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DRY-CURING OF MELON BY INFRARED-CONVECTIVE METHOD

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The article presents the results of research on drying melon of the Torpeda variety in an infrared-convective dryer. The purpose of the study is to develop a method for drying melon using artificial drying, which will ensure reducing of duration of the process, as well as reducing contamination of the product. To solve this problem, a technology for infrared-convective drying of melon has been developed, including preparation of raw materials, peeling and removing seeds, washing, cutting, blanching in a 0.2% solution of citric acid for 3 minutes, infrared-convective drying of slices in a dryer cabinet "Universal-SD-4" at the temperature of heaters 50÷70 ^{0}C and an air speed of 7 m/s, holding at room temperature for 24 hours to moisture levelling, packaging and storage. The study discovered that the combination of infrared heating and convective removal of evaporated moisture made it possible to significantly intensify the dehydration process. It maintains good organoleptic characteristics compared to air-solar drying as well. The duration of the process varied from 5 to 8 hours instead of several days when drying in the sun. All curves are characterized by clearly defined periods of the beginning of drying, constant and decreasing drying rate. The optimal mode of infrared-convective drying is a temperature of 55 ^{0}C and a slice size of 50×50×15 mm, which ensures an elastic texture and light color of dried products. A study of the chemical composition showed that carbohydrates predominate in dried slices (79.8%), and the energy value of 100 g of product is 1348.8 kJ or 322 kcal. The research results contribute to the development of theory and technology of melon drying. The use of the developed method of infrared-convective drying will expand the possibility of industrial processing of melon.

Keywords: melon, dry-curing, infrared-convective drying, kinetics, technology.

ИНФРАҚЫЗЫЛ ЖӘНЕ КОНВЕКТИВТІ ТӘСІЛМЕН ҚАУЫНДЫ ҚАҚТАУ

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Мақалада Торпеда сортының қауындарын инфрақызыл-конвективті кептіргіште қақтау бойынша зерттеулердің нәтижелері келтірілген. Зерттеудің мақсаты – үдерістің ұзақтығын қысқартуға, сондай-ақ өнімнің ластануын азайтуға көмектесетін жасанды кептіру арқылы қауынды қақтау әдісін әзірлеу. Бұл мәселені шешу үшін қауынның инфрақызыл-конвективті кептіру технологиясы әзірленді, оның ішінде шикізатты дайындау, қабығынан тазарту және тұқым ұясын тазалау, жуу, кесу, лимон қышқылының 0,2% ерітіндісінде 3 минут бойы бланширлеу, инфрақызыл-конвективті кептіру, тілімдерді «Universal-SD-4» кептіргіш шкафында қыздырғыштардың температурасы 50÷70 °С және ауа жылдамдығы 7 м/с, ылғалдылықты біркелкі ету үшін бөлме температурасында 24 сағат ұстау, орау және сақтау. Зерттеу нәтижесінде инфрақызыл қыздыру мен буланатын ылғал буының конвективтік жойылуы комбинациясы кептіру процесін айтарлықтай күшейтуге мүмкіндік беретіні анықталды. Бұл сонымен қатар ауада кептірумен салыстырғанда органолептикалық қасиеттердің жақсы сақталуын қамтамасыз етеді.Үдерістің ұзақтығы 5-8 сағат аралығында болды, ал ауа-күн кептіру бірнеше күнге созылады. Барлық қисықтар кептіру басталуының нақты белгіленген кезеңдерімен, тұрақты және кептіру жылдамдығының төмендеуімен сипатталады. Инфрақызыл-конвективті кептірудің оңтайлы режимі 55 °С температура және 50×50×15 мм тілім өлшемі болып табылады, бұл кептірілген өнімдердің серпімді құрылымын және ашық түсті болуын қамтамасыз етеді. Химиялық құрамын зерттеу кептірілген тілімдерде көмірсулардың басым болатынын көрсетті (79,8%), ал 100 г өнімнің энергетикалық құндылығы 1348,8 кДж немесе 322 ккал құрайды. Зерттеу нәтижелері қауын кептіру теориясы мен технологиясының дамуына ықпал етеді.

