

Review

Pork production system and its development in mainland China

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Livestock production and marketing have been driven by the growing consumer demand for high quality and low cost animal protein. As a result, intensive livestock industries have been rapidly developing globally. International trade, especially with China, creates new opportunities and challenges for the emerging international agriculture market. China provides an enormous market for international trade by stimulating its import and export activities. Pigs are the primary farm animals raised for human consumption in China, and the development of pork production systems in China will affect its trade globally. To meet the need for developing international animal agriculture and trade, this article describes the current status of the swine industry, its production in China and the factors that may affect its development. Urbanization, available farmland, grain production, water resources and management practices encompass some of these factors. In addition, the effects of the culture, religion and education of the populations on the development of swine sector in China are also discussed. Understanding the development of the swine production system and its associated factors is critical to assessing China's impact and implication in the emerging international agricultural market.

Key words: Animal agriculture, swine farm, pork production, international trade, China.

INTRODUCTION

China is the world's largest country by population (more than 1.3 billion citizens, approximately 22% of the world's population in 2008; NBSC, 2009). Its economy has been the fastest growing in the world for the past quarter of a century, especially following its market-oriented economic reforms in 1978 and open trade since joining the World Trade Organization (WTO) in 2001 (Rozelle and Swinnen, 2004; Wang and Hu, 2007; Carter et al., 2009). These changes, especially the transformation of agriculture from a Soviet-type centrally planned economy (Government Control System) to a market-oriented economy (Household Responsibility System) and urbanization, have significantly impacted China's economic structure and its patterns of international trade in most areas including the agricultural sector (Lin et al., 1996; Lohmar et al., 2009).

With the development of China's economy, its per capita income has grown rapidly. Increase in household incomes have led to significant changes in the patterns of food consumption which is shifting from grains, legumes, root crops and soybean to livestock derived products. Meat and egg consumption shows a consistent increase while grain consumption of rice, barley and wheat is either steady or declining (Huang and Bouis, 2000). The demand for livestock, especially pork, has and will be further influenced by urbanization, as a process-associated increase in urban populations and higher-income groups (Lu, 2007). Taking advantage of the economic scale, the swine sector has integrated production systems to become an industry.

TYPES OF SWINE FARMS IN CHINA

In general, there are three types of swine farms in China based on the numbers of pigs produced on the farm;

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Table 1. The size of Chinese pig farms in 2003.

Size (number of pigs)	Number of pig farms		Changes from 2002 (%)	Percentage of farms (%)	
	2002	2003		2002	2003
1-9	99,894,369	101,963,901	2.07	94.81	94.48
10-49	4,438,302	4,815,474	8.50	4.21	4.46
Small farms	104,332,671	106,779,375	2.35	99.02	98.94
50-99	790,307	851,429	7.73	0.75	0.79
100-499	212,909	249,016	16.96	0.20	0.23
500-2,999	27,495	33,844	23.09	0.03	0.03
Medium farms	1,030,711	1,134,289	10.05	0.98	1.05
3,000-9,999	3,242	3,388	4.50	0.00307	0.00314
10,000-49,999	862	911	5.68	0.00082	0.00084
Over 50,000	28	30	7.14	0.00003	0.00003
Modern farms	4,132	4,329	4.77	0.00392	0.00401
Total	105,367,514	107,917,993	2.42	100	100

Sources: Ministry of Agriculture of the People's Republic of China; China Animal Agriculture Association; China Animal Husbandry Yearbook of 2004; China Agricultural Information Network; Food and Agriculture Organization of the United Nations.

small (including backyard farms, < 50 head), medium (50-3,000 head), and large (> 3,000 head) (Table 1). With urbanization and production efficiency, China pork and pork production has shifted from backyard and small farms to specialized household (or local community) farms as well as modern intensive farms, especially in the urban areas close to big cities, such as Beijing, Shanghai, and Chengdu (Figures 1a and b).

Small size pig farm

In China, the most popular swine holders are small size pig farms including the scattered pig farms (Table 1). A small size pig farm has average herds with less than 50 pigs, while a scattered farm has even fewer pigs. It is estimated that over 80% of the rural household, or around 180 million farmers, have pigs with an average of 2-3 head per householder.

