CYCLIC CONVECTIVE DRYING OF BEE POLLEN

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ABSTRACT

Effective development of beekeeping is possible on the basis of a sufficient amount of protein feed in the bee family. Pollen and its Perga are indispensable sources of proteins, vitamins and lipids for honey bees. Perga, extracted from the honeycomb, has a humidity of 22÷26%, so quickly loses its properties and its long-term storage is impossible. Many experts believe that convective drying of Perga is the most preferable way to ensure the preservation of biologically active properties. Cyclic convective drying of Perga allows reducing the energy intensity of the process by repeated use of the coolant (hot air), due to the full use of its moisture-intensive potential. The circulation of the coolant inside the dryer is provided by a fan. With the help of the control unit, the drying mode is programmed, while the main fan creates an air flow that circulates through the drying chamber and the air duct, heating with a tubular electric heater. During the drying process, the moisture from the product evaporates, and the temperature loss of the coolant is compensated by the electric heater temperature sender. Periodically, when the coolant humidity reaches the limit values (70% ...75%), the control unit supplies ambient air to the fan and the wet coolant is removed from the air line by another fan. Multiple use of the coolant can reduce the cost of energy for heating the coolant. The investigated batch of honeycombs was placed in the drying chamber; the control unit was set the temperature of the coolant. From time to time, samples of Perga weighing 2 grams were taken from the cells and the current relative humidity of the product was determined. The analysis of empirical dependences allowed establishing the high importance of the coolant circulation rate on the value of the residual moisture of the Perga in the cells. Cyclic convection drying of Perga allows to reduce energy costs by more than 2 times in comparison with conventional convection drying of Perga and to ensure the safety of biologically active substances.

Keywords: bee pollen, drying of pollen, cyclic convective drying, the humidity of the pollen, the preservation of pollen.

INTRODUCTION

Effective development of beekeeping is possible on the basis of a sufficient amount of protein feed in the bee family [1,2,3,4]. Pollen and its Perga are indispensable sources of proteins, vitamins and lipids for honey bees [5, 6].Traditionally, during the formation of a bee's nest for the winter, beekeepers discard the old honeycombs, which are subject to further processing as wax raw materials. The presence of Perga in culled honeycombs leads to losses of wax and significantly worsens its quality, while there is a constant demand for Perga on the market [7, 8].

Perga, extracted from honeycombs, has a humidity of 22÷26%, so it quickly loses its properties and its long-term storage is impossible [9, 10 natural drying of Perga in the air is extremely inefficient and usually leads to spoilage of the product or complete loss of its biologically active properties [11]. Therefore, the necessary artificial drying to a moisture content of 14÷15% (requirements TU 10 RF 505-92 "Dried Perga").

Many experts believe that convective drying of Perga is the most preferable way to ensure the preservation of biologically active properties [12]. However, the high energy consumption of convective drying of pollen in combs is 11.9–19.1 kW•h/kg is a significant disadvantage [6, 13].

To solve the existing problem, we analyzed the operation of mechanized methods for extracting bee pollen from honeycombs, which are based on drying bee pollen and proposed methods of convective cyclic drying bee pollen.

Cyclic convective drying of Perga allows to reduce the energy intensity of the process by repeated use of the coolant (hot air), due to the full use of its moisture-intensive potential [14, 15].

MATERIALS AND METHODS

For analytical studies of the cyclic process of convective drying of pollen using an empirical model of the direct-flow convective drying of pollen in the cell with hot air [13]. The law of change of humidity of Perga with high degree of reliability is described by the equation:

$$w = 0,039306 - 0,001153 \cdot T + 0,000160 \cdot T^2 \qquad (1)$$

where: w is the average drying rate of Perga, T is the temperature, ^{0}C.

The law of change of moisture content of pollen in the cell, depending on the duration of drying is quite accurately described by an exponential equation of the form:

