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Supply and Demand Analysis, Future Demand Forecast, and Countermeasure Studies for Forage Materials in China

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Abstract: With the improvement of living standards, the domestic consumption and production as well as the domestic demand for livestock products such as meat, poultry, eggs, and milk are increasing. Herein, we forecast the future demand for forage materials by analyzing changes in the supply and demand of forage materials in China and the changes in the future demand for domestic livestock and poultry products. The results show that the gap between the supply and demand of forage materials in China will continue to expand in the future; therefore, appropriate expansion of the cultivation of silage corn and development of the grass industry in agricultural areas are required to ensure an adequate domestic forage supply. Additionally, agricultural resources should be fully and rationally utilized, and the cultivation of crops, such as soybeans and rapeseed, should be expanded to increase the effective supply of domestic meals. Meanwhile, China should also completely and reasonably use the overseas agricultural resources to ensure an adequate supply of domestic forage materials.
Keywords: forage materials; supply and demand; forecast; countermeasures

1 Introduction

Corn is the most important component of livestock energy feeds, whereas soybean meal is the most important component of protein feeds. Under current conditions in China, with limited agricultural resources and the rapid development of livestock industries, the demand for raw materials for energy and protein feeds has rapidly increased [1], which has changed the structures of crop cultivation and agricultural product trade.

The demand for forage materials will continue to increase in China as a result of the rising domestic consumption rates of meat, eggs, and milk, which, in turn, is associated with improved living standards. Herein, the supply and demand of forage materials in China are predicted based on projections of the future demand for imported forage materials and of anticipated changes in the domestic demand for meat, eggs, and milk. These findings can assist with the formulation of a policy for modifying the agricultural planting structure in a scientific and rational manner and will contribute to the enhancement of China's food security.

2 Analysis of supply and demand of forage materials in China

Energy and protein feeds and forage demands were analyzed using different types of data on industrial forage obtained from *National Feed Industry Statistics* reports (National Feed Office). Production data on stocks and slaughter capacities relating to pigs, table poultry, egg-laying poultry, aquatic products, dairy cows, beef cattle, and meat sheep were obtained from the *Agricultural Statistics of the People's Republic of China* (China Agriculture

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Press).

2.1 Supply and demand of raw materials for energy feeds

2.1.1 Supply of raw materials for energy feeds

The cultivated area of corn has increased as a result of its increased purchase price. During the period of 2000–2015, the cultivation area of corn increased from 2.306×10^7 to 3.812×10^7 hm^2 (65%), while corn yields increased from 1.06×10^8 to 2.25×10^8 t (112%). Corn, the production of which has shown a clear shift northward at the national scale, is the only crop associated with significant increases in both cultivation areas and yields. Presently, the northern region has surpassed the Huang−Huai−Hai region as the largest corn-producing region in China. Heilongjiang and Inner Mongolia are simultaneously emerging as important new corn-producing provinces. In 2015, the cultivation area of corn in China was 3.812×10^7 hm^2, with the largest area located in Heilongjiang Province (5.821×10^6 hm^2), followed by Jilin Province (3.8×10^6 hm^2) and the Inner Mongolia Autonomous Region (3.407×10^6 hm^2). During the year 2000, the area of corn cultivation in Heilongjiang Province increased the most (4.019×10^6 hm^2), followed by those in the Inner Mongolia Autonomous Region and in Jilin Province, where the areas of corn cultivation increased by 2.109×10^6 and 1.603×10^6 hm^2, respectively.

Wheat and rice are the primary food rations in China. Considering their prices, they are also important substitutes in energy feeds in some regions of China, which generally does not affect people's basic supplies of rations. In China, sorghum and barley are commonly categorized as miscellaneous grains, occupying areas of 8.39×10^5 hm^2 (producing a yield of 2.75×10^6 t) and 4.47×10^5 hm^2 (producing a yield of 1.87×10^6 t), respectively, in 2015. Sorghum and barley are mainly used for industrial and forage purposes. Because the price of corn in China was high during the previous two years, imports of barley and sorghum by domestic feed enterprises increased significantly. In 2015, barley and sorghum imports amounted to 1.07×10^7 and 1.073×10^7 t, respectively.

