Mobile Information System for Determining the Level of Creatine in Food Products

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Abstract

The study of food products to determine the level of creatine in them is an actual task, taking into account the need for this substance for patients with Covid'19 and spinal muscular atrophy. The purpose of our research is to develop a mobile information system for determining the level of creatine in food products. The developed method for determining the level of creatine in food products by the user and the method for determining the level of creatine in food products using a mobile information system provide the user with the opportunity to quickly, conveniently, cheaply and effectively assess the presence and level of creatine in any food products, on the basis of which to build a rational diet from the point vision of body saturation with creatine. The proposed mobile information system for determining the level of creatine in food products provides convenience, low-cost, celerity, miniaturization and automation for measurement of concentration of creatine in any food products. The conclusion obtained from the system regarding the presence and level of creatine in this or that food product is useful and extremely important when preparing the diet of patients, especially patients with Covid'19 and/or spinal muscular atrophy. The proposed approach and mobile information system for determining the level of creatine in food products can be used not only for drawing up the diet of patients, especially patients with Covid'19 and/or spinal muscular atrophy, from the point vision of body saturation with creatine, but also for example, to check the quality of meat products.

Keywords

Creatine, creatine level, determining the level of creatine, mobile information system.

1. Introduction

Today, in Ukraine and the world, the problem of the spread of the Covid'19 pandemic is very acute. Common manifestations in patients with Covid'19 are respiratory (oxygen) insufficiency, dry cough, shortness of breath, and changes in the lungs on computer tomography in the form of opacification and/or consolidation in the form of "frosted glass". There are also numerous behavioral abnormalities that indicate damage to the brain and nervous system of such patients, as well as numerous neuromuscular disorders. Long-term stay of patients (especially the elderly) on oxygen therapy in one position without mobility often leads to muscular dystrophy.

The second acute problem of Ukraine and the world is the increase in the number of spinal muscular atrophy diseases, which arise as a result of genetic mutations and are characterized by damage to skeletal muscles, progressive muscle weakness and muscle atrophy.

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Creatine, which allows muscles to "remember" their initial state and in combination with rehabilitation exercises to return the previous functionality, and also has the property of increasing the body's perception of oxygen and a protective effect on the nervous system, which is extremely important and relevant both in the conditions of today's Covid'19 pandemic and in the conditions of the growing number of spinal muscular atrophy diseases. Creatine can enter the body not only as part of various expensive food additives, but also with food products.

Creatine is a nitrogen-containing carboxylic acid that participates in energy exchange in muscle and nerve cells [1]. Creatine in its free form, as well as in the form of creatine phosphate, is an essential element of muscle tissue. In skeletal muscles, creatine is responsible for energy exchange and contractility. Creatine gives muscles energy, improves protein synthesis and delays the accumulation of lactic acid. Creatine is important as a source of muscle contraction forces [2].

Analysis of a number of clinical applications of creatine [3] associated with neurodegenerative diseases (for example, muscular dystrophy (especially after coma, after prolonged immobilization), Parkinson's disease, Huntington's disease [4]), in the treatment of ischemia of the brain and heart [5], aging [6], diabetes, osteoarthritis, fibromyalgia, adolescent depression [7], provides evidence that creatine can improve physical performance and/or clinical outcomes in these patient groups – for example, creatine allows muscles to “remember” their initial state and in combination with rehabilitation exercises to return the previous functionality, slows down the progression of brain atrophy in patients with Parkinson's disease, protects the heart during an ischemic event, improves the health of elderly patients (cholesterol level decreased, fat accumulation in the liver decreased, muscle mass increased, bone loss minimized), improves glycemic control, improves brain activity by increasing dopamine levels in and functions of mitochondria.

Creatine is a peculiar regulator of energy metabolism. Another important property of creatine is the property of increasing the body's perception of oxygen, thanks to which it also provides a protective effect on the nervous system in conditions of hypoxia, which is extremely important in the conditions of today's Covid'19 pandemic [8-12], since patients with Covid'19 need both increasing the body's perception of oxygen (especially oxygen-dependent patients), as well as protecting the nervous system (which is negatively affected by Covid'19) [3, 4].

