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Live pig markets in eastern Indonesia: Trader characteristics, biosecurity and implications for disease spread

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ABSTRACT

Classical swine fever has been negatively impacting pig production in Nusa Tenggara Timur province in eastern Indonesia since its introduction in the 1990s, with live market trade contributing to disease spread. To understand market trader knowledge and practices regarding pig management, biosecurity, pig movements and pig health (specifically CSF), a repeated survey was conducted with pig sellers and pig buyers at 9 market sites across West Timor and the islands of Flores and Sumba. A total of 292 sellers and 281 buyers were interviewed in 2009 during two periods (rounds), a high-demand month (September) and a low-demand month (November). Information was collected via questionnaire. The majority of traders were male (sellers: 89%; buyers: 87%) with the highest level of completed education being primary school (sellers: 48%; buyers: 41%). The primary occupation of most respondents was farming: 90% of sellers and 87% of buyers were smallholder pig farmers and tended to sell their own home-raised pigs at market (52%). Pigs were sold for monetary gain either for primary (52%) or extra income (44%). Markets tended to be selected based on a good reputation (62%), a location close to residence (62%) and having the desired pig type (59%). Pig sales through markets were reported to be highest from August to October with 31% of sellers trading pigs at two or more markets. Prices at market were significantly higher on Sumba compared to West Timor and cross-bred pigs were significantly more expensive than indigenous pigs. Understanding of CSF and biosecurity was limited: 85% of sellers and 83% of buyers had no prior knowledge of CSF. Fifty-four percent of sellers reported no use of any biosecurity practices at market. Most respondents (88%) were able to recognise at least one clinical sign of a sick pig. Informal pig movements were also identified: 18% of pig buyers purchased pigs directly from other farmers. This study has provided baseline information on market trader activities at live pig markets in NTT that can contribute to the formation of sustainable strategies for improving pig health. Since NTT is the poorest province in Indonesia and pigs play a vital socioeconomic role in this province, market management and farmer education is needed to improve the pig market chain and contribute to socioeconomic development.

1. Introduction

The trade of livestock is a vital part of the economy for many developing countries (Perry et al., 2005). Animals provide a major source of protein, income and assets for poor rural families (Perry et al., 2005; Windsor, 2011). Within Nusa Tenggara Timur (NTT), a province located in eastern Indonesia, the demand for live pigs remains high for various celebratory events including weddings, funerals and traditional ceremonies (Christie, 2007; Johns et al., 2009). Within the province the ability of livestock markets to provide live pigs for purchase is vital (Johns et al., 2009).

The management practices employed at livestock markets have the potential to influence infectious disease spread (FAO, 2010). The introduction of animals from different source locations, the direct contact between animals of unknown health status, combined with minimal effective biosecurity, presents a significant risk (Boklund et al., 2008; Natale et al., 2009; FAO, 2010). Market premises tend to

Abbreviations: CSF, classical swine fever; GLMM, generalised linear mixed model; ICC, intra-cluster correlation coefficient; IDR, Indonesian rupiah; NGO, non-government organization; NTT, Nusa Tenggara Timor; REML, restricted maximum likelihood.

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act as hubs within a movement network, bringing animals from different disease prevalence regions into one location, thus facilitating disease transmission (Robinson and Christley, 2007). Studies have confirmed that the use of biosecurity methods, particularly at markets (due to their high throughput of livestock), can greatly assist in minimising disease spread (Roman et al., 2006; Donaldson, 2008). Simple disinfection of a marketplace each day before the intake of livestock can assist in minimising disease transmission between animals (Kiss et al., 2006).

An infectious disease of pigs that is particularly relevant when investigating the potential for disease spread through the pig marketing chain in eastern Indonesia is classical swine fever (CSF). Similar to other pig diseases of concern in this region, CSF is transmitted by direct contact and via fomites, but it is of greater concern because it is highly contagious and causes substantial socioeconomic loss, including impacts on smallholder farmers (Blome et al., 2010; Madzimure et al., 2013). The importance of CSF is demonstrated by its ranking as a priority animal disease in Indonesia and the national plan to eradicate it by 2020 (Ministry of Agriculture, 2013), a plan with high emphasis on NTT because it is the province with the highest pig population in Indonesia (Dinas Peternakan Propinsi, 2014). First introduced to Indonesia in 1994, believed to be through pig movements from Malaysia, this pestivirus disease with the first confirmed case in Sumatra (Christie, 2007) spread rapidly eastwards across the archipelago. Entry to NTT province was confirmed in 1998 and occurred via movement of pigs from other areas of Indonesia and from Timor Leste (then the Indonesian province of East Timor) (Christie, 2007). Smallholder farmers continue to be severely impacted by this disease, with annual reports continuing to increase (Dinas Peternakan Propinsi, 2014). The high demand for pigs across NTT province still drives the movement of pigs and newly infected islands have been reported as recently as 2011 (Dinas Peternakan Propinsi, 2014). A risk assessment conducted by Leslie (2012) demonstrated a high probability of CSF infected pigs at live pig markets; with actions such as pre-entry inspection to prohibit entry of sick pigs and increased vaccination coverage of the general pig population shown to reduce the probability of infection.

The objective of this study was to describe the practices of pig sellers and pig buyers at selected market sites in NTT province in relation to pig management, biosecurity practices, live pig movement, and knowledge of pig health and CSF. By understanding practices along the market chain, high-risk activities can be targeted for mitigation strategies to improve control of disease spread and therefore reduce economic and social impact.

