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Current status and development prospects of India's pig industry

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ABSTRACT

Pig production and marketing have been driven by the growing consumer demand for high quality and low cost animal protein. As a result, organized and industrial piggery has been rapidly developing globally. For the Indian piggery sector, there exists a well-defined domestic market as well as an enormous market for international trade by stimulating its production activities. To meet the need for developing domestic as well as the international pig production and pork trade, this article describes the current status of the pig industry, its production in India and the factors that may affect its development. Production systems, quality of germplasm, urbanization, available farmland, grain production, water resources, bio-security issues and management practices encompass some of these factors. In addition, the effects of the culture and education of the populations on the development of pig sector in India are also discussed. Understanding the development of the pig production system and its associated factors is critical for assessing India's impact and implication in the emerging international agricultural market.

Keywords: Indian piggery, Patents, Pig diseases, Pig health, Pig production, Processing, Strategies

Pigs are domesticated in various parts of India, especially in South-Central and North Eastern Region (NER), each place has its own locally adapted pig breed, and most households raise at least one or two pigs each year (Mahak *et al.* 2020). Pigs are more valuable alive than dead, acting as efficient converters of kitchen and agricultural scraps into nutrient-rich fertilizer, before becoming pork that could even sometimes be given as a wedding gift, used to curry political or social favour, or eaten as part of local celebrations, especially in NER (Bujarbaruah *et al.* 2007, McAuliffe *et al.* 2017). Although the long tradition of pork consumption in India includes variation across different times, places and social relations, the smallholder model of raising pigs as part of diverse crop and livestock agro-ecosystems, coupled with only occasional meat eating, defines much of the country's pig and pork history (Das and Bujarbaruah 2005, Kakati 2019). The 21st century agricultural and dietary changes however represent radical departures from the small holder production system and consolidation of industry is clearly visible in the last two decades (Kumaresan *et al.* 2007, Anuj *et al.* 2016). It should be noted that the industrialization of pig production is a relatively recent phenomenon globally. In India, too, the speed and scale of change has been phenomenal, conditioned by policies, investments and the transforming economic system.

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Pig population and distribution scenario

According to the 20th livestock Census of India, the country's pig population is just above 9 million (Indian Livestock Census 2019) in comparison to the world population of about 900 million (FAOSTAT Databases 2020). Majority of pig population of the world is in China (~48%) followed by United States of America (~6.5%), Brazil (~4%), Germany (~2.8%) and Vietnam (~2.7%). The position of India in pig production within the Asia is also below the top five, viz. China, Vietnam, Philippines, Japan, and Indonesia. India's contribution to the total pig production in Asia is about 1%, while China alone contributes more than 80% (FAO 2005). The pig population in India had a positive trend over all the duration till the year 2000, except during 1960s. However, during the past 15 years, the growth rate in pig population in India was found to be negative (Indian Livestock Census 2019, Table 1). The reasons might be multi-faceted, but the major ones are surely the socio-cultural inhibition and inadequate financial availabilities. Therefore, the challenge is to reverse the declining growth trend through the application of needed science, technology and development measures.

Pig is widely distributed in all the eco-regions of the country and is an important occupation of the rural society especially the tribal masses. People of certain ethnic groups in the country prefer to keep pigs, especially the black coloured ones, for festivals and ceremonial purposes. The highest pig population is observed in eastern and north eastern (NE) states, followed by northern, southern, central and western India. The highest population is in Assam (2.10

Table 1. Pig population in India

Category	Population in 2012 (in million)	Population in 2019 (in million)	% Change
Pig population–Consolidated			
Exotic/ crossbred	2.46	1.90	–22.76
Indigenous/ non-descript	7.84	7.16	–8.66
Total pigs	10.29	9.06	–12.03
Pig population in major pig producing states			
Assam	1.64	2.10	28.30
Jharkhand	0.96	1.28	32.69
Meghalaya	0.54	0.71	29.99
West Bengal	0.65	0.54	–16.63
Chhattisgarh	0.44	0.53	20.01
Uttar Pradesh	1.33	0.41	–69.37
Nagaland	0.50	0.34	–47.14
Bihar	0.30	0.32	6.25
Karnataka	0.30	0.32	6.25
Mizoram	0.25	0.29	19.26

Source: 20th Livestock Census Data, Department of Animal Husbandry, Dairying and Fisheries, Government of India.

million), succeeded by Jharkhand (1.28 million), Meghalaya (0.71 million) and West Bengal (0.54 million) as depicted in Table 1. The northeastern part of the country houses about 40% of the pig population of the country. Indigenous non-descript pigs (79.03%) mainly cornerstone the pork production in India followed by crossbreds and exotic germplasm (20.97%) (Indian Livestock Census 2019).

Current structure of pig farming in India

Besides different farm types (backyard, commercial), there are two basic sets of pig farm structures in India (Thomas and Sarma 2017). The first set consists of government-operated breeder farms that supply local farms. The State governments operate considerable number of breeder farms, which then supply pigs to smaller local producers. All these various levels of government breeder farms typically operate on a single-site farrow-to-finish farm system and are usually run at 10–50 sow unit capacity (Kumaresan *et al.* 2008a). There has also been a wide range of incoming breeder pigs of differing origins, with various western-breed pigs from Europe and the United States entering these farms in the past decades. The production farms supplied from these government pig breeder farms are typically small commercial or backyard farms with between 2 and 5 sows and on-site finishing (Das *et al.* 2012). The germplasm supplied from these government farms typically include the crossbreds of Landrace, Large White, Hampshire, Duroc breeds (Table 2), however the on-farm data from the producers field indicates that pig growth rates, sow fertility, meat quality and feed conversion figures are not comparable to western levels. Besides these State governments' run pig farms, there exist over 20 pig farms under All India Coordinated Research Projects (AICRP) and Megaseed production units on Pig in different agro-climatic conditions of the country. The performance of these units are monitored and evaluated by ICAR-National Research Centre on Pig. These AICRP units, through their work, could develop over 10 numbers of crossbred, locally adaptable pig germplasm, for further propagation in the respective agro-climatic zones.

