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DRYING KINETICS OF APRICOTS KERNELS

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Abstract. In this paper, we proposed convective and combined methods for drying wet kernels of apricot stones. Kernels of apricot stones are a very ambiguous food product, during their heat treatment in them occurs not only the loss of mass due to the removal of moisture, but also the loss of mass due to biochemical changes occurring at high temperatures. It was experimentally established that the drying process should be carried out in two stages: the first stage lasts until the critical moisture content of 110 % (by total weight of solids) is reached and it should be implemented by convective energy supply (100 °C). The second stage lasts until the equilibrium moisture content of 30 % is reached, using a combined energy supply (convention + UHF) with the strength of the electromagnetic field E = 1.8 * 10^4 V·m^{-1}.

Keywords: *air-solar drying, drying curves, drying speed curves, combined method, kinetic, kernel of apricot stone*

Introduction

Everyone is looking forward to the summer, waiting for apricots. Apricot is a delicious and healthy fruit is a favorite fruit of many children and adults, and apricot seeds, being a very ambiguous food product, are thrown away without even thinking about their taste.

Apricot stones are a healer of human cells. All because their kernel contains a rare vitamin B_{17}, which includes cyanide substance. When cyanide enters the body, cancer cells either die or are healed [1]. In stone kernel, it is concentrated from 35 to 60 % of non-drying fatty oil. Its chemical composition is very similar to peach oil. The composition is dominated by oleic and linolenic fatty acids. The substance contains a low acidity and a minimum degree of viscosity. Also kernels contain: glucoside amygdalin, emulsin, lactase and hydrocyanic acid.

In addition to healing cancer cells, the apricot kernels are the most effective remedy for bronchitis, whooping cough and nephritis. Apricot kernels are useful and due to the fact that they help to fight the human body against various parasites, including worms. In this case, the kernel should be eaten raw. In addition, people with cardiovascular problems consume apricot seeds. Kernels can be eaten raw, dried or roasted, but not more than 20 grams at a time. 100 grams of apricot kernels contain more than 450 kcal [1 - 3].

Apricot kernels are the favorite delicacy of people who want to gain a couple pounds. After all, kernels contain a lot of vegetable oil, which is well absorbed in the human body. In addition, many athletes use the kernel in food, because they provide huge amounts of energy.

Apricot kernels are very often used in medicine. Even in Ancient China, healers used apricot kernel oil to treat skin and joint diseases. In medicine, apricot kernel oil is also used for massage, because it is very well absorbed by human skin. In addition, the oil is added to shampoos, which contribute to the fight against dandruff. In many cosmetic companies, oil is used as an additive for natural creams and scrubs.

Apricot kernels are widely used in cooking in the form of powders, which are added into glazes, ice cream, yogurts, creams and other dairy products.

Materials and Methods

The purpose of this work was an experimental study of the drying process of the kernels of the apricot stones by convective and combined - convection + UHF (high frequency currents) methods.

In general, air-solar drying is applied on unsuitable open areas, this way the apricot stones clutter the territory of factories, raw sites, creating unsanitary conditions. The use of this method of drying, due to the processing time reduces kernels' quality. It is important that during the drying process, the properties of the product are preserved and improved; they play a decisive role, determining its qualitative indicators.

In order to intensify the drying process, increase economic efficiency and improve environmental conditions was proposed the drying of moist kernels of apricot stones by convective and combined (convection + UHF) methods.

The investigations were carried out on the experimental setup already described [4 - 7]. The drying was performed by using moist apricot stones of «Krasnosciokii» variety with the moisture content U^c = 146 %.

To record the weight loss in the studies, a mechanical scale of the type ВНЦ – 200 was used. The speed of air supplied to the drying chamber was maintained constant automatically and was 1.1 $m \cdot s^{-1}$. The air parameters were determined up to the air heater (initial temperature t_0 and relative humidity ϕ_0) and after the air heater (t_1).

In the first part of the study, were studied the kinetics of convective drying at drying agent temperatures of 60, 70, 80, 90 and 100°C. Mass loss was measured every 5 minutes, dehydration was conducted until equilibrium humidity of 30 %.

Figure 1a shows the drying curves U = f (τ) of apricot kernels. As it can be seen from the drying curves, the drying process duration at a temperature of 60°C was 620 minutes, and for a temperature of 100°C, 220 minutes, decreasing by 2.85 times.

Figure 1.b shows the drying rate curves, which are typical curves having a warm-up period, the 1st and 2nd drying periods [8, 9].

