Artículo de investigación

Drying Hawthorn Berries in Drum Dryer Using Blade Agitator

Обоснование сушки плодов боярышника в барабанной сушилке с использованием лопастного перемешивающего устройства

Secado de bayas de espino en un secador de tambor con agitador de cuchillas

Recibido: 9 de junio del 2019 Aceptado: 11 de julio del 2019

Written by:
S. Yu. Shcherbakov[197]
ORCID ID: 0000-0002-8073-0876
https://elibrary.ru/author_items.asp?authorid=485740
I. P. Krivolapov[198]
ORCID ID: 0000-0002-1348-6770
https://elibrary.ru/author_items.asp?authorid=790401
P. S. Lazin[199]
ORCID ID: 0000-0003-1646-1912
https://elibrary.ru/author_items.asp?authorid=908869

Abstract

Perennial provision of high-quality fruits and berries to population is a very important issue. Drying the products is an optimum solution to preserve quality of plant raw materials. This article discusses comparative experimental results of drying hawthorn berries in drying cabinet and drum dryer equipped with rotary cylindrical drum with rigidly fixed blades and internal blade agitator rotating in the contrary direction with respect to the drum. It has been established that drying from initial moisture content of 74.9% to final level of 20% in drying cabinet requires 11 hours at average power consumption of 2.3 kWh/kg of evaporated moisture, whereas drying in drum dryer with agitator requires 7 hours at average power consumption of 1.8 kWh/kg of evaporated moisture to final moisture content of 14%; moreover, it has been experimentally detected that drying in cabinet is heterogeneous over product bulk, the final product moisture content varies from 17.5 to 23.5%. Moisture content as a function of drying time is presented which demonstrates homogeneity of drying resulting in production of high-quality dried berries.

Key words: Drying, hawthorn berries, drying cabinet, drum dryer.

Аннотация

Круглогодичное обеспечение населения плодами и ягодами высокого качества относится к наиболее важному числу задач. Оптимальным решением по сохранению качества растительного сырья является сушка продукта. В статье представлены сравнительные результаты экспериментальных исследований процесса сушки плодов боярышника в сушильном шкафу и барабанной сушильной установке, комплектуемой вращающимся цилиндрическим барабаном с жестко закрепленными на нем лопастями и установленной внутри барабана мешалкой с лопастями, которая вращается в противоположную сторону от барабана. В ходе проведенных исследований установлено, что на сушку при начальной влажности плодов 74,9% до конечной 20% в сушильном шкафу затрачивается 11 часов, при среднем расходе электроэнергии 2,3 кВт/ч испаренной влаги, в то время как сушка в барабанной сушилке с перемешивающим устройством проходит в течение 7 часов при среднем расходе 1,8 кВт/ч испаренной влаги до конечной влажности 14%, кроме того, экспериментально определено, что сушка в сушильном шкафу характеризуется неравномерностью по объему продукта, конечная влажность которого изменяется в пределах от 17,5 до 23,5%. Представлены

[197] Michurinsk state agrarian University, Michurinsk, Russia
[198] Michurinsk state agrarian University, Michurinsk, Russia
[199] Michurinsk state agrarian University, Michurinsk, Russia

экспериментальные зависимости снижения уровня влажности от времени сушки, определяющие, что перемешивающее устройство обеспечивает равномерность процесса сушки, позволяя получать высушенные плоды высокого качества.

Ключевые слова: Сушка, плоды боярышника, сушильный шкаф, барабанная сушилка.

Resumen

El suministro perenne de frutas y bayas de alta calidad a la población es un tema muy importante. El secado de los productos es una solución óptima para preservar la calidad de las materias primas vegetales. Este artículo analiza los resultados experimentales comparativos del secado de bayas de espino en un gabinete de secado y un secador de tambor equipado con un tambor cilíndrico giratorio con cuchillas rígidamente fijas y un agitador interno de cuchillas que gira en la dirección contraria con respecto al tambor. Se ha establecido que el secado desde el contenido de humedad inicial del 74.9% hasta el nivel final del 20% en el gabinete de secado requiere 11 horas con un consumo de energía promedio de 2.3 kWh / kg de humedad evaporada, mientras que el secado en un secador de tambor con agitador requiere 7 horas en promedio consumo de energía de 1.8 kWh / kg de humedad evaporada hasta un contenido de humedad final de 14%; Además, se ha detectado experimentalmente que el secado en el gabinete es heterogéneo sobre el volumen del producto, el contenido de humedad del producto final varía de 17.5 a 23.5%. Se presenta el contenido de humedad en función del tiempo de secado, lo que demuestra la homogeneidad del secado que resulta en la producción de bayas secas de alta calidad.