Hogs housed in small swine farms (also called 'safety net' based on its economic function) are usually low-input pigs of indigenous breeds or hardy crossbreds. Pork production is low, mostly used for home consumption (farm families) and/or to supply predominantly rural markets (local community) with limited competition.

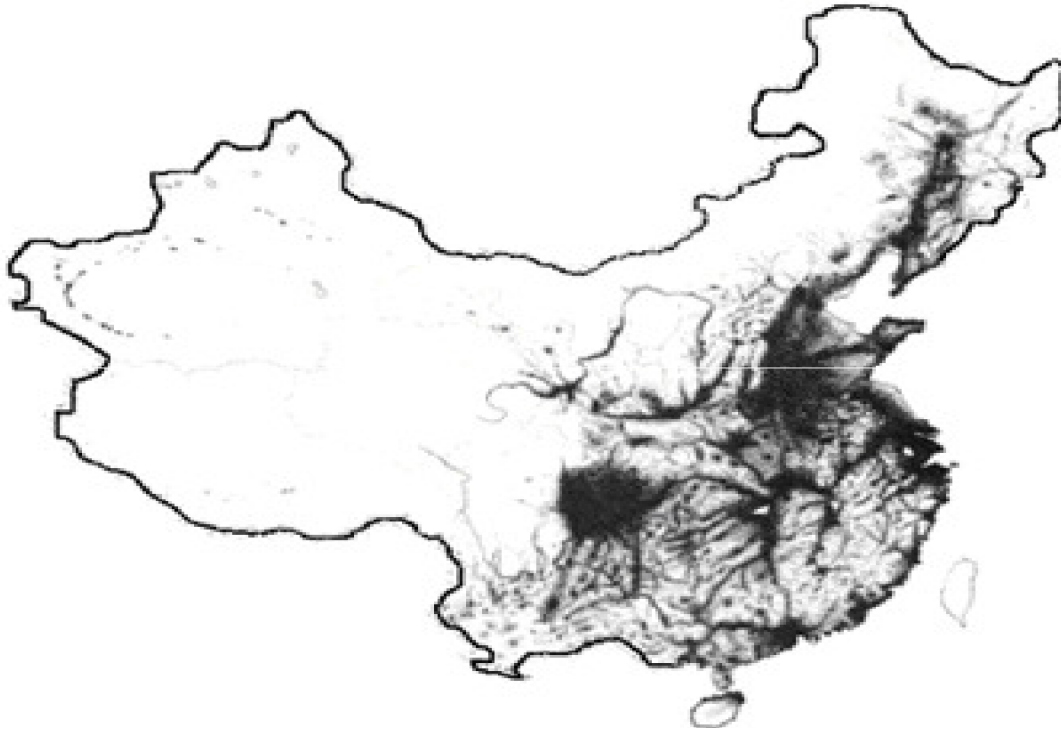
The purpose of traditional pig farming is 'feeding hogs to fertilize crops and have a recipient for table scraps' with little emphasis on quality and efficiency of pork production. Therefore, hogs in the traditional farms frequently consume large amounts of green roughage, based on the location, such as water plants, grass, vegetable leaves, tubers, carrots, pumpkins, fruits, and various crop stalks;

and only fed little grain at early and late stages (Fang and Fuller, 1998). This diet lacks certain essential nutrients, resulting in a low feed efficiency. It results in low costs to raise a hog, but it takes great time of about 200 days for pigs to reach slaughter weight, generating a low net income.

In small pig farm, the farmers and family members are the major stock-keepers. Pig care and welfare is largely dependent on their animal-related experiences, economical status, religion, and education. Hogs housed in the traditional farms are facing several major welfare issues, such as an unbalanced diet, uncontrollable climate conditional change, and disease. In addition, the small pig farmers are under increasing internal and external pressures arising from social, economic and environmental factors. To overcome these problems and to meet consumers' demand for lean and "healthful" meat, pork production is moving towards specialization by adopting more modern management technologies for improving feed efficiency and increasing pork production and food safety. With this movement, the Chinese swine industry has quickly changed the denomination from backyard production of a few pigs to 'large' size operations with more than 50 head annually.

Medium size swine farm

The second type is the medium size pig farm that raises herds from 50 to 3,000. Currently, this production system houses approximately 25% of the total pigs in China. There was an approximate 10% increase in the medium



A.



b.



