

Disease as a constraint on goat production in Lao PDR and trade to neighbouring countries: a review

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ABSTRACT

Goat production in Lao People's Democratic Republic (Lao PDR) is a small but rapidly growing sector owing to strong export demand, primarily from Vietnam. Disease has been identified as one of the major constraints to goat production but there are limited data on causes and effective control strategies. The situation is exacerbated by a lack of veterinary and extension services in rural areas. Information on the major disease and clinical syndromes of goats and their causative agents is needed to develop local and national control strategies and to improve animal welfare. Zoonotic diseases involving goats are also potentially important in terms of live goat trade and public health, albeit research is lacking. This review summarises and evaluates the available published data on caprine diseases in Lao PDR and provides possible disease control strategies to improve goat production in Lao PDR. Surveys and observations suggest that lip and facial dermatitis, eye conditions and diarrhoea are the most common clinical syndromes affecting the health of Lao goats. These clinical syndromes can be considered as priorities for Lao goats. Serological surveys conducted in limited geographical areas of the country have identified moderate seroprevalence of foot and mouth disease (FMD) and low seroprevalence of bluetongue, peste des petits ruminants (PPR), brucellosis and Q fever in goats. Accordingly, the clinical signs associated with the latter diseases were not commonly reported. *Trichostrongylus* spp., *Haemonchus contortus* and coccidia are the main gastro-intestinal parasites identified among Lao goats. Despite these studies, an understanding of the causation of the most common clinical syndromes in Lao goats is still lacking, similar to the situation in many other parts of Southeast Asia. Studies to determine the causation of common clinical syndromes need to be conducted in Lao goats if progress is to be made on overcoming the disease constraint. Similarly, studies are also needed to evaluate interventions that have been introduced to limit the impact of these disease and clinical syndromes. They will likely require changes to goat management and nutrition, in addition to disease-specific interventions.

Keywords: clinical syndromes, constraints, disease diagnosis, endemic diseases, goats, Lao PDR, production, transboundary diseases, zoonoses.

Introduction

Lao People's Democratic Republic (Lao PDR) is a landlocked country in Southeast Asia. The country borders with China to the north, Vietnam to the north-east and east, Cambodia to the south, Thailand to the west and Myanmar to the north-west. Lao PDR is a tropical country with a monsoonal climate, comprising mixed geography with woodlands, grasslands and plateaux (Osborne *et al.* 2021). Poverty is a constant challenge because Lao PDR is a lower middle-income country (LNCCI 2020) with a gross domestic product (GDP) of USD15.7 billion in 2022. Population density is low, with 7,529,475 civilians spread over 236,800 km² of land in 2022 (World Bank 2023). Lao provinces are classified into three geographical regions, namely, northern, central and southern, although geographically it can be divided into lowland and upland zones (ADB 2002), with uplands being the

majority (IFAD and ADB 2018). Farming is an integral part of the Lao culture and employs the majority of people (Osborne *et al.* 2021). Mostly, Laotians practice smallholder mixed farming with both crops and animals (Olmo *et al.* 2022a). Ten per cent of land in Lao PDR is used for agriculture (23,940 km²), although only 6.7% is considered arable (World Bank 2022). Livestock are mainly raised in smallholder farming systems (FAO 2020), which accounted for more than 95% of total livestock production in the country in 2002 (ADB 2002); however, more recent data on this is not readily available. Livestock farmers predominantly rear pigs, cattle, water buffaloes and poultry (Osborne *et al.* 2021). Statistics from 2022 showed that there were 4,408,000 pigs, 2,428,000 cattle and 1,208,634 buffaloes in Lao PDR (FAO 2024). The goat population is small but growing with the total number of goats increasing by 22% from 588,000 in 2017 to 753,860 in 2022 (FAO 2024). Goat production is a small but rapidly expanding livestock sector, driven largely by demand for live goats by neighbouring Vietnam (Walkden-Brown *et al.* 2023).

Disease is identified by farmers as one of the major problems they encounter (Gray *et al.* 2019) and the level of veterinary and extension services available to smallholders is low (Rast *et al.* 2014; Subharat *et al.* 2023). Information on the type and prevalence of diseases in goats in Lao PDR is scattered in both the formal and informal literature. The actual cause of common clinical syndromes is not known definitively. Therefore, the aim of this review is to collate the disparate data on diseases of goats in Lao PDR within the context of goat production, marketing systems and the available veterinary services in the country. This includes information on the major endemic diseases, transboundary and zoonotic diseases, and their potential to affect goat farming and trade in Lao PDR.

Goat production and marketing systems in Lao PDR

In 2011, it was estimated that 6% of all livestock farmers (43,200) reared goats (MAF and FAO 2014), but equivalent data for recent years is not available. Goats are distributed unevenly within the country, with the highest population in the central province of Savannakhet (MAF and FAO 2014). Goats are reared predominantly in smallholder systems and, during 2010–2011, the mean herd size was estimated at 4.6–6.0 in different regions, with only 11–18% of goat-rearing households having more than 10 goats (Table 1) (MAF and FAO 2014). A more recent survey from Savannakhet province in central Lao PDR identified that the goat herd size ranged from 7.3 to 9.2 goats per household (Phengvilaysouk *et al.* 2022). There were 93 small commercial goat farms in 2019, according to the Lao Ministry of Agriculture and Fisheries (Xayalath *et al.* 2021).

Table 1. Percentage of goat farm households (43,200) with different herd sizes in different regions in Lao PDR during 2010–2011 (MAF and FAO 2014).

Region	Farm households with goat herds of different size (%)			Mean number of goats/household
	<5 head	5–9 head	>10 heads	
North	66	23	11	4.6
Central	50	32	18	6.0
South	65	22	12	4.8
Total	59	27	14	5.3

Lao local goats, which are also known as ‘bae’ or ‘katjang’, are raised for meat production, but they are small in size. Their birth weight is usually 2 kg and their mature weight is 25–28 kg (Wilson 2007). Their coat colour is highly diverse with mixed grey/brown and black. Scimitar shaped horns, erect ears and a straight face are additional phenotypic characteristics of local goats (Keonouchanh and Xaypha 2006). There are also low numbers of imported breeds such as ‘Bac Thao’ and ‘French Alpine’ goats. The former breed is a dual-purpose breed from Vietnam, which was imported in 2002 to upgrade local goats (Wilson 2007). More recently, improved meat breeds such as the Boer can be seen in some areas and are believed to be imported from Thailand, although the origin is not well documented (Xayalath *et al.* 2021).

In Lao PDR, goats are utilised only for meat (Burns *et al.* 2018) and are mostly sold to traders from Vientiane and Vietnam (Gray 2006) rather than being kept for home consumption (Gray *et al.* 2019). Goat meat was allegedly not popular among locals in the past owing to its strong odour (Phengsavanh *et al.* 2004) and, in general, red meat is too valuable for home consumption. Importantly, goats provide manure for crops and act as vital cash reserves for farmers (Gray *et al.* 2019; Liehr *et al.* 2024). Up to 27–42% of smallholder household income is from goat sales (Phengsavanh *et al.* 2017). The goat industry is export-oriented and based on sale of live goats, predominantly to Vietnamese traders. There is high market demand for Lao goats in Vietnam where they may be labelled ‘Lao mountain goat’ (Gray *et al.* 2019). A survey from five provinces from northern and central Lao PDR showed that 90–95% of goats produced in these regions were destined for Vietnam and their price is 30% higher than that of Vietnamese crossbreds (Gray *et al.* 2019). The market price of Lao live goats has increased over time. Assuming 25 kg as the average weight of sale goat, the local market price of live goats in 2007 was USD45 (Wilson 2007). The price of adult goats in 2010 and 2014 was approximately USD44 and USD88 respectively (Frangi 2014). More recent data from 2017 indicated that farmers received approximately USD87 for a 20 kg male goat (Gray *et al.* 2019). However, the live goat export process is unofficial and poorly regulated because a formal trade agreement is lacking

(Gray *et al.* 2019). Thus, there is a risk of transmission of transboundary as well as endemic diseases.

