CONTROL OF THE PROCESS OF SPREADING BAST CROP STEMS BASED ON IT TECHNOLOGIES

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Abstract: This research aims to develop a modern method for determining and control the quality of temperature and moisture at the preparatory stages of processing of bast raw materials. Recent studies of domestic and world light industry markets show that currently and shortly, the commodities from natural raw materials will occupy the leading positions. This is because modern society prefers environmentally friendly products from natural raw materials rather than synthetic and artificial ones. In the world production of environmentally friendly products, bast raw material occupies the leading positions as a source of natural raw materials. It is enriched with high hygienic, medical, biological, and protective properties, the preservation of which should be observed at all stages of raw material processing. To achieve this aim, the use of a complex method of control and maintenance of standardized indices of moisture content and temperature based on SHT21 sensors, Zigbee receivers, and transmitters of cc2530 and cc2531 networks, and Raspberry Pl B + microcomputer has been theoretically and experimentally confirmed in the paper. The developed IT technology allows controlling and maintaining quality indices of temperature and moisture content in spreading, drying, storage, and preparation for technological processing of bast straw and retted stalks. The developed information technology facilitates the processing of numerical data maintained in biological spreading. It saves time and money during research in compliance with bast raw materials' regulatory quality parameters for further processing.

Keywords: Microcomputer, Moisture content, Sensors, Sensor network, Oil flax, Spreading, Technical hemp, Temperature.

1 Introduction

Growing bast crops in Ukraine is currently one of the most important areas of agricultural development. Oil flax and technical hemp products are constantly updated and expanded. The full potential of plants from seeds to shive of these crops is used in the industry, as the variety of their applications allows to creating of an ecological range of products to meet human needs in almost all spheres of life [1, 19, 20, 21, 22].

Scientists and entrepreneurs work in tandem, constantly updating and improving all the growing and processing processes. But the improvement of the quality of output raw materials depends on all processes, starting from sowing crops to the yield of finished products.

One of the most important processes in the preparation of quality bast straw is the spreading of straw in the field since the quality of fiber depends largely on the duration of aging of bast straw and the process of growth of fungi and bacteria on straw [5, 6, 11-14, 27, 29]. Spreading of bast crops requires constant control of moisture content and temperature in the process of biological transformation of bast straw stalks into the retted stalks. This process is successful if moisture content and temperature of straw spread in the field are within normalized limits, respectively, the temperature of 36-40ºC and moisture content of 50-60%. Since, at high values of moisture content in straw tapes, there can be a self-heating with the subsequent spontaneous rise in the temperature. This is because when spreading straw in the field, the technological process is carried out using pectin-destroying molds Cladosporium herbarum Link and Alternaria linicola Glov, and if the temperature and moisture content increase, there is another process of creating thermophilic bacteria that cause decomposition of the cellulose itself in the stems [30]. Therefore, it is important and relevant to convert straw stalks into retted stalks to constantly control changes in temperature and moisture content of straw tapes spread throughout the entire area of the field.

Therefore, the aim of the research is to develop the system of control of moisture content and temperature in the stems of bast crops in the process of their spreading in the field to convert straw into retted stalks by biological process.

2 Materials and Methods

The scientific novelty will be based on the use of new information technologies for quality control of the transformation of bast straw into retted stalks with the further introduction of modern computer systems and programs in the process of storage and processing of hemp and flax crops. The scientific and applied research is based on the following approaches:

- The system approach is applied to study the object and subject of the research as complex systems and establish patterns and mechanisms of formation of the system "system quality control of bast raw materials at all stages of its preparation" – a complex object of certain components;
- The phenomenological approach is applied to connect the patterns of internal and external factors of the system and quality control of the technological process of spreading bast raw materials into a single scientific phenomenon that will reveal the essence of the integrity of the system;
- The conceptual approach enables qualitative and quantitative analysis of the interaction of the system of factors in the study of qualitative indices of bast raw materials after spreading;
- The structural and functional approach is applied to distinguish the structural elements in the system objects, define their functions, and the system's principle of operation.

Thus, a set of systematic approaches to the scientific research of quality indices of bast materials with the help of modern information technologies will confirm the research hypothesis and become the basis of scientific principles for the development of the system of bast crops quality control in the process of spreading straw based on information technologies.

To solve the research tasks and achieve the goal, it is planned to use updated theoretical and experimental methods and research methods with the development of an automated quality control system for bast raw materials.

Moisture content and temperature of the raw fiber will be determined using modern computer technologies based on SHT21 sensors, Zigbee receivers, and transmitters of cc2530 and cc2531 networks and Raspberry Pl B + microcomputer.

Based on the research tasks, the breeding varieties of oil flax and hemp grown in Ukraine have been selected for the experiments. Types of oil flax are the following: Glyana, Victoria. Types of technical hemp are the following: YUSO-31 (standard), Yermak's local (standard).