Palabras clave: Secado, bayas de espino, gabinete de secado, secador de tambor.

Introduction

Fruits and berries are highly important for adequate nutrition of humans since they provide all required micronutrients: vitamins and mineral substances (Ogneva, Ponomarenko, Kovalenko, 2015). Long term storage of fruits and berries in natural from is impossible under ordinary conditions since during storage various mold fungi and pathogenic microflora are developed in fruits and berries, which leads to their spoiling.

Analysis of Russian industry of drying facilities reveals that small size equipment for processing of plant raw materials under conditions of private farms is in fact not manufactured. Existing drum driers are not widely used due to low amount of removed moisture and increased expenses for drying, such driers do not comply with modern requirements (Lichko, Kurdina, Mel'nikov, 2008; Shevtsov, 2015). Availability of small size drying facilities of batch type would permit to process raw materials at site of agricultural producer, thus closing process cycle and significantly reducing loss upon transportation and storage of end products.

Hawthorn berries are dried in drying cabinets, sometimes in belt driers. The state of drying procedures and facilities of food industry (Shevtsov, 2015; Lazin, Shcherbakov, 2016; Mesnyankin, 2002; Shcherbakov, Lazin, 2016; Shcherbakov, 2006) evidences long time of drying which leads to decrease in product quality and increase in power consumption. A promising approach to improve hawthorn berries drying is to use batch type drum driers (Lazin, Shcherbakov, 2016; Mesnyankin, 2002; Shcherbakov, Lazin, 2016; Lazin, Shcherbakov, 2017).

Therefore, development of highly efficient drum driers is very important since they provide complete automation of processes and, as a consequence, significant improvement of labor efficiency and quality of end products.

This work is aimed at improvement of hawthorn berries drying in drum driers equipped with blade agitator. The following targets should be achieved: intensification of drying, high quality and environmentally safe dried product upon moderate power consumption and high drying rate; substantiation of design and engineering parameters, as well as operation modes of the proposed drum drier design.

Drum driers are usually not equipped with agitators, hence, drying is not intensive and not homogenous (Lazin, Shcherbakov, 2016; Mesnyankin, 2002), in order to eliminate these drawbacks, it is proposed to install mechanical agitator inside drum; this would permit to accelerate drying significantly. Numerous studies (Shevtsov, 2015; Lazin, Shcherbakov, 2016; Mesnyankin, 2002; Shcherbakov, Lazin, 2016; Shcherbakov, 2006) have confirmed that application of various agitators accelerates drying and product agitation, eliminates lumps and local overheating.

Methods

In order to determine efficiency of hawthorn berries drying in cabinet driers, moisture content of hawthorn berries as a function of drying time, as well as specific power consumption and heterogeneity of hawthorn berries drying were determined.

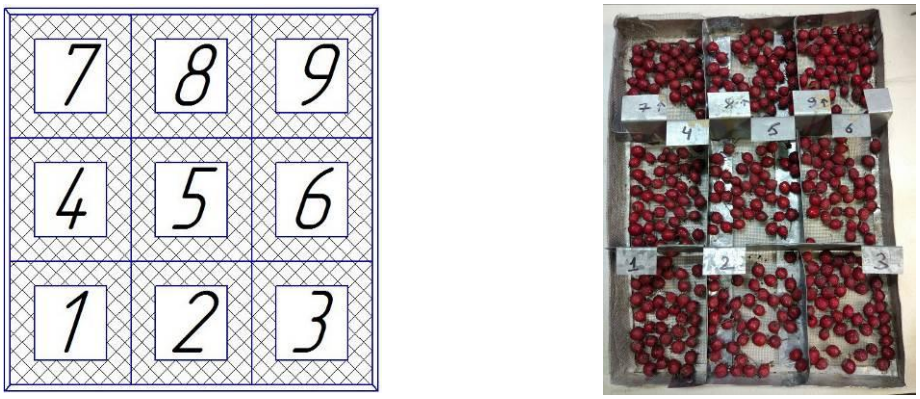
Drying was carried out in a cabinet drier (Fig. 1a), the experiments were performed with blood red hawthorn berries (Crataegus sanguinea Pall). Samples were taken according to (State standard GOST 28561-90, 1990).

a b

Figure 1. Test rig: a) laboratory drying cabinet: 1 - drying chamber; 2 - door; 3 - control unit; 4 - electric heaters; 5 - perforated pan for product; b) EVLAS-2M moisture analyzer.

The perforated pan (Fig. 2) was subdivided into 9 areas, 100 g of hawthorn berries were placed into each area. Moisture content was determined using an EVLAS-2M moisture analyzer (Fig. 1b).

