Development of a Chinese Feed Nutrition Big Data Analysis Platform (Postprint)

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Abstract

The gradual widening of the feed grain gap has caused China' s feed grain security issues to gradually transform into grain security issues. Therefore, comprehensively integrating feed nutrition fundamental data resources and enhancing the nutritional value of all available feed resources has become one of the technical measures for China to ensure long-term national grain security. This study, based on 16 categories of Chinese feed ingredient description specifications and attribute data standards, comprehensively collected and organized in a digital mode over 500,000 entries of existing feed resource data on species, spatial distribution, feed component content, and nutritional value characteristics accumulated from the "Sixth Five-Year Plan" to the "Thirteenth Five-Year Plan" period. Utilizing a MySQL network database and PHP programming language, we developed a new-generation big data analysis platform for feed nutrition (http://www.chinafeeddata.org.cn/) and provided Web data sharing functionality. First, the platform provides visual analysis of all archived data, enabling intuitive comparison of multiple nutrients and various graphical modes for single or multiple feeds. Through QR code technology, it provides real-time sharing and download services for all feed nutrition attribute data and feed physical sample traceability data on mobile terminals. Second, the platform constructs regression models for online prediction of other effective nutrients from known feed proximate nutrients, providing dynamic analysis of nutrient variation in feed ingredients. Finally, based on Geographic Information System technology, the platform integrates feed proximate nutrient and major mineral element content data with their geographical location distributions, achieving distribution query and comparative analysis of geographic information mapping for feed nutrition data, while simultaneously providing various data download methods, facilitating the comprehensive application of existing feed data. The study demonstrates that expanding feed resource data and providing predictive analysis models for feed nutrients can maximize the value of existing feed nutrient data. Further embedding various web computing modules for feed formulation can achieve one-stop service and maximized value-added services for feed nutrition data.

Full Text

Development of China Feed Nutrition Big Data Analysis Platform

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Abstract: The widening gap in feed grain supply is gradually transforming feed grain security into a national food security issue in China. Therefore, comprehensively integrating fundamental feed nutrition data resources and enhancing the nutritional value of all available feed resources represents one of the key technical strategies for ensuring long-term national food security. Based on description specifications and attribute data standards for 16 categories of Chinese feed raw materials, this study digitally collected and organized over 500,000 data entries accumulated from the Sixth Five-Year Plan to the Thirteenth Five-Year Plan periods, covering feed resource types, spatial distribution, chemical composition, and nutritional value characteristics. Utilizing MySQL relational database technology and PHP programming language, a new-generation feed nutrition big data analysis platform (http://www.chinafeeddata.org.cn/) was developed, providing web-based data sharing functionality. First, the platform offers visual analysis of all warehoused data, enabling intuitive comparison of single or multiple feeds across various nutrients and graphic modes. Through QR code technology, it provides real-time mobile sharing and downloading of all feed nutrition attribute data and feed sample traceability information. Second, the platform constructs regression models that predict other effective nutrients from known proximate nutrients online, enabling dynamic analysis of nutrient variation in feed ingredients. Finally, based on Geographic Information System (GIS) technology, the platform integrates proximate nutrient and major mineral element content data with geographical location information, enabling distribution queries and comparative analysis of feed nutrition data geographic information maps, while also providing multiple data download methods to facilitate comprehensive utilization of existing feed data. The study demonstrates that expanding feed resource data and providing predictive analysis models for feed nutrients can maximize the value of existing feed nutrition data. Further embedding various feed formulation network calculation modules can achieve one-stop service for feed nutrition data and maximize data value-added services.

Keywords: feed grain; feed nutrition data; big data; data mining; GIS; feed security

1 Introduction

China is the world' s largest feed producer. In 2020, China accounted for the highest proportion of global feed production at 20.21%, with industrial feed output reaching 253 million tons, representing a 10.4% increase from 2019 [1]. However, as China' s large-scale livestock industry continues to expand, the gap in feed raw materials required for industrial feed processing is widening. In 2021 alone, China' s total grain imports reached 165 million tons, including 96.52 million tons of soybeans. Imports of corn, wheat, barley, and sorghum also increased to 28.35 million, 9.77 million, 12.48 million, and 9.42 million tons, respectively, representing year-on-year increases of 152.3%, 16.6%, 54.5%, and 96% compared with 2020. Additionally, China imported 1.823 million tons of fishmeal [2] and over 5 million tons of various protein meals including sunflower seed meal, rapeseed meal, palm kernel meal, coconut meal, and small amounts of soybean meal. Imports of oilseeds such as rapeseed, sesame, and flax were also substantial. The gap in energy feed corn has gradually expanded since 2020, particularly in 2021 when imports surged to nearly 30 million tons [3]. China' s feed grain security issue is progressively transforming into a national food security challenge. The total consumption of feed grain and industrial grain continues to grow, accounting for an increasing proportion of total grain consumption. The proportion of feed grain consumption relative to total grain production has risen from 20% in the 1950s to the current 40%, and is projected to reach 56.5% by 2030—exceeding half of total grain consumption [1]—which will further highlight China' s food security concerns.