$$W = 18,28548 e^{-0,00592\tau}, \qquad (2)$$

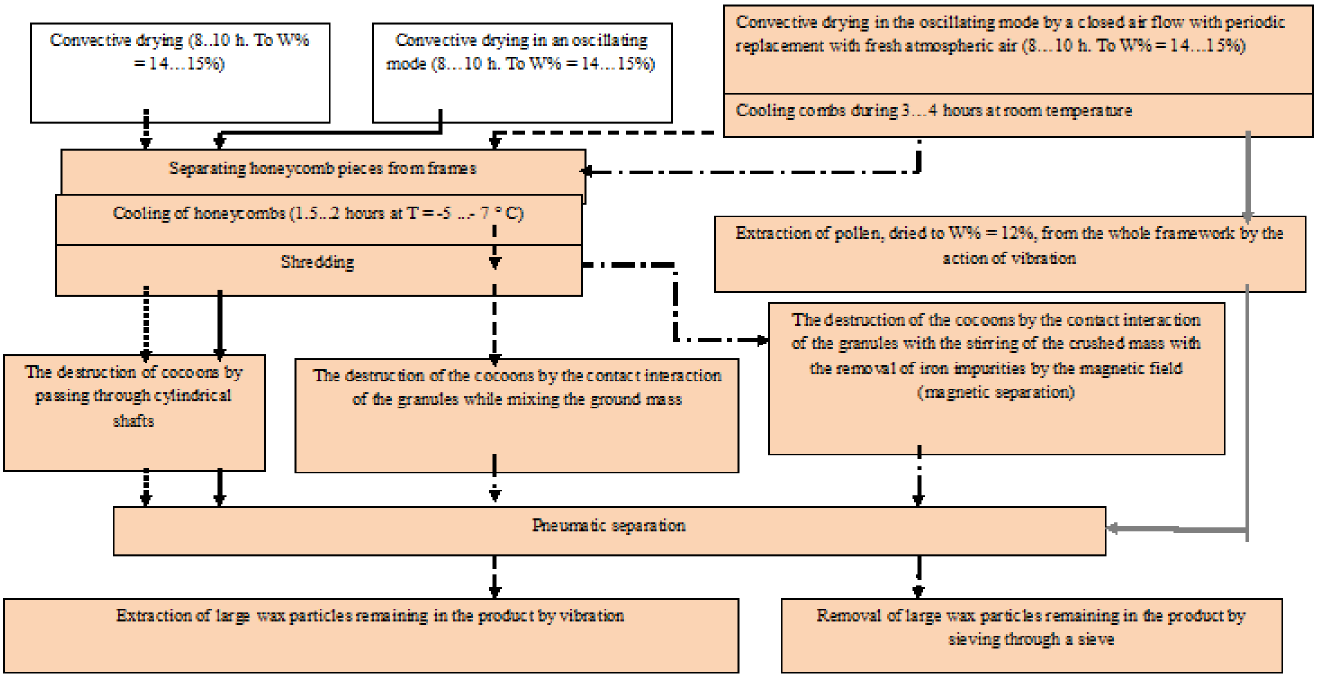

Figure-1. The mechanized energy saving ways of extraction of a perga with preliminary convective drying (the operations offered by us are highlighted in the color (patents of the Russian Federation for an invention No. 2297763, No. 2397639)).

$$W(t) = \frac{1}{z(t)} = \frac{1}{\int_{t_0}^{t} Q(\xi) e^{-\int_{\xi}^{t} P(\tau)d\tau} d\xi + \frac{1}{W_0} e^{-\int_{t_0}^{t} P(\tau)d\tau}} \quad (3)$$

where: ξ - the size-mass characteristics of pollen, %; τ - duration of drying of pollen in the cell, s

Repeating the reasoning (2) we come to the following equations of evaporation in the heating mode:

$$\frac{dW}{dt} = \left[\varphi_0 \cdot \frac{\rho_{NP}(T_{env})}{\rho_{NP}(T)} + \frac{(W_0 - W(t)) \cdot M}{\rho_{NP}(T) \cdot V} - 1\right] \cdot (b \cdot W + c \cdot W^{2,1} + d \cdot W^{2,5}) \quad (4)$$

and in ventilation mode:

$$\frac{dW}{dt} = \left[\varphi_0(T_{env}) \cdot \frac{\rho_{NP}(T_{env})}{\rho_{NP}(T)} - 1\right] \cdot (b \cdot W + c \cdot W^{2,1} + d \cdot W^{2,5}) \quad , (5)$$

where: W_0 is the initial relative humidity of the Perga, %;
φ_0 – initial relative humidity of the coolant, %;
ρ_{NP} – saturated vapor density, kg / m3; T_{env} –

ambient temperature, ^{0}C ;
M is the mass of pollen in the drying unit, kg;
b, c, d – coefficients of proportionality.

After making calculations using the parameters of a commercially available drying unit, it was theoretically established that from the standpoint of minimizing energy consumption when using a heat carrier having a temperature of 41 ° C and a volume of 0.35 m3, for convective cyclic drying of 3 kg of perga should be 11.3 minutes, and the duration of the periods of removal of the coolant should be equal to 2.2 minutes, while for 50 hours of drying energy costs will be 73.08 kWh.

