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Research Article

Value chain analysis and identification of risk spots for infectious disease control in the pig industry, Punjab, India

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Abstract

Pig farming in Punjab state of India is catching the attention of the masses owing to the multifaceted benefits associated with it. The objective of this study was to analyze the pig value chain and identify various risk spots that could lead to the spread of inter-farm diseases. A well-structured and piloted interview schedule (Chronbach alpha = 0.809) was used to collect the data from the respondents. The study was carried out with 350 pig farmers and 15 key informants (veterinarians, traders, butchers, 5 each). Data revealed that young people (mean age 38.55±9.96 years) are starting this business, but only on a modest scale (10 to 30 pigs) in the residential area (59.43%). The majority of farmers (87.42%) bought their pigs from other pig farmers but sold them to traders (63.14%). Being economical, most pig farmers were found feeding kitchen waste to pigs (70.57%). To a large extent, the absence of pig health experts forces the pig farmers (64.86%) to self-treat the diseased animals and vaccinate them. No quarantine, biosecurity/PPE measures at stakeholder levels, assisting in farrowing, no visitors' restriction, improper carcass, and excreta disposal, etc, are risk spots that could spread infectious diseases. The study found Farmers - Traders - the North East market-Consumers as the main chain in the pig industry. Dependency on traders limits the arena of pig marketing and profitability. Animal health policymakers should consider how to safeguard this emerging farming through ensuring marketing, profitability and mitigating the risks identified in this study.

Keywords: India, Pigs, Risk spots, Value chain

Highlights

- Farmers - Traders - the North East market-Consumers is the main chain in the pig industry of the Punjab.
- The pig farming business is highly dependent upon traders or butchers for marketing.
- There exist many risk spots, which makes pig farming highly vulnerable to infectious diseases like African swine fever, Classical Swine Fever, etc.

INTRODUCTION

The pig industry in India is catching a good momentum owing to increased demand for pork in and outside the country. Pig farming once centered in the Northeast pocket of the country, now has become one of the most favored farming among the masses across the country due to its less initial investment, high profitability, high prolificacy, early maturity, short generation interval, and increasing demand for pork. Currently, the country has 9.06 million pigs (BAHS, 2019), which are reared in a traditional small-scale subsistence-driven production system (Chauhan *et al*., 2016).

Punjab- the north western state of the country, after playing a pivotal role in the green and white revolution, is now marching toward a new revolution, i.e., the pink revolution, related to pig farming. Shedding age-old social stigma related to pig farming, all sections of society are now adopting pig farming owing to aforesaid reasons. More than 2000 pig farmers in Punjab (Bhadauria *et al*., 2019) reported having around 52,000 pigs (BAHS, 2019).

Value chain analysis or mapping is a quick and useful method to understand the pig production system, especially when it is a new one. This mapping described the different interlinked activities and actors involved in the input and output value chain of the pig production system. It can be defined as all interlinked activities required and factors involved from procurement, production, and its delivery to the final consumer (Porter, 2008). Value chain mapping also enables us to detect different "risk nodes" in the production system, which render the supply chain susceptible to diseases/hazards. Finding these risk nodes is essential because it allows the organization or disease control authorities to proactively reduce risk

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and strengthen the value chain's resilience, particularly in times when the African Swine Fever disease is posing problems for the nation.

Few value chain analysis studies were conducted in North Eastern States (India) (Deka *et al.*, 2011), while there is a lack of such studies for the Punjab state. Therefore, the present study has been designed to study i) the value chain system in commercial pig farming in Punjab and ii) interventions and practices used by farmers to control infectious/zoonotic diseases along with the identification of various risk spots.

MATERIALS AND METHODS

Study area: The study was conducted (January 2021 to June 2022) in the Punjab state (31.1471°N, 75.3412°E) of India. Even being comprised of largely a non-pork consumer population, the farmers of the state set an example by venturing into this ignored farming. Though the state has only 0.05 M pigs (BAHS, 2019), the rearing practice and breed reared (Large White Yorkshire) make the pigs from this state one of the main sought-after animals for pork production.

Sample size estimation and study design: By taking around 2000 pig farmers in Punjab (Bhadauria *et al.*, 2019) as a sampling frame and assuming about 50% of farmers have a factor of interest, with 5 percent absolute precision and 95 percent confidence, a sample size of 323 was required (Dhand and Khatkar, 2014).

A total of 350 pig farmers and 15 key informants (traders, veterinarians, and butchers, five each) were contacted for an in-depth understanding of the pig value chain in the state (Fig. 1). Pig farmers were selected using snowball techniques, and having more than 10 animals. Informed consent was taken from each individual for his/her voluntary participation in the study.