The main goat production systems in Lao PDR are free-range systems, semi free-range systems, enclosed grazing and fully intensive cut and carry systems (Fig. 1). Whereas the majority of goats are managed extensively in small herds, goats are typically enclosed in housing at night (Gray *et al.* 2019). The quality of goat houses varies, but they are often poorly constructed with locally available materials (Xaypha 2005; Wilson 2007) because of the limited resources available to farmers (Fig. 2). Improved housing design has been implemented by some aid and development projects.

As the majority of goat houses are constructed in a simple manner and are poorly ventilated or waterproofed (Gray *et al.* 2019), the combination of high humidity and ammonia

production during the rainy season, coupled with close proximity between animals for prolonged periods of time favours the transmission of respiratory diseases. However, the majority of goat houses are raised on slatted floors (Millar *et al.* 2022), which prevent faecal accumulation and reduce direct contact with faeces, thereby reducing the risk of coccidiosis and transmission of worm larvae. Furthermore, elevated slatted floors keep hooves dry, reducing the risk of foot infections, although irregular spacing between slats is associated with a significant incidence of foot injury. To be effective in limiting infectious disease, goat houses need to be kept clean with the regular removal of accumulated faeces beneath the floor. The features and consequences of the different systems of housing employed by Lao goat farmers are outlined in Fig. 3.

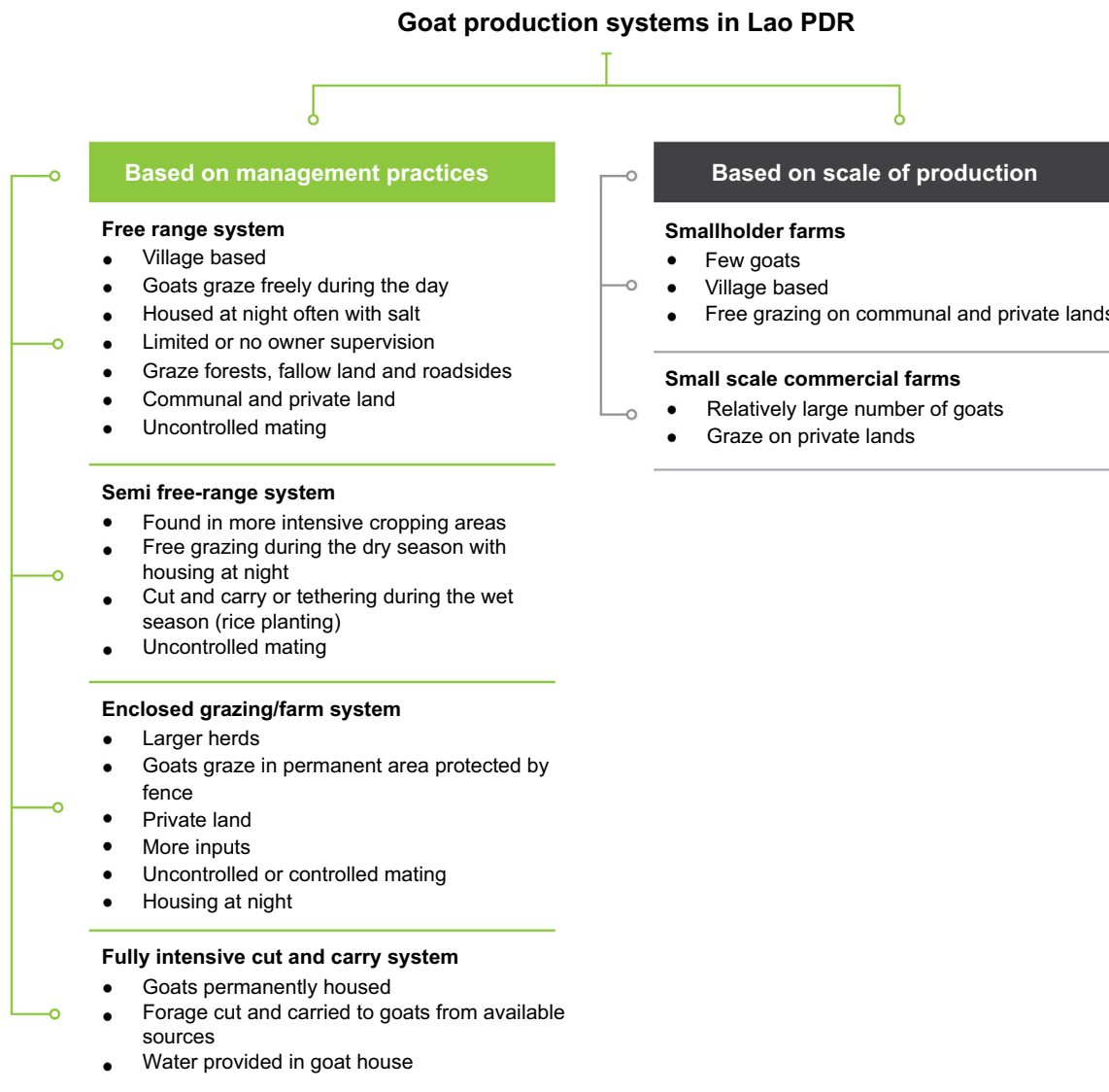


Fig. 1. Goat production systems in Lao PDR. Data for the management practices was retrieved from Phimpachanhvongsod, 2001 as cited by Xaypha (2005) and (Gray *et al.* 2019) and scale of production from Viengvilay *et al.* (2017).



Fig. 2. Examples of typical goat housing and flooring in Lao PDR (Photos courtesy of P. P. Jayasekara, 2022).

The nutritional requirements of Lao goats are met mainly through foraging and unsupervised free grazing on private and communal lands (Sato *et al.* 2014; Gray *et al.* 2019; Olmo *et al.* 2022a). Consequently, there is potential for disease transmission between herds. Roadsides, grasslands, forestlands and other bare lands are used for free grazing during the dry season, while goats are tethered during the rainy season to protect cultivated crops (Xaypha 2005). Lao goats fulfil their feed requirement from local grass and fodder varieties that have seasonal low availability, low nutrient content and energy, and protein supplementation is hardly practiced (Phengvichith and Preston 2011). Some farmers practice supplementary forage feeding during the rainy season (25.9%) and virtually all provide salt in the goat house (Gray *et al.* 2019). Interestingly, practices such as provision of mineral blocks, concentrate feeds and water may be becoming more popular among goat farmers (Millar *et al.* 2022), which in turn has a positive impact on the goat health and production. However, the quality and quantity of feed material is still a significant problem (Windsor *et al.* 2018) affecting goat production in Lao PDR as inadequate feed availability during the late dry, early and late wet seasons has been identified from a farmer survey from central Lao PDR (Olmo *et al.* 2022a). The characteristics of feeding systems employed by Lao goat farmers are summarised in Fig. 4. These have particularly important consequences for diseases involving an environmental component of the lifecycle of the pathogen, such as gastro-intestinal helminth infection.

Reported mortality rates in Lao goats are highly variable and are derived from farmer survey data. Mortality of approximately 50% in kids before they reach weaning age of ~3 months has been reported (Xayalath *et al.* 2021), whereas a mean annual kid mortality of 26.3% has been reported from seven villages in central Savannakhet province on the basis of monthly farmer surveys on stock numbers (Colvin *et al.* 2022). The same study reported a total annual mortality (kid and adult combined) of 37.5%, emphasising the requirement of thorough disease investigation and control, coupled with improved management. A mean annual mortality of 47% (range 10–80%) was reported in another farmer survey from five provinces of northern (Houaphan, Oudomxay and Luang Prabang) and central (Savannakhet and Khammouane) Lao PDR (Gray *et al.* 2019).

