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Developing Strategies of Functional Milk and Meat Products from Herbivorous Animal Husbandry

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Abstract

In the past 40 years, the animal husbandry industry in China has been developed very fast through the technological and social development. It has been changed into a new stage from quantity to quality of the animal products, and more attention has been paid on the healthy food. The functional animal products will be an important breakthrough for the high-quality development of animal husbandry. This paper reviews the current animal husbandry industry and functional products of herbivorous animal husbandry in China and abroad. Several key scientific and technological issues on functional milk and meat are analyzed. Practical exploration including biotechnology (genetic breeding and biosynthesis) and non-biotechnology (feeding technology) on how to develop the production of functional milk and meat is proposed. It is expected that we can study and consolidate the regulation theory and technology of functional milk and meat of herbivorous animal husbandry by supports from the national strategic level. It will be significantly important to guide the sustainable development of herbivorous livestock and human diet consumption, and to build the domestic flagship brand of milk and meat products in China.

Keywords

herbivorous animal husbandry; functional products; milk and meat brand; practical exploration

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Developing Strategies of Functional Milk and Meat Products from Herbivorous Animal Husbandry

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Abstract: In the past 40 years, the animal husbandry in China has been developed fast with the technological and social development. It has been changed into a new stage from quantity to quality of the animal products, and more attention has been paid to healthy food. Functional animal products will be an important breakthrough for the high-quality development of animal husbandry. This paper reviewed China's current animal husbandry and the functional products from the herbivorous animal husbandry in China and abroad. Several key scientific and technological issues on functional milk and meat products were analyzed. Practical exploration including biotechnology (genetic breeding and biosynthesis) and non-biotechnology (feeding technology) on how to develop functional milk and meat products was discussed. It is expected that we should study and consolidate the regulation theory and technology of functional milk and meat products from the herbivorous animal husbandry at the national strategic level. It will be vital to guide the sustainable development of herbivorous livestock and human diet consumption, and to build the domestic flagship brand of milk and meat products in China. DOI: 10.16418/j.issn.1000-3045.20210407004-en

Keywords: herbivorous animal husbandry; functional products; milk and meat brand; practical exploration

Since the 20th century, there has been a common phenomenon that many people in the world have suffered from “illness of affluence”, such as diabetes and cardiovascular and cerebrovascular disease, which causes the concept of functional foods to come into being. In 2017, the report of the 19th National Congress of the Communist Party of China proposed the development strategy of “Healthy China”. Under the background of the great health strategy, the development of functional animal products integrating both nutrition and health serves as an effective means for gradually shaping the new industrial pattern of high-quality development by driving the reform at the supply side of the animal husbandry, and also acts as an important approach to promoting implementation of the healthy China strategy. In 2020–2035, China will march towards the second centennial goal after having built a moderately prosperous society in all respects and achieved the first centennial goal. The demands of the whole society for health products become diversified, differentiated and personalized day by day, and proportion of the animal product consumption, such as meat, eggs and milk, in the dietary pattern of the Chinese people increases year by year. Thus the people's requirements for the quality

of animal products will become more and more rigorous. In the 15 years to come, it is predicted that the size of the middle-income group will grow to 0.8 billion from the current 0.4 billion^[1]. The strong domestic market demand will also promote production and development of high-quality functional animal products while driving the increase in the product output, so as to meet the consumption demand of the middle-income group.

In order to meet the rigid demand of the 1.4 million people in China for animal products, such as meat, eggs and milk, over the past four decades, the animal husbandry has made remarkable achievements in its quantitative growth. Currently, about 1/2 of the pigs, 1/3 of the domestic fowls, 1/5 of the sheep and 1/11 of the cattle in the world are being raised in China, and the animal husbandry ranks at the top the production capacity in the world^[2]. On the one hand, the herbivorous animal husbandry in China sees a huge development potential. The statistical data indicate that the annual meat output in 2019 in China was 77.59 million tons, including 42.55 million tons of pork, 6.67 million tons of beef, 4.87 million tons of mutton, and 18.97 million tons of poultry. Besides, the poultry egg output was 33.09 million tons,

