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Spatiotemporal Analysis of Food Programs of Engineering Education Accreditation in the mainland of China

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Abstract: Engineering education accreditation serves as a globally recognized quality assurance mechanism that ensures the competence and international competitiveness of engineering graduates. However, systematic investigations into accreditation patterns within food-related programs remain limited. This study provides the first spatiotemporal analysis of accredited food program sites in mainland China based on official data from the China Engineering Education Accreditation Association (CEEAA). The results revealed a clear three-phase development process. From 2008 to 2016, accreditation activity was minimal, limited to a few leading universities. Growth accelerated after the accession of China to the Washington Accord in 2016, peaking in 2022 with 19 newly accredited food program sites as the accreditation scope expanded to include fields beyond food science and engineering. Spatially, accredited food program sites were highly concentrated in economically developed eastern and central provinces such as Jiangsu (9 sites), Shandong (7), and Henan (7), while many western and less-developed provinces reported few or no accredited programs. Food science and engineering dominated the accreditation landscape, whereas specialized fields such as grain, dairy, and brewing engineering were accredited in only a handful of universities. Correlation analysis showed that the number of accredited programs was strongly associated with regional economic output (R = 0.7257, $p < 0.001$) and food industry scale (R = 0.7139, $p < 0.001$). These findings highlight significant regional and structural disparities in the accreditation of food programs and provide evidence-based insights for optimizing resource allocation, strengthening support for underrepresented regions, and promoting the development of specialized disciplines. The study offers a novel perspective on the role of engineering education accreditation in shaping the cultivation of engineering talents for the sustainable transformation and upgrading of food industry in China.

Keywords: engineering education accreditation, food program, sustainable development, spatiotemporal analysis, higher education.

INTRODUCTION

The food industry plays a pivotal role in safeguarding public health, ensuring food security, and driving sustainable growth of economy and society [1,2]. With the rapid expansion of global populations and the rising demand for high-quality, safe, and nutritious food, the food industry faces significant challenges related to food safety, sustainable processing, and nutritional adequacy [3-6]. Addressing these challenges requires not only technological innovations in food science and engineering but also a strong foundation of human capital capable of bridging the gap between scientific advances and industrial applications[7,8]. In this context, the cultivation of highly qualified professional talents in food programs has become a strategic priority for both governments and industry stakeholders.

In the era of globalization, engineering education assumes an indispensable role, aiming to cultivate outstanding engineering talent capable of meeting future industrial and societal demands, thereby driving socio-economic development [9,10]. As the core drivers of technological innovation, the quality of engineers produced is directly correlated with future industrial capacity and prospects for sustainable development [11,12]. Consequently, the reform and internationalization of engineering education have emerged as critical trends in global higher education [11,13].

To safeguard and enhance educational quality, engineering education accreditation has become an internationally accepted quality assurance system [14,15]. This framework, often guided by mutual recognition agreements such as the Washington Accord, employs a set of rigorous evaluation standards to ensure that engineering graduates possess competencies that align with globally recognized professional benchmarks [16,17]. Central to the accreditation process are the principles of Outcome-Based Education (OBE) and a commitment to continuous improvement [18-22]. Grounded in international frameworks such as the Washington Accord, accreditation facilitates the mutual recognition of engineering qualifications across signatory nations, thereby enhancing the global mobility and employability of graduates [15-17]. The core objective of accreditation is to elevate the quality of engineering programs by promoting a cycle of continuous improvement and ensuring the achievement of effective learning outcomes [18,19]. And institutions are required to establish a comprehensive, closed-loop system of self-assessment, program evaluation, and quality monitoring [23-25] to guarantee that educational outcomes are effectively aligned with industry requirements and evolving societal challenges [17,19,26]. This international standard of quality assurance not only elevates the intrinsic quality of engineering education but also significantly enhances the global mobility of engineering professionals[27,28].

Within the broader narrative of global sustainable development, a challenge of paramount importance, food systems play a critical role [29,30]. These systems are intrinsically linked to global environmental, social, and economic challenges, including resource scarcity, climate change, and ecosystem degradation [31-33]. A modern and sustainable food system is foundational to achieving global food security, improving human well-being, and preserving planetary health [34,35]. And the establishment of sustainable food systems (SFS) is deeply interconnected with the sustainable development goals (SDGs) of the United Nations, spanning social, economic, and environmental dimensions [7,36,37]. Therefore, cultivating engineering talent equipped with a sustainability-oriented mindset is crucial for constructing a more sustainable world [16,38,39]. Engineering education is a key pathway to achieving sustainable development, while sustainable development is the fundamental mission and ultimate value of engineering education [40].