2.1.2 Demands for raw materials for energy feeds

Our analysis revealed an increase in China's energy feed demand from 1.3×10^8 t in 2001 to 2.4×10^8 t in 2015. The data obtained for 2015 indicated that the energy feed demand of pigs reached 9.5×10^7 t, accounting for 39.2% of the total demand, followed by the feed demands of table poultry and egg-laying poultry, respectively, which were 4.668×10^7 t (19.2%) and 4.369×10^7 t (18.0%). An analysis of the energy feed demands of different regions in 2015 revealed that the demand was highest in Shandong (2.518×10^7 t), followed, in descending order, by Guangdong (2.071×10^7 t), Liaoning (1.842×10^7 t), Henan (1.783×10^7 t), and Hebei (1.737×10^7 t).

2.1.3 Analysis of balance in supply and demand of raw materials for energy feeds

In 2015, the total demand for materials used as components of energy feed in China was approximately 2.4×10^8 t. According to statistics released by the Ministry of Agriculture, China's annual corn yields have exceeded 2×10^8 t in recent years. Annual yields of wheat bran have ranged between 2.2×10^7 and 2.5×10^7 t, and imports of forage barley and sorghum exceeded 1×10^7 t in 2015. Forage prices have influenced the quantities of wheat and rice used in feed, with the quantity of wheat used in feed ranging between 2×10^7 and 3×10^7 t during the peak period of usage. In combination with imported corn, the quantity of basic raw materials used for energy feeds is approximately 3×10^8 t. China's corn deep-processing industry is well-developed, consuming between 5×10^7 and 7×10^7 t of corn annually under normal circumstances. Because of the sharp increase of corn price in the preceding two years, the amount of corn consumed by deep-processing industries in China has been greatly reduced. Specifically, the amount of corn that is annually consumed in deep processing is approximately 5×10^7 t as a result of imports of large quantities of dry and powdered cassava to partially replace requirements for corn starch.

The quantity of raw materials that can be directly used in energy feeds is approximately 2.5×10^8 t. In the southwestern mountainous areas, as well as in some rural areas, the needs for livestock feed were satisfied through supplementation with other agricultural products (e.g., potatoes), as well as weeds and leftovers. Thus, the supply and demand of raw materials for energy feeds is basically balanced.

2.2 Supply and demand of raw materials for protein feeds

2.2.1 Supply of raw materials for protein feeds

Soybean meal is the most important type of meal used in China. The substitutability of soybean meal is affected by many factors, and the demand for soybean meal in livestock and poultry industry is rigid [2]. Soybean meal is produced through a process of soybean oil extraction, which accounts for 78% of processed soybean products. In China, the spring crop of soybean (harvested once per year) is mainly produced in the northeastern region, and the

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summer soybean crop is mainly produced in the Huang-Huai-Hai River basin. Although the domestic demand for soybean has shown a continuous increase, the cultivation area of domestic soybean has decreased as a result of soybean imports [3]. In 2015, the cultivation area of soybean in China was 6.506×10^6 hm^2, and the yield was 1.179×10^7 t. Additionally, the low rate of oil production from domestic soybean crops and the long distances to areas where soybean meal is consumed have weakened the competitiveness of domestic soybean meal compared with other feed components.

Because of the low levels of efficiency in the planting and mechanization of domestic rapeseed, this crop is a relatively weak competitor with regard to attracting farmers [4] and is associated with very limited cultivation areas and yields. At present, domestic soybean meal is mainly produced from imported soybeans, and domestic rapeseed meal is gradually replaced by that produced from imported rapeseed. After the outputs and traded quantities of soybean and rapeseed meals are counted, the total net supply of domestic meal resources is obtained as ~7.8×10^7 t.

2.2.2 Demands for raw materials for protein feeds

Because of the increases in the production of and demand for domestic industrial feeds, the demand for raw materials for protein feeds has increased significantly—from 3.454×10^7 in 2001 to 7.497×10^7 t in 2015. A breakdown of the meal feed quantities required for different types of livestock in 2015 showed that pigs accounted for 31% (2.289×10^7 t) of the total demand for feed meal, followed by table poultry and egg-laying poultry, which accounted for 16% of the total meal feed requirements (1.205×10^7 and 1.168×10^7 t, respectively). Among different provinces in China, the demand for meal feed was highest in Shandong (7.57×10^6 t), followed, in descending order, by Guangdong (6.99×10^6 t), Hebei (5.76×10^6 t), Henan (5.02×10^6 t), Heilongjiang (4.76×10^6 t), and Liaoning (4.53×10^6 t).

