Physico-chemical characteristics of dried green onion semi-finished products and their rehydration ability

Vitalii Shutyuk, Olha Dushchak, Oleksandr Bessarab

National University of Food Technologies, Kyiv, Ukraine

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Corresponding author:

Vitalii Shutyuk
E-mail: schutyuk@i.ua

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Abstract

Introduction. Studies of the drying process of green onions were conducted to determine the physico-chemical characteristics of dried semi-finished products and their ability to rehydrate.

Materials and methods. Green onions were dried at three different drying agent temperatures of 50, 60 and 70 °C. The speed of the airflow through the layer of raw materials was 1.3 m/s. For combined drying, a laboratory setup consisting of a DHG-9000 A drying chamber and an LG MF 6543 AF household microwave oven was used. Color parameters were determined by processing photos in the Adobe Photoshop graphic editor taken with a CANON EOS 80D camera using the HunterLab scale.

Results and discussion. During convective dehydration of green onions at drying agent temperatures of 50 and 60 °C, a constant speed section is observed, namely for 50 °C from 150 to 240 min of drying, and for 60 °C from 90 to 150 min of drying. For an air temperature of 70 °C, the section is almost absent.

The use of a two-stage method of drying green onions is more efficient in terms of energy and dehydration time. This technology involves two stages: the first convective method lasting 60 min at a drying agent temperature of 60 °C and the second one being microwave drying.

When restoring dried green onions, the rehydration rate increases with increasing water temperature from 0.026 min^{-1} at a water temperature of 50 °C to – 0.028 min^{-1} at a temperature of 70 °C. The equilibrium moisture content also increases from 5.65 to 6.15 kg of moisture per kg of dry product, respectively.

The drying temperature affected the parameters L, a, b on the HunterLab scale. Thus, the value of parameter "a" for fresh onions is 34, and for onions dried at a drying agent temperature of 50 °C is –10, for 70 °C it makes –12. The total color difference ΔE is about 33, which indicates a significant influence of drying duration on the color change of green onions.

Conclusions. The obtained results of the study of the physico-chemical characteristics of dried green onions in various ways will allow the production of higher-quality semi-finished products and competitive food products based on them.

Introduction

The global Spices and Seasonings market size was estimated at USD 20.19 billion in 2024 and is expected to grow at a CAGR (compound annual growth rate) of 4.89% from 2025 to 2032 (Spices and Seasonings Market, 2024). The use of spices and seasonings has been around throughout human history, and these natural plant products are included as ingredients in the formulation of various foods and drinks to give them specific taste and aroma (Kochubei-Lytvynenko et al., 2022; Lamkey, 2022; Stabnikova et al., 2021).

Green onion (also known as Welsh onion: *Allium fistulosum* L. belonging to the onion family *Alliaceae*) is originated from Central Asia, and are cultivated and traded around the world now as vegetable being fresh, or as spice being dried and grounded. *Allium* is a large genus of monocotyledonous flowering plants and its representatives including *Allium fistulosum* are widely used as ornamental flowers to decorate garden landscapes. It is a stable ingredient in different culinary dishes and at the same time is well known as a traditional medicinal plant because of its antioxidant, anti-inflammatory, and antimicrobial properties (Kim et al., 2023). Green onions used in folk medicine to treat colds, headaches, wounds, eyesight problems, reduce blood pressure, cholesterol level, fat accumulation and the risk of ischemic heart disease (Singh and Ramakrishna, 2017). Recent research showed in a randomized, double-blind, placebo-controlled trial on humans that Welsh onion green leaves extract may support and enhance immune function in healthy adults and help prevent infectious diseases such as colds and flu (Hirayama et al., 2019).

Allium fistulosum leaves contain, mg/100 g FW: dry matter, 10.6 – 10.8, total sugars, 3.9 – 4.0 (Čepulienė et al., 2024), soluble proteins, 730 (Štajner et al., 2006), and fat, 200 (Kim et al., 2023). Green onion leaves contain also vitamins of group B, μg/100 g FW: thiamine (B1), 0.05; riboflavin (B2), 0.09; niacin (B3), 0.40; and folic acid (B 9), 16 (Singh and Ramakrishna, 2017). Content of minerals consist, mg/100 g FW: calcium, 18; magnesium, 23; phosphorus, 49; iron, 1.2, and zinc, 0.52 (Singh and Ramakrishna, 2017).