The second type of pig farm structure in India is that of private or semi-private farms. The numbers of such farms are still low in most parts of the country, but emergence of private farms is inevitable for consolidation of pig farming. Larger farms are considered more resilient to transient costs and to price issues (Kumaresan *et al.* 2008b). Currently, the private farms are mostly concentrated on such locations, which have proximity to lean-pork markets and/or closer to the major cereal crop production areas. Despite the ever existing demand for local pork, there is a growing demand for leaner pork. Native breed sows are also crossbred to form new lines/varieties. Such crossbreeds have proved more popular locally, with much improved weight gain, reduced back-fat and improved lean carcass percentage. The widespread backyard farm segment in India tends to produce many fatty local-breed pigs, sold to local markets, especially in more rural areas. However, these native pig breeds have generally not formed part of expansion/ consolidations by the commercial private farms, probably

Table 2. List of major indigenous and crossbred pigs in India

Indigenous pig breeds		Crossbred pig breeds	
Name	Home tract	Name	Developed by
Ghoongroo	West Bengal	Rani	ICAR-NRC on Pig, Assam
Niang Megha	Meghalaya	HD-K75	AICRP on Pig, CVSc, Assam
Agonda Goan	Goa	Mannuthy white	AICRP on Pig, CVSc, Kerala
Tenyi Vo	Nagaland	TANUVAS KPM Gold	AICRP on Pig, TANUVAS, Tamil Nadu
Nicobari	Andaman and Nicobar	Asha	ICAR-NRC on Pig, Assam
Doom	Assam	Jharsuk	AICRP on Pig, BAU, Jharkhand
Zovawk	Mizoram	Lumsniang	AICRP on Pig, ICAR-RC for NEH, Meghalaya
Ghurrah	Uttar Pradesh	SVVU-T17	AICRP on Pig, SVVU, Andhra Pradesh
Mali	Tripura	Landlly	AICRP on Pig, ICAR-IVRI, Uttar Pradesh
Purnea	Bihar and Jharkhand		

Source: ICAR-NBAGR website.

Table 3. Pros and cons of piggery intervention in small scale farming system

Parameter	Positive	Negative
Natural	Reduced pressure on remaining natural/organic	–
Social	Increased pork products available for improved nutrition	–
Human	Skills and knowledge developed can be used to further diversify livelihood strategies	Competition with more vital activities for time and attention and extra labour burden
Physical	Improved potential for diversification of farming systems and livelihoods to reduce risks	Reduced area available for staple crops
Financial	Improved overall income and regularity of income, credit worthiness, and savings and more diversified production reduces financial risk	High initial investment cost for sty construction and purchase of pigs

due to their slower growth rates and low feed conversion efficiencies (Devendra and Thomas 2002b).

In general, there are three types of swine farms in India based on the numbers of pigs produced on the farm; small (including backyard farms, <10 head), medium (50–200 head), and large (> 200 head) (Thomas *et al.* 2018b). With urbanization and production efficiency, Indian pig and pork production is slowly being shifting 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 cities.

Small size pig farm: In India, the most popular swine holders are small size pig farms including the backyard pig farms. A small size pig farm has average herds with less than 10 pigs, while a backyard farm has even fewer pigs. Even though, backyard farms accounts for about 65% of the nationwide pig production, it is estimated that over 90% of the pig producers with the rural household sector have pigs with an average of 3–5 head per householder (Rougoor *et al.* 1996). In general, the pigs which are housed in small pig farms are usually the one belongs to low-input pigs of indigenous breeds or hardy crossbreds. Pork production is low, mostly used for home consumption and/or to supply predominantly rural markets (local community) with limited competition (Table 3). The traditional pig farming practices followed in these units gives little emphasis on quality and efficiency of pork production. Therefore, the pigs reared in the traditional farms usually fed with little grain at early and late stages and are frequently provided with large amounts of green roughage, based on the location, such as water plants, grass, vegetable leaves, tubers, carrots, pumpkins, fruits, and various crop stalks. This diet lacks certain essential nutrients, especially the protein, resulting in a low feed efficiency. It results in low costs to raise a hog, but it takes great time of over 300 days for pigs to reach slaughter weight, generating a low net income (Thomas and Das 2012).

The farmers and family members are the major stock-keepers in small pig farms. In such cases, the farm management and welfare of pigs are largely dependent on their economic status, animal-related experiences, religion, education etc. Pigs 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 usually unable to cope up the issues arising from associated social, economic and environmental factors (Jones 1998). To overcome these problems and to meet consumers' demand for lean and 'healthful' meat, pig production in India need to move towards specialization by adopting more modern management technologies for improving feed efficiency and increasing pork production and food safety (Thomas *et al.* 2006). This movement could help the Indian swine industry can quickly change the denomination from backyard production of a few pigs to 'medium' or 'large' size operations with more than 10 head annually.

Medium size swine farm: The second type is the medium size pig farm that raises herds from 50 to 200. Currently, this production system houses approximately 30% of the total pigs in India. There was a substantial increase in the medium size pig farms in India during the past 10 years (approximately >250%) (Thomas *et al.* 2018a). Taking advantage of increased demand for pork and pork products in local markets, many educated youths as well as rural households have shifted their focus to pigs and thus increased their swine herds. The aim of farming has also been shifted to capital gain, with the emphasis on increasing grain feed/compound feed, improving feed efficiency and reducing time to reach slaughter weight (Devendra and Thomas 2002a). In order to increase the pork production, the farmers' focus is mostly placed upon improving the welfare of pigs by controlling and reducing management associated stressors. Such stressors include stock densities, housing environments, disease incidence and climate conditions. In this case, the farmers, and specially trained stock-keepers, play cirtical roles in maintaining the health and welfare of the pigs based on their experiences, economical status, education and religion.

