*Praca oryginalna* *Original paper*

# Diagnosis of liver diseases using ceruloplasmin – a preliminary study

BEATA ABRAMOWICZ[1], ŁUKASZ KUREK[1], PAVOL MUDROŇ[3], CSILLA TÓTHOVÁ[3], MATEUSZ MICHALIK[1], KLAUDIA LUBAS[4], RENATA URBAN-CHMIEL[2]

[1]Department and Clinic of Animal Internal Diseases, Faculty of Veterinary Medicine, University of Life Sciences in Lublin, Akademicka 13, 20-912 Lublin, Poland
[2]Department of Veterinary Prevention and Avian Diseases, Faculty of Veterinary Medicine, University of Life Sciences in Lublin, Akademicka 13, 20-912 Lublin, Poland
[3]Clinic of Ruminants, University of Veterinary Medicine and Pharmacy, Komenského 68/73, 04181 Košice, Slovakia
[4]Faculty of Veterinary Medicine, University of Agriculture in Kraków, Al. Mickiewicza 21, 31-120 Kraków, Poland

*Received 12.09.2025* *Accepted 23.10.2025*

**Abramowicz B., Kurek Ł., Mudroň P., Tóthová C., Michalik M., Lubas K., Urban-Chmiel R.**

**Diagnosis of liver diseases using ceruloplasmin – a preliminary study**

Summary

**The diagnosis of liver diseases currently involves a full clinical examination, an assessment of haematological and biochemical blood parameters, an ultrasound examination, and a biopsy in the case of fatty liver degeneration. Although these tests provide information on the hepatic function, there is a need for a universally applicable marker to diagnose liver disorders in cattle. This study aimed to present the cases of cows with suspected hepatitis and to determine the possibility of assessing the effectiveness of treatment based on preliminary haematological and biochemical blood tests. The tests were performed on tie-stall dairy cattle farms. All diseased animals (16) exhibited a periodic loss of appetite, impaired feed intake, diarrhoea and reduced milk yield. The animals were initially divided into groups of diseased animals (group I) and healthy animals (group II). Based on the authors' own observations and the therapy efficacy, the initially obtained blood test results were divided into two subgroups (cured animals – group Ia, and animals removed from the herd – group Ib). The blood parameters were examined, including RBC, Hgb, Hct, WBC, GGTP activity and Tbil, Chol-T, urea, Cu, Fe and Cp concentrations. The control group animals exhibited the lowest Cp concentration, whereas the group Ib showed the highest concentration. Statistically significant differences were observed among all groups. The authors suggest that Cp could be a valuable parameter for identifying difficult-to-treat patients during routine screening tests and propose that it be incorporated into the basic liver disease test panels.**

**Keywords: liver diseases, dairy cattle, ceruloplasmin**

Liver diseases in dairy cattle represent a major health problem that causes enormous economic losses in intensive dairy cattle farming. The most commonly diagnosed liver diseases include fatty liver degeneration or hepatosteatosis, topical and disseminated inflammatory processes, acute or chronic diseases of the bile ducts (cholangitis), caused primarily by the liver fluke and, less commonly, by gallstones, as well as liver cirrhosis. These disorders can occur in both clinical and subclinical forms. A significant problem is that they are not always diagnosed at early stages of development. In many cases, liver diseases manifest themselves atypically, with characteristic symptoms only becoming apparent at more advanced stages of the disease. The most common clinical signs of liver diseases include loss of appetite or fluctuating appetite, body weight loss and reduced milk production, sometimes accompanied by occasional diarrhoea or indigestion. These symptoms are often misdiagnosed as cases of rumen acidosis, liver abscess, a foreign body in the reticulum, omasal impaction orenteritis, etc (7, 12, 14).

The diagnosis of liver disease currently involves a full clinical examination, the assessment of haematological and biochemical blood parameters, ultrasound examination and, in the case of steatosis, a biopsy is performed. Although extensive investigations are often ordered, it can be difficult for veterinarians to accurately assess the severity of pathological processes in the liver and predict the course of the disease. Performing an extensive range of tests can be costly, and obtaining consent from the animal owner is not always possible.