Инфрақызыл-конвективтік кептірудің әзірленген әдісін қолдану қауынды өнеркәсіптік өңдеу мүмкіндігін кеңейтеді.

Негізгі сөздер: қауын, қақтау, инфрақызыл-конвективті кептіру, кинетика, технология.

ВЯЛЕНИЕ ДЫНИ ИНФРАКРАСНО-КОНВЕКТИВНЫМ СПОСОБОМ

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В статье приведены результаты исследований по вялению дыни сорта Торпеда в инфракрасно-конвективной сушилке. Целью исследования является разработка способа вяления дыни с помощью искусственной сушки, что будет способствовать сокращению продолжительности процесса, а также снижению загрязненности продукта. Для решения поставленной задачи разработана технология инфракрасно-конвективной сушки дыни, включающая подготовку сырья, очистку от кожуры и семенного гнезда, мойку, резку, бланширование в 0,2%-ном растворе лимонной кислоты в течение 3 минут, инфракрасно-конвективную сушку ломтиков в сушильном шкафе «Universal-SD-4» при температуре нагревателей 50÷70 ^oC и скорости воздуха 7 м/с, выдержку при комнатной температуре в течение суток для выравнивания влажности, расфасовку и хранение. В ходе исследования установлено, что комбинация инфракрасного подогрева и конвективного отдвода испаряющихся паров влаги позволили значительно интенсифицировать процесс обезвоживания. Это также обеспечивает хорошее сохранение органолептических показателей по сравнению с воздушно-солнечной сушкой. Длительность процесса варьировалась от 5 до 8 часов вместо нескольких дней при сушке под солнцем. Все кривые характеризуются ясно выраженными периодами начала сушки, постоянной и падающей скоростью сушки. Оптимальным режимом инфракрасно-конвективной сушки является температура 55 ^0C и размер ломтиков 50×50×15 мм, при которых обеспечивается эластичная текстура и светлая окраска вяленой продукции. Исследование химического состава показало, что в вяленых ломтиках преобладают углеводы (79,8%), а энергетическая ценность 100 г продукта составляет 1348,8 кДж или 322 ккал. Результаты исследований вносят вклад в развитие теории и технологии сушки дыни. Применение разработанного способа инфракрасно-конвективной сушки позволит расширить возможность промышленной переработки дыни.

Ключевые слова: дыня, вяление, инфракрасно-конвективная сушка, кинетика, технология.

Introduction

A role of cucurbits crop in nutrition of population is significant, since they are characterized by high nutritional value. They contain a complex of biologically active substances that are diverse in their chemical composition and, therefore, have a therapeutic effect on human body. Melons are generally richer in sugars than watermelons. There is predomination amount of sucrose and share of monosaccharides is lower in melon (approximately the same amount of fructose and glucose) [1]. For example, nutritional value of the Torpedo variety melon is to high content of carbohydrates – up to 8 g, proteins – 0.7 g and fats - 0.2 g. Melon contains vitamins A, C, PP, E, beta-carotene, as well as B vitamins (B1, B2, B5, B9). The micro- and macronutrient composition is represented by potassium, magnesium, silicon, iodine, iron, etc. [2].

Melon (lat. *Cucumis melo*) is a plant of the *Cucurbitaceae* family and one of the most common and massively grown types of melon crop in Kazakhstan. The vast majority of this product is consumed in fresh view. National statistical data analysis on melon crop harvest demonstrates a stable increase [3]. Industrial processing of melon, like watermelon, has not yet distributed. Meanwhile in recent years scientific interest in the field of processing of cucurbits crop has increased. Research interests cover studies in chemical composition, development of methods and devices for storing and processing melon, creation of new melon products etc. Among traditional melon products such as melon honey, concentrate, jam, compotes, juice etc. dried melon occupies a leading position. At air-solar drying, the products acquire an elastic consistency and become suitable for long-term storage. Dried melon is high-caloric since it contains a high concentration of sugars. It is believed that all useful substances are preserved quite well in it, since air-solar drying is a type of cold drying, when dehydration of the product occurs at low air temperatures.