2.2.3 Analysis of supply and demand balance of raw materials for protein feeds

Domestic soybean production in China, which is basically for food consumption, is declining, leading to very limited production of soybean meal. Consequently, soybean imports are unavoidable for satisfying the domestic demand for a large quantity of plant proteins. In recent years, the total supply of domestic meal resources has been approximately 8.35×10^7 t. This quantity is inclusive of domestically produced soybean, rapeseed, peanut, cottonseed, and sunflower seeds, along with crushed and imported soybean, rapeseed, and dry distillers grains with solubles. Moreover, limited exports of soybean meal are subtracted from this figure.

In summary, supplies of domestic plant proteins are sufficient owing to the importation of large quantities of soybean. Thus, the supply and demand of protein feeds is basically balanced, entailing a small surplus.

2.3 Supply and demand of crude forage

2.3.1 Supply of crude forage

Crude forage mainly comprises straw, forage grass, and silage corn, which are required for breeding and developing ruminants in China [5−7].

Currently, the total amount of straw produced from cereals and legumes in China is approximately 5.6×10^8 t. Of this amount, the quantity that can be used as forage to feed herbivorous livestock is 1.4×10^8 t. Ten provinces (three northeastern provinces, along with Henan, Hebei, Shandong, Jiangsu, Anhui, Sichuan, and Hunan) account for more than 80% of the total production of forage straw, with the production level being highest in Henan Province (1.5×10^7 t) [7].

Green manure is used not only for fertilizing fields and increasing yields but also as a highly nutritious animal feed. Data obtained from the *China Agriculture Yearbook* indicate that in the last two decades, the area of green forage cultivation was largest in 2003 (3.532×10^6 hm^2). However, from 2004 onward, the cultivation area has decreased steadily, and in recent years, it has remained constant at approximately 2×10^6 hm^2. Data for the last two years indicate that Inner Mongolia had the largest cultivation area (2.47×10^5 hm^2), followed by Jiangxi (7.8×10^4 hm^2), Ningxia (7.7×10^4 hm^2), and Chongqing (6.7×10^4 hm^2).

Silage corn is playing an increasingly important role in animal husbandry production in China. The processing of silage corn into silage forage allows the preservation of its nutritional value and provides a sufficient annual supply of high-quality feed for livestock.

2.3.2 Demand for crude forage

Among the ruminants that are bred in China, dairy cows are associated with the most rapid development, the largest farming scale, and the greatest demand for commercial forage.

(1) Demand for silage corn

Taking the stock number of dairy cows in China as 1.507×10^7 in 2015, the potential demand for corn silage was 3.07×10^8 t. The results of an investigation indicated that the average value of the corn storage capacity per hectare in Shandong was approximately 52.5 t. The required cultivation area of silage corn for breeding dairy cows in China is 5.857×10^6 hm^2. The silage corn demands of the major dairy cattle breeding provinces (and autonomous regions), including Inner Mongolia, Xinjiang, Hebei, Heilongjiang, Shandong, and Henan, are all above 2×10^7 t, and the cultivation areas required to meet these demands equal 9.22×10^5, 8.32×10^5, 7.63×10^5, 1.127×10^7, 7.513×10^5, and 4.189×10^5 hm^2, respectively.

Taking the stock number of beef cattle as 7.732×10^7 in 2015, the actual potential silage corn demand was 1.058×10^7 t, and the required cultivation area for silage corn was approximately 2.013×10^5 hm^2. Taking the silage corn demand of five sheep to be equivalent to that of one cow, the actual potential silage corn demand was approximately 6×10^6 t, and the cultivation area of silage corn was approximately 1.167×10^5 hm^2.

To satisfy the potential demand of silage corn for dairy and beef cattle, and for meat sheep in China, 6.175×10^6 hm^2 of silage corn would need to be cultivated, accounting for approximately 16% of the total cultivation area of corn in China, which was 3.813×10^7 hm^2 in 2015.