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and milk output 32.98 million tons^[3]. By comparison with the meat consumption pattern of Chinese people, grain-fed pork and poultry accounted for 79%, while the grass-fed beef and mutton only occupied 15%. The unreasonable proportion of the grain-fed pork and poultry reveals that the structure of the animal husbandry in China is in a badly irrational situation, and the natural resource endowment in China fails to match the byproduct resource of the planting industry (China has about 400 million hectares of grassland, ranking at the first place in area in the world, and the crop straw each year is about 800 million tons). Compared with the countries having developed herbivorous animal husbandry (for example, the grass-fed beef and mutton outputs in New Zealand and Australia account for 79% and 65%, respectively^①). In this way, the herbivorous animal husbandry in China has a huge development potential. On the other hand, in view of the agricultural development trend in China under the new development stage, idea and pattern, it is inevitable for China to take the path of high-quality transformation development in the herbivorous animal husbandry. The functional agriculture will become the third development stage after high-yield agriculture and green agriculture, and functional agricultural products are deemed as the development direction for high-end foods in the future^[4]. At present, some of the animal products in China have encountered structural surplus: Common similar products are high in quantity but low in price, and high-quality products cannot meet the demand for consumption. With cows as an example, the consumers lack confidence in consuming the domestic dairy products, and therefore the import of milk powder has increased significantly, leading to a severe imbalance between supply and demand of the domestic fresh and raw milk. As a result, development of the domestic functional meat and milk products from the herbivorous animal husbandry is not only the primary task for high-quality development of the herbivorous animal husbandry, but also the new breakthrough to rebuild national brand and regain the customers' confidence, and the only way to driving Chinese animal husbandry to reach the world's advanced level.

1 Status quo of development of the functional animal products both in China and abroad

Functional animal products are functional foods made from animal products. Besides the basic attributes of foods, such as nutrition and sensory functions, functional foods can positively contribute to the human health, such as improvement of the body immune function disease prevention, promotion of health and regulation of body functions. In general, the development of functional foods can be divided into three phases. Specifically, functional foods in the first phase are

mainly various fortified foods, which are the raw functional foods having not been verified through any experiment, and most of the functional foods in China fall into this category. Functional foods in the second phase are those having certain functions in physiological regulation that have been verified through human or animal experiments. For functional foods in the third phase, their functional components have been studied thoroughly; that is to say, the structures, content and mechanisms of action of the functional factors are identified based on the functional foods in the second phase, and the functional factors have their stable forms. Currently, research and development of functional foods conducted by developed countries, such as Europe and the US, almost stay in the third phase.

The functional agricultural products researched and developed in China at present are mainly the foods that are rich in mineral elements (such as Selenium, Calcium and Zinc) and have the features of functional goods in the first phase. Functional egg is a kind of animal product receiving a lot of studies. For example, the Selenium-enriched egg is the egg laid by the hen fed with inorganic Selenium or organic Selenium fodder having a high Selenium content, and then Selenium is transformed into organic Selenium and deposited in the egg. The human body can absorb up to 80% of the organic Selenium contained in the egg, and thus the Selenium-enriched egg is a good Selenium nutritional supplement. Additionally, the content of cholesterol, fatty acid, phospholipid, amino acids, minerals, vitamins, carotenoid, etc., contained in the egg can also be regulated and controlled by the hen fodder to produce the functional eggs for population groups with nutritional requirements such as the children and the elderly, which has been reported widely^[5].

Herbivorous beef and mutton are the sources for good proteins that have low cholesterol content and are rich in amino acids and other minerals essential to the human body. Beef contains a great number of functional components, such as conjugated linoleic acids, carnitine, sarcosine, and biohydrogenation intermediates, to which pork and poultry are incomparable. It positively contributes to the human health, such as reduction of fat intake and prevention of diabetes, cancer and cardiovascular disease. In China, there have been some reports about functional milk and meat products from the herbivorous livestock. For example, the national geographical indication product "Baizi Mutton", which has been well known for its fresh and tender meat without mutton flavor, is a kind of high-quality chevon having high protein but low fat content, and with abundant free amino acids and a number of trace elements. Moreover, colostrum has been deemed as a highly potential functional food as it is rich in bioactive substances, such as immune globulin, lactoferrin and cytokines, which can improve the body immune function and promote growth and development. At present, research

① FAO. Livestock Primary. (2020-12-22). <http://www.fao.org/faostat/en/#data/QL>.

and development of the functional milk and meat products from herbivorous livestock in China are still in the initial stage (the first phase products). With enhancement of the people's health consciousness and mining of the functional food market, we should research and develop the functional milk and meat products from herbivorous livestock based on the characteristics of the third phase functional foods, and should also improve the product technology to guide the production of the herbivorous livestock and people's scientific diets, which is of great strategic significance.