The biochemical blood tests commonly included in the panel are alkaline phosphatase (AP), gamma-glutamyl transpeptidase (GGTP), total and indirect bilirubin and cholesterol levels, as well as triglyceride, urea and albumin levels, the total protein content, glucose concentration, glutamate dehydrogenase (GLDH), sorbitol dehydrogenase (SDH), nonesterified fatty acid (NEFA) and free fatty acid (FFA) contents (2).

These tests provide valuable information about the functional status of the liver; however, efforts are being made to find a more universal marker that could be used to diagnose liver disorders in cattle, as the performance of large numbers of tests significantly increases the costs of diagnosis and therapy. A liver biopsy is often considered to be a conclusive test for degenerative liver disease, but it is not performed in many cases due to the reluctance of animal owners' and concerns about the risks associated with it. Imaging techniques such as ultrasound and radiography (X-rays) have replaced biopsies to a large degree, but they also have their limitations due to the need for specialized equipment, which is often more advanced than that used for per rectal examinations. The size of the organs, such as the liver in cattle, plays a crucial role in effective diagnostic imaging. Ultrasound equipment may not be capable of detecting all of the relevant problems due to the large size and position of the organ, this factor limits its use in common veterinary practice (8, 9, 12).

At present, research is being conducted with the aim of detecting liver dysfunction and status at an early stage for the reasons mentioned above. In human medicine, serum ceruloplasmin (Cp) concentration testing is emerging as a means of assessing liver status (11, 21). Cp is the main glycoprotein synthesized by liver cells and it is classified as a mild-to-moderate acute phase protein. The structure of the compound consists of six copper (Cu) atoms, which make up over 90% of its composition. One of its functions is to aid in the metabolism of iron (Fe), the concentration of which increases over the course of the inflammatory process (8, 9). As a protein which is largely composed of copper ions, ceruloplasmin is often used as a marker of copper accumulation in the liver and as an indicator of the copper and iron status in the body (1, 8, 9, 17). Cp is becoming an increasingly important diagnostic marker for liver disease in human medicine, thereby allowing for precise and accurate diagnoses. For instance, the diagnosis of Wilson's disease involves the determination of ceruloplasmin levels. This genetic disease affects copper metabolism and can lead to liver failure. Low ceruloplasmin levels are indicative of this condition. Additionally, ceruloplasmin levels are used to diagnose cirrhosis, hepatic encephalopathy, and inflammation in patients with liver steatosis (11, 18, 21). Ceruloplasmin can be used as an objective indicator of cattle health and as a marker of animal welfare. In cattle, Cp is currently being used diagnostically as an acute phase protein in response to inflammatory processes which may arise against a background of various tissue injuries (8, 19, 20).

Early diagnosis of liver diseases in cows is a difficult and costly process that mainly relies on clinical examination of the animal and the ordering of laboratory blood tests as well as an ultrasound examination and, in certain cases, a liver biopsy. Currently, in the biochemical blood test panel, the most commonly included parameters are the activity of alkaline phosphatase (AP), gamma-glutamyl transferase (GGTP), glutamate dehydrogenase (GLDH), as well as the concentration of bilirubin, cholesterol, triglycerides, urea, total protein, albumin, glucose, and non-esterified (NEFA) or free fatty acids (FFA).The objective of this study was to determine the usefulness of ceruloplasmin determination in hepatic diagnostic panels to assess the severity of liver disease and its prognostic significance in diseases of this organ.

## Material and methods

The study describes clinical cases of dairy cows aged 3 to 6 years, which were between the 10$^{th}$ and 100$^{th}$ day of lactation. The animals were diagnosed with hepatitis based on a clinical examination, additional blood tests and an ultrasound examination. The cows were kept on the tethered housing systems for cattle in the Silesia region (Poland), in three herds comprising 50-200 Holstein-Friesian (HF) cows. For further analyses, 16 cows with an average milk yield of over 9,000 litres during lactation, with a body condition scoring (BCS) of 3/5, were selected. However, animals that were diagnosed with parasitic or infectious diseases, injuries, perinatal problems or severe metabolic diseases were excluded from the study. All of the farms used the total mixed ration (TMR) feeding system, and the feed ration consisted of the same ingredients: maize silage, maize grain, hay silage, grass silage, hay, straw, pellets, own cereals, feed additives with a protein content ranging from 18% to 24%, a premix and a mineral and vitamin supplement. Feed rations were developed on the basis of milk yield, the current physiological period, and the body weight of the cows.