(2) Demand for forage grass

The development of the dairy industry requires increasing quantities of forage grass, especially high-quality hays. To satisfy the demand for high-quality forage in China, annual imports of alfalfa have increased, reaching 1.004×10^6 t in 2014 and 1.68×10^6 t in 2016. According to standard and scientific breeding practices established for dairy cows, the average annual consumption of hay per cow is approximately 2 t. Taking the total number of dairy cows in China as 1.5×10^7, the required annual supply of high-quality hay is 3×10^7 t; and taking the production of high-quality hay per hectare as 9 t, 3.33×10^6 hm^2 of planting land is required.

2.3.3 Analysis of supply and demand of crude forage

Domestic supplies of crude forage cannot satisfy the demand in China. However, the current demand can be reduced by decreasing the production performance of herbivorous livestock, supplementing feeds with other forage crops and crop straw (e.g., from potato and oil crops), and increasing the conversion rate of straw feed. The above data pertain only to the forage supply and demand relating to the basic nutritional requirements of herbivorous livestock.

With the rapid development of the breeding industries for dairy and beef cattle, as well as meat sheep, and continuous advances in industrialization, the demand for forage grass will increase further. Consequently, the gap between the supply and demand for high-quality forage grass will widen.

3 Projection of future forage demands in China

Three future scenarios for animal protein consumption in China (at low, medium, and high scales) were projected, in alignment with anticipated future changes in China's food consumption structure (especially Taiwan) [8,9]. The average annual consumption rates of meat, eggs, and milk for each of the three scenarios were, respectively, 72.5, 22.8, and 40.5 kg/person/year (first scenario); 80.5, 24.0, and 45.0 kg/person/year (second scenario); and 88.6, 26.4, and 49.5 kg/person/year (third scenario). The three predicted scenarios are shown in Table 1; however, because of limited space, only the analysis of the second scenario (the medium-scale demand scenario) is presented here.

3.1 Projected demands for meat, eggs, and milk

The total projected consumption of meat in China in 2020 is 9.744×10^7 t. The projected demands for pork, beef, mutton, and poultry meat are 6.145×10^7, 8.53×10^6, 5.41×10^6, and 2.205×10^7 t, respectively, and those for eggs and milk are 3.201×10^7 and 5.05×10^7 t, respectively.

The total projected consumption of meat in China in 2025 is 1.074×10^8 t. The projected demands for pork, beef, mutton, and poultry meat are 6.572×10^7, 9.39×10^6, 6.4×10^6, and 2.589×10^7 t, respectively, and those for eggs and milk are 3.357×10^7 and 5.718×10^7 t, respectively.

The total projected consumption of meat in China in 2030 is 1.11×10^8 t. The projected demands for pork, beef, mutton, and poultry meat are 6.664×10^7, 9.89×10^6, 6.9×10^6, and 2.752×10^7 t, respectively, and those for eggs and milk are 3.385×10^7 and 6.06×10^7 t, respectively.

The total projected consumption of meat in China in 2035 is 1.145×10^8 t. The projected demands for pork, beef, mutton, and poultry meat are 6.757×10^7, 1.038×10^7, 7.4×10^6, and 2.916×10^7 t, respectively, and those for eggs

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and milk are 3.414×10^7 and 6.41×10^7 t, respectively.

3.2 Projected medium-scale scenario for forage demand

Projected forage demands up to 2035 were simulated according to predictions of the per capita consumption of meat, eggs, and milk and improvements in breeding technologies.

The total projected demand for raw materials for energy feeds in China is 3.5×10^8 t. The projected requirements for raw materials for energy feeds for pigs, beef cattle, meat sheep, table poultry, dairy cattle, egg-laying poultry, and aquaculture are 1.214×10^8, 1.6×10^7, 1.706×10^7, 7.031×10^7, 3.06×10^7, 5.195×10^7, and 4.238×10^7 t, respectively.

