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DIETARY SUPPLEMENTS CONTAINING COLLAGEN – ANALYSIS AND AVAILABILITY ON THE POLISH MARKET®

Suplementy diety zawierające kolagen – analiza i dostępność na polskim rynku®

Key words: dietary supplements, collagen, source of collagen, Polish market.

Supplements containing collagen vary in quality. Therefore, the aim of this study was to analyze the collagen content in products available on the Polish market, as well as their price, source of collagen origin, and declarations and claims of producers placed on product labels. The study was conducted in selected Polish online shops, and additionally the data were verified in some stationary shops in the Mazovia region. The material for the study was the information from product labels and descriptions available on websites. The analysis covered 30 dietary supplements containing collagen in various forms: in liquid, tablet and capsule form and in powder form. Only 13% of the supplements were pure single-ingredient substances, and the rest functioned as multi-ingredient supplements. The most common collagen booster used in supplements was vitamin C. The products analyzed differed in terms of the source of collagen. Most were supplements with collagen of marine origin. Among the collagen properties most often declared on product labels, strengthening of joints and tendons, bones, skin, hair and nails was mentioned. The costs of treatment in the tested products varied and very often were not proportional to the content of the active substance in the tested supplement.

Słowa kluczowe: suplementy diety, kolagen, źródło kolagenu, rynek polski.

Suplementy zawierające kolagen, różnią się jakością. Celem pracy było przeanalizowanie zawartości kolagenu w produktach dostępnych na polskim rynku, jak również ich ceny, źródła pochodzenia kolagenu oraz deklaracji i oświadczeń producentów umieszczonych na etykietach produktów. Badanie przeprowadzono w wybranych, polskich sklepach internetowych oraz dodatkowo zweryfikowano dane w części sklepów stacjonarnych na Mazowszu. Materiał do badań stanowiły informacje z etykiet produktów oraz opisy dostępne na stronach internetowych. Analizie poddano 30 suplementów diety zawierających kolagen w różnej postaci: w płynie, w tabletkach i kapsułkach oraz w formie proszku. Zaledwie 13% suplementów miało charakter czystej substancji jednoskładnikowej, a pozostałe funkcjonowały jako suplementy wieloskładnikowe. Najczęstszą substancją wspomagającą kolagen stosowaną w suplementach była witamina C. Produkty poddane analizie różniły się ze względu na źródła otrzymywania kolagenu. Najwięcej było suplementów z kolagenem pochodzenia morskiego. Wśród najczęściej deklarowanych na etykietach produktów właściwości kolagenu, wymieniano wzmacnianie: stawów i ścięgien, kości, skóry oraz włosów i paznokci. Koszty kuracji w sprawdzonych produktach były zróżnicowane i bardzo często nie były proporcjonalne w stosunku do zawartości substancji aktywnej w badanym suplementcie.

INTRODUCTION

The main protein produced by the human body is collagen, which is present in bones, tendons and ligaments, muscles, as well as skin and hair [16]. Its loss occurs with age. Compared to young adults, collagen synthesis in the body in people around the age of 80 can decrease by up to 75% [9],

and supplementation with bioactive collagen peptides can counteract this process.

Collagen proteins are becoming increasingly popular on the market, and manufacturers of foodstuffs, dietary supplements are meeting the expectations of consumers by introducing new products with these proteins. More and more people see the need to use collagen preparations for cosmetic

and therapeutic purposes in the prevention of diseases of the musculoskeletal system, among others [8] such as rheumatoid arthritis (RA). One way of alleviating the disease symptoms of RA is prevention in the form of maintaining physical activity appropriate to the patient's age [2] and taking dietary supplements containing collagen peptides [12].

The aim of this study was to analyze collagen content in products available on the Polish market, as well as their prices, sources of collagen origin and declarations and claims placed by producers on the labels of these product.