Based on the experimental data, the drying rates in the first period were calculated. Table 1 shows the drying temperature, t_1, °C; critical humidity, u_{cr}, %; drying rate in the 1st period, $\left(\frac{dU}{d\tau}\right)$, $\% \cdot s^{-1}$, the drying rate constants of the 1st, K_1, and the 2nd, K_2, periods, warm-up time, $\tau_{warm\text{-}up.}$, min, and drying time of the 1st, τ_1, min, and 2nd, τ_2, min, periods. In the second part of the experiment, was studied the influence of high-frequency heating in combination with the convective method of energy supply on the kinetics of drying under various regimes of electromagnetic field strength E = $8.75 \cdot 10^3$ $V \cdot m^{-1}$ and E = $1.8 \cdot 10^4$ V m^{-1}.

Table 1

Experimental data on the drying kinetics of apricot stones by the convective method

№	t_1, ˚C	U_{cr}, %	$\left(\frac{dU}{d\tau}\right)_1$, $\%\cdot s^{-1}\cdot 10^3$	K_1, $\%\cdot m^{-2}\cdot s^{-1}$	K_2, $s^{-1}\cdot 10^6$	$\tau_{warm\text{-}up}$, min	τ_1, min	τ_2, min	τ_{total}, min
1	60	90	6.46	58.6	1.6	100	240	280	620
2	70	90	8.62	63.5	3.2	89	184	232	505
3	80	95	11.18	65.9	4.0	78	158	169	415
4	90	95	15.74	84.35	4.98	59	122	137	318
5	100	95	23.61	107.1	5.6	35	91	94	220

The results of the studies are shown in Figure 2a, b in the form of drying curves and drying rate curves.

As can be seen from the graphs, the imposition of high-frequency electromagnetic fields in combination with the convective method greatly intensifies the drying process.

At the same time, as the intensity of the electromagnetic field increases, the period of drying process for different temperatures decreases. Thus, at a temperature of 60°C and an electromagnetic field strength of $8.75\cdot 10^3$ V· m^{-1}, the drying process time to 30 % humidity was 410 minutes, and at $1.8\cdot 10^4$ V· m^{-1} it was 370 min. - decreased by 40 min.

If we compare the dehydration process at minimal temperature and intensity of the electromagnetic field (t = 60°C and E = $8.75\cdot 10^3$ V· m^{-1}), with the maximum temperature and field intensity (t = 100°C and E = $1.8\cdot 10^4$ V · m^{-1}), the dehydration time from 146 % to 30 % decreased by 2.8 times.

Reducing the duration of the apricot stones drying is due to a more intensive release of heat per unit volume of kernels with an increase in the intensity of the electromagnetic field

In the case of high-frequency heating of dielectrics and semiconductors, heating is uniformly distributed over the entire volume due to the arising polarizing effects.

Therefore, the speed of the process of drying the kernels using UHF rapidly increases as the material warms up and, after reaching the maximum value, begins to decrease. In this case, the greater the intensity of the electric field, the shorter the time of increase and subsequent decrease in the drying rate, i.e. 1 st and 2 nd periods.

When the temperature of the drying agent 60 °C (Figure 2b) and electromagnetic field strength E = $8.75\cdot 10^3$ V · m^{-1} maximum rate was 0.00741 $\%\cdot s^{-1}$, and at the same temperature, and E = $1.8\cdot 10^4$ it was 0.00873 $\%\cdot s^{-1}$, i.e. increased by 17.8 %. With increasing temperature, the value of the maximum rate of the drying process also increases. If the maximum rate is 0.00741 %· s^{-1} at a temperature of 60 ° C and E = $8.75\cdot 10^3$ V· m^{-1} (Figure 2b), then at the temperature of 100°C (Figure 2b) and with the same intensity, the rate was 0.0147 $\%\cdot s^{-1}$, i.e. increased 2 times.

