

UDC 664.8.047

THE ENERGY-EFFICIENT CHAMBER DRYER FOR DRYING MEAT PRODUCTS[https://doi.org/ 10.15673/fst.v18i4.3142](https://doi.org/10.15673/fst.v18i4.3142)

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Cite as Vancouver style citation

Petrova Zh., Paziuk V., Samoilenko K., Vyshnevskiy V. Et al. The energy-efficient chamber dryer for drying meat products. Food science and technology. 2024;18(4):74-81.
[https://doi.org/ 10.15673/fst.v18i4.3142](https://doi.org/10.15673/fst.v18i4.3142)

Цитування згідно ДСТУ 8302:2015

The energy-efficient chamber dryer for drying meat products. / Petrova Zh. et al. // Food science and technology. 2024. Vol. 18, Issue 4. P. 74-81.
[https://doi.org/ 10.15673/fst.v18i4.3142](https://doi.org/10.15673/fst.v18i4.3142)

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Abstract. Chicken meat is in critical demand as it is a staple in many diets around the world. This is crucial to meeting the demand for high-quality meat on a global scale. Chicken breast is a popular and widely used source of protein. Therefore, preserving fresh meat plays an important role in combating global food shortages. One type of meat preservation is the drying process, which has a centuries-old history in many cultures around the world. Since it is not necessary to use monosodium glutamate, sodium nitrite, food colorings, flavorings, anti-caking agents, etc. Today, there are known methods of drying meat in chamber, duct, cabinet dryers, as well as in the open air. Considering the duration of these drying methods, the raw materials are specially treated before drying. The main disadvantages of the convective method of drying meat in chamber, channel, and cabinet dryers are the loss of soluble proteins in the dry product and the significant duration of the process, therefore, improving existing technologies is an urgent task. The requirements for modern food products are to preserve the biologically active substances of meat raw materials after drying and to reduce energy consumption for the process. Another important criterion for the quality of dried meat is its ability to absorb water during use. This article presents the results of experimental studies of the kinetics of drying chicken meat in a developed energy-efficient chamber dryer using a change in the direction of the heat flow. The process can be intensified by either preliminary preparation of the raw materials for drying or by increasing the heat carrier temperature. This paper highlights an experimental study where the main parameter, for the purpose of intensification, is the change in the direction of the coolant flow during the process. This reduced the process time by 20%. When analyzing the drying process, it was proven that due to the applied change in the direction of the heat flow for 120 min, more intensive evaporation of moisture from the tested sample occurs and the drying duration is reduced. Energy consumption and efficiency of the drying process were calculated depending on the change in flow direction.

Key words: dried meat, dehydration kinetics, convective drying, chamber dryer.

Introduction. Formulation of the problem

The production of meat products at the stage of development of civilization acquires new forms of consumption, which is associated with the development of human life and the development of modern meat processing technologies. Meat spoils very quickly and its microbial load very quickly exceeds the permissible limit, even if it is stored in the refrigerator [1]. For many years, fermentation processes were used for long-term storage of meat using salting and heat treatment of meat (frying, drying, cooking, smoking). With the development of refrigeration systems for storing meat in meat processing industries, chilled and frozen meat was actively used, which in turn went to the production of

sausages, canned food and meat semi-finished products.

With the change in the speed of life of a person experiencing a shortage of cooking time, there was a change in the culture of consumption with a gradual transition to the use of ready-made dry meat products. The national dry products produced by traditional or innovative technologies in the countries of America, Europe, Asia and Africa include jerks, glasses, biltong, pemmican, pastirma, nikki, yukola and others. Modern assortment of dry meat products includes meat flakes, chips, sticks and others [2-8].

Dry meat products are of high nutritional value, due to the inclusion of fat and connective tissue with a high content of valuable protein.

When obtaining dry meat products completely or partially exclude sodium, nitrites and other useless ingredients that are traditionally used in the production of meat products. Dry meat products are a significant source of B vitamins and easily digestible iron. 100 grams of meat contains up to 40% of the daily dose of vitamin B₅, up to 64% of the daily dose of vitamin B₂, more than 100% of the daily dose of vitamin B₁₂. Digestibility of iron from animal raw materials is 5–8 times higher than digestibility of iron of plant materials.

Also, on the modern development of the production of functional meat products, they are enriched with vitamins, trace elements (zinc, selenium), unsaturated fatty acids (omega-3, conjugated fatty acids), bioactive peptides, dietary fibers, vegetable proteins, antioxidants, microorganisms with probiotic properties [9]. The expediency of creating specialized therapeutic and preventive meat products by enriching them with functional ingredients is due to the fact that protein-rich meat raw materials in combination with physiologically functional components enhance their therapeutic effect.