Allium fistulosum leaves is a good source of β-carotene, and its content in leaves was 4.63 mg/100 g of fresh weight (FW) (Umehara et al., 2006). The main carotenoid determined in the onion leaves was lutein, followed with β-carotene, neoxanthin, violaxanthin, and antheraxanthin, with total content of carotenoids 5.47 mg/100 g FW (Kopsell et al., 2010). However, much higher carotenoid content, 287 mg/100 g FW was reported in (Štajner et al., 2006). Content of vitamin C in green onions consisted 16.1 mg/100 g FW (Štajner et al., 2006).

Green onion leaves are rich in polyphenolic compounds, containing, μg/100 g FW: p-coumaric acid,11.05; ferulic acid, 499.01; isoquercitrin, 29.14; quercitrin, 73.22; quercetol, 101.97; kaempferol, 153.94 (Vlase et al., 2013), and especial high content of flavonoids, 4.66 g/100 g FW (Štajner et al., 2006). Due to high content of these bioactive compounds, *Allium fistulosum* leaves exhibit significant antioxidant activity (Chang et al., 2013).

Green onion possess antibacterial properties, and it was shown inhibition effect of water, ethanolic, and petroleum ether extracts from leaves of *Allium fistulosum* on the growth of opportunistic pathogens, mainly bacteria *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Escherichia coli* (Kumbhkar et al., 2023).

Green onions are a low-calorie product containing around 32 kcal/100 g FW (Kim et al., 2023). Being rich in biological active compounds and low in fat and calorie, green onions are fully satisfy requirements of diet for weight management and obesity prevention (Stabnikova and Paredes-Lopez, 2024; Sung et al., 2018).

Therefore, the physical and chemical characteristics of fresh green onions have been well studied. However, when harvested, spice plants may lose quality during drying, which

is fundamental process to keep the product good quality. The changes occurring in the green part during the drying process to obtain semi-finished products have not been sufficiently investigated, and there is not enough data on the ability of dried semi-finished products to rehydrate.

Drying is one of the most commonly used methods for preserving the material with high initial moisture contents helping to maintain minerals, inhibit microbial activity, as well as reduce transportation costs, handling, and storage. It removes much of the water from the plant soon after physiological maturity aiming to reach the moisture content ideal for long-term storage. Post-harvest conservation by drying relies on the fact that microorganisms, enzymes, and the metabolic mechanism require a certain amount of water to perform their activities. Reducing the water available in the plant will consequently reduce water activity, the rate of chemical reactions, the enzymatic degradation, and the microorganism growth (Hansen et al., 1993). However, due to undesirable changes in the quality of products dried with the pre-treatments and drying conditions, this process needs further studies (Maskan, 2000).

Thus, the aim of the present study was to investigate the drying process of green onions and their ability to rehydrate to determine the modes that allow producing higher quality semi-finished products.

Materials and methods

Materials

Green onions of the Parade variety was used in the research. When selecting raw materials for analysis, the following indicators were taken into account: the presence of a green stem of the uniform color, a light and pleasant taste with notes of onion and aroma, and the absence of defects.

Methods

Determination of physical-chemical characteristics of green onion

Green onion leaves (only green part) were washed and cut into pieces about 1 cm long. To determine the composition of the raw material generally accepted standard methods were used. Content of vitamin C was determined according to (Mohammed et al., 2014)

Kinetics of drying

To study the kinetics of dehydration, a layer of raw material with a height of about 3 cm of material was used. Green onions were dried at three different temperatures of the drying agent 50, 60 and 70 °C (taking into account the limitation of the browning temperature). The speed of the air flow through the layer of raw material was 1.3 m/s. All experimental results were obtained during drying by weighing the samples every 15 minutes until a constant weight was reached. Next, the mass fraction of moisture in the dried samples was determined. The mass fraction of moisture at different drying times was determined from the mass of the sample and its final moisture content. The obtained samples were analyzed using the dimensionless coefficient of moisture content (W, kg of moisture/kg of material).