Figure 1. Distribution of swine farms and the factors affecting their development in Mainland China. a) The geographic population distribution in Mainland China. Each dot represents 5,000 persons; b) the geographic distribution of swine farms in Mainland China; and c) main rivers in Mainland China. (Sources: Noll, P. and B. Noll, 2009; Editorial Board of the Series National Atlas of China, 1996; Fabiosa (2005); and The International Institute for Applied Systems Analysis, 1999).

size pig farms from the year 2002 to 2003, especially in farms with pigs from 100 to 499 and 500 to 2,999 (17 and 23.1%, respectively; Table 1). In total, from 2002 to 2006, the numbers of medium size swine farms were increased to approximately 204%. Taking advantage of increased demand for pork and pork products in local markets, many rural households have shifted their focus from crop production to hogs and thus increased their swine herds. The aim of farming has also been shifted from “fertilizer for crop cultivation” to capital gain, with the emphasis on increasing grain feed, improving feed efficiency and reducing time to reach slaughter weight. To increase pork production, the farmers’ focus is placed upon improving pig welfare by reducing and controlling management-associated stressors, such as housing environments, stock densities, climate conditions and disease incidence. Farmers, and specially trained stock-keepers, play major roles in maintaining the pigs’ health and welfare base on their experiences, economical status, religion, and education.

Modern intensive swine farm

The last farm type is the modern intensive swine farm

(also called ‘industrialized’ swine farm) with 3,000 and more pigs. In contrast to the previously discussed systems that focus on providing animal products for farm families and the local community, modern intensive swine farms are specialized economic enterprises. Pork production relies on grain-based feed and modern technological advances as well as management skills.

In the modern intensive swine farm, hogs are kept purely as a commercial venture by a firm. They are intensively reared under strictly regulated conditions and are provided with all necessary inputs, including new technologies for transportation, food preservation, disease prevention, feed efficiency and advance management technology. There is a trend in the swine sector to simplify and specialize with an ability to grow more pigs in less space. Chinese government encourages the development of modern swine farms to meet the rising demand for meat consumption. In 2007, the State Council announced the “regulation on Implementing the Law of the People’s Republic of China on Corporate Income Tax” to reduce corporate income tax from 33 to 25%. In addition, swine holders have received great profits resulting from the currently high prices of pork products. To take advantage of emerging opportunities for growth,

China's modern intensive swine farms have been developed rapidly, some of them reaching size and scope similar to those in the U.S. For example, the China National Cereal, Oils and Foodstuffs Corp (COFCO) has invested \$1.36 billion in Hubei province to build a 500,000 head reproducible sow breeding base (The PigSite, 2008). Additionally, several centers for pig breeding and swine disease prevention research have been established in China (USDA's Grain Report, 2008c). Foreign companies are also encouraged to invest in swine rearing farms in China through joint ventures. A U.S. investment bank, for example, has bought over 10 farms in Jiangxi and Fujian Provinces; and the Tangrenshen Company in Hunan Province recently undertook a new 10 million swine project (The PigSite, 2008).

Currently, modern intensive pig farms account for less than 1% of the total pig farms and less than 5% of total hog production in China (Table 1). With rising demand for pork and pork products, the modern intensive production system will be continuously developed and will be the dominant producer in the pork market in China. These developments will translate into more concentrated swine rearing firms in the future, pushing backyard and small operators out of the swine business.

Large-scale pork production enterprises are generally located around big metropolitan area (high density of population), such as Beijing, Shanghai, and Guangzhou, to serve the growing demand of urban consumers (for example, labor migration and urbanization) (Figure 1b). Similar to the swine farms in other countries, the modern swine farms in China are facing several major pig welfare and environmental issues, such as housing condition, group size, stock density, air quality (odor, ammonia production), climate conditions, disease and food safety, and environmental contamination as well as worker availability and safety. One way to overcome some of these challenges is to move the large production units out of the cities, away from the areas with dense populations. It could be similar to the relocation of animal agriculture made by the U.S. livestock sector in the mid-20th century. During that time, the U.S. red meat processing was moved out of the cities to small towns in the Midwest and Great Plains.

