

Gelatin: advantages and disadvantages of gelatin from plant and animal sources

Hossein Elyasi¹, Hadis Rahimi¹, Asghar Sepahvend²

¹ Student Research Committee, Faculty of Medicine, Lorestan University of Medical Sciences, Khorramabad, Iran ² Razi Herbal Medicines Research Center, Lorestan University of Medical Sciences, Khorramabad, Iran Corresponding Author, Razi Herbal Medicines Research Center, Lorestan University of Medical Sciences, Khorramabad, Iran. E-mail:

fungimed44@yahoo.com

Article Info	Abstract
Article type: Review Article	Gelatin is a solid and transparent material that has wide application in various industries,
	especially for the production of food and pharmaceutical. This material is mainly made from
	meat, skin and bones of pigs and cows around the world. The industrial process of gelatin
Article History:	production is a long and costly process. It seems; these sources of gelatin production may be
Received: 28 September 2019 Received in revised form: 18 April 2020 Accepted: 16 June 2020 Published online: 16 June 2020	harmful to health. Therefore, this study was aimed at reviewing the alternative sources of gelatin
	production and the disadvantages and benefits of each of them. Relevant articles were searched
	from Google Scholar, Pub Med, Scopus, Science direct, and Cochrane library. According to the
	results of this article, gelatin with a source of animal can have many harmful effects on human
	health. While it is possible to produce good and useful gelatin using plant sources. Nowadays,
Keywords: Gelatin, Medicine, Medicinal herbs, Traditional medicine	from materials such as agar, pectin, carrageenan and konjac that are mentioned above, and as
	well as other materials, very good gelatins are prepared. And further researches are needed to
	find the rich sources of good gelatins or to find plants that have appropriate gelatin. In total, in
	gelatin, there are 18 types of amino acids, and of 10 amino acids needed for the body, 9 are in
	gelatin. In total, gelatin is introduced safe by the FDA.
	Note: This article has been revised and rewritten due to the request of the corresponding author

from the journal "Plant Biotechnology Persa" due to the use of unreferenced contents. In October 2023, the journal "Plant Biotechnology Persa " accepted the revised version of article following the COPE rules. Formerly title of paper: Gelatin, halal or haram?.

Introduction

Gelatin is a solid, transparent or semi-transparent substance, colorless, in (when it is dry) and more or less tasteless that comes mainly from collagen in the skin, flesh and bones of animals [1]. It is commonly used as a jelly agent in the food, pharmaceutical, photographic and cosmetic industries. Gelatin is mainly an unmodified hydrolyzed form of collagen in which the collagen protein is converted to smaller peptides and has a wide molecular weight range in relation to physical and chemical methods of denaturation based on what kind of hydrolysis process is used in gelatin production [2, 3]. Gelatin is used as a clearing agent in many beverages, volatile plasma, and stabilizer in many vaccines and in many other products. Gelatin is available in forms of

Plant Biotechnology	Persa 202	20; 2(1): 35-4	1.
---------------------	-----------	---------	---------	----

DOI: 10.29252/pbp.2.1.35



NG \bigcirc The Author(s).

Publisher: Ilam University of Medical Sciences

How to cite: Elyasi H, Rahimi H, Sepahvand A. Gelatin: advantages and disadvantages of gelatin from plant and animal sources. Plant Biotechnology Persa. 2020; 2(1): 35-41.

sheet, granule or mainly powder [4-7]. Gelatin is a mixture of peptides and proteins that are made of collagen hydrolysis made from bone, skin, and connective tissue of animals such as pigs, cows, fishes, and chickens [8].

In 2016, worldwide gelatin production is reported to be around 400,000 tons per year [9]. Gelatin is a byproduct of the meat and leather industry and fish have recently been considered as one of its sources of production. Generally, the process of preparing gelatin from animal sources, that most important of which is the skin, flesh and bone of pig, lasts for several weeks [10-12]. In the pharmaceutical industry, gelatin is mainly used to make hard and soft capsules and also as a very useful material for the production of pills, emulsions, suppositories and syrups [13]. In total, gelatin is introduced safe by the FDA. Most of the amino acids needed in the body are present in gelatin and there are not just sulfur containing amino acids [14, 15]. Gelatin is also used in industries such as adhesives, military industries, banknote paper making, moisture absorption, and so on. Gelatin-based adhesives are used to attach two organic pieces, such as fruits and vegetables. Also in the textile industry, gelatin is used as a material for shining, coating, cotton, leather, silk and wool fulfillment [16-19].

