Potential Use of *Lactobacillus plantarum 1UHCC* as a Bio-hydrolyzer in the Development of the Sustainable Food Industry in Indonesia

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Abstract

The purpose of this study aimed to evaluate the potential and performance of *Lactobacillus plantarum 1 UHCC* (*L.plantarum 1UHCC*) bacteria as bio-hydrolyzer of the food industry in Indonesia. As much as 100g of fresh hide from Balinese cattle were used as a substrate. The fermentation time was carried out at 3 time levels, namely: 24 hours (T-24); 48 hours (T-48) and 72 hours (T-72). The bacteria were used *L.plantarum* which was isolated from milkfish extract. The results showed that in the solution of *L.plantarum* bacteria using collagen substrate of cattle hide, pH values were increased and the lactic acid levels were decreased significantly. The pH value and the lactic acid level of the solution were respectively around 5.77±0.03-6.13±0.02 and 1.65±0.26-2.02±0.05%. The total bacteria has increased and dissolved protein has decreased for fermentation time, but in general it is not significant. Total bacteria and dissolved proteins respectively 4.5±0.98-5.5±2.2 Log_{10}CFU/mL and 36.98±3.37-40.25±1.54 mg/mL. The application of 24 hours (T-24) fermentation time to *L.plantarum* bacteria using collagen substrate of cattle hide skin was considered as the optimum time to be applied in the fermentation process. Bacteria *L.plantarum 1UHCC* has the ability to hydrolyze collagen protein components, especially collagen extracts from cattle hide. Bacteria *L.plantarum 1UHCC* has the potential to be developed as a bio-hydrolyzer organism. Bacteria *L.plantarum 1UHCC* plays a very important role in the development of the food industry, especially in Indonesia.

Keywords: Bacteria, Cattle hide, Collagen, Fermentation, *L.plantarum 1UHCC*

1. Introduction

At present, the need for a bio-hydrolyzer in the food processing industry is increasing. This need increases with the development of human needs for food. The use of bio-hydrolyzer of microorganisms is increasingly needed. The use of bacteria as a bio-hydrolyzer is an option. in Indonesia, the need for bio-hydrolyzer is very much needed in food processing. The activity of each bacterium as a bio-hydrolyzer is different for each type and variant. The performance of each type of bacteria in the protein decomposition process differs from one another. The use of bacteria in breaking down proteins has been widely applied in the fields of food processing such as meat, milk, fish and eggs. To produce maximum performance, the bacteria must be able to grow well in the medium. Collagen protein extract from cattle hide is one of the potential growth media for bacteria. This is because collagen protein contains a number of essential amino acids.

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acids needed for the growth process and a source of nutrition for bacterial microorganisms.

Cattle hide and bone are one of the livestock by-products that rich in protein compounds, especially collagen protein. Cattle hide is composed of several layers which are dominated by the dermis layer. This layer consists of 70-85% collagen protein (Sarkar, 1995; Said et al., 2015; Said et al, 2019). In addition to producing collagen, Bali cattle in Indonesia are the main meat-producing (Abustam et al., 2018)

Collagen is one of the dominant types of structural proteins produced from animal body tissues (Zeugolis et al., 2008). Until now, collagen has been widely used in the food industry as gelling, stabilizing, foaming and emulsifying agents (Bhuimbar et al., 2019; Sato, 2019). Utilization of collagen extract in the food industry includes food supplements to prevent osteoporosis, osteoarthritis and premature aging (Rogart et al., 1999; Tian et al., 2011). The development of collagen extract has also directed as a health food containing natural antioxidants and texturing agents that will reduce the use of chemical preservatives (Pal and Suresh, 2016).

Utilization of collagen extract as an additive in functional food has not been widely developed. One effort that can be was to apply fermentation technology in the production process of collagen extract. The application of fermentation technology can be done was to obtain benefits as functional foods that are good for health, facilitate the absorption process in the digestive tract and extend the shelf life of the product (Solomons, 2002). Collagen extract can be added into the processed meat products such as nuggets, meatballs and dairy products such as ice cream. Based on economic considerations, the fermentation process provides several advantages including: increasing production volume, reducing energy use and minimally produced waste so that is more environmentally friendly (Haq et al., 2003).

The application of fermentation technology in the food industry by involving the role of microbial lactic acid bacteria (LAB) has been developed to produce functional food (Safari et al., 2012). The use of microbes from the type of Lactobacillus plantarum (L.plantarum) bacteria has been widely applied in the food processing industry. L.plantarum bacteria has been widely applied in food processing industries made from meat, milk, eggs and fish (Ummadi and Curic-Bawden, 2010; Fioramonti et al., 2003).