Generally, natural mating with minimum human intervention occurs among Lao goats (Keonouchanh and Xaypha 2006; Gray *et al.* 2019). This carries the risk of spreading venereal diseases such as brucellosis which can cause abortion. The rate of abortion is not documented among Lao goats. A maximum of 3 kids/litter with a mean value of 2.1 ± 0.13 has been reported (Phengsavanh *et al.* 2004). Annual kidding rate of 60–88.2% has been reported from Songkhone, Sepon and Phin districts of Savannakhet province of central Lao PDR (Phengvilaysouk *et al.* 2022). Kid birth weight was 1.1–1.5 kg, and weaning weight was 9.7 kg Xayalath *et al.* (2021). Lao kids take 6–8 months to reach 15 kg of bodyweight (Xayalath *et al.* 2021). The average liveweight of adult goats was between 25 and 35 kg (Keonouchanh and Xaypha 2006)

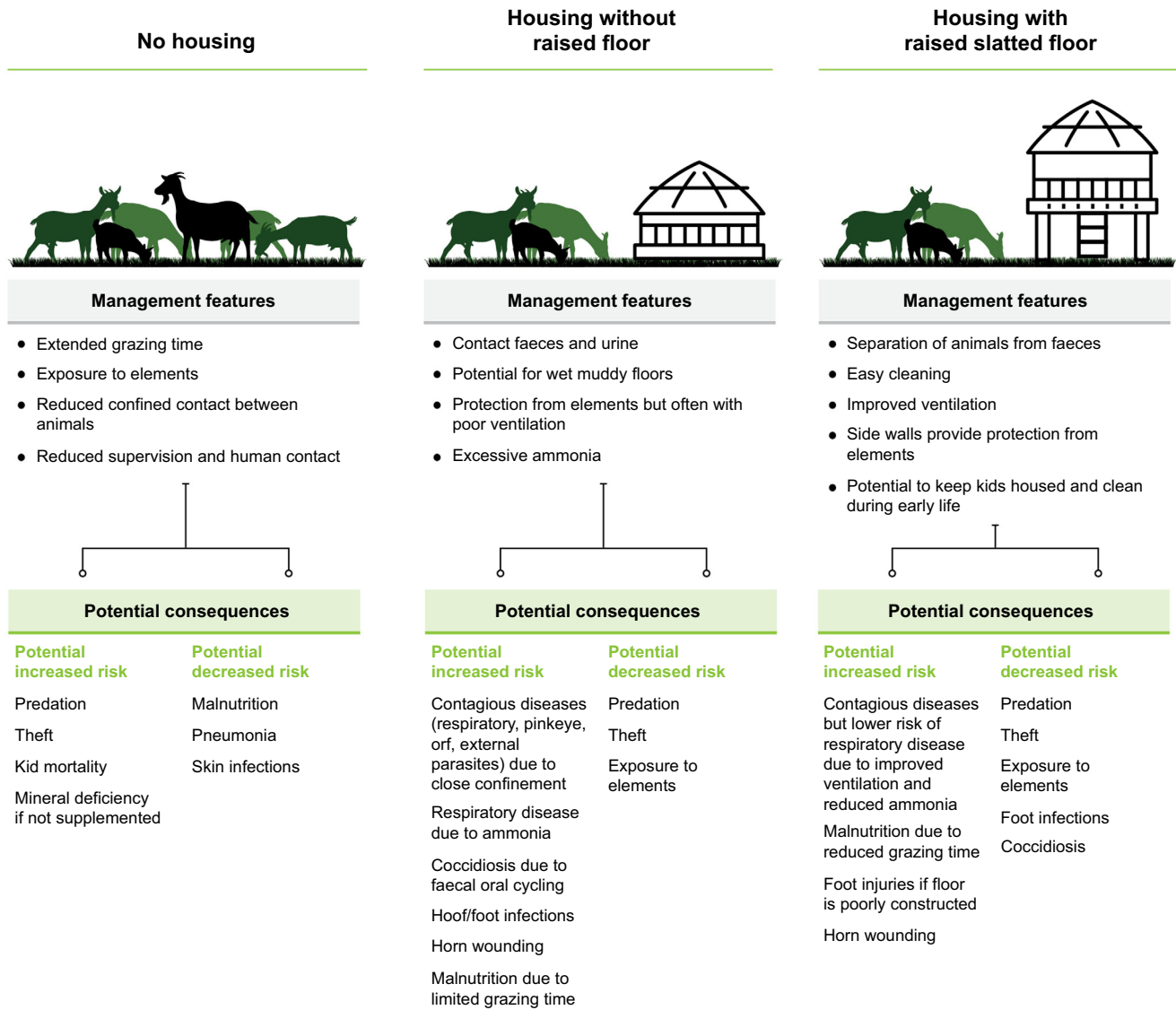


Fig. 3. Characteristics of different systems of goat housing in Lao PDR.

and it took more than a year for goats to reach 20–25 kg weight (Phengsavanh *et al.* 2004). A farmer survey conducted in the northern Luang Prabang province reported age of first kidding at 12–18 months and a kidding interval of six months. Does were described as producing a single kid at first kidding, whereas subsequent kiddings had higher probabilities of twins (ADB 2002). The role of disease on reproductive performance of Lao goats is not documented.

Availability and structure of veterinary services to farmers in Lao PDR

Similar to other developing countries, Lao PDR has a limited capacity in the provision of animal health services (Rast

2014). Available veterinary services in Lao PDR can be broadly classified into the following three sectors: public sector, private sector and stakeholder institutions/organisations (Bastiaensen *et al.* 2011). Government veterinary and livestock services are organised at a national level within the Department of Livestock and Fisheries (DLF) of the Ministry of Agriculture and Forestry (MAF). Services provided at the regional and district levels are by staff of the Provincial Agriculture and Forestry Offices (PAFO) and the District Agriculture and Forestry Offices (DAFO). The National Animal Health Laboratory (NAHL) under the DLF is located in Vientiane and is responsible for disease diagnosis, containing disease outbreaks, conducting veterinary research, training students and government staff, providing technical support to provincial laboratories and collaborating with international laboratories.