EFFECTS OF AVAILABLE RESOURCES ON SWINE INDUSTRY IN CHINA

The high demand for animal derived products has important implication for the development of animal agriculture, especially modern intensive swine farms. However, whether China can feed itself, providing enough livestock productions including pork and pork productions, is affected by multiple factors such as population growth (massive growth is unavoidable, projected about 1.48 billion in 2050), dietary change (reduce feed crop demand for meat), urbanization (increase in city population and

activities), available arable land (decline, degradation, and soil erosion), water supply (deficit and pollution), disasters (drought and flood), policies and economic arrangements (increase or decrease production efficiency), modern marketing institutions and infrastructure, and scientific and technological development and adaptation (increase efficiency and productivity) (FAO, 1998). The question being asked is:

What is China's capacity to increase its agricultural production and at what costs?

Population, arable land, and swine farm relationship in China

China has the largest population in the world, approximately 1.3 billion people in 2008, and projected to be close to 1.5 billion in 2020. Such a huge population imposes substantial stress on its natural resources including arable land. China has about 22% of the world population, but only 7% of the world's arable land (Geissler, 1999). China's farmland is 10 times less per capita compared to that of the U.S. (Knapp, 2009). The average per capita availability of farmland could be less than 0.08 ha/person by the year 2025, resulting from conversion of farmland to industrial, residential and transportation uses and soil erosion as well as desertification (Smil, 2006). China's economy and animal agriculture are further affected by the uneven distribution of the population and farmland throughout the entire country (Figures 1a and b). The limitations in topography, soil condition and temperature have restricted cultivation to only about 15% of the total land area in China.

China's farmland has been further reduced by urbanization. Urbanization attracts rural labor and increase urban population and allocation area. As at 2005, China has over 60 metropolitan areas with populations greater than 750,000, most of them are at the east (coast) and central areas (Figure 1a). The unremitting urbanization, such as conversion of farmland to industrial, residential and transportation uses, has devoured massive amounts of fertile farmland, resulting in threatening grain supply and development of animal agriculture. For example, in 2008, a total of 191.6 thousand ha of cultivated land was used for construction purpose (NBSC, 2009).

In addition, land degradation (resulting from intensive chemical, fertilizers and pesticides application), land erosion (stressed land by farming steep hillsides or damaged surface covers), and the increasing risk of floods are growing threats to China's food supply (Long et al., 2006; Yu, 2008). Between 1950 and 1999, 9.2 billion tons of soil spilled into the Yellow River, raising its bed by as much as 4 m. This is a consequence of a severe soil erosion problem. In 2008, 24800 ha of cultivated land was destroyed by disasters (NBSC, 2009). Now, China has more than 3.5

million sq km of eroded land, of which 1.6 million sq km is due to water and 1.9 million due to wind. In 2000, land erosion caused economic losses of a total of 200 billion yuan (\$29 billion), 2.25% of the country's GDP. If the erosion continues at its current rate in northeastern China, crop output could fall by as much as 40% over the next 50 years, and in the southwest, about 100 million people will be at risk of losing their land over the next 35 years.

Based on the limitation of arable farmland and high demand for quality food and meat, the Chinese government has encouraged development of animal agriculture, especially the swine industry, to secure economic and society stability in urban areas. Modern swine farms are rapidly developing and are highly concentrated at the provinces with high percentage of arable land and feed mills, that is, the middle and low Yangtze River region and South-East China. The modern swine farm distribution is more economically efficient when reducing costs for transportation and securing feed supply.

However, urbanization and development of animal agriculture have reached an environmental carrying-capacity, that is, the modern intensive swine farms located at a narrow region with high density of human population and limited water resources. Environmental debt is growing daily; China is now faced with the challenging prospect of increasing the productivity of its animal agriculture, while simultaneously reducing the level of pollution from this activity, such as air quality, manure waste, and soil and water contamination (Brubaker, 2004).