All the diseased animals exhibited a periodic loss of appetite or permanently impaired feed intake, diarrhoea and reduced milk yield. A clinical examination of the animals concerned revealed a liver percussion area extension of varying degrees and the presence of clearly marked pain found on palpation and percussion of this area. The diseased cows were administered liver protection preparations containing sorbitol, acetylmethionine, choline hydrochloride, betaine, lysine hydrochloride, artichoke, gentian and *Ginkgo biloba* extracts, as well as vitamins A and E, iron, manganese, copper, cobalt, selenium, sodium propionate, colloidal silica, dextrose and menbutone solution, together with *Zingiber officinale*, *Allium sativum*, *Andrographis paniculata*, *Azadirachta indica*, *Balanites roxburghii*, *Centratherum anthelmenticum*, *Eclipta alba*, *Phyllanthus emblica*, *Terminalia chebula*, *Trigonella foenumgraecum*, *Trachyspermum ammi*, as well as oak bark, common calamus and common tormentil. The therapy resulted in a clear improvement in the health of nine animals (increased milk yield, reduced pain in the liver area, and return of appetite). In contrast, seven animals were

excluded from further breeding due to the lack of treatment effects (no milk yield recovery, progressive emaciation, persistent liver pain and too high animal treatment costs). Based on the above observations, the diseased cows were divided into two subgroups: Ia, comprising nine cows, and Ib, comprising seven cows. Anamnesis morbi and clinical examination in the two subgroups revealed no differences, whereas the division was carried out based on the treatment efficacy. Since these farms carried out regular animal monitoring, 10 randomly selected animals showing no clinical signs, with a normal liver ultrasound image, were used to assess the blood test results obtained in the group of diseased animals.

Blood tests were conducted according to the principles of dairy herd monitoring carried out at the Department of Animal Internal Diseases, based on the authors' original panel of laboratory liver disease tests. Blood samples from animals in the control group were collected as part of a screening program aimed at monitoring the health status of cattle herds. The analyses were performed to assess metabolic disorders within the herd and to implement preventive measures related to the herd owners' efforts to enhance milk production. The blood was collected from the external jugular vein of the cows under study, at a volume of 10 mL, into tubes containing $K_3$EDTA and tubes for serum testing before any treatment was applied. The morphological examination determined the following: red blood cell count (RBC), haemoglobin (Hgb), haematocrit (Htc) and the leukocyte (WBC) using an automatic Horiba scil Vet abc Plus analyser (Horiba, France). Gamma-glutamyl transpeptidase (GGTP) activity, as well as total bilirubin (Tbil), total cholesterol (Chol) and urea concentrations, were determined in the serum using a Horiba ABX Pentra 400 automatic analyser (Horiba, France). The concentrations of copper (Cu) and iron (Fe) in serum samples were determined using the flame atomic absorption spectrometry (FAAS) method by Avanta PM, GBC, Australia. Ceruloplasmin (Cp) was determined using a commercially available Bovine Ceruloplasmin ELISA test kit (MyBioSource, San Diego, USA) in accordance with the procedure provided by the manufacturer.

The results of haematological and biochemical tests were statistically analysed using the U Mann-Whitney test. The calculations were performed at $p < 0.05$ and $p < 0.001$ significance levels.

## Results and discussion

The cows under study were observed for two weeks after blood sampling. Clinical signs, including appetite disorders and periodic diarrhoea, disappeared in most animals within five to seven days after the administration of liver-supporting preparations. After 48 to 72 hours, an increase in milk yield was observed in some of the cows, yet it took from two to three weeks for them to return to full milk production. Depending on the individual cow, between the 3rd and 10th day of treatment a reduction in the liver percussion area and a decrease in pain in the hepatic region were observed. Most of the animals, according to their owners, showed no initial problems after two weeks following the commencement of the therapy. However, seven cows receiving treatment failed to respond correctly to the treatment despite the therapeutic measures taken. Other drugs were subsequently used on these animals but failed to produce the desired therapeutic effect. Ultimately, the owners of the dairy cattle decided to either send them for slaughter or euthanise them due to a significant drop in milk production as well as emaciation. The blood test results for the studied animals are provided in Tab. 1 and 2.