Experimentally verify the theoretical results obtained by investigating:

- the effect of theoretically established drying regimes on the energy intensity of the technological process;
- the influence of the regimes of cyclic convective drying on the change in moisture of the pollen when it is dried in a honeycomb and in bulk.

For these purposes, an installation for convective cyclic drying of pollen has been developed (Figure-2). The installation consists of a housing 1, the internal volume of which is divided by a partition 8, installed at an angle to the horizon of the fan 4 and the air flow guides 9, 10, 11, into a drying chamber 2 and a return air duct 3. The drying chamber is a vertically positioned air channel the side walls of which are inside, the guiding strips 7 are placed in a rectangular manner. The front wall of the drying chamber is made in the form of a door 17 equipped with locks 14 and a handle 13. The return air duct is an air duct, On the side walls of which fans 5, 12 are installed in the holes. An electric heater 6 is installed inside the channel. An air temperature sensor 16 is placed in the drying chamber. Guides to the drying chamber also serve to place baking trays with a mesh bottom, which are designed to dry the pollen in the form of granules.

The workflow is as follows. The product prepared for drying is placed in the drying chamber of the installation. For this purpose, the honeycomb frames with the parchment are placed on the guide strips 7 of the drying chamber 2, at a distance of 30÷40 mm from each

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other on each tier. When drying pegs in the form of granules or pieces of Perg honeycombs separated from the framework, the product is placed on trays, which instead of honeycombs are fixed on the guide strips. The door 17 is closed and ensure its tight fit by means of locks 14.

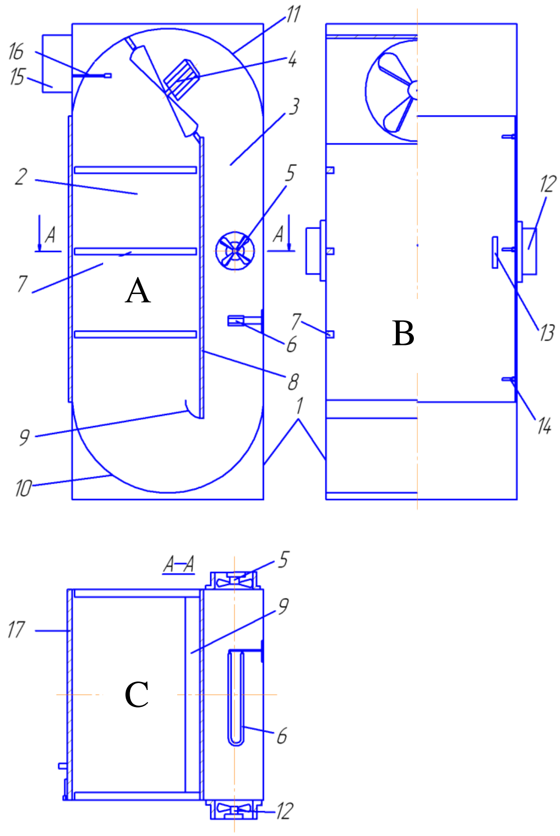

Figure-2. Installation for drying of Perga (designations in the text): A – section of the side view; B – front view; C - section top view.

Select the necessary drying program in the control unit 15 and turn it into operation, while the fan 4 creates an air flow that rushes down the air duct 3 into the zone of operation of the electric heater 6, where it is heated and enters the drying chamber 2. The circulation of the coolant inside the drying plant is provided by the air flow guides 9, 10, 11. During the drying process, moisture from the product evaporates, and the temperature lost by the coolant is maintained thanks to the temperature sensor 16, which closes and opens the power supply circuit of the electric heater.

Control of air flow rates between the cells in the drying chamber was performed using the ATT-1004 thermo anemometer. The energy consumption for drying of pollen in a drying installation was measured using meter stamps SO-505 GOST 6570-96 N. the Duration of the cyclic convective drying of batches of the product were set with the electronic timer brand "TGE-2" with an accuracy of ±1s.

The studied batch of honeycombs was placed in the drying chamber, the control unit was set to the temperature of the coolant 40±20^{0}C. Each tested batch of honeycombs, consisting of 14 frames, had a mass of 12.5±0.3 kg. Periodically, every 10 hours of drying, the drying chamber was opened, two honeycombs were sampled with a mass of 2 grams of Perga and the current relative humidity of the product was determined according to the standard procedure given in TU 10 RF 505-92 "Dried Perga".