A well-organized interview schedule designed to collect data from the respondents was developed. The interview schedule comprised of socio-demographic characteristics (age, gender, education status, family type, land holding, and training on pig farming); farm

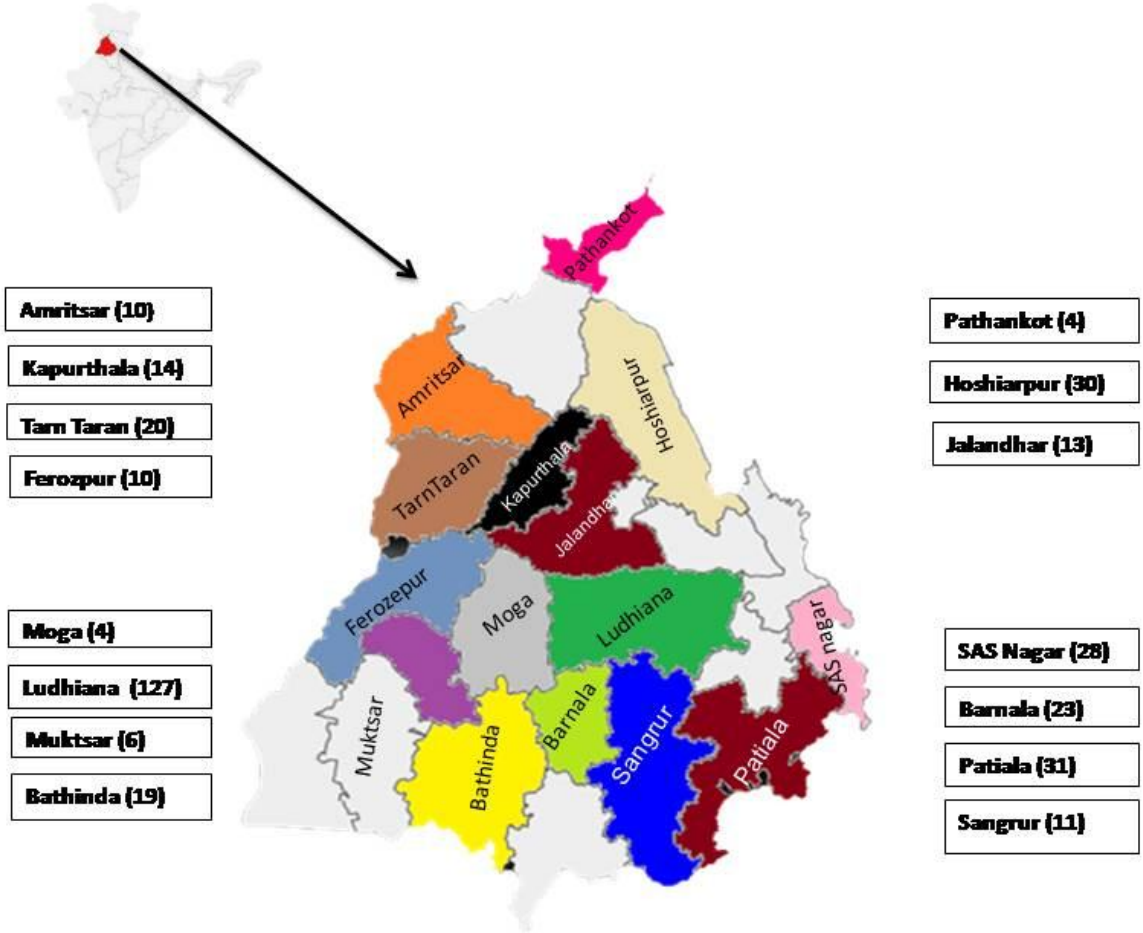

Fig. 1. Location of the pig farmers (n=350) involved in the study

characteristics (location of the farm, type of pig house, and number of animals), input value chains systems (purchase of new animals, feeding, management, and health); output value chains system (sale of animals, value addition of pork, disposal of carcass, and excreta) and interventions/practices used by farmers to control the infectious/zoonotic diseases. Aside from these, risk nodes/spots were identified in the chain with the help of experts from the University from where disease can further spread to other farms. The interview schedule was pretested on 20 commercial pig farmers from all over Punjab. Accordingly, necessary modifications were made to the schedule to make it more convenient and easier for respondents. The results of this work are not used in the final data analysis.

Statistical analysis of data: The data so collected were entered into an excel sheet, and descriptive analysis including mean and frequency was done. Based on the data, a value chain flow diagram and risk spots (input and output chains) were constructed. Value chain and risk spots so developed were validated through discussion with pig farmers (n=37) during one seminar of pig farmers held at the University.

