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AUTOMATIC SEMIFLUID MASS DISPENSER

AUTOMATYCZNY DOZOWNIK MASY PÓŁPŁYNNEJ

Abstract

The article presents an innovative method for hair dye dispensing and a prototype device enabling automatic dispensing of hair dyes and other semifluid substances. The dispenser makes it possible to programme colour compositions and to precisely dispense the programmed amounts of dyes from three different tubes to combine colours and achieve the desired, known or new, colour and tonal value, as requested by the client. With the dispenser's software, the hairdresser can create interlinked databases of applications and mixtures and ensure rational management of the substances used. The modern design, compact structure, and automated operation decide on the innovativeness of the dispenser.

The article discusses the genesis of the project, the functional and technical assumptions of the innovative device, as well as the design and development of the prototype and performance of functional tests, paying particular attention to the presentation and description of the following: (1) the original structural solutions; (2) the operation of functional modules that are responsible for positioning and identifying dye tubes, dispensing dyes in precisely defined amounts, monitoring the composition of the colour formula, and ensuring optimum dye use; and (3) the user interface. The structure of the device was developed by joining metal structural elements produced with the use of technologies typical for machine construction with commercial components (drives and controllers) and components produced with the use of additive manufacturing technologies responsible for the complete integration and design of the device. The original structural solution of the device is protected by intellectual property rights under patent applications.

Keywords: tube squeezing, semifluid substance dispensing, automatic dispenser

Streszczenie

W artykule przedstawiono nowatorską metodę dozowania farb do włosów oraz prototypowe urządzenie umożliwiające automatyczne dozowanie farb do włosów i innych półpłynnych substancji. Dozownik umożliwia programowanie kompozycji kolorystycznych oraz precyzyjne dozowanie zaprogramowanych ilości barwników z trzech różnych tub w celu łączenia kolorów i uzyskania pożądanej, znanej lub nowej wartości kolorystycznej i tonacyjnej, zgodnie z życzeniem klienta. Dzięki oprogramowaniu dozownika fryzjer może tworzyć powiązane ze sobą bazy danych aplikacji i mieszanek oraz zapewnić racjonalne zarządzanie stosowanymi substancjami. Nowoczesny design, zwarta konstrukcja oraz zautomatyzowana obsługa decydują o innowacyjności dozownika.

W artykule omówiono genezę projektu, założenia funkcjonalne i techniczne innowacyjnego urządzenia, a także zaprojektowanie i wykonanie prototypu oraz wykonanie badań funkcjonalnych, zwracając szczególną uwagę na przedstawienie i opis: (1) oryginalne rozwiązania konstrukcyjne; (2) działanie modułów funkcjonalnych odpowiedzialnych za pozycjonowanie i identyfikację tub z barwnikiem, dozowanie barwników w ściśle określonych ilościach, monitorowanie składu receptury kolorystycznej oraz zapewnienie optymalnego wykorzystania barwnika; oraz (3) interfejs użytkownika. Konstrukcja urządzenia została opracowana poprzez połączenie metalowych elementów konstrukcyjnych wykonanych w technologiach typowych dla budowy maszyn z komponentami komercyjnymi (napędy i sterowniki) oraz komponentami wytwarzanymi z wykorzystaniem technologii wytwarzania przyrostowego odpowiedzialnych za pełną integrację i zaprojektowanie urządzenia . Oryginalne rozwiązanie konstrukcyjne urządzenia jest chronione prawami własności intelektualnej na podstawie zgłoszeń patentowych.

Słowa kluczowe: wyciskanie tubki, dozowanie półpłynnej substancji, automatyczny dozownik

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1. Introduction

When it comes to creating mixtures with specific composition, precise dosing of individual components constitutes a major problem. This concerns gaseous, solid, liquid and semiliquid substances. The Łukasiewicz–Institute for Sustainable Technologies in Radom, Poland, carries out research to address this problem in the process of prototype device design, development and manufacture. Some of the solutions developed in response to the needs expressed by business owners and scientific institutions include the following: a painting robot (dosing of paints) [1]; chambers for gasometric testing (dosing of components of the gaseous atmosphere) [2, 3]; a chamber for concrete carbonation testing (dosing of CO2); VOC chambers (dosing of air streams of different humidity) [4, 5]; a device for erosion testing (dosing of an abrasive agent) [6]; and a production line for the production of cable moisture barriers (dosing of a powder superabsorbent) [7].