The rigid demand for grain from livestock farming has driven rapid price increases in major feed ingredients such as corn and soybean meal. Facing global energy issues and supply chain disruptions, macro-level adjustments to China' s "grain-cash crop-feed" ternary planting structure are needed, positioning feed crop cultivation plans more prominently. At the micro-level, there is a need to broadly explore feed resources, utilize all available feed ingredients, and improve feed resource utilization value through precise nutritional evaluation, full nutrient exploitation, and optimized feed formulation design. These combined macro and micro approaches will comprehensively safeguard China' s feed grain supply in the coming period.

Feed nutrition fundamental data constitutes the basic scientific support for feed processing and represents an important component of the grain processing industry. Over the 40-plus years since reform and opening up, China' s feed processing industry has experienced emergence, development, and maturation, evolving into a large industry with solid theoretical foundations, complete technical categories, rich product varieties, and stable market development. Currently, the most significant constraint on China' s feed processing industry development is the serious insufficiency of feed resource reserves. The protein resource gap has gradually expanded, and the rapid increase in dependence on international markets for energy feed resources—particularly corn—has transformed feed grain security into a primary contradiction in China' s food security issue. Therefore, how to develop and exploit all available feed raw material resources in China, improve resource utilization efficiency, and gradually alleviate resource constraints presents both severe challenges and unprecedented opportunities for China' s feed science research.

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2 Data Preparation and Sources

The China Feed Nutrition Big Data Analysis Platform was constructed based on the legacy data from the portal website www.chinafeeddata.org.cn of the China Feed Database Information Network Center. Data sources include both domestic and international feed nutrition data. Domestic feed nutrition data primarily originated from feed nutritional value evaluation data accumulated since the Sixth Five-Year Plan period. The starting point was the research project "Livestock and Poultry Feed Database and Screening Optimal Feed Formulation Technology for Pigs and Chickens" (65-3-13), assigned by the State Council' s "Electronic Computer and Large-Scale Integrated Circuit Leading Group" in 1983 and jointly undertaken by the former Institute of Animal Science of the Chinese Academy of Agricultural Sciences and the former Department of Animal Husbandry of Beijing Agricultural University. During the Seventh Five-Year Plan period, the "China Feed Database Software Development" national scientific and technological 攻关 project (75-05-05-05) established the "China Feed Database." Since 1989, when the then Ministry of Agriculture approved the establishment of the China Feed Database Information Network Center at the Chinese Academy of Agricultural Sciences, the center has annually collected, organized, and supplemented data on newly emerging feed raw material types and major nutrients, continuously improving China' s feed nutrition data resources. The platform primarily serves the value-added utilization of feed science data, particularly providing scientific support for feed formulation optimization calculations and new feed product development, and offering fundamental data for the scientific and rational utilization of various bulk feed raw materials and unconventional feed resources that do not yet constitute commercial commodities, thereby alleviating the persistent gap in China' s feed resources and gaining industry-wide recognition.

From 1990 to 2021, the platform has continuously published 32 editions of the "China Feed Composition and Nutritional Value Tables" [4-6]. During the Thirteenth Five-Year Plan period, research results from the national science and technology basic project "Investigation and Database Construction of Major Livestock and Poultry Feed Resources Distribution in China" (2014FY111000) [7] were added, including spatial attribute data (county/city, longitude, latitude, etc.) and proximate nutrient and major mineral element content data for 40 typical feed raw materials across 31 provinces, totaling approximately 50,000 records from 4,047 feed samples. International feed nutrition data primarily referenced publications from the United States, Japan, Brazil, France, Russia, and well-known feed nutrition companies such as DEGUSSA and CVB.