Rehydration rate

The rehydration rate analysis was performed with samples dried at 50, 60 and 70 °C. In all cases, the mass fraction of moisture in the sample was less than 10.4%. The samples were weighed, placed in a special paper bag, weighed again, and then immersed in heated water. At a certain time, they were removed from the water and weighed. The rehydration rate was calculated using equation (1) (Krokida et al., 1997). The weight of the moistened bag was determined earlier.

$$d(W)/d\tau = -k(W - W^{eq}), \quad (1)$$

where W is the moisture content in the material during rehydration, kg/kg; τ is the rehydration time, min.; k is the rehydration rate, min^{-1}; W^{eq} is the equilibrium moisture content in the material, kg/kg.

Color

Color parameters were determined by processing photos in Adobe Photoshop taken with a CANON EOS 80D-camera на штативі QZSD (Beike) Q160H. The color parameters on the HunterLab scale were L (light or black-white axis), a (green-red axis) and b (blue-yellow axis). For each sample of green onion (fresh or dried at 50, 60 or 70 °C) five repetitions were made, the photos were previously blurred in a graphics editor. Another generalizing color parameter was the total color difference (ΔE):

$$\Delta E = \sqrt{(L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2} \quad (2)$$

Statistics

All experiments were carried out at least in triplicate, and mean ± standard deviation are shown.

Results and discussion

Proximate composition of green onion

Proximate composition of green onion and the content of vitamin C is shown in Table 1.

Table 1

Proximate composition of green onion

Plant object	Moisture content, %	Total sugars, %	Proteins, %	Fats, %	Fiber, %	Vitamin C, mg/100 g
Green onion	93±0.5	3.2±0.4	1.1±0.4	0.1±0.02	1.5±0.2	15.4±1.0

The most important component determine the yield and quality of dried products are the content of dry matter, sugars, and main biochemical components (Martinazzo et al., 2016). It was found that the average content of moisture varied between 91 and 92%. It is worth noting that the content of sugars is one of the most important characteristics that determine the possibility of drying a particular type of raw material (Luciano et al., 2007). Content of total sugars in green onion was 3.2±0.4% FW. It was shown that the predominant sugars in green onions are monosaccharides, namely glucose and fructose (Kim et al., 2023), but they also consist of maltose, rhamnose, galactose, arabinose, mannose, and xylose in low amounts (Singh and Ramakrishna, 2017). The total carbohydrate content of the studied sample was 4.9%, with fiber accounting 53% of the total amount of carbohydrates. Low contents of protein, 1.2%, and fat, 0.8%, were determined in fresh green onion with the moisture content 93%. The content of vitamin C in the green onion was 15.4%. Green onion with established chemical composition were used as origin material for further studies.

Kinetics of drying

The process of heat treatment of raw materials was considered complete when the control value of moisture content W_c = 0.104 kg/kg (10.4%) was reached. Studies of the process of drying green onions under constant conditions at different temperatures showed that increasing the temperature of the drying agent significantly reduces the drying time (Kumar et al., 2021; Yevchuk et al., 2023). Thus, at a hot air speed of 1.3 m/s, the duration of drying raw materials is more than 300 min at a temperature of 50 °C and less than 150 min at 70 °C (Figure 2).

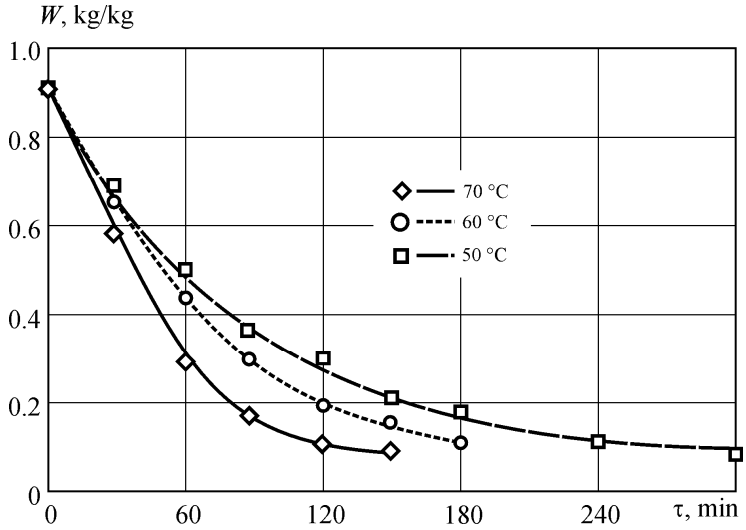

Figure 2. Change in content of moisture in green onions during drying at different temperatures and drying agent speed of 1.3 m/s