One area that requires preparation of semifluid (semiplastic) mixtures is hair colouring [8]. In the colouring process, one or a combination of different dyes can be applied. No matter what the case is, the dye use needs to be rationally managed, which means that an optimum amount of the dye needs to be used to obtain the desired end result (colour or tone).

"Kuźnia Fryzjerska Wojciech Jewuła" – a chain hair salon offering high-quality hairdressing services and related training services – approached the Łukasiewicz–Institute for Sustainable Technologies with a proposal of a project financed by the European Union revolving around the development of an easy-to-use in-salon hair dye dispenser to facilitate the hair colouring process. The device would enable any amounts of the hair dye to be dispensed from the three easily removable and replaceable tubes with commercial hair dyes placed inside. By making it possible to precisely dispense the dye in the required amounts, the control system with an intuitive user interface also enables rational management of the dye and its use. With data archived on a regular basis, the device can quickly retrieve the data about: the colour formulas specified for individual clients; the amount of each dye used; and the necessity to refill dyes to ensure undisturbed operation of the salon or chain of salons.

Thus formulated project was carried out at the Prototyping Centre at the Łukasiewicz Research Network–Institute for Sustainable Technologies (Łukasiewicz–ITEE) in Radom, in cooperation with Wojciech Jewuła, the owner of a chain of hair salons.

2. Technological assumptions

Based on the above-described functional features, the following technical assumptions were adopted to design and develop a prototype dispenser (Fig. 1):

- the dispenser shall be a portable device and in its size and design it should resemble a coffee machine;
- the dispenser shall be equipped with a cartridge with three sockets for dye tubes enabling (a) the dye to be automatically (i.e. controlled via software) dispensed from the tubes in predefined amounts, with the use of a toothed mechanism, to a container placed in a fixed position, and (b) each tube to be easily replaced manually, regardless of the amount of the dye actually used;
- the tube containing the dye should have the size of 220 mm x 50 mm (height x width);
- the tube should have the volume of 100–120 ml;
- the dye should be dispensed to a dye bowl typically used in hair salons, with the maximum size of 75 mm x 150 mm (height x diameter) placed on the plate of the electronic weighing scales;
- the amount of the dye dispensed from the tube shall be monitored based on the weight of the dye in the bowl;
- the dye should be dispensed with the accuracy of ±1 g;
- the device should be operated via a touch panel activating individual functions controlled by the relevant modules of the software of the electronic controller; and
- the power supply should have the voltage of 230 V and the frequency of 50 Hz.

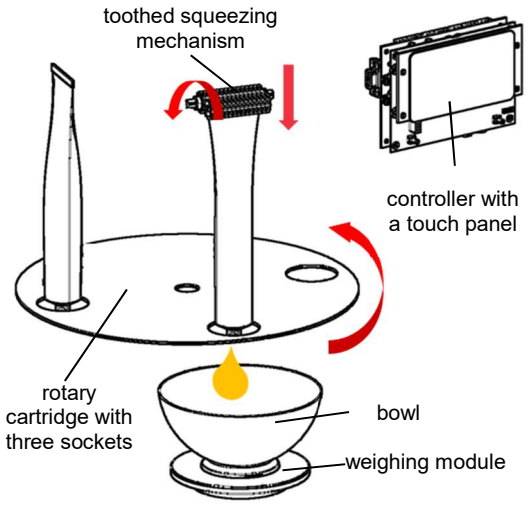


Fig. 1. Concept of the dispenser

To operate the device, dye tubes need to be placed in the cartridge sockets (dyes that are most frequently used can be stored in the cartridge permanently), and then a new or saved colour formula must be selected on the touch panel. The dye is dispensed automatically and once the process is completed, the hairdresser removes the bowl with the dyes and mixes them to obtain the desired end result (appropriate hair colour and/or tone).