At the same time, the disadvantages of air-solar drying are long duration of the process, as well as product contamination, which affects the safety of the finished product. According to some data, the duration of air-solar drying of melon reaches 10-12 days [4].

The purpose of this research is to develop a method for dry-curing melon using artificial dehydration, which will promote duration reduction of the process, as well as decreasing contamination of the product.

Existing researches have been aimed at improving the elements of drying technology, ensuring maximum preservation of nutritional and taste properties of products, as well as high efficiency of the process. Thus, the focus of research on melon dehydration is on issues of pre-processing of raw materials and choice of drying method, which affect reducing the duration of the process and maintaining the quality of the finished product.

Ulisses M. Teles et al proposed a process of osmotic dehydration in a vacuum followed by air drying of melon. Before dehydration, melon cubes with a side size of 3 cm were blanched in steam at a temperature of 100 ^{0}C for two minutes. The osmotic solution was prepared from sucrose and distilled water with addition of citric acid and sodium benzoate [5].

Coelho T. J. da S. et al noted that preliminary osmotic dehydration contributes to good preservation of dry substances during further drying [6]. Moreover, pre-treatment in an osmotic solution of salt and sugar helped reduce duration of air drying of melon to 6.8 hours [7].

At the same time, this makes the process multi-stage, which increases its labor intensity and cost, and complicates the technology. A change in taste (due to osmolytes) is possible, as well as a partial loss of water-soluble vitamins.

Another example of application of osmotic dehydration in sucrose solution in combination with ultrasound and vacuum as a pre-treatment in melon drying revealed increase in drying efficiency, preservation of carotenoids and organoleptic properties. Drying process was carried out in a fixed bed dryer at a temperature of 60°C and an air speed of 2 m/s [8]. In this case, precise control of ultrasonic treatment parameters is important to prevent destruction of cell walls.

Kizatova M. Ye. et al have studied the method of convective drying of melon slices with preliminary holding in absolute alcohol. The optimal process parameters are determined to be a drying temperature of 55 °C, a process duration of 11 hours, and a slice thickness of no more than 0.5 cm [9]. When carrying out this process, it is necessary to take into account the change in taste and organoleptic properties that may occur when held in absolute alcohol.

Application of a solar tunnel dryer for drying melons with slice thicknesses of 2, 4 and 6 mm and processed in a 1% ascorbic acid solution was investigated [10]. In this case, the process lasts two days, a drying curve demonstrates the absence of a period of constant drying rate, and impact of thickness on the quality of the product is insignificant. The disadvantages of this method are long duration of the process, dependence on weather conditions and risk of microbiological contamination.

The idea of combining low-temperature convective drying and microwave processing of bitter melon (*Momordica charantia L.)* has the interest. Microwave irradiation has demonstrated effectiveness in removing moisture from the material during convective low-temperature air drying. The combination of both methods showed a significant effect on the retention of biologically active compounds and antioxidant capacity [11].

Another example of rehydrating sliced bitter melon using microwaves showed that the latter significantly accelerates the diffusion of moisture during low-temperature drying. To study the drying kinetics, a full factorial design was used with microwave power densities (1.5, 3.0 and 4.5 W/g) and air-drying temperatures (20, 25 and 30°C) [12].

In both cases, the risk of local overheating of the product and the resulting deterioration of its structure must be taken into account.

The influence of traditional and new pre-treatment methods (immersion in ethanol solution, citric acid solution, ultrasound and hot water blanching) on drying and some physical properties of melon fruits was studied. Pre-treatment significantly reduced the drying time, increased the rehydration capacity and reduced the shrinkage rate of melon fruits. The highest recovery (28.13%) was achieved when immersed in 100% ethanol solution. The smallest color change was observed in samples blanched at 60 and 70°C [13]. As in the study described above, exposure to ethanol can affect changes in the taste and organoleptic properties of the product, so the processing time should be limited.

In all the cases described above, the melon was dried using the convective method, which is suitable for drying a wide range of products. In this case, the temperature, speed and humidity of the air can be adjusted, which permits to optimize the drying process for a specific product.