The maximum rate of change in the mass fraction of moisture significantly depends on the temperature of the drying agent (Fig. 3). Thus, an increase in the hot air temperature from 50 to 70 °C for 30 minutes of dehydration led to an increase in the maximum rate of change

in moisture content in green peas from 0.0083 kg/(kg·min) to 0.0115 kg/(kg·min) (Kumar et al., 2021). In the curves of the dehydration rate of green onions for drying agent temperatures of 50 and 60 °C, a constant speed section is observed, namely for 50 °C from 150 to 240 min of drying (0.001 kg/(kg min)), and for 60 °C from 90 to 150 min of drying (0.004 kg/(kg min)). For an air temperature of 70 °C, the section, in our opinion, is not significant and in Fig. 2 is absent, which is confirmed by its decrease for temperatures of 50 and 70 °C from 90 to 60 min.

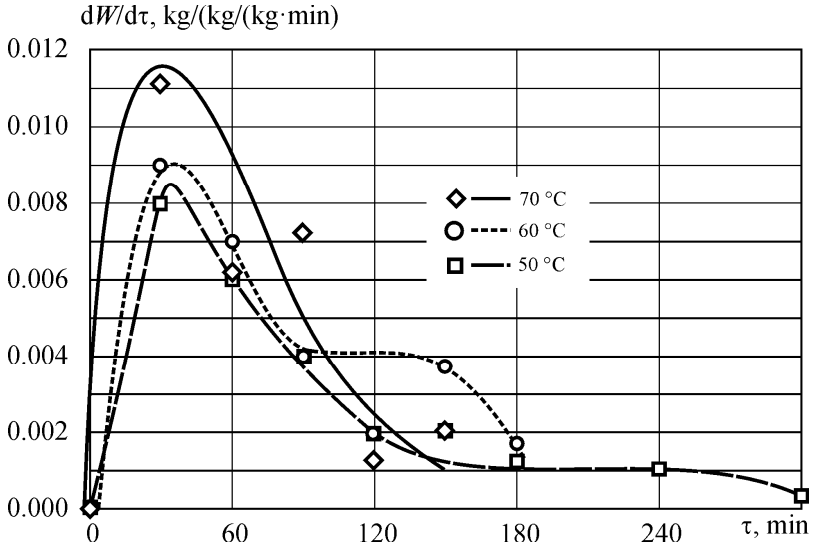

Figure 3. Change in rate of dehydration of green onions during drying at different temperatures of drying agent and speed of 1.3 m/s

The experiments conducted to determine the kinetics of green onion drying confirmed the feasibility of combining microwave and convective methods (Fig. 3). They indicate that the duration of drying by microwave is significantly shorter compared to the traditional convective method. Thus, for green onions, the difference in the duration of drying by these methods is about 130 minutes.

Using only microwave drying for green onions significantly reduces the duration of the process, but the quality of the product received deteriorates due to partial carbonization of the tissues. In this case, one of the main reasons affecting the quality of dried products is the need to change the power of the microwave emitter, due to the periodicity of the installation, and microwave emitters have discrete positional power control, which cannot sufficiently provide the necessary change in the drying mode.

Given the significant energy costs of microwave drying, the authors conducted additional studies that involved drying in two stages: the first is a convective method lasting 60 min (to a moisture mass fraction of 0.41 kg/kg); the second is microwave drying. The two-stage drying method proved to be effective and significantly reduced the dehydration time, these results correlate with the results of combined dehydration of banana, carrot and grape (Dehnad et al., 2012). In addition, it was achieved to obtain dry green onions with a lower moisture content compared to the convective method.