The human body contains, depending on the muscle mass, from 100 to 150 g of pure creatine. Its daily consumption is up to 2 g. Our body can synthesize approximately 1 g of the substance per day [13].

The study of the amount of creatine in the human body is included in the package of human tests "Blood Biochemistry Extended", which is recommended for patients with Covid'19 and spinal muscular atrophy in order to study the functioning of the liver, kidneys, mineral exchange and metabolism in the body. Such a package of analyzes determines the level of creatinine (the end product of creatine breakdown) in the human body.

The concentration of creatinine in the blood depends on its formation and excretion. Its formation directly depends on the state of muscle mass. Figure 1 shows the reference values (normal values) and values of the creatinine level in the body of a real person (a 46-year-old man) suffering from spinal muscular atrophy, which confirms the low level of creatinine (and, accordingly, the low level of creatine) in people with this disease.

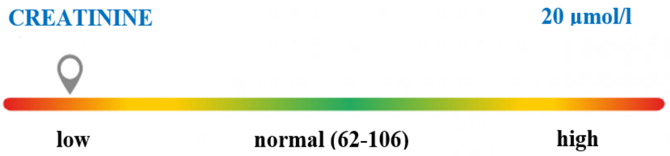

Figure 1: Reference values (normal values) and values of creatinine level in the body of a real person suffering from spinal muscular atrophy

Although creatine is naturally synthesized in the human body (endogenous), it is obvious that half of the creatine required by humans comes into the body with food (exogenous). Of course, many different bio-supplements containing creatine have been created, but, of course, it is much more appropriate to eat properly and get creatine from food.

The main sources of creatine are meat and fish, but dairy products and berries can also contain creatine. It is known that beef contains 4.5 g of creatine per 1 kg, pork – 5 g per 1 kg, salmon - 4.5 g per 1 kg, tuna – 4 g per 1 kg, cod – 3 g per 1 kg, flounder – 2 g per 1 kg [13]. But there is no information about the presence of creatine in other products (for example, in various meat products).

So, the study of food products to determine the level of creatine in them is *an actual task*, taking into account the need for this substance for patients with Covid'19 and spinal muscular atrophy.

2. Survey of Research

Food products can be tested for creatine in them by various methods. The most widely used method is the Popper's method, which is based on the Jaffe color reaction (formation of the orange-colored tautomer of creatinine picrate), which consists in the reduction of creatinine with picric acid in a strongly alkaline medium with the formation of a red-orange color, and the intensity of the color is determined colorimetrically or photometrically (Figure 2) [14].

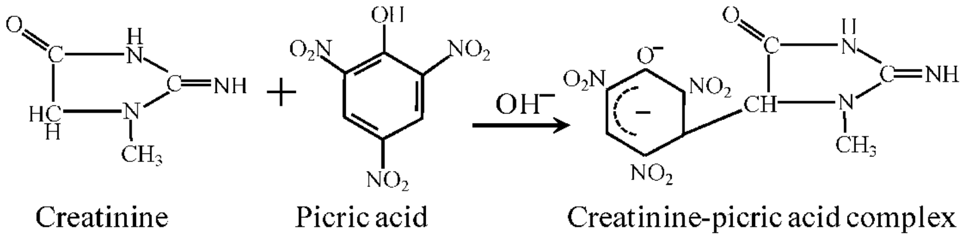

Figure 2: Jaffe color reaction [14]

Let's consider the -known tools for detecting and determining the level of creatine.

The paper [15] proposed the integrated system for determining the human serum creatinine concentration based on Jaffé reaction theory, whih consists of the paper-based chip and a smart detection device.

The paper [16] is devoted to the development of the fluorescence-based bioassay for creatinine using fluorescence intensity with applying 3D translation stage, micro-spectrometer, laser diode for measurement of the various concentrations of serum creatinine.

Paper [17] proposed new colorimetric Tyndall effect-inspired assay for low-cost, simple, specific, point-of-care, and sensitive detection of creatinine by making use of silver nanoparticles as colloidal nanoprobes for visual signaling of light scattering.