3 Results

3.1 Selection of Optimal Components for the Information Method of Control and Determination of Moisture Content and Temperature of Bast Raw Materials in the Field

The first stage of the development of the system of control of qualitative indices of straw stalks of fibrous raw materials was the selection of accessories of modern information servers, sensors, computers, etc.

Raspberry Pl B+ is a single board computer designed by British Raspberry Pi Foundation [16] (Figure 1).

Figure 1 – Raspberry Pl B+

Raspberry Pl B + is designed by Broadcom BCM2835 (SoC) system, which includes a 700 MHz ARM processor, VideoCore IV graphics processor, and 512 or 256 megabytes of RAM. There is no hard drive; instead, SD card is used. This hardware component allows playing H.264 video in 1080p resolution.

The following criteria chose microcomputer Raspberry Pl B+:

- RAM;
- Processor speed;
- Peripherals.

Capabilities of Model B +:

- GPIO: now 40 PINs instead of 26, as in the previous model;
- USB ports: now 4 USB 2.0 ports, instead of 2 ports in Model B;
- MicroSD: A microSD version has replaced the SD card slot;
- Low energy consumption: the developers managed to reduce energy consumption to 0.5-1W;
- Sound: reduce noise, improve sound quality;
- Improved form factor: the developers have made the board more efficient and convenient to work with.

Characteristics:

- Broadcom BCM2835 SoC (CPU, GPU, DSP and SDRAM);
- CPU: 700 MHz ARM1176JZF-S core (ARM11 family);
- GPU: Broadcom VideoCore IV, OpenGL ES 2.0, 1080p30 h.264 / MPEG-4.

AVC high-profile decoder:

- Memory (SDRAM): 512 MB;
- Video outputs: HDMI;
- Audio outputs: 3.5 mm jack, HDMI;
- MicroSD port;
- 10/100 Ethernet RJ45 port.

The SHT21 model was chosen as its module is designed for accurate measurement of moisture content and temperature. The sensor uses a chip with an I2C interface, which provides industrial measurement accuracy (Figure 2).

Figure 2 – Sensor SHT21

Calibration data is recorded at the factory and stored in independent memory. This guarantees the sensor a complete replacement with another without calibration or software change. SHT21 is ideal for measuring humidity, dew point, and temperature.

Characteristics:

- Relative humidity sensor accuracy: ± 3% RH (max.), 0-80% RH;
- Accuracy of temperature sensor: ± 0.4 °C (max), - 10 85 °C;
- Operating range: 0 to 100% RH;
- Operating temperature range: -40 to + 125 °C;
- Sensor operating voltage range (1.9 3.6 V);
- Supply voltage of the module: 5 - 6V;
- Current in active mode: 150 μa;
- Standby current: 60 pA;
- Interface: I2C;
- Heater: integrated on the chip;
- 3x3 mm DFN case.

Zigbee is a standard for a set of high-level communication protocols using small, low-power digital receivers, based on the IEEE 802.15.4-2006 standard for personal wireless networks, such as wireless headphones connected to mobile phones via shortwave radio waves [15]. The technology is defined by the Zigbee specification, which is designed to be simpler and cheaper than other personal networks, such as Bluetooth. Zigbee is designed for mobile devices that require long battery life and secure data transmission over the network.

The Zigbee Alliance is a group of companies that maintain and publish the Zigbee standards; it also publishes application profiles, allowing manufacturers to create compatible products. The current list of application profiles is published or is already under development:

- Home automation;
- Rational use of energy (Zigbee Smart Energy 1.0/2.0);
- Automation of commercial construction;
- Telecommunication programs;
- Personal and hospital supervision;
- Remote control.

Zigbee protocols are designed to use embedded applications that require low data rates and low power consumption. The objective of Zigbee is to create an inexpensive network designed to solve a wide range of tasks. The network can be used in industrial control, built-in sensors, medical data collection, invasion or fumigation alerts, building and home automation, etc. The created network consumes very little energy - individual devices, according to Zigbee certification, allow electric batteries to work for two years.

The Zigbee qualification process involves a complete verification of the requirements on the physical layer. Such intense attention to the physical layer gives numerous advantages, as all radios designed from this set of semiconductor elements will have the same computational characteristics. On the other hand, if the physical layer is not certified, improper operation can reduce battery life in other devices connected to the Zigbee network. Where other protocols may hide poor sensitivity or have other hidden problems revealed in weakened response, Zigbee Radio has strict engineering limitations that affect both power consumption and bandwidth.

Thus, the Zigbee network has been chosen for further research because it is possible to build a sensor network on its basis, allowing data to collect at a distance. The distance from the extreme sensor to the microcomputer in this research will not influence the quality of the indices because the markers transmit data to each other within the Zigbee network.

