Received: 02 October 2022, Accepted: 21 December 2022

Review Article

Journal of Advanced Veterinary Research
(2023) Volume 13, Issue 1, 141-149

Indigenous Goat Genetic Resources in Indonesia: Current Status and Future Improvement

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Abstract

Goats have made an important contribution to household income and food security, especially in rural areas. Goats have provided meat and milk as high-quality protein sources, and are an integral part of rural livelihoods and an insurance against future emergencies. Nearly 19.22 million heads of goats are distributed throughout the Islands of Indonesia, most of which belong to indigenous breeds, which possess phenotypic and genetic diversities that are indispansable for their conservation and genetic improvement programs. Despite their considerable diversities, not all the indigenous goats are fully characterized and harnessed. Unfortunately, some are classified as at risk of extinction. Since small-scale farmers with traditional production systems dominate in the country, goat productivity is relatively low. However, the indigenous goats are still important genetic resources due to their adaptive traits that are relevant to climate change and low maintenance. This review gives an overview of the current knowledge, production system, and future improvement of the indigenous goat genetic resources in Indonesia.

KEYWORDS
Conservation, Genetic Characterization, Genetic Improvement, Indigenous Goats, Indonesia

INTRODUCTION

At present, the agricultural resources contribute around 10.21% to the total gross domestic product (GDP) in Indonesia, whereas the contribution of the livestock sub-sector reaches 1.69%. Livestock also contributes 16.52% to the total agricultural GDP (crops, livestock, agricultural services, and hunting), making it a promising agricultural sector for poverty alleviation and food security in Indonesia through its production of meat, milk, eggs, hides, and skins (Ditjenpkh, 2021). Among many types of livestock, small ruminants like goat make an important contribution to household income and food security. Goats provide meat and milk as high-quality protein sources, and are an integral part of Indonesia's rural livelihood and an insurance against future emergencies. They have also been kept by smallholder farmers for social, religious, and cultural purposes, in a wide range of production systems, from extensive and semi-extensive farms to intensive farms. A recent report showed that approximately 19.22 million goats are scattered throughout 34 provinces in Indonesia, in which four provinces, e.g., Central Java, East Java, Lampung, and West Java contribute significantly (55%) to the total goat population (Ditjenpkh, 2021).

The Indonesian goat population is composed of a number of indigenous, exotic, and developed breeds. The indigenous breeds have been regarded to have specific adaptations to survive and reproduce under harsh environments and poor quality feed, and are resistant to disease and parasite challenges, making them suitable for their use in traditional and low-external-input production system. The indigenous goat breeds also possess specific phenotypic and genetic characteristics that are indispensable for their conservation and genetic improvement programs. Yet, both the phenotypic and genetic characteristics are essential to provide fundamental information in the effective and sustainable management of the indigenous breeds, and are a reasonable representation of genetic differences among breeds (Michael *et al*., 2016; Maharani *et al*., 2019). However, in developing countries like Indonesia there are no formal breeding programs. This leads to sub-optimal conservation and genetic improvement programs of the indigenous goat breeds.

The first step in the design of the breeding program is the definition of the breeding objective, which includes understanding the characteristics of production systems and identification of specific preferred traits (Ouédraogo *et al*., 2020; Tyasi *et al*., 2022). To date, there are several attempts in the characterization of the indigenous goat breeds in Indonesia, both phenotypically (Maharani *et al*., 2014; Alawiansyah *et al*., 2020; Nasution *et al*., 2020; Susilorini *et al*., 2020; Endrawati *et al*., 2022; Rahmawati *et al*., 2022) and genetically (Batubara *et al*., 2011; Oka *et al*., 2011; Zein *et al*., 2012; Pakpahan *et al*., 2016; Susilorini *et al*., 2022), as well as screening for candidate genes related to economically important traits (Maharani *et al*., 2019; Antonius *et al*., 2020). In general, most of these studies found considerable genetic and phenotypic diversities, which are valuable for the breed or population identification and classification, as well as the basis for designing and implementing appropriate breeding programs for indigenous goats. This review is thus aimed to gather information

ISSN: 2090-6277/2090-6269/

about indigenous goat genetic resources in Indonesia, especially their current status, production system, and future improvement.