The role of bacteria as decomposers of carbohydrates in the fermentation process, can also play a dual role as protein decomposers. Enzymes produced by bacteria are able to break down certain proteins that are specific in nature. Bacteria that produce enzymes to break down proteins can benefit from the proteins break down. One example is the use of L.helveticus bacteria which are used to break down meat and milk proteins to produce antihypertensive compounds (Fuglsang et al., 2003) and Bacillus subtilis FNCC 0059 for the broiler feather (Said et al., 2018).

Until now, the application of L.plantarum to break down collagen protein in cattle hide to produce a less known compound. To maximize the potential of L.plantarum 1UHCC in breaking down collagen protein, this study is very important and needs to specifically study the performance of bacteria during the fermentation process. This study was aims to evaluate the potential and performance of Lactobacillus plantarum 1 UHCC (L.plantarum 1UHCC) bacteria as bio-hydrolyzer of the food industry in Indonesia.
2. Materials and Methods

2.1 Research materials

The study was uses raw materials from fresh Balinese cattle hide, male, 3 years old. Cattle hide obtained from Tamangapa Slaughterhouse, Makassar City, South Sulawesi, Indonesia. The isolate of *L. plantarum* 1UHCC was result of isolation from milkfish extract media. *L. plantarum* 1UHCC isolate obtained from the Lab. Microbiology, Faculty of Mathematics and Natural Sciences, Hasanuddin University, Makassar. Bacterial growing media using MRS-broth (Oxoid M0359); nutrient broth (HIMEDIA Ref M002-5006); bacteriological agar (Oxoid LP0011); aquadest (One Med/Water One); alcohol 70% (One-Med). The equipment used includes: incubator (Memmert BE 400); electric oven (Memmert 100-800); laminar flow (AIRTECH) shaker (IKA KS 260 basic); autoclave (YXQ.SG41.280); hot plate (Stuart SD162); micropipette (HUAWEI 14060806); vortex (Vortex IKA 3); analytical scales (Je-B scale/KERN ALS 220-4N); pH meter (Hanna HI 8424); erlenmeyer (SCHOTT DURAN); petri dish (ANUMBRA).

2.2 Research methods

2.2.1 Preparation of bacterial culture

One ampoule of *L. plantarum* 1UHCC bacterial isolate was propagated using nutrient broth + agar bacteriological + aquadest to make a culture with a concentration of *L. plantarum* 1UHCC 5%. A total 5.2 g of MRS-broth media were dissolved in 100 mL of aquadest and homogenized. A total 50 mL of bacterial growing media were made. Based on the amount of the solution, as much as 47.5 mL was then put into the erlenmeyer tube as a growing medium. The tube was covered with aluminum foil. The solution was sterilized using an autoclave at a temperature of 120-125ºC for 45 minutes. The solution was then cooled in laminar flow. The culture of *L. plantarum* 1UHCC bacteria was then inoculated into the media.

2.2.2 Cattle hide preparation

A number of one sheet of fresh cattle hide washed with running water. Cattle hide was heated at 90ºC in a container for 15 minutes. Hair on cattle hide was removed using special equipment. The hide was cut into cubes with a size of 1x1 cm. The hide was weighed and dried in an oven at 50ºC for 24 hours. Cattle hide samples were sterilized in 70% alcohol.

2.2.3 Research design and data analysis

Data were analyzed by variance based on a Completely Randomized Design (CRD) with the SPSS statistical program (one-way ANOVA). The treatment that showed a significant effect, then performed a significant difference test with Duncan’s Multiple Range Test (DMRT) at the level of 5% (Steel & Torrie, 1991).

2.2.4 Parameter analysis

Total bacteria (Log10 CFU/mL) (Boczek *et al.*, 2014). The total plate count (TPC) method was used to calculate the total *L. plantarum* 1UHCC bacteria. A number of 1 mL of *L. plantarum* 1UHCC solution was diluted in 9 mL of sterile aquadest. The solution was homogenized with vortex. The dilution process was carried out from 10⁻¹ to
10^{12}. The dilution media was incubated at 37°C for 24 hours. The basis for calculating the colony is 25-250, which is done 3 times (triploid).

pH value (León et al., 2008); (Rahman et al., 2008). The pH meter was calibrated using pH 4 and pH 7. The solution was heated at 70°C and homogenized. The pH value of the solution was then measured at room temperature.