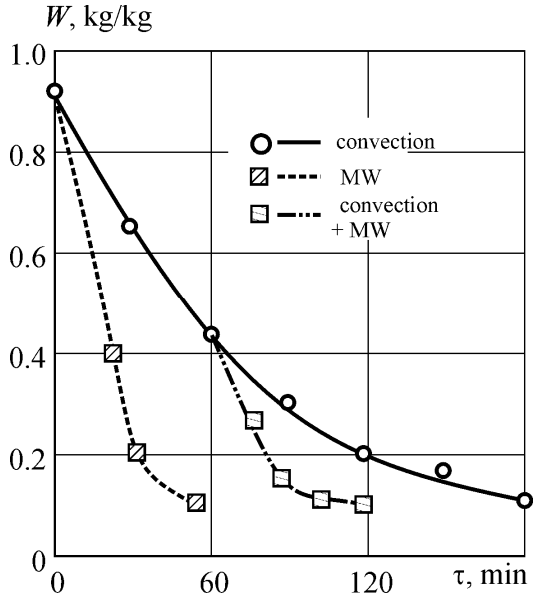

Figure 3. Change in moisture content of green onions during drying process by microwave and convective methods in different combinations

Rehydration rate

The kinetics of rehydration of dry green onions was studied at water temperatures of 50, 60 and 70 °C. The results of measuring the mass fraction of moisture in the material show that the rehydration rate and equilibrium humidity are higher for higher water temperatures (Fig. 4). Thus, for a temperature of 50 °C, the equilibrium humidity is 5.5 kg/kg, and at 70 °C it is 6.0 kg/kg. Moreover, the data indicate that the equilibrium moisture content during hydration is reached after 120 s, and almost three quarters of the equilibrium state of the product is reached by 30 s of the rehydration process.

The kinetics of rehydration of dried green onions depending on the water temperature (see Fig. 4) can be described with sufficient accuracy in the form of logarithmic dependences given in Table 2; while the rehydration rate determined by equation (1) increases from 0.026 min^{-1} at a water temperature of 50 °C to – 0.028 min^{-1} at a temperature of 70 °C. Also, with increasing hydration temperature, the value of the equilibrium moisture content W^{eq} increases from 5.65 to 6.15 kg/kg, respectively (Fig. 5). The obtained data and dependences correspond in nature to the results of studies (Shutiuk et al., 2014) on the rehydration of potatoes, mushrooms, pumpkins, apples and carrots.

Color

During the drying of green onions, significant color changes occurred. The drying temperature affected the parameters L, a, b. The parameters L and “a” of the dried samples differed significantly from the fresh material (Fig. 6).

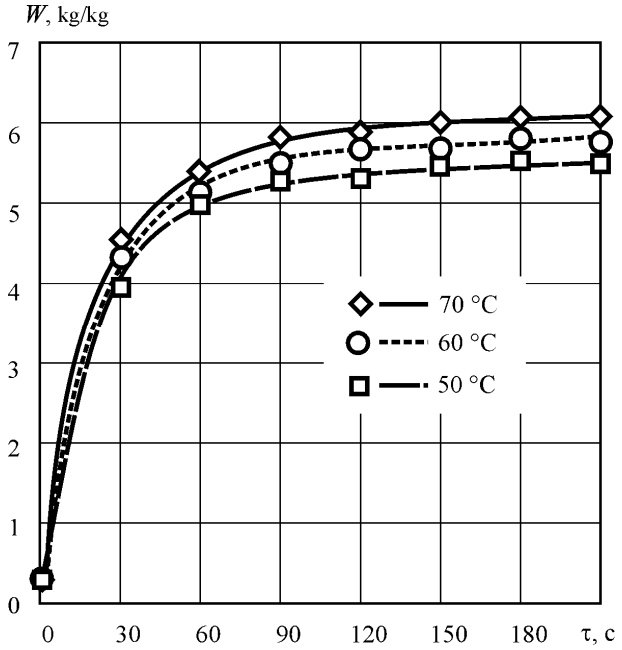

Figure 4. Change in moisture content of dried green onions depending on temperature of water during hydration

Table 2

Correlation of mass fraction change of green onions during rehydration

Water temperature (t, °C)	**Regression equation** *(W = f(τ))*	**R²**
50	$W = 1.0325\ln(\tau) + 0.3643$	0.9856
60	$W = 1.0915\ln(\tau) + 0.3798$	0.9844
70	$W = 1.1412\ln(\tau) + 0.3939$	0.9840