Goat Domestication and Its Dispersal in Indonesia

Goat (*Capra hircus*) is among the first domesticated livestock species that is adapted from bezoars populations (*Capra aegagrus*) in West Asia (Naderi *et al*., 2008). This is evidenced by a molecular analysis that modern domestic goats and the benzoars share the same mitochondrial DNA haplogroup (Naderi *et al*., 2008). The initial goat domestication is documented in the Fertile Crescent at ≈10,000 years ago (Zeder and Hesse, 2000; Amills *et al*., 2017; Daly *et al*., 2018). Ever since that time, goats have played an important role in the Neolithic agricultural revolution and the advance of human civilization. Nowadays, approximately 1 billion individuals of domestic goats are spread across the five continents, with their excellent adaptability to desert, mountain, and tropical areas where other livestock species can not (Amills *et al*., 2017). The goats have been raised for varying purposes, e.g., nutrition (animal protein source), economy, tradition, and religion.

Although the initial domestication of goats is thought to have begun in West Asia, their migration route to Southeast Asia and local evolutionary history are little known. Recently, Cai *et al*. (2020) indicated a close genetic affinity of both modern and ancient Chinese goats with the Neolithic population from the Fertile Crescent, suggesting that Chalcolithic eastern Fertile Crescent goats are the ancestors of the Chinese goats. The Etawa goats from Indonesia have been detected to share the same maternal haplogroup with the Mongolian, Korean, Japanese, and Bangladeshi (Black Bengal) indigenous goats, as well as the benzoar (Nomura *et al*., 2013). Pakpahan *et al*. (2016) revealed that Indonesian goats like Samosir, Muara, Peranakan Etawa (PE), Jawarandu, Kacang, Lakor, Gembrong, and Marica came from the same maternal origin. Similarly, a recent molecular study by Susilorini *et al*. (2022) using 12 microsatellite markers showed a close genetic relationship among indigenous goats in Indonesia (e.g., Kacang, Senduro, and PE). Nomura *et al*. (2012) used 26 microsatellite markers to reveal the genetic lineage in East Asian indigenous goat populations. They noted a high genetic differentiation between Kacang and Japanese goat populations, which is most likely due to the fact that the Islands of Indonesia and Japan are located farthest from the goat domestication center of West Asia. On the other hand, the Kacang goat was detected as in the same cluster with the Black Bengal goat population from Bangladesh (Nomura *et al*., 2012).

Goat Breeds in Indonesia and Their Importance

The agro-ecological conditions of Indonesia can be divided into: dry land – dry climate, dry land – wet climate, highland, lowland irrigation, and tidal swamp (Syuaib, 2016). In this wide agro-ecological environments, a number of goat genetic resources are found and have been a source of income and animal protein (meat and milk production), thus reducing food insecu-

Table 1. List of goat breeds present in Indonesia and their estimated risk level from the FAO-DAD-IS database (2022).

Breed	Alternative Breed Name	Type of Breed	Use of the Breed	Risk Level	Distribution
Bligon	Jawarandu	Indigenous	Meat and milk production	Unknown	Cilacap, Central Java Province
Boer	None	Exotic	Meat production	Not at risk	North Sumatra, Lampung, and East Java
Boerka Galaksi Agrinak	None	Synthetic	Meat production	At risk	Loka Penelitian Kambing Potong Sungai Putih, Deli Serdang
Etawa	None	Exotic	Meat and milk production	Unknown	Central-Java and also on Madura island; Sumbawa island; and Sumatera island in Padang Mangatas
Gembrong	None	Indigenous	Meat production, fancy, and religious ceremonies	At risk	Eastern part of Bali Island, especially in the villages of Bug-bug, Seraya, Culik, and Kubu in Karangasem District
Kacang	None	Indigenous	Meat production	Unknown	Especially in Java and Sumatera, and spread in other parts of Indonesia
Kaligesing	Peranakan Etawa (PE) Kaligesing	Indigenous/ Synthetic	Meat and milk production	Unknown	The breed is kept by villagers in Donorejo, Kaligesing district of Purworejo, and is distributed within Central Java, West Java, West Sumatera, Lampung.
Kejobong	None	Indigenous	Meat production	Not at risk	Existing in 18 sub-districts of Purbalingga district of Central Java Province
Kosta	None	Indigenous	Meat production	Unknown	Mainly in districts of Pandeglang, Serang and Tangerang, province of Banten
Lakor	None	Indigenous	Meat production	Unknown	Mainly in Lakor Island, South West Maluku District, then spreads to East Timor, NTT, NTB, Ambon and Papua
Panorusan Samosir	None	Indigenous	Meat production and religious ceremonies	Not at risk	Samosir District, North Sumatera Province
Peranakan Etawa	None	Synthetic/ Indigenous	Meat and milk production	Unknown	Lampung, Central Java, East Java, Bali, and West Nusa Tenggara
Saanen	None	Exotic	Milk production	Unknown	Java
Saburai	None	Synthetic/ Indigenous	Meat and milk production	Unknown	Lampung Province
Senduro	None	Indigenous	Meat and milk production	Unknown	Mainly in Lumajang subdistrcit then distributed to other district such as Malang, Jember