The total projected demand for raw materials for protein feeds in China is 1.1×10^8 t. The projected requirements for raw materials for protein feeds for pigs, beef cattle, meat sheep, table poultry, dairy cattle, egg-laying poultry, and aquaculture are 3.275×10^7, 1.85×10^6, 1.38×10^6, 1.406×10^7, 2.308×10^7, 1.367×10^7, and 2.119×10^7 t, respectively.

The total projected demand for silage corn in China is 5.09×10^8 t. The demand for silage corn for beef cattle, meat sheep, and dairy cattle are 1.565×10^7, 1.138×10^7, and 4.828×10^8 t, respectively. Moreover, the projections of the total yield of silage corn and the total cultivated area are 60 t/hm^2 and 8.467×10^6 hm^2, respectively.

The total projected demand for high-quality hay in China is 4.815×10^7 t. The projections of the yield and cultivation area of high-quality forage are 9 t/hm^2 and 5.351×10^6 hm^2, respectively.

Table 1. Projection of future forage demands in China. ($\times 10^4$ t)

Scenarios	**Low-scale**				**Medium-scale**				**High-scale**			
Year	2020	2025	2030	2035	2020	2025	2030	2035	2020	2025	2030	2035
Energy feeds	26 662	26 946	28 398	29 849	28 479	31 429	33 198	34 968	31 326	34 572	36 518	38 465
Protein feeds	8 314	8 964	9 476	10 000	8 799	9 677	10 231	10 799	9 679	10 645	11 254	11 879
Silage corn	34 592	39 397	42 592	45 880	38 348	43 775	47 324	50 978	42 183	48 152	52 056	56 076
High-quality hay	3 261	3 723	4 024	4 334	3 624	4 136	4 471	4 815	3 986	4 550	4 918	5 297

4 Recommendations for ensuring sufficient forage supply

To alleviate future shortages in raw materials for feeds (especially protein feeds, silage corn, and forage), the following recommendations are offered.

4.1 Moderate reduction of the area used for grain corn cultivation and large-scale expansion of the area used for silage corn cultivation

Demands for silage are greatest in the Inner Mongolia Autonomous Region and in the provinces of Xinjiang, Hebei, Heilongjiang, Shandong, and Henan, which should be prioritized as the main regions for silage development in China. The costs of transporting silage corn over long distances are high. Because peasants are dispersed, cultivate small areas, and face difficulties harvesting their crops, the farmers usually purchase silage corn from other nearby peasants that engage in production on a larger scale. Therefore, the question of whether silage corn can be planted on a large scale is an important one, as this will influence its supply.

4.2 Development of grass industries in agricultural areas

In China, only approximately 10% of the land is suitable for farming. However, the area of land that can be used for agriculture is four times greater than the existing area of cultivated land. Grass–crop rotations can increase rather than reduce grain yields, and the forage grass that is produced can be used as fodder for animals, which can improve the national dietary structure and lead to a multifold increase in agricultural output values. The development of grassland agriculture not only makes full use of land and resources but also allows one to establish a potential supply of grain when demand for food rises.

4.3 Increase of domestic soybean and rapeseed yields and of domestic meal supplies

In the main corn- and soybean-producing areas, rationally implemented corn and soybean rotation can improve soil conditions, reduce inputs of chemical fertilizers and pesticides, and improve the sustainable production capacity of agriculture. Expansion of the cultivation area and yield of rapeseed in the Yangtze River Basin would not only increase the supply capacity of protein meal and vegetable oil but also improve the condition of the soil and increase the sustainable production capacity of cultivated land resources in this region.

4.4 Optimal usage of internationally procured agricultural resources

China's agricultural resources cannot satisfy its requirements for agricultural products to sustain the economic and social development of the country now or in the future. Making optimal use of internationally procured agricultural resources is a necessity, which is in accordance with the national globalization strategy for the new era.

In light of the need to consolidate existing trade channels and to take advantage of key opportunities arising from the Belt and Road Initiative, preferential measures should be established to encourage domestic enterprises, institutions, and individual investors to expand their businesses to cater to international markets and to develop their agricultural resources through various forms of cooperation. Further recommendations include strengthening trade relations with neighboring countries, developing countries, and new economic entities; developing logistics and industrial parks for processing imported agricultural products at domestic border ports; and encouraging raw-material processing through preferential policies related to various fields such as finance and taxation.

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