Initial moisture content was 74.9%. The experiment duration was 11 h at 60°C, every hour the product from each area was weighed. Herewith, power consumption for all drying process was monitored.



a b

Figure 2. Layout of segments on pan (a); perforated pan with hawthorn berries (b).

Hawthorn berries drying in cabinet drier was compared with drying in drum drier.

Schematic view of this design is illustrated in Fig. 3.

Figure 3. Drying drum: 1 – heat insulating casing; 2 – blade agitator, 3 – agitator drive; 4 – drum drive; 5 – control unit; 6 – charge opening; 7 – discharge opening; 8 – heating chamber; 9 – fan.

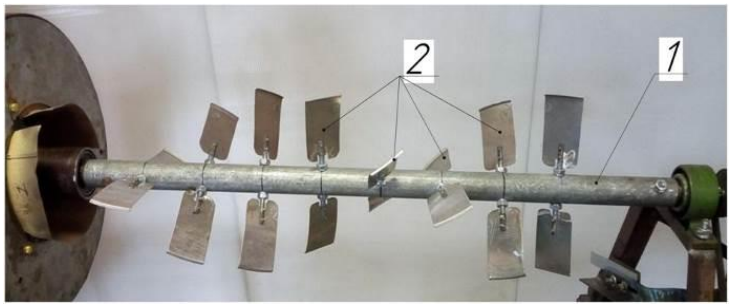


Figure 4. Agitator installed inside drum: 1 – shaft; 2 – blades.

The assembly is comprised of the casing 1: cylindrical drum with heat insulation and rigidly fixed blades installed under slight inclination (2–3°) on supports; inside the drum the blade agitator 2 is installed with the drive 3 which rotates the drum clockwise, the control unit 5 is provided, the product is charged via the charge opening 6, and discharged via the discharge opening 7, the heating chamber 8 is comprised of body and tubular electric heaters for air heating, air is supplied by the fan 9.

The drum drier operates as follows. Wet product is charged via the charging opening into drying drum which rotates clockwise, herewith, the product is mixed by the agitator (Fig. 4) which rotates counterclockwise. Drying is homogeneous, hot air is supplied into the drum from two sides. Opposite rotations of the drum and the agitator together with constant impact of hot air during agitation make it possible quickly produce high quality, evenly dried product without lumps and deposits. When drying is finished, the product is discharged via the discharging opening.

Several experiments were performed aimed at determination of drying efficiency and quality as well as at determination of moisture content as a function of time with and without agitator using the assembly illustrated in Fig. 3. The experiments were performed with blood red hawthorn berries (Crataegus sanguinea Pall). The initial moisture of the berries determined by an EVLAS-2M moisture analyzer was 74.5%. During the experiments, each 60 min samples were taken at least three times for determination of moisture content in three areas of the drum (Fig. 7). Duration of each experiment was 420 min at 60°C. Power consumption for all drying process was monitored.

Results and Discussion

According to the obtained dependence (Fig. 5), the duration of drying in cabinet from initial moisture content of 74.9% to final moisture content of 20% was 11 hours at average power consumption of 2.3 kWh/kg of evaporated moisture.

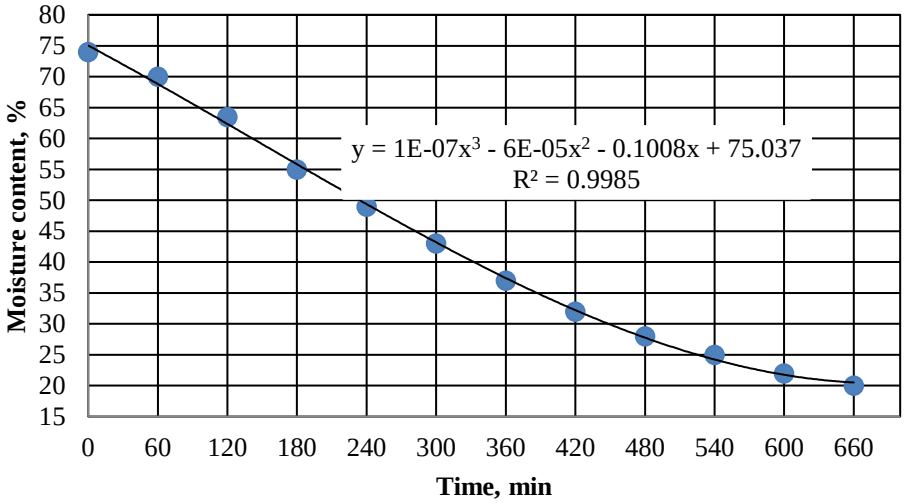


Figure 5. Moisture content of hawthorn berries as a function of drying time.