**Tab. 1. Laboratory test results for the groups under study, expressed in SI units**

| Parameter | Reference values according to Dirksen (4) | | Diseased cow group (Group I) | Control group (Group II) |
|---|---|---|---|---|
| RBC × $10^{12}$/L | 5.00-8.0 | X ± SD<br>Median | 6.78 ± 0.97$^{a}$<br>6.76 | 6.29 ± 0.74$^{a}$<br>6.12 |
| Hgb (g/L) | 90-140 | X ± SD<br>Median | 100.60 ± 7.86$^{a}$<br>102.00 | 93.82 ± 7.14$^{b}$<br>90.00 |
| Hct (L/L) | 0.28-0.40 | X ± SD<br>Median | 0.31 ± 0.03<br>0.31 | 0.30 ± 0.02<br>0.31 |
| WBC × $10^{9}$/L | 5.00-10.00 | X ± SD<br>Median | 9.84 ± 3.00<br>10.50 | 8.85 ± 3.26<br>8.40 |
| Cu (µmol/L) | 12-20 | X ± SD<br>Median | 12.36 ± 2.97<br>12.29 | 11.98 ± 1.37$^{b}$<br>11.90 |
| Fe (µmol/L) | 13-44 | X ± SD<br>Median | 34.52 ± 9.38<br>31.38 | 36.49 ± 6.77<br>38.11 |
| GGTP (U/L) | up to 20 | X ± SD<br>Median | 45.78 ± 8.91$^{a}$<br>44.00 | 26.00 ± 4.90$^{b}$<br>27.00 |
| Tbil (µmol/L) | up to 8.5 | X ± SD<br>Median | 4.20 ± 1.19$^{A}$<br>3.08 | 1.31 ± 0.19$^{B}$<br>1.37 |
| Chol-T (mmol/L) | 1.80-5.20 | X ± SD<br>Median | 4.37 ± 1.19$^{a}$<br>4.22 | 3.12 ± 1.50$^{b}$<br>2.56 |
| Urea (mmol/L) | 1.66-7.47 | X ± SD<br>Median | 2.92 ± 1.03<br>2.64 | 4.71 ± 1.59<br>4.61 |
| Cp (mg/dL) | | X ± SD<br>Median | 340.66 ± 154.09$^{A}$<br>277.95 | 25.83 ± 7.20$^{B}$<br>25.36 |

Explanations: a, b – significance of differences between mean values in groups before and after treatment at $p < 0.05$; A, B – significance of differences between mean values in groups before and after treatment at $p < 0.01$; X ± SD – the mean ± standard deviation

Based on the haematological blood test results (Tab. 1), a statistically significant difference was observed in haemoglobin concentration and the white blood cell. The other haematological parameters showed no statistically significant differences. As regards the biochemical blood test results, considerably higher values and statistically significant ($p \leq 0.01$) differences were noted for GGTP activity and the T-bil, urea and ceruloplasmin concentrations, whereas statistically significant ($p \leq 0.05$) differences were noted for the cholesterol and Fe concentrations. The ceruloplas-

min value was 15-fold higher than that noted in healthy cows. After observation and treatment were completed, it was found that some of the cows did not respond to the therapy applied. Therefore, the diseased cows were divided into two subgroups to compare their results (Tab. 2). The haematological tests yielded no significant differences, except for the white cell count, which was significantly higher in the subgroup Ib animals. In most cases, the biochemical blood tests showed no statistically significant differences between the subgroups. However, a statistically significant difference was found for bilirubin, with its average value falling within the accepted reference range (4) in both subgroups. The urea concentration was statistically significantly lower in subgroup Ib than that in subgroup Ia. The only exception in the tests conducted was the Cp concentration, which was statistically significantly higher in the subgroup in which no treatment effects were achieved. The resulting difference for this parameter was the only significant element differentiating the two subgroups of diseased animals.