2. Methods

A repeated survey was conducted in the eastern Indonesian province of NTT on West Timor and the islands of Flores and Sumba. Nine live animal markets (Fig. 1) were selected across the province (three on each island) where face-to-face interviews were conducted with pig sellers and pig buyers during two interview periods: September 2009 and November 2009 (University of Sydney Human Ethics Approval No: 08-2009/11866).

2.1. Study area

The selected study area was NTT province in eastern Indonesia. West Timor and the islands of Flores and Sumba were selected as study sites because pig production in these areas is a substantial part of smallholder farming and approximately 70% of the provincial human population resides on these islands (Statistics Indonesia, 2010). NTT is an archipelago comprising 566 islands with a total land area of 47,349 km^2 (only 2.5% of Indonesia's total). The predominant religions in the area are Roman Catholic and Protestant. Agriculture is the primary income source for the majority of households, and is mostly subsistence farming. Live pig markets play an important role in pig trade, providing a formal trade route for inter- and intra-island movement. The seasons – a wet season spanning from December to March and a dry season from April to November – influence pig movements along the market chain due to transportation challenges. Both time periods were investigated to understand different risks of disease spread and therefore to help target control strategies.

2.2. Selection of interview rounds

The study was conducted across two interview rounds to incorporate a high and a low demand period for pigs. This was to allow for the identification of any annual trends in relation to the number of pigs entering and leaving a marketplace, as well as the number of pig sellers and buyers depending on cultural and seasonal variations. Information on cultural activities and seasonal influences were obtained from local experts (local and government veterinarians from each island). Based on such expert opinion, September was selected as the most appropriate month for the high-demand period and November for the low-demand period.

There is high pig demand and larger numbers of pigs moved from June to September across all three islands. In West Timor, this time period is considered 'wedding season', in Flores there are abundant communion celebrations during September and in Sumba farmers sell their pigs ahead of the approaching dry season due to the resulting limited feed sources. November was a low-demand month due to households preparing for Christmas celebrations by fattening previously purchased pigs and few traditional ceremonies during this month in Sumba.

2.3. Selection of markets and pig traders

Purposive selection was used to recruit appropriate market sites for the study. Market selection was based on the following criteria: large numbers of pigs being moved through the market (>20 on a selling day); markets located in Flores, Sumba or West Timor; from local knowledge classified as an important and well known market for pigs (expert opinion from the Provincial Livestock Animal Health Department); and accessible by vehicle. It was necessary to select markets using this process because there was no sampling frame of live pig markets available from the Provincial Livestock Services. Moreover, due to the limited resources in this area, it was important to select key markets involved in the movement of large pig numbers to investigate potential hubs for disease spread, so as to focus on disease control strategies (Table 1).

At each market location, the target was to complete 16 questionnaires with sellers and 16 with pig buyers, totalling 288 seller and 288 buyer interviews across both interview rounds. Preliminary estimates from experts suggested that the number of pig sellers at a marketplace ranged from approximately 5 to 25 individuals. By interviewing 16 sellers per market per round, it was assumed that >50% of sellers present at a market site would be interviewed. Due to budget restraints, the maximum number of interviews that could be conducted was 288 sellers and 288 buyers (with targets of 96 sellers and 96 buyers per island across the two survey rounds).

If the target number of 16 sellers was not present at a particular market, a complete census of sellers was undertaken. Additional buyer questionnaires were then completed to obtain a total of 32 interviews per site per visit. During each market visit, the total number of sellers and buyers were estimated through observations ("head counts") to calculate the proportion of the total represented by the 32 individuals interviewed. For the nine selected markets, information about the number of sellers present on a market day