It has been established that drying in cabinet is characterized by high heterogeneity (Fig. 6): from 17.5 to 23.5% of final moisture content, that is, 20–25% of the end product will be either under- or over-dried with regard to the required moisture content, hence, the dried product will be characterized by low quality.

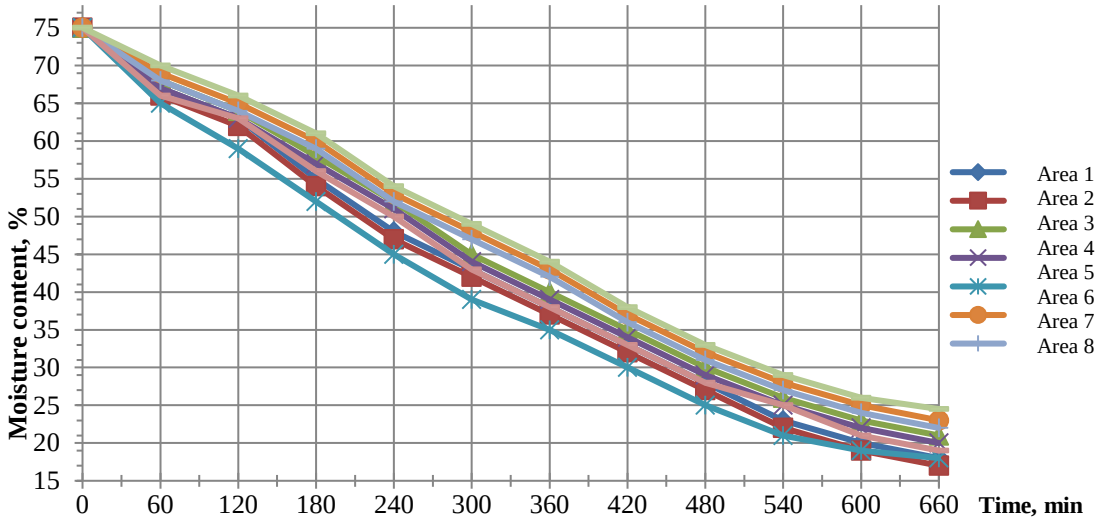


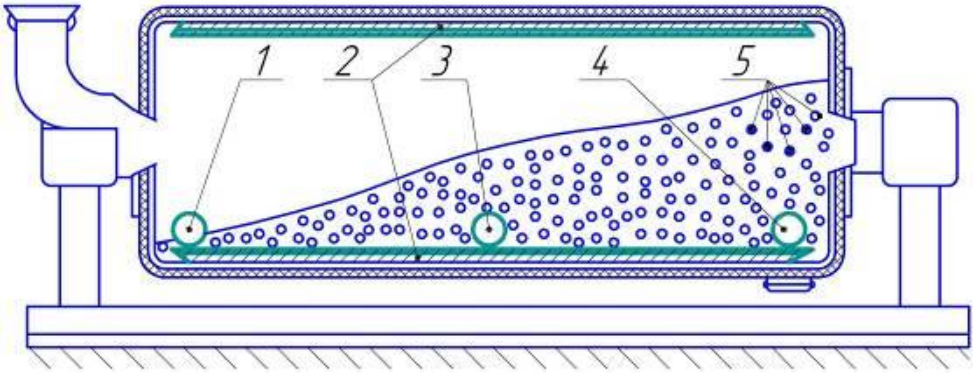
Figure 6. Moisture content of hawthorn berries as a function of drying time in various pan areas.

In the first experiment (Fig. 7a), the drying was performed without agitator; since the drum dryer was inclined at 3° to the horizon it can be seen that during drying major portion of berries is moved to area 3.

ISSN 2322- 6307

In the second experiment (Fig. 7b), drying was performed with agitator installed directly in the drum, the drum dryer was inclined at 3° to the horizon. The agitator blades move hawthorn berries in the drum, simultaneously lifting them to a certain height, as a consequence, the product is agitated downwards the drum, thus creating homogeneous agitation and distribution of hawthorn berries inside the drum in all three areas.

a.