Against this backdrop, engineering education in the mainland of China, particularly within food programs, faces a unique set of opportunities and challenges. As the largest manufacturing power of the world and home to the largest engineering education system, China shoulders a significant responsibility for future technological and industrial development and the quality of engineering graduates in the mainland of China has a decisive impact on future technological development [41,42]. Since becoming a full signatory to the Washington Accord in 2016, China has entered a new phase of accelerated reform in engineering education, with program accreditation serving as a key instrument for quality enhancement [43-46]. Food programs, such as food science and engineering and food quality and safety, are of strategic importance to food security, modernization of the food industry and public health[47]. However, despite this strategic significance, a systematic analysis of the spatiotemporal evolution, regional disparities, and structural characteristics of accredited food programs in the mainland of China is currently lacking in the academic literature.

To address this research gap, this study conducted a comprehensive spatiotemporal and statistical analysis of official data from the China Engineering Education Accreditation Association (CEEAA) to systematically investigate the developmental trends and distribution patterns of accredited food program sites in the mainland of China. The findings are intended to provide an empirical basis for understanding the interplay between engineering education and food industry development, and generate policy-relevant insights into how accreditation outcomes can be optimized to support the sustainable transformation of the food industry. Taken together, these contributions underscore the strategic role of food-related engineering education in advancing food safety, nutrition, and sustainability for the future of global food systems.

MATERIALS AND METHODS

Data Sources

Data on accredited food programs was collected from the official website of the China Engineering Education Accreditation Association (CEEAA), which publishes the annual list of accredited programs and institutions. The dataset covers the period 2008-2023 and includes 5 program types: Food science and engineering, food quality and safety, grain engineering, dairy engineering, and brewing engineering. For each program, the year of accreditation, institution, and geographic location were recorded.

Data regarding provincial Gross Domestic Product (GDP) and the output values of primary, secondary, and tertiary industries were obtained from the National Bureau of Statistics of China. And data for the total output value of the food industry and the number of food enterprises above the designated scale in the region were sourced from 2023 China Food Industry Yearbook [48]. Supplementary information, including institutional profiles and regional classifications, was retrieved from the Ministry of Education of China and the official websites of the respective universities.

Statistical Analyses

All statistical analyzes were performed using R software (version 4.3.1, R Foundation for Statistical Computing, Vienna, Austria). Figures were generated with the packages ggplot2 and pheatmap. The Ward method was adopted as the clustering algorithm, and Euclidean distance was used as the dissimilarity measure. Cluster dendrograms were generated to visualize relationships among provinces and universities based on the number and type of accredited food program sites.

Pearson’s correlation coefficients (R) were calculated to assess the relationship between the number of accredited food program sites and economic indicators, including GDP, industrial output values, and food industry metrics in correlation analysis. Statistical significance was evaluated at $p < 0.05$.

Visualization and Mapping

Geographical distributions of accredited food programs were mapped using ArcGIS 10.8 (ESRI, Redlands, CA, USA). Choropleth maps were constructed to show the spatial distribution across provinces, and bubble plots were used to illustrate the relative scale of accredited sites.

RESULTS

Temporal Growth of the Accredited Food Program Sites

As shown in Figure 1, from 2008 to 2016, the number of accredited program sites remained relatively low, ranging from 1 to 3 sites per year, suggesting that engineering education accreditation in food programs was still in its nascent stage. In 2008, the Food Science and Engineering program in Jiangnan University and Ocean University of China was initially accredited, followed by Nanchang University in 2009, underscores the early involvement of historically strong institutions in shaping the trajectory of quality assurance within the engineering education of food.

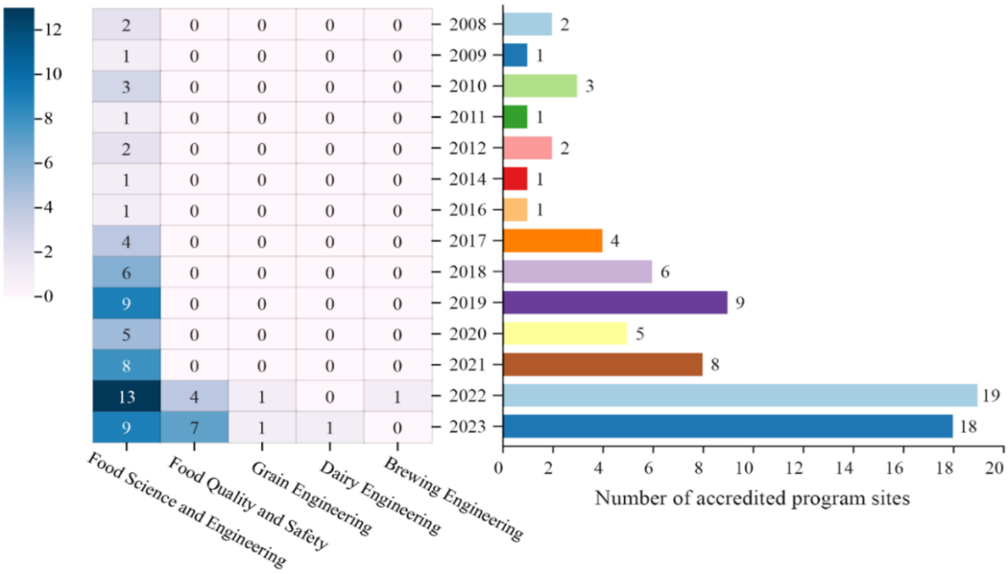

Figure 1: The numbers of accredited food program sites in different years

Afterwards, a noticeable increase of the number of accredited food program sites was observed between 2017 and 2021, with nine program sites accredited in 2019. This growth was largely driven by the impetus of the formal accession of China to the Washington Accord.