2 Frontier science and technology issues during the development of functional milk and meat products from the herbivorous animal husbandry

Overall objective of study on the functional milk and meat products from herbivorous livestock. Scientific and technological innovation shall be made for the functional milk and meat products from herbivorous livestock at three levels of “target analysis–animal production–human health”, to analyze the formation mechanism of the important functional components in the milk and meat products, develop technologies for improving the functional component targets of milk and meat products from herbivorous livestock, and elucidate the relationship between milk and meat nutrition and human health. This will provide basic theoretical support for guiding precise ration design and conducting research and development of the third phase functional milk and meat products from herbivorous livestock. The main research strategies are shown in Figure 1.

Theoretical issues about formation of the functions of milk and meat products from herbivorous livestock. The research shall be mainly centered on two aspects, viz., biological foundation of herbivorous livestock and nutrition process regulation and control. ① From the aspect of biological

foundation, it is necessary to clarify the hereditary basis of the important functional components of milk and meat products from herbivorous livestock (such as conjugated linoleic acid, carnitine and sarcosine contained in fresh and raw meat, and lactoferrin and lecithin contained in fresh and raw milk), analyze and manifest the key target genes of those components as well as their precursors. ② From the aspect of nutrition process regulation and control, it is necessary to identify the chemical structures and biosynthetic process of the important functional components during the development of the herbivorous livestock, as well as the accumulation rule, threshold range, influencing factors, regulation mechanism of their precursors; in addition, we should also analyze how the quality and functions of the milk and meat products are regulated and controlled by digestion, absorption, transport pathway and distribution of the key nutrients in the fodder (such as carbohydrate, protein and lipids). For example, in fat metabolism, most of the unsaturated fatty acid is hydrogenated into saturated fatty acid by microorganisms in the rumen of herbivorous livestock, and thus the relationship between hydrogenation of the unsaturated fatty acid in the rumen and generation of the conjugated linoleic acid contained in the milk and meat products shall be determined.

Technical issues about animal production based on enhancement of the functional components in milk and meat products. The main issue in herbivorous livestock production is how to improve the functional components with biological and non-biological technologies on the basis of guaranteeing the output and quality of the milk and meat products. ① For fresh and raw meat, the meat quality is generally evaluated with indicators such as muscle pH, color, water holding capacity, tenderness, intermuscular fat content, thiobarbituric acid reactive substance value and flavor score. From the perspective of the functional components of fresh and raw meat, the issues about herbivorous livestock breeding requiring attention are that on the environmentally friendly basis, the content of the important functional components

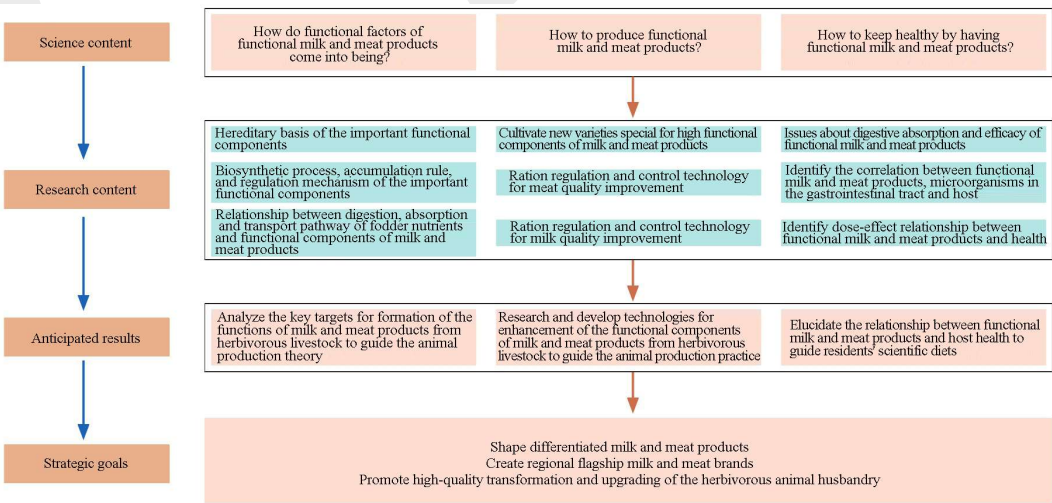


Figure 1 Strategic research roadmap on functional milk and meat products from herbivorous animal husbandry

