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Protein Oxidation in dairy products and effects on intestinal health

Jiayi Han

Faculty of Food Science and Engineering, Northwest A&F University, Yangling, China, 712100

19931426870@163.com

Abstract. Lipid oxidation and microbial action have long been attributed to reduced food quality, but the effect on quality has only been gradually noticed in recent years. In food systems, protein oxidation can occur naturally and can also be triggered by processing. Therefore, the oxidation phenomenon is very common in the processing process of protein food. It is very important to study the detailed oxidation mechanism of protein. The new problem is the intake of oxidized protein impacts the health of the human body and intestinal microorganisms in its role, microorganisms in the human body intake of oxidized protein's detailed role is not clear. However, it is undeniable that the gut microbiota plays a vital role in human gut health, and it is very important to study the detailed function of the human gut microbiota after ingestion of oxidized proteins. This study conducted a detailed analysis of food processing to create a protein oxidation environment, protein oxidation mechanism, protein oxidation modification on human intestinal health, and digestion characteristics. Besides, the study also analyzes the role of microorganisms and puts forward the insufficiency. The paper also provides references and help for protein oxidation research.

Keywords: Protein, oxidation, intestinal microorganisms, human health.

1. Introduction

Protein is an important part of dairy products, which determines the nutritional value of dairy products. Various oxidized derivatives of milk protein in the processing process also affect human health by affecting the intestinal flora and its digestive characteristics. Although the detailed environment and mechanism of protein oxidation have been well established in many studies, there is still no complete study on the specific effects of oxidized proteins on human gut microbes and health [1-2].

This paper summarizes the oxidative stress environment of milk and dairy products in the processing process and introduces the mechanism of milk and dairy product oxidation and its impact on human health. The study expects to provide a further reference for the study of the link between oxidized protein and body health.

2. Oxidative stress environment during the storage and processing of milk and dairy products

The proteins in food raw materials are easily subject to the erosion of reactive oxygen species and reactive nitrogen species produced in the processing process of food, such as homogenization, sterilization, and drying [3], causing protein polymerization, degradation, and interaction with other food components to produce complexes [4]. Milk is a complex colloidal system, rich in unsaturated

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fatty acids and highly active fat hydrolase and fat oxidase. In the process of raw milk processing and storage, fat hydrolase catalyzes the hydrolysis of milk lipids to form free fatty acids, and fatty acids make it easy to produce lipid radicals and active lipid oxidation products under the action of endogenous fat oxygenase [5]. While the protein backbone is affected by these active free radicals [6], its secondary and tertiary structures undergo conformational changes to enable protein oxidation and aggregation [7], thus causing a drastic change in the sensory quality and nutritional properties of dairy products. In addition, the products of lactose sialylation reaction of the lactose in milk will also aggravate the occurrence of the protein oxidation process [8], ultimately hindering proteolysis by digestive enzymes [9]. Therefore, oxidative modification is highly susceptible to the combined action of oxidative stress environments such as reactive oxygen species, lipid peroxidation radicals, and glycosylation products.

It has been proved that the whey protein isolate can form heterogeneous aggregates dominated by disulfide bonds under oxidative stress, but the effect of this oxidative modification on the different processing characteristics of the protein is inconsistent [10-11], which is closely related to the milk composition and content [12], especially significantly influenced by factors such as the composition and structure of proteins. However, it is not clear to what extent the oxidative stress environment such as reactive oxygen species produced during heat treatment and lipid radicals and peroxide products present in bovine milk affect the oxidation of bovine milk protein, respectively.

3. The occurrence mechanism and research method of protein oxidation

Reactive oxygen species (ROS) and free radicals formed in the oxidative stress environment have extremely strong reactivity, which can directly or indirectly act on proteins to cause their covalent structural modification [13]. Among these, the amino acid side chain group is usually the site of the initial oxidant attack [2]. In general, all the amino side chains of the protein can be oxidative by ROS, such as oxidation can lead to hydroxylation of aromatic groups and aliphatic amino acids, aromatic amino acid residues, nitrosylation, sulfation oxidation of methionine residues, chlorination of aromatic groups and primary amino groups, and a series of amino acid residues into groups and their derivatives [3], [13]. Oxidative modifications of amino acid side chains cause changes in primary structure, while bases, disulfide bonds, and tyrosine bridges cause polymerization and aggregation of proteins [14], [15], and alter its secondary and tertiary structures, resulting in significant changes in solubility and functionality [7], and further affecting many biological processes.