MATERIALS AND METHODS

The research was conducted in selected Polish online stores, and additionally data was verified in selected stationary stores on the territory of the Mazovia region in August and September 2019. Information about the supplements was obtained in the following online shops: www.aptekagemini.pl, www.gshpolska.pl, www.pharmovit.pl, www.bingospa.eu, www.finshop.pl, www.sklepdietetyczny.pl, www.vodanaturalna.pl, www.vitalabo.pl, www.japanstore.pl, www.aptekawaw.pl, www.formeds.com.pl, www.swansonshop.pl, www.kenayag.pl, www.topwitaminy.pl, www.medicaherbs.pl, www.colway.pl, www.cfarm24.pl, www.kolagen.pro, www.noblehealth.pl, www.sfd.pl, www.biogo.pl, www.pbc24.pl, www.testosteron.pl, and in stationary shops such as Rossmann, Tesco, Lidl in Warsaw and Siedlce, and additionally in the Dietitian's Clinic in Siedlce. The material for the study consisted of information placed on product labels and product descriptions available on websites. The prices, sources of collagen origin and declarations placed by producers on the labels of these products were checked. Excel 2016 was used to analyze the data.

RESULTS AND DISCUSSION

Forms of dietary supplements with collagen

During the study, 30 products containing collagen were analyzed. Dietary supplements in various forms (Fig. 1) were available on the market in the same proportions: liquid collagen, collagen in powder form and, collagen in capsules and tablets (33.3% respectively).

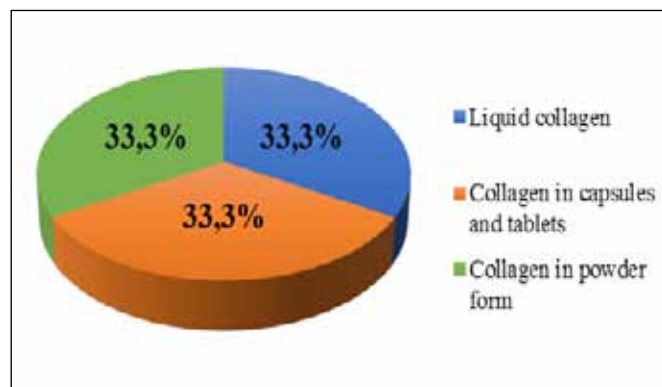


Fig. 1. Form of presence of collagen in products.

Rys. 1. Forma występowania kolagenu w produktach.

Source: Own study

Źródło: Badanie własne

In addition to the various forms of collagen present in products, it may also be present as a denatured or hydrolyzed collagen. The most commonly used forms are denatured collagen and hydrolyzed collagen. Denaturation and hydrolysis processes break down the peptides into shorter chains and, after sufficiently long treatment, even into single amino acids. However, such strong processing of peptides should be avoided because of the breakdown of collagen and loss of its therapeutic properties [15, 21].

Collagen type II (CII) denaturation refers to the process of breaking down peptide chains of amino acids and most commonly this process is used to process gelatin protein supplements by heating [21]. It is well known that protein denaturation is an irreversible process and completely inactivates peptides, which reduces the benefits of their use in joint disease. It is important to bear in mind that some manufacturers of collagen type II (CII) supplements do not use the protein denaturation process by advertising their product as non-denatured collagen, i.e. UC-II active in the prevention of arthritis, among others [11].

Form of preparations (one or multiple ingredients)

Share in the analyzed market of dietary supplements of single- and multi-ingredient products is presented in Fig. 2.

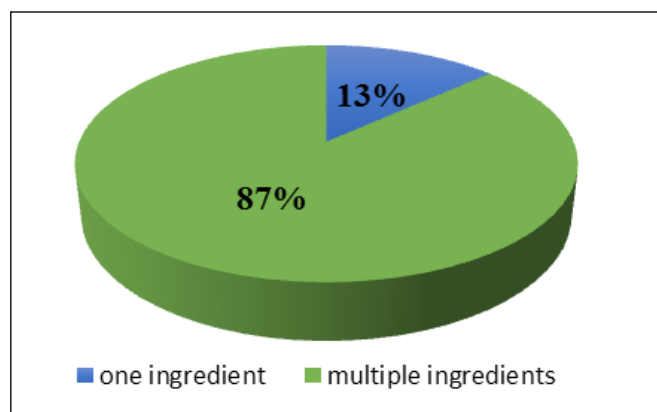


Fig. 2. Share in the analyzed market of dietary supplements of single- and multi-ingredient products.

Rys. 2. Udział w analizowanym rynku suplementów diety produktów jedno i wieloskładnikowych.

Source: Own study

Źródło: Badanie własne

Most of the dietary supplements with collagen on the market were in the form of multicomponent preparations and rarely were there only preparations with pure collagen. Only 13% of the supplements were in the form of pure single-ingredient collagen and 87% as a multi-ingredient supplement (Fig. 2). Pure collagen was most often found in liquid or powdered form. In multi-ingredient products, vitamin C and/or hyaluronic acid were most commonly added. In many collagen preparations sold in liquid form – a preservative was added, and an anti-caking agent was added to food supplements sold in capsule or tablet form.