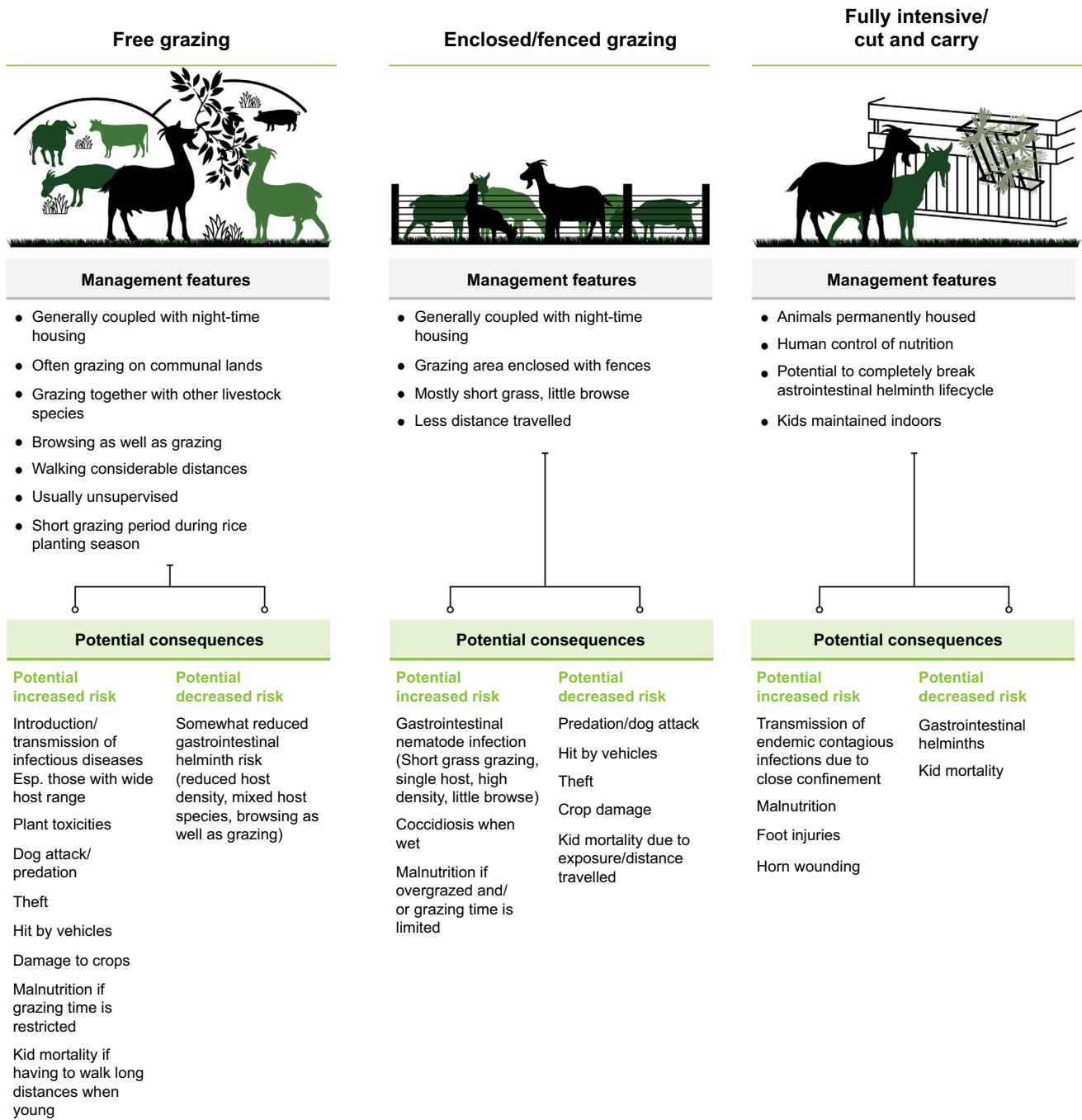


Fig. 4. Characteristics of different systems of goat feeding in Lao PDR.

Previously known as the National Animal Health Centre (NAHC), NAHL is the national technical reference centre for animal disease diagnosis and livestock product quality testing. It is the World Organization for Animal Health (WOAH, formerly OIE) focal veterinary laboratory in Lao PDR and comprises five diagnostic units, namely, virology, bacteriology, parasitology, BSL-3 (Biosafety level-3 for highly pathogenic avian influenza diagnosis) and the food safety unit together with a separate animal production centre. The animal production centre is

responsible for animal vaccine production and dissemination around all provinces. They produce vaccines for pigs (classical swine fever), poultry (Newcastle disease and fowl cholera) and large ruminants (haemorrhagic septicaemia and blackleg) but not for goats or other small ruminants. The division of veterinary science under the DLF is in charge of organising animal vaccination at the government level. Other than the NAHL, there are basic provincial laboratories that conduct necropsies and sample collection to be sent to the NAHL.

A significant constraint identified is the limited number of qualified veterinarians and village veterinary workers (VVWs) in Lao PDR (Hansen 1997). Before 2009, there was no university level training of veterinarians within the country. Instead, veterinarians were sent away for training in various countries (Bastiaensen *et al.* 2011). In 2009, the National University of Laos (NUOL) established the Faculty of Agriculture to provide veterinary education with Bachelor and Master degrees in animal science and a Bachelor degree in animal production. The first graduates were in 2014 (WHO 2017). Because of the limited number of veterinarians, most veterinary services are provided by animal science diploma and degree holders (Subharat *et al.* 2023). VVWs have a legally defined role in Lao PDR and work closely with farmers to provide a basic animal health service (Bastiaensen *et al.* 2011). They are private entrepreneurs, selected on the basis of their willingness to work as VVWs, to conduct animal vaccination, parasite control and provide veterinary service such as treating and advising on animal diseases, although they are not always well trained, sometimes receiving training from different international projects. VVWs charge fees from farmers for the services provided (Frangi 2014).

A recent farmer survey identified that most goat farmers (85%) attain advice and veterinary treatments, predominantly traditional treatments, from neighbours. The majority purchase veterinary medicine from shops without veterinary advice (74%). Fewer purchase medicine from VVWs (18.6%) or from veterinarians (4.7%) (Phengvilaysouk *et al.* 2022). Vaccination is not widely practiced and the lack of vaccination and deworming (Xaypha 2005; Gray *et al.* 2019; Millar *et al.* 2022) owing to limited budget and shortage of appropriate vaccines (Frangi 2014) may contribute to high disease prevalence in Lao goats.

A considerable proportion of livestock farmers use traditional medicine to treat their goats and several sources corroborate similar methods. This includes using carambola juice, lime juice, salt, vinegar and boiled bark from specific local native trees to wash vesicular lesions of foot and mouth disease (FMD), orf-like lesions and surface lesions (Nampanya *et al.* 2015; Windsor *et al.* 2017; Phengvilaysouk *et al.* 2022). Similarly, carbonated drinks such as Pepsi[®] have been used to treat bloat (Phengvilaysouk *et al.* 2022). The efficacy of these remedies is unknown but the cost is presumably low.

A lack of definitive disease diagnosis is considered to be a contributor to a high disease incidence in Lao goats (Gray 2006) and there is a limited diagnostic capacity for goat diseases at the national laboratory in Vientiane between 2004 and 2014 (Frangi 2014). Even outbreaks of FMD in Lao goats have gone undiagnosed owing to limited availability of diagnostic resources (Singanallur *et al.* 2020). NAHL allocates its limited resources towards control of cattle and pig diseases because they are the major livestock species in Lao PDR, and transboundary diseases such as FMD because of economic losses and zoonotic diseases.

Disease surveillance systems are not well established in Lao PDR. The lack of an effective disease surveillance system has important implications for formalising trade, particularly for live animals. There are two market channels for goats in Lao PDR, namely, a domestic and an export market channel largely to Vietnam (Bui *et al.* 2023). The goat trade to Vietnam is based on movement of live goats across the border and three market chains have been identified, namely, north-eastern, northern and southern (Gray *et al.* 2019). It is estimated that monthly 2000–3000 goats are being exported to Vietnam (Windsor *et al.* 2018). Although there are notional inspections and certification on the Lao side of the border (Gray *et al.* 2019), goats largely enter Vietnam in an unregulated manner (Bui *et al.* 2023).

In 2018, the National Animal Disease Surveillance Network (NADSN) was established in Lao PDR as a joint venture of the Lao government (NAHL, DLF) and Mahidol Oxford Tropical Medicine Research Unit (MORU), so as to increase animal disease diagnosis, biosafety and biosecurity capacities (Siengsan-Lamont *et al.* 2022). Under the NADSN, there are projects targeting animal disease surveillance in slaughter houses, laboratory capacity building and biosafety and upgrades to biosecurity at NAHL and provincial laboratories. Such surveillance programs have targeted transboundary and zoonotic diseases in cattle and pigs (FMD, brucellosis, Q fever) and pet coronavirus and other zoonoses in domestic animals. Further, the support has been given to improve the disease reporting system from district levels to the NAHL by introducing monthly Google reports and emergency reports. Currently, active surveillance is being conducted for highly pathogenic avian influenza (HPAI), antimicrobial resistance (AMR), Q fever, FMD, brucellosis and pet coronavirus. However, goats are not included in these surveys despite their growing importance (Siengsan-Lamont and Blacksell 2021). Although the inclusion of goats in disease surveillance would be desirable, the small size and informal nature of the production and marketing systems for goats mitigate against this because goats are largely exported live without going through a slaughterhouse.

Major endemic disease and clinical syndromes and their impact

Animal disease is consistently identified as one of the major constraints to the livestock industry. In a poverty-assessment survey conducted by the Asian Development Bank (ADB), 70% of survey respondents identified animal diseases as a major problem where external intervention is required (ADB 2002). More recent surveys have ranked diseases as a major constraint on goat production specifically, and it is identified as an area where interventions are likely to be highly beneficial. In semi-structured surveys of goat farmer groups in 27 villages across 14 districts and five provinces, 93% of

farmers ranked diseases as the number one constraint in goat farming (Gray *et al.* 2019). Other surveys in Xaythany district of Vientiane Capital, central Lao PDR in 2008 (Kongmanila *et al.* 2008), and Savannakhet province, central Lao PDR (Olmo *et al.* 2022a), also identified diseases as one of the impediments to goat production. Additionally, internal parasites were also identified as constraints to goat production by Windsor *et al.* (2018). Questionnaire-based surveys have also been used to identify the main health problems based on clinical signs, observed by goat farmers. Identified health problems include orf-like lip and facial dermatitis, eye conditions, diarrhoea, bloat and lameness (Gray *et al.* 2019; Millar *et al.* 2022; Olmo *et al.* 2022a; Phengvilaysouk *et al.* 2022). Some of the commonly seen clinical signs in Lao goats from Savannakhet province of central Lao PDR are indicated in Fig. 5.