Modern intensive swine farm: The third farm type is the modern intensive swine farm (also called 'industrialized' swine farm) with 200 and more pigs. It is important to note that compared to the previously discussed systems that focus mostly on providing animal products for farm families and the local community, the modern intensive pig farms are specialized economic enterprises with higher herd strength (Thomas and Sarma

2017). Also, the production of pork mainly relies on grain-based feed and management skills as well as modern technological advances. In the modern intensive swine farm, pigs are kept purely as a commercial venture by a firm. In this case, the pigs are reared intensively under strictly regulated conditions and are usually provided with all essential inputs, some of which include improved technologies for transportation, preservation of food, prevention of disease, feed efficiency and improved management technology (Gupta *et al.* 2007). It is worthy to note that with the emergence of modern pig farming practices, there exists a clear trend in the swine sector in India to simplify the production practices with an ability to grow more pigs in less space. It is very much essential that India's pig development policies shall focus and encourage the development of modern swine farms to meet the rising demand for meat consumption as well as to meet the objective of doubling farmers' income (Sourabh *et al.* 2017).

Currently, modern intensive pig farms account for less than 5% of the total pig production in India (Thomas *et al.* 2020). It is well understood that with the rising demand for pork and pork products, the modern intensive production system will develop continuously and will be the dominant contributor in the pork market in the country. These developments will help to translate the Indian piggery into a more organized swine rearing sector in the future. At present, the large-scale pork production enterprises in the country are generally located around big metropolitan area (high density of population), to serve the growing demand of urban consumers. However, it is important to note that similar to the pig farms in other countries, the modern pig farms in India will also face several major pig welfare and environmental issues, which include housing condition, stock density, herd size, air quality i.e. odour and ammonia production, climate conditions, increased incidences of diseases and concerns about food safety, and environmental contamination as well as labour availability and safety (Edwards *et al.* 1989, Cheneau *et al.* 2004). One way to overcome some of these challenges will be to establish the large production units out of the cities, away from the areas with dense populations.

Animal health and industrialized pig production

The industrialized pig production practices with high concentrations of pigs sharing a limited airspace and producing large quantities of waste/effluent, and with the demands associated with the intensive production such as reproduction, lactation, early weaning, rapid growth rates are extremely prone to disease. This could be attributed to the build-up of potential pathogens in the environment and presence of carrier animals, viz. older breeding stock; vertical and lateral spread as a result of close contact especially when age groups are mixed together, inadequate ventilation and poor temperature control, stress associated with high stocking densities, handling and transport, changes in feed etc. Other major contributing factors are emergence of new serotypes or mutations of endemic organisms, difficulty in maintaining adequate levels of hygiene with effective cleaning and sanitation, multifactorial disease complex due to the interaction and/or synergism of several organisms that become endemic in a population (Mahanta *et al*. 1986, Kemp *et al.* 1989, Harris 1998, Amit *et al*. 2015).

The major health problems in industrialized pig production systems (Table 4) can be classified into three categories as described below:

- 'Endemic diseases' that become established in a population. Such diseases are generally propagated from older animals in a continual manner, especially from breeding sows and boars to younger ones. Also, once established these diseases are transferred laterally between animals of similar age and the chances of such transmissions are high when stocking densities are high.
- The second type of diseases is 'epizootic diseases' that cause sudden outbreaks. Such cases generally occur due to the introduction of a pathogen from outside or when the herd immunity declines or is suppressed. Such sudden disease outbreaks could also

Table 4. Animal and human health risk factors and management options in industrialized pig production systems in India

Major risk factors	Risk management options
• Establishing herds with pigs carrying endemic pathogens	• Establish herds with minimal disease/SPF stock
• One site farrow-to-finish continuous production systems	• Pig production confined to specific isolated areas
• Inability to de-populate for cleaning and disinfection	• Multi-site production systems
• Close contact and mixing of different age groups	• All-in-all-out management of farrowing sows, weaners, growers and finishers
• High stocking densities	• Early weaning
• Poor ventilation, high dust and gas levels	• Strict biosecurity
• Ineffective disposal and treatment of effluent	• Efficient disposal and treatment of effluent
• Inadequate biosecurity	
• Lack of effective veterinary services for diagnosis and control of disease outbreaks	• Regular independent veterinary consulting services
• Inappropriate and excessive use of antimicrobials especially in feed.	• Use of improved technology e.g. artificial insemination, vaccinations, abattoir health monitoring and disease surveillance.

be associated with emergence of new strains or mutations of endemic pathogens developing in the population.

- The third type of disease is 'stress induced diseases' which often involve pathogens present in the population that cause disease when the animals are under stress. The examples of such stressors include sudden changes in environmental conditions, transport, overcrowding and high stocking densities, changes in the feed, excessive reproductive demands, and to some extent, early weaning.

Diseases associated with industrialized pig production in India

A wide range of diseases in pigs have been reported in India countries and it is also likely that outbreaks of disease in the past may not have been accurately diagnosed. In addition, new diseases also appear to be emerging. Diseases and pathogens that have been reported in pigs in India are most likely to become a greater health risk where large populations of pigs are kept under intensive conditions especially if adequate biosecurity precautions are not taken (Sarma 2007). Many medium and large pig production systems that have been established in the country mainly belong to the traditional farrow-to-finish systems. Such systems often characterized with very close mixing of pigs of different age groups with minimal opportunity to manage even the farrowing sows and litters (Wilson and Johnson 1981, Valarcher *et al.* 2005). These units are more often established with pigs from a variety of sources that can be carrying a large number of potential pathogens. Replacement stock also often comes from a variety of sources and of unknown health status with no adequate quarantine before entry (Patra *et al.* 2014). Biosecurity is highly compromised and has usually been very poor or non-existent with staff regularly in contact with pigs from outside and entry of unauthorized vehicles. Further, adequate perimeter fencing do not exist in some cases to stop other animals or people coming in contact with the pigs.

Effluent disposal is usually into large ponds in close proximity to the buildings and often subject to overflowing in the wet season into local rivers and waterways. The facilities for effective effluent treatment systems to remove pathogens are virtually non-existent in most of the farms. As a result, these herds are often infected with a multitude of pathogens viz. bacterial, viral and parasitic, many of which find their way into the effluent becoming a human health hazard (Rajkhowa 1996, Sarma and Bostami 2008). Disease control in most of these farms is based on vaccination programmes (wherever available) and continuous use of high levels of combinations of antibiotics and anti-bacterial agents without adequate supervision or veterinary advice.

