method [19]. Carotene content was measured as the relation of its mass in milligram (mg) to the mass of dry matter of alfalfa in kilogram (kg).

Alfalfa is dried at a temperature of 125 °C was stored in opaque plastic bags indoors at a temperature of 15-20 °C during 180 days from September 15, 2017 to March 13, 2018. Samples selected and carotene content determined in the period of 30 days. Carotene content in alfalfa which is dried by solar drying stored in similar conditions was determined for comparing.

RESULTS

Results of the experimental studies on determination effect of microwave-vacuum drying temperature on carotene content in the dried alfalfa are shown in Figure-2.

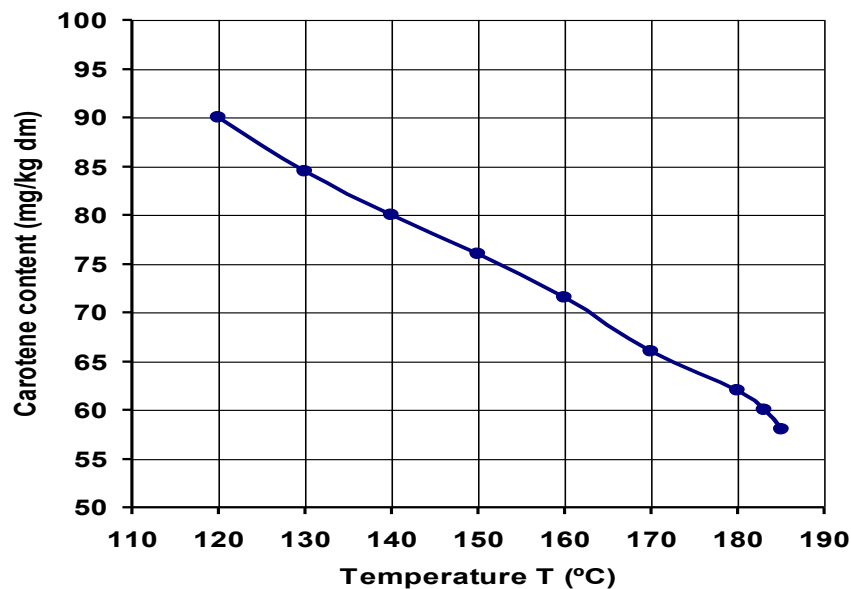


Figure-2. Effect of microwave-vacuum drying temperature on carotene content in dried alfalfa.

These results correspond to results of earlier researches [7, 11, 20, 21, 22] according to which the level of carotene destruction increases in case of increase in temperature of drying. Temperature of 120-140 °C is rational for microwave-vacuum drying of alfalfa as the minimum reduction of carotene content is observed in case of this mode. For example, carotene content in dried alfalfa decreases by 23 % in comparison with the carotene content in green alfalfa at a drying temperature of 125 °C.

Relationship of carotene content in dried alfalfa from heating temperature the almost linear in case of heating temperature from 120 to 180 °C. Carotene destruction speed considerably increases in case of heating temperature more than 180 °C.

The Figure-3 illustrates relationship of carotene content in alfalfa from a method and temperature of drying.