The most substantial growth occurred between 2022 and 2023, peaking at 19 newly accredited sites in 2022, indicating an accelerating trend in the accreditation of food programs and a rapid expansion of accreditation activities during this period. The primary reason for the growth is that, from 2019, the scope of accreditation was no longer limited to Food Science and Engineering and other food-related programs, such as food quality and safety, grain engineering, dairy engineering and so on, were also included in the accreditation system. However, due to the impact of the COVID-19 pandemic beginning in 2019 and coupled with the time-consuming nature of the accreditation process, a substantial increase in the number of accredited programs did not become evident until 2022. This growth phase may also be interpreted as a manifestation of regional and institutional recognition of the strategic importance of engineering education in ensuring national food safety, industrial innovation, talent development and sustainable development.

Geographical Distribution of the Accredited Food Program Sites

The geographical distribution of accredited food program sites in the mainland of China demonstrates pronounced regional disparities (Figure 2). Provinces and municipalities in the eastern and central regions account for the highest number of accredited food program sites. Jiangsu leads the nation with 9 accredited food program sites, followed by Shandong (7) and Henan (7). Other provinces in these regions, including Shanghai (5), Zhejiang (4), Hubei (4) and Anhui (3) also report relatively high numbers of accredited food program sites, indicating strong institutional capacity and sustained investment in food engineering education. These provinces are also major centers of the agri-food industry, which likely promote the alignment between regional industrial demands and academic program development.

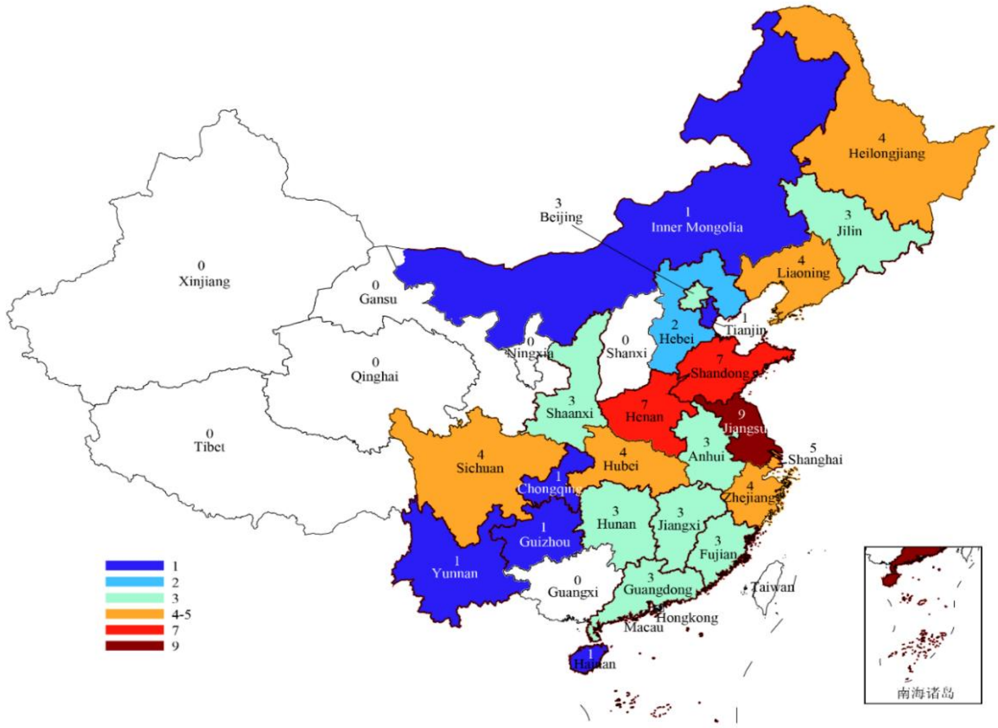

Figure 2: Geographical distributions of the accredited food program sites

In the central-southern region, Hunan, Jiangxi, Fujian and Guangdong each host 3 accredited food program sites, reflecting a moderate and balanced distribution. Similarly, in the northeastern region, Liaoning (4), Jilin (3) and Heilongjiang (3) display medium-level accreditation activity. In the western region, Shaanxi and Sichuan report 4 and 3 accredited program sites, respectively. These provinces, serving as major agri-food industry centers, illustrate how industrial demand can drive the growth and orientation of academic programs.