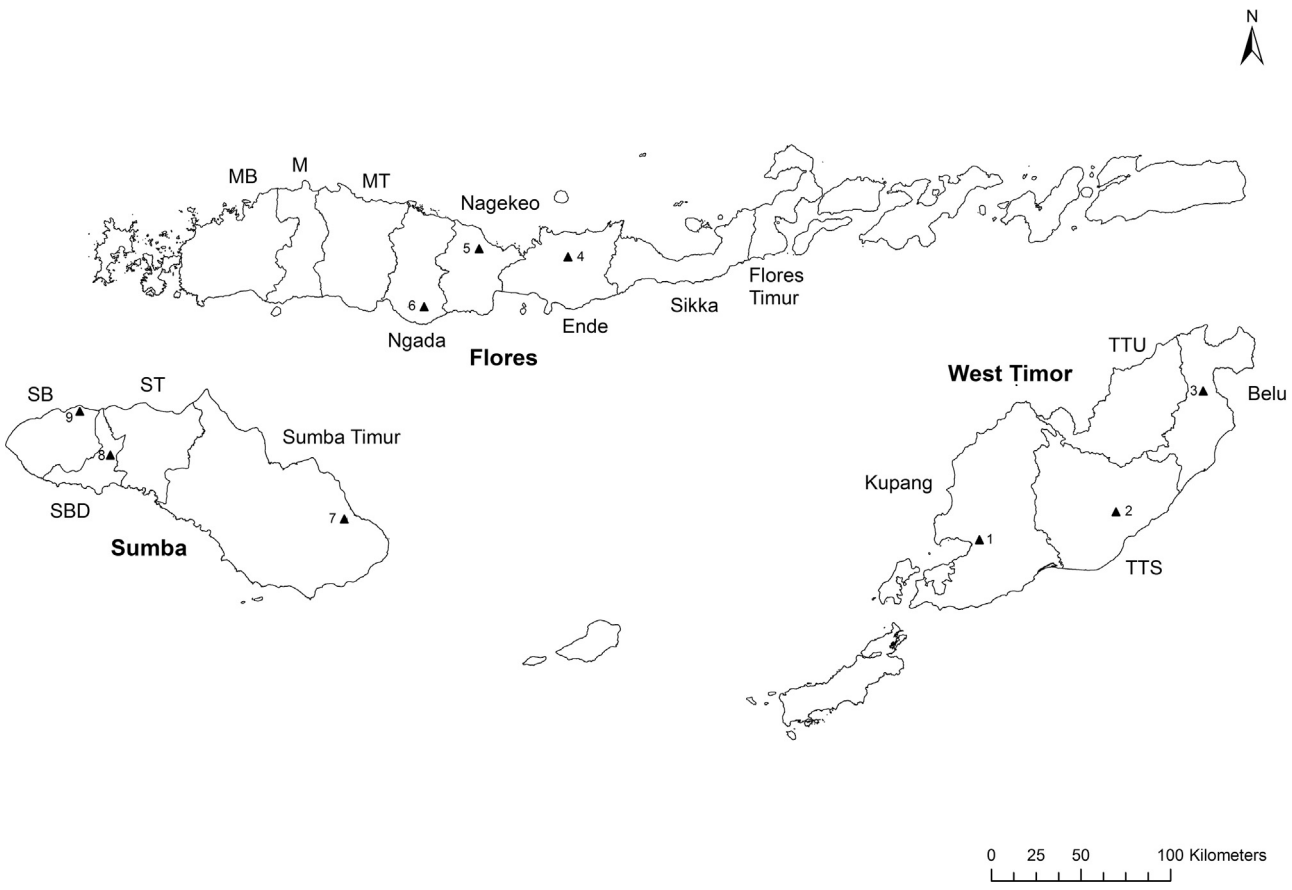

Fig. 1. Selected market sites across Nusa Tenggara Timur province in eastern Indonesia for inclusion in a pig movement study, 2009; 1. Camplong Market, 2. Niki Niki Market, 3. Halulik Market, 4. Detusoko Market, 5. Mataloko Market, 6. Mbay Market, 7. Melolo Market, 8. Waikabubak Market, 9. Wetabula Market.

required for proportional sampling of sellers or a census of sellers could not be obtained prior to the study. This was due to the absence of – or the inability to contact – market managers and a lack of recorded data.

2.4. Data collection

Three interview teams of four people each were recruited and trained for data collection. Individuals were recruited from Nusa Cendana University, West Timor and two local non-government organisations (NGOs), Yaspem Maumere from Flores and Yayasan Cendana Mekar from Sumba. Two questionnaires were developed for seller and buyer respondent types focusing on obtaining information regarding pig management, biosecurity practices, live pig movement and knowledge of pig health and CSF. The questionnaires were developed in English and then translated into Bahasa Indonesia. The questionnaires comprised both open- and closed-ended questions. The majority of questions were checklist and short answer type responses. Arrival at market was between 4 am and 7 am, according to location, in order to maximise interview numbers. Traders were approached in the market and their participation was requested. If willing, consent was gained. Otherwise, if unwilling, another seller or buyer was approached. On completion of the interviews, all respondents received a T-shirt for participating with information promoting CSF vaccination. They were only told of the T-shirt on completion of the interview so as not to influence their decision to participate. Following the first round of interviews, the names of all of the individuals interviewed were listed and this was referred to during the second interview round to ensure that no respondents were interviewed a second time.

2.5. Data analysis

Standard descriptive analyses were conducted separately on data obtained from the seller and buyer interviews using Genstat

Table 1
Market locations selected for pig movement study in West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009.

Location	Market	District	Subdistrict	Village	Market Days
West Timor	Camplong	Kupang	Fatuleu	Camplong	Friday-Saturday
	Niki Niki	TTS	Amanuban Tengah	Niki Niki	Wednesday
	Halulik	Belu	Tasifeto Barat	Naitimu	Thursday
Flores	Detusoko	Ende	Detusoko	Detusoko	Tuesday- Wednesday
	Mataloko	Ngada	Golewa	Mataloko	Saturday
	Mbay	Nagekeo	Aesesa	Mbay 1	Saturday
Sumba	Melolo	Sumba Timur	Umalulu	Lumbukori	Thursday-Friday
	Waikabubak	Sumba Barat	Kota Waikabubak	Wailiang	Every Day
	Wetabula	Sumba Barat Daya	Loura	Wetabula	Every Day

11th Edition (PC/Windows XP, 2006, VSN International Ltd., Hemel Hempsted, UK). Initially data were checked and edited for missing values and outliers. Descriptive analyses were used to describe general management of pigs in the marketplace, pig movements and knowledge of pig health and CSF. For individuals that also kept pigs at their residence, management features were analysed. Continuous variables were described by means, quartiles and ranges. For categorical variables of interest, proportions were calculated at an island and interview round level and significant differences were identified using the chi-square test. When the chi-square test indicated overall significance (P-values < 0.05) for variables with multiple categories, a z-test using a Bonferroni adjustment was used to compare categories and identify those that were significantly different.