Most of the described research approaches are characterized by multi-stage and significant energy costs, and also require the use of additional reagents. In this context, infrared drying appears to be an effective alternative. It provides reduction in duration of the process due to increased heat and mass transfer, high quality of the finished product due to uniform and gentle heating, and minimizing the risk of microbiological contamination [14, 15]. It is believed that IR rays directly heat the moisture in the product, accelerating evaporation. Due to the gentle temperature regime and short drying time, destruction of vitamins, antioxidants and aromatic compounds is reduced. This is especially important for melon, which are rich in sugars, aromas and sensitive to overheating. Based on the above mentioned, it is proposed to use infrared-convective method of drying melon, which combines advantages of both techniques.

Materials and research methods

In this work, research was carried out on drying melon in an infrared cabinet dryer. In infrared drying, moisture in product is absorbed by infrared radiation. In this case, radiation is not absorbed by tissue of product being dried, so infrared drying is possible at moderate temperatures. The advantages of infrared drying include high preservation of biologically active substances and vitamins, high drying speed, low specific energy consumption, high rehydration capacity of dried product and preservation of taste characteristics.

The infrared dryer is an electric cabinet of the “Universal-SD-4” brand with tiered sections with tubular heating elements having a special coating (Fig. 1). Above each tier of tanks, two baking trays for drying products are arranged in a row, which are removed from the guides in opposite directions. The baking trays are loaded from the front and back sides of the cabinet, which are closed with doors. Deflectors are installed at the bottom and top of the dryer. The cabinet has a hood with an exhaust fan on top. A control unit is installed on the side wall of the cabinet. Operation of the dryer is based on a combination of ration and convective drying methods. Evaporation of moisture in a product occurs through thermoradiation heating by infrared radiation of a certain wavelength range, and moisture removal is due to forced convection of the vapor–air mixture. Internal surface of the dryer is a system of screens that creates a targeted reflection of radiation, air movement and moisture removal. The control unit provides automatic maintenance of the ambient temperature not higher than the set value, as well as forced air circulation through the product [16].

The operating principle of the dryer is based on application of infrared-convective method of drying products. This combined method provides evaporation of moisture from product using thermal heating (infrared radiation) and remove it from drying chamber by forced air convection.

Figure 1. Infrared drying cabinet “Universal-SD-4”.

The object of research was the melon of the Torpedo variety, which grows widely in the Turkestan region. The melon has an elongated shape, bright yellow color and is covered with a net of veins, flesh is white, juicy and slightly oily.

Prepared melon was weighed, peeled, cleaned from seeds, washed and sliced. The melon was cut into slices measuring 180×50×15 mm and 50×50×15 mm. Slices were weighted and blanched in 0.2% citric acid solution for 3 minutes. After draining the citric acid solution, the blanched slices were placed on baking sheets and dried in infrared dryer “Universal-SD-4”.

Infrared convective drying of melon slices was carried out under the following conditions:

- heating temperature 50...70 °C in increments of 5 °C;
- air speed 7 m/s;
- melon slices were dried until the humidity reached 20%.

Time interval for measuring mass of dried material was 1 hour. Final product was held for 1 day at room temperature and air humidity of no more than 75% to equalize the humidity throughout the entire volume. The choice of drying temperature ranges is substantiated by necessity to maximize preservation of biochemical composition of investigated product at a sufficiently high intensity of drying process. To speed up the drying process, preserve color and increase rehydration capacity of dried products, melon slices were blanched in a 0.2% citric acid solution.

The content of dry substances, proteins, carbohydrates and fats in investigated material was determined according to the following regulatory documents:

- GOST 28561-90. Processed fruit and vegetable products. Methods for determining dry matter or moisture [17];
- GOST 26183-84. Food products. Method for determining total nitrogen and calculating protein content [18];
- GOST 8756.13-87. Processed fruit and vegetable products. Methods for determining sugars [19];
- GOST 8756.21-89 Processed fruit and vegetable products. Methods for determining fat [20].

Results and discussion

The finished dried product was in view slices, with a consistency ranging from soft, dense, elastic and sticky to brittle, an intense melon odor and a color ranging from yellowish to dark brown.