In food systems, protein oxidation can occur naturally (i. e. in situ autooxidation) and can also be triggered by processing [16]. Among them, the basic heat-related processing of sterilization, homogenization, concentration, drying, and other related processing processes in dairy processing will also induce milk protein oxidation, thus reducing the necessary amino acid content, increasing the base content, reducing protein solubility and changing hydrophobicity [17]. These structural disruptions and aggregation will further affect the texture formation and digestion properties of proteins [16],[18]. However, there is a lack of oxidative modification and mechanism of protein in the processing of milk. Traditional protein oxidation is mainly studied from the total proteins of living organisms and individually known proteins [3], [19], which has limitations. Proteomics has become an effective technical means for studying the redox state of proteins [20], redox proteomics can analyze the redox-related protein modification and redox regulation system from the overall level, which can not only obtain the protein oxidative damage map but also explore the related signaling pathways [21] of protein oxidation modification, as well as the response mechanism of food raw materials to processing conditions. So far, redox proteomics has been widely used in the analysis of relevant protein oxidation [22-23], but the oxidative modification mechanism of food protein in food processing.

4. Effect of protein oxidative modifications on digestive properties and intestinal health

The oxidative stress environment existing in the milk system very easily leads to oxidative modification of protein amino acid side chains and further denaturation and aggregation of proteins. From the perspective of nutrition, the partial oxidative modification of protein will lead to the loss of

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essential amino acids, and the decomposition and reunion of protein structure will affect the digestion of milk protein and the bioavailability of essential amino acids [17]. Excessive oxidation may lead to the loss of the nutritional value of food even produce toxic substances, and affect human health.

Digestibility is one of the important criteria of protein nutritional quality. Compared with the effect of protein oxidation on the loss of essential amino acids, the effect of oxidation on protein digestibility has been controversial. It has been shown that heat treatment improves digestibility [24], but oxidation during heat treatment may also lead to protein crosslinking to form aggregate [10], which reduces the protein digestibility [15], [25], by reducing the restriction site. When oxidation is severe to a certain extent (such as cooking), oxidation-induced protein motivation and aggregation are negatively correlated with the efficiency of pepsin, while there is no corresponding relationship between chymotrypsin and trypsin [26]. These results show that the differences in protease recognition and catalytic sites of different food proteins and different digestion models will lead to obvious differences in the digestion rate and degree of digestion. At present, heating is an indispensable treatment of dairy product processing, but heat treatment will also lead to higher structural changes in milk protein, affecting the digestive properties of protein.

In addition, gut microbes play an important role in protein digestion and metabolism, especially directly affecting the metabolic process in the intestine [27]. Eating oxidized proteins will cause changes in the intestinal microenvironment [28], among which the most significant is the increasing abundance of potentially pathogenic bacteria and the decline in the number of probiotics. The metabolites of these bacteria will change, and then destroy the intestinal barrier function [29], thus making harmful substances more likely to enter the blood circulation, causing a systemic inflammatory reaction.

5. Conclusion

Although the research on the structural characteristics and processing characteristics of specific oxidized proteins in milk is relatively mature at home and abroad, the influence of protein oxidation in the processing process on its digestive properties and body health is still in the initial stage, and the influence on intestinal microorganisms is still in the exploratory stage. Studies that change their digestion and nutritional value after protein oxidation are not clear, and the specific role of gut microbes is also unclear. The relationship between the digestive glycolytic properties caused by milk protein oxidation during processing and its structural changes has not been fully elucidated.

Therefore, it is important to explore the detailed role and mechanism of gut microbes in the human ingestion of oxidized proteins.

References

[1] Mahmoodani F, Perera CO, Abernethy G, Fedrizzi B, Chen H. Lipid oxidation and vitamin D3 degradation in simulated whole milk powder as influenced by processing and storage [J]. Food Chem., 2018,261: 149-156.

[2] Xiong Y L, Guo A . Animal and plant protein oxidation: chemical and functional property significance [J]. Foods, 2020, 10(1):40.

[3] Hellwig M . Analysis of Protein Oxidation in Food and Feed Products [J]. J. Agric. Food Chem., 2020, 68(46): 12870-12885.

[4] Alavi F, Momen S, Emam-Djomeh Z, Salami M, Moosavi-Movahedi AA. Radical cross-linked whey protein aggregates as building blocks of non-heated cold-set gels [J]. Food Hydrocoll. 2018, 81:429-441.

[5] Ostdal H , Bjerrum M J , Pedersen J A , et al. Lactoperoxidase-induced protein oxidation in milk[J]. J. Agric. Food Chem., 2000, 48(9):3939-3944.

[6] Wang Z , He Z , Emara A M , et al. Effects of malondialdehyde as a byproduct of lipid oxidation on protein oxidation in rabbit meat[J]. Food Chem., 2019, 288:405-412.

[7] Wüst J, Pischetsrieder M. Methionine sulfoxide profiling of milk proteins to assess the influence of lipids on protein oxidation in milk[J]. Food & Function, 2016, 7 (6): 2526-2536.