(branched-chain amino acid, phospholipid, conjugated linoleic acid, biohydrogenation intermediates, sarcosine and carnitine) should be increased with technologies such as amino acid balance and anion-cation balance in ration, synchrony index of ration energy and nitrogen release, and functional green additive; besides, the proper addition form, amount of addition and production cost of the functional regulating agent as well as animal-tolerant dose should also be studied. ② For fresh and raw milk, China has specified strict production and quality standards, which provide rigorous threshold limits for indicators such as butter-fat percentage, lactoprotein and non-fat milk solids in fresh and raw milk. Provided that the industrial standards have been satisfied, the issue to which the milk-producing herbivorous livestock husbandry shall pay attention is how to increase the content of the important functional components (such as lecithin, conjugated linoleic acid and lactoferrin) in fresh and raw milk, and the dose effect and production cost of the regulating agent used in fresh and raw milk should also be concerned.

Theoretical basis issues about the functional components in milk and meat products from herbivorous livestock and human health. The followings are mainly included: the issue about digestive absorption and efficacy of the important functional components contained in milk and meat products in the human body to identify the functional classification of the milk and meat products; the response of the tissues and organs such as the body's immune system, liver, and gastrointestinal tract and its microorganisms after intake of the functional components in milk and meat products from herbivorous livestock by population groups of different ages; the dose-effect relationship and the spatio-temporal effects between intake of the functional component and human physiological process; developing diet plans for population groups of different health conditions in different physiological stages based on the content of the functional components in milk and meat products from herbivorous livestock.

3 Practical exploration of development of the functional milk and meat products from herbivorous animal husbandry

3.1 Cultivate new varieties with genetic improvement method

The excellent genetic background of the livestock is the basis for cultivating an improved variety. The effective means to producing the functional animal product rich in a specific functional component is to cultivate a variety of the livestock with high expression of the important functional component gene by variety breeding or genetic engineering method. For example, lactoferrin, a core nutritional protein extracted from milk, has multiple healthcare functions such as immunoregulation and bone growth promotion. Researchers both in

China and abroad have obtained the human lactoferrin gene by body cell clone technology, and cultivated the human lactoferrin-cloned dairy cattle, which thus increased the content of recombinant human lactoferrin in fresh and raw milk^[6]. High intermuscular fat is the basis for making up marbling in beef and mutton, and is also one of the important factors affecting the meat quality. Intermuscular fat deposition is closely related to the variety, management, nutrition and hereditary basis of herbivorous livestock. The scientific research team for ecological grass and animal husbandry of Chinese Academy of Sciences identified the relevant genes affecting the intermuscular fat deposition in sheep at the early stage, and screened out and construct the gene screening chip for meat quality traits based on the sheep varieties in China. For producing high-quality mutton, breeding of new snowflake mutton varieties having high intermuscular fat content was being carried out with selective breeding and breeding technology. Additionally, milk and meat products from herbivorous livestock contain phospholipid which can improve cardiovascular health, metabolic disease and nerve health; especially beef and mutton contain high concentration of sarcosine and carnitine which can help human muscle grow and increase strength. These functional components are important functional components in the milk and meat products from herbivorous livestock that are different from pork and poultry products, but they have received less attention up to now. The indigenous herbivorous livestock provenance with high expression of phospholipid, sarcosine or carnitine was cultivated by genetic improvement method and analyzing the master control genes of the important functional components, such as phospholipid, sarcosine and carnitine in the milk and meat products from herbivorous livestock, which is a development direction for achieving the functionalization of milk and meat products.

3.2 Change the synthetic process of functional components by regulating and controlling ration formula

With a digestive organ different from the monogastric animal-rumen, the herbivorous livestock exhibits a unique mechanism for digestive metabolism for the key nutrients in the animal body. For example, through fermentation by rumen microorganisms, carbohydrates such as crude fiber are degraded into short-chain fatty acid which is used as the main energy source for the animal, and protein is degraded into ammonia nitrogen and further generated into microproteins containing various necessary amino acids; in addition, unsaturated fatty acid is hydrogenated into saturated fatty acid. Researchers both in China and abroad have conducted explorations on the regulation and control of important functional components in milk and meat products from the perspective of nutrition metabolism of the herbivorous livestock for many years, which were mostly centered on conjugated linoleic acid. The milk and meat products from herbivorous livestock contain a high content of conjugated