RESULTS

Socio-demographic characteristics

The majority of farmer respondents were male 99.14%), had a nuclear family (84%), and had piggery as their main occupation (88.96%). The average age of respondents was 38.55±9.96 years, ranging from a minimum of 20 years to a maximum of 61 years. Further, the majority of pig farmers (56%) studied were landless. Around one-fourth (25.14%) of pig farmers were illiterate (Table 1). Training is an effective tool to understand and enhance scientific knowledge (Hundal *et al*., 2016), but the majority (58%) did not attend any such training. Among key informants, all, but one (veterinarian) were male. All veterinarians were young (Mean age: 28 years) and had postgraduate degrees (M.V.Sc). On average, they had visited 2 pig farms in the last 6 months. As for butchers, 60% were working

Table 1. Socio-demographic characteristics of pig farmers (n=350)

	Category	Frequency (n=350)	Percentage (%)
Gender	Male	347	99.14
	Female	3	0.86
Family type	Nuclear	294	84.00
	Joint	56	16.00
Education	Illiterate	88	25.14
	Primary (up to 8th standard)	102	29.14
	High School (9-10th standard)	61	17.43
	Higher Secondary (+1-+2th standard)	92	26.29
	Graduation	7	2.00
Main occupation	Pig Farming	311	88.86
	Agriculture	24	6.86
	Government/Private Job	15	4.29
	Other	0	0.00
Landholding	Land Less	196	56.00
	Marginal (≤2.5 acre)	52	14.86
	Small (>2.5 to ≤ 5.0 acre)	60	17.14
	Semi medium (>5.0 to ≤ 10.0 acres)	39	11.14
	Medium (>10.0 to ≤ 25.0 acre)	0	0.00
	Large (>25.0 acres)	3	0.86
Experience in pig farming (years)	1-5 years	74	21.14
	6-10 years	151	43.14
	11-20 years	86	24.57
	More than 20 years	39	11.14
Pig farming training	Not attended the training course	203	58.00
	Attended the training course	147	42.00

Table 2. Pig farms characteristics

	Category	Frequency (n=350)	Percentage (%)
Breeds of pig	Large White Yorkshire (LWY)	319	91.14
	Other (Duroc and Hampshire)	31	8.86
Location of pig farm	Inside residential area	208	59.43
	Away from residential area	142	40.57
	< 1 km away	68	47.88
	> 1 km away	74	52.11
Type of pig house	Katcha	15	4.29
	Pucca	228	65.14
	Mixed (Katcha + Pucca)	107	30.57
Total no of animal	10-30	236	67.43
	31-50	69	19.71
	>50	45	12.86

in rural areas, and 80% reported slaughtering pigs regularly. Two butchers reported that they keep pigs on their own and, as per need, slaughter them. The rest reported that they purchase pigs from other pig farmers. All five traders have their vehicles to transport pigs.

Farm characteristics

The majority of pig farmers were found rearing Large White Yorkshire breeds (n=319, 91.14%), having animals ranging between 10-30 (67.43%), and had not attended any training related to pig farming (59.43%). Only 11.14% had more than 20 years of experience. The study found that 59.43% of the farms were located inside the residential area, and the rest (40.57%) were located away (Table 2).

Value chain analysis

The total value chain mapping is comprised of input and output chains.

Input value chains: The chains that go towards the farms come under this section.

Out of 350 farmers, the majority of pig farmers purchased piglets from local farmers (n=306; 87.42%) with their own experience and skills (90.57%). The majority of pig farmers found feeding kitchen waste to pigs (70.57%) that they were collecting from the hotel industry, messes, marriage palaces or vegetable markets, etc. Three types of feeding patterns, *viz.* feeding of kitchen waste alone, feeding of concentrate alone (15.71%), and feeding combination of both kitchen waste and concentrate (13.71%), were practiced (Fig. 2). Further, in the concentrate feeding section, most farmers relied on readymade feed as often the dealer delivered the feed on the farm itself.

The majority of pig farmers (64.86%) reported self-treatment to diseased animals, and only 18.29% sought the services of authorized veterinarians. A large proportion of pig farmers were found practicing vaccination and deworming (80.57%), castration of male animals (74.86%), injecting iron to piglets (80.57%), and needle teeth cutting (94%) on their own. "We don't have other option as majority veterinarians don't treat the diseased pigs"- quoted one of the pig farmers. Surprisingly, veterinarians as key informants revealed that they have never sent the pig sample or issued a health certificate for sale-purchase as they were never approached by the farmers for the same. Further, the recent outbreak of FMD, classical swine fever, and colibacillosis was reported by the pig farmers (41.43%). Veterinarians contacted (n=5) reported that they vaccinated pigs in their area against FMD disease using a new needle for each pig, as corroborated by Ito *et al.* (2019). It is worth mentioning here that the State Animal Husbandry Department vaccinated the cloven-footed animals against FMD twice a year, but their priority remained the dairy animals. However, for Classical Swine Fever, pig farmers have to purchase its vaccine from Punjab Veterinary Vaccine Institute, Ludhiana, and reported injecting the same on their own.