There exist many important zoonoses, that could become a human health risk associated with industrialized pig production systems in India if allowed to become endemic in these herds. The most common methods of transmission of such diseases are contact, handling or consumption of contaminated pork or pork products, through direct contact with infected pigs where the pathogens are being shed or excreted in the environment through faeces, urine or airborne mode (Perry *et al.* 2002, Paris 2002, Thomas *et al.* 2011). It is possible to establish pig herds free from many of these zoonoses by considering the epidemiology of these diseases, therefore reducing the risk of contamination of pork products produced for human consumption. The measures for reducing the risk associated with zoonoses involves establishing specific pathogens free herds where possible, effective implementation of vaccination programs and using the best possible hygiene in the herds, ensuring strict biosecurity measures, effective treatment of effluents to eliminate potential pathogens, effective disposal of effluents so as to avoid the possibility of contamination of soils, waterways or domestic water supplies, implementing measures to avoid cross contamination with pigs in lairage and between carcasses at the abattoir and at meat processing plants (Lekule *et al.* 2003, Cano *et al.* 2007).

Challenges for modern pig farming in India

Pig farming globally faces challenges related to shortages and rising prices of common feed components, particularly corn and soybeans, as they are mostly used for human consumption or diverted to biofuel production. Pig farming worldwide also faces increasing government oversight and rising costs related to waste disposal and potential environmental issues. There are several further challenges more specific to current pig farming in India, some of which are further explained here.

1. *Non-availability of quality germplasm:* The bulk of the pig population in India is indigenous type with low growth rate and productivity (Sahoo *et al.* 2012). However, it is worthy to note that these breeds are very well adapted to harsh climate, poor nutrition and tropical diseases. A sizeable population of pigs in the country belong to the non-descript category, mostly due to indiscriminate breeding and intermixing of breeds. Low productivity of these indigenous animals is attributed to the poor exploitation of their genetic potential and little stress on selection of animals used for breeding. This could also partially be attributed to the frequent intermixing which takes place among these breeds.
2. *Endemic nature of pig diseases:* Major pig diseases, viz. CSF, PCV and foot and mouth (FMD) viruses are widespread and endemic in pigs in India. India has also reported cases of two notifiable diseases i.e. PRRS and ASF, in the recent past. FMD vaccine is provided free by the government to the producers (Sakamoto and Yoshida 2002, McOrist and Done 2007). However, the availability of vaccines for CSF is limited and currently no vaccine is available in the country for PRRS, PCV and ASF (Yang 2008). Further, the number of animal vaccine manufacturers in India, both at semi-governmental and private level,

are very much limited.

3. The level of relevant training and expertise (people with skills, experience, education) of farm managers and attendant veterinarians is often low. This is a major problem, even on farms with considerable investment and expansion (Sarma *et al.* 2016). Similarly, very few state veterinary laboratories can offer pig farmers services in the basic disciplines of pathology, microbiology and epidemiology. This lack of suitable diagnostic ability affects the extent and duration of disease outbreaks and on the overall level of education and training available to farms.
4. *Lack of a distinctive voice in terms of pig farmer groups/companies:* This has a number of knock-on effects. For example, the typical figures for farm costs/ requirements are analyzed by government administrators only and there is no clear voice on the need for suitable facilities with respect of pig production, marketing and the need for suitable veterinary laboratories at State/ regional level (Rozelle and Swinnen 2004). A single voice would also facilitate independent and accredited training programmes aimed at farm management and disease control measures.

Strategies for the development of the piggery sector in India

Result oriented interventions to improve pig production could deliver significant livelihood benefits for tribal and other marginalized groups engaged in piggery. Presently, the local feed resources define the scale of production of backyard enterprises and therefore, improved feed resources and feeding practices will be the key interventions to increase the productivity and profitability of small-scale backyard piggery. Educating farmers on breeding, feeding and health care management, modern husbandry practices together with knowledge on zoonotic diseases and market-oriented production systems will help in producing good quality pork from healthy pigs, which can fetch better price (Naidu and Kondaiah 2004, Chander and Mukherjee 2005). Therefore, it is the high time to develop client-oriented and needs-based extension programs using participatory methods involving stakeholders that address how to improve production with limited household resources, could maintain their pigs in good health and to breed productive crosses.

Conservation of indigenous germplasm: Use of available indigenous breeds for low-income rural communities could be helpful because they require low inputs. Improvement of pigs through cross breeding could be carried out in commercial and large-scale farms, as most of these farms have capacity to provide continuous intensive inputs (Das *et al.* 2012). The genetic makeup of the pig will have the highest impact on its ability to grow muscle (Sahoo *et al.* 2012). Since the characteristics related to meat production (body weight gains, efficiency of feed conversion, and dressing percentage) are moderate to highly heritable, selection of breeding stock can bring about considerable improvement. The aim is to increase the frequency of desired genes in the stock, thus increasing superior germplasm in the base population at the expense of the undesired genes. Countries that have developed livestock industries, maintain special breeding flocks to supply superior germplasm to commercial flocks (Patrick and Ananth 1989). The exotic breeds of pigs like Large Black, Hampshire, Large White Yorkshire, Landrace and Duroc have shown a good performance under the local conditions and thus they can be raised on the basis of selective breeding. In case of free range rearing, attempts in grading up of the local non-descript with exotic can be a feasible approach. However, it is important to ensure that there exist measures for simultaneous improvement of feeding and management.

Production of improved germplasm: In order to ensure profitable pig production, there exist need to have specific breeds, which must produce fast and efficient growing young ones. The bulk of the pig population in India is indigenous type with low growth rate and productivity (Giuffra *et al.* 2000). However, these indigenous pig breeds are very well adapted to the harsh climate, poor plane of nutrition and the diseases present in tropical climate. As indicated above, low productivity of the indigenous animals is due to poor exploitation of genetic potential, little stress on selection of animals used for breeding and frequent intermixing takes place among breeds.