Analysis of recent research and publications

The existing methods of drying meat raw materials are accompanied by processes of heat and mass transfer, the intensity and depth of which significantly affect the chemical composition, structure, physical and organoleptic properties of products. Drying can be performed at a relatively low temperature for a long time or at elevated temperature with short-term effect.

One of the main problems when drying meat products is the hardening of the surface or the formation of a crust. The surface layer is harder and less permeable than the inside of the product. A sharp increase in hardness was found during drying in cured meat products when the water content reaches a critical value [10].

It was to investigate the effects of meat fiber directions and air conditions on moisture and temperature developments, shrinkage, and effective diffusivity constants compared to homogenous minced meat samples. The lean meat with three fiber directions and minced meat samples were dried at temperatures of 48 and 70°C and air flow rates of 0.5, 1.0, and 1.7 m/s [11].

A literary analysis of convective drying modes of meat unfermented products of small sizes made it possible to establish a minimum process temperature of 49 °C. The authors indicated that this temperature is the standard value of the mass fraction of moisture is reached maximum after 20 hours of treatment. At a drying temperature over 77°C, the duration of treatment is reduced to a minimum of 8 hours [4,12,13].

Drying of beef meat with superheated steam and convective drying (drying medium temperature 130, 160 or 180°C; drying medium flow rate 35, 45 or 55 kg/h.

sample thickness 3 mm, 6 mm, 9 mm or ground beef). Reducing the sample thickness or increasing the transferred heat, by increasing the temperature or velocity of the drying medium, result in accelerating the drying process. Temperatures above 160°C, however, cause changes within the and its surface and prevent the bound moisture from getting to the meat's surface to evaporate. This so-called case-hardening effect is worse for air drying than for superheated steam drying and results in even longer drying times and higher final moisture contents. Superheated steam drying reduces the water activity faster than air drying at the beginning of the drying process, but the same values are reached at the end of the drying run. Furthermore, the study proves that the absence of oxygen during superheated steam drying leads to prevention or minimization of lipid oxidation reactions, thus resulting in low peroxide values. Undesired quality changes like off-flavors and off-odors hardly develop during superheated steam drying even at high temperatures and long drying times [14].

Also, to intensify the process before convective drying, scientists conduct preliminary heat treatment of meat. Drying can also be carried out by sublimation, while significantly reducing the number of microorganisms in the raw material, reducing its volume. Advanced technology deserves wider use in the modern processing industry, especially when working with expensive perishable livestock products. But at the same time, 7–8 times more energy is spent on the process, which leads to an increase in prices.

The next modern method of drying meat products, which has an experimental character – vacuum-infrared. Uneven evaporation of moisture leads to excessive compaction of the upper layer, which added hardness and at the same time brittleness of consistency, when a mechanical force is applied, the structure of the sample collapses to form chips [15].

Drying raw materials at an air temperature of 80° C leads to a faster heating of raw materials by 1.5 times than at 60 °C and the process continues until the final humidity 10.85%. Due to drying at an air temperature of 80°C, the following characteristics of dried meat are obtained: fragile, brittle, excessively dry, difficult to wet.

As a result of experimental studies, the authors proposed in the vacuum-infrared drying of poultry meat mode with a temperature of 60°C, duration of treatment – at least 60 minutes. Advantage of vacuum-infrared over convective drying – reduction of drying duration by 3.3–3.5 times.

In this work, a modified mathematical model was constructed and solved in order to describe quantitatively the dynamic behavior of the primary and secondary drying stages of the freeze drying of turkey breast meat in trays [16].

In the study [17], instant controlled pressure drop (DIC) was used as a novel texturing pretreatment of fresh chicken breast meat, before hot airflow drying, in order to modify the texture of the meat and obtain a

controlled expansion. Three different drying techniques were compared: conventional hot airflow drying, freeze drying, and swell drying (a combination of DIC and hot airflow drying). Saturated steam pressure had a significant impact on the expansion ratio. The higher the expansion ratio, the better the different functional qualities. Microstructural changes reduced drying time, and increased rehydration kinetics and water holding capacity [17].

In the paper [30] the influence of spray drying conditions on the physicochemical properties of chicken meat hydrolysate powder is investigated.

This research [18] investigated the effects of convective air drying on the quality of raw and cooked chicken breast meats at 60, 70, and 80°C. Raw samples were cut into sizes of 20 mm × 20 mm × 7 mm and cooked samples were precooked in hot water and cut into similar sizes. It was observed that cooked samples had a lower initial moisture content and dried faster than the raw samples. Rehydration capacity was lower in the cooked samples, which could be due to the rigid structure resulting from the precooking process. This further reduced the imbibition of water into the sample.

The purpose study [19] is to examine beef dehydration during the salting and the drying steps of Kaddid's production. Salting of beef was run at different brine concentrations (15 and 26.5%) and by dry salting. Experimental drying kinetics were measured at three air temperatures (30, 40, and 50°C) and two air velocities (1.5 and 2.5 m/s).