The paper [18] proposed the electromechanical lab-on-a-chip platform for point-of-care detection of the levels of serum creatinine using colorimetric enzyme-linked immunosorbent assay.

The paper [19] developed the novel assay platform based on the hand-held Raspberry Pi detection system and microfluidic sliding double-track paper-based chip for determining the creatine level in human urine.

Paper [20] is devoted to the development of the colorimetric sensing platform for monitoring the creatinine based on the regulation effect of creatinine on the peroxidase-mimicking activity of MoO3–Cu2+ system.

The paper [21] demonstrated of the electrochemical metallization system on the commercially available screen-printed electrode strip, which is then utilized for monitoring the concentration of creatinine in an aqueous mixture.

The paper [22] proposed the novel creatinine voltammetric sensor with high sensitivity and selectivity, which show excellent performance in real sample analysis of plasma.

The paper [23] proposed the sensitive and species-specific duplex realtime PCR assay on the basis of the simultaneous amplification of fragments of the muscle creatine kinase for the identification of quality of meat products.

The paper [24] is devoted to the development of new LC-MS/MS method for detection and quantification of creatine by multiple reaction monitoring mode on the basis of the esponse surface methodology and hydrophilic interaction chromatography for the chromatographic parameters' optimization.

The paper [25] is devoted to the development of the method on the basis of the aggregation of cysteamine functionalized gold nanoparticles for effective detection of creatine in biological fluids.

The paper [26] proposed the cost-effective portable chemiluminescence quantification platform for detection and quantification of creatinine in blood serum on the basis of the high-quality camera sensor in conjunction with a raspberry-pi single board computer.

The paper [27] described the new concept, which is based on the one-step, simple, and non-enzymatic detection system of creatine in the food supplements based on the Pt electrode using an elemental analyzer.

The paper [28] described the colorimetric probes for blood creatinine and urinary creatinine detections using metal nanoparticles (for example, using starch-stabilized silver nanoparticles for creatine detection).

The paper [29] proposed the non-enzymatic highly sensitive creatine sensor on the basis of the antimony-doped tin oxide aggregated nanoparticles and glassy carbon electrode using electrochemical reduction phenomena.

As the survey of research showed, the known tools and systems for detecting and determining the level of creatine are mainly focused on detecting creatine in biological fluids (blood, urine, etc.) or in the food supplements, but not in food products. In addition, almost all these tools are expansive and bulky, and require additional support and complicated operations.

Most methods also require pretreatment of samples and expensive equipment and reagents, that is, they can only be performed in laboratory conditions. Since half of the creatine required by a person enters the body with food, and creatine can enter the body not only as part of various expensive food additives, but also from food products, therefore *the purpose of our research* is to develop a mobile information system for determining the level of creatine in food products. To develop such a mobile information system for determining the level of creatine in food products, it is necessary to conduct an analysis of the subject area for the detection of creatine by the Popper method based on the Jaffe color reaction, develop rules and a method for determining the level of creatine in food products, which will be the basis of a mobile information system for determining the level of creatine in food products, as well as to design a mobile information system for determining the level of creatine in food products.

3. Mobile Information System for Determining the Level of Creatine in Food Products

Let's conduct *an analysis of the subject area* on the detection of creatine by the Popper's method based on the Jaffe color reaction. In general, Popper's method based on the Jaffe color reaction consists of the following steps:

1. to prepare the analyzed sample (broth or decoction of the food product to be analyzed for creatine presence)
2. to prepare a 1%-th aqueous solution of picric acid
3. to prepare a 10%-th solution of sodium hydroxide
4. to prepare a boiling water bath
5. to pour 2 ml of the analyzed sample (broth or decoction) into the dish
6. to add 3 drops of 1%-th picric acid solution
7. to add 5 drops of 10%-th sodium hydroxide solution
8. to mix the contents of the dish
9. to put the dish in a boiling water bath for 15 minutes
10. to evaluate the color of the analyzed sample, on the basis of which to draw a conclusion about the presence and level of creatine in the studied food product (if creatine is present in the analyzed sample, the sample turns orange or red, otherwise it remains pale yellow)