3.2 Developing the Control System of Moisture Content and Temperature of Bast Crops in the Process of Spreading

Moisture and temperature of bast stalks are important technological characteristics, as moisture content influences their storage and the biological process of spreading in the field during the transformation of straw stalks into retted stalks and the mechanical processing of fiber separation from the woody part of the stalks. Thus, the main characteristics of the quality of bast fibers after machining the stems, such as the content of shive in the fiber and its strength, directly depend on the primary moisture content of the stems that are fed for processing [7]. Therefore, it is important to establish the stems of bast crops' optimal moisture values to obtain high-quality fiber with the lowest content of shive and high strength after machining the stems in decorticators in the processes of crumpling and scutching on scutching machines [17, 18, 24].

Based on the above mentioned, it was proposed to use the following working hypotheses to perform the task:

- Utilization of own raw materials at processing enterprises using oil flax stalks and technical hemp;
- A developed modern system of quality control of the processing of bast raw materials can be used for automatic control of moisture content and temperature based on IT technologies;
- Control of temperature and moisture will improve the quality of processing of fibrous raw materials: reduce the content of impurities, increase fiber yield, preserve the environmental properties of the products;
- Modern quality control system of bast raw materials, in contrast to the existing standardized methods, will increase the accuracy of indicators and save time for their identification;
- The received materials will have high indices of moisture absorption, air permeability, sanitary and hygienic properties, making the light industry products of proper quality.

Thus, to prove the hypotheses at the first stage of the research, the existing methods of moisture control of bast fibers were analyzed. Standardized humidity parameters, according to which the stems of bast crops of flax, oil flax, technical hemp should be processed using the technologies of harvesting, storage, the biological process of obtaining retted stalks, and machining of stems in obtaining fiber have been set in previous scientific works of domestic scientists. However, the normalized values of moisture of straw, retted stalks, and fibers of bast crops, which are given in the relevant standards DSTU 4149:2003, DSTU 8422:2015, and TUU 01.1-05480298-002.2018 do not correspond to the optimal values of humidity depending on the type and variety of bast crops. They require systematic control of moisture content at each stage of the technological process of bast stalks processing [25].

After theoretical research of the methods of system humidity control, it was concluded that, in the modern environment of information technologies, the construction of a sensor network based on sensors and the microcomputer will be the most expedient method of collecting data of the moisture content and temperature of bast crops stalks in the processes of spreading, storage, preparation for processing.

Also, the substantiation and experimental confirmation of the application of the developed complex information method of control and maintenance of the normalized indices of moisture content and temperature of bast fiber-based on SHT21 sensors and the Raspberry Pl B + microcomputer were carried out. This technique allows immediate determining of the moisture content and temperature of the fibrous raw material at any time with accurate measurement data, and what is more important, it is easily used at a reasonable price. Due to the technique using a sensor network, it is possible to obtain indices of humidity and temperature of the spreading of bast crops without additional costs and effort, the information comes from different areas of the field to the computer in the form of graphs, and it is stored on the server.

Based on the Raspberry Pl B + microcomputer, Zigbee receivers and transmitters of the cc2530 and cc2531 networks, and SHT21 humidity sensors, a sensor network was built to monitor the moisture content and temperature of the bast fiber during its drying in the process of spreading it the field.

According to the technology of spreading, the fibrous raw material is aged in the field under the open sky. According to this technique, rows of bast-fibrous stems of 25-40 cm wide and a distance between rows of 5 m are formed. Thus, to obtain humidity indices from all points, to monitor temperature and moisture content during the aging process, sensors were installed at a distance of 5-15 m from each other.

The marker consists of three main parts: a Zigbee transmitter, a 3.7V battery, and SHT21 temperature and humidity sensors; this structure diagram is shown in Figure 3.

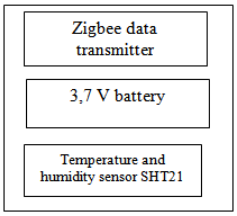

Figure 3 – Structure diagram of the marker

The system of data collection, processing, and transmitting to the server was built based on this structure. Such markers form a sensor network that collects data on humidity and temperature in all areas of the field where the sensors are installed and transmits them to the microcomputer for further processing.

After saving the indicators from the sensors in its own MySQL database, the microcomputer generates a JSONE array of all collected data from the markers, adds the time of data collection in the format "Y-m-d h:i," its gps coordinates lat, lng and a secret key using which the server identifies the microcomputer having sent the data.

This unique key also provides security when receiving them from microcomputers. After that, this data is sent to the server via the global Internet; the scheme of data transmission is shown in Figure 4.