**Dissolved protein (mg/mL) (AOAC, 1995).** Determination of dissolved protein using the Lowry method. A total of 1.5 g of sample was inserted into a scale tube. A total of 7.5 mL of aquadest was added and then homogenized with vortex. The centrifugation process was carried out for 15 minutes. The supernatant was then boiled with a hotplate. A total of 2 mL of the supernatant was added with 1 mL of 10% TCA dilution. The mixture was centrifuged for 15 minutes. A total of 0.1 mL of TCA was added 1.9 mL of aquadest and 2.5 mL of Lowry reagent. The mixture was homogenized and stored at room temperature for 10 minutes. A total of 0.5 mL of folin reagent was added to the mixture and incubated at room temperature for 30 minutes to form a blue color. The absorbance was measured using a spectrophotometer with λ = 660 nm. The results obtained were compared with a standard bovine serum albumin (BSA) solution. Soluble protein levels were determined using the regression equation y = ax + b, dissolved protein (mg/mL) (x) = (y-b)/a, where; a = 3.520; b = 0.058; y = absorbance; R^2 = 0.992.

**Total acid (%) (AOAC, 1995).** A total of 10 mL of suspension was added with three drops of PP indicator, and then titrated with 0.1N NaOH solution. Testing was done 3 times. The number of mL titrations can be determined through discoloration to the pink color. The test results are determined by the equation, total acid (TA) (%) = (V_1)(N)(B)/(V_2)(1,000), where; V_1=volume of NaOH (mL); V_2=volume of suspension solution L.plantarum (mL); N=normality of NaOH (0.1); molecular weight of lactic acid (90).

### 3. Results and Discussions

#### 3.1 Total Bacteria

Total bacteria is one of the parameters needed to evaluate the condition of bacterial growth on a collagen extract substrate from cattle hide at different fermentation processes. Comparison of the growth of *L.plantarum 1UHCC* bacteria on the substrate of cattle hide collagen extract was presented in Figure 1. Based on Figure 1, the results show that during the 24-hour fermentation period (T-24) to 72 hours (T-72) there was a significant decrease in the total *L.plantarum 1UHCC* bacteria (P<0.05) respectively (5.5±2.29 Log_{10} CFU/mL); (4.7±0.99 Log_{10} CFU/mL) and (4.5±0.98 Log_{10} CFU/mL). Statistically, the three treatments did not show significant differences (P>0.05). Fermentation time determines the difference in the number of microbes (Sun et al., 2010).
One of the factors that cause an increase in microbial population of bacteria \(L.\text{plantarum} \ 1\text{UHCC}\) is the availability of sufficient nutrients, including protein. Cattle hide is rich in collagen compound which is one of the important nutrients for microbial growth. Availability of sufficient nutrients will increase bacterial productivity. Productivity is described as a biomass output per unit of fermentation time (Stanbury et al., 2003). Lactic acid bacteria such as \(L.\text{plantarum}\) need a source of amino acids or peptides to grow (Savijoki et al., 2006). The results showed high population and speed of growth of \(L.\text{plantarum}\) bacteria during the fermentation process. This is because the nutrients needed by bacteria are available in very large quantities on the substrate. Collagen contained in cattle hide is rich in protein compounds, especially amino acids glycine, proline and hydroxyproline (Nagai et al., 2008).

### 3.2 pH Value

pH value is a parameter that is directly related to the fermentation process, especially lactic acid bacteria. A change in pH indicates a fermentation activity. The fermentation process is a process of changing carbohydrates into acids and water and several other products. The description of the change in pH of the solution containing \(L.\text{plantarum} \ 1\text{UHCC}\) bacteria during the fermentation process was presented in Figure 2. The results of the study (Figure 2) showed that the pH of the solution significantly increased during the process of fermentation. Statistically, the increase in fermentation time had a significant effect (\(P<0.05\)) on the increase in pH of the solution. At 24 hours fermentation time (T-24), the pH of the solution showed a value of 5.87±0.08. Furthermore, at 48 hours fermentation time (T-48) slightly decreased (5.77±0.03), but increased again at 72 hours fermentation time (T-72) (6.13±0.02). Changes in pH occur...
due to fermentation activities. This process converts carbohydrates into acidic compounds. Related to this, an increase in pH up to 72 hours of fermentation time (T-72) was caused by the low carbohydrate content in cow skin substrate so that the amount of lactic acid formed was very small. The \textit{L. plantarum} 1UHCC bacteria are able to metabolize these organic acids. Organic acids can then be utilized by \textit{L. plantarum} as a carbon source (Filannino \textit{et al.}, 2014; Lerena \textit{et al.}, 2016). Research has been reported by Ge \textit{et al.}, (2019), that \textit{L.plantarum} 1UHCC bacteria can inhibit protein oxidation during the process of fermentation on processed meat (sausage), increase protein degradation and provide comparative antioxidant effects as strains for commercial purposes. Changes in pH value can be caused by the production of organic acids during the fermentation process. This can affect antioxidant activity through changes in the content and structure of phenolic compounds (Mousavi and Mousavi, 2019). The \textit{L.plantarum} bacteria can free phenolic compounds after being acidic and enzymatic from polymerized phenolic compounds during fermentation (Hur \textit{et al.}, 2014).