Swine farming and grain production relationship in China

In China, it is estimated that 72% of total grain products are used for feed animals (USDA's Grain Report, 2007). The rapid increase in China's population and a great demand for meat has an enormous impact on feed-grain market (Bingsheng, 2001; Zhou et al., 2008). However, China is faced with severe challenges in safeguarding grain security due to rising living standards, decreasing arable land, increasing water shortages and climate changes (natural disaster). The Chinese government has made a mid- and long-term grain security plan, aimed at achieving grain production of at least 500 billion kg by 2010 and more than 540 billion kg by 2020 to meet increasing population and developing economic needs (China Daily, 2008). To meet these goals, the Chinese government has issued several policies which include reduced agricultural taxes, raised subsidies, and introduced minimum state grain-purchasing prices. In 2007, grain output was 501.5 million tons and further rose to 505 million tons in 2008 (Grains New, 2009). The self-sufficiency rate was 98%. Currently, China's grain

supply and demand are basically balanced, but the situation is expected to worsen in the long-term (Zhou et al., 2008). However, there is limited room to increase arable land because of industrialization and urbanization that are taking farmland away from grain production (China Daily, 2008). Self-sufficient levels could be down to less than 90% by 2020. Loss of farmland, coupled with the increase in animal production means that feed-grain supplies, will be continuously dwindling and the price of corn will climb. Facing the changing corn market, family-based rural backyard and local community-based small pork productions are losing ground to more concentrated and specialized pork operations.

To stabilize the grain market, the Chinese government has increased sown area for grain; however, China's agricultural land area is very limited at only 0.42 ha of arable land per person (Fabiosa, 2005). In addition, available farmland may reach or close to its limit because of heavy use of fertilizer and irrigation, growing multiple-cropping, and raising two or three crops per year. China's government exhausts all avenues to improve grain production as well as its productivity in the use of grain. One promising area for raising pig production is to increase feeding efficiency through balanced diets from commercially mixed feed formulations and application of advanced technologies to reduce production costs such that the production cost for one pound pork carcass weight was about \$0.35 - 0.39 in the U.S., while it went up to \$0.60 in China in the year 2000 (Amponsah and Qin, 2000; Pig International, 1998). Although the current changes of the economy affect hog prices and pork production through the changes of ethanol prices and corn prices, there is still a huge gap to be improved in pork production in China.

On commercialized swine farm, feed cost is about 60-70% of the total swine production cost in China (Amponsah and Qin, 2000; USDA Gain Report, 2008c). To increase feed efficiency and decrease feed cost, the Chinese government is encouraging the development of feed mills. In China, most mills are collectively owned or state owned. In order to subsidize pork production, the Chinese government operates feed grain mills at a lesser cost, thereby indirectly subsidizing domestic hog producers to meet economic developmental needs. However, limited arable land prevents China from becoming a large-scale feed-grain producer (Fuller, 1997). According to Food and Agriculture Organization (FAO) data (1998), currently, China must feed 13.0 people for each hectare of arable land, whereas Europe must feed 4.1 people, and the U.S. needs to feed only 1.4 people with the same arable area. Land scarcity limits China's ability to continue increasing its livestock production to meet the growing domestic demand without increasing its imports of livestock feedstuffs.

However, China's uncertain direction in biotechnology policy could limit feed grain imports, since the U.S. and other suppliers make wide use of genetically modified

varieties of feed grains and oilseeds. Currently, the use of genetically modified (GM) crops in the food supply is not a major concern issue in China.

However, the government is developing regulations to control GMO products. If China imposes stringent labeling or traceability requirements that apply to feed grains and feed products, it will raise internal feed costs to China's livestock producers and slow the sector's growth (Fuller et al., 2001).

Water resources, grain production, and swine farm relationship in China

Another major limitation of agriculture in China is water. Water shortage has become a bottleneck restricting sustainable development of the economy in China (Brown and Halweil, 1998). The regional distribution of water resources does not match the agricultural demand, and massive water diversion projects have dislocated the entire country. Based on water supply, agricultural zones in China can be subdivided into three natural zones: the monsoon zone in the east, the arid inland zone in the northwest, and the Qinghai-Tibet Plateau inland zone in the southwest. These subdivisions account for 45, 30 and 25% of all land, respectively. The eastern monsoon zone is agricultural; the northwest and southwest are pastoral. In the north and west regions, large parts of the existing agricultural areas cannot be cultivated at their full potential due to insufficient rainfall, and water shortage-associated desertification.