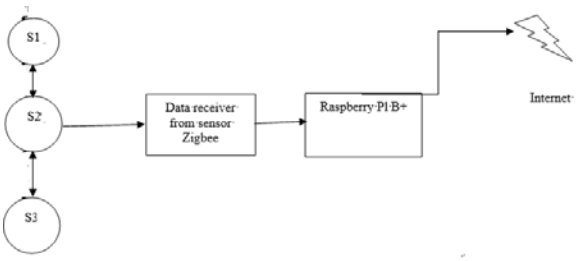

Figure 4 – Scheme of data transmission to the server

After downloading the data, the server validates it with the validator of the Larevel framework, checks whether the token is specified in the array in the server database, and if all data is validated, it is stored in the MySQL database.

A response is sent to the server, which certifies the successful data reception. After performing these operations, the user will be able to see all the collected data in the form of graphs on the page of their company. Opening their page for the first time, the user can see a map of the area where the process of spreading takes place and the latest humidity and temperature indices at all sensors (Figure 5).

Figure 5 – Page of temperature data

On the "Humidity" tab, the user can see dependency diagrams of the change in moisture content over time for the entire period of storage/drying or for the selected period of time (Figure 6).

Figure – Page of humidity data

Also, the user can choose the type of storage or drying, depending on which notifications will be formed about the achievement of the desired moisture content or deviations from the temperature and humidity by more than 10%. One of the additional functions of this technique is that the user can choose from which sensors he/she wants to check the humidity or temperature, the data will be immediately displayed on his/her page. Information on the lack of connection with the sensors and when the marker battery is less than 20% is also transferred to the computer.

When the optimum drying temperature of bast stalks and humidity of 19% is reached, the user is notified that the drying process has been stopped, and what optimal parameters for collecting spreading have been achieved, and with what indicators the raw material can be sent for storage or prepared for further processing. This technique is still used in the storage and preparation of raw materials for processing to preserve all the qualitative properties of the future bast fiber and its products. This program is created in English and Ukrainian versions, based on the needs of both domestic and foreign consumers – representatives of the industrial complex for processing of bast straw or retted stalks.

4 Discussion

Moisture content is the most important index of the quality of any raw materials and products. Bast raw materials are no exception. It is possible to obtain bast straws under optimal conditions of spreading the technological process, namely at certain values of moisture content and temperature. The process of its storage also requires certain moisture content, and rational processing of retted stalks, which will allow obtaining fiber of proper quality, is also possible at certain values of moisture content of raw materials [7, 24]. It is due to a certain moisture content of retted stalks, the conditions in which the wood of bast plants becomes brittle, and the fiber remains elastic, as a result of which the fiber is easily separated from the wood after machining are created.

Thus, during the entire technological process of primary processing of bast raw materials, it is necessary to control its moisture content. Currently, the existing methods for determining the moisture content of bast straw, retted stalks, long and short fibers, which are listed in the current regulations, are imperfect. Some of these methods are time-consuming, while other rapid methods do not give accurate measurement results. Thus, domestic scientists have a task to determine the moisture content of bast raw materials by methods that will reduce the test time and provide more accurate measurement results throughout the processing process. Analysis of foreign scientists' scientific works [3, 4, 8, 9, 10, 28] did not help solve this problem because the research on determining moisture content by modern methods was carried out in most cases using cotton raw materials.

Modern information methods have been proposed to solve this problem, which has not been used yet in determining the moisture content of bast raw materials. Preliminary research conducted by the scientists of Kherson National Technical University in determining the moisture content of straw and bast straw raw materials using modern information technology has led to the scientific hypothesis that the improvement of this technique will make it possible to control moisture content not only in the initial stages of processing raw materials but to control the quality of the whole technological process [23, 25, 26].

Thus, on the results of the analysis of the studies of domestic and foreign scientists, it can be confirmed that the proposed method of comprehensive research on the quality of bast raw materials will have no analogs in Ukraine and will be the key to the further practical development of the light industry.

5 Conclusion

In the production of environmentally friendly products, on a global scale, bast raw materials are characterized by leading position, a source of natural raw materials, distinguished by hygienic, biological, medical, and protective properties, preserving which should occur at all stages of the processing process. The performed research gave impetus to the development of modern systems for control of moisture content and temperature in the process of spreading and further processing processes.

The developed information technologies, which at the same time control and maintain high-quality indices of raw materials for fibrous materials, will be of great scientific importance for both Ukraine and the world scientific community and will bring the existing ideas of both domestic and foreign scientists in the field of light industry to a qualitative new scientific level.

The results of the research are planned to develop modern automated quality control systems at all technological stages of processing fibrous raw materials up to the yield of finished products. Also, the existing software product for control and maintenance of all quality indices of bast raw materials will be improved, allowing domestic processing enterprises to sell high-quality, competitive products.

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