3. 3D model and documentation of the system

The CAD 3D model of the dispenser was developed based on the adopted technical assumptions and concept of the device. The model built in the CAD Autodesk Inventor system [9] allowed the spatial geometric and kinematic analysis of the adopted structural solutions. The front view of the model of a complete device is presented in Figure 2. Body 1 (Fig. 2) is a metal structure made of steel sheet in which all modules and mechanisms are mounted; the front surface is protected with fixed covers (2) and a moveable cover (6). Covers (2) and (6) were made with the use of 3D printing technology and their plasticity allows them to be easily shaped to give the device an attractive design; the use of the additive manufacturing technology also means that a company logo or other branding elements can easily be placed on the cover(s). In the base of the device, under the dispensing mechanism, a weighing scales plate is mounted; this is where a bowl into which the dyes are to be dispensed is placed. Once the moveable cover is lifted, the user gains access to the cartridge and can place the dye tubes in or remove them from individual sockets. The touch panel located in the fixed cover enables the user to programme colour formulas and gives them access to the available automatic functions of the device.

Figure 3 presents the internal structure of the dispenser. In the central part of the body, under the movable cover, a rotary cartridge (3) is mounted on an axis (4) (Fig. 3) in which three squeezing modules (7) are peripherally mounted (every 90 degrees) to dispense the dye from tubes (1). The cartridge can be put into rotary motion by a stepper motor (6) with synchronous transmission (5) and it can be placed in positions enabling the dye to be dispensed from the tube directly to the bowl, or in a standby position, in which the tubes are closed by closing modules (11) protecting the dye from drying. Each cartridge position is identified by optical sensors (8) and set by a electromagnetic lock (9).

In the body, under the cartridge and directly above the weighing scales plate, a scraper (10) is mounted to separate the amount of the dye dispensed from the tube to the bowl underneath. In the base of the body, a weighing scales plate (2) is mounted – with it the amount of the dispensed dye can be monitored.

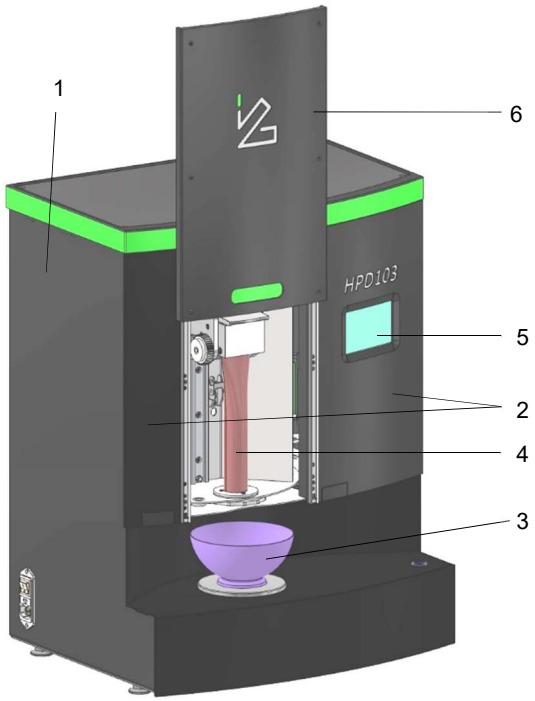


Fig. 2. CAD 3D model of the dispenser (general view): 1 – body, 2 – fixed covers, 3 – bowl, 4 – tube, 5 – touch panel, 6 – moveable cover