**Tab. 2. Laboratory test results for the diseased cows**

| Parameter | Reference values according to Dirksen (4) | | Group I | |
|---|---|---|---|---|
| | | | Ia | Ib |
| RBC × $10^{12}$/L | 5.00-8.0 | X ± SD<br>Median | 6.86 ± 1.23<br>6.64 | 6.67 ± 0.44<br>6.81 |
| Hgb (g/L) | 90-140 | X ± SD<br>Median | 104.11 ± 4.43$^{a}$<br>103.00 | 95.33 ± 9.29$^{b}$<br>96.50 |
| Hct (L/L) | 0.28-0.40 | X ± SD<br>Median | 0.32 ± 0.03<br>0.33 | 0.30 ± 0.02<br>0.30 |
| WBC × $10^{9}$/L | 5.00-10.00 | X ± SD<br>Median | 9.19 ± 2.71<br>10.50 | 10.81 ± 3.40<br>10.60 |
| Cu (µmol/L) | 12-20 | X ± SD<br>Median | 12.27 ± 3.54<br>11.90 | 12.52 ± 1.91<br>12.90 |
| Fe (µmol/L) | 13-44 | X ± SD<br>Median | 35.03 ± 11.08<br>31.38 | 33.76 ± 7.00<br>31.23 |
| GGTP (U/L) | up to 20 | X ± SD<br>Median | 44.00 ± 4.95<br>44.00 | 48.45 ± 12.99<br>49.05 |
| Tbil (µmol/L) | up to 8.5 | X ± SD<br>Median | 1.84 ± 0.86$^{A}$<br>1.37 | 7.72 ± 3.61$^{B}$<br>7.44 |
| Chol-T (mmol/L) | 1.80-5.20 | X ± SD<br>Median | 4.56 ± 1.20<br>4.22 | 4.09 ± 1.23<br>3.93 |
| Urea (mmol/L) | 1.66-7.47 | X ± SD<br>Median | 3.46 ± 0.95$^{a}$<br>3.66 | 2.11 ± 0.45$^{b}$<br>2.07 |
| Cp (mg/dL) | | X ± SD<br>Median | 244.12 ± 43.32$^{A}$<br>251.53 | 514.43 ± 121.24$^{B}$<br>486.00 |

Explanations: a, b – significance of differences between mean values in groups before and after treatment at $p < 0.05$; A, B - significance of differences between mean values in groups before and after treatment at $p < 0.01$; X ± SD – the mean ± standard deviation

The liver is a crucial organ that regulates metabolic processes occurring in the animal body. Liver functions include maintaining homeostasis in carbohydrate, lipid, and protein metabolism, involvement in detoxification processes and the storage of nutrients, and ensuring the proper course of digestion and absorption of nutrients. These hepatic activities ensure a sufficiently high milk production and the development of foetuses while, at the same time, impacting the cows' feed intake. Any disturbance to the hepatic activity affects the functioning of the entire organism and is a serious problem in cows (5). Liver dysfunction often manifests itself in a subclinical form or with atypical symptoms, making it difficult to diagnose using traditional clinical methods or basic laboratory tests. The liver-related problems, most commonly diagnosed in humans and animals, are degenerative conditions (fatty liver disease and liver cirrhosis), with multifactorial hepatitis currently being increasingly recognised. In cattle, hepatitis is usually caused by non-infectious factors; e.g. acidosis of the rumen or digestive tract, parasitic factors (the liver fluke and the lancet liver fluke) or toxaemias, most commonly of uterine origin. In all cases, the treatment involves the administration of preparations that strengthen the hepatic function and rebuild the liver cells, as well as analgesics. Laboratory analysis panels are an important part of the liver function assessment. Unfortunately, due to the high cost of the determinations, cow breeders are reluctant to have additional tests performed or limit them to the "necessary" minimum. Methods are currently being sought that would, on the one hand, limit the number of additional examinations and, on the other hand, enable the precise diagnosis of liver diseases in high-yielding cows (2, 3, 5, 12, 15).

The authors' research focused on finding an indicator that would enable both researchers and medical practitioners working in the field to make a correct prognosis of the animal's condition. In liver inflammatory conditions, additional examinations, such as a biopsy and an ultrasound examination, showed no changes to differentiate the patients in terms of the success of the therapy. The most important parameters in the diagnostic panel for identifying liver disease in the studied animals included bilirubin concentration and GGTP activity. Based on scientific studies, these indicators enable the assessment of the liver's condition and guide the further treatment strategy for diseased cows. As regards the authors' own study, the results obtained for the individual cows provided no answers as to the actual condition of the animal. The average values of the parameters concerned varied between the individual groups but failed to provide an answer as to why a positive therapeutic effect was not obtained in some of the animals under study, and consequently a decision was made to exclude them from further use (16).