To identify significant differences between pig count data, a generalised linear mixed model (GLMM) was used. The model consisted of four fixed effects: interview round (high-demand, low-demand), breed (indigenous, cross-bred), age group, and island. For age group, analyses were conducted only on pig age groups of a marketable age (≥2 months of age), including weaners, growers, fatteners, sows and boars. The random effects included in the model were seller or buyer ID and a term for market nested within island. An additional GLMM model was fitted to analyse on-farm herd size per seller. The model consisted of two fixed effects: interview round and island. All three islands were included in these analyses as age groups were not distinguished. The random effects included a term for market nested within island. A Poisson distribution was used in both models with a logarithmic link function to account for the presence of count data and predominantly lower pig numbers in the dataset. Due to the application of a GLMM, the calculation of the intra-cluster correlation coefficient (ICC) could not be performed.

The presence of variations in pig sale prices at market were analysed using a restricted maximum likelihood (REML) model. An error occurred on Flores during data collection with the misclassification of pig age groups. As a result, only data from West Timor and Sumba were analysed for age group price comparisons. The final REML model included fixed effects for interview round, breed, age group and island (including interactions) and random effects for seller ID and a term for market nested within island. Due to misclassification of identified pig age groups from Flores, only data from West Timor and Sumba were included in this model. The sale price data required Log_e transformation following assessment for normality. Clustering (or similarity) between sale prices was anticipated at the seller, market and island levels and was assessed for market and seller by calculation of the ICC. Clustering was considered high if ICC values were >0.1 (Dohoo et al., 2003).

3. Results

3.1. Seller and buyer numbers

A total of 574 interviews were completed within markets: 292 pig sellers (round 1: 144; round 2: 148) and 281 pig buyers (round 1: 144; round 2: 137) across nine market sites. The respondents interviewed comprised 21–100% of the estimated total number of pig sellers and from 18 to 100% of the estimated total number of pig buyers present in the market on the day of interviewing. The number of sellers per market was higher than originally estimated for some of the markets. The sample of nine markets across these three islands represented 10% of documented live pig markets identified by the Provincial Livestock Services.

3.2. Pig trader demographics

A greater proportion of sellers and buyers were male (Tables 2 and 3). The mean age of sellers and buyers were 39.61 ± 10.12 and 41.85 ± 10.10 years, respectively. The highest education completion rate was primary school amongst pig sellers (48%; 140/292; Table 2) and buyers (41%; 115/280; Table 3). The majority of sellers were Roman Catholic (57%; 167/292; Table 2) and Protestant (39%; 114/292), and similar with buyers (Table 3). Buyers and sellers from Flores were primarily Roman Catholic (99%; 188/190) and a small proportion of respondents from Sumba practiced *Marapu* (10%; 20/192), a traditional local religion.

3.3. Seller and buyer characteristics

Multiple roles for sellers in the market place were identified. Approximately half of the sellers sold only their own pigs (52%; 152/292), whilst the majority of the remaining individuals reported being permanent sellers (individuals that remain at market, purchasing and re-selling pigs that have been bought from sellers coming to market, typically not selling their own pigs) (41%; 120/292). The remaining 7% (20/292) were pig collectors (middlemen purchasing pigs from different farms or sources and selling directly to sellers at the market and sometimes including their own pigs, as disclosed via general interview comments). Both sellers and buyer respondents were also found to be smallholder pig farmers (sellers: 90%; 260/289 and buyers: 87%; 245/281) with a mean herd size of 2.7 ± 1.1 pigs per herd at their residence. Additional factors influencing the role of a seller included seasonal changes and the need for money. One respondent reported becoming a seller only when in need of additional money for events such as sending children to school. One other seller stated that he remained a permanent seller during the dry season and then returned to agricultural work in the fields during the wet season. On average pig sellers had been selling pigs at market for 5.6 ± 4.3 years. The major reasons for selling pigs were for primary income (52%; 153/292) and extra income (44%; 127/292). Other economic reasons for selling pigs included family costs such as household necessities (10%; 13/127) and education costs (9%; 12/127). Only a small proportion of individuals reported selling pigs in response to high demand (2%; 7/292).

The selection of a specific market as a location to sell pigs was usually dictated by its reputation as a good market (62%; 180/292). The location of a market close to a respondent's residence increased its chance of usage (45%; 130/292). Few pig sellers selected markets based on large buyer numbers and markets where higher prices could be obtained (6%; 17/292). For buyers, the most frequently reported market selection characteristic was based on the types of pigs sold at a market (59%; 164/278). Other common responses included choosing a market due to its close proximity to a residence (32%; 89/278), or due to cheaper pig prices (14%; 38/278).

Buyer respondents reported purchasing live chickens (68%; 86/127; Table 3), live goats (36%; 46/127), and live dogs (29%; 37/127) at market in addition to pigs. Results showed that it was not as common to purchase live cattle or buffaloes at market (cattle: 8%; 10/127 and buffalo: 2%; 3/127). Only 3% (9/281) of live pig buyers reported ever purchasing pig meat at markets.

For buyers, pigs were primarily kept as a source of income (64%; 181/281) and for use in traditional ceremonies (47%; 131/281). Their end use was mostly to sell (40%; 113/281); slaughter for consumption in a traditional ceremony (32%; 105/281); and to add to their on-farm herd (33%; 92/281; Table 3). Sumba had a significantly higher number of pigs purchased for use in traditional ceremonies ($P < 0.001$; Table 3).

Table 2
Demographics and characteristics of 292 pig sellers interviewed at live animal markets across West Timor, Flores and Sumba, eastern Indonesia, 2009.