3.3 Dissolved Protein
Soluble protein is a component that shows the amount of oligopeptides that are easily absorbed by the digestive tract. The use of mannan-oligosaccharide (MOS) has the greatest proliferative effect on \textit{L.plantarum} ATCC14917 in vitro (Cao \textit{et al.}, 2019). Comparison of the amount of dissolved protein on the substrate of cattle hide collagen extract using \textit{L.plantarum} 1UHCC bacteria was presented in Figure 3.

![Figure 2](attachment:image.png)

\textit{Figure 2}. The pH value of \textit{L.plantarum} 1UHCC bacteria on substrate collagen extract of cattle hide on the application of different fermentation times; $a,b,c$ Different superscripts in each treatment showed significant differences ($P<0.05$); T-24=fermentation time for 24 hours; T-48=fermentation time for 48 hours; T-72=fermentation time for 72 hours
Based on the Figure 3, the results showed that the increase in fermentation time by \textit{L.\textit{plantarum} 1UHCC} bacteria on the substrate of cattle hide collagen extract reduced dissolved protein. However, statistically, the treatment was not significantly different (P>0.05). At 24 hours fermentation time (T-24), total dissolved protein was 40.25±1.54 mg/mL. Furthermore, at 48 hours and 72 hours of fermentation, both of them decreased by 37.83±0.86 mg/mL and 36.98±3.37 mg/mL respectively. The difference in the amount of dissolved protein was related to the condition of the substrate used. The substrate affects the maximum speed of the enzyme in breaking down the substrate. Protease enzymes play an important role in hydrolyzing proteins. This enzyme can break down protein bonds into peptides. Peptidase can break peptide bonds into amino acids. The amount of dissolved protein is an indication of the amount of protein undergoing the degradation process by the activity of the proteolytic enzyme \textit{L.\textit{plantarum} 1UHCC} bacteria.

Immunoreactivity of a protein was affected by changes in the primary structure. During the process, proteins can be degraded, aggregated, folded, and crossed. This will cause changes in immunoreactivity (Rahaman \textit{et al}, 2016). Some metabolites such as antimicrobial peptides can play a role in the performance of lactic acid bacteria (LAB) and its metabolism. This can affect microbial safety, total population and the ecology of fermented products (Todorov \textit{et al}., 2017)

3.4 Total Acid
The total acid content measured by the titration method was equivalent to lactic acid levels as a result of the fermentation process of \textit{L.\textit{plantarum} 1UHCC} bacteria. The
LAB were a type of bacteria that are widely distributed in Indonesia. The LAB can be produced from carbohydrate fermentation. The LAB plays an important role in maintaining normal conditions and maintaining the stability of the digestive tract from pathogen bacteria (Hooper and Gordon, 2001; Bäckhed et al., 2005). Description of changes in lactic acid levels in a solution containing \( L_{\text{plantarum}} \) 1UHCC bacteria using collagen extract of cattle hide as a substrate was shown in Figure 4.

![Figure 4. Total acid (%) of \( L_{\text{plantarum}} \) 1UHCC bacteria on substrate collagen extract of cattle hide on the application of different fermentation times; \( ^{ab} \)Different superscripts in each treatment showed significant differences (\( P<0.05 \)); T-24=fermentation time for 24 hours; T-48=fermentation time for 48 hours; T-72=fermentation time for 72 hours]

Based on Figure 4, it can be seen that the difference in fermentation time has a significant effect (\( P<0.05 \)) on the acid content of the solution containing \( L_{\text{plantarum}} \) 1UHCC bacteria using a collagen extract of cattle hide. Increased fermentation time significantly reduces acid levels. Fermentation time for 24 hour (T-24); 48 hours (T-48) and 72 hours (T-72) produce acidic levels of 2.02±0.05%; 1.82±0.08% and 1.65±0.26% respectively.