rity and poverty. According to the Domestic Animal Diversity Information System (DAD-IS, 2022), goat breeds in the country are composed of indigenous, synthetic, and developed breeds (Table 1). Synthetic breed is used to define breeds that are resulted from crossbreeding programs, while developed breeds refer to exotic breeds that have been imported to Indonesia and selected for certain traits of economic importance.

Goats are found in different provinces of Indonesia, but they are mostly distributed in the Island of Java (Figure 1). The breeds found in Java include Bligon, Boer, Etawa, Kacang, Kaligesing, Kejobong, Kosta, Peranakan Etawa, Saanen, and Senduro goats. The other breeds like Samosir and Gembrong goats are only found in Samosir District of North Sumatra and Karangasem District of Bali, respectively. Based on their risk level, Gembrong goat becomes the only indigenous breed being categorized as at risk; Kejobong and Samosir goats are classified as being not at risk; while the remaining breeds are still unknown. Goats rearing in the country are usually attributed to several purposes, including a source of income and animal protein (meat and milk production), saving, and cultural values. The Samosir goat, for example, which has been kept by indigenous residents for generations on Samosir Island in the middle of Lake Toba, Samosir Regency, North Sumatra Province, has an important role in the celebration of traditional indigenous culture and religion (Pakpahan *et al*., 2022).

Goat Population

According to the Ditjenpkh (2021), the goat population in Indonesia has shown a continuously increasing trend from 2011 to 2021, except in 2016 with a sharp decline (Figure 2). Figure 3 shows that approximately 19.22 million goats are recently distributed in the Islands of Indonesia (Ditjenpkh, 2021). East Java

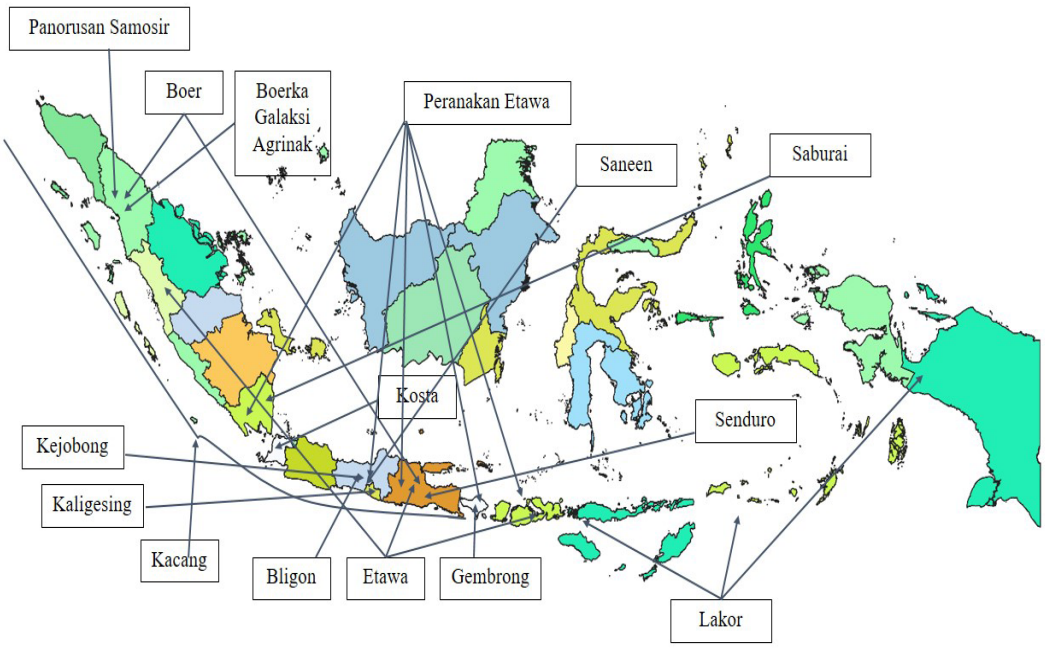

Figure 1. A map showing the distribution of several goat breeds in Indonesia.