The people of Rome have a lot of caution in taking gelatin because eating gelatin with a horse source is forbidden. In addition, many people around the world are vegetarians (Vegans) like many Hindus that do not use gelatin with an animal source, even non-vegetarian Hindus do not use cow gelatin [20-22]. So far, alternatives to animal gelatin such as agar, carrageenan, pectin, Konjac, etc. have been identified. The biggest problem with these gelatins that has not been able to replace them with animal gelatin has been the lack of cost-effective and unavailable sources of them [23].

It is also understood from this content that in the event of a state of emergency these prohibitions can also be permitted if the person is really in an emergency and does not exceed his limits and only consumes as much as it needs. So far, there have been many harms in the use of pork Including dysentery, infectious jaundice, a red wind like disease that appears in humans in the form of red and painful spots with intense burning on the hands, atherosclerosis, joint pain and poisoning that is due to the high amount of fat and uric acid found in pork and the occurrence of a variety of parasitic agents, including Entamoeba histolithic [24-31].

This research is a review and library study with focusing on interpretative texts and internet searches were performed by entering the keywords in the google scholar, PubMed, Magiran and science direct databases. The purpose of this study is to provide a variety of sources of gelatin production and examine them. We want to introduce vegetable and safe gelatin as a substitute for animal gelatin.

Background research

In 2013, Mariod et al. conducted a review of various types of gelatin and their sources for the presentation of various gelatins it was stated in this study that gelatins can be prepared from alternative sources such as fish except for animal [32]. Petrov et al., In a survey in 2015 to find out the properties of several types of gelatin for the manufacture of pharmaceutical capsules, concluded that the capsules prepared with collagen-derived gelatin had the highest concentrations (and only glycerol with water was added) while the lowest concentration was related to gelatin prepared from carrageenan [33]. In the 2013 Elzoghby review of the properties of gelatin as a carrier, especially for the production of carrier nanoparticles, gelatin was introduced as an important carrier of the drug as well as a substance used in gene therapy [34]. Bonilla et al. in 2016 examined a combination of gelatin and polysaccharide chitosan with several herbal extracts for their properties as food preservatives and showed that these compounds have antioxidant, antimicrobial and good preservative properties for all kinds of food [35]. In 2016, Al-Hassan determined the best properties of gelatin prepared from Greasy grouper fish in a study of gelatins derived from several types of fish as replacements for prohibited gelatins and even replacing animal gelatin. Also, all gelatins of fish origin, prepared in this study showed better properties than bovine gelatin [36].

Methodology

Relevant articles were searched from Google Scholar, Pub Med, Scopus, Science direct, and Cochrane library. In the first search we obtain 406 articles, 183 articles were excluded in first screening for duplication and inappropriation of their content (this step was done by study on abstracts). Finally, 55 articles were included that matched with our subject.

Animal gelatins

Animal gelatins are derived from animal sources, especially pigs, cattle, and animals such as fish and poultry but due to more economic efficiency, they are mainly made from pigs or cows. However, the process of preparing gelatin from animal sources is a long and costly process because the meat, skin, and bone of the animal must first be prepared, and then crushes into small pieces and subsequently extracted for several weeks by different processes with a large amount of different chemicals [37-39]. The mentioned operations are considered to be major disadvantages of animal gelatin in terms of industry because it takes a lot of time and money to prepare animal gelatin. Other great disadvantage of animal gelatin that, despite the vast efforts of companies and factories to keep it secret is the entrance of pathogenic and harmful agents from animal meat and body to gelatin and the harmful effects of these gelatins with unsafe sources on the human body, that in recent years it is becoming clear [40,41].

Swine gelatin

Swine gelatin is extracted from the skin, flesh, bone and connective tissues of the pig's body. The advantage of pig's gelatin is cost-effectiveness and the availability of its source and very high breeding [42].

Because of the pig's lifestyle, feeding and its biological structure, the amount of antibodies produced by the body of this animal is greater than the rest also; the amount of growth hormones produced in the body is greater than the body of other animals and humans. This high level of antibody and growth hormone naturally enters the muscle tissue of the pig; in addition, pork has a very high level of cholesterol, other lipids, and uric acid which can unsafe to humans [48-51].