In summary, this study encompasses approximately 500,000 total data records with over 6 million data items. Regarding data standardization and specification, the platform overcame the limitations of the international eight-category feed raw material classification system by further subdividing into 16 subcategories based on the characteristics of individual nutrients or combinations of multiple nutrients in each feed raw material category. Following the international Dublin Core Element metadata standard, the platform formulated description specifications for 16 categories of Chinese feed raw materials, forming a distinctive Chinese feed raw material classification method that addresses the technical bottleneck of digital description and database management caused by the complexity of feed types and processing technologies in China. By comprehensively considering the evolution of evaluation methods and indicators for feed raw materials' effective energy values, digestible and metabolizable proteins, amino acids, and minerals, the platform established attribute data standards for 16 categories of Chinese feed raw materials.

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3 Platform Development

3.1 Main Challenges in Platform Development

First, regarding data processing, feed raw material nutrient data are influenced by numerous factors including origin, variety, processing conditions, and storage techniques. The China Feed Nutrition Big Data Analysis Platform must accurately reflect data sources and backgrounds. In addition to data obtained from projects undertaken by the authors' research team, extensive collection and digital organization of nutritional data on feed resources from relevant literature are required to increase sample sizes of the same varieties and characteristic parameters, continuously expanding data resource construction and the platform' s fundamental data volume to enhance data representativeness and reference value.

Second, regarding technology development, there is a need to deeply explore correlations among nutrients in feed raw materials. Nutritional values of feed raw materials exhibit variation, and the platform' s data represent arithmetic means of numerous feed raw material samples. Therefore, dynamic models for feed raw material nutritional values must be established to predict effective nutrient data—which would otherwise require animal feeding experiments—from proximate nutrient data, and these models must be embedded into platform construction.

Third, regarding data security and maintenance, on one hand, the massive data storage system used for platform construction must provide high-level data protection and support disaster recovery functions. On the other hand, research on security management and sharing technologies for the feed nutrition big data platform is needed, with strict formulation of confidentiality catalogs, time limits, hierarchies, and declassification conditions for network and archival data to ensure data publication and sharing comply with national regulations.

3.2 Platform Development Technical Route

[Figure 1: see original paper]

3.3 Platform Overall Architecture

As shown in [Figure 2: see original paper], the platform' s overall architecture comprises two major components: digitization of feed nutrition attribute data and digitization of feed sample spatial data. The attribute data digitization architecture includes attribute data indexing, attribute data digitization, attribute data warehousing, and attribute data visualization. The spatial data digitization architecture includes spatial data indexing, spatial data digitization, spatial data filtering, and spatial data warehousing. The platform provides visualization analysis and comparison of all warehoused data, synchronously integrating feed nutrient queries and spatial distribution queries using GIS analysis technology. This ultimately enables geographic information thematic map analysis of feed types or varieties at the national level, designated feed types at the national level, all feed types within specified provinces, and designated feed types within specified provinces.

3.4 Key Platform Construction Technologies

The big data analysis platform primarily manages digital feed nutrient data that can be described numerically.

(1) Data Management Methods. The platform' s database design employs MySQL 8.0.28 Chinese version network database. This database provides multiple storage engines suitable for different applications, allowing users to select appropriate engines for high-performance service experiences. It supports various popular programming languages including C, C++, Java, Perl, PHP, etc. Platform development utilizes PHP language, a general-purpose open-source scripting language that incorporates advantages from C, Java, and Perl. It is easy to learn, widely used, primarily suitable for Web database development, and offers superior database access performance and efficient management.

(2) Data Analysis Methods. The first approach is direct visualization comparison of original data. For example, comparing different nutrients within the same feed category, such as proximate nutrient profiles, protein and amino acid profiles, amino acid utilization profiles, and mineral element profiles, with display formats including curves, histograms, and column charts. Through visual comparison, the impact of origin, variety, processing conditions, and storage techniques on nutrient composition data of the same feed raw material can be intuitively reflected. The second approach is model analysis, primarily predicting unknown nutrients from known nutrients. Typical models employed include multiple linear regression models and single-factor orthogonal polynomial regression models. These methods are primary approaches for large-sample multivariate data analysis. The dynamic models established can effectively predict variations in feed raw material nutritional values, particularly providing effective nutrient data rather than merely attribute description data, thereby promoting value-added data utilization.

(3) Data Query Methods. The first method for global platform queries is full-text retrieval, enabling comprehensive coverage of database record contents including characters, Chinese text, and numerical data. The second is QR code query technology, facilitating the transfer of queried data, text, and images. The third is GIS-based query [8], primarily achieving integration of designated feed attribute data with corresponding spatial location data to enable spatial distribution queries of data characteristics and obtain various types of thematic maps. For example, spatial distribution maps of nutrient abundance and deficiency characteristics for specified nutrients such as corn, wheat, and soybeans across China.