Collagen sources

Collagen sources quoted by manufacturers in the dietary supplements analyzed are presented in Fig. 3.

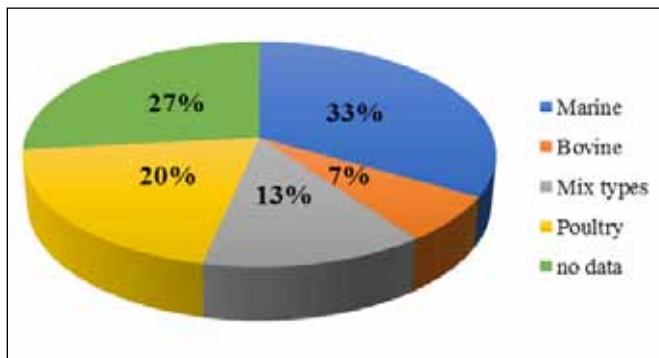


Fig. 3. Collagen sources in the dietary supplements (%).

Rys. 3. Źródła kolagenu w suplementach diety (%).

Source: Own study

Źródło: Badanie własne

The analyzed products differed in the source of collagen. Most of the analyzed supplements contained collagen of marine origin from sea fish (33%), then from poultry (20%) and from bovine (7%). A large percentage of supplements (27%) did not contain information about the source of collagen on the label, which is important information for buyers of such products. However, as many as 13% of the supplements contained a mixture of collagens from different sources.

The most commonly used sources of collagen are raw materials of animal origin such as fish, chicken, porcine or bovine origin [7, 8]. Excellent parts of animals, from which collagen is obtained are tendons, skins and bones. The prevalence of animal (pork and beef) peptides was such that gelatin became synonymous with collagen, and in the physically active community, gelatin and fruit jellies with gelatin were seen as sufficient to strengthen joints [20].

Chicken and other poultry fowl can also be a source of collagen procurement. Due to its high availability and relatively low price, chicken is the most available and currently the cheapest meat on the market. Collagen in chicken meat from chicken meat occurs mainly in connective tissue [13]. Meat from chicken breast contains about 2.5% of collagen, and meat from thigh parts contains about 6% [13]. Chicken meat is also an excellent source of amino acids [17]. Another source of peptides and thus collagen is saltwater fish and freshwater. The use of this source was in response to epidemic diseases in cows and pigs - Creutzfeldt-Jakob disease and the swine flu epidemic [7]. Approximately 30% of waste in the form of skins, heads and bones remains in the fish processing process. Using this waste to obtain collagen is therefore most appropriate. As a result of the spread of civilization diseases such as hypertension, the extraction of collagen from fish seems to meet the industrial demand for this raw material [19].

Researchers all over the world are trying to find a plant-based source of collagen that can be used by vegetarians and vegans. Such products include Rejuvenat-

ed Veggiecol which, according to the manufacturer, contains a patented formula of collagen, hyaluronic acid and over five hundred natural ingredients, including vitamin C, zinc and copper to boost collagen levels. The main ingredients in Collageno Vegetal by Borinquen Natural are carrot extract, methylsulfonylmethane (MSM), glucosamine, hyaluronic acid and vitamin C. These ingredients are supposed to stimulate in the human body the natural synthesis of collagen in cells.

Collagen-enhancing additives

Figure 4 shows the types and frequency of collagen-enhancing additives in the dietary supplements analyzed.

The most common collagen-supporting additive (Fig. 4.) used in dietary supplements was vitamin C (used in 28% of the products). This vitamin was found alone or with other vitamins and minerals. Vitamin C was the most commonly used as a supporting additive, having been used in 28% of the products. 14% of the products contained fruit and plant extracts in the formulation. Examples of extracts were goi fruit extract, field horsetail extract, or carrot juice. B vitamins, vitamin A, vitamin E and minerals such as magnesium, zinc, manganese, calcium were used in 28% of the products. Manufacturers also added hyaluronic acid - in 11% of the products, glucosamine and chondroitin - in 5% of the analyzed products. Only 9% of the analyzed supplements did not contain any supporting additives.