Several allergic reactions including anaphylaxis due to the administration of intravenous injection of swine gelatin based plasma substitutes has been reported so far [52-61]. Allergic reactions have been identified after using varicella and MMR vaccines actually is due to the excipient that made of swine gelatin [62-64].

Bovine gelatin

Cow gelatin is also prepared just like swine gelatin, which has many of its properties and disadvantages. Bovine gelatin like swine gelatin has been used extensively and its source (meat and animal body) is why it still has a lot of mentioned risks especially. Several researches suggest allergic reactions to bovine gelatin due to the presence of bovine gelatin specific IgE and α -Gal [66]. Another very important problem is that Bovine Madness Agent (BSE) is easily transmitted from the cow body into its gelatin because this is a very persistent prion and in the case of gelatin made from meat and even more difficult conditions it can still be transmitted to gelatin [67].

Fish gelatin

Fish gelatin is made from fish skin and bone [68]. This type of gelatin also has its own limitations and complications including the fact that the source of it, that is, fish has not always been available everywhere, fish is also a valuable and expensive food, and it is not very economical to turn into gelatin [69]. Fish gelatin can also contain gelatin specific IgE and cause various allergies but it is much less than swine and bovine gelatin [70].

Vegetable and Seaweed Source Gelatins

Although in general, the word gelatin is referred to as a collagen-based jelly preparation made from animal tissues, but today, gelatin-like materials are prepared from vegetable sources with different formulations. They have very good properties; they are often very useful and not allergenic because almost all of them are made of safe and non-allergenic polysaccharides. If a suitable herbal source for the production of gelatin be discovered, herbal gelatinous products can be substituted for animal gelatins. Various researches on plant gelatins have proven their proper properties for the production of drugs [71-74]. Along searching for valuable plants such as figs, grapes, olives, cedrus and ocimum basilicum, there were not found any articles or studies on the extraction or preparation of gelatin in various Internet sources, while for example; ocimum basilicum has a high jelly agent which, if wet, secretes it out. During searches about pomegranate it was found that its skin is a good source for extracting pectin [74,57].

Agar

Agar is a jelly material like herbal gelatins. The agar is made mostly of polysaccharide agarose, which is a supportive material in the cell wall of some seaweed and released by boiling [75]. These algae are known as agarophyte and they belong to the red algae race. The gelatin agar in fact is made up of two materials: the first linear polysaccharide agarose and the second heterogeneous mixture of smaller molecules called agaropectin [76]. Agar has been used extensively for microbiological testing and culture media preparation it can be used as a laxative and also as an appetite suppressant. Most importantly, it has all the applications of animal gelatins [77]. Agar is a substance that is indigestible by most organisms so can make a good culture medium that will not be destroyed by the growth of microbes. Agar contains some minerals and vitamins, including calcium, iron, zinc, potassium, magnesium, folate and high levels of fiber. It can also be useful for weight loss in obese people [78]. In general, agar is considered as a healthy and beneficial gelatin that so far, no allergic reactions or adverse effects have been reported, but because of its laxative property is not suitable for people with diarrhea. Despite its high benefits, due to the lack of resources, it is less economically efficient.

Pectin

Pectin is a structural heteropolysaccharide found in the primary cell wall of terrestrial plants. Pectin is commercially available in the form of a white to brown powder and mainly extracted from citrus [79]. Pectin has all the applications of animal gelatin in addition, it is considered as a fiber source. Chemically, pectin is rich in galacturonic acid and its maximum amount is in premature fruit [80]. Pectin is in fruits such as pears, apples, peaches, plums, oranges and other citrus fruits, while there are a small amount of pectin in soft fruits like cherries, grapes and strawberries. About 30% of orange peel is composed of pectin, while the edible portion of the orange has a range of 0.5 to 3.5% pectin. And a soft fruit like cherry have about 0.4% pectin [81]. Most of the production of pectin is from orange peel and apple scum that both of which are side products in the production of juice. The pectin production process is much faster and easier than animal gelatin [82]. Pectin has a high positive effect on the intestines and excretion in human, it also has the ability to dispose of heavy metals from body. Pectin has good properties for drug production and now it is used to produce some medications such as pastille pills. The use of pectin by the World Health Organization and the American Food and Drug Administration is known safe [83].