Agricultural land in China is farmed intensively but in many areas, it could be more productive on a unit of labor basis if water supply were sufficient. Extensive irrigation is the key to China's ability in maintaining agricultural production. In China, there are four major rivers, Yellow River (north), Yangtze River (central), Pear River (south), and Huai River (between Yellow River and Yangtze River), as well as multiple small rivers in the east and south of China (Figure 1c) (The IIASA, 1999). These rivers drain most parts of the eastern and central regions but not the western regions of China. However, due to climate change, these rivers flood yearly, resulting in land erosion. Water resources, like in some regions of the world, is the major factor affecting swine farm development through multiple factors. These factors include maintaining and developing farmland, planting and growing of grain, and urbanization and industrialization by population growth. These factors cause rivers to run dry and ground water table to fall. Especially in the west, northeast, and north provinces of China, arid and semi-arid regions are facing great problem of water shortage. China's arable land can be increased if enough water supplies existed. For example, in 2008, over 1.179 million ha of farmland was developed with effective irrigation and another additional 1,390 million ha of farmland was guaranteed by water-saving irrigation system (News from Grain, 2008).

However, in China, swine farms are concentrated at the same geographic regions that also allocate numerous farmlands and a great density of humans, that is, the middle and low Yangtze River region and South-East China (Figures 1b and c). The geographic distribution of developing swine farms has resulted in pollution of many rivers and lakes, leading to further reduction of usable water resources. Even the water quality is continuously improved. In 2008, monitoring of water quality on 409 sections of the seven major water systems in China showed that 45.0% of the section was below the national quality standard Grade III for surface water; and 20.8% were worse than Grade V (NBSC, 2009). It is a critical issue for China to improve the quality and availability of water for developing animal sectors, such as swine production. China will provide a huge market for internal pork exports including U.S. pork producers (Amponsah et al., 2003).

EFFECT OF RELIGION ON DEVELOPMENT OF THE SWINE INDUSTRY IN CHINA

Throughout history, animals, including pigs, have played an important role in human lives. In China, since ancient times, Chinese people have recognized animals as their properties, and animal husbandry has played important economic roles. Animal meat, especially pork and pork products is a main source of food for Chinese people. However, the relationship between humans and animals is affected by culture and religion. As at 2004, the country had five officially recognized religions, Buddhism, Taoism, Islam, Catholicism, and Protestantism. Among them, Buddhism and Islam have different restrictions regarding killing animals and eating animal meat, especially pigs.

Buddhism

Buddhism teaches that; animals are sentient beings, no different from humans in their ability to feel suffering; animals possess Buddha nature and therefore an equal potential to become enlightened; rebirth, any human could be reborn as an animal, and any animal could be reborn as a human. Based on the doctrine, if a human looked far enough back in one's infinite series of lives, he or she would eventually perceive a relationship with every animal in some way. The Buddhist belief in rebirth (*Juen hiu*) which teaches that ultimately humans and animals are part of a single family since we are to be reborn into one existence (human or animal) after another until it becomes the permanent; that is, a god (Harvey, 1990). Particularly in China, an important way of demonstrating Buddhist piety is to release animals (*fang sheng*) that one bought from markets, particularly birds or fish, into their natural environments.

The Hui Hui community in China evolved into ten ethnic groups and two systems: the Uighurs, the Kazaks, the

Khalkhas, the Uzbeks, the Tajiks and the Tatars living mainly in the Xinjiang Uighur Autonomous Region, and the Huis, the Salas, the Dongxiangs and the Bao'an live mainly in the Chinese inland. They inhabit six major regions, such as Nanjing, Suzhou, Xining, Guanzhong, Yunnan, and Beijing (Vipassana Foundation, 2008). In China, based on the different analyses, the percent of the population that adheres to Buddhism ranges from 16 to 21% (about 200 millions) (Wu, 2007), although not all of them adhere to a vegetarian diet. These widely held religious beliefs should be taken into account in further development of Chinese animal husbandry, including the swine sector.