Results and discussion

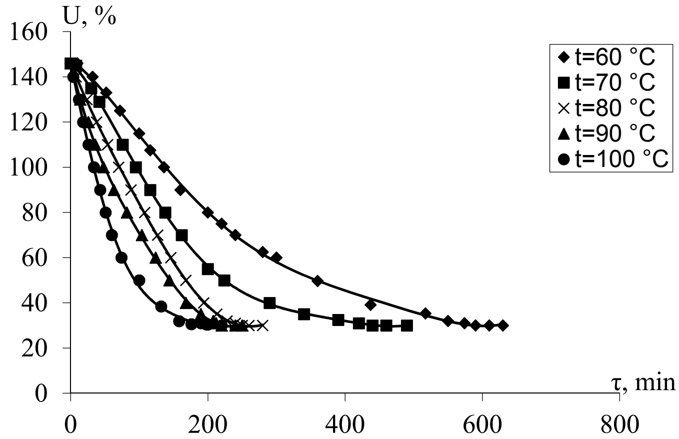
Taking into account [4 - 8], it can be assumed that, judging by the nature of the drying rate curves for apricot kernels, the physico-mechanical and physico-chemical forms of the bond of moisture to the material are inherent.

As for the convective method, the kinetic characteristics of the drying process were calculated for the combined method of convection + UHF for different field strengths, the values of which are given in Table 2.

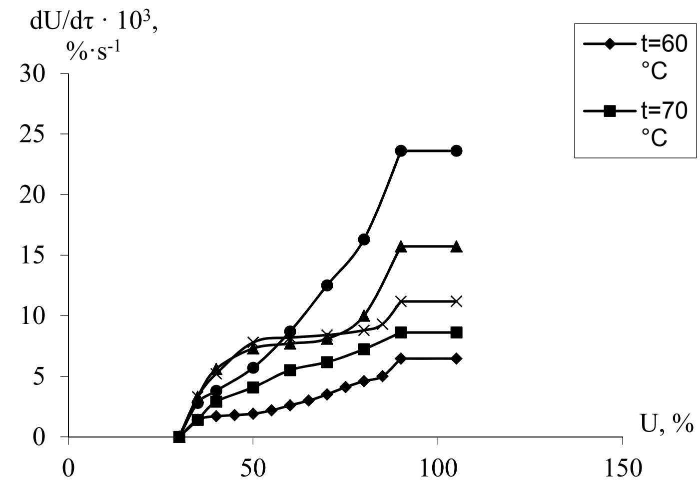
Table 2

Experimental data on the drying kinetics of apricot kernels in a combined method - convection + UHF

№	t_1, ˚s	U_{cr},%	$\left(\frac{dU}{d\tau}\right)_1$, %·s^{-1}· 10^3	K_1, %·m^{-2}·s^{-1}	K_2, s^{-1}·10^6	$\tau_{warm-up.}$, min	τ_1, min	τ_2, min	τ_{total}, min
The electric field strength E = 8,75·10^3 V· m^{-1}									
1	60	70	7.41	67.2	3.53	80	235	85	410
2	70	69	8.93	65.8	4.09	56	223	61	340
3	80	69	9.59	56.6	4.65	28	193	59	280
4	90	70	11.61	62.2	5.86	25	187	48	260
5	100	70	14.72	76.8	6.45	17	165	33	215



a)



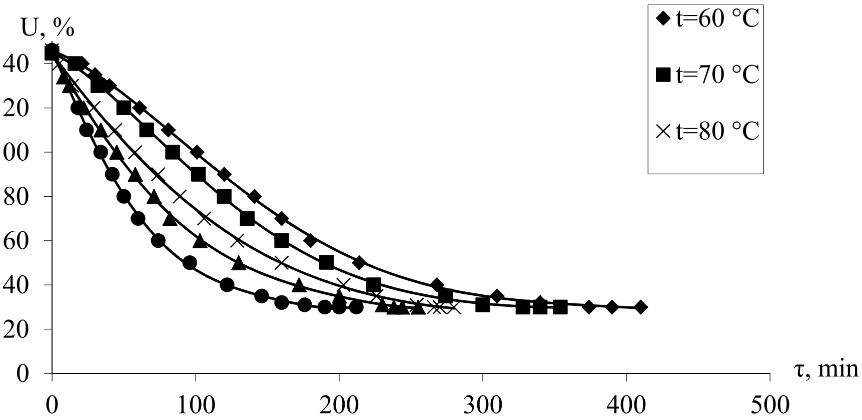
b)

Figure 1. The drying curve (a) and drying rate (b) of kernels of apricot stone by convective energy supply