Konjac

It is a plant from family Araceae and in Japan, China, Korea and Myanmar is cultivated a comestible plant. This plant also has a jelly agent called konjac gelatin and used as an alternative gelatin for vegetarians. About 40% of konjac gelatin is made from glucomannan [84]. This gelatin alone has many healing properties, including detoxification, tumor suppression, blood stasis alleviation, and smooth the phlegm [85]. The gelatin made from the konjac is free from calories and has high fiber content instead and that's why it's suitable for people with diabetes, obese people, diabetics and many other people. Nourishing konjac gelatin increases the production of butyric acid from normal intestinal flora and improves gut movements [86]. One of the problems

with this gelatin is its edible size because the jelly is not digested in the human body and if children eat a large piece of it, there is a risk of choking. Konjac gelatin oral intake results in less IgE production and reduces the risk of dermatitis [87].

Carrageenan

Carrageenan is a family of linear sulfate polysaccharides made from edible red algae. Carrageenan is a very suitable gelatinizing agent in the food industry and due to the high binding power it has with proteins, it is used in dairy and meat products. It is not used due to health hazards and concerns in pediatric products and pharmaceuticals [88].

Conclusion

Our aim in this study was a comprehensive review of various types of sources, products and characteristics of different gelatins that in the near future, it will result in the production of gelatins with industrial and production advantages. Nowadays, from materials such as agar, pectin, carrageenan and konjac that are mentioned above, and as well as other materials, very good gelatins are prepared. And further researches are needed to find the rich sources of good gelatins or to find plants that have appropriate gelatin.In total, gelatin is introduced safe by the FDA. It is concluded that vegetable gelatin is safe and not allergenic and vegetable gelatin can replace animal gelatin.

Authors' contribution

All authors contributed equally to the manuscript.

Conflicts of interest

The authors declared no competing interests.

References

- Shaw G, Lee-Barthel A, Ross ML, et al. Vitamin C-enriched gelatin supplementation before intermittent activity augments collagen synthesis. Am J Clin Nutr. 2017 Jan 1; 105(1):136-43.
- 2. Mariod AA, Fadul H. gelatin, source, extraction and industrial applications. Acta Sci Pol Technol Aliment. 2013 Jun 30; 12(2):135-47.
- 3. Schortgen F, Lacherade JC, Bruneel F, et al. Effects of hydroxyethylstarch and gelatin on renal function in severe sepsis: a multicentre

randomised study. The Lancet. 2001 Mar 24; 357(9260):911-6.

- 4. Hoque ME, Nuge T, Yeow TK, et al. Gelatin Based Scaffolds for Tissue Engineering-A Review. Polym Res J. 2015 Jan 1; 9(1):15.
- 5. Ishida K, Kuroda R, Miwa M, et al. The regenerative effects of platelet-rich plasma on meniscal cells in vitro and its in vivo application with biodegradable gelatin hydrogel. Tissue engin. 2007 May 1;13(5):1103-12.
- Yang D, Li Y, Nie J. Preparation of gelatin/PVA nanofibers and their potential application in controlled release of drugs. Carbohydr Polym. 2007 Jun 25; 69(3):538-43.
- Kantaria S, Rees GD, Lawrence MJ. Gelatinstabilised microemulsion-based organogels: rheology and application in iontophoretic transdermal drug delivery. J Control Release. 1999 Aug 5; 60(2):355-65.
- 8. Ahmad T, Ismail A, Ahmad SA, et al. Recent advances on the role of process variables affecting gelatin yield and characteristics with special reference to enzymatic extraction: A review. Food Hydrocoll. 2017 Feb 28; 63:85-96.
- Lee JH, Kim MR, Jo CH, et al. Specific PCR assays to determine bovine, porcine, fish and plant origin of gelatin capsules of dietary supplements. Food chem. 2016 Nov 15;211:253-9.
- 10. Serra IR, Fradique R, Vallejo MC, et al. Production and characterization of chitosan/gelatin/ β -TCP scaffolds for improved bone tissue regeneration. Materials Sci Engineering: C. 2015 Oct 1; 55: 592-604.
- Sun J, Huang Y, Wang W, et al. Application of gelatin as a binder for the sulfur cathode in lithium-sulfur batteries. Electrochim Acta. 2008 Oct 15; 53(24):7084-8.
- 12. Lin H, Cheng AW, Alexander PG, et al. Cartilage tissue engineering application of injectable gelatin hydrogel with in situ visible-lightactivated gelation capability in both air and aqueous solution. Tissue Engineering Part A. 2014 Apr 7; 20(17-18):2402-11.
- Prosekov A, Petrov A, Ulrich E, et al. Physical and Chemical Properties of Capsule Shell Based on Plant Analogues of Pharmaceutical Gelatin. Biol Med. 2015; 7(2): 2.
- 14. Hayakawt T, Mochizuki C, Amemiya T, et al. Bone response of gelatin composite including the apatite prepared from an amino acid

calcium complex. J Oral Tissue Engin. 2015; 12(3):115-20.