In contrast, provinces and municipalities in the western and less economically developed regions have far fewer accredited food program sites. Chongqing, Guizhou, Hainan, Yunnan, Inner Mongolia and Tianjin, record only 1 accredited food program site each. While, Guangxi, Tibet, Xinjiang, Qinghai, Gansu, Ningxia and Shanxi have no accredited food-related program of engineering education.

Notably, Beijing and Shanghai, despite their smaller geographic size, host a relatively high number of accredited program sites, 3 and 5 respectively, demonstrating the influence of concentrated educational resources and policy support in metropolitan areas.

Collectively, the spatial distribution of accredited food program sites in the mainland of China demonstrates a pronounced regional imbalance, shaped by both historical development policy and current educational investment priorities [49]. These findings highlight the need for a more balanced national strategy to promote engineering accreditation in underserved areas, thereby fostering inclusive and sustainable development of food engineering education across China.

Analysis of the Distribution of Accredited Food Program Sites across Provinces

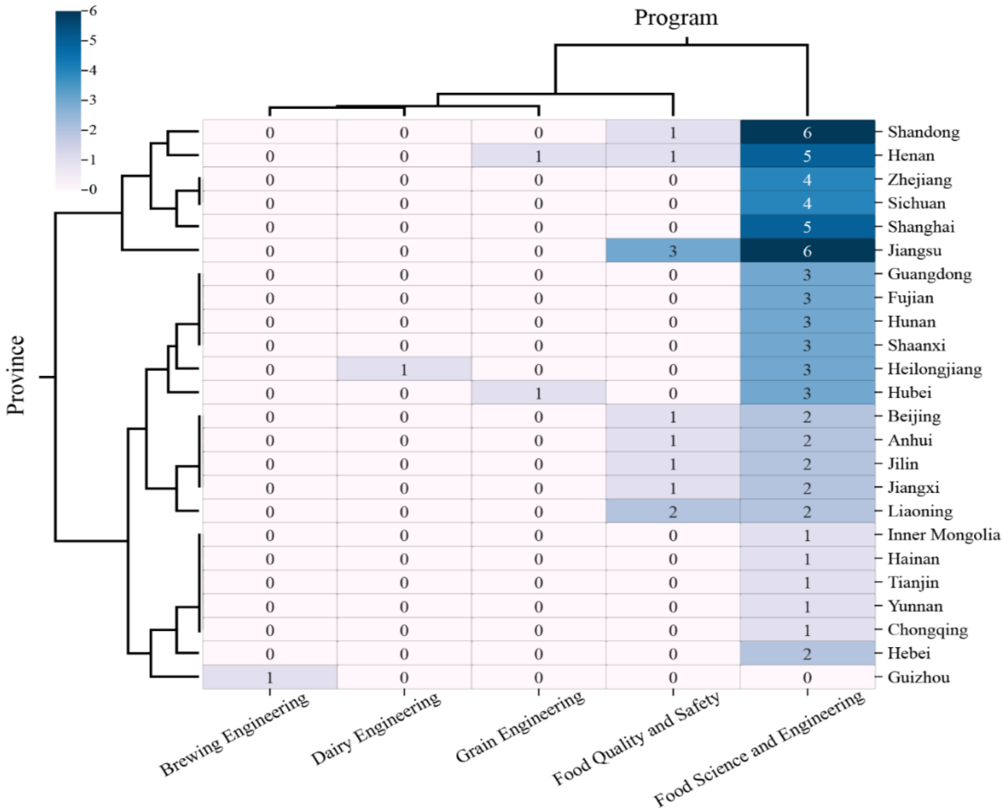

Figure 3: Cluster analysis of the distribution of accredited food program sites

To elucidate regional patterns and provide deeper insights into the disparities in accredited food programs of engineering education across the mainland of China, a hierarchical cluster analysis was performed based on the number and type of accredited food program in each province. The dataset includes five program types: food science and engineering, food quality and safety, grain engineering, dairy engineering, and brewing engineering and the numbers of each program sites.

As illustrated in Figure 3, the horizontal clustering results reveal that that food science and engineering constitutes a distinct and dominant cluster, representing the most widely distributed program with accreditation across 23 provinces. Along with food quality and safety, it accounts for the most prevalent program types, particularly concentrated in Jiangsu, Shandong, and Henan. In contrast, more specialized programs such as Brewing Engineering, Dairy Engineering, and Grain Engineering are sparsely distributed, with accreditation confined to a limited number of provinces, including Henan, Hubei, Guizhou, and Heilongjiang, thereby underscoring the uneven distribution of these programs across the country.