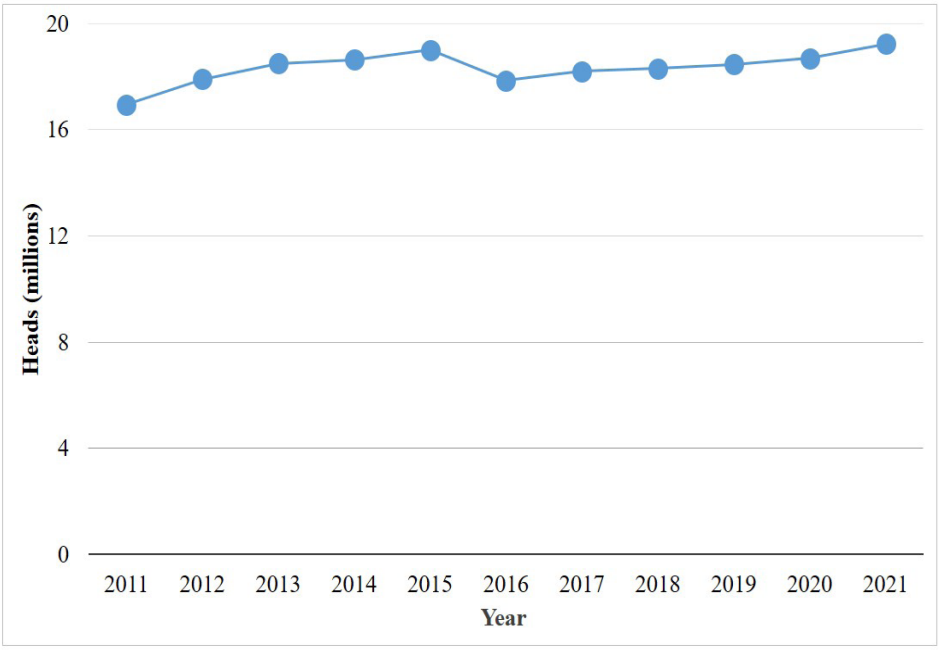

Figure 2. Goat population trends in Indonesia from 2011 to 2021. Data was retrieved from a report by Ditjenpkh (2021).

and Central Java provinces contribute the most (20% each) to the total goat population, followed by Lampung (8%), West Java (7%), and East Nusa Tenggara (5%), while the remaining provinces together add another 40% of the total goat population. Even though there is an increasing trend of the goat population during 2016-2021, there is however no report that classifies the goat population based on the types/breeds. In contrast to the national trend, a report showed a decline in goat population in Samosir Regency, that is the Samosir goat, from 9,821 heads in 2013 to 6,139 heads in 2017 (Ginting *et al*., 2019).

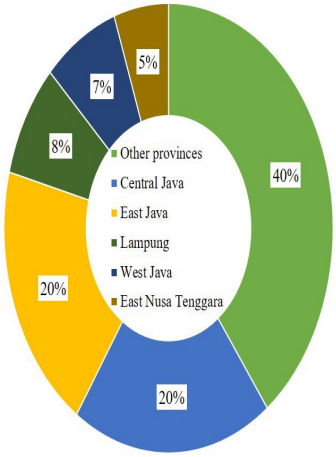

Figure 3. Population share of goats by provinces in 2021 with a total population of 19.22 million goats. Data was retrieved from a report by Ditjen PKH (2021).

Even though goat keeping is a particularly secondary occupation, but it serves as an essential source of income for smallholders in the form of an asset that can be readily turned into immediate cash. In Indonesia, goats are preferred to sheep by indigenous farmers since the goats are better suited to the local climatic conditions and natural environments (Putra and Agunga, 2014). Goats in Indonesia have been kept by livestock farmers for both meat and milk production. Among many types of goat, the Kacang goat is the most dominant breed for meat production and widely distributed across the country. The other breeds like PE and Bligon, are the dual-purpose breeds, for both meat and milk production, which produce 0.5 to 1.5 liters of milk per day. The center of dairy goats in Indonesia is in the Central Java Province, including Tegal, Cilacap, Purworejo, Sragen, and Banyumas regencies. There is a National Breeding Center for dairy goats (PE and Saanen) in Bayumas Regency. The dairy goats have also been kept by livestock keepers in the Provinces of West Java (Bandung, Sumedang, Sukabumi, and Garut), DI. Yogyakarta (Sleman and Kulonprogo), East Java (Malang, Blitar, Banyuwangi, and Lumajang), West Sumatra (Nagari Bukik Batubuah), Lampung (Kota Metro), North Sumatra (Asahan), and Aceh (Banda Aceh) (Sumarmono, 2022).