Microbiological and physicochemical characteristics were evaluated for fresh, salted, and dried meat. Drying, when combined with dry salting, leads to higher salt content at the equilibrium and allows more dehydration in the product. The absence of true lactic fermentation after salting and drying was confirmed by the small change in pH and lactic acid bacteria proliferation during salting and drying. [19].

Although the proposed drying methods intensify the process, but vacuum-sublimation is a cost method that requires additional convective drying at the end of the process, the vacuum-infrared method at the recommended drying temperature of 60°C dries the material only to 22.53%, which also requires additional convective drying to reduce humidity.

That is, with all the above methods, it is optimal to use convective drying. The convective method of drying can also be intensified by conducting a thermal preliminary treatment of meat before drying (two-stage treatment), but unfortunately the studies do not indicate how much the process is accelerated. Convective method of drying food, vegetables and fruits is widespread and is used in dryers of various types, such as: chamber, tunnel, conveyor, vibration, etc. [20-23]. Specific heat consumption in existing chamber and tunnel dryers is 6700 - 8900 kJ/kg of evaporated moisture [24].

The purpose of the work is to study the drying of meat in a convective energy-efficient chamber drying

plant, developed at the Institute of Engineering Thermophysics of NAS of Ukraine, Kyiv.

To achieve the goal, it is necessary to solve the following **tasks**:

- to improve the energy-efficient chamber dryer with combined heating of the coolant;
- to study the kinetics of drying chicken meat on an energy-efficient chamber dryer with combined heating of the coolant;
- determine the optimal dehydration regimes in order to reduce the duration and increase the drying speed;
- to investigate the Rebinder number criterion as the main indicator of drying energy efficiency optimization;
- determine the energy costs of the process depending on the change in the flow direction.

Research materials and methods

B Institute of Engineering Thermophysics of NAS of Ukraine was designed and manufactured energy efficient chamber dryer with combined heating of the coolant and with a single load of 60–80 kg of raw materials. The installation allows you to reduce the energy costs of the process and explore the kinetics of the process of convective drying of meat (Fig. 1).

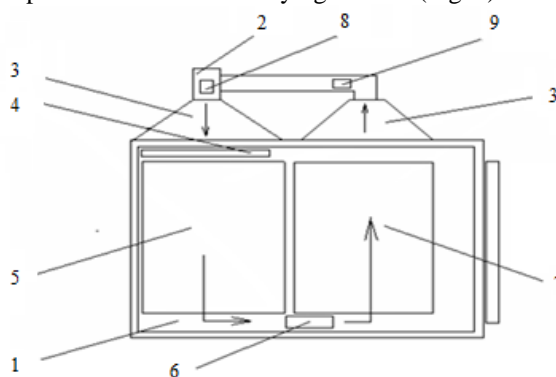


Fig. 1. Scheme of an energy-efficient chamber dryer with combined heating of the heat carrier:

- 1 – chamber, 2 – centrifugal fan, 3 – diffuser, 4 – first battery of heating elements, 5 – first trolley, 6 – second battery of heating elements, 7 – second trolley, 8 – damper, 9 – compensating damper

The advantage of an energy efficient chamber dryer with combined heating of the coolant is the possibility of loading 2 trolleys with 20 pallets (5, 7) in each into the chamber (1) at a time into different drying zones. The design provides for the installation of the first and second battery of heating elements (4, 6) inside the drying chamber opposite the pallets of trolleys, which is absent in the second structures, where the heating elements are removed and installed outside the drying chamber, this is due to the possibility of product ignition during drying. In this design, thick-film heating elements are installed and developed, which exclude the ignition of the product and allow to save electricity consumption up to 30 % (Fig. 2).

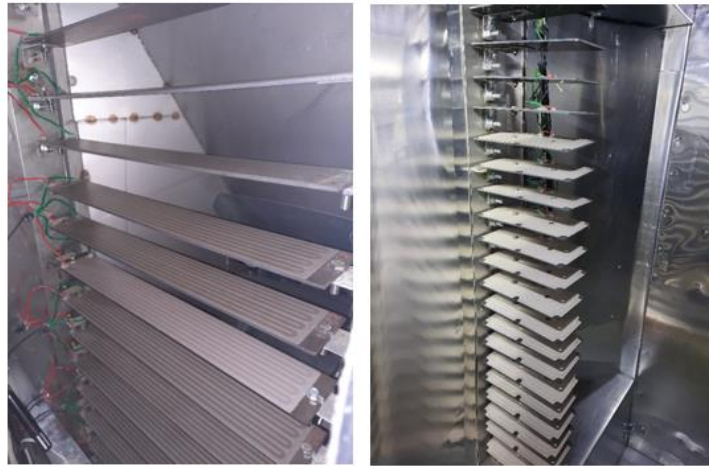


Fig. 2. Thick-film heating elements are installed in a chamber dryer

The dampers (8, 9) provided by the design create a flow circulation in the drying chamber (1) with a partial release of the spent wet coolant, which in turn increases the energy efficiency of the process.