Of course, this method is also more suitable for use in laboratory conditions than at home. However, at home, you can use an affordable and quick tool to determine the level of creatine in food. Such a tool is test paper strips impregnated with a mixture of 1%-th solution of picric acid and 10%-th solution of sodium hydroxide in a ratio of 3:5. In the presence of such test paper strips, a person needs only:

1. to pour the analyzed sample (broth or decoction) into the dish
2. to put a paper test strip in it

3. to put the dish in a boiling water bath for 15 minutes
4. to evaluate the color of the analyzed sample, on the basis of which to draw a conclusion about the presence and level of creatine in the studied food product

Such procedures are quite easy to perform at home, even for a sick person. The cost of a paper test strip measuring 2x5 cm is minimal – 0.04 UAH (0.001 USD), that is, the purchase of paper strips is also available to any person, even a low-income person.

The main problem is the correct assessment of the color of the analyzed sample and the correct conclusion about the presence and level of creatine in the food product under study, because a person who needs to determine the presence of creatine in food products may not distinguish colors (colorblindness), may have vision problems, due to which it will be difficult for her to assess the intensity of the color reaction and reach a conclusion about the creatine presence in the analyzed samples.

Therefore, a mobile information system for determining the level of creatine in food products will be developed precisely to evaluate the color of the analyzed sample and form a conclusion about the presence and level of creatine in the studied food product.

Let's develop a scale for evaluating the color of the analyzed sample in order to determine the presence and level of creatine in the studied food product – Figure 3.

0	1	2	3

Figure 3: Scale for evaluating the color of the analyzed sample in order to determine the presence and level of creatine in the studied food product

In this scale:

1. color 0 means the absence of creatine
2. color 1 means the presence of a low level of creatine
3. color 2 means the presence of an average level of creatine
4. color 3 means the presence of a high level of creatine

Then *the rules for evaluating the color of the analyzed sample in order to establish the presence and level of creatine in the studied food product* will have the following form:

1. if by analyzing the intensity of RGB (red, green and blue) it is determined that the paper test strip has the color 0 from the scale for evaluating the color of the analyzed sample in order to determine the presence and level of creatine in the studied food product, then creatine is absent in the studied product
2. if by analyzing the intensity of RGB it is determined that the paper test strip has the color 1 from the scale for evaluating the color of the analyzed sample in order to determine the presence and level of creatine in the studied food product, then creatine is present in the studied product, and the level of creatine is low
3. if by analyzing the intensity of RGB it is determined that the paper test strip has the color 2 from the scale for evaluating the color of the analyzed sample in order to determine the presence and level of creatine in the studied food product, then creatine is present in the studied product, and the level of creatine is average
4. if by analyzing the intensity of RGB it is determined that the paper test strip has the color 3 from the scale for evaluating the color of the analyzed sample in order to determine the presence and level of creatine in the studied food product, then creatine is present in the studied product, and the level of creatine is high

Considering the analysis of the subject area, *the method of determining the level of creatine in food products by the user* consists of the following steps:

1. to install a mobile information system in the form of a mobile application on a smartphone
2. to pour the analyzed sample (broth or decoction) into the dish
3. to put a paper test strip in it
4. to put the dish in a boiling water bath for 15 minutes

5. to scan the received color of the paper test strip using the developed mobile information system in the form of a mobile application that determines the concentration of creatine by analyzing the intensity of RGB
6. in the mobile application, to read the conclusion about the presence/absence and level of creatine in the studied food product

Considering the developed rules for evaluating the color of the analyzed sample in order to determine the presence and level of creatine in the studied food product, *the method of determining the level of creatine in food products by the mobile information system* consists of the following steps:

1. to scan the color of the paper test strip
2. to recognize the color of the paper test strip by analyzing the intensity of RGB
3. to compare the recognized color of the paper test strip with the scale for evaluating the color of the analyzed sample in order to determine the presence and level of creatine in the studied food product
4. to apply the developed rules for evaluating the color of the analyzed sample in order to establish the presence and level of creatine in the studied food product
5. if rule 1 triggered, then give the conclusion to the user: "creatine is absent in the studied food product"
6. if rule 2 triggered, then give the conclusion to the user: "creatine is present in the studied food product, the level of creatine is low"
7. if rule 3 triggered, then give the conclusion to the user: "creatine is present in the studied food product, the level of creatine is average"
8. if rule 4 triggered, then give the conclusion to the user: "creatine is present in the studied food product, the level of creatine is high"
9. if none of the rules triggered, then give the conclusion to the user: "problems with color recognition, repeat the scan of the test strip"