Production System

In general, Asian agricultural systems can be classified into three broad categories as either landless, crop-based, or rangeland-based. The landless production system was split into two types: (i) intensive industrial pig and poultry production and (ii) extensive systems involving small ruminants, cattle and camels (Devendra, 2007). Based on this classification, livestock production systems in Indonesia differ in terms of their resource availability and use, as well as the potential to adopt and use technologies that demand different resource inputs (Agus and Widi, 2018). Goat rearing system in the country can be categorized into extensive, semi-intensive, and intensive systems (Masrah *et al*., 2016; Aku *et al*., 2022). Goats in the extensive system are usually reared in the open field for the whole day without cage and are fed any natural feed resources available in the field, while those in the intensive rearing system are continuously kept under housing in confinement in which they are stall fed. Even though the intensive rearing system has the advantage of close supervision and control over the animals, the system requires more labor and high cash input. Rahadi *et al*. (2020) reported the intensive rearing system as the most preferred system in Muna Regency of Southeast Sulawesi. The example of a poor goat housing system in resource-poor smallholders can be shown in Figure 4. In some regions of Indonesia, livestock keepers also use semi-intensive rearing system, which is a combination of limited free range grazing and stall feeding. This system includes stall feeding, shelter during night, and 3 to 5 hour daily grazing, and browsing on pasture. The cost of feed has somewhat increased compared to the extensive rearing method (Shivakumara and Kiran, 2019). This rearing system is dominant in Siompu Island, Indonesia (Rahadi *et al*., 2022).

Challenges in Goat Farming

Challenges in livestock production are faced by almost every livestock keepers, and more especially by smallholder farmers. Goat farmers are generally faced with numerous challenges, including lack of genetically superior breeding animals, a lack of financial support, a shortage of high-quality feed, marketing problems, and low adoption of breeding and feed technology (Rasyid *et al*., 2018; Liang and Paengkoum, 2019). The majority of the goats in Asia are in the hands of small-scale farmers, many of them have poor resources and landless (Devendra and Liang, 2012). In Indonesia, smallholder livestock keepers have generally low level of formal education. As noted by several reports, the majority of the livestock keepers have only access to primary education (elementary school) (Tatipikalawan, 2017; Sarwanto and Tuswati, 2018; Prabowo and Widodo, 2021). The low level of formal education might lead to a lack of technology adoption, which further becomes the causes of low livestock production. Training of farmers will therefore empower them and improve the potential success of breeding programs. Furthermore, a better level of formal education would be advantageous because education is a good indicator of the potential of the smallholders to be more active in adopting new and more advanced management and production programs, for example, recording keeping, which is important for goat management and breeding decisions.

Apart from the above mentioned challenges, diseases or parasites also adversely affect the goat enterprise. Beriajaya (2005) noted a significant reduction in goat production due to nematode parasites. Gastrointestinal infections (e.g., *Haemonchus* spp., *Ostertagia* spp., *Trichostrongylus* spp., *Trichuris* spp., *Bunostomum* spp., and *Moniezia* spp.) also naturally affect the hematology and blood chemistry of small ruminants (Baihaqi *et al*., 2020). The prevalence of diseases and parasites might be due to the high cost of drugs, lack of veterinarians, and long distance to health care centers.

Phenotypic and Genetic Characteristics

Kacang goat

Kacang goat is one of the indigenous goat breeds in Indonesia, which is kept by livestock keepers for meat production. Ka-

cang goats are widely distributed in wide agro-ecological conditions of Indonesia. They have been crossed with imported goats to produce new goat breeds with optimal production of meat and milk. The results of this crossbreeding are Peranakan Etawa (Kacang x Etawa) and Senduro (Kacang, Etawa, and Jawarandu) goats. A microsatellite analysis by Susilorini *et al.* (2022) showed that Kacang goats have a close genetic distance with Senduro (0.055) and PE (0.077), while a long genetic distance has been observed between Kacang and Saneen goats (0.269). Based on the mitochondrial cyt *b* gene analysis, the Kacang and PE goats have differences in amino acid sequences, including a synonymous mutation (codon site 164th) and two non-synonymous mutations (sites 16th and 231th) (Lestari *et al*., 2017).