In analysing the wide range of results, the authors focused on the serum ceruloplasmin concentration in the diseased cows. In recent years, there has been an increase in the number of scientific and practical reports on the use of ceruloplasmin (Cp) in diagnosing liver diseases in human medicine (11, 21). Cp is among the main glycoproteins synthesised by liver cells and is classified as a mild-to-moderate acute-phase protein. In its structural composition, it contains six copper (Cu) atoms, which make up more than 90% of its components, and one of its functions is to be co-involved in the metabolism of iron (Fe), the concentration of which increases with the development of the inflammatory process (8, 9). As a protein that is mostly made up of copper ions, it is often used as a marker for copper accumulation in the liver and as an indicator of the status of the copper and iron contents of the body (1, 8, 17). In human medicine, Cp is increasingly being included as a marker in diagnostic panels for liver diseases to enable their correct diagnosis. Cp is used to diagnose liver cirrhosis, hepatic encephalopathy and inflammatory conditions in patients suffering from fatty liver (6, 11, 18, 21). In contrast, other authors (10, 13, 21) noted that high Cp levels are associated with the risk of developing non-alcoholic fatty liver disease and inflammatory conditions affecting the liver. Ceruloplasmin can serve as an objective indicator of the health status of cattle, and be used as a marker of health and welfare of animals. Currently, Cp is used in cattle for diagnostic purposes as an acute-phase protein in response to inflammatory processes caused by tissue damage – an acute-phase protein (8, 19, 20). To date, no information on its use as a parameter differentiating the patient's condition in the course of liver diseases has been found in any studies on the diagnosis of liver diseases in cows. Unfortunately, no information on such a situation in the course of animal liver disease could be found in the available literature. The authors state that determining Cp can indicate which cows might develop an inflammatory liver condition, potentially excluding them from further production. Based on the authors' research, Cp can be a useful parameter for identifying patients resistant to treatment at the screening level. This is the first such study presented in veterinary literature. The results offer a basis for including Cp in the standard examination panel for liver diseases.

The measures applied in the present paper involving the use (in diagnostic tests) of ceruloplasmin levels in the serum of cows with symptoms of hepatic dysfunction may provide a critical starting point for the further development of diagnostics for liver diseases in high-yielding dairy cattle. Due to the lack of data to clarify the relationships between the increase in the serum Cp concentration and the condition of the cows, research should be continued with the involvement of a larger and more representative number of cows in which standard therapeutic procedures have failed to bring about the expected recovery.