- 15. Nakano Y, Tobe T, Choi-Miura NH, et al. Isolation and characterization of GBP28, a novel gelatin-binding protein purified from human plasma. The J Biochem. 1996 Oct 1; 120(4):803-12.
- 16. Hanani ZN, Roos YH, Kerry JP. Use and application of gelatin as potential biodegradable packaging materials for food products. Int J Biol Macromol. 2014 Nov 30; 71: 94-102.
- Licodiedoff S, Koslowski LA, Scartazzini L, et al. Conservation of physalis by edible coating of gelatin and calcium chloride. Intern Food Res J. 2016 Dec; 1: 23(4).
- 18. Kevadiya BD, Rajkumar S, Bajaj HC, et al. Biodegradable gelatin-ciprofloxacinmontmorillonite composite hydrogels for controlled drug release and wound dressing application. Colloids Surf B Biointerfaces. 2014 Oct 1; 122:175-83.
- Cui Q, Yashchenok A, Zhang L, et al. Fabrication of bifunctional gold/gelatin hybrid nanocomposites and their application. ACS Appl Mater Interfaces. 2014 Jan 16; 6(3):1999-2002.
- 20. Håkonsen H, Lees K, Toverud EL. Cultural barriers encountered by Norwegian community pharmacists in providing service to non-Western immigrant patients. Int J Clin Pharm. 2014 Dec 1; 36(6):1144-51.
- Brown R. How Gelatin Becomes an Essential Symbol of Muslim Identity: Food Practice as a Lens into the Study of Religion and Migration. Religious Studies Theol. 2016; 1;35(2):185.
- 22. Robinson K, Hoey M. Religion and drugs. Student BMJ. 2009; 1; 17.
- Domínguez-Courtney MF, López-Malo A, Palou E, et al. Optimization of mechanical properties of carboxymethyl cellulose, carrageenan and/or xanthan gum gels as alternatives of gelatin softgels capsules. Optimization. 2015; 2(11): 2.
- Nanji A, French S. Relationship between pork consumption and cirrhosis. The Lancet. 1985 Mar 23; 325(8430):681-3.
- 25. Murphy KJ, Parker B, Dyer KA, et al. A comparison of regular consumption of fresh lean pork, beef and chicken on body composition: a randomized cross-over trial. Nutrients. 2014 Feb 14; 6(2):682-96.

- 26. Wang XQ, Terry PD, Cheng L, et al. Interactions between pork consumption, CagA status and IL-1B-31 genotypes in gastric cancer. World J Gastroenterol: WJG. 2014; 7; 20(25): 8151.
- 27. Gonwong S, Chuenchitra T, Khantapura P, et al. Pork consumption and seroprevalence of hepatitis E virus, Thailand, 2007–2008. Emerging Infec Dis. 2014; 20(9):1531.
- 28. Bouvard V, Loomis D, Guyton KZ, et al. Carcinogenicity of consumption of red and processed meat. Lancet Oncol. 2015; 1; 16(16): 1599.
- Song P, Lu M, Yin Q, et al. Red meat consumption and stomach cancer risk: a meta-analysis. Journal of cancer research and clinical oncology. J Cancer Res Clin Oncol. 201; 140(6):979-92.
- 30. Tuyet-Hanh TT, Sinh DX, Phuc PD, et al. Exposure assessment of chemical hazards in pork meat, liver, and kidney, and health impact implication in Hung Yen and Nghe An provinces, Vietnam. Int J Public Health. 2017; 1; 62(1):75-82.
- 31. Sudjadi, Wardani HS, Sepminarti T, et al. Analysis of porcine Gelatin DNA in a commercial capsule shell using real-time polymerase chain reaction for halal authentication. Intern J Food Properties. 2016; 1; 19(9):2127-34.
- 32. Mariod AA, Fadul H. gelatin, source, extraction and industrial applications. Acta Sci Pol Technol Aliment. 2013; 30; 12(2):135-47.
- 33. Petrov A, Dyshlyuk L, Koroleva O, et al. Light Transmission Coefficient and the Thickness of Soft Capsule Shells Derived from Plant Analogs of Pharmaceutical Gelatin. Biol Med. 2015; 7(2): 2.
- 34. Elzoghby AO. Gelatin-based nanoparticles as drug and gene delivery systems: reviewing three decades of research. J Control Release. 2013; 28; 172(3): 1075-91.
- 35. Bonilla J, Sobral PJ. Investigation of the physicochemical, antimicrobial and antioxidant properties of gelatin-chitosan edible film mixed with plant ethanolic extracts. Food Biosci. 2016; 1; 16:17-25.
- 36. Al-Hassan AA. Extraction and Characterization of Halal Gelatin from Fish Skin. J Agricultural Vet Sci. 2016; 21; 9(1).
- 37. Mironova MM, Kovaleva EL. Comparative Analysis of Quality Assessment Requirements