The \( L_{\text{plantarum}} \) bacteria have good probiotic properties. This bacterium can tolerate the environment in the digestive tract. These bacteria can also metabolize and synthesize bacteriocin, which has a strong inhibitory effect on the growth of gram-positive and gram-negative bacteria. The \( L_{\text{plantarum}} \) 1UHCC bacteria are initially used to ferment milk and other dairy products (Spano and Massa, 2006). These bacteria are relatively resistant to acids and high fermentation temperatures because of their ability to produce bacteriocins (Gong et al., 2010).
Conclusion

Application of L. plantarum 1UHCC as a hydrolyzing agent significantly decreases total bacteria, dissolve protein and total acid, but does not affect the pH value at different fermentation times. The 24 hour (T-24) fermentation time showed the most optimum fermentation time of L. plantarum 1UHCC to be applied to the collagen extract of cattle hide. The 24 hours (T-24) fermentation time process provides the best characteristics compared to other fermentation, especially in collagen extracts. Bacteria L. plantarum 1UHCC has the potential to be developed as a bio-hydrolyzer agent for the development of the food industry, especially those containing collagen extracts.

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References

Abustam, E., Said, M.I., and Yusuf, M. (2018). The effect of antioxidant activity of liquid smoke in feed supplement block on meat functional of muscle longissimus dorsi. Proceeding. TOP Conf. Ser. Earth Environ Sci, 119 012 046.

AOAC. (1995). Official Methods of analysis of the association of official agricultural chemist. Washington: AOAC Int.

Bäckhed, F., Ley, R.E., Sonnenburg, J.L., Peterson, D.A., & Gordon, J.I. (2005). Host-bacterial mutualism in the human intestine. Science, 307, 1915-1920.

Bocek, L.A., Rice, E.W., & Johnson, C.H. (2014). TOTAL VIABLE COUNTS | Pour Plate Technique, Editor(s): Carl A. Batt, Mary Lou Tortorello, Encyclopedia of Food Microbiology (Second Edition), Academic Press, 625-629.

Bhuimbar, M.V., Bhagwat, P.K., & Dandge P.B. (2019). Extraction and characterization of acid soluble collagen from fish waste: Development of collagen-chitosan blend as food packaging film. Journal of Environmental Chemical Engineering, 7(2), doi.org/10.1016/j.jece.2019.102983.

Cao, P., Wu, L., Wu, Z., Pan, D., Zeng, X., Guo, Y., & Lian L. (2019). Effects of oligosaccharides on the fermentation properties of Lactobacillus plantarum. Journal of Dairy Science, 102(4), 2863-2872.

Filannino, P., Cardinali, G., Rizzello, C., Buchin, S., De-Angelis, M., Gobbetti, M., & Di-Cagno R. (2014). Metabolic responses of Lactobacillus plantarum strains during fermentation and storage of vegetable and fruit juices. Applied and environmental microbiology, 80(7), 2206-2215.

Fioramonti, J., Theodorou, V., & Bueno, L. (2003). Probiotics: what are they? What are their effects on gut physiology? Best Practice & Research Clinical Gastroenterology, 17(5), 711-724.

Fuglsang, A., Rattray, F.P., Nilsson, D., and Nyborg, N.C.B. (2003). Lactic acid bacteria: inhibition of angiotensin converting enzyme in vitro and in vivo. Antonie van leeuwenhoek, 83, 27-34.

Ge, Q., Chen, S., Liu, R., Chen, L., Yang, B., Yu, H., Wu, M., Zhang, W., & Zhou G. (2019). Effects of Lactobacillus plantarum NJAU-01 on the protein oxidation of fermented sausage. Food Chemistry, 295, 361-367.

Gong, H.S., Meng, X.C., & Wang, H. (2010). Plantaricin MG active against Gram-negative bacteria produced by Lactobacillus plantarum KLDS1.0391 isolated from “Jiaoke”, a traditional fermented cream from China. Food Control, 21, 89–96.
Haq, K.H., Mukhtar, H., Daudi, S., Ali, S., & Qadeer, M.A. (2003). Production of protease by a locally isolated molds culture under lab condition. *Biotechnology* 2(1), 30-36.

Hooper, L.V., & Gordon, J.I. (2001). Commensal host-bacterial relationship. *Science*, 292, 1115–1118.

Hur, S.J., Lee, S.Y., Kim, Y.C., Choi, I., & Kim, G.B. (2014). Effect of fermentation on the 363 antioxidant activity in plant-based foods. *Food chemistry*, 160, 346-356.