Vertically, the provinces cluster into four major groups. The first group, consisting of Jiangsu, Shandong, Henan, Zhejiang, Sichuan and Shanghai, hosts the largest number of accredited food program sites. Notably, within this group, the program of food science and engineering dominates in terms of accreditation, with Jiangsu leading the group with a total of 9 accredited food program sites (6 in food science and engineering and 3 in food quality and safety). Henan demonstrates a broad program profile, including food science and engineering (5) and food quality and safety (1), as well as grain engineering (1). Collectively, these provinces function as central hubs of food engineering education, likely supported by strong industrial bases and favorable policy environments. They serve as national benchmarks for comprehensive food engineering education, reflecting a mature higher education infrastructure, and diversified industrial demand.

The second group consists of Hubei, Heilongjiang, Shaanxi, Hunan, Fujian, and Guangdong, which exhibits a moderate number of accredited program sites in food science and engineering programs. In this group, the grain engineering in Hubei and the dairy engineering in Heilongjiang are notable, as both have successfully attained accreditation under the national engineering education framework. Another group includes Beijing, Anhui, Jilin, Jiangxi, and Liaoning, each of which has obtained accreditation in the programs of Food Science and Engineering and Food Quality and Safety, respectively, reflecting a balanced yet more limited program portfolio compared with other groups.

The fourth group comprises provinces with relatively low number of accredited program sites, including Inner Mongolia, Hainan, Tianjin, Yunnan, Chongqing, Hebei and Guizhou, each hosting only a single accredited program. Notably, the accreditation of engineering education in Guizhou is confined to niche fields such as brewing engineering, which likely reflects localized specialty industries (e.g., traditional fermentation) designed to cultivate targeted talents. Nevertheless, the overall scale of program offerings in these provinces remains limited, likely due to disparities in educational resources and weaker industrial demand for specialized food engineers. In contrast, western and less economically developed provinces, including Tibet, Xinjiang, Qinghai and Ningxia, lack accredited food programs entirely, underscoring a pronounced regional development gap in engineering education accreditation.

Taken together, the clustering patterns reflect a combined influence of industrial maturity, historical investment in higher education and regional policy support. Provinces with more diversified and abundant accredited food program sites are predominantly concentrated in economically developed regions with strong agri-food sectors. In contrast, the limited presence of accredited food program sites in western provinces highlights the need for targeted capacity-building efforts, including faculty development, infrastructure enhancement and incentive-based promotion of accreditation. Overall, the clustering analysis reveals an uneven geographic distribution of accredited food program sites, highlighting the importance of national policy interventions to promote more balanced development and strengthen capacity-building in food engineering education across diverse provincial contexts.

Correlation of Accredited Food Programs with Economic Conditions and Food Industry

To investigate the factors associated with the prevalence of accredited food program sites, a correlation analysis was performed to examine the relationship between the number of accredited program sites and various provincial economic indicators. As illustrated in Figure 4, the results of correlation analysis revealed a significant positive correlation between the number of accredited food program sites and the development level of regional economies and the food industry. Regions with more robust economies and larger industrial scales consistently host a greater number of accredited food program sites, suggesting a synergistic relationship between economic development and the establishment of specialized higher education.