Vitamin C is one of the factors influencing the absorption and collagen synthesis in the body. Kjaer et al [6] showed that supplementation with vitamin C and other minerals had a positive effect on hernia healing outcomes in men. The study by Ivanov et al [5] showed a beneficial effect of vitamin C supplementation on the synthesis of more type I and V collagen in the arteries.

Cost of collagen treatment

The costs of collagen treatment in the analyzed products were very often not proportional to the content of active substance in the supplement.

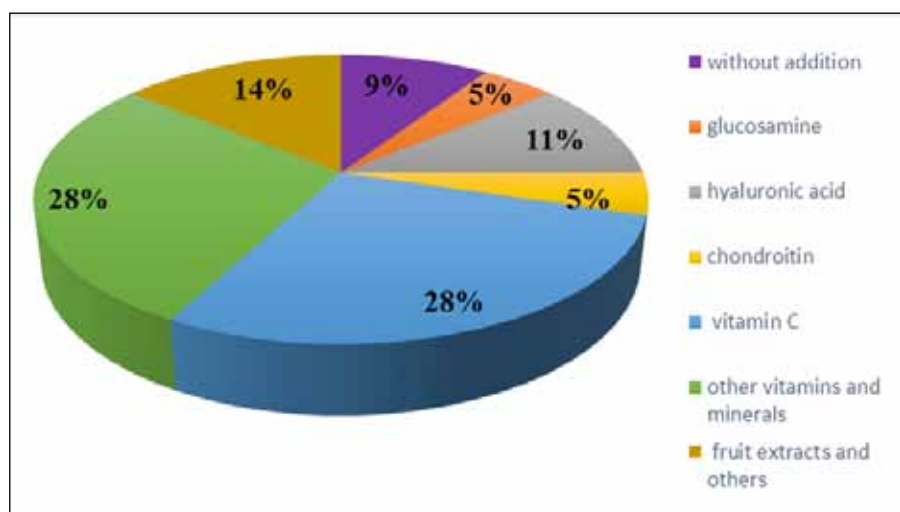


Fig. 4. Collagen-supporting additives in food supplements (%).

Rys. 4. Dodatki wspomagające działanie kolagenu w suplementach diety (%).

Source: Own study

Źródło: Badanie własne

The amount of active substance in the analyzed liquid products ranged between 216 mg and 20000 mg in a daily dose. The lowest cost of using a single dose of the liquid collagen supplement was PLN 3.08, and the dose of the active substance offered at this price was 9650 mg of collagen. In contrast, the average cost of the liquid collagen supplement was PLN 7.96 for an average daily dose of 5633 mg. The amount of active substance in the analyzed collagen supplements in capsules and tablets was between 10 and 4000 mg in a daily dose. The lowest cost of using a single dose of collagen supplement in tablets and capsules on the Polish market was PLN 0.59, and the highest was PLN 6.34. The collagen powder supplements analyzed on the Polish market contained between 1500 and 10000 mg in the recommended daily intake. The lowest daily cost of using a single dose of collagen powder supplement was PLN 0.68 and the highest was PLN 3.29, while the average cost of a daily dose was PLN 2.09.

Declaration of health-promoting properties

The declaration of health-promoting properties of products containing collagen serves manufacturers and distributors as an additional asset and an incentive to purchase a given product. Figure 5 presents the health-promoting properties most frequently declared by manufacturers of dietary supplements with collagen.

Many manufacturers claimed several benefits of a single food supplement. Among the most frequently claimed properties of collagen on the labels of the products, strengthening of tendons and joints, skin, bones, hair and nails were mentioned. Most of them concern improvement of joints and tendons skin condition (25 declarations) (Fig. 5), then skin condition. 20 products indicated a strengthening effect in this regard. Also, a very high number of benefits declared by producers concerned the improvement of bone density, where such a declaration concerned 18 products. Strengthening effects on hair and nails were declared for 11 products. In individual cases, a positive effect on eyes for 3 products, on teeth and on the metabolism for 2 products, and on the immune system for 1 product (Figure 5).