Most of the pig farmers studied (85.43%) found managing their farm on their own or with the help of their family members; the rest hired the labour (s) to perform the daily chores (Fig. 2). Out of the total of 51 labourers, 13 reported parallel working on other nearby dairy or poultry farms that too without following any biosecurity measures.

Output value chains: The majority of pig farmers sell their pigs to traders (63.14%), followed by other farmers

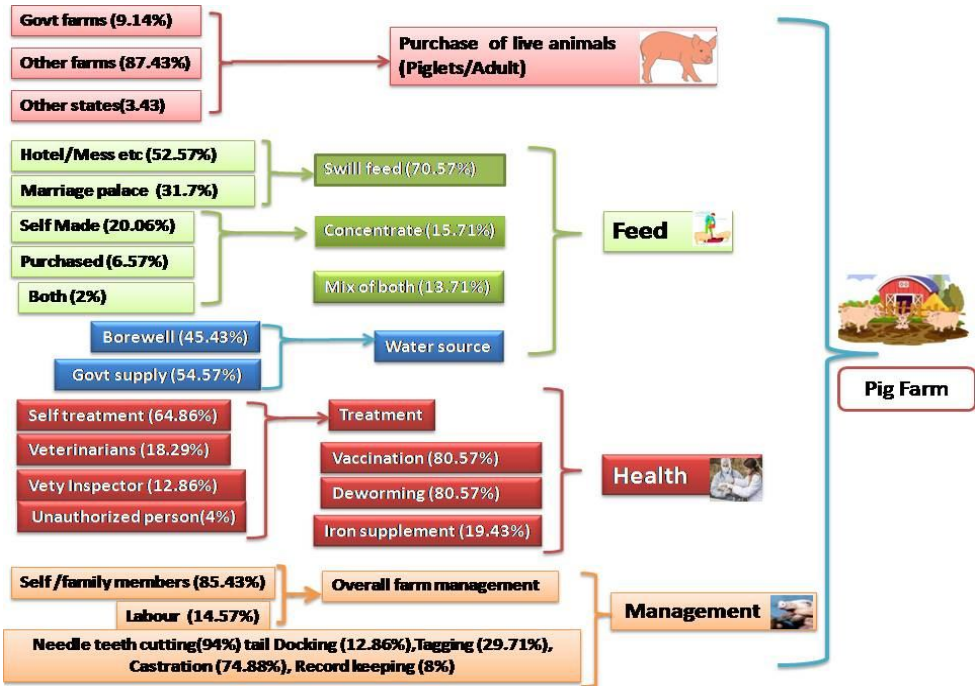

Fig. 2. Overview of pig industry input value chains created based on interviews with 350 pig farmers and 15 key informants