Wahyuni *et al.* (2016) characterized the physical characteristics of the Kacang goats raised in Muna Barat Regency and found a wide variation in body coat color, that is, black, brown, light brown, black-white, brown-white, brown-black, white, ask, and brown-black-white. A combination of white and brown has also been reported for the body coat color of the goat (Alawiansyah *et al*., 2020). The Kacang goat is characterized by semi-pendulous ear and the presence of horn (Wahyuni *et al*., 2016). It is known as a small goat breed, which can reach a body weight of 24.63 kg at adult age (more than one year) (Alawiansyah *et al*., 2020). The range values of body weight and body measurements of the Kacang goat (aged 1-2 years) have been reported by several studies, e.g., body weight (17 to 24 kg), body length (49 to 60 cm), withers height (49 to 62 cm), chest girth (57 to 59 cm), chest depth (21 to 23 cm), shoulder width (11 to 12 cm), rump height (51 to 53 cm), rump width (11 to 12 cm), and cannon circumference (6 to 7 cm) (Wahyuni *et al*., 2016; Alawiansyah *et al*., 2020; Depison *et al*., 2020). Furthermore, a multivariate analysis showed that the Kacang goat has smaller cranium measurements than the PE and Kejobong goats, which are also categorized as indigenous goat breeds in Indonesia (Suryani *et al*., 2013).

Gembrong goat

Gembrong goat is among the indigenous genetic resources that is originated from Karangasem Regency, Bali Province (Oka *et al*., 2011; Maharani *et al*., 2014). It is mainly found in the village of Tumbu, Karangasem (Hasinah *et al*., 2015). It is characterized by a shiny-and-long white coat that cover their whole body parts, including their neck and face. Its population has been reported to be 26 individuals in 2014, being categorized as an endangered breed (Maharani *et al*., 2014). Based on a mitochondrial DNA analysis, the Gembrong goat has been reported to have a close genetic relationship with the Kacang and PE goats, suggesting that they might come from the same maternal lineage (Oka *et al*., 2011). Also in this mtDNA analysis (550 bp), a total of 16 individuals (12 Gembrong goats, 3 Kacang goats, and 3 PE goats) have been sequenced, and a polymorphic site at base number 231 was found, forming two haplotypes (Oka *et al*., 2011). Zein *et al.* (2016) studied Gembrong goats from Tumbu and Bukbuk Villages of Karangasem Regency using hypervariable-I (HVI) mitochondrial DNA and found a very close genetic distance (0.0%) within Gembrong goats raised in those villages, suggesting no genetic variation that might be due to inbreeding and declining population size.

Although the Gembrong goat is characterized as an endangered breed, little is known about its potential development. Gembrong goats have mostly pure white coat color and exhibit uniform morphological characteristics, with average adult body weight of 29.15 kg for male and 18.20 kg for female (Suyasa and Parwati, 2015). Gembrong goats have also the following characteristics: weaning weight (1.23 kg for male; 1.30 kg for female), horn length (13.17 cm for male; 4.40 cm for female), hair length (9.14–11.07 cm for male; 5.30-8.80 cm for female), and beard length (19.79 cm for male; 7.30 cm for female) (Suyasa and Parwati, 2015).

Bligon goat

Bligon goat is a crossbreed between PE and Kacang goats, which are widely distributed in Cilacap Regency, Central Java Province (Rahmatullah *et al*., 2022). It is also known as Jawarandu goat (Rahmawati *et al*., 2022). It has a convex facial profile and its ear is pendulous, while its body coat color varies, from black, white, a combination of white and black, to a combination of white and brown (Rahmatullah *et al*., 2022). A recent study by Rahmawati *et al*. (2022) identified the physical and morphological characteristics of Bligon goats raised in three agro-ecological zones (highland, lowland, and coast) of Bantul Regency, Special Region of Yogyakarta. Based on physical characteristics, the Bligon goats have variation in hair color (a combination of brown, black, and white), body hair (striped and white), crest color (white and a combination of brown, black, and white), mane ruff (rewos)

Figure 4. Goat housing system (An example of goat farming in Ternate Island, Indonesia).

color (a combination of brown, black, and white), and ear shape (open and folded). Meanwhile, the body measurements of Bligon goats among the three agro-ecological zones significantly differ, of which the goats raised in the coastal zone have higher body measurements than those raised in the lowlands, while those in the lowlands are larger than the highlands (Rahmawati *et al*., 2022). In general, a range value of body weight (26 to 41 kg), body length (60 to 75 cm), shoulder height (62 to 76 cm), chest girth (64 to 79 cm), and ear length (19 to 25 cm) has been reported for the adult Bligon goat (Murdjito *et al*., 2011; Budisatria *et al*., 2021; Rahmawati *et al*., 2022).