Energy-efficient chamber dryer with combined heating of the coolant operates in automatic mode with the ability to control the temperature and speed of the coolant, the time of the experiment. Also, sensors are installed that measure the temperature and humidity of the drying agent at 3 points of the drying chamber. To measure the energy costs of the drying process, a digital electricity meter is installed [25].

Results of the research and their discussion

The nature of the drying process is most accurately described by the drying duration and rate curves. Fig. 3 shows the drying curves of ground chicken meat at the following drying parameters: heat carrier temperature $t = 60\text{ }^{\circ}\text{C}$, heat carrier velocity $V =$

3 m/s , material thickness $\delta = 5\text{ mm}$, moisture content of air $d = 10\text{ kg/g}$ dry air.

The process occurs 300 minutes. The 1,1' curve shows the drying mode without changing the direction of flow, and 2,2' – with a change in the direction of coolant flow. As seen, the temperature of the material increases gradually throughout the process for both modes (curves 1',2'). Curves 1,2 indicate a change in the moisture content of the material. As can be seen from Fig. 3, after changing the direction of the heat carrier flow for 120 minutes (curve 2), the removal of moisture in the event of a change in the coolant flow becomes more intense, starting from 150 minutes of the experiment. That is, the moisture content of the material in the regime without a change in the flow of the heat carrier is 18% at the 300th minute, and in the regime with a change in the direction of the flow, the sample under study has the same moisture content already at 250 minutes.

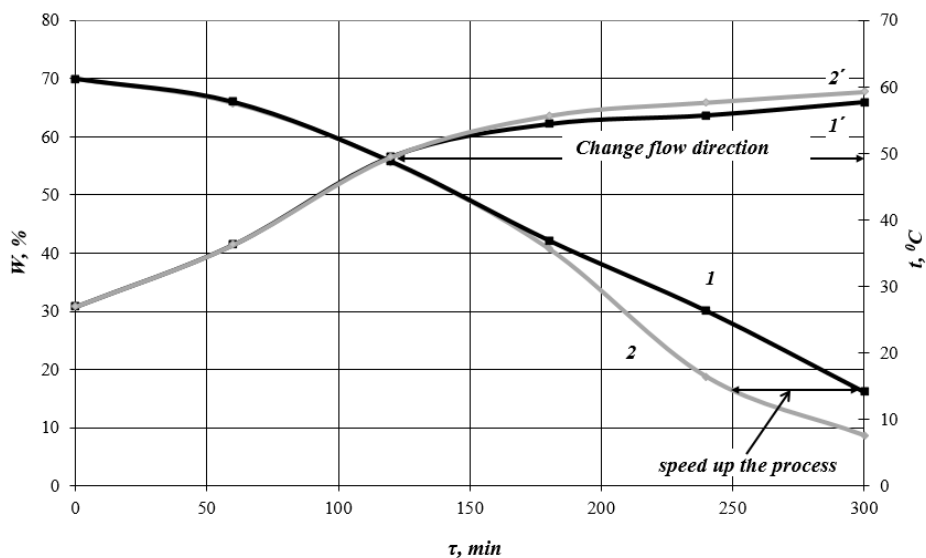


Fig. 3. Drying curves of minced chicken meat in an energy-efficient chamber dryer at

$t = 60\text{ }^{\circ}\text{C}$, $V = 3\text{ m/s}$, $\delta = 5\text{ mm}$, $d = 10\text{ kg/g}$ dry air: 1 – without changing the flow direction; 2 – with flow direction change; 1' – temperature in the middle of the material without changing the direction of flow; 2' – temperature in the middle of the material with a change in flow direction

The final temperature of heating the meat during drying without changing the direction of flow of the drying agent is 57.7 °C, with a change in the direction of flow 59.3°C. The intensity of the drying process in the chamber dryer is limited by the heating temperature of the product, therefore, drying is carried out at low temperature parameters of the coolant, which should not exceed 60°C. Therefore, a change in the flow direction of the drying agent is selected to accelerate the drying process.

This method reduces the drying time by 50 minutes or 20%, which is also confirmed by the data obtained earlier [7]. It is most advisable to change the direction for 120 minutes or after 2 hours, in the area of reducing the removal of moisture from the material.

We obtained drying curves and drying rate on an energy efficient chamber dryer with combined heating of the coolant. Drying rate curves (Fig. 4) show the change in material moisture per unit time (dW/dt). As can be seen from the figure, the maximum drying rate without changing the flow direction of the drying agent is 0.22 %/min. (curve 1), and with a change of 0.37 %/min. (curve 2). Consequently, the maximum drying rate with a change in coolant flow is 1.68 times higher.