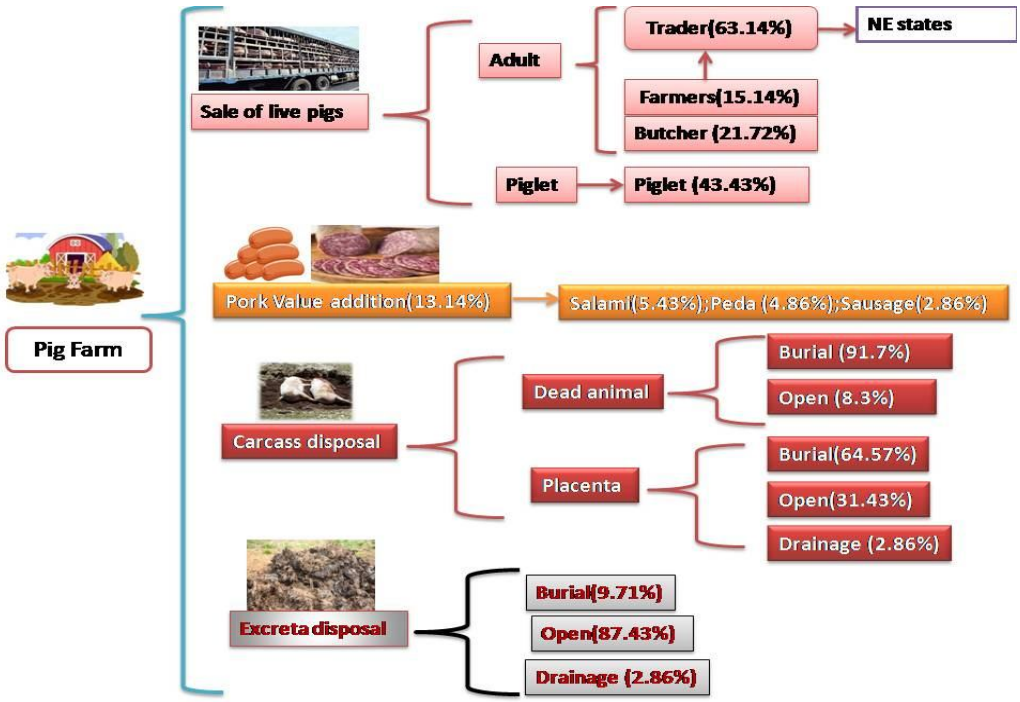

Fig. 3. Overview of pig industry output value chains created based on interviews with 350 pig farmers and 15 key informants

(21.71%) and local butchers (15.14%). Some farmers were also reported as acting middlemen (11.43%) and further selling the pigs to traders (Fig. 3). The data revealed that the major value chain includes Farmers - Traders - North East market- Consumers dominant in the state pig industry. The other two include Farmer - Farmer - Traders - Consumer and Farmer - Butcher - Consumer, but are less prevalent. Regarding market

rate information to sell the pigs, the majority of farmers relied on other farmers/farmer associations (74.86%), followed by middlemen (22.29%) and others (2.86%). The standard operating procedures (SOPs) do exist, but adherence to these guidelines in true spirit is questionable, as African swine fever disease spread its tentacles from NE states to the whole country.

Only 13.14% (n=46) of farmers reported adopting the process of value addition of the pork by making salami, peda/kebabs, and pork sausage. Further, out of these farmers, 33 reported slaughtering pigs on their own, and the rest took the help of butchers. Butchers (n=5) reported purchasing live pigs from farmers without taking any health certificates, slaughtering them at the shop (n=3) or home (n=2) without using any protective means (n=3), and never condemning the pork for any reason. The same chopper (n=1) and same surface (n=2) were found to be used to cut the meat of different species. The butchers reported that they cleaned the surface and cutter, but observation found otherwise. They simply mop the surface and cut with a piece of dirty cloth. Furthermore, they usually keep the raw meat of different species in the same refrigerator/freezer.

The majority of farmers reported to dispose carcasses away from the farm (74%) with the burial method (91.71%) (Fig. 3). In responding to the question "Where do you dispose of the placenta?", the majority (64.57%) reported following the burial method, followed by open disposal (31.45%), and 2.86% threw it in the drainage.

The majority of farmers reported disposing of the excreta in the open (87.43%), followed by the burial method (9.71%) and throwing in the drainage (2.86%). Some farmers reported using dung as farm yard manure in their fields.

Risk spots analysis in the value chain: There are various risk nodes/spots from where infectious or zoonotic diseases can enter the pig farm. Identification of these nodes can help in curbing the spread of infectious diseases to other places through different means (Fig. 4).