Drying of each batch of honeycombs at the investigated coolant flow rate lasted for 50 hours [6, 13]. The experiments were carried out with double repetition.

RESULTS

As a result of statistical processing of experimental data, the dependences were established (2), (3), (4), which are presented graphically in Figure-3.

For models (6), (7), (8) the values of R^2 determination coefficient are 0.997; 0.998 and 0.999, respectively, which confirms the adequacy of empirical dependences to experimental data.

$$W_1(t) = 21,657 - 0,192 \cdot \tau + 0,001857 \cdot \tau^2 \qquad (6)$$

$$W_2(t) = 21,918 - 0,244 \cdot \tau + 0,002339 \cdot \tau^2 \qquad (7)$$

$$W_3(t) = 21,2 - 0,239 \cdot \tau + 0,002286 \cdot \tau^2 \qquad (8)$$

where: W_1; W_2; W_3 – the residual relative humidity of the Perga (%) at the coolant circulation rates V, belonging to the intervals: 1,3..1.6 m / s; 2.2..2.5 m / s; 3.4..3.7 m / s, respectively; τ-drying time (hours).

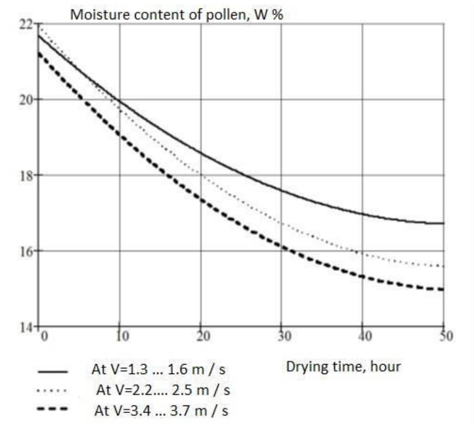

Figure-3. Graphic dependence of the residual moisture of the Perga in the honeycomb (W,%) on the duration of convective cyclic drying (t, hours) at different speeds (V, m/s) of coolant circulation.

Statistical analysis of the experimental results allows us to assert that the duration of the coolant circulation cycles in the studied time range does not have a significant effect on the drying process. It is experimentally established that the rational speed of air circulation at a temperature of 40 ÷ 42 ^{0}C in the process of cyclic convective drying of Perga in honeycombs should be in the range of 2.2÷2.5 m/s. At this speed for 50 hours of drying it is possible to reduce the humidity of the Perga in the honeycomb from 21.6% to 15.5%, the specific energy consumption by one percent of reducing the humidity of the Perga in the honeycomb 12.2 kWh/%, the total energy consumption for drying a batch of cells weighing 12.5±0.3 kg, consisting of 14 frames is 74.4 kWh.

DISCUSSIONS

According to the data of Table-1, the least favorable method of stabilization for Perga is the storage of Perga at +6°C. After 3 months of storage, the oxidizing ability of Perga begins to fall (25 seconds before storage and 30 seconds after 3 months.) and the amount of crude protein is reduced from 22.8% to 17.8%. The most favorable, according to our data, for Perga proved to be a method of storage at -18°C and stabilization by drying at 40°C with ventilation. They had minimal effect on the change of biochemical components and parameters in the samples. When removing the indicators after 3 and 6 months of storage, the oxidizing ability of Perga in one and in the other case did not change, minimal changes were found in the percentage of crude protein. With the method of stabilization by drying at 40°C with ventilation, a slight decrease in the content of flavonoid compounds was observed (from 3.0% to 2.5% after 6 months of storage). In the case of storage of Perga at -18°C, the value of this indicator remained stable after 6 months of storage. A favorable condition for the preservation of the biological properties of Perga is its preservation with honey. This method is most often proposed in the literature for the preservation of Perga and its storage in domestic conditions, which in General is justified and confirmed by our research. When stored for 6 months, this method of preservation provides the relative stability of the most important components: the content of crude protein and flavonoid compounds, as well as the oxidizing ability.

Table-1. The Influence of different methods of drying, cooling and preservation on the biologically active properties of Perga during its storage.