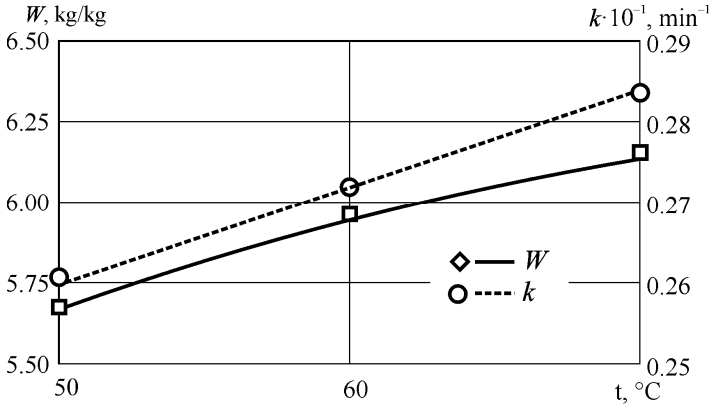

Figure 5. Effect of hydration temperature on rehydration coefficient (*k*) and equilibrium moisture content (W^{eq})

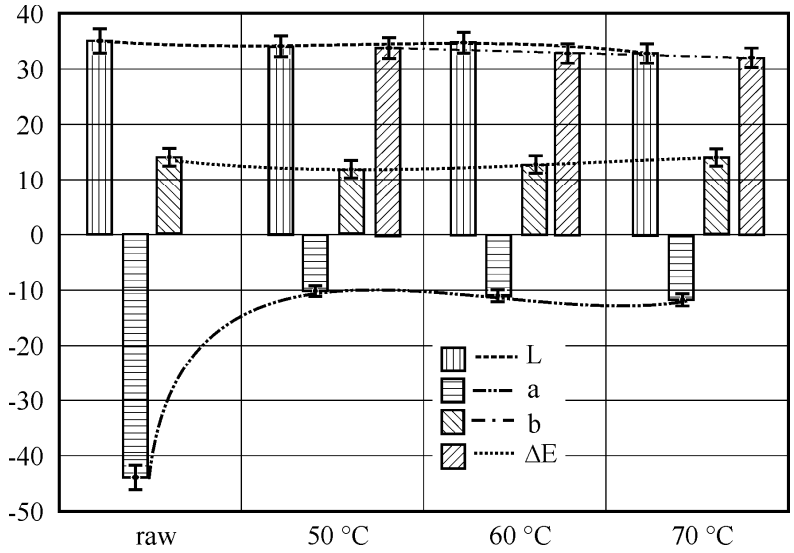

Figure 6. Changes in color parameters of raw green onions and those dried at different drying temperatures in the Lab color system

The parameters L are higher in the dried product (lighter), and the parameters a have significantly smaller negative values, which indicates a decrease in the intensity of the green color. Thus, the value of the parameter "a" for fresh onions is 34, and for those dried at a drying agent temperature of 50 °C it is 10, for 60 °C it makes 11 and for 70 °C it is 12 (respectively). The total color difference ΔE is about 33, which indicates a significant influence of the drying duration on the color change of green onions. The greatest color changes during drying occur at a drying agent temperature of 70 °C (Fig. 7).

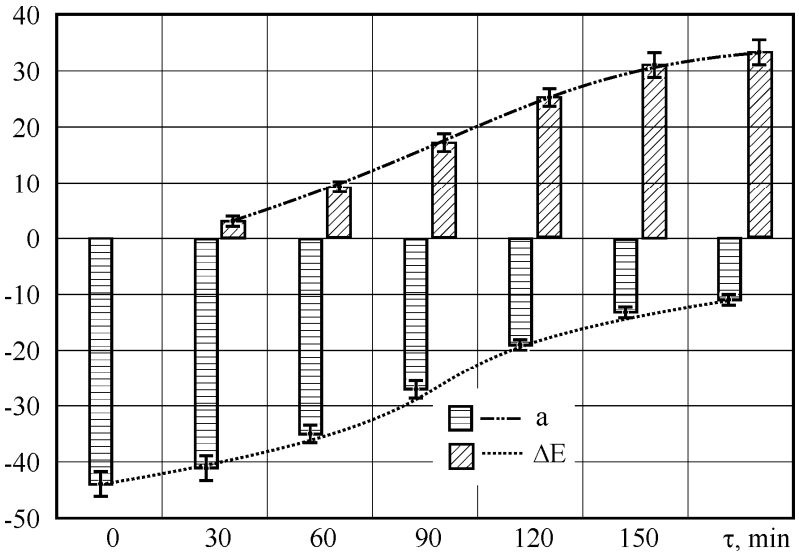

Figure 7. Changes in color parameters a and ΔE in the Lab color system of green onions drying at a drying agent temperature of 70 °C