The use of collagen type II (CII) for chronic diseases such as RA (Rheumatoid Arthritis) clearly alleviates the effects of the disease. Administration of CII to patients is completely safe and beneficial to improve health [10]. The administration of low doses of CII has given positive results for joint pain, chronic back pain [4, 18], which increased during exercise [10]. In the case of osteoarthritis, Guzman et al [3] showed that the use of CII results in an alleviation of disease symptoms. The benefits associated with CII administration are associated with a lower immune response, with less production of IgG specific to type II collagen. Interferons can be stimulated with higher doses of collagen, although it was observed that during oral

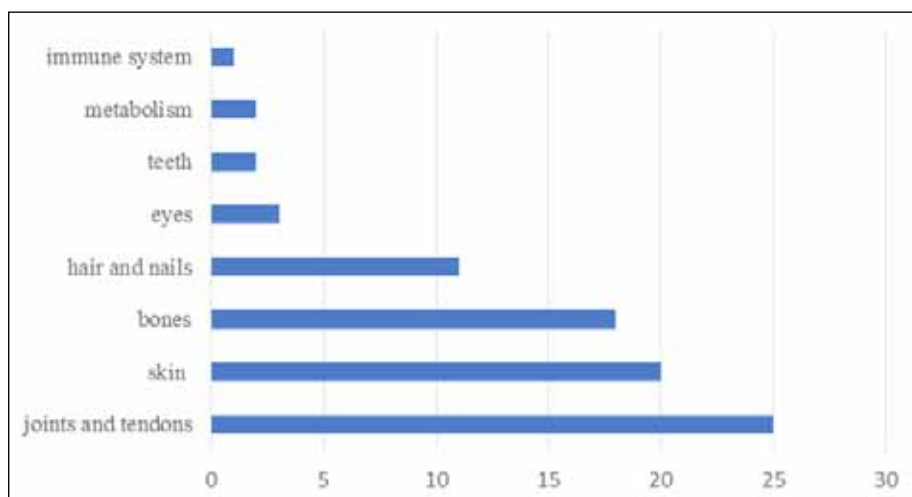


Fig. 5. The health-promoting properties most frequently declared by manufacturers of dietary supplements with collagen (number of declarations).

Rys. 5. Właściwości prozdrowotne najczęściej deklarowane przez producentów suplementów diety z kolagenem (liczba deklaracji).

Source: Own study

Źródło: Badanie własne

supplementation this did not affect the outcome of the study [14]. Type I collagen makes up about 80% of the total collagen found in the human dermis [1]. Numerous studies confirm the effectiveness of collagen in skin care and regeneration [22] that is why collagen is one of the most commonly used substances in cosmetology.

Products containing collagen are well widespread on the Polish market, however, there is still a lack of offer for food enriched with collagen proteins. Such functional food products are available on foreign markets. Examples of such products with added collagen are e.g. chocolate bars, chocolate creams, chocolates and drinks available on the US market, candies, coffee and gin available on the UK market, and beer with collagen available in Japan or bread mix in RPA.

CONCLUSIONS

1. The dietary supplements with collagen analyzed were available in various forms: collagen in liquid, capsule and tablet form as well as in powder form.
2. Only 13% of the supplements were pure single-ingredient substances, and the rest functioned as multi-ingredient supplements. The most common collagen booster used in supplements was vitamin C.
3. The products analyzed differed in terms of the source of collagen. Most were supplements with collagen of marine origin.
4. Among the collagen properties most often declared on supplement labels, strengthening of joints and tendons, bones, skin, hair and nails was mentioned.
5. The costs of treatment in the tested products varied and very often were not proportional to the content of the active substance in the tested supplement.

WNIOSKI

1. Analizowane suplementy diety z kolagenem występowały w różnej postaci: kolagen w płynie, w kapsułkach i tabletkach oraz w postaci proszku.
2. Zaledwie 13% suplementów miało charakter czystej substancji jednoskładnikowej, a pozostałe funkcjonowały jako suplementy wieloskładnikowe. Najczęstszą substancją wspomagającą kolagen stosowaną w suplementach była witamina C.

3. Produkty poddane analizie różniły się ze względu na źródła otrzymywania kolagenu. Najwięcej było suplementów z kolagenem pochodzenia morskiego.
4. Wśród najczęściej deklarowanych na etykietach suplementu właściwości kolagenu, wymieniano wzmacnianie stawów i ścięgien, kości, skóry oraz włosów i paznokci.
5. Koszty kuracji w sprawdzonych produktach były zróżnicowane i bardzo często nie były proporcjonalne w stosunku do zawartości substancji aktywnej w badanym suplementcie.