Indicator	Before setting the experience	Perga with honey		Perga, dried in various ways				Perga native (fresh from the bee's nest) stored at different temperatures					
		3 мес	6 мес	At a temperature of + 40^0C with ventilation		At a temperature of 50^0C under vacuum		+6^0C		-6^0C		-18^0C	
				3 months	6 months	3 months	6 months	3 months	6 months	3 months	6 months	3 months	6 months
Humidity, %	19.8	-	-	12.8	13.5	12.0	13.2	20.8	21.0	21.0	21.3	21.0	20.8
Oxidizability, s	25.0	22.0	22.0	25.0	25.0	24.0	25.0	30.0	28.0	25.0	25.0	25.0	25.0
Flavonoid,%	3.0	2.8	2.5	2.7	2.5	2.5	2.0	3.0	2.5	3.1	2.8	3.1	3.0
pH	4.01	4.05	4.03	4.01	4.01	4.00	4.00	4.07	4.18	4.03	4.10	4.01	4.04
Crude protein, %	22,8	23.4	23.2	20.0	20.1	19.5	19.7	17.8	17.5	18.1	18.0	21.7	19.8

CONCLUSIONS

Cyclic convective drying of Perga is a highly effective way to reduce the moisture content of the product and can reduce energy costs by more than 2 times in comparison with the convective drying of Perga. To ensure the process of cyclic convection drying of Perga in honeycombs, the rational circulation speed should be in the range of 2.2÷2.5 m / s, and the air temperature - $40÷42^0$ C. The low speed of the cyclic drying process avoids overheating of the Perga and ensures the safety of biologically active substances.

REFERENCES

[1] Almeida-Muradian L. B. 2007. Carotinoids and carotene sustainability during storage of dried bee pollen pellents / L. B. Almeida - Muradian, M. Moriya // 40th Apimondia international cultural congress. Melbourne. pp. 164-165.

[2] Benson K. 1984. Cleaning and handling pollen / Benson K. // American Bee Journal. 131(24): 303-305.

[3] 1980. Biochemistry and microbiology of bee - collected almond (Prunus dulcis) pollen and bee bread / G. M. Loper [*et al.*] / / Apidologie. N2 11 (1). p. 63-73.

[4] Davis A. R. 1991. Mixed loading of pollen from Echium plantagineus and Airschfeldia incana, Lzgreze Fass by an individual honey bee (Apis mellifera L.) / A. R. Davis // American Bee Journal. 131(910): 649-655.

[5] Gilliam M. 1989. Microbiology of pollen and bee bread: taxonomy and enzymology of molds / M. Gilliam, D.B. Prest, B. J. Lorenz // Apidologie. (91): 53-68.

[6] Kashirin D. E. 2013. Energy-Saving technologies of extraction of Perga from honeycombs by specialized means of mechanization: thesis for the degree of doctor of technical Sciences/ D. E. Kashirin. - Saransk. p. 497.

[7] Manning R. 2001. Fatty acids in pollen: A review of their importance for honey bees / R. Manning // Bee World. 82(92): 60-75.

[8] Pat. No. 2297763 of the Russian Federation. IPC A01K 59/00. The method of extracting pollen from combs / D. E. Kashirin. - Declared. 05.12.2005; publ. 27.04.2007, Byul. No. 12. – 4p.

[9] Pat. No. 2397639 of the Russian Federation. IPC A01K 59/00. The method of extracting pollen from combs / D. E. Kashirin. - Declared. 17.04.2009; publ. 27.08.2010, bul. (24): 5.

[10] Schmidt J.0. 1989. Chemical composition of the fresh pollen and bee bread pollen stored at different temperatures / RP. Singh, P. N. Singh // Nat. Acad. Sci. Lett. 12(27): 233-239.

[11] Standifer L. N. 1980. Biochemical and microbiology of pollen collected by honey bees from almond Prunus Dulcis / Standifer L. N., W. F. McCaughey, S. E. Dixon // Apidologie. 2(22): 163-17L.

[12] Szczesna T. 1999. Amino acids of bee - collected pollen / T. Szczesna, H. Rybak - Chmielewska // XXXVI International congress of Apimondia. - Vancouver.p. 271.

[13] Szczesna T. 2007. Concentration of selected elements in honeybee-collected pollen / selected in Journal of Apicultural science. 51(21): 5-13.

[14] Szczesna T. Water content of pollen loads harvested at different periods of the beekeeping season / T. Szczesna, H. Rybak - Chmielewska // International conference on recent trends in apicultural science. - Finland, 2007. - P. 100.

[15] 1997. The use of honey and pollen in the chemotherapy of cancer patients / patents [*et al.*] / / XXXVth International apicultural congress. - Bucharest.p. 423.