Post-purchase, unhygienic practices and non-

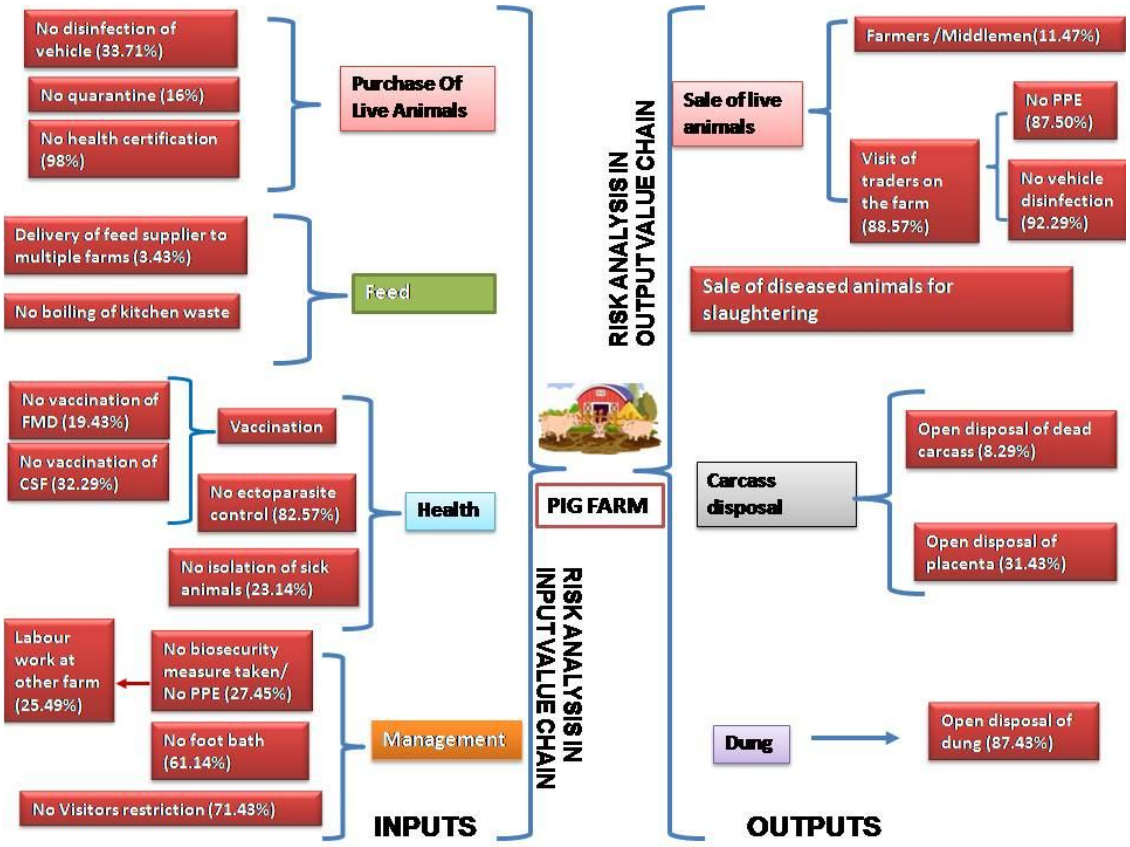

Fig. 4. Overview of risk analysis in pig value chain (inputs and outputs) created based on interviews with 350 pig farmers and 15 key informants

quarantine measures at the farm may predispose the farm to the entry of pathogens and diseases. The majority of farmers in the study did not use quarantine practices when introducing newly purchased animals into the farm. Fifty-six (16%) of the 350 respondents did not provide separate pens after the purchase of the new pigs before mixing them with other pigs, unlike the rest. Surprisingly, nearly one-fourth (23.14%) of farmers did not follow an isolation regimen for sick animals to ward them off from spreading the infection to the other livestock on the farm.

One-third (n=118, 33.71%) of respondents did not take any disinfection measures for the transport of newly purchased pigs. The vast majority of 323 (92.29%) did not disinfect vehicle tyres before entering the farm, thereby predisposing the farm to the spread of inter-farm infection. Further, farmers (n=12, 3.43%) reported that feed suppliers delivered feed to other pig farms as well on the same day without following any biosecurity measures, which could increase the chances of inter-farm contamination. The majority (n=289, 82.57%) of the farmers in the study did not use any ectoparasiticide on their pigs at farms (Fig. 4). Almost one-fourth (19.43%) of pig farmers did not vaccinate their pigs against FMD and CSF. The study found that 32 (37.71%) pig farmers assisted sows during their farrowing with their naked hands. Personal Protective Equipment (PPE) and other safety measures like tyre disinfection are vital for personal and farm safety. The use of different PPE by farmers, middlemen/traders/ visitors/butchers was almost non-existent in the present study. The majority (n=214, 61.14%) of the farmers in the study did not provide foot baths at farm entry, which was essential to control the entry of pathogens/ infection into the pig farm (Fig. 4). The majority of farmers, 250 (71.43%), did not restrict entry into the farm premises. Unauthorized entry, no provision of PPE, or other safety measures may lead to the entry of any infection or pathogenic variant into the farm, so it becomes of utmost importance to restrict useless entries into the farm. The majority (n=310, 88.57%) of farmers revealed that purchasers or traders regularly come to their farms to collect pigs.

A diseased animal could pose an economic loss to the farmer if mortality occurs. Out of the total respondents that were doing value addition (13.14%), 17.40% of farmers also slaughtered diseased animals. This might be due to the non-availability of pig health services as reported previously by Ogbuewu *et al.* (2012). Out of 350 (n=29, 8.29%), farmers disposed of the carcass of a dead pig in an open area. Similarly, 110 (31.43%) farmers disposed of the placenta by an open disposal method (Fig. 4). While validation of value chain and risk spots with pig farmers (n=37) during the seminar at the University, gaps in knowledge, attitude, and practices were the major reasons cited for no adherence to scientific recommendations. However, it is worth mentioning here that the Veterinary University regularly organizes technical seminars for livestock farmers, including pig farmers, for inculcating scientific temperament among the farming community.