Efficient breeding system: An entrepreneur in the piggery sector always give more importance to the productive and reproductive criteria of pigs which they house such as daily weight gain, feed conversion efficiency and better fertility rates. Also, selection of individual animals from a herd for breeding purpose is more important than the selection of a particular breed (Bujarbaruah *et al.* 2007). The primary traits of reproduction that are normally recorded in a pig farm are litter size at birth, strength and vigour of litters, litter size at weaning, milking ability and temperament of sow. Importance shall be given to the sow with large number of survivable litter and which can attain marketable weight at an age of 8 months or less, while selecting for breeding. Also, efforts should be taken by each producer at the time of setting up his herd to purchase pigs from a reliable disease free herd with pedigree records. Further, once the herd is established the selection of the gilts and boars for replacement in the breeding herd should be based on the types and performance. In order to ensure economic viability of the farm, judicious culling and replacement of animals in a herd is necessary. If optimal managemental conditions are followed in the farm, it could easily lead to two farrowings in a year. It is important that, for every 10–15 sows, two boars must be maintained for maximum fertility (Das *et al.* 2012). The consumer desire for healthy pork products in the recent past has directed the breeders to evolve designer pigs with lower back fat thickness and lower fat percent of retail carcass weight.

Right nutritional approaches: It is well established that

nutrition is the key non-genetic factor which can influence pig production and the studies revealed that even genes are expressed in the presence of optimum nutrition. Pigs, being monogastric animals, are able to transfer nutrients and feed additives directly to muscle and tissue (Pingali 2007). The animal industry has been aware of the need for better nutritional intake of the animal to maximize lean growth. In order to maximize the muscle development, feed with specified amino acid ratio and not just by total protein content is essential. However, in many a times the availability of feeds and fodder is not commensurate with their requirements. A gigantic gap of about 44% concentrate, and 36% each of green fodder and dry roughages exists between the demand and supply of animal feed resources in the country (Ranjhan *et al.* 1971, Reddy *et al.* 2001). Therefore, there exist, a clear need to look beyond the traditional feed resources available to alleviate the demand for pig feeds. Development of feeding strategies based on cheap feed stuffs which are available locally such as leaf meals, oil cakes, grain by-products and root tubers like tapioca and sweet potato, which are not extensively used presently, is must for low income communities. Exploitation of un-conventional feed resources, viz. leftover from kitchen/ hotel/ cold storage in replacing the balance rations will help in minimize the cost of production. Also, improving the digestibility of the local feed resources has a direct effect on feed requirement by the pig industry. Therefore, it is very much essential to solve the feed problem before the farmer can be convinced that he should not let his pig roam around for scavenging.

Setting up pig villages/ nucleus herd: Community-based or cluster based systems need to be developed and private-sector investments shall be encouraged to better meet the unsatisfied demand for improved breeding stock and quality piglets in the country. It is also important to explore the possibility of introducing artificial insemination in sows and need-based training program for smallholders on the care and management of breeding stock (Das *et al.* 2012). For example, ICAR-National Research Centre on Pig has launched 'Mega Seed Project' with the aim to incorporate highly prolific germplasm under field condition and distribute the improved germplasm to the farmers from the nucleus herd.

Setting up hygienic yet affordable pig slaughter houses and retail pork shops: Even though pork and pork products are acceptable to a section of population, they are not finding widespread acceptance since, the existing production, processing and marketing conditions are very unsatisfactory (Thomas and Sarma 2017). Meat spoils and become unacceptable for human consumption in a matter of hours particularly in hot, unhygienic conditions. Also, there exists no routine pre- or post-mortem inspection of slaughter pigs, especially in the rural areas, because of inadequate manpower and the absence of physical infrastructure for slaughtering and selling of pork (Grandin 1996). This position has deterred many elite pork consumers from eating pork. The need of the hour for wholesome meat production in the country are addressing the above mentioned deficiencies in public health measures through a risk assessment along the production-to-consumption value chain, establishing required infrastructure and inspection (manpower and physical resources) facilities and training all the stakeholders in meat hygiene and food safety.

Augmenting value addition in processed pork products: It is reported that value addition of meat is very much limited in the country and less than 2% of total meat is processed into products for trade in India as compared to more than 60% in developed countries. However, the demand for processed meat is ever increasing in the country and hence, there exist substantial scope in the pork processing and value addition sector. A new trend is observed in the recent past that apart from poor and a section of elite urban people, the middle class people in India are also gradually developing taste for pork and pork products (Thomas *et al.* 2018). In order to process pork to meet consumer requirement with sustained demand, quality of pork is an important consideration. The important palatability factors that determine acceptability of pork and pork products are colour, aroma, tenderness, juiciness and flavour. Desirable quality pork has a firm, dry surface with a pinkish red colour (Thomas *et al.* 2006). In order to make good quality meat products the following factors are very essential, viz. careful selection of raw material, proper handling, hygiene and suitable equipments. Also, in order to tap the potential of traditional pork products, their processing technologies need to be refined/standardized and validated.

Disseminating cheaper housing patterns and scientific managemental practices: While designing the housing for the pigs, it is essential to give importance to those designs which could give maximum comfort to pig, so that their growth is optimum. Dampness, draft and overheating should not be allowed to occur (Kumaresan *et al.* 2008). Dissemination of simple, relevantly designed pig houses affordable for poor rural population, for example, low cost houses with ample sanitation, proper ventilation and better hygiene conditions to control parasites and pathogens affecting pigs is a major intervention in the production of wholesome meat production (Bujarbaruah *et al.* 2007). In order to protect the animals from common diseases, periodical deworming and timely vaccination must be planned. Feeding of the sows during pregnancy is most important for increase in litter size. The studies indicate that providing a good grower ration to sows and gilts, seven to ten days before breeding could significantly increase the ovulation rates in them. Also, breeding sows and gilts should be fed a limited but well balanced ration until the last six weeks of pregnancy and subsequently full feeding should be resumed. Pigs should be vaccinated against classical swine fever at the age of 2–4 weeks and breeding pigs should be tested invariably for brucellosis and leptospirosis. As a routine farm practice, all the piglets at the time of weaning should be vaccinated against classical swine fever. Piglet anemia can be prevented and

cured by timely supplying iron either orally or by injection. Animals purchased for the farm should be purchased from disease free herds as far as possible and the newly purchased animals should be quarantined away from the farm for a period of three to four weeks.