Lip and facial lesions are one of the commonly identified health problems in Lao goats. Orf, FMD, dermatophilosis and goat pox are the likely differential diagnosis for lip and facial lesions. In the absence of formal diagnosis, most of the lip and facial lesions were presumptively identified as orf (Gray *et al.* 2019; Olmo *et al.* 2022a). Orf is also known as scabby mouth, contagious ecthyma or pustular dermatitis. Goat farmer interviews in 2016 in the Xaythany district of Vientiane Capital of central Lao PDR disclosed that orf, FMD and sore mouth as some of the most important diseases in their herds (Windsor *et al.* 2017). The farmers from five provinces have also specified orf and FMD as important diseases (Gray *et al.* 2019). In a recent survey, lip and facial lesions that resemble orf were reported by 74% of smallholder farmers (Millar *et al.* 2022). Also, there is an earlier report of unconfirmed deaths of goats with symptoms of orf or goat pox (Frangi 2014). Orf was ranked as the main cause of goat mortalities by 14.4% of farmers in the survey (Gray *et al.* 2019). A relatively moderate herd prevalence of FMD (13%) has been reported by goat farmers from central province of Savannakhet (Olmo *et al.* 2022b) and FMD was identified as the main cause of goat mortalities by only 1.5% of farmers in a survey (Gray *et al.* 2019). The generally low seroprevalence of FMD in other studies (see below) suggest that FMD is not a major cause of lip and facial lesions and mortality in goats in Lao PDR. This is supported by the findings of Windsor *et al.* (2017) who identified orf as the probable cause of lip and facial lesions in an opportunistic study using 32 serum samples and eight tissue samples from goats with lip and facial lesions from central Xaythany district. The disease was diagnosed on the basis of characteristic histopathological lesions in tissue samples and animals being negative for FMD antibodies in serum samples by using an enzyme-linked immunosorbent assay (ELISA).

Eye conditions have been identified as a problem in goats in Xaythany district in Vientiane Capital of central Lao PDR (Windsor *et al.* 2017) and 11.9% of farmers from Phin, Sepon and Songkhone districts in Savannakhet province of central Lao PDR reported presence of sore eyes in their goats.



Fig. 5. Commonly seen clinical signs in Lao goats from Savannakhet province of central Lao PDR: (a) orf like lesions, (b) eye lesions, (c) diarrhoea, (d) purulent nasal discharge, (e) pale conjunctivae, and (f) skin parasites – lice (Photos courtesy of T. Xaikhue, 2022).

Moreover, blindness has been reported by 10.3% of farmers in Phin district, whereas it was not reported by farmers from Sepon and Songkhone districts of Savannakhet province of central Lao PDR (Phengvilaysouk *et al.* 2022). Eye conditions in goats can result from pinkeye, entropion or foreign bodies. If not promptly treated, eye conditions can lead to painful ulceration and permanent blindness. Further, goats face difficulties in finding feed, resulting in a loss of body condition. A recent study from Savannakhet province of central Lao PDR has

identified pinkeye as the reason for eye conditions and *Mycoplasma conjunctivae* as the likely causative agent (Jayasekara *et al.* 2023).

Clinical signs associated with the diseases in gastro-intestinal tract such as abdominal pain, bloat and diarrhoea are also commonly identified among Lao goats (Windsor *et al.* 2017; Gray *et al.* 2019; Phengvilaysouk *et al.* 2022). Presence of bloat was reported by 20.7% and 21.4% of farmers from Phin and Songkhone districts of Savannakhet province of central Lao PDR respectively (Phengvilaysouk *et al.* 2022). In a separate survey, 35.6% of respondents reported bloat as the main cause of goat mortalities (Gray *et al.* 2019). However, it is unclear if there is a confusion between bloat as cause of death and finding bloated goats after death, which is a natural phenomenon in the absence of gas eructation. A recent disease investigation study was unable to identify any case of pre-death bloat (ACIAR 2024). Diarrhoea has been frequently reported by over 38% of farmers as the main constraint (Millar *et al.* 2022; Olmo *et al.* 2022a; Phengvilaysouk *et al.* 2022). In another survey, 50.6% of farmers reported diarrhoea as the cause of mortality in Lao goats (Gray *et al.* 2019). Diarrhoea in goats can have several causes that are dependent on age. Bacteria and viruses are mainly responsible for neonatal diarrhoea, whereas parasites (nematodes, coccidia) and bacteria tend to cause diarrhoea in growers and adults. It is assumed that internal parasites are mainly responsible for diarrhoea in Lao goats (Xaypha 2005; Gray *et al.* 2019), contributing to high kid mortality leading to farmers not being able to meet market demand (Phengsavanh *et al.* 2004). Even though there were no epidemiological studies on nematodes in Lao goats until 2004 (Sani *et al.* 2004), gastro-intestinal nematodes have been suspected as

the most problematic parasite group in Lao goats (Gray 2004). Further, coccidia and worms were identified as responsible for goat deaths in northern Saysathan district of Xayaboury province during the period from 2008 to 2011 by Frangi (2014), although no details are provided. A summary of the published investigations on gastro-intestinal parasites in Lao goats is available in Table 2. *Trichostrongylus* spp., *Oesophagostomum* spp. and *Haemonchus* spp. have been identified from coproculture and *Trichostrongylus colubriformis*, *Oesophagostomum* spp. and *Haemonchus contortus* were identified using DNA from adult worms recovered from a necropsy (Sato *et al.* 2014). Gastro-intestinal parasites reduce feed intake, thereby lowering the weight gain and also causing mortality in goats. The haematophagous parasite *H. contortus* causes anaemia and is a particularly important cause of mortality.

Pale conjunctivae and other mucous membranes are common clinical sign in Lao goats and indicate anaemia. Anaplasmosis and haemonchosis are the potential causes of anaemia in Lao goats. Clinical cases with signs of anaplasmosis have been reported in Lao PDR with laboratory confirmation based on blood samples (Frangi 2014). However, information on seroprevalence is not available. Adult worms and eggs of *H. contortus* have been found in parasite studies (Phengvichith and Ledin 2007; Sato *et al.* 2014). As indicated earlier, haemonchosis is a major cause of anaemia and mortality in small ruminants throughout the humid tropics.

Control of gastro-intestinal nematode infection is complex and an integrated parasite approach involving multiple strategies is generally advocated (Whitley *et al.* 2014). These involve management practices that disrupt the lifecycle of the parasites, coupled with judicious use of anthelmintic chemicals to maintain efficacy. From a gastro-intestinal nematode

Table 2. Summary of published investigations into gastro-intestinal parasites in Lao goats.