The developed method for determining the level of creatine in food products by the user and the method for determining the level of creatine in food products using a mobile information system provide the user with the opportunity to quickly, conveniently, cheaply and effectively assess the presence and level of creatine in any food products, on the basis of which to build a rational diet from the point vision of body saturation with creatine.

The developed method for determining the level of creatine in food products by the user and the method for determining the level of creatine in food products by a mobile information system are the basis for the mobile information system for determining the level of creatine in food products, which will be implemented in the form of a mobile application, which on the basis of the determination of creatinine concentration by analysis of the intensity of RGB, forms a conclusion about the presence and level of creatine in any food products.

The structure of the mobile information system for determining the level of creatine in food products is presented in Figure 4.

The proposed mobile information system for determining the level of creatine in food products provides convenience, low-cost, celerity, miniaturization and automation for measurement of concentration of creatine in any food products.

The conclusion obtained from the system regarding the presence and level of creatine in this or that food product is useful and extremely important when preparing the diet of patients, especially patients with Covid'19 and/or spinal muscular atrophy.

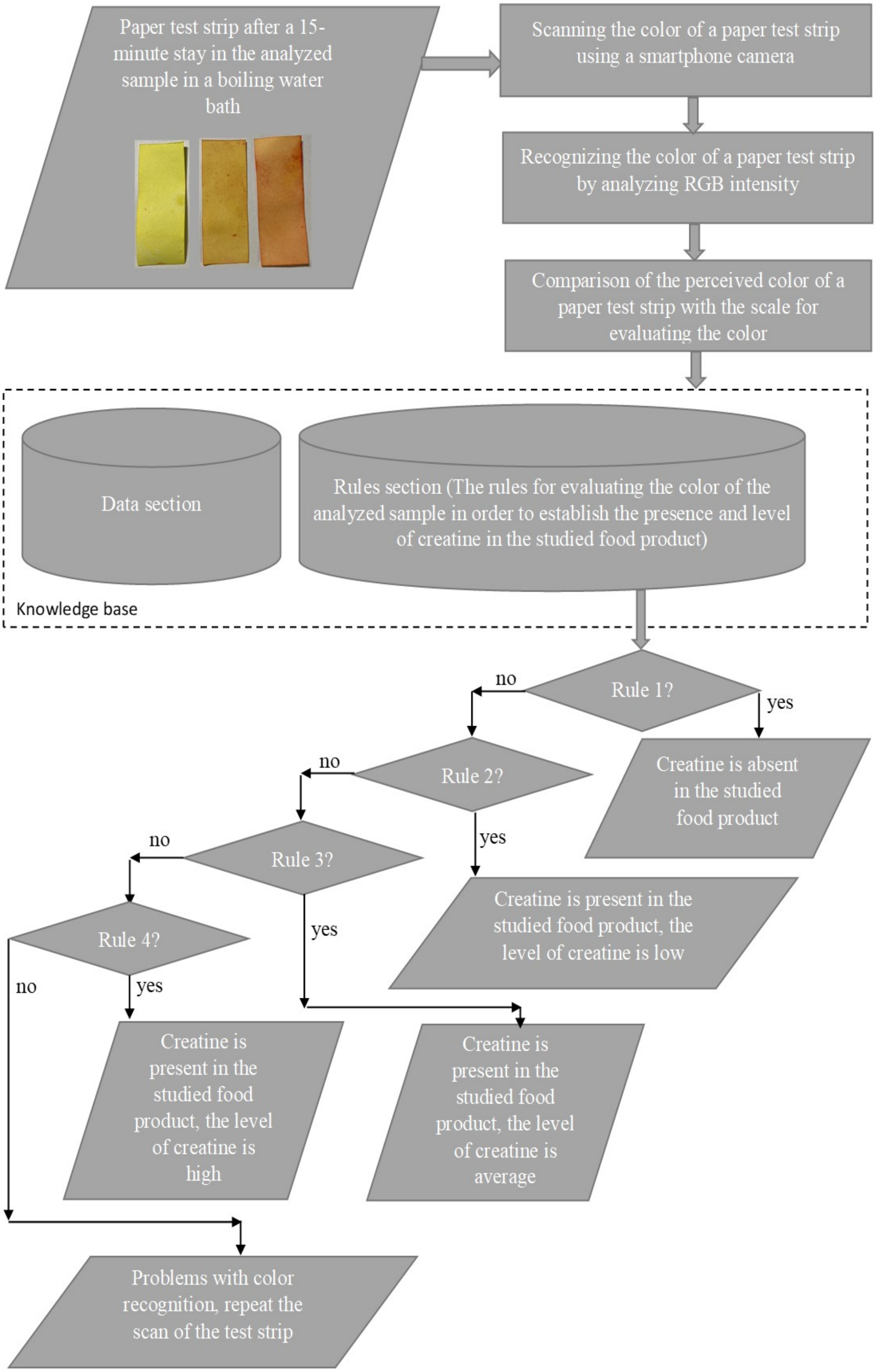

Figure 4: Structure of mobile information system for determining the level of creatine in food products

4. Results & Discussion

Let's consider the operation of the proposed mobile information system for determining the level of creatine in food products.