Promoting intensive and integrated pig farming: The existing system of rearing pigs in most part of the country as a subsidiary farm activity in backyard with minimum shelter to utilize garbage and leftover grains available to produce meat for family use, should move towards intensive system of production involving good breeding stocks and better nutritional input to produce marketable quality pork and pork products (Das and Bujarbaruah 2005). In areas with shortage of land to grow feeds and in large cities, the intensive swine production system is economically viable because of availability of industrial by-products. Also, integration of pig farming with other livestock and crops could result in effective and full utilization of the inputs such as feed, land, manpower, capital etc. (Das *et al.* 2012). Further, integrated pig farming can surely play a role in increasing the employment opportunities, nutritional security and income of rural populations and has received considerable attention in the recent years.

Ensuring micro credit facilities: Lack of sufficient working capital is a recurring constraint among pig farmers and traders in the country. Pork and piglet traders mostly depended on local money-lenders to run their business (Naidu and Kondaiah 2004, Bujarbaruah *et al.* 2007). Most of the government-sponsored schemes extend credit to Self Help Groups (SHGs) but not to individual members. Thus, extension of micro-credit through NGOs may be a viable alternative. In the same way, insurance coverage for the pigs of small-scale producers may be possible through the Group Insurance Schemes of insurance companies, which will ensure an effective, farmer-oriented extension service (Patrick and Ananth 1989).

Potential of piggery towards doubling of farmer's income and achieving SDGs

It is very well understood that piggery has tremendous potential to contribute towards attaining the vision of doubling of farmer's income by 2022 by the Government for a developed and prosperous country with healthy and gainfully employed people (Neha *et al.* 2019). Piggery could also very well fit into the rural based agricultural and livestock production systems, and can provide a better option to the farmers to mitigate the risk of production failures thereby increase the profitability in a more sustainable way (Wendy *et al*. 2020). Sustainable Development Goals (SDGs) were adopted by the United Nations General Assembly on 25 September 2015 and six years since the adoption of the SDGs by the Governments, it is now well understood that piggery sector could immensely contribute not only towards achieving these SDGs. However, there exists a felt need to augment/ improve the specific aspects of piggery towards achieving the full potential of piggery sector in the country. Some of the relevant points are outlined in Table 5.

Technical support in offering from ICAR-National Research Centre on Pig

ICAR-National research Centre on Pig, located at Guwahati, Assam, is relentlessly working with the vision to bring in excellence in pig production, health and product processing through innovative research in order to provide technology backstopping for quality germplasm, enhanced pork production, employment generation and poverty reduction among socially and economically weaker sections through medium of pig husbandry. The institute is coordinating 15 All India Coordinated Research Project on Pig and seven Megaseed centres on pig, located in different parts of the country. Institute could very well offer the technical assistance to improve piggery sector in the country. Some of the possible areas of collaboration are listed below: Implementing and improving "Pig Breeding Policy" in the states; conducting "pig disease diagnosis, surveillance and monitoring"; establishing "liquid Boar Semen processing labs" for facilitating artificial insemination in pigs; establishing "Micro pig abattoirs" at a cost of about ₹10 lakh/unit to ensure hygienic pig slaughter; establishing "IoT based traceability and meat inspection" systems; quality control of pork and pork products (residues-veterinary drugs/pesticides; heavy metals; adulteration; microbiology etc.), among others.

Technical support to entrepreneurs/start-ups through 'Agri-Business Incubation' centre

ICAR has established Agri-business Incubation (ABI) centres in different ICAR institutes to nurture early stage innovative startups and entrepreneurs. ABI centres act as a platform for the speedy commercialization of the technologies and reinforcing of public private partnerships through an interfacing and networking mechanism between R&D institutes, industries and financial institutions, thereby contributing to knowledge based economy. Technology applications, skill development and developing the service sector that solves the problem of glut, unemployment, and waste management will definitely contribute to change the agriculture and allied sectors into an organized sector. Agri Business Incubation Centre of ICAR-NRCP was sanctioned by ICAR under XIIth Plan Scheme of National Agricultural Innovation Fund (NAIF) Component II (Incubation Fund). The institute has created a state-of-the-art Agri-business Incubation Centre to support operations on technology based business projects. The facility has incubation space for 8 incubatees, a meeting room and utility space. The incubation space is well equipped with computers and accessories with internet connectivity for running the office activities of the incubatees. The meeting room provides a very good space for the entrepreneurs to meet and interact with the investors and scientists. ABI Centre is providing all the necessary support to the entrepreneurs to validate and upscale the technologies and encourage their reach to the end user for an attractive business proposition. ABI Centre is also facilitating the innovator and the researchers to turn their ideas into commercial venture. Further, the ABI centre also

Table 5. Areas which need further thrust to augment the output from piggery sector in the country and to attain the specific SDGs.