Data type/variable		Category	Number of sellers	WT (%)	Flores (%)	Sumba (%)
Demographics	Gender	Male	260	33	32	35
		Female	32	28	56	16
	Education	School not attended[a]	41	54	24	22
		Primary school	143	33	42	25
		Secondary school	80	23	29	49
		High school	27	30	26	44
		University	1	100	0	0
	Religion	Catholic	167	21	60	19
		Protestant	114	54	0	46
		Marapu	11	0	0	100
Characteristics	Reason/s for selling pigs[b]	Primary income	153	31	30	39
		Extra income	127	37	37	26
		Family & education costs	25	0	52	48
		Family tradition	23	0	0	100
		High demand	7	29	0	71
	Market choice[b]	Close to residence	130	28	49	22
		Popular	177	38	15	47
		High demand	21	24	19	57
		Good price	10	40	40	20
		Opening hours	17	18	76	6

[a] School not attended or primary not completed.
[b] Multiple options could be selected.

Table 3
Demographics and characteristics of 281 pig buyers interviewed at live animal markets across West Timor, Flores and Sumba, eastern Indonesia, 2009.

Data type/variable		Category	Number of buyers	WT (%)	Flores (%)	Sumba (%)
Demographics	Gender	Male	245	32	31	37
		Female	36	44	42	14
	Education	School not attended[a]	35	43	31	26
		Primary school	116	28	38	34
		Secondary school	69	35	25	41
		High school	53	38	26	36
		University	8	50	50	0
	Religion[b]	Catholic	161	22	55	23
		Protestant	110	52	2	46
		Marapu[c]	9	0	0	100
Characteristics	Type/s of other animals purchased[d,e]	Poultry	86	27	9	64
		Goat	46	50	11	39
		Dog	37	14	8	78
		Cattle	10	70	30	0
		Buffalo	3	0	67	33
	Pig usage[d]	Sell	113	35	27	37
		Traditional ceremony	105	18	14	68
		On-farm herd	92	15	45	40
		Home consumption	29	48	34	17
		Religious ceremony	22	27	9	64
		Wedding	6	0	50	50
		Family party	6	100	0	0
	Market selection[d]	Pig type	163	38	13	49
		Close to residence	89	31	47	21
		Lower price	38	24	50	26
		Opening hours	10	30	20	50

[a] School not attended or primary not completed.
[b] 1 buyer did not provide a response.
[c] *Marapu* is a traditional local religion found predominantly on the island of Sumba.
[d] Multiple options could be selected.
[e] Only 127 buyers purchased other types of animals in addition to pigs.

3.4. Pig volume and breed

The survey recorded the exact numbers of pigs brought to market by the interviewed sellers. A total of 450 and 349 pigs, respectively, across the high-demand and low-demand periods were recorded as being brought by seller respondents. On average 50 pigs were present at a 'typical' market on a given day, ranging from 11 to 105. No significant interactions were identified amongst the fixed effects in the GLMM model. No significant differences were detected in the number of pigs brought per seller to market across interview rounds ($P = 0.180$; round 1: 1.98 ± 1.08, round 2: 1.78 ± 1.16) or islands ($P = 0.898$; West Timor: 2.05 ± 1.39, Flores: 1.82 ± 1.39, Sumba: 1.78 ± 1.38). Individuals from Wetabula Market in Sumba had the highest average number of pigs per seller (6.19 ± 4.96) and Mbay Market in Flores had the lowest (0.75 ± 0.63). Overall the total number of pigs brought to the market by an individual seller ranged from one to 25. A higher proportion of indigenous breed pigs were sold at market in comparison to cross-breeds ($P < 0.001$; indigenous breed: 75.6% (604/799); cross-breed: 24.4% (195/799)).

A total number of 326 indigenous bred pigs and 196 cross-bred pigs were purchased across market sites. Buyers from Sumba

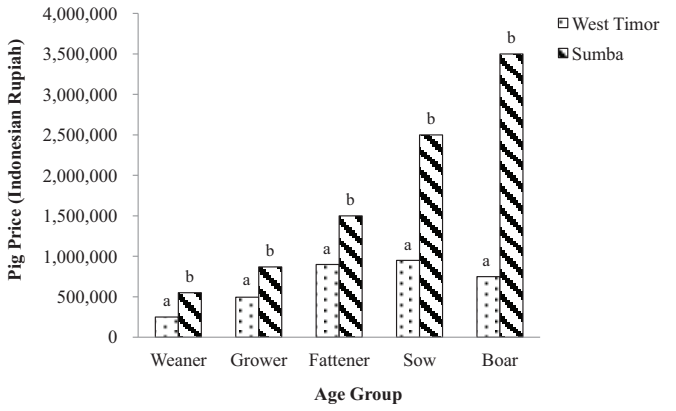

Fig. 2. Mean price of pigs being sold in markets by 292 pig sellers across West Timor and Sumba in Nusa Tenggara Timur, eastern Indonesia (currency: Indonesia Rupiah), 2009; [a,b] columns without a common letter differ significantly within age group ($P < 0.05$).

purchased a significantly higher proportion of cross-bred pigs compared to West Timor and Flores ($P > 0.001$; West Timor: 8%, 18/217; Flores, 10%, 21/217; Sumba: 82%, 178/217). The largest proportion of indigenous pigs was purchased in West Timor and Sumba ($P > 0.001$; West Timor: 42%, 155/370; Flores, 12%, 44/370; Sumba: 46%, 171/370).