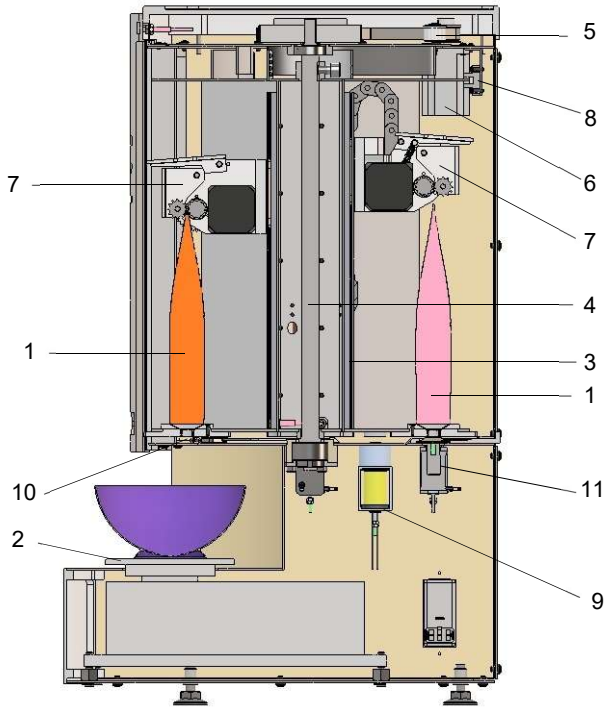


Fig. 3. CAD 3D model of the dispenser (section): 1 - tube, 2 – weighing scales plate, 3 – cartridge, 4 – axis, 5 – synchronous transmission, 6 – stepper motor, 7 – squeezing module, 8 – optical sensor, 9 – electromagnetic lock, 10 – scraper, 11 – closing module

Figure 4 presents the structure of the squeezing mechanism. The weight-bearing element of the mechanism is the slide guide composed of a sliding block (1) (Fig. 4) and a guide rail (2) connected to the rotary cartridge. The initial load of the slide guide is adjusted in a way preventing the sliding block to fall when all elements connected to it are in the vertical position. The sliding block is connected to the C-shaped module body in which the stepper motor putting a drive roller (4) into motion is mounted. An open dye tube (10) is placed in a rotary threaded socket (9) and its opening is closed off by toothed drive and clamping rollers. The rollers are placed in the clamping position by a latch (5) and a spring (6). When the drive roller rotates, the tube is placed between the toothed rollers (4 and 7), as a result of which the dye is dispensed. As a result of the gradual emptying of the tube, the sliding block (1) and the squeezing mechanism move downwards, until the proximity sensor (8) signals that the tube is completely empty. The amount of the dispensed dye can be initially programmed by means of specifying the number of the steps of the stepper motor (3).

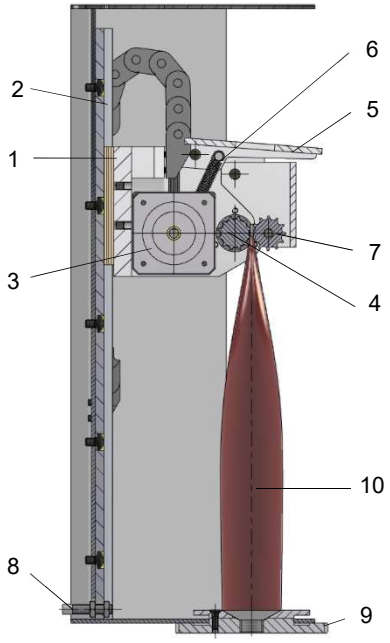


Fig. 4. CAD 3D model of the dispenser (section): 1 – sliding block, 2 – guide rail, 3 – stepper motor, 4 – drive roller, 5 – latch, 6 – spring, 7 – clamping roller, 8 – proximity sensor, 9 – socket, 10 – tube

4. Measuring and control system

Figure 5 presents a block diagram of the measuring and control system.