Relevant SDG	Areas that need attention to achieve the SDG
SDG 1- No poverty and SDG 2- Zero hunger	1. Promotion of piggery based entrepreneurships at village level and the support thereof. 2. Ensuring that the crossbred/ improved germplasm goes to the correct hands, where provisions for better feeding and management options are available. 3. Creating a "Corpus fund for insurance of piggery sector" [effective mechanism for fast settlement of claims]. 4. Improving veterinary service delivery system—Affordable and quality veterinary service at the farmer's door step.
SDG 3 – Good health and well being	1. Strengthening the disease monitoring, diagnostic and reporting systems of Veterinary Departments, which in turn facilitate the health certification process required for exports. 2. Bringing pig vaccinations under 'compulsory vaccination' schemes as in the lines of dairy sector, which will also facilitate in establishing designated Disease Free Zones (DFZ) for animal sourcing [In-turn facilitates exports]. 3. Enhancing the monitoring on pig transport through the borders with respect to disease transmittance and outbreaks. 4. Improving bio-security measures in the farms—proactive steps are essential to prevent the entry of ASF, PRRS, etc. 5. Increasing the capacity of vaccine production centres to meet the country's requirement. Option for new units can also explore.
SDG 4 – Quality education	1. Let us understand the commercial pig production – need to provide exposure visits for the stakeholders to those countries where it is present. 2. Effective skill development mechanism need to be enforced in the area of scientific pig production, pen side disease diagnosis, hygienic pig slaughter and value addition of pork.
SDG 5 – Gender equality	1. Effective mechanism to be implemented to ensure selection of women beneficiaries' w.r.t. pig germplasm distribution or skill development programme.
SDG 6 – Clean water and sanitation and SDG 7 – Affordable and clean energy	1. Promotion schemes for mechanization in piggery sector, as in production or processing. 2. Development of SOPs and water and carbon foot prints in complete piggery value chain [ICAR-NRCP could offer technical support]. 3. Implementation of schemes to ensure efficient waste disposal from the farms. Most of the cases, the wash remains in the premises and result in flaring of mosquitoes and flies. It also results in bad smell and incidence of *Japanese Encephalitis*, too.
SDG 8 – Decent work and economic growth	1. Strict laws need to be enforced to prevent the scavenging system of pig rearing. It will help to improve the image of piggery in the society as well as help to reduce the incidence of *Neuro-cysticercosis* in consumers. 2. Implementation of new schemes to promote value chain completion at the site of production. Such measures will support the economic growth in the production sites.
SDG 9 – Industry, innovation and infrastructure	1. Development of micro-entrepreneurship in the clusters—This model is for completion of value chain within the cluster itself.
SDG 10 – Reduced in-equalities	1. Implement mechanism to ensure cohesive participation of all stakeholders associated with piggery sector.
SDG 11 – Sustainable cities and communities	1. Implement effective mechanism to demarcate the pig production and processing areas in the municipal/city areas. 2. Enforcement of FSS Act to prevent unauthorized/ clandestine pig slaughter and retailing to ensure supply of quality pork to the consumers. 3. Implement risk assessment and monitoring system with respect to the risk factors associated with production and marketing of pork viz. residues, antibiotics, growth hormones, etc.
SDG 12 – Sustainable consumption and production	1. Promoting "Integrated pig production" [integrating with fishery, paddy etc.] 2. Focus on Traceability: Efforts need to made to ensure 'premise identification' and 'group/lot identification' for ensuring traceability. 3. Establishing "Liquid Boar Semen processing labs" at multiple points to promote Artificial Insemination and planned breed improvement. 4. Focus on producing protein rich grasses (e.g. Berseem, leucerne) as an alternate pig feed. Pig can very well digest grass as it is omnivorous in nature. Explore the options of effectively using jackfruit, tapioca and sweet potato [utilization of unconventional feed resources]. 5. Ensure convergence of departmental schemes/ activities to avoid duplication and effective implementation.

(*Contd...*)

(Table 5. *concluded*)

Relevant SDG	Areas that need attention to achieve the SDG
SDG 13 – Climate action	1. Implementation of schemes to promote "Climate resilient pig housing". 2. Focus on effective "Disaster management of pigs", especially during flood period.
SDG 14 – Life below water	1. Promotional schemes for piggery–fishery–paddy integration.
SDG 15 – Life on land	1. Implementation of schemes to utilize the barren land/ river bank as fodder production units, which will in turn provide quality feed to pig as well as become a means to prevent soil erosion.
SDG 16 – Peace, justice and strong institutions	1. Ensure cohesive action among the institutions associated with piggery sector, as outlined under sl.no.8. 2. Also, promote capacity building of professionals, institutions and stakeholders associated with piggery sector.
SDG 17 – Partnerships for the goals	1. Shift the developmental focus to 'cluster oriented' approaches, whereby the state will be able to develop a comprehensive database for particular cluster (Private pig breeding farms in the lines of poultry). 2. Establish "Strategic co-operation with northern states" for making raw material for pig feed available in the state at affordable price.

extends support for starting, diversifying and up-scaling of commercial piggery/ allied services/pork processing/quality control sectors to the promising entrepreneurs. The centre focuses on incubation and business development programmes, including entrepreneurship skill development activities (Thomas *et al*. 2020). The list of startups established with the technical support of ABI centre of ICAR-NRCP are presented in Table 6.

Intellectual property regime and piggery sector

Science, technology and innovation are considered to be the key drivers of the economic development of nations, including India. Research publications and patent generation are two critical indicators for assessing the quality of scientific endeavours of a nation. As per global indicators, India is ranked amongst the top 5 countries in terms of number of research publications, however, its global ranking is much lower in the indicator of Intellectual Property Rights (IPRs). IPRs can play a significant role in achieving the country's development goals, as they affect agricultural and rural development (Ramesha 2011). The main impact of IPRs is through their relationship with the transfer of traditional and modern technologies, and making IPRs support rather than hinder sustainable development. However, developing countries like India have a less homogeneous livestock-agro-socio-economic environment in which farmers operate. It is well accepted that IPRs can help to stimulate economic growth and reduce poverty. The concerns about the impact of IPs are now becoming important for research outcome auditing. The importance of intellectual property protection to develop the scientific and technological capacity of developing countries and benefits derived from the enhanced level of growth has now become a matter of common understanding (Singh and Chakarborty, 2015 and 2019).