DISCUSSION

Input value chain: Regarding pig farm location, it is worth mentioning here that country's Pollution Control Board has kept pig farming in the green category industry, and it should be away from the residential area and boundary of the village. Unlike dairy farming, keeping pigs in a residential area is objectionable to some residents and can lead to clashes and police cases. No objection certificate must be obtained from the competent authority to start pig farming outside earmarked industrial areas.

The study found that the majority of farmers purchased piglets from fellow farmers. At present, only five government pig farms (Patiala, Gurdaspur, Hoshiarpur, SAS Nagar and Ferozepur) are in Punjab with a limited stock of Large White Yorkshire (mainly). These government farms can supply piglets to only a few farmers. This forces the farmers, especially new entrants, to purchase the piglets from other farmers. Besides the Large White Yorkshire breed, other fast-growing breeds of pigs are also catching the demand, and few farmers (3.43%) were found purchasing them from other states (Fig. 1).

Owing to tremendous increases in concentrate/ ingredients cost in recent times, farmers are shifting to the economical way of swill feeding (Sivakumar *et al.*, 2009). Demand-driven business of collecting and delivering the swill to farm gates in a processed or cleaned way is also catching up in the state. High moisture content and everyday variable nutrient composition in swill are the bottlenecks that hinder the growth of animals. If somehow, it could be processed to dry form, it would be a great source of nutrition not only for pigs but for other animals also. Farmers reported that the expenditure on rearing pigs to 100 kg on concentrate varies from Indian Rupees 6000 to 10500, while on swill feeding, it varies from 2000 to 8500 Indian Rupees depending upon the cost of concentrate or swill. Over half of the pig farmers studied (54.57%) have a government water supply at their farms. Surprisingly, nearly all the farmers never

got the feed and water tested for aflatoxin and suitability for drinking, respectively. This study found that majority farmers self-treating the diseased animals owing to a paucity of pig experts. Less exposure of veterinarians to pig diseases during their Bachelor of Veterinary Sciences and Animal Husbandry degree course or in the field might be the reason for their less expertise.

Output value chain: Sidhu *et al.* (2019) also reported a similar marketing channel found in this study. All traders have their customized trucks (2 or 3 storeys) to fetch 150–250 pigs in one trip to North Eastern state(s) of the country. They usually collected this number of pigs by visiting 4 to 8 farms in a single day. This journey took 50-65 hours depending upon the number and time of halts (generally 2 or 3). Further, depending on the season, demand, and other conditions, about 20–25 trips were conducted per year. Interestingly, traders reported that they spent an average of 0.57 million per trip and earned 0.2 million per trip, excluding taxes, labour costs, feed costs, and vehicle wear and tear. Butchers though have a significant role in the prevention of cross-contamination and meat borne diseases, but owing to a lack of knowledge, they were not found using PPE measures (Khanal and Poudel, 2017). Ki *et al.* (2017) discussed soil burial as the most widely used disposal method for pig carcasses. The incineration method is a more scientific way of disposal, but due to labour intensive and expensive, it is not popular (Rahman *et al.*, 2008).

Risk spots analysis in the value chain: Pig farms in Punjab are usually run under a single roof, with different pens separated by 3–4-foot-high walls. The upper portion is common. No farmer has an outside quarantine unit, and they keep them in a pen in the same shed. The period for keeping newly purchased pigs in a pen varied between 10 and 30 days. Further, no farmer was found following the all-in and all-out system. Alarcón *et al.* (2021) opined that a stronger biosecurity system could increase output and reduce the need for antibiotics to prevent transmission, either inside or across farms.

Infectious diseases like African Swine Fever, Classical Swine Fever, or other viral diseases can be mechanically transmitted to a new farm if due precautions are not followed. Casal *et al.* (2007) suggest that farm premises should not be accessible by vehicles. It is vital to have a parking lot, a loading dock for trucks and a perimeter fence with gated access. Vehicles used to transport animals between farms or to slaughterhouses and drivers from these vehicles can have an important role in the transmission of pathogens between farms (Lowe *et al.*, 2014). No one was found disinfecting the tyres of the vehicle they use, according to the veterinary officers contacted.

Ecto-parasites can spread viral diseases like African Swine Fever, Classical Swine Fever, etc., besides hindering the overall growth of the animals. Therefore, their control is of the utmost importance. Rahman *et al.* (2008) reported that less than 40% of the farmers practiced ectoparasitic control at their farms. Less FMD vaccination in pigs could hinder the government's efforts to make the state FMD free. Being cloven-footed animals, pigs like ruminants are also prone to FMD. Likewise, CSF can also spread inter-farm through different means.