(4) GIS Analysis Platform Support System. This system is based on the WEB GIS module of "Baidu Private Network Map (Du Geographic Information System, DUGIS)" [8]. This system offers significant advantages in spatiotemporal data services, spatial visualization analysis services, and data management, meeting the requirements for spatial analysis of feed nutrition big data, particularly providing technical support for analyzing the spatial distribution attributes of feed sample nutrients and abundance-deficiency patterns of specific nutrients.

(5) Data QR Code Conversion Technology. The platform employs Quick Response (QR) code technology, which, in addition to advantages such as large information capacity, high reliability, ability to represent Chinese characters and images, and strong security and anti-counterfeiting features, also offers ultra-high-speed and omnidirectional reading capabilities [9]. This satisfies the requirements for identification and traceability of feed composition and profiles. While facilitating convenient data sharing and downloading, it enables classified and graded limitation of published and shared content, providing reliable technical assurance for the security management of the feed nutrition big data platform.

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4 Platform Main Functions

The platform provides visualization analysis of all warehoused feed nutrient data, enabling intuitive comparison of single or multiple feeds across various nutrients and graphic modes. Simultaneously, through QR codes, it provides real-time mobile sharing and downloading of all feed nutrition attribute data and feed entity sample traceability images. Second, the platform constructs regression models that predict other effective nutrients from known proximate nutrients online, providing dynamic analysis of nutrient variation in feed raw materials. Finally, based on GIS technology, the platform integrates proximate nutrient and major mineral element content data with geographical location information, enabling distribution queries and comparative analysis of feed nutrition data geographic information, while also providing various data download methods.

4.1 Online Visualization Analysis of Feed Nutrients

4.1.1 Profile Analysis of Single or Multiple Feed Nutrient Contents [Figure 3: see original paper] illustrates the selection of a single feed—corn—for dynamic analysis of a specified series of nutrients (amino acids). The amino acid composition profile can be analyzed online, allowing clear identification of abundance-deficiency patterns of individual amino acids. The resulting graphics can be downloaded as files or transferred to mobile phones by scanning the QR code below for convenient sharing. Additionally, multiple feeds can be simultaneously selected for comparative analysis across multiple nutrients. As shown in [Figure 4: see original paper], specifying four feed raw materials (corn, extruded corn, wheat, and rye) for comparison of six amino acids' standardized ileal digestibility (SIAA) data for pigs, the output graphic mode can be preselected as line charts, column charts, etc. This approach can be extended to various comparative analyses of other nutrients across multiple feeds.

4.1.2 QR Code-Based Attribute Data and Traceability Queries Based on feed sample collection scene images and test data, this study constructed a QR code-based data and image query system to facilitate nutrient data queries and traceability of sample origins for convenient access. The system generates corresponding QR codes for each feed sample, enabling interconnectivity with the backend database. Once data in the database are modified or supplemented, scanning the QR code shown in [Figure 5: see original paper] allows feed attribute data including images to be accessed on mobile devices.

4.1.3 Dynamic Analysis of Nutrient Variation in Major Feed Ingredients [Figure 6: see original paper] presents dynamic variation analysis of crude protein and crude fiber in 163 soybean meal samples from the feed database, including data from the National Research Council (NRC) 2012 "Nutrient Requirements of Swine" [10] and the French National Institute for Agricultural Research (INRA) 2008 "Feed Composition and Nutritional Value Tables" [11]. The figure effectively reflects that with improvements in soybean varieties and extraction/dehulling technologies, crude protein content has steadily increased to approximately 48%. In contrast, crude fiber content shows greater fluctuation but is primarily concentrated around 6.5%. After statistical analysis and processing, the crude fiber data published in the nutrient composition tables are represented by the arithmetic mean values indicated by green dots in [Figure 6: see original paper] [7].

[Figure 7: see original paper] shows the distribution of calcium and phosphorus content variations across different batches of five phosphate sources (dicalcium phosphate, monocalcium phosphate, defluorinated tricalcium phosphate, calcium dihydrogen phosphate, and tricalcium phosphate). The results indicate significant differences in calcium and phosphorus content between batches. Therefore, when utilizing relevant data, detection-based values must be used as the foundation; otherwise, incorporation into formulation calculations will result in substantial errors affecting the actual calcium and phosphorus content in diets.