## Reference


1. *Barboza P. S., Blake J. E.*: Ceruloplasmin as an indicator of copper reserves in wild ruminants at high latitudes. J. Wildl. Dis. 2001, 37 (2), 324-331, doi: 10.7589/0090-3558-37.2.324.
2. *Bobe G., Young J. W., Beitz D. C.*: Invited review: Pathology, etiology, prevention, and treatment of fatty liver in dairy cows. J. Dairy Sci. 2004, 87, 3105-3124, doi: 10.3168/jds.S0022-0302(04)73446-3.
3. *Breukink H. J.*: Pathophysiology of the liver in high yielding dairy cows and its consequences for health and production. Isr. J. Vet. Med. 1997, 52 (2-3), 66-72.
4. *Dirksen G., Krankheiten von Leber und Gallenblase, Dirksen G., Gründer H. D., Stöber M.*: Innere Medizin des Rindes 4th ed. Parey im Blackwell, Berlin, Germany, 2002, p. 649-664.
5. *Faccin T. C., Kommers G. D., Galiza G. J., Pupin R. C., Madureira R. C., Lemos R. A.*: Chronic liver disease in cattle associated with ingestion of Brachiaria spp. Ciencia Rural. 2016, 46, 2036-2042, doi: 10.1590/0103-8478cr20160297.
6. *Han I. W., Jang J. Y., Kwon W., Park T., Kim Y., Lee K. B., Kim S. W.*: Ceruloplasmin as a prognostic marker in patients with bile duct cancer. Oncotarget. 2017, 8 (17), 29028-29037, doi: 10.18632/oncotarget.15995.
7. *Hayirli A.*: The role of exogenous insulin in the complex of hepatic lipidosis and ketosis associated with insulin resistance phenomenon in postpartum dairy cattle. Vet. Res. Comm. 2006, 30, 749-774.
8. *Hussein A. H., Staufenbiel R., Müller A. E., El-Sebaie A., Abd-El-Salam M.*: Ceruloplasmin activity in Holstein dairy cows: effects of lactation stages and anticoagulants. Comp. Clin. Pathol. 2012, 21, 705-710, doi: 10.1007/s00580-010-1161-8.
9. *Hussein H. A., Staufenbiel R.*: Variations in copper concentration and ceruloplasmin activity of dairy cows in relation to lactation stages with regard to ceruloplasmin to copper ratios. Biol. Trace Elem. Res. 2012, 146, 47-52, doi: 10.1007/s12011-011-9226-3.
10. *Kang N. L., Zhang J. M., Lin M. X., Chen X. D., Huang Z. X., Zhu Y. Y., Liu Y. R., Zeng D. W.*: Serum ceruloplasmin can predict liver fibrosis in hepatitis B virus-infected patients. World J. Gastroenterol. 2020, 21, 3952-3962, doi: 10.3748/wjg.v26.i27.3952.
11. *Liu Z., Wang M., Zhang C., Zhou S., Ji G.*: Molecular functions of ceruloplasmin in metabolic disease pathology. Diabetes Metab. Syndr. Obes. 2022, 3 (15), 695-711, doi: 10.2147/DMSO.S346648.
12. *Manthorpe E. M., Jerrett I. V., Rawlin G. T., Woolford L.*: Clinical and pathologic features of acute bovine liver disease in Australia. J. Vet. Diagn. Invest. 2021, 33 (5), 875-883, doi: 10.1177/10406387211025829.
13. *Nobili V., Siotto M., Bedogni G., Ravà L., Pietrobattista A., Panera N., Alisi A., Squitti R.*: Levels of serum ceruloplasmin associate with pediatric nonalcoholic fatty liver disease. J. Pediatr. Gastroenterol. Nutr. 2013, 56, 370-375.
14. *Pinsent P. J. N.*: The diagnosis of disease of the bovine liver: A Clinician's view. The Bovine Practitioner 1983, 18, 165-168, doi: 10.21423/bovine-vol1983no18p165-168.
15. *Rich L. J., Dunavant M. L.*: Serum enzymes in bovine practice. The Bovine Practitioner 1972, 7, 8-12, doi: 10.21423/bovine-vol1972no7p8-12.
16. *Sutherland M., Huddart F., Lowe G., Cox N., Cuttance E., Schütz K.*: Relationship between gamma-glutamyl transferase (GGT) concentrations and lying behaviour in dairy cattle. NZJASP 2020, 80, 24-28.
17. *Suttle N. F.*: Relationships between the concentrations of trichloroacetic acid-soluble copper and caeruloplasmin in the serum of cattle from areas with different soil concentrations of molybdenum. Vet. Rec. 2008, 162, 237-240.
18. *Tapper E. B., Sengupta N., Lai M., Horowitz G.*: Understanding and reducing ceruloplasmin overuse with a decision support intervention for liver disease evaluation. Am. J. Med. 2016, 129 (1), 115.e17-22, doi: 10.1016/j.amjmed.2015.07.019.
19. *Tharwat M.*: Ultrasonographic findings in cattle and buffaloes with chronic hepatic fascioliosis. Trop. Anim. Health. Prod. 2012, 44, 1555-1560.
20. *Weber C., Hametner A., Tuchscherer A., Losand B., Kaintz E., Otten W., Singh S. P., Bruckmaier R. M., Becker F., Kaintz W., Hammon H. M.*: Variation in FAT mobilization during early lactation differently affects feed intake, body condition, and lipid and glucose metabolism in high-yielding dairy cows. J. Dairy Sci. 2013, 96, 165-180.
21. *Zeng D. W., Dong J., Jiang J. J., Zhu Y. Y., Liu Y. R.*: Ceruloplasmin, a reliable marker of fibrosis in chronic hepatitis B virus patients with normal or minimally raised alanine aminotransferase. World J. Gastroenterol. 2016, 22 (43), 9586-9594, doi: 10.3748/wjg.v22.i43.9586.


**Corresponding author: Łukasz Kurek, DVM, DSc, Department and Clinic of Animal Internal Diseases, University of Life Sciences in Lublin, Akademicka 13, 20-912 Lublin, Poland; e-mail: lukasz.kurek@up.lublin.pl**