Many zoonotic pathogens can infect pigs, including *Leptospira*, *Streptococcus*, *Salmonella*, *Brucella*, *E. coli*, and others. Kaur *et al.* (2020) reported the seroprevalence of pig brucellosis to be 16.7 percent by the Rose Bengal Plate Test (RBPT) and 12.5 percent by competitive ELISA in Punjab. Unsanitary practices during farrowing and sow assistance could be a major risk spot for spreading infectious/zoonotic diseases through handlers.

No PPE measures adoption might increase the chances of inter-farm zoonotic infection and infection via transport, which were also reported by Fosse *et al.* (2008). Changing clothes and boots before entering the farm are vital to curbing the potential risk of disease spread on the farm (Alarcón *et al.*, 2021). No butcher was found using face masks, shoe covers, or headgear while cutting and delivering to consumers in the shop. Previously, it was also found that the majority of butchers (60%) slaughter animals at the shop (Dione *et al.*, 2016), and further, poor hygienic practices at the slaughter and retail points could contaminate the meat (Deka *et al.*, 2011).

The provision of a foot bath with active disinfectant at the entry level and following the minimum contact time recommendation helps in controlling microbial transmission. A quick splash of soiled footwear in a foot bath is unlikely to do much more than provide a false sense of security (Bowman and Shulaw, 2001). Kouam *et al.* (2020) also reported that a very small number of pig farms had the facility of a functional footbath.

Health certification and exchange of medicine/ vaccination records during the sale/purchase of live pigs are almost absent. Profit-driven lure and absence of stringent regulation could be the main reason.

Inter-farm visits of purchasers or traders on the same

day with vehicles pose a big risk of disease transmission. Alarcón *et al*. (2021) suggested that a limited flow of people (guests, truck drivers, and personnel) or vehicles into or out of a facility can reduce contaminants entering the farm.

This may be hazardous as it poses a risk of airborne infection too. The flies over the carcasses may become a factor in the mechanical transmission of diseases. Scavengers like dogs and birds can transmit pathogens to other areas. A government facility comprising a post-mortem room and incinerator where the carcasses could be destroyed should be established for scientific disposal of livestock carcasses (Singh *et al.*, 2020). Poor/improper disposal of waste or excreta generated from livestock poses a serious public concern related to the quality of the environment and biosecurity issues (Ogbuewu *et al*., 2012). Further, open disposal of dung invites flies or mosquitoes, which are potential vectors of serious diseases. Farmers should be encouraged to install biogas plants for dung disposal due to their well-quoted benefits.

The strength of this study lies in the fact that it provides insight into all actors and activities involved in the pig value chain aside from the identification of risk spots which could aid and guide the development of realistic disease control measures. Being the role model for other northern states of the country to start pig farming, we assumed that a similar chain does exist in these northern states, and the results of the present study can be extrapolated to these states also. Risk spots identified should be kept in mind while framing the policy for pig farming in the country. Further, epidemiological studies or risk analyses should be conducted to confirm and quantify the risks identified in this study. Farm registration, trading license, earmarked vehicles, animal tagging, capacity building of all actors including veterinarians, and framing rules for starting and making farm infrastructure are recommended to make this farming a sustainable venture in the future.

Farmers, traders, butchers, veterinarians, and suppliers are the main actors in the pig value chain in descending order. However, Farmers – Traders – North East market – Consumer is a major prevalent chain in the country. The pig farming business is highly dependent upon traders or butchers for marketing. No or less provision of public pig health services forces farmers to self-treat or cull the animals for slaughter. The adoption of biosecurity and personal protection measures is almost negligible. Many risk spots could potentiate inter-farm disease transmission. This makes pig farming highly vulnerable to infectious diseases like African Swine Fever, Classical Swine Fever, etc. Traders and butchers should be included in outreach programmes to prevent the spread of infectious diseases and to produce wholesome meat. Animal health policymakers should consider how to safeguard this emerging farming through ensuring marketing and profitability by mitigating the risks identified in this study.

Conflicts of interest: The authors declare no conflict of interest in this study.

Author's contributions: JS, YSJ, RKS: Conception and design; GS, JS: Performed acquisition of data; GS, JS, YSJ: Performed statistical analysis of data; JS, YSJ, RKS, GS: Performed interpretation of the results.

Data availability statement: All the data supporting the research findings have been presented in this paper. The corresponding author is willing to provide the raw data upon reasonable request.

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