León, P.G., Lamanna, M.E., Gerschenson, L.N., & Rojas, A.M. (2008). Influence of composition of edible films based on gellan polymers on l-(+)-ascorbic acid stability. *Food Research International*, 41(6), 667-675.

Lerena, M., Rojo, M., Sari, S., Mercado, L., Krieger-Weber, S., & Combina, M. (2016). Malolactic fermentation induced by Lactobacillus plantarum in Malbec wines from Argentina. *South African Journal of Enology and Viticulture*, 37(2), 115-123.

Pal, G.K., & Suresh, P.V. (2016). Sustainable valorisation of seafood by-products: Recovery of collagen and development of collagen-based novel functional food ingredients. *Innovative Food Science & Emerging Technologies*, 137, Part B, 201-215.

Mousavi, Z.E., & Mousavi, M. (2019). The effect of fermentation by Lactobacillus plantarum on the physicochemical and functional properties of liquorice root extract. *LWT-Food Science and Technology*, 105, 165–168.

Nagai, T., Suzuki, N., & Nagashima, T. (2008). Collagen from common minke whale (*Balaenoptera acutorostrata*) unresa. *Food Chem*, 111(2), 296-301.

Rahaman, T., Vasiljevic, T., & Ramchandran, L. (2016). Effect of processing on conformational changes of food proteins related to allergenicity. *Trends in Food Science & Technology*, 49, 24-34.

Said, M.I., Abustam, E., Wahab, A.W., Taba, P., Gani, A., & Wahid, A.M. (2019). Effect of ethanol used in a degrading process on Bali cattle bones on the physicochemical properties of extracted collagen. *Bulg. J Agric. Sci*, 25(2), 418-423.

Said, M.I., Abustam, E., Yuliati, F.N., & Mide, M.Z. (2018). Characteristics of feather protein concentrates hydrolyzed using Bacillus subtilis FNCC 0059. *OnLine J on Biol. Sci.*, 18(2), 138-146.

Saidi, G.S., & Guizani, N. (2008). Interactions and properties of gellan polymers on (+)-ascorbic acid stability. *Food Research International*, 41, 555.

Saharan, V.K., Bhargava, A.K., & Koul, R.K. (1995). Extraction and purification of Collagen from scapula of Bali cattle (*Bos taurus indicus*). *Folia Microbiol*, 40(6), 555.

Safari, R., Motamedzadegan, A., Ovissipour, M., Regenstein, J.M., Gildberg, A., & Rasco, B. (2012). Use of Hydrolysates from Yellowfin Tuna (*Thunnus albacares*) Heads as a Complex Nitrogen Source for Lactic Acid Bacteria. *Food and Bioprocess Technology*, 5(1), 73-79.

Said, M.I., Abustam, E., Wahab, A.W., Taba, P., Gani, A., & Wahid, A.M. (2019). Effect of ethanol used in a degreasing process on Bali cattle bones on the physicochemical properties of extracted collagen. *Bulg. J Agric. Sci.*, 25(2), 418-423.

Saidi, G.S., & Guizani, N. (2008). Interactions and properties of gellan polymers on (+)-ascorbic acid stability. *Food Research International*, 41, 555.
Tian, Y., Peng, Z., Gorton, D., Xiao, Y., & Ketheesan, N. (2011). Immunohistochemical analysis of structural changes in collagen for the assessment of osteoarthritis. *Proc. Inst. Mech. Eng H*, 225(7), 680-687.

Todorov, S.D., Stojanovski, S., Iliev, I., Moncheva, P., Nero, I.A., & Ivanova, I.V. (2017). Technology and safety assessment for lactic acid bacteria isolated from traditional Bulgarian fermented meat product “lukanka”. *Brazilian Journal of Microbiology*, 48(3), 576-586.

Ummadi, M., and Curic-Bawden, M. (2010). Use of Protein Hydrolysates in Industrial Starter Culture Fermentations. In Pasupuleti V. K. and Demain A.L. (Eds.). *Protein Hydrolysates in Biotechnology*, 91-114. Dordrecht: Springer Netherlands.

Zeugolis, D.I., Khew, S.T., Yew, E.S.Y., Ekaputra, A.K., Tong, Y.W., Yung, L.Y., Hutmacher, D.W., Sheppard C., & Raghunath, M. (2008). Electro-spinning of pure collagen nano-fibres–Just an expensive way to make gelatin? *Biomaterials*, 15, 2293-2305.