3.5. Pig prices

For pig prices, only West Timor and Sumba were compared due to issues with data accuracy on Flores. No significant interactions amongst the fixed effects in the price models were found. Pig prices were significantly higher in Sumba compared to West Timor for all marketable age groups ($P < 0.05$; Fig. 2). The cost of cross-bred pigs was found to be significantly higher than indigenous breeds for weaners ($P < 0.05$; indigenous: IDR 546,538 ± 275,478; cross: IDR 745,455 ± 239,222), growers ($P < 0.001$; indigenous: IDR 1,054,630 ± 898,270; cross: IDR 1,662,500 ± 1,095,910), sows ($P < 0.001$; indigenous: IDR 1625,641 ± 980,593; cross: IDR 3,313,158 ± 1,480,225) and boars ($P < 0.001$; indigenous: IDR 2,185,345 ± 1,640,088; cross: IDR 3,981,818 ± 1,208,457). [Note: in November 2009, US$1 = IDR 9465.33]. No difference was detected for price variations across interview rounds ($P = 0.217$; high-demand period: IDR 1,519,464 ± 1,356,981; low-demand period: IDR 1,487,149 ± 1,329,997). The level of clustering was found to be high at the pig seller level (ICC = 0.49) and at the market level (ICC = 0.24).

3.6. Knowledge and attitudes towards biosecurity, disease and animal health services

It was found that 54% (158/291) of sellers reported no use of any biosecurity practices at market. When a pig was sick at the market or in their home herd, the majority of pig sellers used traditional medicine (76%; 213/279), slaughtered their pig and distributed the meat (10%; 27/279) or did nothing (15%; 41/279). A significantly higher proportion of respondents from Sumba were found to distribute the meat from a pig that was believed to be sick (West Timor: 0%, 0/27; Flores: 7%, 2/27: Sumba 93%, 25/27). For the 90% (260/289) of sellers that kept pigs at home, disposal of pigs that had died in their herd varied. Forty-nine percent (141/288) buried pigs, 17% (49/288) would throw the pig away, 9% (25/288) sold the dead pig for consumption and 15% (43/288) reported consumption of the meat themselves with 6% (17/288) specifying that this only occurs when the deceased pig is believed not to have died from disease.

Table 4
Reasons for high pig demand during the year reported by 224 pig sellers from West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009.

Reasons for high-demand months	Number of Sellers	Percentage
Traditional activities	100	44.64
Party season	63	28.13
Wedding	55	24.55
First communion	40	17.86
Money from harvest available	14	6.25
Christmas	14	6.25
School expenses	14	6.25
Funeral	11	4.91

Only 1% (3/273) of respondents stated that they would report a sick pig to animal health authorities, with a further 11% (30/273) stating they would report a pig death occurring at the market. A key issue identified for low reporting rates was a lack of personnel to which to report cases (26%; 57/217). This was found to be significantly higher in West Timor compared to Flores ($P < 0.05$: West Timor: 51%, 29/57; Flores: 12%, 7/57; Sumba: 37%, 21/57) with respondents stating there were no officers or animal health workers available in the market or village. Furthermore, these pig sellers had minimal knowledge about who to report to (10%; 21/217) and why there was a need for reporting (4%; 9/217). Due to concerns of financial loss, some people choose not to report (5%; 10/217). Sellers from Sumba reported the most concern about a price reduction or loss of a sale due to reporting.

3.7. Pig movements to and from market

For those individuals that brought their own home-raised pigs to sell (52%; 152/292), Flores had the highest proportion of sellers using home-raised pigs as their primary source (47%; 71/152), significantly higher than Sumba ($P < 0.001$; 24%, 37/152). Trading of pigs at multiple locations was common (44%; 129/292), and this was found to be similar across all islands ($P = 0.202$; West Timor: 40%, 52/129; Flores: 33%, 43/129; Sumba: 27%, 34/129).

Eighty-one percent (231/285) of sellers stated that if they were unsuccessful selling a pig at market, the pig would subsequently be taken home. Only 2% (6/285) reported that they would sell their pig at a cheaper price in the event of not being able to trade their pig on a selling day. A further 16% (46/285) left their pig at market until sold. For those sellers returning with pigs to their residence, 66% (153/231) placed this animal back in their herd, allowing direct contact with other pigs in the herd.

The months of August, September and October were identified as high-demand months for the pig trade, supported by both seller and buyer data ($P < 0.001$; Fig. 3). The reasons for this high demand can be seen in Table 4, and were similarly reported by buyers. January–March were identified as the lowest-demand months during the year (Fig. 3) by sellers and buyers. For pig sellers, during the rainy season, focus was placed on agricultural production as the primary food and income source (30%; 87/292). The rainy season also deterred farmers from transporting pigs to market (24%; 69/292). A reduction in the frequency of traditional ceremonies and cultural events also led to a reduction in the pig trade during this period (37%; 107/292).