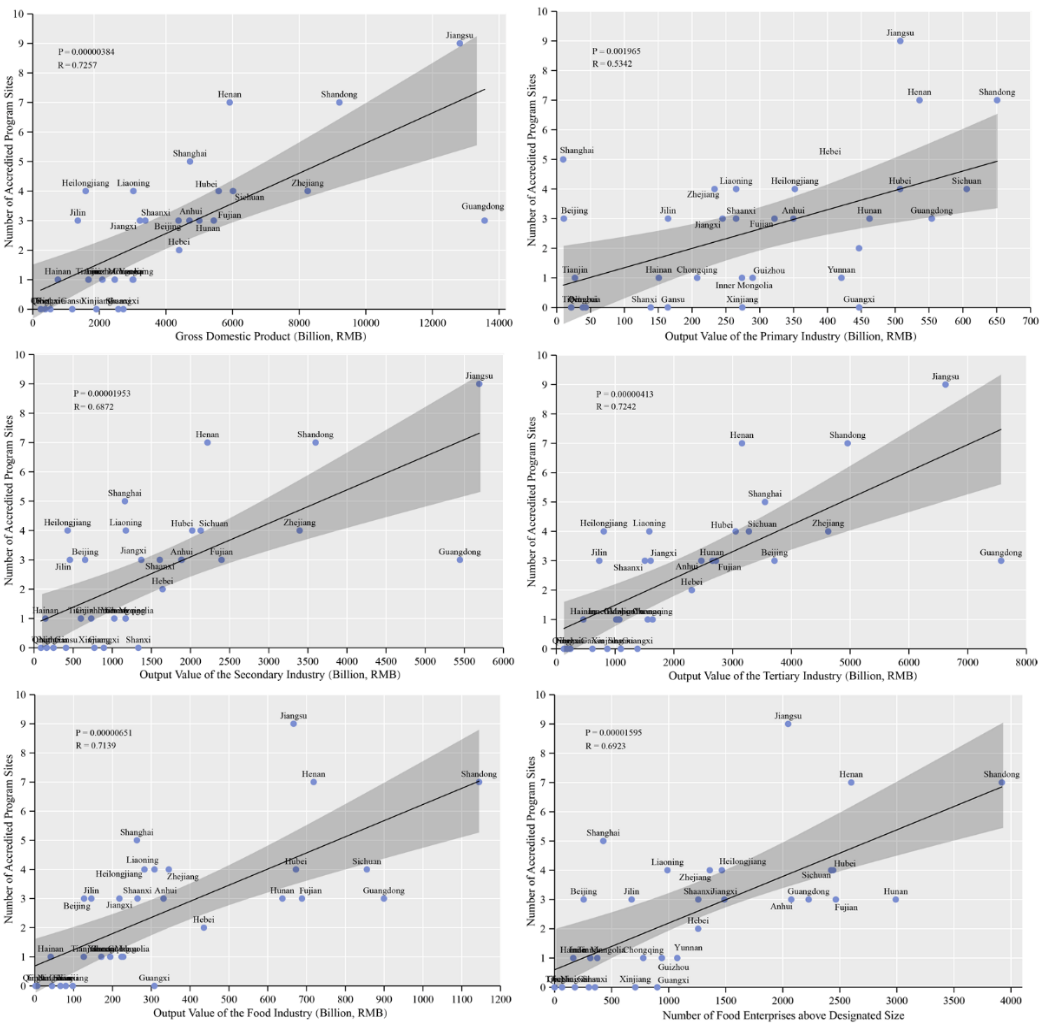

Figure 4: Correlation between accredited food programs and regional economic development

A significant positive correlation was observed between the number of accredited food program sites and provincial Gross Domestic Product (GDP) ($R = 0.7257$, $p < 0.001$). When disaggregated by industrial sector, this association was particularly pronounced with the output values of the tertiary (services) and secondary (industry and construction) industries, with correlation coefficients of $R = 0.7242$ ($p < 0.001$) and $R = 0.6872$ ($p < 0.001$), respectively. A moderate, yet statistically significant, positive correlation with the output value of the primary industry (agriculture, forestry, animal husbandry, and fishery) was also found ($R = 0.5342$, $p < 0.002$).

Similarly, this trend was mirrored within the food industry itself. A strong positive correlation was identified between the number of accredited food program sites and the total output value of the food industry ($R = 0.7139$, $p < 0.001$). Furthermore, a significant positive correlation was found with the number of food enterprises above the designated scale ($R = 0.6923$, $p < 0.001$).

In summary, the findings indicated that the prevalence of accredited food programs is closely intertwined with both macroeconomic health and the scale of the food industry. Regions with higher economic output and a larger industrial base are more likely to support a greater number of accredited higher education programs[50]. This suggests a symbiotic relationship wherein regional economic and industrial development fosters the growth of specialized, high-quality professional education, which in turn may support further industrial advancement. This trend is strongly aligns with the findings that there is an inextricable connection between the economy and the scale of higher education [51].

Analysis of the Distribution of Accredited Food Program Sites in Different Universities

To gain a more detailed understanding of the distribution of accredited food program sites in different universities, cluster analyses were conducted. As illustrated in Figure 5, the hierarchical clustering dendrogram indicates that *food science and engineering* (outermost ring) is the most widely accredited food program, present in nearly all listed universities except Guizhou University, Chuzhou University, and Changshu Institute of Technology. By contrast, specialized programs such as *brewing engineering, dairy engineering* and *grain engineering* are far less common, with accreditation limited to a small number of universities, including Guizhou University, Northeast Agricultural University, Henan University of Technology, and Wuhan Polytechnic University. Additionally, the food quality and safety program has also achieved accreditation of engineering education in Chuzhou University, Changshu Institute of Technology and 9 other universities. These patterns suggest that specialized and emerging programs are still emerging in the accreditation landscape and could benefit from stronger policy guidance and institutional support to foster their development.

As presented in Figure 5, Guizhou University emerges as a distinct cluster, being the only institution accredited for brewing engineering under engineering education standards. Chuzhou University and Changshu Institute of Technology are grouped together, as both have achieved accreditation exclusively in the food quality and safety program. Henan University of Technology and Wuhan Polytechnic University cluster due to their dual accreditation in grain engineering and food science and engineering, while Northeast Agricultural University stands apart with its unique combination of dairy engineering and food science and engineering accreditation. A broader cluster includes Beijing Technology and Business University, Dalian Polytechnic University, Jiangnan University, Jilin University, Jiangsu University, Nanchang University, Qingdao Agricultural University, Shenyang Agricultural University, and Henan University of Science and Technology, all of which have obtained accreditation in both food quality and safety and food science and engineering. By contrast, the remaining universities form a separate group, characterized solely by accreditation in food science and engineering.