To determine the efficiency of heat and mass exchange in the chamber drying plant, an analysis of the Rebinder number was carried out.

The Rebinder number is equal to the ratio of the consumption of the amount of heat for heating the material to the amount of heat for evaporation of moisture from it in an infinitesimal period of time, which is also called the criterion for optimizing the drying process.

$$Rb = b \frac{c}{r} \quad (1)$$

where: b – drying temperature coefficient;
 c – specific heat of material, kJ/kg K;
 r – specific heat of moisture evaporation, кДж/кг.

Drying temperature coefficient b is a derivative of the average temperature of the material θ from the moisture content of the material W :

$$b = \frac{d\theta}{dW} \quad (2)$$

Analysis of the Rebinder number when drying meat without changing the direction of the drying agent flow shows (Fig. 5) that in the chamber dryer the heat exchange process is initially ineffective (up to 40% moisture content), most of the energy is spent on heating the material, and not on evaporation of moisture from it. Effective evaporation of moisture from the material is observed from 40 to 16%, the heating of the material is slow.

Change of flow direction (pos. 1) to counterflow (pos. 2) from 40% humidity allows you to further increase the intensity of evaporation of moisture from the material, although the heating stage at the initial stage remains (drying to 40% humidity) - the direction of flow during this period does not change.

Specific heat consumption for drying chicken meat was calculated by electricity consumption per meter and the amount of evaporated moisture from the material. As can be seen, from Fig. 6, the highest heat consumption during drying is at the beginning and at the end of the process. Smaller columns indicate specific heat consumption with change of flow direction, larger columns - without change of flow direction. By the time the flow direction changes 120 minutes, the specific heat consumption is 4684 kJ/kg of evaporated moisture, then, depending on the change in the flow direction for 120 minutes to a total time of 240 minutes, the energy consumption of heat decreases and amounts to 4603-4608 kJ/kg of evaporated moisture. With the fact that without changing the direction of flow from 120 to 240 minutes, they increase and amount to 4729-5087 kJ/kg of evaporated moisture. At the end of the process for 300 minutes, the heat consumption from the change in flow direction is reduced by 4.5 %.

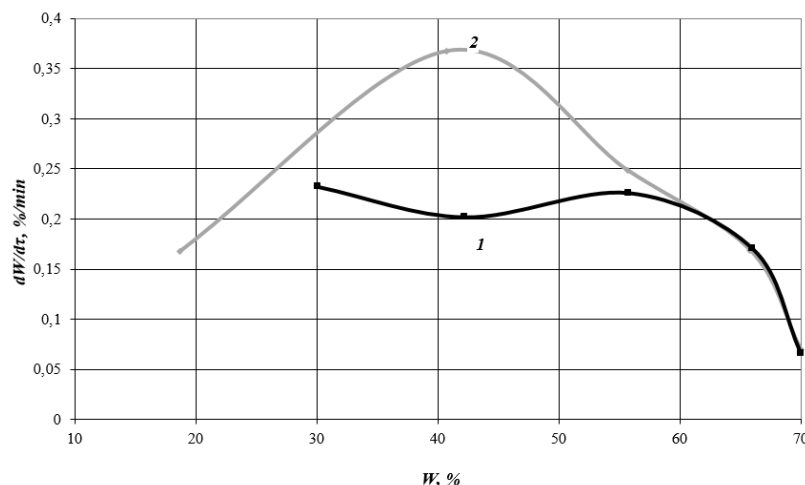


Fig. 4. Drying speed curves of ground chicken meat in an energy-efficient chamber dryer at $t = 60$ °C, $V = 3$ m/s, $\delta = 5$ mm, $d = 10$ kg/g dry air:
 1 – without changing the flow direction; 2 – with flow direction change