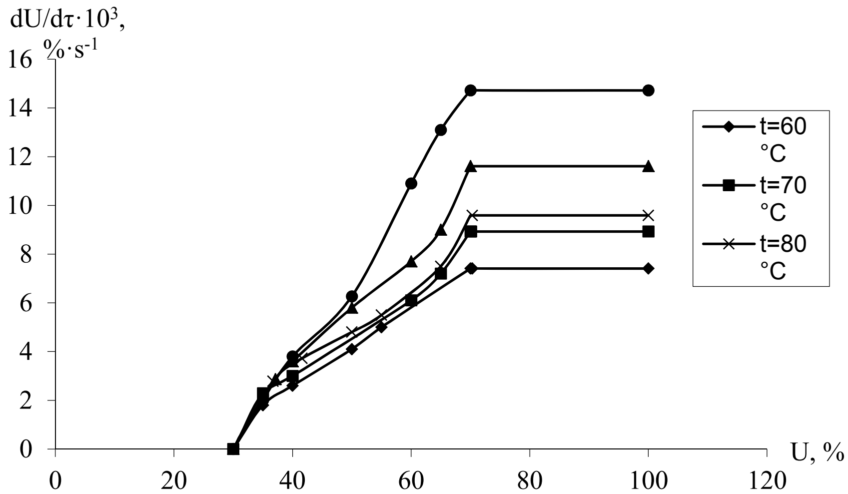
For the 2nd period the drying rate constant K_2 at temperature 60°C has changed with an increase in electromagnetic field intensity from $3.53 \cdot 10^{-6}$ s^{-1} to $4.04 \cdot 10^{-6}$ s^{-1} which represents 14.4 %. The influence of temperature from 60 ° C to 100 ° C led to an increase of the drying rate constants from $3.53 \cdot 10^{-6}$ to $6.45 \cdot 10^{-6}$ at E = 8.75 10^{3} V m^{-1}, i.e. by 82.7 % , and at E = $1.8 \cdot 10^{4}$ V m^{-1}, the increase of K_2 from $4.04 \cdot 10^{-6}$ s^{-1} to $9.55 \cdot 10^{-6}$ s^{-1} was 136 %.

These values show that the effect of UHF on drying is significant, especially in the 2nd period. This is obviously due to the influence of UHF on the structure of the product and on the state of water in the material.

The obtained results of studies of the drying process of apricot stone kernels in the convective heat input (Figure 1) and the combination of convective heat supply with heating in the electric field of high frequency currents (Figure 2) showed that the kernels are a complex organic product.



a)



b)

Figure 2. The drying curve (a) and drying rate (b) of kernels of apricot stone in a combined way at an electromagnetic field with the strength E = 8.750 $V \cdot m^{-1}$

During the heat treatment process, in the kernels of apricot stone the mass loss occurs not only due to the removal of moisture (which is typical for most wet materials), but also due to biochemical changes occurring in them at high temperatures. Therefore, the rationale for the drying method for such products as kernels of apricot stone should be carried out considering these features. Studies have shown that the most prolonged is the drying process with convective heat supply. Thus (Figure 1), the duration of dehydration at a temperature of the drying agent 60 °C was 620 minutes and at 100 °C - 215 minutes. With a combined power supply and at the same temperatures and field strength $E = 1.8 \cdot 10^4$ V·m^{-1}, the drying time is 365 and 145 min, respectively, i.e. it decreased more than 2.5 times. If we compare the drying time at the minimum temperature of the convective method with the maximum values (100 °C and $E = 1.8 \cdot 10^4$ V·m^{-1}) of the combined method of dehydration of apricot stone kernels, then the process intensifies more than 3 times.

The application of various drying methods has an effect on the nature of the ongoing process. So, with convective heat input, the curve of drying speed includes two periods - a period with a constant speed and a period with a falling rate [2 - 4].

As the Figure 1 shows, with a convective heat supply, the drying rate increases with a drying agent temperature from 0.0065 %·s^{-1} to 0.0236 %·s^{-1}. With the use of combined energy supply, the intensity of dehydration increases in proportion to the temperature of the hot air and the intensity of the electromagnetic field. Thus, at a temperature of 100°C and $E = 1.8 \cdot 10^4$ V·m^{-1}, compared with a temperature of 60°C and $E = 8.75 \cdot 10^3$ V·m^{-1}, it increased almost 3 times.

Conclusions

From the carried out studies, it can be seen that high-frequency heating in combination with a convective energy supply method is more promising for the process of dehydration of apricot stone kernels. The drying process is best carried out, as studies have shown, in two stages. In the first stage, prior to obtaining a critical moisture content 110 % of the kernel, a convective energy supply (100 ° C) should be carried out, in the second stage, using a combined energy supply (convention + UHF) at an electromagnetic field strength $E = 1.8 \cdot 10^4$ V m^{-1}.

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