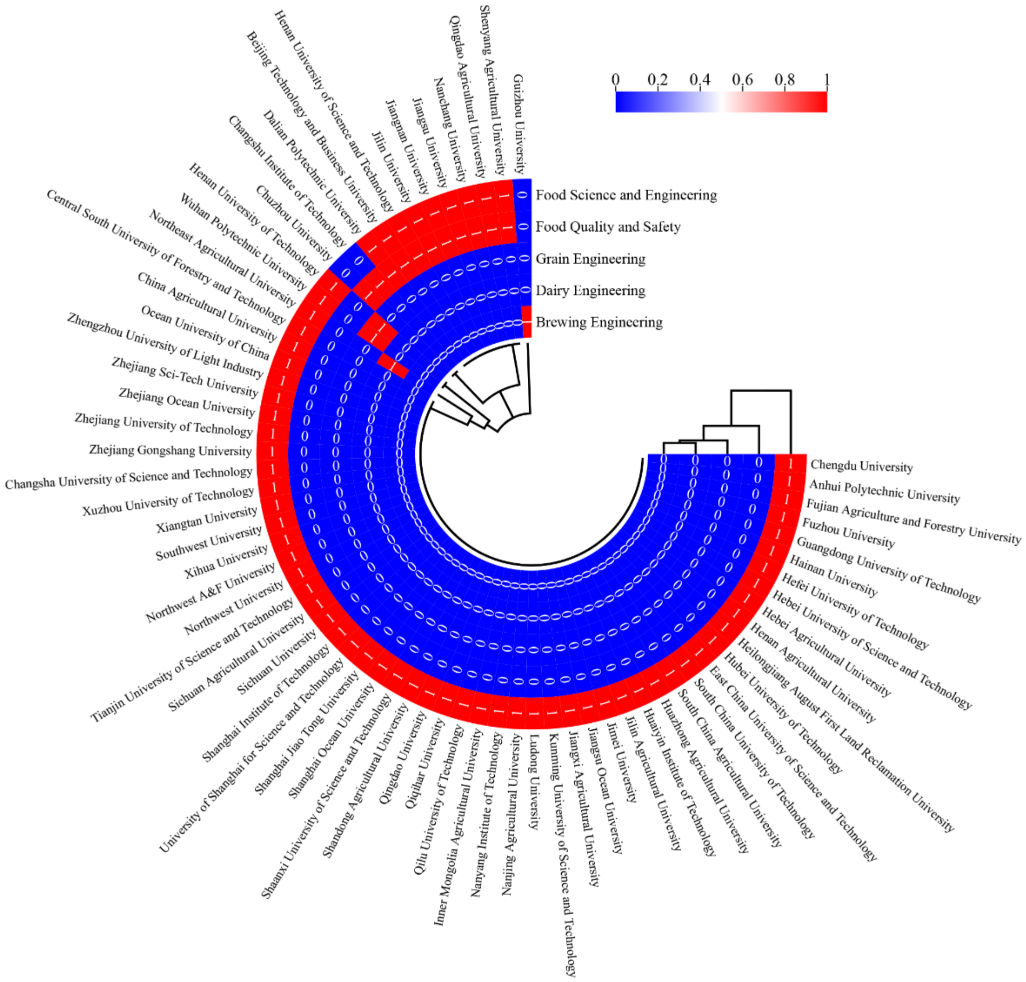

Figure 5: Cluster analysis of the distribution of accredited food program sites in universities

Several leading universities, including Jiangnan University, Jilin University, and Beijing Technology and Business University and so on, have obtained accreditation across multiple programs, such as food science and engineering, and food quality and safety. These universities have well-established traditions in food engineering education and maintain strong connections with industry and research institutions. Such advantages enable them to offer diverse programs that are closely align with national strategic priorities.

The current distribution of accredited food program sites across universities reflects a dynamic interplay between historical academic strengths, regional industrial needs, and strategic educational reforms. The observed clustering pattern underscores the importance of sustained expansion of accreditation, both across institutions and within specialized subfields, to cultivate robust and adaptable engineering talents for sustainable development of food industry in the mainland of China.

DISCUSSION

Temporal Dynamics of Accredited Food Program Sites

The temporal dynamics of accredited food programs exhibits distinct phased characteristics. The initial period (2008-2016) was marked by slow development, reflecting a preliminary exploratory stage for engineering education accreditation in the field of food. The participating institutions were predominantly leading universities with a strong historical foundation in the field, such as Jiangnan University, Ocean University of China and Nanchang University, whose pioneering efforts laid the foundation for the subsequent expansion of accreditation activities in food engineering education. A significant increase in accreditations occurred after 2017, reaching a peak in 2022, primarily driven by the policy momentum following official accession of China to the Washington Accord. This international agreement substantially incentivized universities in mainland China to pursue accreditation, aiming to enhance program quality and elevate the global competitiveness of graduates through internationally recognized standards.