Islam

The primary religion of the ten of fifty-six nationalities in China, such as Hui, Uigur, Kazak, Uzbek, Kirgiz, Tartar, Tajik, Dongxiang, Baoan, Salar, is Islam. Nearly all of the nation's Muslims are members of ethnic minority nationalities; most belong to the Sunni branch, but there are also large numbers of citizens from Tajik that are Shia decent. The total population of Muslim citizens is approximately 20 million (other sources estimate the Islamic population of China to be over 37 million) (Pervis, 2005). The distribution of the Chinese Muslim population is characterized by being 'scattered widely and concentrated in small groups. In the Northwest, particularly Shaanxi, Gansu, Ningxia, Qinghai, and Xinjiang, they live and intermarry with local people, and eventually become permanent inhabitants.

Muslims are prohibited from eating pork and the flesh of other animals that have not been ritually slaughtered. Pork is forbidden in Islam according to the Text of Qur'an; and Chinese Muslims call those meats 'diet'. Such religious beliefs should also have a great impact on Chinese animal husbandry, especially the swine industry development. This is currently evident in the regional relative popularity of swine farming in China. In the Western regions of China, the majority of the population is Muslim and subsequently, there are fewer settled pig farms in that region (Figure 1b). Pork consumption is low in Ningxia where the Islam religion plays a predominant role.

CONCLUSION

Since 1978, China has introduced structural and economical reforms through decentralization and privatization that have increased both domestic private investment and direct foreign investment, resulting in rapid development of its economy. China's agricultural economy becomes the largest in the world and China leads import and export of agricultural products globally. High income has led to changes in Chinese dietary habits, which shifted from grain to meat-based. Animal husbandry, mainly the

swine sector, has greatly expanded to meet this rising demand. Swine production is currently undergoing a drastic change from small farms and backyard to large production facilities (modern intensive swine farms). However, with the farmland and water resources stretched to the limit and the labor costs rising, China is facing great challenge to maintain the rapid growth in its economy. It is the authors' opinions that the best way to develop and improve animal husbandry in China should be to implement a cost-effective maintenance system to meet human needs but without abuse of animals, and based on its special situation and limited resources. The most important issues encompass improvement of nutrition, genetics and breeding, housing, health maintenance and disease prevention, handling facilities and techniques, training of stock-keepers and environmental protection, as some of those mentioned in the U.S. and other countries globally.

REFERENCES

- Amponsah W, Qin XD (2000). Pork. In: Colyer D, Kennedy PL, Amponsah WA, Fletcher SM, Jolly CM (Eds.), *Competition in Agriculture: The United States in the World Market*. NY: The Haworth Press, Inc., pp. 235-250.
- Amponsah W, Qin XD, Peng XH (2003). China as a potential market for U.S. Pork exports. *Rev. Agr. Econ.*, 25: 259-269.
- Brown L, Halweil B (1998). China's water shortage could shake world food security. *World Watch*, 11: 10-21.
- Brubaker D (2004). Trade and growth of animal agriculture in the world International competition: The China Model. In: *Local and Global Considerations in Animal Agriculture: The Big Picture*. Washington, DC., pp. 5-8.
- Carter CA, Zhong F, Zhu J (2009). Development of Chinese Agriculture since WTO Accession. *EuroChoices*, 2: 10-16.
- China Daily (2008). China outline first multi-year grain security plan. http://www.chinadaily.com.cn/bizchina/2008-11/13/content_7202034.htm (Accessed 25 April 2009). Pg 1
- Fabiosa JF (2005). The Impact of Ownership Structure on the Performance of China's Feed Mill Sector. *Midwest Agribusiness Trade Research and Information Center*, Iowa State University. Pp 1-26
- Fang C, Fuller F (1998). Feed-grain consumption by traditional pork-producing households in China. *The Center for Agricultural and Rural Development*. Iowa State University. Pp 1-20
- FAO (Food and Agriculture Organization of the United Nations) (1998). *Poverty alleviation and food security in Asia lessons and challenges*. Regional Office for Asia and the Pacific, Food and Agriculture Organization of the United Nations, Bangkok. Annex 3
- Fuller F (1997). China's Food and Feed Grain Supply and Demand. The workshop entitled *Challenges and Opportunities for Sustainable Agriculture in China*, Beijing, China. P.10
- Fuller F, Tuan F, Wailes E (2001). Rising Demand for Meat: Who will feed China's hogs? *China's Food and Agriculture: Issues for the 21st Century*, pp. 17-19.
- Geissler C (1999). China: The soybean-pork dilemma. *P. Nutr. Soc.*, 58: 345-353.
- Grain News (2009). China commodities report: 2008 domestic grain output up 0.7% -- four straight years of growth. http://www.grainnet.com/articles/China_Commodities_Report_2008_Domestic_Grain_Output_up_0.7_Fourth_Straight_Year_of_Growth-69508.html (Accessed 12 March 2009). P. 1-4
- Harvey P (1990). *Introduction to Buddhism*. Cambridge University Press, Cambridge. P. 120.
- Huang JK, Bouis H (2000). Structural changes in the demand for food in Asia: Empirical evidence from Taiwan. *Agr. Econ.*, 26: 57-69.
- Knapp R (2009). *China: A teaching workbook*. Columbia University