Location and year	Methods	Results	Reference
Xaythany district of Vientiane Capital and Pakseng district of Luang Prabang province (2015–2017)	Faecal samples (N = 434) – modified McMaster technique	Average EPG for, <i>Strongylus</i> spp. = 471 <i>Moniezia</i> spp. = 52 <i>Trichuris</i> spp. = 9 Coccidia = 1032	Windsor <i>et al.</i> (2018)
Songkhone district of Savannakhet province (2010)	Faecal samples (N = 14) – modified McMaster technique Faecal samples (N = 14) – coproculture and modified Baermann technique Necropsy (N = 1) – adult worms from GIT under light microscope Adult worms from GIT – PCR and sequencing	<i>Trichostrongylids</i> (93%) with average 1728 EPG <i>Haemonchus</i> spp. (69%) <i>Oesophagostomum</i> spp. (15%) <i>Trichostrongylus</i> spp. (16%) <i>Cooperia</i> spp. (0%) <i>Trichuris</i> spp. <i>T. colubriformis</i> <i>H. contortus</i> <i>Oesophagostomum</i> spp.	Sato <i>et al.</i> (2014)
Livestock Research Centre, Vientiane Capital (2005)	Faecal samples (N = 32) – modified Wisconsin sugar flotation technique	<i>H. contortus</i> <i>Strongylus</i> spp. Coccidia oocysts	Phengvichith and Ledin (2007)

N, sample size; EPG, eggs per gram; GIT, gastro-intestinal tract.

infection perspective, village production systems in Lao PDR benefit from uncontrolled grazing on common land together with other species, and also the housing of goats on slatted floors at nights. These have a dilution effect on the burden of infective larvae on pastures available to infect the goats (Barger 1999). Because of this, the burdens faced tend not to be overwhelming (Windsor *et al.* 2018). However, with intensification of production and placing of goats on fenced pastures, the parasite challenge can be expected to increase and increase the importance of appropriate and timely anthelmintic treatment in control. Fortunately, there appears to be little resistance to the currently available anthelmintics used to treat goats in Lao PDR on the basis of a faecal egg count reduction study from central Savannakhet province using 127 goats (Xaikhue *et al.* 2023). The efficacy of three locally available anthelmintics, namely, albendazole, ivermectin and levamisole, was evaluated against untreated controls.

Less frequent health problems have also been identified in Lao goats from farmer surveys. A study in three districts (Phin, Sepon and Songkhone) of Savannakhet province of central Lao PDR showed that 7.5%, 1.5%, 7.5% and 1.5% of goat farmers had observed skin parasites, skin problems, weak legs and coughing in their goats respectively (Phengvilaysouk *et al.* 2022). Further, lameness was reported (Windsor *et al.* 2017) owing to foot aches by 1.5% of farmers and owing to trauma from the slatted floor of goat pen by 1.5% of goat farmers (Phengvilaysouk *et al.* 2022). Abortions have also been reported in limited number of villages and suspected clinical cases of tetanus have been reported without laboratory confirmation (Frangi 2014). In addition, there is a record on mosquito-transmitted lumbar paralysis among exotic bucks in Lao PDR but not in native goats (Gray 2004).

Presence and importance of major transboundary and zoonotic diseases

The risk of transboundary (Windsor *et al.* 2017) and zoonotic diseases is also a major problem associated with livestock production in general in Lao PDR because of their economic and public health importance. It is believed that Lao PDR was free from peste des petits ruminants (PPR) and goat pox until 2004 (Gray 2004). A subsequent serological study identified PPR antibodies in a small number of goat sera by ELISA (Table 3). However, because of the apparent absence of disease manifestation of PPR in Lao PDR, these seropositive samples may indicate cross-reaction with other morbilliviruses such as measles or canine distemper, imported pre-vaccinated goats, or circulation of a less virulent virus (Burns *et al.* 2019). However, Lao PDR is classified as a country without an official status for PPR by the WOA (OIE-WAHIS 2023a).

Lao PDR is classified as an FMD endemic country and outbreaks of serotypes O, A and Asia 1 have been reported among cattle, buffalo and pig populations. No information

was available on FMD presence in goats during 1996–2006 (Khounsy *et al.* 2009). Subsequent serological surveys with the use of ELISA have shown a low to moderate seroprevalence of FMD among goats with clinical evidence of infection reported in one study (Table 3). FMD outbreaks in goats have been recorded in 2013–2015 and 2017–2019 (OIE-WAHIS 2023b).

Zoonotic diseases where goats are heavily involved include brucellosis (*Brucella melitensis*), Q fever (*Coxiella burnetii*) and orf (orf virus). A small early study of only six goats in Xayaboury province of northern Lao PDR did not detect antibodies against brucellosis and Q fever by semiquantitative indirect ELISA (Douangneun *et al.* 2016). A much larger subsequent serological survey with 1458 samples from five provinces from northern, central and southern Lao PDR found low overall seroprevalence of brucellosis (1.4%) and Q fever (4.1%; Table 4). The same study has also identified the risk factors of these two diseases (Table 4). Although a small proportion of Lao goats appear to have some exposure to brucellosis and Q fever pathogens, the risk of clinical disease has not yet been determined (Burns *et al.* 2018) and clinical diseases have not been reported (OIE-WAHIS 2023b).

Orf is another zoonotic disease that is believed to be present in Lao PDR and has been diagnosed with histology of tissue samples with clinical signs of suspected orf or FMD cases in 2016. These samples were negative for the FMD antibodies (Windsor *et al.* 2017). Another potential zoonotic link with goats is human infection with *T. colubriformis*, which has been shown in Lao PDR (Sato *et al.* 2011), and which shows genomic identity with *T. colubriformis* recovered from goats (Sato *et al.* 2014). Such findings further indicate the importance of continuous surveillance of zoonotic diseases in goats for timely control and prevention measures.

Melioidosis is another neglected zoonotic disease that was confirmed in Lao goats once in 2003, but for which detailed published data are not yet available (Dance *et al.* 2018). Anthrax was reported in Champasak province of southern Lao PDR in 2008 with the death of two domestic goats, confirmed by clinical signs and bacteriology and was successfully controlled (OIE-WAHIS 2023c). However, data on the prevalence of other important zoonotic diseases, such as leptospirosis and capripox among Lao goats, are not available.

Implications for domestic and international trade in goats

The apparent low prevalence of transboundary and zoonotic diseases in Lao goats is beneficial to the trade of Lao goats to neighbouring countries, although accurate certification of disease status in exported goats remains a challenge. However, the close proximity to China, Thailand and Vietnam where some of these diseases are endemic poses a risk to the Lao goat population, particularly because of the extent of unregulated movement of goats across country borders. Knowing the

Table 3. Summary of studies into the seroprevalence of transboundary diseases in Lao PDR.

Disease	Province	Study period	N	SP (%)	Clinical cases reported	Reference	
Bluetongue	Xayaboury	2013–2015	6	100	Not	Douangneun <i>et al.</i> (2016)	
PPR	Attepeu	2016–2017	11	9.1	Not	Burns <i>et al.</i> (2019)	
	Savannakhet		89	0.6			
	Vientiane Capital		444	0.3			
	Xayaboury		273	2.5			
	Xiangkhouang		255	3.1			
	Total		1072	1.7			
FMD	Vientiane Capital	2016	32	0	Suspected	Windsor <i>et al.</i> (2017)	
	Borkeo	2017–2018	76	50	Not	Singanallur <i>et al.</i> (2020)	
	Luang Namtha		74	1.4			
	Luang Prabang		75	0			
	Xayaboury		75	12			
	Khoumoune		80	27.5			
	Savannakhet		60	8.3			
	Xiangkhouang		76	1.3			
	Champasak		75	1.3			
	Total		591	13			
		Vientiane Capital, Vientiane and Xiangkhouang	2018	288	15	Not mentioned	Xaydalasouk <i>et al.</i> (2021)
		In 9 provinces	2019	19	21.1	Reported. Only 19 goats were included together with 602 large ruminants	MacPhillamy <i>et al.</i> (2022)

N, sample size; SP, seroprevalence; PPR, peste des petits ruminants; FMD, foot and mouth disease.

Table 4. Summary of studies into the seroprevalence of the zoonotic diseases- brucellosis and Q fever together with their risk factors (Burns *et al.* 2018).

Province	N	Brucellosis		Q fever	
		SP (%)	Risk factors	SP (%)	Risk factors
Attepeu	194	1.6	Vientiane Capital, introduced Boer mixed breed, commercial production system, adult age, large farm size	1.6	Vientiane Capital, introduced Boer mixed breed, age >3 years
Savannakhet	279	0		0.4	
Vientiane Capital	447	4		10.7	
Xayaboury	273	0		2.9	
Xiangkhouang	265	0		0	
Total	1458	1.4		4.1	

N, sample size; SP, seroprevalence.

disease status of goats in neighbouring countries is valuable to Lao PDR, so as to implement specific disease control and prevention measures to promote the trade of Lao goats. Further, such disease control measures are beneficial to safeguard other livestock species in Lao PDR and to improve the value of their products. A summary of major transboundary and zoonotic diseases present in China, Thailand, Vietnam and Lao PDR goats are outlined in Table 5.