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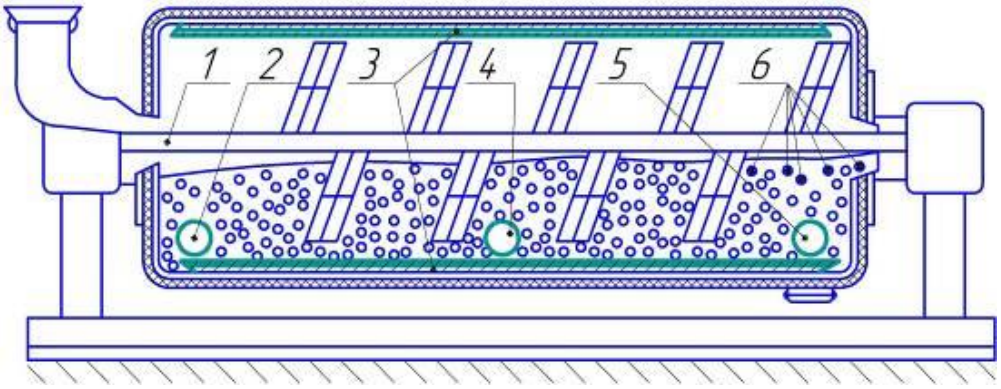

Figure 7. Distribution of hawthorn berries in drum dryer: a) without agitator: 1 - area 1, 2 - rigidly fixed blades, 3 - area 2, 4 - area 3, 5 - hawthorn berries; b) with agitator: 1 – agitator, 2 - area 1, 3 -rigidly fixed blades, 4 - area 2, 5 - area 3, 6 - hawthorn berries.

Experimental results with and without agitator in drum drier are illustrated in Fig. 8.

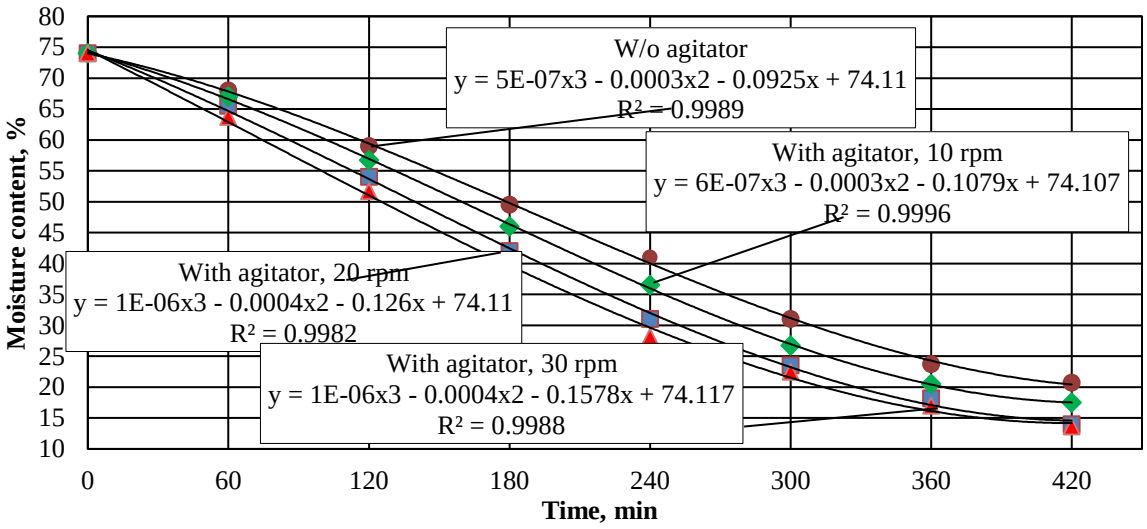

Figure 8. Moisture content of hawthorn berries as a function of drying time in drum dryer with agitator (at 10, 20, 30 rpm) and without agitator at 60°C.

It can be seen in Fig. 8 that drying in drum drier with agitator is more intensive, final moisture content upon drying in 420 min without agitator was 20.7%, whereas in the case with agitator, final moisture content at 10 rpm was 17.5 %, at 20 rpm – 14%, at 30 rpm – 13.5%.

Conclusion

It has been revealed that:

- Hawthorn berries are mostly dried in convective drying cabinets and almost never in drum dryers;
- Drying in cabinet is slow (11 hours from initial moisture content of 74.9 % to final moisture content of 20%) requiring high power consumption of 2.3 kWh/kg of evaporated moisture accompanied by high heterogeneity from 17.5 to 23.5% of final moisture content;
- Application of blade agitator in drum dryer provides homogeneous agitation and distribution of hawthorn berries in the drum inclined at 3°;
- Drying in drum drier with agitator is more intensive, final moisture content upon drying in 420 min without agitator was 20.7%, whereas in the case with agitator, final moisture content at 10 rpm was 17.5 %, at 20 rpm – 14%, at 30 rpm – 13.5%, at average power consumption of 1.8 kWh/kg of evaporated moisture.

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