Budisatria *et al*. (2021) studied the reproductive performances of Bligon does raised in Gunung Kidul Regency, that is, service per conception (S/C; 1.2±0.4 times), gestation period (5.0±0.1 month), litter size (1.7±0.5 head), post partum mating (3.2±0.4 month), kidding intervals (8.4±0.5 month), kid crop (226.1±70.6%), doe reproduction index (2.3±0.7 head/year), and doe productivity (20.1±5.9 kg/head/year). Slightly similar results were obtanied by Murdjito *et al*. (2012), who reported 1.23±0.5 time for S/C, 1.74±0.45 head for litter size, 95.0±45.5 days for post partum mating, and 8.53±1.93 for kidding intervals.

Peranakan Etawa goat

Peranakan Etawa (PE) goat is a crossbreed derived from Kacang and Etawa (Jamnapari goat from India) (Sumartono *et al*., 2016). It is a dual-purpose goat that is widely distributed in Indonesia for both meat and milk production. The center of the PE goat production in Indonesia is in Kaligesing District, Purworejo Regency. In East Java Province, especially in Lumajang Regency, a dual-purpose breed termed as Senduro goat is also derived from the Etawa goat (Rifa'i *et al*., 2021). The dominant coat color of the PE goat is white (Hasinah *et al*., 2021), but another report identified two coat color variants, that is, a combination of white and black and a combintation of white and brown, with its convex facial profile (Rasminati, 2013).

The quantitative characteristics of the PE goats have been reported by several studies from different locations. A range value of 38 to 43 kg (body weight), 61 to 75 cm (body length), 65 to 75 cm (shoulder height), and 73 to 79 cm (chest girth) has been reported (Ramdani and Kusmayadi, 2016; Nafiu *et al*., 2020). In addition, the productivity of PE does (more 3 year-old) raised in three different agro-ecological zones (lowland, middle, and highland) of Lumajang Regency, East Java, has been reported being 1.75±0.43, 1.80±0.40, and 1.85±0.36 for litter size, 4%, 2%, and 0.5% for preweaning mortality percentage, 10.75±2.36, 11.53±1.67, and 12.92±2.86 kg for weaning weight, 9.38±1.10, 8.90±1.13, and 8.56±0.59 months for kidding intervals, 23.28±5.51, 27.89±5.10, and 33.46±7.72 kg/year for doe productivity index, respectively (Sumartono *et al*., 2016).

Samosir goat

Samosir goat, also known as Panorusan Samosir, is one of the indigenous goat breeds from Samosir Regency, North Sumatra. This breed has unique traits that make them suitable for the indigenous agro-ecological condition. The breed has also the ability to survive under low-quality feed and high resistance to indigenous diseases and parasites (Mirwandhono *et al*., 2019). The breed has been kept by Batak tribal people who live on Samosir Island for generations for several purposes, including sources of income and animal protein (Pakpahan *et al*., 2022). The Batak tribal people practiced animistic religion or known as Parmalim during ancient times and used the Samosir goat for cultural events. The goats used for these events are the male goats with white bodies, heads, legs, horns, and hooves (Simanjuntak, 1978; Pakpahan *et al*., 2022). To date, there has been no clear information on the current population of Samosir goats, but in general a report noted that goat population in Samosir Regency is around 9,700 heads (BPS, 2015). Ginting *et al*. (2019) identified five factors that cause a decline in the Samosir goat population, including feed availability, disease, breeder's experience, indigenous culture, and marketing of productive ewes. Among these factors, the indigenous cultural events like offering to the ancestors, Margondang (a wedding ceremony), and death ritual contribute the most to the declining population size.

A recent study by Damanik *et al*. (2020) showed that the Samosir goats (aged 6-12 months) have a body weight of 9.04±1.03 vs. 6.88±0.80 kg, body length of 43.59±1.48 vs. 42.13±0.077 cm, shoulder height of 38.32±0.78 vs. 37.30 cm, chest girth of 42.13±41.38 vs. 41.38±0.68 cm, for males and females, respectively. In general the Samosir goat has relatively similar physical and morphological characteristics as compared with other indigenous goat breeds in Indonesia, but the Samosir goat has dominant white coat color. Pakpahan *et al*. (2022) defined four variations of coat color in Samosir goats, e.g., white, white-brown, white-black, and white-brown-black. A mitochondrial DNA cyt *b* gene analysis revealed that Samosir goats are separated with other indigenous Indonesian goats (Gembrong, Muara, PE, Kacang, and Jawarandu) and formed a single clade (Pakpahan *et al*., 2022).