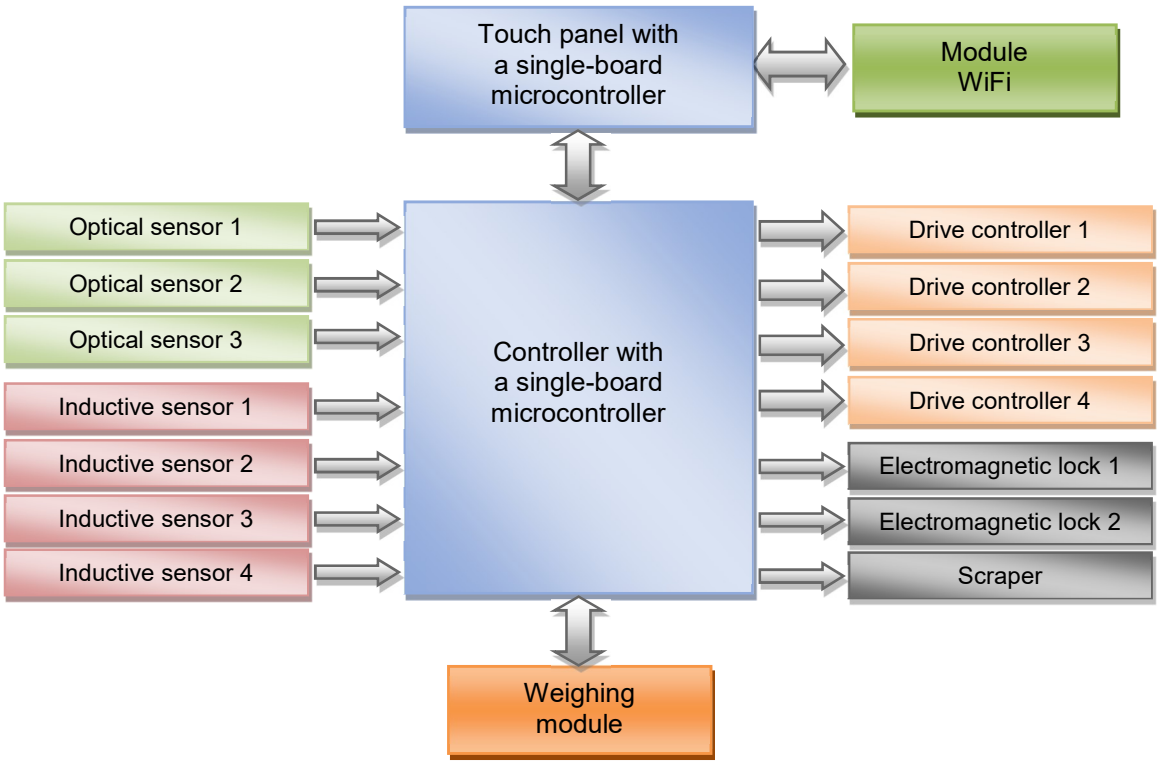


Fig. 5. Block diagram of the measuring and control system

The user panel is made of a 4” TFT display. The single-board microcontroller is responsible for displaying the properly designed graphics. The microcontroller is a programmable module (microcomputer) equipped with universal input and output ports with pin wire housings [10]. Because of the insufficient number of input/output ports and misalignment between control elements and sensors, the authors designed an additional printed circuit board (PCB) with a single-board microcontroller (Fig. 6). The board plays the role of the main controller.

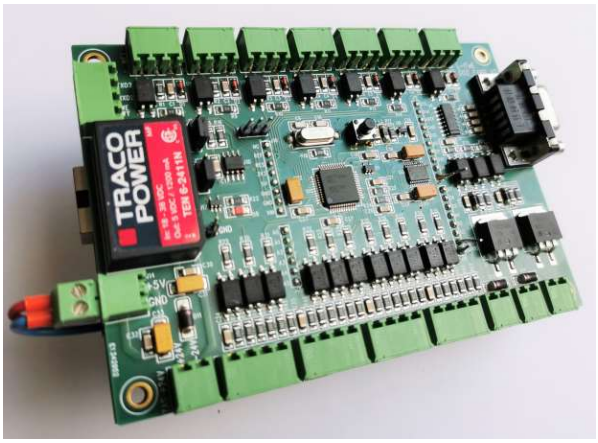


Fig. 6. View of the mounted PCB of the dye dispensing controller

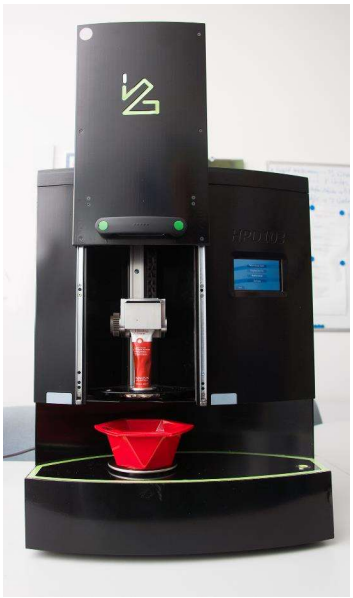
A dedicated control system was designed for the microcontroller. The information is exchanged between the microcontrollers of the panel and controller by means of a universal asynchronous receiver transmitter (UART). Signals from optical and inductive sensors are transmitted to the controller. The use of optocouplers enables the signals from +24 V sensors to be aligned with the operating voltage of the microprocessor system (i.e. +5 V and +3.3 V). Optocouplers also create galvanic insulation and increase resistance to electromagnetic interferences.