China is considered an endemic country for PPR (Liu *et al.* 2018), and Xinjiang and Tibet are classified as areas with

higher risk (Gao *et al.* 2021). The disease was officially reported for the first time from Ngari region of south-western Tibet in 2007 Liu *et al.* (2018), followed by an outbreak in 2013 in Xinjiang. In both outbreaks, a number of goats died (Liu *et al.* 2018). High seroprevalence of PPR in both sheep and goats has been reported from several regions of China, including, Yunnan, Jiangsu, Anhui, Hubei and Guizhou (Wu *et al.* 2016). The shared border with Yunnan province to northern Lao PDR possesses a threat of PPR incursion. Serological studies have shown that the rate of PPR infection in Chinese

Table 5. Records of major transboundary and zoonotic diseases in China, Thailand, Vietnam and Lao PDR goats (OIE-WAHIS 2023b).

Disease	Last reported			
	China	Thailand	Vietnam	Lao PDR
Bluetongue	NR	NR	NR	NR
PPR	2023 ^A	2021	NR	NR
FMD	2019	2020	2021	2019
Sheep pox and goat pox	2016	NR	2008	NR
Brucellosis – <i>B. abortus</i>	2016 ^A	NR	NR	NR
<i>B. melitensis</i>	2019 ^A	2022	NR	NR
Q fever	NR	NR	NR	NR
Orf	NR	NR	NR	NR
Melioidosis	NR	NR	NR	NR
CAE	2019	2022	NR	NR
Anthrax	2019 ^A	NR	2014	2008

NR, not reported in goat herds; PPR, peste des petits ruminants; FMD, foot and mouth disease; CAE, caprine arthritis and encephalitis.

^AReported in sheep and goat mixed herds.

goats is higher than in sheep in Tibet (Wang *et al.* 2009). Further, strain identification of PPR virus from goats has been performed on samples from Xinjiang (Bao *et al.* 2014; Li *et al.* 2017) and various other parts of China (Su *et al.* 2015; Wu *et al.* 2016). A national PPR eradication program has been implemented with the aim of eradicating PPR in China by 2020 (Liu *et al.* 2018). Currently China is reported as being in its eradication stage of PPR (Legnardi *et al.* 2022) and with no official reports of PPR in goat-only herds (OIE-WAHIS 2023a). However, in 2023 PPR was reported from sheep and goat mixed herds (OIE-WAHIS 2023b). Most of the available reports on Q fever in goats is in Chinese language, although 12% (176/1440) overall seropositivity has been reported for the period of 1989–2013. During this period, higher seropositivity was reported from Anhui province of central China, north-eastern provinces and inner Mongolia. Further, seroprevalence has been reported in Yunnan province (El-Mahallawy *et al.* 2015). Furthermore, 4.8% seroprevalence has been reported in Hubei province of central China (Li *et al.* 2018). Of 50 *B. melitensis* strains isolated from Xinjiang province in a 6-year period (2010–2015), only one was from goats. Further, *Brucella abortus* has not been isolated from goats (Sun *et al.* 2016). Furthermore, only 12 *Brucella* strains have been isolated from goats of 600 strains collected from 29 provinces including Yunnan province between 1953 and 2013. However, it was not clear whether any of the goat isolates belonged to Yunnan province or not (Tian *et al.* 2017). Tibet, Xinjiang and Qinghai provinces in western China have been identified as animal FMD hotspots during the period from 2010 to 2016 (Ma *et al.* 2017). Further, south-western and central China have been identified as hotspots for FMD serotype A and serotype O respectively in all animals from 2010 to 2019 (Gao and Ma 2021). Furthermore, western,

southern, including Yunnan province, northern and eastern areas of China have been reported as high-risk areas of animal FMD in 2010–2020 (Haoran *et al.* 2021). Orf is a nationally important zoonotic disease in China and clinical cases have been reported in goats during 2009–2011 from different provinces including Yunnan (Zhang *et al.* 2014). In 2017, clinical cases were reported in north-eastern China (Yu *et al.* 2020). Interestingly, *orf* virus has been also isolated from blood (32.4%), saliva (53%) and milk (44.7%) of asymptomatic dairy goats (Ma *et al.* 2022). The seroprevalence of bluetongue in goats in seven regions of China during the period from 1988 to 2019 was 28.1% (41,263/12,182) and the highest prevalence among both sheep and goats was recorded from Yunnan province (35.7%) (Liu *et al.* 2021). Similarly, seroprevalence in goats has been reported from Hubei province (13.31%) (Luo *et al.* 2017) and Xinjiang province (Ma *et al.* 2019; Yang *et al.* 2021). Clinical cases of goat pox have been seen in 2009 in Chongqing municipality of China, which is closer to Hubei province (Chu *et al.* 2011). Goat deaths owing to melioidosis were reported in Guangxi province in 2009 (Zheng *et al.* 2019). Several cases of caprine arthritis and encephalitis (CAE) from different provinces (Gansu, Shandong, Sichuan, Shaanxi and Guizhou), which are away from Lao PDR have been documented in Chinese language (Wang *et al.* 2023).

In Thailand, human brucellosis caused by *B. melitensis* has been reported and was primarily associated with direct contact with infected goats (Paitoonpong *et al.* 2006; Techapornroong and Ekgat 2018). Low overall seroprevalence of *B. melitensis* (1.4%) was reported in Thai goats in 2013 (Sagarasaerane *et al.* 2017). Seroprevalence of brucellosis in both sheep and goats between 2013 and 2015 was reported at 0.72% (Peck *et al.* 2018). Another study from Thailand reported very low seroprevalence of brucellosis, 0.6% (3/500), among goats in Chiang Mai province of northern Thailand (Kladkempetch *et al.* 2017). Further, a study in north-eastern provinces during 2017–2020 showed 6.8% seroprevalence; however none of these provinces share borders with Lao PDR (Rerkyusuke *et al.* 2022). Further, 8.3% herd-level seroprevalence has been reported from Sa Kaeo province, Thailand, sharing a border with Cambodia (Colombe *et al.* 2018). Moreover, Thailand is a Q fever endemic country and 3.5% seroprevalence has been reported in samples from northern Chiang Mai and north-eastern Nakornratchasima provinces (Doung-Ngern *et al.* 2017). Herd-level seroprevalence of Q fever has been reported as 33.3% in goats from Sa Kaeo province (Colombe *et al.* 2018). Higher seroprevalence of Q fever (46.61%) has been reported from north-eastern provinces, which are not sharing common borders with Lao PDR (Rerkyusuke *et al.* 2022). Clinical disease of FMD in goats has been reported from northern Chiang Mai province (Chomnanpood and Gleeson 1992). Further, 5.9% overall seroprevalence of CAE in three provinces of western Thailand (Lin *et al.* 2011) and 3.5% (68/1925) seroprevalence have been reported from five parts of Thailand including the borders with Lao PDR (Mongkonwattanaporn *et al.* 2021). In Thailand, 31 clinical cases of melioidosis have been reported

over a 5-year period from 2006 to 2010 in areas not sharing borders with Lao PDR (Limmathurotsakul *et al.* 2012). In total, 65 cases of melioidosis in goats have been also reported in Thailand over a 10-year period from 2006 to 2015 and animal cases were reported from north-eastern Thailand, bordering Lao PDR (Kongkaew *et al.* 2017). Further, 0.33% seroprevalence has been reported during 2005–2006 among 6576 goats, covering 18 provinces including Chiang Rai Province, Thailand, which borders Lao PDR. However, the information on the presence of seroprevalent goats particularly in Chiang Rai Province is not available (Srikawkheaw and Lawhavinit 2007). Thailand was officially recognised as PPR free until 2017 (Qingdao 2017) but in February 2021 the first occurrence of PPR in domesticated goats was reported. This was the first report of PPR in Southeast Asia (OIE-WAHIS 2023d). No evidence of orf and goat pox virus infections in Thai goats are available (OIE-WAHIS 2023b).