Notably, the expansion of the accreditation scope, from the singular food science and engineering program to include additional programs such as food quality and safety and grain engineering, served as a direct catalyst for the surge in accreditations observed in 2022. However, the onset and subsequent impact of the COVID-19 pandemic from 2019 disrupted processes such as application reviews and on-site evaluations, creating a lag effect that explaining the approximately three-year gap between the policy implementation and the peak in accredited programs. This growth trend is not merely quantitative, it also reflects a strategic national emphasis on sustainable development in food, food security, industrial innovation, and talent development, to which regional governments and higher education institutions have responded proactively.

Regional Imbalance of Accredited Food Program Sites

The geographical distribution of accredited food program sites exhibits a pronounced imbalance, with a high concentration in the central and east regions and a sparse presence in the west. This pattern is closely correlated with the distribution of higher education resources and the level of regional economic development in the mainland of China. Provinces such as Jiangsu, Shandong and Henan are not only major centers for agriculture and the food industry but also leaders in higher education. This has fostered a virtuous cycle between industrial demand and talent supply that has resulted a high concentration of accredited food program sites. The success of these regions highlights that a strong local industrial base and sustained investment in education are critical drivers for the advancement of engineering education accreditation.

In contrast, western and less-developed regions have lagged significantly in this accreditation wave, with some provinces reporting no accredited food programs at all. This underscores a substantial gap in higher education development across regions and indicates that these areas may face challenges in cultivating food engineering talent that meets contemporary standards. Similar regional disparities have been documented in broader higher education studies, where economic development strongly influences accreditation outcomes [52]. Despite their smaller geographic sizes, municipalities such as Beijing and Shanghai, with highly concentrated educational resources, exhibit a high density of accredited food program sites, further highlighting the central role of quality resources in driving the accreditation of food programs.

Program Structure and Institutional Characteristics of Accredited Food Program Sites

From the viewpoint of program structure, food science and engineering program occupies a dominant position within the accreditation system, consistent with its role as a core discipline and its alignment with broad industry demand. By contrast, specialized programs such as brewing engineering and dairy engineering account for only a small number of accreditations, concentrated in a limited set of universities, Guizhou University for brewing engineering and Northeast Agricultural University for dairy engineering. This phenomenon, on the one hand, reflects a deliberate effort to align institutional specialization with local industrial ecosystems in order to cultivate targeted talent. On the other hand, it highlights considerable potential for expanding accreditation to encompass more specialized and emerging subfields, thereby enhancing the overall adaptability and diversity of engineering education in the food field.

At the institutional level, accredited food programs display a clear tiered pattern. Leading universities, such as Jiangnan University and Jilin University, have achieved multi-program accreditation based on strong disciplinary foundations, while most regional universities focus on food science and engineering accreditation. This differentiated landscape underscores the diverse missions and strategic orientations across universities. More importantly, it signals a key direction for the next stage of accreditation: encouraging leading universities to pursue excellence across multiple programs, while supporting regional universities in developing specialized, high-quality programs that meet needs of economic and social development.

CONCLUSIONS

This study provides the first systematic spatiotemporal analysis of accredited food program sites of engineering education in the mainland of China According to CEEAA data from 2008 to 2023. The findings revealed three distinct phases of development: an initial exploratory stage with limited participation (2008-2016), moderate growth after China's accession to the Washington Accord (2017-2021), and accelerated expansion in 2022-2023 following the broadening of accreditation scope.

Significant regional disparities were identified. Eastern and central provinces, such as Jiangsu, Shandong, and Henan, concentrated the majority of accredited food programs, while western and less-developed regions had few or none. This imbalance reflects the strong influence of economic development, industrial demand, and higher education capacity on accreditation outcomes. Correlation analyses further demonstrated that the number of accredited food program sites was strongly associated with regional GDP and the scale of the food industry, underscoring the symbiotic relationship between economic growth and higher education development.

At the program level, food science and engineering stand out as the core accredited program in the accreditation landscape. In contrast, specialized programs, such as grain engineering, brewing engineering and dairy engineering, were accredited only in a handful of universities, highlighting structural disparities in program development. At the institutional level, only a limited number of leading universities have attained accreditation across multiple food programs, whereas most universities focus on a single program, thereby reinforcing institutional differentiation.

In conclusion, although China has made substantial progress in the accreditation of food programs over the past decade, significant disparities remain across regional, programmatic, and institutional dimensions. To address these gaps, policies should focus on optimizing resource allocation, enhancing support for central and western regions, and promoting the development of specialized and emerging programs. Such targeted measures will contribute to a more balanced, inclusive, and high-quality accreditation system, thereby reinforcing the cultivation of engineering talents for the sustainable transformation and upgrading of food industry in China.

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