Table 6. List of startups established through the technical support of ABI centre of ICAR-National Research Centre on Pig

Name and address of the firm	Technical support extended by ICAR-NRCP	Brand established by the startup	Stage of incubation
Arohan Foods Pvt Ltd, Assam	Technology for processing value added pork products Technology for micro pig abattoir	Choice Pork Natural	Graduated
Sayuri Farms, Assam	Technology for processing value added pork products	Pigzee's	Graduated
Amora Foods, Assam	Technology for processing value added pork products	International House of Sausages	Growth stage
Symbiotic Foods Pvt. Ltd, Assam	Artificial Insemination Technology using chilled boar semen	–	Early stage
Borluit Farms, Assam	Technology for processing value added pork products Technology for micro pig abattoir	– –	Early stage
Mr G N Nagesh, Karanataka	Technology for micro pig abattoir	Pork Paradise	Growth stage
Emergent Dream Works Infra Developers Pvt. Ltd, Telengana	Establishment of commercial pig breeding farm Technology for processing value added pork products Technology for micro pig abattoir	Peppa Pork	Early stage
Mr Rubul Deka, Assam	Artificial Insemination Technology using chilled boar semen	–	Early stage
Paras Farms, Jharkhand	Technology for micro pig abattoir	–	Early stage

Table 7a. A glimpse of worldwide patent applications filed/grated in the area of pig research and development based on keyword search

Keyword	Patent applications filed/granted			
	All text fields	Title	Title, abstract, and claim	Claim
Pig	864,061	24,972	121,722	104,701
Pig and pork	36,490	334	10,026	5,945
Pig and transport	88,281	78	2,527	1,877
Pig and human health	90,846	01	965	282
Pig and diagnostics	56,680	20	1,138	742

Source: https://worldwide.espacenet.com

Table 7b. Top five patent filing and inventing countries with applicant organizations in pig research sector

Keywords	Patent filing office (PFO)		Applicant organizations/individuals		Nationality of inventor	
	Country	Patent applications	Name of applicant	Patent applications	Country	Patent applications
Pig	China	66,021	Nippon Steel Corp, Japan	524	United States of America	14,388
	United States of America	19,386	Siemens Ag, Germany	387	China	5,007
	Japan	10,459	Muyuan Food Co Ltd., China	324	Germany	3,575
	Germany	8,772	Huazhong Agricultural University, China	311	Korea (South)	3,136
	WIPO	5,114	Nippon Kokan Kk, Japan	267	Japan	1,823
Pig and pork	China	5,452	University Nanjing Agricultural, China	35	China	459
	Korea (South)	563	Wuhu Hongyang Food Co Ltd., China	31	Korea	452
	Japan	201	Huazhong Agricultural University, China	26	United States of America	67
	Russian Federation	97	University Guangxi, China Co Ltd., China	19	Spain	38
	WIPO	62	Wuhe Tongshifu Food	19	Russian Federation	34
Pig and transport	China	946	Voest Alpine Ind Anlagen, Germany	25	United States of America	394
	United States of America	308	Voest Alpine Ind Gmbh, Germany	19	Germany	181
	Japan	301	JFE Steel Corp, Japan	18	Austria	83
	Germany	154	Nippon Steel Corp, Japan	16	Korea (South)	75
	European Patent Office	154	Po Hang Iron & Steel, South Korea	12	Netherlands	43
Pig and human health	China	97	Evolve Biosystems Inc, USA	5	United States of America	142
	WIPO	59	Han Min Suop (NA)	4	China	26
	Singapore	53	Han Sang Kwan, South Korea	4	Korea (South)	20
	United States of America	50	Bradner James E, USA	3	Canada	17
	Australia	36	Chang Alice, USA	3	United Kingdom	16
Pig and diagnostics	China	262	Dongguan Pengzhi Biotechnology Co Ltd., China	21	United States of America	266
	WIPO	187	Huazhong Agricultural University, China	12	Germany	62
	United States of America	140	Boehringer Ingelheim Vetmed, USA	11	Korea (South)	62
	Japan	111	Intervet Int Bv,, USA	11	Canada	52
	Korea (South)	101	Jiangsu Acad Agricultural Scl, China	10	United Kingdom	50

Source: https://worldwide.espacenet.com

In the recent past, the pace of pig farming in the country has changed and become more technology intensive. These changes are more becoming visible with industrial/ commercial farming, precision feeding, herd management etc. Many technologies are generated in the field of piggery sector in India, mostly by the public funded institutions, including Indian Council of Agricultural Research and State Agricultural and Veterinary Universities, but the level of technology commercialization and entrepreneurship development is quite low. Researchers, innovators and companies have now started prompt action to protect their IPs and ICAR-National Research Centre on Pig has 3 granted Indian patents and 9 granted copyrights, falling in the area of pig transport, hygienic pork transport and pig hair/fibre utilization.

A glimpse of worldwide patent applications filed/grated in the area of pig research and development is presented in Table 7a and 7b. To get these glimpses five pig research related key words were selected, viz. Pig, Pig AND Pork, Pig AND Transport, Pig AND Human Health, Pig AND Diagnostics, which were searched on five levels (All Text Fields, Title of the Research, Title-Abstract-Claim, and Claim alone) on *espacenet* [Patent Search Engine of European Patent Office (EPO)].

In general claims are known as the heart of the patent document/application, which can express the rights/strength of an innovation. Here, also we have searched these key words in the claims of patent application and found that China is leading Patent Filing Office (PFO) which published/granted highest number patent applications in the field of pig research and development, followed by United States of America (USPTO), Japan (JPO), WIPO, Germany, and South Korea. But, it is very interesting to know that the inventors of these applications are mostly belongs to USA, South Korea, China, Germany and United Kingdom (UK). The applicant organizations are having their presence in China, USA, Japan, Germany, and South Korea.

Conclusion

Indian consumers eat more pork than ever before, with wealthier and younger generation consumers preferring industrially produced meat, which is viewed by the consumers as more strictly regulated, and therefore, safer. Industrial pig farming is gaining steady momentum in greater volumes in India and of course in a faster pace than ever before. It is a capital- and resource-intensive sector that has become highly productive, highly profitable, but need to be supported with appropriate policies and business options. In order to augment the pig production and processing system in the country, it is inevitable that substantial Government support is needed through subsidies, investments and favorable policies for medium- to large-scale industrial operations. However, framing of effective policy to ensure that smallholder farmers will not be opt out of the pig production due to the increased consolidation of the industry. Agribusiness firms shall come up and control much of the production and sale of pork, through production arrangements with commercial farmers, and with financial support from public and private investment. Yet, food safety issues, public health problems, effluent management and environmental pollution associated with the piggery sector are increasingly becoming bottlenecks. It is expected that this dialectic between pork's sociopolitical importance in India and its mounting externalities will surely shape country's policy towards pork production, trade and consumer choices in the coming decade.

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