Developed melon drying technology is presented in Fig. 2.

Melon acceptance
↓
Weighting
↓
Peeling
↓
Removing seeds
↓
Washing
↓
Slicing with sizes 180×50×15 mm and 50×50×15 mm
↓
Blanching (in 0.2% citric acid solution for 3 min)
↓
Placing on baking sheets in one layer
↓
Infrared-convective drying
(temperature 50÷70 ºC, air speed 7 m/s)
↓
Keep at room temperature for 24 hours to equalize humidity
↓
Packaging
↓
Storage

Figure 2. Melon dry-curing technology in infrared dryer.

Fig. 3 and 4 demonstrate the drying curves of melon slices with sizes of 180×50×15 mm and 50×50×15 mm under established conditions.

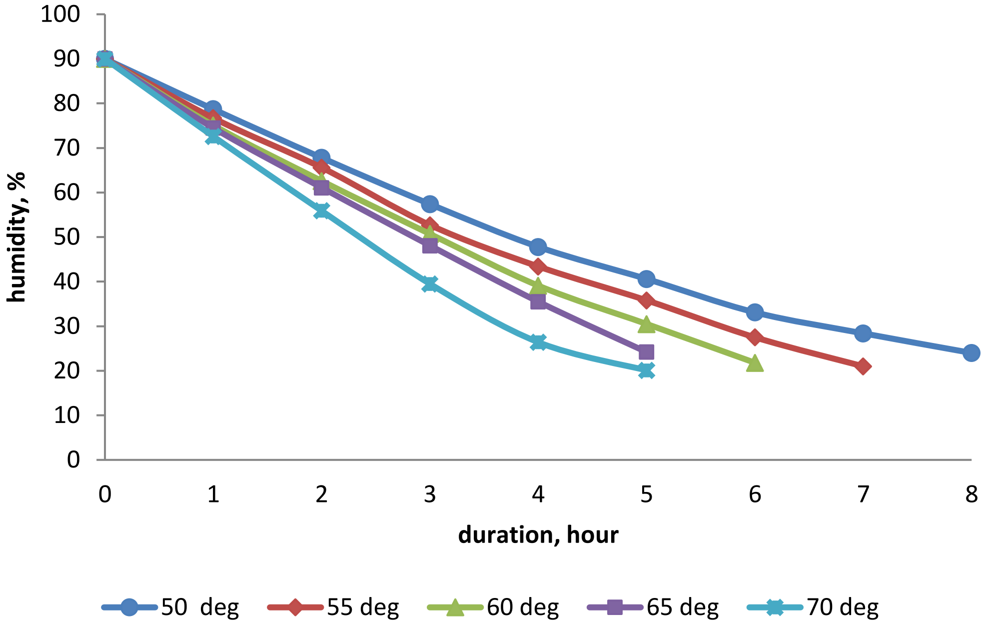

Figure 3. Drying curves of melon slices with a size of 180×50×15 mm at heating temperatures of 50÷70℃ in infrared dryer.