linoleic acid, which positively contributes to the human health with regards to reduction of fat intake and prevention of diabetes, cancer and cardiovascular disease. Studies have revealed that the content of conjugated linoleic acid in milk and meat can be improved with the methods such as increasing the proportion of coarse fodder in the ration of herbivorous livestock and changing the variety and quantity of the fatty acid^[7,8]. When studying the application of plant functional components to regulate and control the quality of herbivorous animal products at the early stage, the scientific research team for ecological grass and husbandry of Chinese Academy of Sciences has discovered that the quality of the mutton sheep can be improved and the proportion of unsaturated fatty acid in the muscle can be increased by adding catechin (3.0–4.0 g/kg) to the ration of the mutton sheep^[9]; by adding tannin to the ration of the lactating goat, the content of monounsaturated fatty acid and polyunsaturated fatty acid in the goat milk increase linearly with the amount of tannin addition^[10]. Up to now, few studies are reported about the improvement of the important functional components, such as phospholipid, sarcosine and carnitine, in the milk and meat products from herbivorous livestock via ration regulation and control. As these components are significant in the milk and meat products from herbivorous livestock and for human nutrition, it is necessary to intensify research and development of the targeted ration preparation technology and functional fodder products by aiming at these important functional components.

3.3 Targeted synthesis of the precursor substances of the functional components in milk and meat products from herbivorous livestock

In recent years, remarkable progress has been made in synthetic biology for transforming the genetic materials and metabolic pathways of microorganisms. The *de novo* design synthesis ability of the DNA sequence has been developed from a certain simple gene to the genome of the whole microorganism, and under this background, the genomes of the virus and the prokaryote, and the chromosome of the eucaryon have been synthesized successfully one after another. With constant breakthroughs made in the synthetic biology technology, the researchers can introduce a complicated exogenous metabolic pathway into the body of a specific microorganism host and conduct engineering transformation to achieve orthogenesis. As for herbivorous livestock, numerous complicated microorganisms such as bacteria, fungi, archaea and protozoa inhabit its rumen, with diversified species and complicated functions, and can be used as the natural resource bank for various functional components (such as amino acid, fatty acid and vitamin). With synthetic biology, the synthetic pathways of the precursor substances of functional components in herbivorous livestock shall be explored, so as to construct corresponding synthetic pathways for the microorganisms in the rumen mode; the metabolic pathways of the precursor substances of functional

components which have been functionally verified shall be combined and synthesized in the form of function cluster; besides, combinational optimization of the synthesis network shall be achieved by means of exploring efficient synthetic element, increasing the copy number of the key rate-limiting enzyme and introducing the molecular control circuit. Targeted transformation of specific microorganisms in the rumen of herbivorous livestock to synthesize the precursor substances of functional components, and promotion of the synthesis and deposition of functional meat traits (such as branch-chained fatty acid and flavor amino acid) and milk components (such as conjugated linoleic acid, phospholipid and lactoferrin) in the herbivorous livestock have a huge potential for improving the quality of the milk and meat products from herbivorous livestock, which remains to be explored.

4 Policy suggestions

In herbivorous animal husbandry, the development of functional milk and meat products is still in the exploratory stage. Carrying out basic research, making major technological breakthroughs and developing key products centering on functional milk and meat products from herbivorous livestock at the national strategic level are significant for constructing differentiated functional milk and meat products from herbivorous livestock, creating flagship milk and meat brands, advancing the herbivorous animal husbandry of China to a high-quality development road, and guiding the consumers to healthy diet. Two policy suggestions are proposed with regards to high-quality development of the herbivorous animal husbandry.

(1) Improve organization and management. It is necessary to further reinforce the top-level design, and arrange relevant scientific and technological resources for technology research and development for functional products from the herbivorous animal husbandry and development of the products in a coordinated way. Close cooperative relationships with the top academic institutions and scientists both in China and abroad shall be established actively and positively, so as to form a community for scientific research, gain the initiative and right of speech, and seize the commanding height in a number of fields. Additionally, a top academic team and a number of top academic research platforms should be constructed.

(2) Increase the input to scientific research. At the national strategic level, the governments at all levels should play their leading roles in policy making. They should deploy the major scientific and technological tasks for development of the industry chain and increase the government inputs to fundamental research based on the consumption demands in different areas and of different population groups and; by centering on functional products from the herbivorous animal husbandry. Moreover, enterprises and social capital should

also be guided to invest in technology research and development for functional milk and meat products from herbivorous livestock and development of the products.

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