4.1.4 Online Prediction of Other Nutrients from Known Nutrients

Based on large sample data in the database, with the goal of predicting lysine (Lys) content in cereal grains (feeds numbered with "407" prefix in the database), crude protein (CP) content was selected as the sole independent variable, yielding 481 usable samples. After regression statistical analysis of all data, the results are shown in [Figure 8: see original paper]. The model obtained through linear regression is presented in Equation (1):

$$\text{Lys } (\%) = 0.159 + 0.017 \times \text{CP } (\%) \quad n = 481, R^2 = 0.58, \text{RSD} = 0.025, P < 0.01$$

Regression analysis indicates that the model generally converges to a linear relationship ($P < 0.01$), but the correlation coefficient is not very high ($R^2 = 0.58$). The reason is that under the premise of selecting all cereal grain feeds as a large sample, Lys content exhibits considerable dispersion. If processed according to specific feed types within cereal grains—for example, separately treating corn, wheat, barley, sorghum, and their processing by-products—the dispersion can be significantly improved. Research by Pan et al. [12] has confirmed that classification-based prediction of feed energy values through such processing substantially improves model regression performance.

4.2 GIS-Based Analysis

4.2.1 Spatial Attribute Analysis of Feed Chemical Composition The feed samples and distribution regions incorporated into GIS visualization analysis are shown in [Figure 9: see original paper], involving 40 types of commonly used livestock and poultry feeds distributed across 31 provinces. Data primarily originated from the Ministry of Science and Technology' s special basic work project "Investigation and Database Construction of Major Livestock and Poultry Feed Resources and Their Mineral Element Content and Distribution in China" (2014FY111000) [7]. After digital processing, all data were networked and entered into the China Feed Nutrition Big Data Analysis Platform.

As shown in [Figure 9: see original paper], selecting all feed raw materials and provinces yields proximate nutrient content data for 4,003 feed samples, primarily including dry matter, crude protein, crude fat, crude fiber, crude ash, and nitrogen-free extract, generating a national geographic information map of feed chemical composition spatial attributes. If only one province is selected, such as Sichuan Province, with all feed types checked, a geographic information map of feed chemical composition for the designated province is obtained for intra-provincial comparison. Conversely, if only a single feed such as corn is selected across all provinces, a national geographic information attribute map for all 1,163 corn samples is obtained to compare nutrient characteristics across different longitudes, latitudes, or regions. Therefore, by selecting different combinations of feed types and sampling regions, visualization analysis of different feed nutrients and spatial attributes (geographic locations) can be freely performed to obtain various thematic geographic information maps and comparative analyses of nutrient characteristics among different feed samples. The rich map information displayed in [Figure 10: see original paper] cannot be expressed by structural databases. Circles in different colors and shades represent different feed samples and sampling locations (based on specific longitude and latitude), and can also display scenarios with different sample numbers at the same location and for the same feed type. For example, the top portion of [Figure 10: see original paper] uses Renshou County, Meishan City, Sichuan Province as an example, where the platform automatically pops up a window displaying proximate nutrient content data for two corn-rapeseed meal samples from Tacheng City, Xinjiang. Utilizing GIS spatial attribute characteristics allows convenient viewing of data for different feed types across different regions, and the "Data View" module enables rapid browsing of all proximate nutrient data for all feed samples. This approach facilitates quick queries, comparisons, and visualization-based macroscopic analysis of feed attribute data based on spatial distribution.

4.2.2 Geographic Information Mapping and Analysis of Major Mineral Elements in Feed Samples Similar to [Figure 9: see original paper], under the major mineral element content option for feed samples, selecting all feed raw materials and all provinces yields major mineral element content data for 4,037 feed samples, generating a national geographic information map of major mineral element content and spatial attributes. If only one province is selected, such as Henan Province, with all feeds checked, a geographic information analysis map of major mineral element content for 244 different feed samples from the designated province is obtained ([Figure 11: see original paper]), facilitating comparison of mineral element content patterns across different feed types within the same province. Similarly, circles in different colors and shades represent different feed samples and sampling locations (primarily based on counties and cities). The top portion of [Figure 11: see original paper] uses Song County, Luoyang City, Henan Province as an example, where the platform automatically pops up a window displaying major mineral element content data for wheat samples. Conversely, if only a single feed such as corn is selected across all provinces in [Figure 9: see original paper], a national geographic information map of major mineral element content for all 1,163 corn samples is obtained to compare abundance-deficiency patterns of major mineral elements across different longitudes, latitudes, or regions. Furthermore, utilizing GIS spatial attribute characteristics allows convenient viewing of major mineral element data for different feed types across different regions. The "Data View" module enables rapid browsing of all major mineral element content data (calcium, phosphorus, sodium, magnesium, copper, iron, manganese, zinc, selenium, chromium, lead, arsenic, etc.) for all feed samples, and allows querying of relevant results for any of the 40 typical feed raw materials in the platform. This facilitates quick queries, comparisons, and visualization-based macroscopic analysis of major mineral element data based on feed spatial distribution.