Similar results with color changes were obtained in study (Demirhan and Özbek, 2014) during drying of basil in various ways. When using the microwave drying method, a sharp change in the values of a from –44 to –7 and, accordingly, the total color difference ΔE to 37 is observed (Fig. 6), which is explained, according to the Lab system, by the degradation of the green pigment of chlorophyll and its transition to yellow.

The use of the combined drying method at the stage of the beginning of the decreasing rate of dehydration (see Fig. 3) significantly reduces the duration of the process, but has less effect on the loss of green pigment compared to microwave drying. Thus, the value of the parameter a for the microwave drying method is –7, for the convective method it is –11, and for the combined method –9 (Fig. 8) significantly reduces the duration of the process, but has less effect on the loss of green. Accordingly, the use of the combined drying method allows not only to reduce the dehydration time compared to the convective method, but also to lose less green pigment compared to the microwave method.

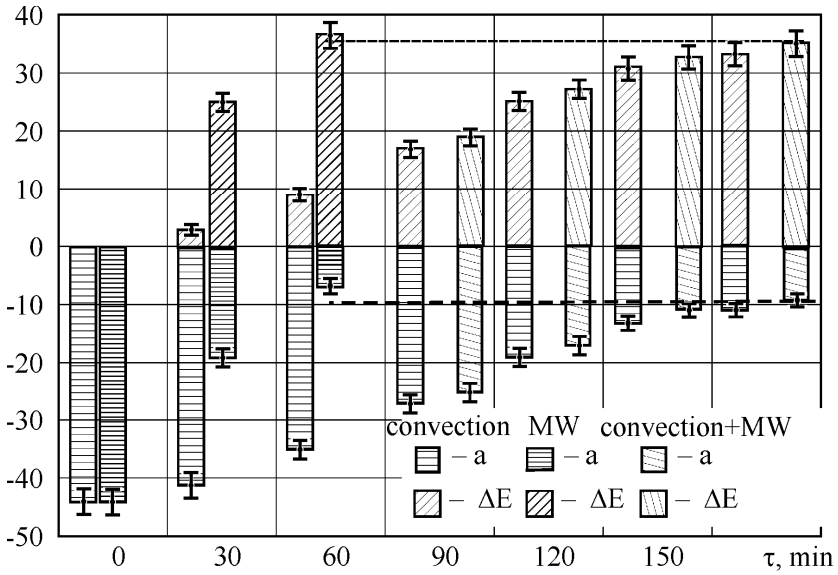

Figure 8. Changes in color parameter a and the total color difference ΔE of raw green onions during drying in different ways

Conclusions

1. The results of the research show that the dehydration rate of green onions for drying agent temperatures of 50 and 60 °C shows a constant speed section, namely for 50 °C from 150 to 240 min of drying (0.001 kg/(kg min)), and for 60 °C from 90 to 150 min of drying (0.004 kg/(kg min)); and for an air temperature of 70 °C, the section is almost absent.
2. The two-stage method of drying green onions is more effective and significantly shorter in terms of dehydration time. It involves two stages: the first convective method lasting

60 min (to a mass fraction of moisture of 0.41 kg/kg) at a drying agent temperature of 60 °C and the second one being microwave drying.

3. The rehydration rate increases with increasing water temperature from 0.026 min^{-1} at a water temperature of 50 °C to – 0.028 min^{-1} at a temperature of 70 °C. The value of the equilibrium moisture content W^{eq} also increases from 5.65 to 6.15 kg/kg, respectively.
4. The drying temperature affected the parameters L, a, b on the HunterLab scale. Thus, the value of parameter a for fresh onions is 34, and for onions dried at a drying agent temperature of 50 °C is –10, for 60 °C it is –11 and for 70 °C it makes –12 (respectively). The total color difference ΔE is about 33, which indicates a significant influence of drying duration on the color change of green onions.

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