The majority of pig buyers transported their pig/s directly home following purchase at market (91%; 255/281). Only 6% (17/281) reported transporting a pig directly from one market to another to sell. The most common transportation methods utilised by pig buyers leaving the market were trucks and motorbikes (34%; 95/281 and 28%; 78/281, respectively). It was found that 28% (79/281) of respondents purchased pigs at two or more markets. This did not differ significantly across islands ($P = 0.997$; West Timor: 35%, 28/281; Flores: 32%, 25/281; Sumba: 33%, 26/281). In addition to

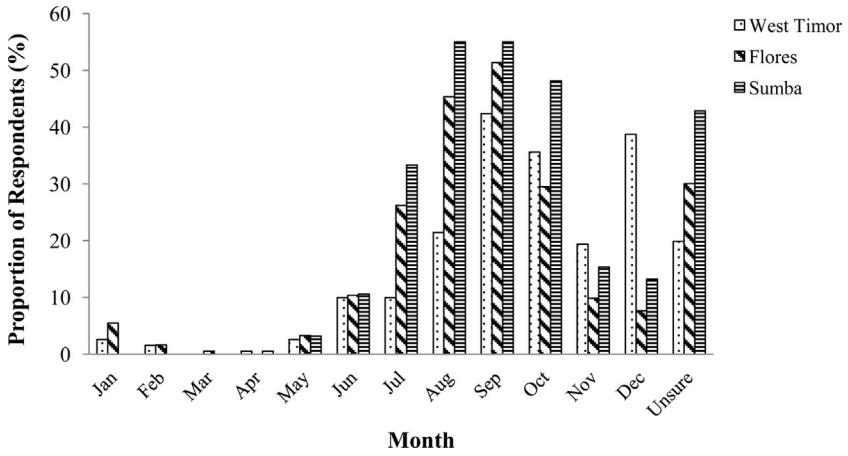

Fig. 3. Months selected by 290 pig sellers and 273 pig buyers as the highest demand months for pigs sold at market across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009.

purchasing live pigs from the market, respondents also purchased pigs directly from other farmers within a village (18%; 50/281). Sumba had the largest proportion of pig buyers reporting direct purchase from farmers ($P > 0.001$; West Timor: 12%, 6/50; Flores: 8%, 4/50; Sumba: 80%, 40/50). The primary motives for purchasing pigs were to sell them (40%; 113/281; Table 3) or for use in a traditional ceremony (37%; 105/281). A significantly higher number of buyers from Sumba were found to procure pigs for ceremonial purposes compared to Flores and West Timor ($P < 0.001$; West Timor: 19%, 20/105; Flores: 13%, 14/105; Sumba: 68%; 71/105).

3.8. Knowledge of pig health and classical swine fever

Pig buyers were questioned regarding any steps taken to ensure that the pigs they purchased were healthy. Eighty percent (224/279) confirmed they do check pigs visually prior to purchase. Methods of checking included assessing the overall physical condition (63%; 141/224), the condition of the eyes (18%; 41/224), and observing bristles on the body (17%; 37/224). Pig buyers were questioned about their knowledge of pig health. A large proportion (88%; 247/281) of respondents were aware of at least one sign that indicated that a pig was sick, similar across islands ($P = 0.717$). A loss of appetite (66%; 162/247), red eyes (62%; 152/247) and tiredness (61%; 151/247) were the most commonly identified signs.

The majority of pig sellers (85%; 247/290) and pig buyers (83%; 234/281) did not know what CSF was. For the 36 seller respondents and 43 buyer respondents with some knowledge, the majority were from Sumba (81%; 64/79), several were from West Timor (19%; 15/79), and no individuals from Flores reported any previous knowledge of CSF. Of the respondents reporting to have knowledge of the disease, only 82% (65/79) could identify at least one clinical sign. Diarrhoea (85%; 55/65), anorexia (78%; 51/65), an unsteady gait (40%; 26/65) and fever (38%; 25/65) had the highest levels of recognition in association with CSF. A large proportion of respondents also recognised skin discolouration, specifically either red or purple marks on the skin, as a sign of the disease (55%; 35/65). The most commonly reported source of CSF information was field extension officers (44%; 16/36). Additional information sources included the newspaper (39%; 14/36), family and friends (39%; 14/36) and other sellers at the market place (14%; 5/36).

4. Discussion

Live animal markets represent high-risk locations for disease transmission (FAO, 2010). We found that live pigs dominated market trade in NTT, with minimal pork sales. This trend has been identified in other areas of the developing world, and is likely due to limited cold chain facilities and preference for fresh meat (Salin and Nayga, 2002; Lapar et al., 2009). In developing countries, the ability to trade livestock is a vital part of the economy and livelihood of rural households, with linkages between markets and villages critical for trading (Perry et al., 2005).

Along the formal pig market chain from village to live pig market there are points that allow mixing of susceptible and CSF infected pigs, increasing the risk for spread of this national priority pig disease. Starting at the village level, there is minimal biosecurity and pig housing systems such as tethering. Free roaming facilitates contact with other local village pigs. Transportation of up to 30 pigs in one vehicle (Kira and Kasman, 2011) and travelling distances of up to 140 km (Leslie, 2012) enable direct contact between pigs and potential disease transmission. At the market level with no inspection and no biosecurity, the likelihood of both direct contact and fomites presents a risk for CSF infection. Understanding this market chain will allow the development of targeted mitigation strategies to assist in the control of CSF.

The market chain described demonstrates the integration of roles with smallholder farmers being both pig sellers and buyers, with few collectors involved. Over half of the sellers sold only their own pigs at market. This is in contrast to the live bird market chain in Bali, eastern Indonesia where middlemen, such as collectors, have specific roles along the market chain collecting poultry from a variety of sources and taking them to market (Santhia et al., 2009; Roche et al., 2014). Forty-four percent of sellers traded pigs at more than one market indicating an extensive movement network of live pigs that can contribute to disease spread. Understanding the extent of these networks assists with the implementation of surveillance and control strategies, as demonstrated in other livestock species including poultry (Van Kerkhove et al., 2009; Martin et al., 2011) and cattle (Aznar et al., 2005). Lemke et al. (2006) and Madzimure et al. (2013) have suggested that pig-production households located closer to urban areas are more likely to be driven by market demand while in rural areas pigs are utilised more for sociocultural, financial and subsistence purposes. Leslie et al. (2015a,b); Leslie et al. (2015a,b) reported the presence of both formal movement pathways via markets and informal pathways between villages across NTT province following a survey with smallholder farmers, corresponding with these current results.