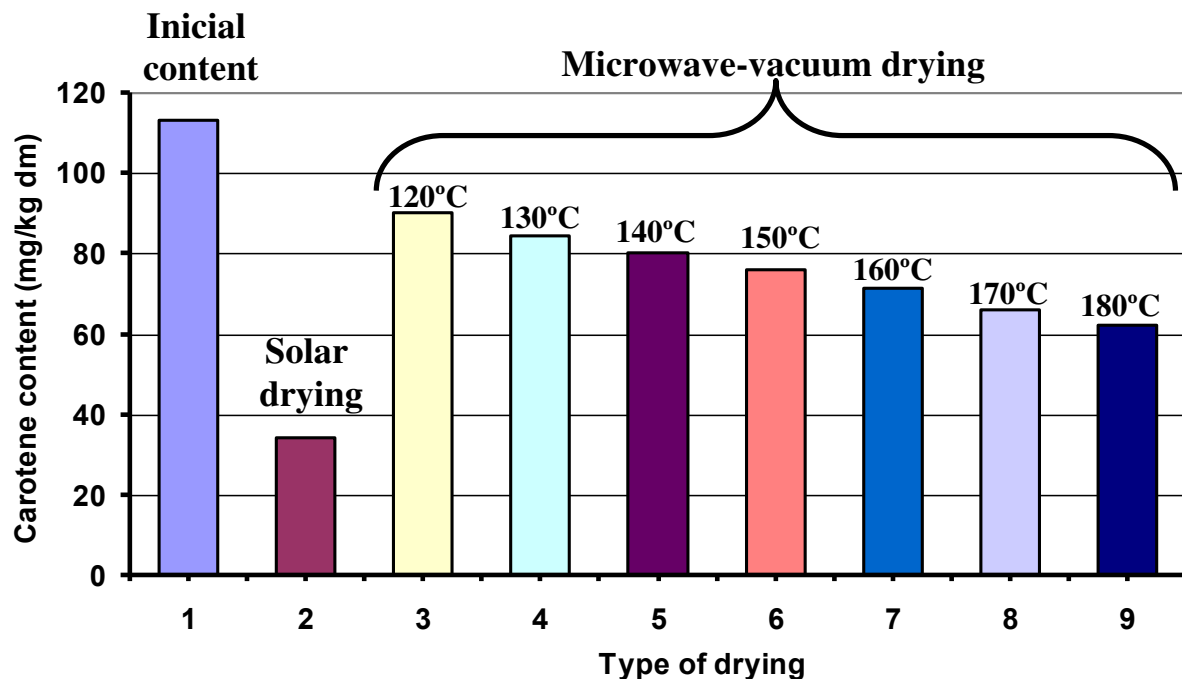


Figure-3. Effect of drying method and drying temperature on carotene content in alfalfa:

1 - initial carotene content; 2 - carotene content after solar drying; 3-9 - carotene content after microwave-vacuum drying at a temperature: 3 - 120 °C; 4 - 130 °C; 5 - 140 °C; 6 - 150 °C; 7 - 160 °C; 8 - 170 °C; 9 - 180 °C



Results of experiments show that the carotene content in alfalfa dried by method of microwave-vacuum drying several times as much then carotene content in alfalfa dried by method of solar drying.

It is set that the mode the microwave-vacuum drying of alfalfa with minimum temperature of heating of 120-140 °C is most effective for carotene destruction preventing.

The apparatus for microwave-vacuum drying operate in the continuous operation. The crushed green alfalfa moves via the drying camera being exposed to heating. The heating temperature depends on the residence time of alfalfa particles in the drying camera which is defined by efficiency of the drying apparatus.

Effect of drying apparatus efficiency on temperature of alfalfa microwave-vacuum drying is shown in Figure-4.

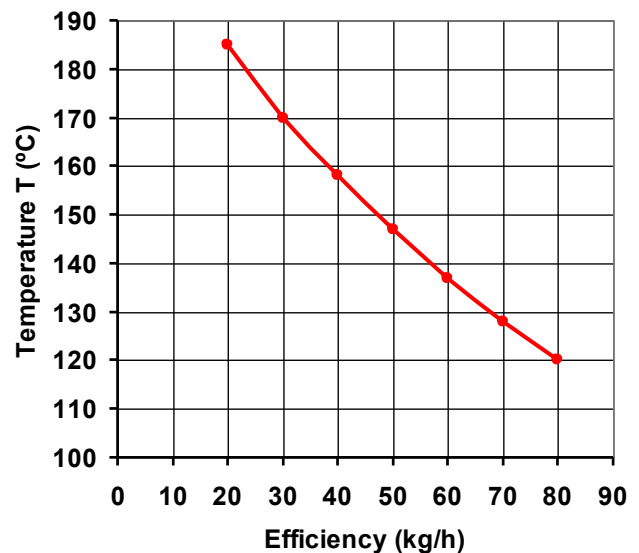


Figure-4. Effect of drying apparatus efficiency on temperature of alfalfa microwave-vacuum drying.

It is set that the alfalfa heating temperature decreases in case of increase the drying apparatus efficiency. The optimum alfalfa heating temperature of 120-140 °C is reached with a apparatus efficiency of 60-80 kg/h. Alfalfa microwave-vacuum drying time with a apparatus efficiency of 60-80 kg/h does not exceed 5 seconds. The results of an experiment shown in Figure-4 need to be considered when scaling the test drying apparatus for industrial application.

Change of moisture content in the dried alfalfa depending on initial moisture content of green alfalfa is shown in Figure-5.