for Gelatin Used in Drug Production. Pharmaceutical Chem J. 2017; 1; 50(12):820-5.

- Hoogenboom LA, Van Eijkeren JC, Zeilmaker MJ, et al. A novel source for dioxins present in recycled fat from gelatin production. Chemosphere. 2007; 30; 68(5):814-23.
- 39. Nicolas-Simonnot MO, Tréguer V, Leclerc JP, et al. Experimental study and modelling of gelatin production from bone powder: elaboration of an overall kinetic scheme for the acid process. Chem Engin J. 1997; 1; 67(1):55-64.
- 40. Asyakina LK, Belousova OS, Avstrievskih AN, et al. Study of organoleptic, physical-chemical and technological properties of the plant analogues of pharmaceutical gelatin production for soft capsules. Foods Raw Materials. 2015; 3(1): 6.
- 41. Jamaludin MA, Zaki NN, Ramli MA, et al. Istihalah: analysis on the utilization of Gelatin in food products. In2nd International Conference on Humanities, Historical and Social Sciences, IPEDR 2011 (17): 8.
- 42. Hafidz RM, Yaakob CM, Amin I, et al. Chemical and functional properties of bovine and porcine skin gelatin. Intern Food Res J. 2011; 18(2011):813-7.
- Hess AS, Islam Z, Hess MK, et al. Comparison of host genetic factors influencing pig response to infection with two North American isolates of porcine reproductive and respiratory syndrome virus. Genetics Selection Evolution. 2016; 20; 48(1):43.
- 44. Niederwerder MC, Rowland RR. Is There a Risk for Introducing Porcine Reproductive and Respiratory Syndrome Virus (PRRSV) Through the Legal Importation of Pork?. Food Environ Virol. 2017; 1; 9(1):1-3.
- Jaques T. Cadbury and pig DNA: when issue management intersects with religion. Corporate Communications: An International Journal. 2015; 5; 20(4): 468-82.
- 46. Islam MT. Awareness, Emphasized on Swine Meat Consumption. Asian Journal of Ethnopharmacol Med Foods. 2016:11.
- 47. Curtis EE. Science and Technology in Elijah Muhammad's Nation of Islam. Nova Religio: The Journal of Alternative and Emergent Religions. 2016; 1; 20(1):5-31.
- 48. Barbin DF, ElMasry G, Sun DW, et al. Nondestructive assessment of microbial contamination in porcine meat using NIR

hyperspectral imaging. Innovative Food Sci Emerging Technologies. 2013; 31; 17:180-91.