For the *first experiment*, the user used a decoction of pork lard, put a paper test strip in it for determining the creatine, placed the dish in a boiling water bath for 15 minutes, and then scanned the resulting color of the paper test strip using the developed mobile information system in the form of a mobile application.

The proposed mobile information system for determining the level of creatine in food products performed the color scanning of the paper test strip, the color recognition of the paper test strip by RGB intensity analysis, and the comparison of the recognized color of the paper test strip with the scale for evaluating the color of the analyzed sample. The results of such a comparison are presented in Figure 5.

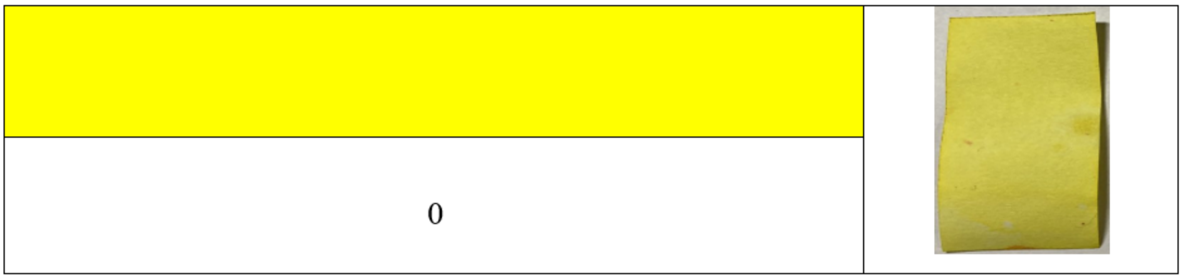

Figure 5: Comparison of the recognized color of the paper test strip with the scale for evaluating the color of the analyzed sample for the first experiment

There was a search for a rule among the rules for evaluating the color of the analyzed sample in order to establish the presence and level of creatine in the studied food product. Rule 1 triggered, so the user received the conclusion "Creatine is absent in the studied food product".

For the *second experiment*, the user used a chicken broth, put a paper test strip in it for determining the creatine, placed the dish in a boiling water bath for 15 minutes, and then scanned the resulting color of the paper test strip using the developed mobile information system in the form of a mobile application.

The proposed mobile information system for determining the level of creatine in food products performed the color scanning of the paper test strip, the color recognition of the paper test strip by RGB intensity analysis, and the comparison of the recognized color of the paper test strip with the scale for evaluating the color of the analyzed sample. The results of such a comparison are presented in Figure 6.