The aforementioned rapid queries and data analysis comparisons of feed nutrients based on network databases and GIS technology not only provide convenience for data users but also facilitate data downloading and sharing. However, deeper statistical analysis and mining require specialized micro-level research. Relevant preliminary studies have been conducted in this area. For example, Liao et al. [13], Chen et al. [14], and Zhang et al. [15] reported statistical analysis patterns of regional content characteristics of major mineral elements or specific mineral elements in feed. Among these, Liao et al. [13] found that mineral element contents (calcium, copper, manganese, zinc, and selenium) in different types and regions of feed raw materials in China vary considerably. The copper, manganese, zinc, and selenium contents in commonly used basal diets for pigs and chickens in various regions can partially or fully meet the requirements of pigs and chickens for these nutrient elements. However, in actual diet formulation design for livestock and poultry, due to complex sources of feed raw materials and cross-regional usage patterns such as "northern grain to the south" and "southern grain to the north," coupled with significant differences in utilization rates of certain mineral elements in plant-based feeds, careful consideration is required. For instance, the feed composition tables in the NRC's "Nutrient Requirements of Dairy Cattle" [16] indicate that utilization rates of iron, copper, manganese, zinc, iodine, and selenium in plant feeds are 10%, 4%, 0.75%, 15%, 85%, and 100%, respectively, showing a pattern where higher content correlates with lower utilization. Therefore, in data selection for specific feed formulation optimization, feed nutrient utilization data should be prioritized. The feed data tables compiled in the authors' team's previously published works, including "Comprehensive Technology Platform for Precision Pig Farming" [17], "Dairy Cow Nutrition Parameters and Typical Diet Formulations" [18], and "Evolution, Models, and Feed Composition Tables of the CNCPS System" [19], all summarized feed nutrient utilization data to ensure accuracy in formulation calculations. Thus, rational utilization of mineral elements inherent in feed raw materials is a complex and technically demanding consideration.

5 Summary and Outlook

Feed nutrition fundamental data is the basic scientific support for the feed processing industry and an important component of the grain processing industry. Over the past 40-plus years of reform and opening up, China's feed processing industry has experienced emergence, development, and maturation, evolving into a large industry with solid theoretical foundations, complete technical categories, rich product varieties, and stable market development. Currently, the most significant factor constraining the development of China' s feed processing industry is the serious insufficiency of feed resource reserves. The protein resource gap has gradually expanded, and the rapid increase in dependence on international markets for energy feed resources—particularly corn—has transformed feed grain security into the primary contradiction in China' s food security issue. Therefore, how to develop and exploit all available feed raw material resources in China, improve resource utilization efficiency, and gradually alleviate resource constraints presents severe challenges but also unprecedented opportunities for China' s feed science research.

The China Feed Nutrition Big Data Analysis Platform created in this study comprehensively and digitally collected and organized existing feed resource types, spatial distribution, feed nutrient content, and nutritional value characteristic data, as well as livestock and poultry nutrient requirement data. The platform provides visualization analysis and comparison of all warehoused data, GIS-based distribution queries and abundance-deficiency pattern analysis of feed nutrient spatial attributes, and various data download methods including Excel spreadsheets, PDF, and QR code data transfer modes, offering convenient platforms and analytical tools for querying and sharing existing feed science data.

The platform's current functional services require further expansion, primarily in three aspects: First, strengthening feed nutrition data resource construction to expand the platform's fundamental data volume; second, categorically providing empirical or mechanistic models that predict unknown effective nutrients from known basic data, particularly adding computational tool modules for effective predictive models; and third, comprehensively embedding online web-based feed formulation optimization systems and complete nutrient diagnosis systems for formulations to provide computational tools for developing new feed products, such as low-protein diet optimization technology. Ultimately, this will achieve one-stop feed nutrition data services and maximize data value-added utilization.

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Note: Figure translations are in progress. See original paper for figures.