In Vietnam, the first human brucellosis with *B. melitensis* was reported in 2016–2017 from four provinces towards the Cambodian border. With the history of exposure to goats in these human cases, it was assumed that the responsible pathogen is widely present among the Vietnamese goat population, particularly in the south (Campbell *et al.* 2017). Further, herd mortality resulting from goat pox ranging from 5.1% to 7.4% has been reported from six provinces of northern Vietnam, including Nghe An province bordering Lao PDR (Pham *et al.* 2020). Also, it was identified that the isolated goat pox virus is closely related to the goat pox viruses currently circulating in China, India and Pakistan (Pham *et al.* 2021). Even though, PPR was not reported in any animal species during the period from 2005 to 2013 (EFSA AHAW Panel (EFSA Panel on Animal Health and Welfare) 2015), a study had shown low seroprevalence of PPR (2%) among 283 goats from Ha Giang Province, which borders China, without apparent clinical signs (Maillard *et al.* 2008). However, Vietnam is still classified as a country without an official record for PPR (OIE-WAHIS 2023a). Being an FMD-endemic country, FMD has been reported in Vietnamese goats. Considerably low FMD prevalence (0.41%) was recorded collectively for sheep and goats from a nationwide surveillance from 2007 to 2017 (Lee *et al.* 2020). However, published information on the presence of bluetongue, Q fever, orf, melioidosis and CAE in Vietnamese goats is not available (OIE-WAHIS 2023b).

Prevention and control of transboundary animal diseases requires coordination among responsible authorities within each country and also political support. Control is challenging and typically requires disease-screening centres at the most popular border-crossing sites with suitable disease diagnostic aids and competent personnel. Other measures include ensuring adequate supplies of appropriate vaccines in a vaccine bank, active and passive surveillance for the diseases of interest, control of animal movements and synchronised vaccination programs between border countries (Gongal *et al.* 2022).

Discussion and conclusions

This review has shown that the mortality rates in Lao goats are high on the basis of past surveys (Gray *et al.* 2019; Xayalath *et al.* 2021; Colvin *et al.* 2022). It has also identified that disease is a major cause of such mortalities. Poor health in Lao goats is mainly associated with several endemic clinical syndromes, while poor nutrition and poor husbandry practices also play a significant role. The most prominent endemic syndromes appear to be orf-like lip and facial lesions, eye conditions ('pinkeye') and diseases of the gastro-intestinal tract. Knowing the cause of some of the endemic syndromes is needed to help design appropriate treatment and control measures for a more productive goat industry in Lao PDR. This is important, given the recent increase in contribution of goats to the local and potential national income, and formed the basis for this review of the existing literature on goat diseases in Lao PDR.

High mortality and prevalence of disease and clinical syndromes in Lao goats are likely to be influenced by management systems and nutrition. The widespread use of extensive free-grazing unconstrained by fences is likely to mitigate against very heavy gastro-intestinal worm burdens and strongyle faecal egg, which generally tend to be moderate rather than very high (Windsor *et al.* 2018). For the smaller number of farmers who use cut and carry systems, the risk of worm infections is further reduced. In contrast, unsupervised grazing on communal lands can increase the risk of disease transmission from other goats and farm species. Further, inadequate nutrition associated with low forage availability or quality, increases host susceptibility to infections including gastro-intestinal nematode infection. The immunosuppression occurs as a result of inadequate supply of certain nutrients that are needed for optimum function of immune cells or because of increased nutritional demand as a result of environmental, physiological and management stresses (Caroprese *et al.* 2015) or because of changes in intestinal microbiota (Guo *et al.* 2022). Improving farmer knowledge on supplementary feeding, development of forage plots and extension of grazing time available for goats are likely to be advantageous in assisting disease control. Good housing with raised well-designed slatted floors, good ventilation and protection from the elements are protective for diseases transmitted by faecal–oral cycling such as coccidiosis (Smith and Sherman 2009) or respiratory disease (Constable *et al.* 2017), which is exacerbated by high ammonia concentrations (Smith and Sherman 2009). However, dirty, crowded goat shelters without raised floors will facilitate ammonia production and respiratory infections, especially during the rainy season under conditions of high humidity and wet floors.

The poor availability of veterinary services (Subharat *et al.* 2023) is a likely contributory factor to the mortality and disease problems in Lao goats. Strengthening the provision of veterinary services, which include diagnostic, extension

and veterinary health workers, is needed and would benefit all livestock industries, not just goats. Strengthening of the VVW network would be beneficial because of the finite availability of qualified veterinarians in Lao PDR. While more training is needed for VVWs and village volunteers in diagnosing and treating goat diseases and ensuring that they have appropriate drugs with proper labelling for treatment is also desirable, the challenges in ensuring an effective VVW system in the field are acknowledged. Educating VVWs on the links between management practices and disease is something to consider, to introduce a role in prevention rather than only treatment of disease.

The available studies on transboundary and zoonotic diseases in Lao goats indicate low seroprevalence, except for FMD. Thus, transboundary and zoonotic diseases appear to have little impact on current goat production and trade, with a possible exception of FMD when it occurs as a result of involvement of multiple host species. However, further studies with greater geographic spread need to be conducted to confirm the low prevalence of these diseases. Such diseases represent a modest risk to the export trade because countries may close cross-border trade in live animals as a result of disease outbreaks in Lao PDR. The largely informal nature of the live-goat trade would make such closures difficult to implement. However, formalising the trade would likely require development of disease-certification procedures on the Lao side that would be difficult to implement effectively because of inadequate knowledge within Lao PDR, and insufficient human and financial resources. The informal trade, which also includes Lao PDR as a transit country in some cases, also poses a risk of disease incursions into Lao PDR, although it is not clear whether Lao goats have a superior disease status overall compared with the goats in neighbouring countries.

To conclude, goat diseases are an inadequately explored area in Lao PDR (Burns *et al.* 2018). Lao goats suffer from many endemic diseases and clinical syndromes and there is serological evidence that several transboundary and zoonotic diseases circulate in the country. The opportunity for Lao goat farmers to grow their household income through goat production is constrained by mortalities and endemic disease and clinical syndromes. Knowledge of disease causation, which pathogens are circulating and basic disease epidemiological data such as disease risk factors are very limited for Lao goats, despite being critical for informing appropriate disease control and treatment. Those are important areas for future research. Lack of correct disease diagnosis and using this information to design appropriate disease-control strategies have been identified as having the utmost importance for a more productive goat enterprise in Lao PDR (Gray *et al.* 2019). Even though some progress has been made in this area with provisional diagnosis of orf, detailed diagnosis of pinkeye and some characterisation of gastro-intestinal helminth burdens and species involved, many of the endemic disease problems of goats in Lao PDR remain poorly understood and

managed. Overcoming this is a challenge for the Lao Government, non-governmental organisations (NGOs) involved in rural development and international agricultural research and development agencies. Because lip and facial dermatitis, eye conditions and diarrhoea are the most common clinical syndromes in Lao goats, these can be considered as the major priorities for determining causation. Gastro-intestinal nematode infections can also be expected to increase in importance with intensification of the production system. Information on disease causation can be used to inform appropriate control measures for the most common disease and clinical syndromes to lower the disease burden, which can exert a significant impact on Lao goat health and production. The link between management practices and disease is another recommended area of future research, with the application of good husbandry practices, nutrition and reproduction management being likely to reduce the disease burden. In addition, strengthening veterinary services in terms of surveillance systems, disease diagnostics, and field veterinary capacity, together with empowering extension workers with proper knowledge of diseases, should form part of strategies to improve disease control in Lao goats. However, the practicability, cost and durability of such interventions need to be carefully evaluated before being introduced to Lao PDR.

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