DOI: 10.54254/2753-8818/33/20240915

[8] Luna C, Estévez M. Oxidative damage to food and human serum proteins: radical-mediated oxidation vs. glyco-oxidation [J]. Food Chem. 2018, 267: 111−118.
[9] Mehta B, Deeth H. Blocked lysine in dairy products: formation, occurrence, analysis, and nutritional implications[J]. Compr Rev Food Sci F, 2016, 15: 206-218 .
[10] Anema SG. The Thermal denaturation of the total whey protein in reconstituted whole milk [J]. Int J Dairy Technol, 2017, 70 (3): 332-338.
[11] Deeth HC. Chapter 10 - the effect of UHT processing and storage on milk proteins [M]. Bolandand H. Singh. Milk Proteins (Third Edition). Academic Press. 2020: 385-421.
[12] Cui GX， Yuan F， Degen A A， Degen SM. Liu JW. et al. Composition of the milk of yaks raised at different altitudes on the Qinghai-Tibetan plateau[J]. Int Dairy J，2016, 59: 29-35.
[13] Hellwig M. The chemistry of protein oxidation in food [J]. Angew Chem Int Ed Engl, 2019, 58(47):16742-16763.
[14] Wu X, Li F, Wu W. Effects of oxidative modification by 13-hydroperoxy octadecadienoic acid on the structure and functional properties of rice protein [J]. Food Res. Int. 2020, 132: 109096
[15] Ma J, Wang X, Li Q, Zhang L, Wang Zh, Han L, Yu Q. Oxidation of myofibrillar protein and crosslinking behavior during processing of traditional air-dried yak (Bos grunniens) meat about digestibility [J]. LWT, 2021,72:110984.
[16] Patrícia D, Berton-Carabin CC , Nieuwkoop M , et al. Protein oxidation and in vitro gastric digestion of processed soy-based matrices[J]. J. Agric. Food Chem. 2019, 67（34）: 9591–9600.
[17] Feng X , Li C , Ullah N , et al. Susceptibility of whey protein isolates to oxidation and changes in physicochemical, structural, and digestibility characteristics[J]. J Dairy Sci., 2015, 98(11):7602-7613.
[18] You Xiangyu, Huang Huimin, Wu Wei, Wu Xiaojuan. Effect of peroxyl radical oxidation on the pepsin digestion properties of rice bran protein in vitro [J]. Chinese Journal of Grain and Oil, 2019,34 (4): 69-74
[19] Krämer AC, Thulstrup PW, Lund MN, Davies MJ. The key role of cysteine residues and sulfenic acids in thermal-and H2O2-mediated modification of β-lactoglobulin [J]. Free Radical Biol. Med., 2016, 97: 544-555.
[20] Dyer J, Clerens S, Grosvenor A, et al. Proteomic tracking of hydrothermal Maillard and redox modification in lactoferrin andβ-lactoglobulin: location of lactosylation, carboxymethylation, and oxidation sites[J]. J Dairy Sci,, 2016, 99(5): 3295-3304
[21] Smythers A, Lowery S, Slone D, et al. Redox proteomics unveils novel role of LARP1 along the photosynthetic TOR pathway[J]. Free Radic Biol Med, 2020, 159:S32-S33.
[22] Butterfield DA, Debra Boyd-Kimball. Redox proteomics and amyloid β-peptide: insights into Alzheimer disease[J]. J Neurochem, 2019, 151(4): 459-487
[23] Yu J, Li Y, Qin Z, et al. Plant chloroplast stress response: insights from thiol redox proteomics [J]. Antioxid Redox Sign. 2020, 33(1): 35-57.
[24] Zhou CY, Pan DD, Sun YY, et al. The effect of cooking temperature on the aggregation and digestion rate of myofibrillar proteins in Jinhua ham[J]. J Sci Food Agric, 2018,98(9): 3563-3570.
[25] Jiang Zhmao, Liu Xiao, Zhang Shuwen, Pang Xiaoyang, Liu Lu, Lu Jing, Lu Jiaping. Effects of heat treatment on in vitro digestion properties of fresh milk and recovered milk proteins [J]. Food Science, 2018,39 (8): 33-38
[26] Santé-Lhoutellier V, Astruc T , Marinova P , et al. Effect of meat cooking on physicochemical state and in vitro digestibility of myofibrillar proteins.[J]. J. Agric. Food Chem. 2008, 56(4):1488-1494.
[27] Gentile CL, Weir TL. The gut microbiota at the intersection of diet and human health. Science 2018, 362 (6416): 776-780.

DOI: 10.54254/2753-8818/33/20240915

[28] Estévez M, Luna C. Dietary protein oxidation: a silent threat to human health? [J] Crit. Rev. Food Sci. Nutr. 2017, 57 (17): 3781−3793.
[29] Xie F, Sun S, Xu A, Zheng S, Xue M, et al. Advanced oxidation protein products induce intestine epithelial cell death through a redox-dependent, c-jun N-terminal kinase and poly (ADP-ribose) polymerase-1-mediated pathway [J]. Cell Death Dis. 2014, 5: 1006