Figure 6: Comparison of the recognized color of the paper test strip with the scale for evaluating the color of the analyzed sample for the second experiment

There was a search for a rule among the rules for evaluating the color of the analyzed sample in order to establish the presence and level of creatine in the studied food product. Rule 2 triggered, so the user received the conclusion "Creatine is present in the studied food product, the level of creatine is low".

For the *third experiment*, the user used a pork broth, put a paper test strip in it for determining the creatine, placed the dish in a boiling water bath for 15 minutes, and then scanned the resulting color of the paper test strip using the developed mobile information system in the form of a mobile application.

The proposed mobile information system for determining the level of creatine in food products performed the color scanning of the paper test strip, the color recognition of the paper test strip by RGB intensity analysis, and the comparison of the recognized color of the paper test strip with the scale for evaluating the color of the analyzed sample. The results of such a comparison are presented in Figure 7.

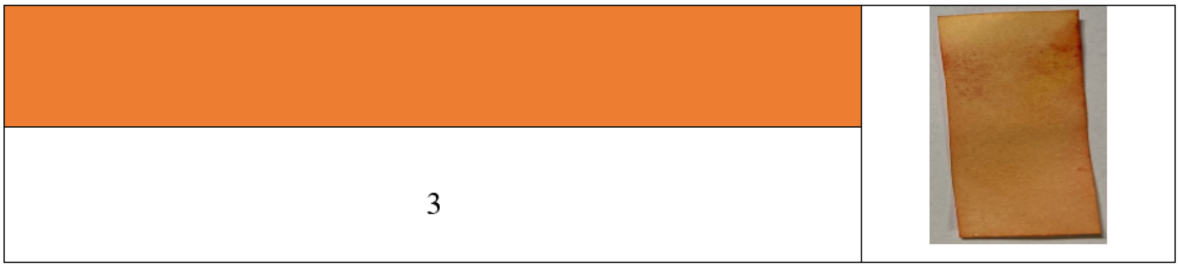

Figure 7: Comparison of the recognized color of the paper test strip with the scale for evaluating the color of the analyzed sample for the third experiment

There was a search for a rule among the rules for evaluating the color of the analyzed sample in order to establish the presence and level of creatine in the studied food product. Rule 4 triggered, so the user received the conclusion "Creatine is present in the studied food product, the level of creatine is high".

The functionality of the proposed mobile information system for determining the level of creatine in food products was specially tested on products for which the level of creatine is well known. The correctness of the proposed mobile information system for determining the level of creatine in food products is confirmed by the correct determination of the level of creatine for all three products (pork lard, chicken, pork).

The proposed approach and mobile information system for determining the level of creatine in food products can be used not only for drawing up the diet of patients, especially patients with Covid'19 and/or spinal muscular atrophy, from the point vision of body saturation with creatine, but also for example, to check the quality of meat products.

5. Conclusions

The study of food products to determine the level of creatine in them is an actual task, taking into account the need for this substance for patients with Covid'19 and spinal muscular atrophy.

As the survey of research showed, the known tools and systems for detecting and determining the level of creatine are mainly focused on detecting creatine in biological fluids (blood, urine, etc.) or in the food supplements, but not in food products. In addition, almost all these tools are expansive and bulky, and require additional support and complicated operations. Most methods also require pretreatment of samples and expensive equipment and reagents, that is, they can only be performed in laboratory conditions. Since half of the creatine required by a person enters the body with food, and creatine can enter the body not only as part of various expensive food additives, but also from food products, therefore the purpose of our research is to develop a mobile information system for determining the level of creatine in food products.

The developed method for determining the level of creatine in food products by the user and the method for determining the level of creatine in food products using a mobile information system provide the user with the opportunity to quickly, conveniently, cheaply and effectively assess the presence and level of creatine in any food products, on the basis of which to build a rational diet from the point vision of body saturation with creatine.

The proposed mobile information system for determining the level of creatine in food products provides convenience, low-cost, celerity, miniaturization and automation for measurement of concentration of creatine in any food products. The conclusion obtained from the system regarding the presence and level of creatine in this or that food product is useful and extremely important when preparing the diet of patients, especially patients with Covid'19 and/or spinal muscular atrophy.

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