For pig buyers within NTT, there were a variety of drivers boosting the sale of live pigs, such as weddings, funerals, traditional ceremonies and parties. Overall, traditional ceremonies were found to have the greatest influence on consumers, particularly in Sumba. Weddings also greatly influence demand because pigs are a part of a

dowry payment, which can often consist of up to 40 pigs, depending on the social status of the bride. The most common sources used to purchase live pigs were identified as live pig markets and directly from farmers. The majority of purchased pigs were found to be indigenous which corresponds with a survey by Johns et al. (2009) that found a preference for indigenous pigs in West Timor and Flores. Among locals it is believed that indigenous pigs produce better meat quality. This was also found by Madzimure et al. (2013) with smallholder pig farmers in South Africa reporting better meat characteristics – such as taste and tenderness – from indigenous pig breeds.

Annual movement trends for both sellers and buyers showed a strong seasonal influence. Periods of high frequency and high-volume animal movement can lead to an increase in direct contact between susceptible animals (Webb, 2006). The months of August through to October were reported to be peak movement months corresponding with high numbers of traditional ceremonies and weddings. A continual supply of pigs to meet the cultural demand is important during these periods, further driving movements across and between islands. The wet season occurs from December through to March, and the dry season from April to November (Asih et al., 2009). The heavy rainfall experienced during the wet season can often hinder transportation into and out of villages. During this time farmers' efforts are concentrated on other agricultural activities such as working in the fields. Also corresponding with Leslie et al. (2015b) a large number of respondents were unsure about the months of the year when pigs were in high demand (Fig. 3). This was due to the farmers only selling pigs when they needed money.

A market survey and an observational study (Leslie, 2012) identified a severe lack of biosecurity at live pig markets across the province with both sellers and buyers having minimal knowledge about CSF and biosecurity practices. Market management practices of concern included the direct contact between pigs of all age groups from a variety of different villages, unregulated pig entrances into markets, large pig volumes entering and exiting premises, absence of effective cleaning procedures and the reuse of uncleaned transportation vehicles. The use of biosecurity and surveillance at live animal markets incorporating inspection, cleaning and minimising the trade of sick pigs has implications for infectious pig diseases. Of these, CSF is a major concern for the Indonesia government (Pritchard et al., 2005; Webb, 2006; Ministry of Agriculture, 2013). Additional mitigation strategies could include improving vaccination coverage or implementing inspection prior to market transportation. A risk assessment conducted by (Leslie, 2012) concluded that pre-entry market inspection can significantly reduce the probability of a marketplace being infected with CSF. However, for this mitigation strategy to be effective, it needed to be executed very strictly. Only when the probability of detection was >75% was a notable reduction seen in the probability of a marketplace being infected. In addition, by increasing vaccination coverage for CSF across the province, a significant reduction was observed in the number of infected and clinical pigs present at market. There are, however, logistical constraints around increasing vaccination coverage. A recent study in Bhutan investigated the use of an oral bait vaccine for CSF, motivated by the logistical problems of vaccinating backyard pigs in more remote areas (Monger et al., 2015). These types of approaches can be assessed through further investigations using tools such as risk assessment and participatory research to aid in the development of sustainable and accepted control strategies (Nampanya et al., 2012; Roche et al., 2014).

Pig sellers and buyers had relatively good knowledge of clinical signs that allowed them to identify sick pigs. This has also been found with smallholder pig farmers in Tanzania (Kagira et al., 2010). However, respondents were not able to associate a particular illness with specific signs and knowledge of CSF-specific signs was minimal. Considering CSF is endemic in this region, its presentation differs compared to outbreaks following introduction (Edwards et al., 2000). There is currently a lack of documentation regarding the impacts of CSF under endemic situations with further research required to understand the level of socioeconomic loss associated with this disease in eastern Indonesia.

The implementation of farmer educational programs can be effective in improving farmer knowledge and awareness for animal diseases (Msoffe et al., 2010; Nampanya et al., 2012). By developing these skills, this can provide farmers with the ability to improve their pig health and on-farm production. Thorpe and Jemaneh (2008) identified gaps in the knowledge of smallholder pig farmers regarding pig health across South-East Asia. This is an area that needs to be improved through increased capacity building and improved communication between the government and rural villages. The current pig practices at market, including lack of biosecurity, extensive movement networks and trading of sick pigs, pose concern for emerging and zoonotic diseases such as influenza (Nidom et al., 2010). As demonstrated by Young et al. (2014), improving knowledge, attitudes and practices on-farm can lead to advancements in smallholder farmer livelihoods and animal health. Market sites can be used as venues where education and interventions can be targeted at both traders and smallholder farmers.

5. Conclusion

This study has generated some important baseline information on live pigs markets in NTT province. It has highlighted the multiple roles of smallholder farmers along the market chain, for both formal market movements and informal movements directly between villages. Lack of biosecurity and large numbers of pigs at live animal markets have the potential to influence disease spread. The results from this study need to be utilised for future investigations into the development of appropriate mitigation strategies for CSF that may be implemented in market settings or at a village level.

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