- 49. Mozzicato SM, Tripathi A, Posthumus JB, et al. Porcine or Bovine Valve Replacement in Three Patients with IgE Antibodies to the Mammalian Oligosaccharide Galactose-alpha-1, 3-Galactose. J Allergy Clin Immunol Pract. 2014; 2(5):637.
- 50. Abente EJ, Santos J, Lewis NS, et al. The molecular determinants of antibody recognition and antigenic drift in the H3 hemagglutinin of swine influenza A virus. J Virol. 2016; 15; 90(18): 8266-80.
- 51. Vegosen L, Breysse PN, Agnew J,et al. Occupational Exposure to Swine, Poultry, and Cattle and Antibody Biomarkers of Campylobacter jejuni Exposure and Autoimmune Peripheral Neuropathy. PloS One. 2015; 4;10(12): 0143587.
- 52. Jones TH, Muehlhauser V. F-coliphages, porcine adenovirus and porcine teschovirus as potential indicator viruses of fecal contamination for pork carcass processing. Int J Food Microbiol. 2017; 16; 241: 237-43.
- 53. Pensaert MB, Sanchez RE, Ladekjær-Mikkelsen AS, et al. Viremia and effect of fetal infection with porcine viruses with special reference to porcine circovirus 2 infection. Vet Microbiol. 2004; 4; 98(2): 175-83.
- 54. Milios KT, Drosinos EH, Zoiopoulos PE. Food Safety Management System validation and verification in meat industry: Carcass sampling methods for microbiological hygiene criteria–A review. Food Contr. 2014; 30; 43:74-81.
- 55. Goyette-Desjardins G, Auger JP, Xu J, et al. Streptococcus suis, an important pig pathogen and emerging zoonotic agent—an update on the worldwide distribution based on serotyping and sequence typing. Emerg Microbes Infect. 2014; 3(6): 45.
- 56. Okello AL, Burniston S, Conlan JV, et al. Prevalence of endemic pig-associated zoonoses in southeast Asia: a review of findings from the Lao People's Democratic Republic. Am J Trop Med Hyg. 2015; 6; 92(5): 1059-66.
- 57. Gabriël S, Johansen MV, Pozio E, et al. Human migration and pig/pork import in the European Union: What are the implications for Taenia solium infections?. Vet Parasitol. 2015; 30; 213(1):38-45.
- 58. Papuc C, Goran GV, Predescu CN, et al. Mechanisms of oxidative processes in meat and

toxicity induced by postprandial degradation products: A Review. Compr Rev Food Sci Food Saf. 2017; 1; 16(1): 96-123.

- 59. Schook LB, Collares TV, Darfour-Oduro KA, et al. Unraveling the swine genome: implications for human health. Annu Rev Anim Biosci. 2015; 3: 219-44.
- 60. McKenney ML, Schultz KA, Boyd JH, et al. Epicardial adipose excision slows the progression of porcine coronary atherosclerosis. J Cardiothorac Surg. 2014; 3; 9(1): 2.
- 61. Bogdanovic J, Halsey NA, Wood RA, et al. Bovine and porcine gelatin sensitivity in milk and meat-sensitized children. J Allergy Clin Immunol. 2009; 124(5):1108.
- 62. Martelli P, Ferrari L, Morganti M, et al. One dose of a porcine circovirus 2 subunit vaccine induces humoral and cell-mediated immunity and protects against porcine circovirusassociated disease under field conditions. Vet Microbiol. 2011; 5; 149(3): 339-51.
- 63. Pool V, Braun MM, Kelso JM, et al. Prevalence of anti-gelatin IgE antibodies in people with anaphylaxis after measles-mumps-rubella vaccine in the United States. Pediatrics. 2002 Dec 1; 110(6): 71-.
- 64. Sakaguchi M, Nakayama T, Inouye S. Food allergy to gelatin in children with systemic immediate-type reactions, including anaphylaxis, to vaccines. J Allergy Clin Immunol. 1996; 31; 98(6):1058-61.
- 65. Uyttebroek A, Sabato V, Bridts CH, et al. Anaphylaxis to succinylated gelatin in a patient with a meat allergy: galactose- α (1, 3)-galactose (α -gal) as antigenic determinant. J Clin Anesth. 2014; 30; 26(7): 574-6.
- 66. Pinson ML, Waibel KH. Safe administration of a gelatin-containing vaccine in an adult with galactose-α-1, 3-galactose allergy. Vaccine. 2015; 3; 33(10): 1231-2.
- 67. Brown P, Will RG, Bradley R, et al. Bovine spongiform encephalopathy and variant Creutzfeldt-Jakob disease: background, evolution, and current concerns. Emerging infect Dis. 2001; 7(1): 6.
- Karim AA, Bhat R. Fish gelatin: properties, challenges, and prospects as an alternative to mammalian gelatins. Food Hydrocoll. 2009; 31; 23(3):563-76.