REFERENCES

- [1] **FRANTZ C., K.M. STEWART, V.M. WEAVER. 2010.** "The extracellular matrix at a glance". *Journal of Cell Science* 123: 4195-4200.
- [2] **GĘBKA D., K. KĘDZIORA-KORNATOWSKA. 2012.** „Korzyści z treningu zdrowotnego u osób w starszym wieku”. *Problemy Higieny i Epidemiologii* 93(2): 256–259.
- [3] **GUZMAN R.E., M.G. EVANS, S. BOVE, B. MORENKO, K. KILGORE. 2003.** "Monoiodoacetate-induced histologic changes in subchondral bone and articular cartilage of rat femorotibial joints: an animal model of osteoarthritis" 31(6):619–24.
- [4] **HERMANN G.F., T. RIVKINA, D. LAVINO. 2008.** "Pain management in cervical chronic myofascial trigger points: prn homeomesotherapy vs. Conventional mesotherapy – results of a cohort, controlled clinical trial". *Physiological. Regulating Medicine Jan* (1):3–10.
- [5] **IVANOV V., S. IVANOVA, T. KALINOVSKY, A. NIEDZWIECKI, M. RATH. 2016.** "Inhibition of collagen synthesis by select calcium and sodium channel blockers can be mitigated by ascorbic acid and ascorbyl palmitate". *American Journal of Cardiovascular Disease* 6(2): 26–35.
- [6] **KJAER M., A. KRUSE, S. FREDERIKSEN, I. INGEMANN NISSEN, N. WILLUMSEN, G. VAN HALL, L. NANNESTAD JORGENSEN, J.R. ANDERSEN, M.S. ÅGREN. 2017.** "Multinutrient Supplementation Increases Collagen Synthesis during Early Wound Repair in a Randomized Controlled Trial in Patients with Inguinal Hernia". *The Journal of Nutrition*. <https://www.clinicaltrials.gov/ct2/show/NCT03221686?id=NCT03221686&draw=2&rank=1>
- [7] **KOZŁOWSKA J., A. SIONKOWSKA. 2011.** „Właściwości kolagenu wyizolowanego z łusek ryb z gatunku *Esox Lucius*". *Inżynieria biomateriałów* 109–111: 24–26.
- [8] **KRASNOWSKA G. 2005.** „Charakterystyka i wykorzystanie białek kolagenowych”. *Medycyna weterynaryjna* 61 (3).
- [9] **LEÓN-LÓPEZ A. A. MORALES-PENALOZA, V.M. MARTÍNEZ-JUÁREZ, A. VARGAS-TORRES, D.I. ZEUGOLIS, G. AGUIRRE-ÁLVAREZ. 2019.** „Hydrolyzed Collagen--Sources and Applications". *Molecules* 24: 4031.

REFERENCES

- [1] **FRANTZ C., K.M. STEWART, V.M. WEAVER. 2010.** "The extracellular matrix at a glance". *Journal of Cell Science* 123: 4195–4200.
- [2] **GEBKA D., K. KEDZIORA-KORNATOWSKA. 2012.** „Korzyści z treningu zdrowotnego u osob w starszym wieku”. *Problemy Higieny i Epidemiologii* 93(2): 256–259.
- [3] **GUZMAN R.E., M.G. EVANS, S. BOVE, B. MORENKO, K. KILGORE. 2003.** "Monoiodoacetate-induced histologic changes in subchondral bone and articular cartilage of rat femorotibial joints: an animal model of osteoarthritis" 31(6): 619–24.
- [4] **HERMANN G.F., T. RIVKINA, D. LAVINO. 2008.** "Pain management in cervical chronic myofascial trigger points: prn homeomesotherapy vs. Conventional mesotherapy - results of a cohort, controlled clinical trial". *Physiological. Regulating Medicine Jan* (1): 3–10.
- [5] **IVANOV V., S. IVANOVA, T. KALINOVSKY, A. NIEDZWIECKI, M. RATH. 2016.** "Inhibition of collagen synthesis by select calcium and sodium channel blockers can be mitigated by ascorbic acid and ascorbyl palmitate". *American Journal of Cardiovascular Disease* 6(2): 26–35.
- [6] **KJAER M., A. KRUSE, S. FREDERIKSEN, I. INGEMANN NISSEN, N. WILLUMSEN, G. VAN HALL, L. NANNESTAD JORGENSEN, J.R. ANDERSEN, M.S. AGREN. 2017.** "Multinutrient Supplementation Increases Collagen Synthesis during Early Wound Repair in a Randomized Controlled Trial in Patients with Inguinal Hernia". *The Journal of Nutrition*. <https://www.clinicaltrials.gov/ct2/show/NCT03221686?id=NCT03221686&draw=2&rank=1>
- [7] **KOZŁOWSKA J., A. SIONKOWSKA. 2011.** „Wlasciwosci kolagenu wyizolowanego z łusek ryb z gatunku *Esox Lucius*". *Inzynieria biomaterialow* 109–111: 24–26.
- [8] **KRASNOWSKA G. 2005.** „Charakterystyka i wykorzystanie białek kolagenowych”. *Medycyna weterynaryjna* 61 (3).
- [9] **LEON-LOPEZ A. A. MORALES-PENALOZA, V.M. MARTINEZ-JUAREZ, A. VARGAS-TORRES, D.I. ZEUGOLIS, G. AGUIRRE-ALVAREZ. 2019.** "Hydrolyzed Collagen--Sources and Applications". *Molecules* 24: 4031.