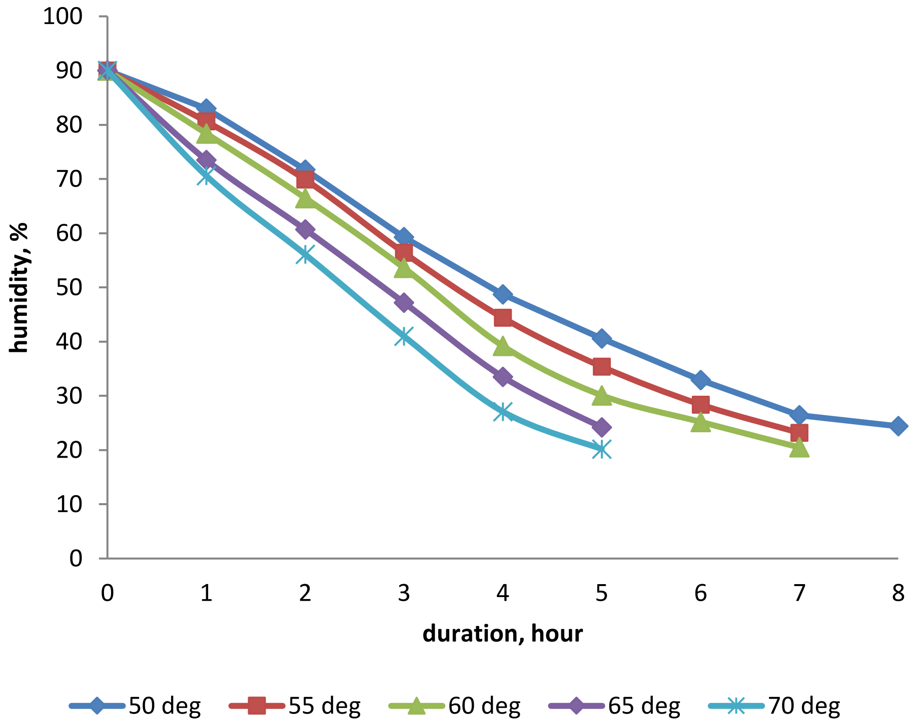

Figure 4. Drying curves of melon slices with a size of 50×50×15 mm at heating temperatures of 50÷70℃ in infrared dryer.

As can be seen from the drying curves (Fig. 3 and 4), size of melon slices had almost no effect on drying efficiency, and at heating temperatures of 50÷70℃ the process duration varied from 5 to 8 hours. This drying duration is typical for modes where intensive convective heat exchange is employed. In the case under investigation, combination of infrared heating and convective removal of evaporated moisture vapor made it possible to significantly intensify the dehydration process while maintaining good sensory characteristics compared to solar drying. All curves are characterized by clearly defined periods of the beginning of drying, constant and decreasing drying rate.

Sensory characteristics of melon slices with sizes of 180×50×15 mm and 50×50×15 mm are described in Tables 1 and 2.

Table 1. Sensory indicators of dry-cured melon slices with sizes 180×50×15 мм

Heating temperature, C	**Indicators**				
	appearance	**texture**	**colour**	**smell**	**taste**
50	elongated sticky slices	moderately dense, elastic	yellow with brown tint	smell is peculiar to melon, intense	taste is peculiar to melon, there is no foreign aftertaste
55	elongated slices	dense, elastic	yellow with brown tint		
60	elongated slices	solid	yellow with brown tint		
65	elongated slices	brittle	brown		
70	elongated slices with signs of burning	brittle	Brown with dark brown tint		Taste peculiar to melon, crispy

Table 2. Sensory indicators of dry-cured melon slices with sizes 50×50×15 мм

Heating temperature, C	**Indicators**				
	appearance	**texture**	**colour**	**smell**	**taste**
50	sticky slices	dense, elastic	yellowish	smell is peculiar to melon, intense	taste is peculiar to melon, there is no foreign aftertaste
55	sticky slices	dense, elastic	yellowish		
60	sticky slices	dense, medium hard	yellow with brown tint		
65	sticky slices	Medium hard	yellow with brown tint		
70	sticky slices sticky slices	dense, brittle	brown		

It can be concluded from analysis of sensory indicators in Tables 1 and 2 that at maximum heating temperatures 65 and 70 °C the consistency of dried melon becomes brittle, the taste is crispy, and the color becomes brown and dark brown. The worst indicators were observed for slices 180 mm long. The brown color is due to the caramelization reaction that occurs under the influence of temperatures. Since an elastic consistency and light color are preferred for dried melon, the optimal infrared drying mode is a temperature 55 ° C and a slice size 50×50×15 mm. This temperature level is close to 50 °C, which is determined to be optimal for achieving optimal chewy texture of dried melon [21].

Data on chemical composition of melon slices dried at 55 °C with dimensions of 50×50 ×15 mm are given in Table 3.

Table 3. Chemical composition of dry-cured melon

Product	**Proteins, g**	**Carbohydrates, g**	**Fats, g**	**Energetic value, kJ /100 g product**
Dry-cured melon	0,65	79,8	0,1	1348,8

As can be seen from data presented, carbohydrates predominate in dried slices (79.8%), and energy value of 100 g of product is 1348.8 kJ or 322 kcal, which is significantly lower compared to traditional sugary confectionery products, e.g. chocolate.