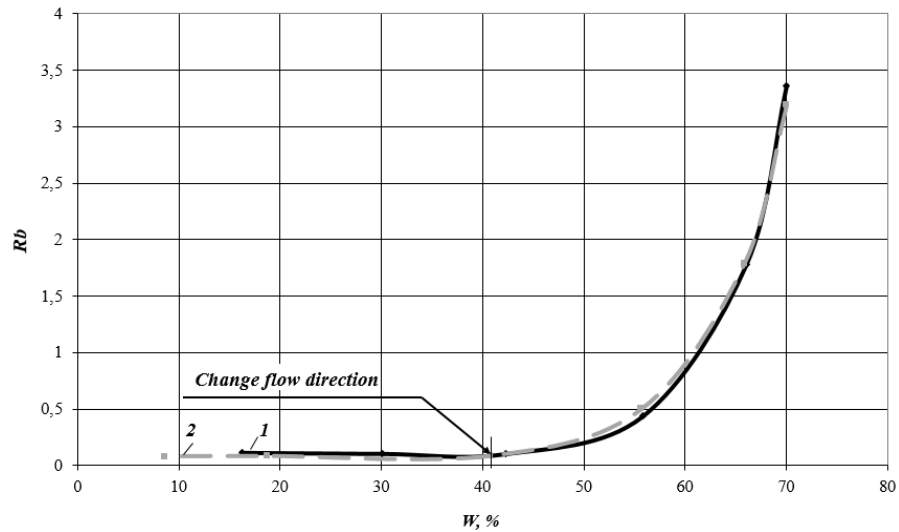


Fig. 5. Changing the Rebinder number from the humidity of chopped chicken meat: $t = 60\text{ }^{\circ}\text{C}$, $V = 3\text{ m/s}$, $\delta = 5\text{ mm}$, $d = 10\text{ kg/g}$ dry air:
 1 – without changing the flow direction; 2 – with flow direction change

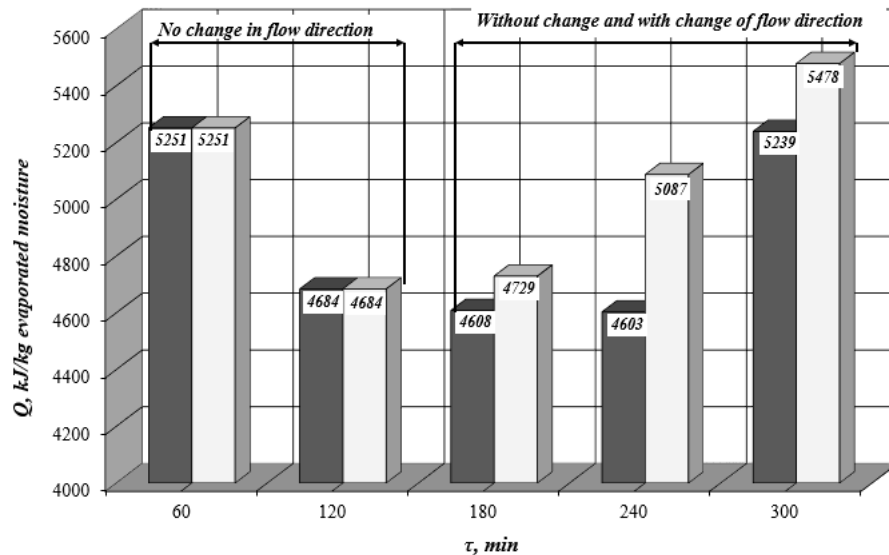


Fig. 6. Specific heat consumption from the time of drying minced chicken meat in an energy-efficient chamber drying plant: $t = 60\text{ }^{\circ}\text{C}$, $V = 3\text{ m/s}$, $\delta = 5\text{ mm}$, $d = 10\text{ kg/g}$ dry air

Although it must be said that, regardless of the change in the heat flow, the efficiency of the plant is quite high and less than analogues in which the heat consumption is 6700-8900 kJ/kg of evaporated moisture, that is, the developed plant is 28–70% economical from modern types of drying plants. This is due to the installation of new modern heaters and the design of the drying plant with coolant recirculation.

The quality of the dryer is evaluated by its energy efficiency η (coefficient of performance), which is determined by the ratio of useful energy $Q_{usefull}$ to all spent on the process Q_{spent} :

$$\eta = \frac{Q_{usefull}}{Q_{spent}} \quad (3)$$

If the calculation is made per kilogram of evaporated moisture, then the formula has this form:

$$\eta = \frac{r}{Q_{kolor}} \quad (4)$$

where: r – specific heat of moisture evaporation, kJ/kg.

Q_{kolor} – spent energy for heating the coolant in the heater, kJ/kg of evaporated moisture.

Using formula 4, we calculate the coefficient of performance of dryers. With a load of 45 kg of material and a drying time of 300 minutes, coefficient of performance is $\eta = 45.8\%$. It's corresponds to the best performance indicators for chamber dryers. It is possible to predict that with a larger load of the dryer, the energy consumption per kilogram of evaporated moisture will decrease, coefficient of performance increase.

The Institute of Engineering Thermophysics of NAS of Ukraine, also conducted research on drying plant raw materials, developed heat technologies for

processing and created energy-efficient drying plants [25-29].

Conclusion

1. Improved energy-efficient chamber dryer with combined heating of the coolant due to changing the direction of the coolant flow;

2. The article presents studies on the intensification of the process of drying chicken meat on an energy-efficient chamber dryer with combined heating of the coolant. For the intensification parameter, from the impossibility of increasing the temperature of the coolant and based on the quality indicators of the product, a change in the direction of flow during the drying of meat was chosen.

3. It is determined that it is advisable to change the direction of heat flow for 120 minutes, as a result of which the drying time is reduced by 20% and the rate is increased by 1.68 times.

4. The heat and mass exchange criterion of Rebinder indicates that the nature of the drying process does not change from a change in the direction of the flow, but more intense evaporation of moisture from the material occurs.