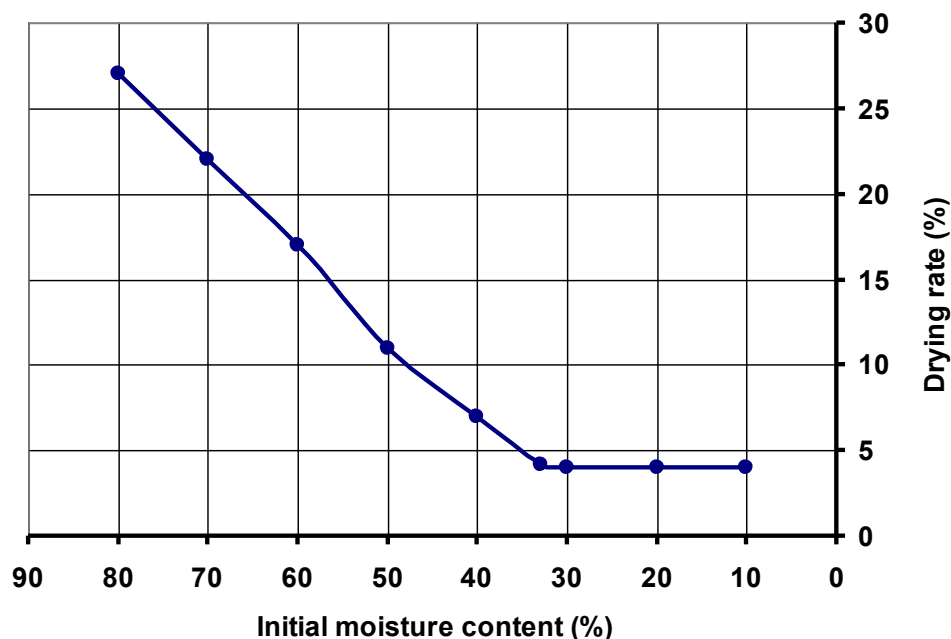


Figure-5. Change of moisture content in the dried alfalfa depending on initial moisture content of green alfalfa.



It is set that the drying rate defined as change of alfalfa moisture content during its moving through one section of the drying camera decreases in case of reduction of initial moisture content of green alfalfa. It is set that further decreasing of drying rate does not happen and it remains to a constant in case of reduction of alfalfa initial moisture content lower than the level of 32-33 %. This fact hypothetically is interpreted by the fact that deleting of chemically bound water from plant tissue begins in case of alfalfa moisture content of 32-33 %. A lot of energy is necessary for implementation of this process.

The change diagram of carotene content in dried alfalfa during the winter storage period is shown in Figure 6.

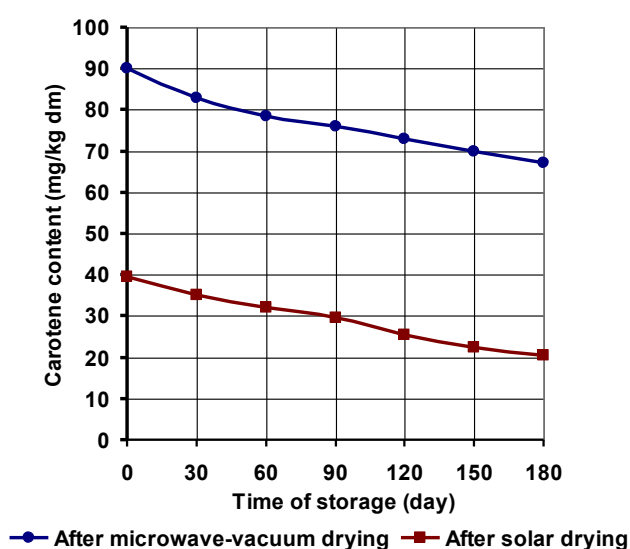


Figure-6. Change carotene content in dried alfalfa during the winter storage period.

It is set that the carotene content in alfalfa which is dried by microwave-vacuum drying method during 180 days decreased by 25.5 %. Carotene content in alfalfa which is dried by solar drying method during 180 days decreased by 48.1 %.

Decreasing of carotene content in alfalfa which is dried by microwave-vacuum drying method was observed most intensively during 0-60 days since the beginning of storage. Carotene content decreased by 13.8 % during this period. Carotene content in alfalfa decreased by 11.7 % in comparison with initial content during the period of 60-180 days since the beginning of storage.

Carotene content in alfalfa which is dried by solar drying method decreased uniformly during the all storage period of 0-180 days.

Results of this experiment prove that application of a microwave-vacuum drying method ensures good safety of carotene in the dried alfalfa during the winter retention period.

DISCUSSIONS

Results of experiments confirmed efficiency of a microwave-vacuum drying method for dehydration of vegetable raw materials. Discovery the fact of high carotene safety during a microwave-vacuum drying of green plants, in particular alfalfa is new experimental result.

Low level of carotene destruction during of a microwave-vacuum drying is explained by the fact that use of vacuum allows to realize drying at lower temperature. Low level of carotene destruction during the storage period of the dried alfalfa hypothetically is explained by the carotene isomerization causing transformation of β -carotene into α -carotene that reduces its oxidation by air oxygen.

CONCLUSIONS

Application of a microwave-vacuum drying method ensures good carotene safety in a alfalfa not only directly after drying, but also during the winter period of its storage.

Temperature of 120-140 °C is rational for microwave-vacuum drying of alfalfa as the minimum reduction of carotene content is observed in case of this mode. It is set that the carotene content in alfalfa which is dried by microwave-vacuum drying method during storage period of 180 days decreased only by 25, 5 %.

The microwave-vacuum drying method with use of the apparatus of the continuous action is perspective for the organization of alfalfa industrial drying, and also other forage and officinal herbs.

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