The use of three optical sensors enables the position of the rotary cartridge to be successfully detected. Inductive sensors are used to detect how much dye has been dispensed from and left in the tube. One of the inductive sensors informs the user about the position of the cover. The controller outputs generate signals fed to the stepper motor controllers. One of the stepper motors is responsible for rotating the cartridge with tubes, while the other three drive the squeezing rollers in each socket. The control follows a fixed algorithm in a closed feedback loop. What is used as the feedback is the information about the currently measured amount of the dispensed dye obtained from the weighing module. This information is transmitted to the controlled via RS232 in accordance with the protocol delivered by the manufacturer of the weighing module. The communication with the client database is possible via the WiFi module directly cooperating with the microcontroller of the touch panel.

5. Prototype verification

The prototype dispenser was built based on the adopted assumptions, developed model and technical documentation (Fig. 7a). The prototype was equipped with a complete set of control instrumentation and software to verify the correct operation of the individual units and software controlling the automatic implementation of functional procedures.

a)



b)

c)

Fig. 7. Prototype of the in-salon hair dye dispenser: a) prototype, b) squeezing module with cam clamping roller mechanism, c) ealstic cut-off valve (at the bottom of the socket)

The verification and functionality tests were carried out in the actual operating conditions [11]. Particular attention was paid to the efficiency and accuracy of dye dispensing. The tests were carried out on different types of commercially available tubes and they focused, in particular, on the possibility to squeeze out all their content. During verification tests, it was found that the tube clamping mechanism located between the drive (4) and clamping rollers (7) (Fig. 4) is not stable and, in the case of some tubes, it loosens during operation, which discontinues the dye dispensing process. The faulty clatch mechanism was replaced with a self-locking cam clamp (Fig. 7b), which proved effective and reliable. The replacement of the mechanism did not solve another problem concerning the impossibility to squeeze the dye out of a tube characterised by higher rigidity (thicker steel and dye). This problem will be addressed in the future research in which modifications will be introduced to the teeth of the squeezing rollers, and torque will be increased. Yet another problem identified at the time of the verification tests concerned the separation of the dye from the tube opening, which, despite the use of the mechanical scraper (10) (Fig. 3) powered by the electromagnet, turned out to be challenging. In the case of some substances, particularly those dispensed in small amounts, the use of the scraper did not ensure that the substance be scraped into the bowl completely and in a "mess-free" manner. To make this function more effective, an elastic cross-slit valve (Fig. 7c) was used in the socket (9) (Fig. 4) to cut-off the substance dispensed from the tube. Additional tests revealed that the effective separation of the dispensed amount of the dye also requires simultaneous application of a mechanical scraper and cut-off valve. A technical assumption that we failed to achieve concerns the dispensing accuracy of ±1 g. We managed to achieve some sort of accuracy of ±3 g, which the project partner found satisfactory, but we will work on this issue in the research to follow.

The original structural solution of the dispenser developed at the Łukasiewicz–ITEE and the entire concept of the device are the subject of patent applications [12, 13, 14, 15]. and they are protected by intellectual property rights.

6. Summary

The prototype in-salon hair dye dispenser developed at the Łukasiewicz–ITEE enables colour formulas to be easily programmed and dyes (up to three) to be dispensed in the required amounts as part of an automated procedure. The concept and the modus operandi of the dispenser were developed in cooperation with and as commissioned by a company owning a chain of hair salons. The dispenser is an innovative mechatronic device equipped with electronic controllers that can be used for the purpose of in-salon hair colouring; it also has attractive design. The functional tests of the prototype confirmed that the functional parameters assumed at the concept stage were achieved, and they revealed the need for further improvement, particularly as regards the dispensing accuracy and use of dyes sold in tubes characterised by high rigidity or of untypical size. The original structural solution of the dispenser developed at the Łukasiewicz–ITEE is the subject of patent applications.

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12. Zgłoszenie patentowe P.438056 Mechanizm i sposób do zautomatyzowanego procesu wyciskania substancji.
13. Zgłoszenie patentowe P.438057 Mechanizm zamykania tuby z masą półpłynną.
14. Zgłoszenie patentowe P.438058 Zgarniacz, separator mas półpłynnych wyciskanych z tubek.
15. Zgłoszenie patentowe P.438059 Urządzenie do dozowania mas półpłynnych konfekcjonowanych w tubkach