- [10] LUGO J.P., Z.M. SAIYED, F.C. LAU, J.P. MOLINA, M.N. PACKDAMAN, A.N. SHAMIE, J.K. UDANI. 2013. „Undenatured type II collagen (UC-II®) for joint support: a randomized, double-blind, placebo-controlled study in healthy volunteers”. *Journal of the International Society of Sports Nutrition* 10(1): 48.
- [11] MARONE P.A., F.C. LAU, R.C. GUPTA, M. BAGCHI, D. BAGCHI. 2010. “Safety and toxicological evaluation of undenatured type II collagen”. *Toxicology Mechanisms and Methods* 20(4):175–189.
- [12] MATYSKA-PIEKARSKAE., E. ŁUSZCZEWSKI, J. ŁĄCKI, I. WAWER. 2006. „Rola stresu oksydacyjnego w etiopatogenezie reumatoidalnego zapalenia stawów”. *Postępy Higieny i Medycyny Doswiadczalnej* 60: 617–623.
- [13] MICHALCZUK M., A. SIENNICKA. 2010. „Właściwości dietetyczne mięsa różnych gatunków drobiu utrzymywanych w alternatywnych systemach chowu”. *Przegląd Hodowlany* 11.
- [14] MIN S.Y., K.S. PARK, M.L. CHO, J.W. KANG, Y.G. CHO, S.Y. HWANG, M.J. PARK, C.H. YOON, J.K. MIN, S.H. LEE, S.H. PARK, H.Y. KIM. 2006. “Antigen-induced, tolerogenic CD11c+, CD11b+ dendritic cells are abundant in Peyer’s patches during the induction of oral tolerance to type II collagen and suppress experimental collagen-induced arthritis”. *Arthritis and Rheumatism* 54(3): 887–98.
- [15] MOSKOWITZ R.W. 2000. “Role of collagen hydrolysate in bone and joint disease”. *Seminars in Arthritis and Rheumatism* 30(2): 87–89.
- [16] NOWICKA-ZUCHOWSKA A., A. ZUCHOWSKI. 2019. „Kolagen – rola w organizmie i skutki niedoboru”. *Lek w Polsce, Farmakoterapia* 29 (11/12): 342–343.
- [17] ORKUSZ A. 2015. Czynniki kształtujące jakość mięsa drobiu grzebiącego. Praca przeglądowa. *Nauki inżynierskie i technologiczne* 1(16).
- [18] PAVELKAK., R. SVOBODOVA, H. JAROSLOVA. 2012. “MD-Lumbar, MD-Muscle, MD-Neural in the treatment of low back pain”. *Physiological Regulating Medicine* <https://guna.com/product/physiological-regulating-medicine-2012/attachment/3-6-pavelka-pdfmd-lumbarmd-muscleandmd-neuralinthreatmentoflowbackpain-k-pavelkar-svobodovh-jaroovaacute>
- [19] PLISZKA M., J. BORAWSKA, M. ŚWITAJ, M. DAREWICZ. 2015. „Białka pstrąga tęczowego jako potencjalne źródło biologicznie aktywnych peptydów”. Praca oryginalna. *Medycyna Ogólna i Nauki o Zdrowiu* 21(3): 322–327.
- [20] SHAW G., A. LEE-BARTHEL, M. LR ROSS, B. WANG, K. BAAR. 2017. “Vitamin C-enriched gelatin supplementation before intermittent activity augments collagen synthesis”. *The American Journal of Clinical Nutrition* 105(1): 136–143.
- [10] LUGO J.P., Z.M. SAIYED, F.C. LAU, J.P. MOLINA, M.N. PACKDAMAN, A.N. SHAMIE, J.K. UDANI. 2013. “Undenatured type II collagen (UC-II(R)) for joint support: a randomized, double-blind, placebo-controlled study in healthy volunteers”. *Journal of the International Society of Sports Nutrition* 10(1): 48.