- Press, Columbia, pp. 1-12.
- Lin JY, Cai F, Li Z (1996). The lessons of China's transition to market economy. *Cato J.*, 16: 201-231.
- Lohmar B, Gale B, Tuan F, Hansen J (2009). China's ongoing agricultural modernization: Challenges remain after 30 years of reform. *USDA Econ. Inf. Bull.*, p. 51.
- Long KL, Heig G K, Wang J, Li XB, Luo,M, Wu,XQ, Zhang M (2006). Land use and soil erosion in the upper reaches of the Yangtze River: Some socio-economic considerations on China's Grain-For Green program. *Land Degrad. Dev.*, 17: 589-603.
- LuA (2007). China's rural population shrinks to 56% of total. http://news.xinhuanet.com/english/2007-10/22/content_6925292.htm 2007 (Accessed 12 March, 2009).
- NBSC (National Bureau of Statistics of China) (2009). Statistical Communique of the People's Republic of China on the 2008 National Economic and Social Development. <http://chinadataonline.org/freesource/zixunshow.asp?id=4872009> (Accessed 12 March, 2009).
- News from Grain (2008). The 2008 land grab for food and financial security. <http://www.grain.org/nfg/?id=6102008>(Accessed 16 March, 2009).
- Pervis D (2005). Opportunities in the food market of China. *Agri-Food Trade Service, Agriculture and Agri-Food Canada*. Pp. 1-73.
- Pig International (1998). The production cost comparison. *Watt Publishing Company*. Mt. Morris, Illinois. USA, 28: 18-24.
- Rozelle SA, Swinnen J (2004). Success and failure of reform: Insights from the transition of agriculture. *J. Econ. Lit.*, 42: 404-456.
- Smil V (2006). Japan and China: The next fifty years. *Japan Focus*, September 5, 2006.
- The IIASA (The International Institute for Applied Systems Analysis) (1999). Main rivers in China. [http://www.asu.edu/clas/asian/China%20Physical%20Geography%20\(for%20Academic%20Decathlon\).ppt1999](http://www.asu.edu/clas/asian/China%20Physical%20Geography%20(for%20Academic%20Decathlon).ppt1999)(Accessed 10 March, 2009).
- The PigSite (2008). People's Republic of China: Agricultural Situation: Livestock and Products 2008. <http://www.thepigsite.com/articles/2425/peoples-republic-of-china-agricultural-situation-livestock-and-products-2008>(Accessed 20 March, 2009).
- USDA's Gain Report (2007). People's Republic of China, Grain and Feed. Gain Report Number: CH7015, pp. 1-34.
- USDA's Gain Report (2008). People's Republic of China, Agricultural Situation Livestock and Products. Gain Report Number: CH8078. Pp. 1-21.
- Vipassana Foundation (2008). Buddhists around the world. http://thedhamma.com/buddhists_in_the_world.htm2008(accessed 16 July, 2008).
- Wang Y, Hu A (2007). Multiple Forces Driving China's Economic Development: A New Analytic Framework. *China World Econ.*, 15: 103-120.
- Wu J (2007). Religious believers thrice the estimate. *China Daily*, p. 1.
- Yu X (2008). Land Erosion "threat to food supply". http://www.chinadaily.com.cn/bizchina/2008-11/22/content_7230508.htm2008(Accessed 20 November, 2008).
- Zhou ZY, Tian W, Malcolm B (2008). Supply and demand estimates for feed grains in China. *Agric. Econ.*, 39: 111-122.