Genetic Improvement Strategies

Genetic improvement is a particularly powerful tool for increasing livestock productivity and efficiency because it offers permanent and cumulative results (FAO, 2007). In livestock populations, the genetic improvement mainly involves selective breeding of males and females that, when mated, are expected to produce offspring with better performance than the average of each parent. It has been accepted that the goal of any livestock improvement program is to achieve rapid genetic gain for particular traits of economic importance. Livestock farming, especially small ruminants in many developing countries like Indonesia, is characterized by small-scale farmers, which usually do not practice appropriate and well-organized breeding objective. This factor can be a constraint in livestock development, coupled with the lack of infrastructure, low-input, and low-output production systems, which result in low livestock production. All of these factors make smallholder livestock improvement difficult to achieve the expected increase in livestock productivity to meet the growing demand for animal products. Therefore, the livestock management and practice by smallhorders needs to be upgraded.

Scientists have highlighted the key steps for genetic improvement strategies of small ruminants in smallholder production systems, including identifying the existing structures, institutions, and indigenous breeding practices, and building upon these foundation programs where there are opportunities for sustainable genetic improvement (Kosgey and Okeyo, 2007). Clear structures and effective collaborations between different stakeholders are also imperative for the organization and successful implementation of smallholder livestock improvement strategies (Ibeagha-Awemu *et al*., 2019).

In the past, the government of Indonesia has placed much emphasis on importing exotic breeds and cross-breeding with indigenous stock as a strategy for genetic improvement. A good example of this cross-breeding is the PE goat, which is derived from Kacang (the indigenous goat) and Etawa or known as Jam-

napari from India. Currently, there is a recognition of the need to focus genetic improvement efforts on the indigenous genetic resources that are well adapted to the diverse agro-ecologies and production environments in the country. There is also a need for active and real participation of farmers to ensure effective consideration of their interests, needs, and expectations, the identification of real problems, and adequate on-herd solutions. Therefore, the government of Indonesia has introduced a community-based breeding program (CBBP) as a strategy for smallholder farmers to improve livestock breeds (Tiesnamurti *et al*., 2020). The CBBP has been a suitable program for low-input livestock production systems by smallhorder farmers within geographical boundaries that have a common interest to work together for the improvement of their genetic resources (Mueller *et al*., 2015). The program is more frequent with keepers of small ruminants, in particular smallholders of indigenous breeds.

The CBBPs have been valuable solutions for genetic improvement of small ruminants in developing countries (Haile *et al*., 2019; Tiesnamurti *et al*., 2020; Weldemariam and Mezgebe, 2021). To successfully build the CBBP, some points need to be considered, including empowerment of farmers, providing a suitable breeding stock by breeding institutions (e.g., government, private companies, and smallholder farmers), and understanding of the livestock production systems. Scientists have highlighted some factors that are needed to consider before implementing the CBBP, including selecting targeted breed and communities, characterization of targeted sites and breeds, defining breeding objective, assessment of alternative breeding plans, and development of breeding structure (Haile *et al*., 2018; Tiesnamurti *et al*., 2020). The CBBP must also consider the importance of bottom-up approaches and involvement of indigenous institutions in the planning and implementation stages, along with organizational, technical and financial support (Mueller *et al*., 2015). Although the CBBP is a viable solution for genetic improvement in smallholder production systems, there are some challenges of the program, including difficulty of pedigree and performance recording, year round lambing/kidding pattern, uncontrolled mating system, unwillingness of farmers to keep all young rams/bucks until the time of selection, shortage of incentives for participant farmers, and incompatible cooperative society proclamation (Weldemariam and Mezgebe, 2021).

CONCLUSION

It is notable that Indonesian goat populations consist of a number of indigenous breeds, which belong to smallholder farmers and are crucial for household income, food security, and cultural aspects. Despite the importance of indigenous goats, few efforts have been made for both conservation and genetic improvement strategies. Some reports suggest sufficient levels of phenotypic and genetic diversity, which are valuable for genetic improvement of the indigenous goats. Genetic diversity is important for the indigenous goats to adapt to diverse and changing climatic condition, as well as production objectives, and is a key parameter to use in conservation and improvement programs. Training and capacity building of livestock keepers and animal breeding specialists are urgently needed, along with the collaboration between institutes, universities, and government to ensure the sustainable utilization of the indigenous goats through the CBBP.

ACKNOWLEDGMENTS

This study was supported by the Faculty of Agriculture, Universitas Khairun (779/UN44.C4/PP01/2022).

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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