- [11] MARONE P.A., F.C. LAU, R.C. GUPTA, M. BAGCHI, D. BAGCHI. 2010. “Safety and toxicological evaluation of undenatured type II collagen”. *Toxicology Mechanisms and Methods* 20(4): 175–189.
- [12] MATYSKA-PIEKARSKAE., E. LUSZCZEWSKI, J. LACKI, I. WAWER. 2006. „Rola stresu oksydacyjnego w etiopatogenezie reumatoidalnego zapalenia stawów”. *Postępy Higieny i Medycyny Doswiadczalnej* 60: 617–623.
- [13] MICHALCZUK M., A. SIENNICKA. 2010. „Wlasciwosci dietetyczne miesa roznych gatunkow drobiu utrzymywanych w alternatywnych systemach chowu”. *Przegląd Hodowlany* 11.
- [14] MIN S.Y., K.S. PARK, M.L. CHO, J.W. KANG, Y.G. CHO, S.Y. HWANG, M.J. PARK, C.H. YOON, J.K. MIN, S.H. LEE, S.H. PARK, H.Y. KIM. 2006. „Antigen-induced, tolerogenic CD11c+, CD11b+ dendritic cells are abundant in Peyer’s patches during the induction of oral tolerance to type II collagen and suppress experimental collagen-induced arthritis”. *Arthritis and Rheumatism* 54(3): 887–98.
- [15] MOSKOWITZ R.W. 2000. “Role of collagen hydrolysate in bone and joint disease”. *Seminars in Arthritis and Rheumatism* 30(2): 87–89.
- [16] NOWICKA-ZUCHOWSKA A., A. ZUCHOWSKI. 2019. „Kolagen – rola w organizmie i skutki niedoboru”. *Lek w Polsce, Farmakoterapia* 29 (11/12): 342–343.
- [17] ORKUSZ A. 2015. Czynniki kształtujące jakość mięsa drobiu grzebiącego. Praca przeglądowa. *Nauki inżynierskie i technologiczne* 1(16).
- [18] PAVELKAK., R. SVOBODOVA, H. JAROSLOVA. 2012. “MD-Lumbar, MD-Muscle, MD-Neural in the treatment of low back pain”. *Physiological Regulating Medicine* <https://guna.com/product/physiological-regulating-medicine-2012/attachment/3-6-pavelka-pdfmd-lumbarmd-muscleandmd-neuralinthreatmentoflowbackpain-k-pavelkar-svobodovh-jaroovaacute>
- [19] PLISZKA M., J. BORAWSKA, M. SWITAJ, M. DAREWICZ. 2015. „Bialka pstraga teczowego jako potencjalne zrodlo biologicznie aktywnych peptydow”. Praca oryginalna. *Medycyna Ogolna i Nauki o Zdrowiu* 21(3): 322–327.
- [20] SHAW G., A. LEE-BARTHEL, M. LR ROSS, B. WANG, K. BAAR. 2017. „Vitamin C-enriched gelatin supplementation before intermittent activity augments collagen synthesis”. *The American Journal of Clinical Nutrition* 105(1): 136–143.

- [21] **WRIGHT N.T., J.D. HUMPREY. 2002.** "Denaturation of Collagen Via Heating: An Irreversible Rate Process". Annual Review of Biomedical Engineering 4: 109–128.
- [22] **ŻELASZCZYK D., A. WASZKIELEWICZ, H. MARONA. 2012.** „Kolagen – struktura oraz zastosowanie w kosmetologii i medycynie estetycznej”. Estetologia Medyczna i Kosmetologia 2(1): 14–20.

- [21] **WRIGHT N.T., J.D. HUMPREY. 2002.** "Denaturation of Collagen Via Heating: An Irreversible Rate Process". Annual Review of Biomedical Engineering 4: 109–128.
- [22] **ZELASZCZYK D., A. WASZKIELEWICZ, H. MARONA. 2012.** „Kolagen – struktura oraz zastosowanie w kosmetologii i medycynie estetycznej”. Estetologia Medyczna i Kosmetologia 2(1): 14–20.