5. The energy consumption from the flow direction change is reduced by 4.5% and amounts to 5239 kJ/kg of evaporation moisture release, and the unit efficiency increases by 2%.

References

- Rostami H, Dehnad D, Jafari SM, Tavakoli HR. Evaluation of physical, rheological, microbial, and organoleptic properties of meat powder produced by Refractance Window drying. *Drying Technology*. 2018; 36 (9):1076-1085. DOI: 10.1080/07373937.2017.1377224
- Burfoot D, Everis L, Mulvey L, Wood A, Betts R. Literature review on microbiological hazards associated with biltong and similar dried meat products. Food Standards Agency. Aviation House 2010; WC2B 6NH.
- Cherono K. Infrared drying of biltong: effect of pretreatment and drying conditions on the drying characteristics and product quality. Literature review and project proposal. School of Engineering University of KwaZulu-Natal Pietermaritzburg. 2013; 43 p.
- Harrison J, Harrison M. Fate of Escherichia coli O157:H7, Listeria monocytogenes, and Salmonella typhimurium during preparation and storage of beef jerky. *Journal of Food Protection*. 2006; 59:1336-1338.
- Heinke W, Laing E, Viljoen C. Isolation and identification of yeasts associated with intermediate moisture meats. *Food technology and biotechnology*. 2000; 1 (38): 69-75.
- Ignasi V, Meda V, Panigrahi S. Thin-layer drying characteristics of beef jerky. North Central CSBE /ASABE inter sectional Meeting, Saskatoon 2006; 5-7.
- Principles of Preservation of Shelf-Stable Dried Meat Products. FSRE Shelf-Stable 2005; 15:156-170. Available from: <https://meathaccp.wisc.edu/validation/assets/Principles%20for%20preservation.pdf>
- Quick guide on processing jerky and Compliance guideline for meat and poultry jerky produced by small and very small plants. Update compliance guideline. USDA 2007. Available from: https://www.haccpalliance.org/wp-content/uploads/sites/12/2022/01/Compliance_Guideline_Jerky.pdf
- Lisitsyn A.B. Functional meat products for the population of ecologically disadvantaged regions [in russian]. *Storage and processing of agricultural raw materials*, 2002, 9, 9 – 11.
- Gou P, Comaposada J, Arnau J, Pakowski Zd. On-Line Determination of Water Activity at the Lean Surface of Meat Products During Drying and Its Relationship with the Crusting Development. *Drying Technology*. 2005; 23(8):1641-1652. DOI: 10.1081/DRT-200065033
- Karabacak MS, Esin A, Cekmecelioglu D. Drying Behavior of Meat Samples at Various Fiber Directions and Air Conditions. *Drying Technology*. 2014; 32(6):695-707. DOI: 10.1080/07373937.2013.855784
- Buege D, Searls G, Ingham S. Lethality of commercial whole muscle beef jerky manufacturing processes against Salmonella serovars and Escherichia coli O157:H7. *Journal of Food Protection*. 2006; 69:2091-2099.
- Calicioglu M, Sofos J, Samelis J. Destruction of acid-adapted and non-adapted Listeria monocytogenes during drying and storage of beef jerky. *Food Microbiology*. 2002; 19:545-559.
- Speckhahn A, Szrednicki G, Desai DK. Drying of Beef in Superheated Steam. *Drying Technology*. 2010; 28(9):1072-1082. DOI: 10.1080/07373937.2010.505547
- Ivanov IV, Gurinovych GV. Study of vacuum-infrared drying of chicken owl chips. [in Russian]. *Food Processing Technology*. 2013; 3:22 – 26.
- Cumhur Ö, Şeker M, Sadıkoğlu H. Freeze drying of turkey breast meat: Mathematical modeling and estimation of transport parameters. *Drying Technology*. 2016; 34 (5):584-594. DOI: 10.1080/07373937.2015.1064945.
- Mounir S. Texturing of Chicken Breast Meat as an Innovative Way to Intensify Drying: Use of a Coupled Washing/Diffusion CWD Phenomenological Model to Enhance Kinetics and Functional Properties. *Drying Technology*. 2015; 33(11):1369-1381. DOI: 10.1080/07373937.2015.1030029
- Hii CL, Itam CE, Ong SP. Convective Air Drying of Raw and Cooked Chicken Meats. *Drying Technology*. 2014; 32 (11):1304-1309. DOI: 10.1080/07373937.2014.924133
- Chabbouh M, Hajji W, Ahmed S, Farhat A, Bellagha S, Sahli A. Combined Effects of Osmotic Dehydration and Convective Air Drying on Kaddid Meats: Kinetics and Quality. *Drying Technology*. 2011; 29 (13): 1571-1579. DOI: 10.1080/07373937.2011.582973
- Ajala AS, Ngoddy PO, Olajide JO. Statistical modeling and simulation of drying cassava chips in tunnel dryer. *Intl. Journal of Emerging Trend in Engineering and Development*. 2012; 2 (7):585-586.
- Cáceres-Huambo BN, Menegalli FC. Simulation and Optimization of Semicontinuous Industrial Tunnel Dryers for Fruits. *Drying Technology*. 2009; 27:428-436.
- Chou SK, Hawlader MNA, Chua K.J. On the drying of food product in a tunnel dryer. *Drying Technology Journal*. 1997; 15:857-880.
- Maroulis Z, Saravacos G. Modelling, simulation and design of drying processes. *Proceedings of the 13th International Drying Symposium*. 2002; vol. A:38.
- Snezhkin YF, Boryak LA, Khavin OO. Energy-saving thermal technologies of food powders production from secondary raw materials. *Naukova dumka*; 2004 (in Russian).
- Snezhkin YuF, Petrova ZhO, Paziuk VM, Vyshnevskiy VM, Malaschuk NS. Energy-Efficient Chamber Dryer with Thick Alloy Heating Elements. *Energotehnologii i Resursosberezenie*. 2023; 75 (2):85-95.