Conclusion

The purpose of this study was to develop a method of dry-curing melon using artificial dehydration, which will promote duration reduction of the process. This purpose was achieved through development of technology for infrared-convective drying of melon slices in an infrared dryer. The work carried out experimental studies of infrared-convective drying of melon slices at a heating temperature 50÷70 ºC and an air speed 7 m/s. The slices size was 180×50×15 mm and 50×50×15 mm. The study found that the combination of infrared heating and convective removal of evaporated moisture vapor made it possible to significantly intensify the dehydration process while maintaining good sensory characteristics compared to air-solar drying. The process duration varied from 5 to 8 hours, while air-solar drying lasts several days. All curves are characterized by clearly defined periods of beginning of drying, constant and decreasing drying speed. Different slice sizes had almost no effect on drying intensity, but had an impact on sensory characteristics of dried products. The optimal mode of infrared-convective drying is a temperature 55 ºC and slice size 50×50×15 mm, which ensures an elastic texture and light color of dried products. Investigation of chemical composition revealed that carbohydrates predominate in dried slices (79.8%), and energy value of 100 g of product is 1348.8 kJ or 322 kcal. Employment of developed method of infrared-convective drying will expand the possibility of industrial processing of melon.

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ИССЛЕДОВАНИЕ КОМПОНЕНТНОГО СОСТАВА ЭКСТРАКТА *ARTEMISIA RUTIFOLIA* ГУСТОГО

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Изучение фитохимического состава растений рода Artemisia представляет собой актуальное направление современной фармацевтической науки, учитывая их широкую биологическую активность. Настоящее исследование посвящено анализу химических компонентов надземной части Artemisia rutifolia. Целью работы являлась изоляция, идентификация и характеристика основных биологически активных соединений из спиртового экстракта данного растения с применением современных аналитических методов. Основные направления исследования включали экстракцию, фракционирование и спектроскопическую идентификацию выделенных веществ. Научная значимость исследования заключается в расширении знаний о химическом составе экстракта Artemisia rutifolia, что открывает перспективы для создания на его основе новых ЛП и БАДов. Практическая ценность работы заключается в выделении биологически активных веществ с потенциальной фармакологической активностью. Методология исследования включала получение спиртового экстракта, последующее жидкость-жидкостное фракционирование с экстракционным бензином и хлороформом, а также очистку на колонке с применением сефадекса LH-20. Структура выделенных соединений установлена с использованием ЯМР-спектроскопии и с аутентичными образцами. В результате исследования из экстракта Artemisia rutifolia были выделены и идентифицированы три соединения: монотерпен камфора, флавонол кастицин и стериновый гликозид даукостерин. Проведенный спектральный анализ подтвердил их химическую структуру и высокую степень чистоты. Вклад данной работы состоит в детальной характеристике компонентов перспективного лекарственного растения, что обогащает фармакогностические данные о роде Artemisia. Полученные результаты могут быть использованы для дальнейших фармакологических исследований и разработки новых ЛП и БАДов.

Ключевые слова: *Artemisia rutifolia*, полынь рутолистная, ультразвуковая экстракция, экстракт, ЯМР-спектроскопия, химический состав.

ARTEMISIA RUTIFOLIA ҚОЮ ЭКСТРАКТЫСЫНЫҢ КОМПОНЕНТТІК ҚҰРАМЫН ЗЕРТТЕУ

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Artemisia туысына жататын өсімдіктер кең биологиялық белсенділікке ие болғандықтан, олардың фитохимиялық құрамын зерттеу қазіргі фармацевтикалық ғылымның өзекті бағыттарының бірі болып табылады. Бұл зерттеу Artemisia rutifolia өсімдігінің жер үсті бөлігінен алынған экстракт құрамындағы химиялық компоненттерді талдауға арналған. Зерттеу мақсаты – заманауи аналитикалық әдістерді қолдана отырып, осы өсімдіктен спиртті экстракт алу арқылы негізгі биологиялық белсенді