DOI: 10.29252/pbp.2.1.35

- Haug IJ, Draget KI, Smidsrød O. Physical and rheological properties of fish gelatin compared to mammalian gelatin. Food Hydrocoll. 2004; 31; 18(2):203-13.
- 70. Fujimoto W, Fukuda M, Yokooji T, et al. Anaphylaxis provoked by ingestion of hydrolyzed fish collagen probably induced by epicutaneous sensitization. Allergol Int. 2016; 65(4): 474-6.
- 71. Strauss G, Gibson SM. Plant phenolics as crosslinkers of gelatin gels and gelatin-based coacervates for use as food ingredients. Food Hydrocoll. 2004; 31; 18(1):81-9.
- 72. Rocasalbas G, Francesko A, Touriño S, et al. Laccase-assisted formation of bioactive chitosan/gelatin hydrogel stabilized with plant polyphenols. Carbohydr Polym. 2013; 15; 92(2):989-96.
- Coetzee J, Merwe CF. Penetration rate of glutaraldehyde in various buffers into plant tissue and gelatin gels. J Microsc. 1985; 1; 137(2):129-36.
- 74. Yan M, Li B, Zhao X, et al. Physicochemical properties of gelatin gels from walleye pollock (Theragra chalcogramma) skin cross-linked by gallic acid and rutin. Food Hydrocoll. 2011; 31; 25(5):907-14.
- 75. Frank D, Eyres GT, Piyasiri U, et al. Effects of agar gel strength and fat on oral breakdown, volatile release, and sensory perception using in vivo and in vitro systems. J Agric Food Chem. 2015; 13; 63(41): 9093-102.
- 76. Kumari A, Prasad A. Assessment of agar gel immunodiffusion test for seroprevalence of infectious bursal disease infection. Indian J Comparative Microbiol Immunol Infect Dis. 2015; 36(2): 90-1.
- 77. Zong Y, Han JH, Oh YJ, et al. Release Profile and Antimicrobial Activity of Nisin Control-released from Agar Gel Foods. Food Engeen Prog. 2017; 28; 21(1): 36-41.
- 78. Wang Z, Yang K, Brenner T, et al. The influence of agar gel texture on sucrose release. Food Hydrocoll. 2014; 31; 36: 196-203.
- Kay RM, Truswell AS. Effect of citrus pectin on blood lipids and fecal steroid excretion in man. Am J Clin Nutr. 1977; 1; 30(2):171-5.
- Mohnen D. Pectin structure and biosynthesis. Curr Opin Plant Biol. 2008 Jun 30; 11(3):266-77.

- Thakur BR, Singh RK, Handa AK, et al. Chemistry and uses of pectin—a review. Crit Rev Food Sci Nutr. 1997; 1; 37(1): 47-73.
- 82. Grassino AN, Halambek J, Djaković S, et al. Utilization of tomato peel waste from canning factory as a potential source for pectin production and application as tin corrosion inhibitor. Food hydrocoll. 2016; 31; 52: 265-74.
- 83. Tkalec G, Knez Ž, Novak Z. Fast production of high-methoxyl pectin aerogels for enhancing the bioavailability of low-soluble drugs. J Supercritical Fluids. 2015; 31; 106:16-22.
- 84. Li J, Wang Y, Jin W, et al. Application of micronized konjac gel for fat analogue in mayonnaise. Food Hydrocoll. 2014; 31; 35: 375-82.
- 85. Jimenez-Colmenero F, Cofrades S, Herrero AM, et al. Konjac gel for use as potential fat analogue for healthier meat product development: Effect of chilled and frozen storage. Food Hydrocoll. 2013; 31; 30(1): 351-7.
- 86. Jiménez-Colmenero F, Triki M, Herrero AM, et al. Healthy oil combination stabilized in a konjac matrix as pork fat replacement in low-fat, PUFA-enriched, dry fermented sausages. LWT-Food Sci Technol. 2013 Apr 30; 51(1): 158-63.
- 87. Li MY, Feng GP, Wang H, et al. Deacetylated Konjac Glucomannan Is Less Effective in Reducing Dietary-Induced Hyperlipidemia and Hepatic Steatosis in C57BL/6 Mice. J Agric Food Chem. 2017 Feb 17; 65(8): 1556-65.
- Bhowmick B, Sarkar G, Rana D, et al. Effect of carrageenan and potassium chloride on an in situ gelling ophthalmic drug delivery system based on methylcellulose. RSC Advances. 2015; 5(74):60386-91.