26. Pazyuk V, Petrova Zh, Chepeliuk O. Determination of rational modes of pumpkin seeds drying. Ukrainian Food Journal. 2018; 7 (1):135-150.
27. Paziuk V, Vyshnevskiy V, Tokarchuk O, Kupchuk I. Substation of the energy efficient schedules of drying grain seeds. Bulletin of the Transilvania University of Braşov Series II: Forestry • Wood Industry • Agricultural Food Engineering. 2021; 14 (63), 2:137–146.
28. Petrova Zn, Pazyuk V, Samoilenko K, Chepeliuk O. Effect of treatment modes on quality and antioxidant properties of tomato and beet processing products. Ukrainian Food Journal. 2018; 7(2):291-302.
29. Snezhkin YuF, Paziuk VM, Petrova ZhO, Tokarchuk OA. Determination of the energy efficient modes for barley seeds drying. INMATEH - Agricultural Engineering. 2020; 61(2):183-192.
30. Kurozawa LE, Morassi AG, Aparecida VA, Park KJ, Hubinger MD. Influence of Spray Drying Conditions on Physicochemical Properties of Chicken Meat Powder, Drying Technology. 2009; 27 (11):1248-1257. DOI: 10.1080/07373930903267187.

ЕНЕРГОЕФЕКТИВНА КАМЕРНА СУШАРКА ДЛЯ СУШІННЯ М'ЯСНИХ ПРОДУКТІВ

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Анотація. М'ясо курятини має вирішальний попит, оскільки є основним продуктом в багатьох раціонах світу. Це має вирішальне значення для задоволення потреб у високоякісному м'ясі в світовому масштабі. Куряча грудинка є популярним та широко використовуваним джерелом білку. Тому, збереження свіжого м'яса відіграє важливу роль у боротьбі з глобальним дефіцитом продовольства. Одним із видів консервації м'яса є процес сушіння, який має багатотисялітню історію в багатьох культурах світу. Оскільки при цьому не потрібно застосовувати глутамат натрію, нітрит натрію, харчові барвники, ароматизатори, антизлежувачі та ін. На сьогодні відомі способи сушіння м'яса в камерних, каналних, шафових сушарках, а також на відкритому повітрі. Враховуючи тривалість даних способів сушіння сировини перед сушінням спеціально обробляють. Основними недоліками конвективного методу сушіння м'яса в камерних, каналних, шафових сушарках є втрати в сухому продукті розчинних білків та значна тривалість процесу, тому удосконалення існуючих технологій є актуальним завданням. Вимоги до сучасних продуктів харчування є збереження біологічно активних речовин м'ясної сировини після сушіння та зниження енерговитрат на процес. Також важливим критерієм якості висушеного м'яса є його здатність до поглинання води в процесі використання. В даній статті представлено результати експериментальних досліджень кінетики сушіння м'яса курятини на розробленій енергоефективній камерній сушарці із застосуванням зміни напрямку теплового потоку. Інтенсифікувати процес можливо за рахунок або попередньої підготовки сировини до сушіння, або підвищення температури теплоносія. В даній роботі висвітлено експериментальне дослідження, де основним параметром, з метою інтенсифікації, є зміна напрямку потоку теплоносія протягом процесу. Завдяки цьому була знижена тривалість процесу на 20%. При аналізі процесу сушіння було доведено, що за рахунок застосованої зміни напрямку теплового потоку на 120 хв, відбувається більш інтенсивне випаровування вологи із досліджуваного зразка та зменшується тривалість сушіння. Розраховано енергетичні витрати та к.к.д. на процес сушіння в залежності від зміни напрямку потоку.

Ключові слова: м'ясо сушене, кінетика зневоднення, конвективне сушіння, камерна сушарка.