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Review Article

Growth and Reproductive Performance of the Indigenous Kedah-Kelantan (KK) Cattle: A Review

Mohammed Sirajul Islam[1,2], Nurhusien Yimer Degu[1]*, Abd Wahid Haron[1], Faez Firdaus Jesse Abdullah[1], Mark Hiew Wen Han[1] and Wan-Nor Fitri[1]

[1]Department of Veterinary Clinical Studies, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[2]Bangladesh Livestock Research Institute, Savar, Dhaka-1341, Bangladesh

ABSTRACT

Kedah-Kelantan (KK) cattle plays a significant role for beef industry in Malaysia. KK cattle is a well-adapted local breed reared by traditional farming system with low quality feeds. KK cows normally produce a calf per year, which attracts farmers for commercial production. Currently, KK cattle is playing an important role for profitable beef production in Malaysia since the imported exotic breeds, crossbreds, and synthetic breeds of cattle could not perform to their full potential for sustainability of the livestock industry in the country. Consequently, nowadays, importance of the unique Malaysian beef breed (KK) has been increasing gradually in consideration to the changing climatic situation and adaptibility. Meanwhile, it is required to know the productive and reproductive performance of KK cattle for a further long term sustainable breeding program. As such reviewing growth performance, age at puberty and maturity, semen quality, scrotal biometry, libido efficiency, conception rate, service per conception, and calving interval are fundamental. There exist limited systemic studies and in-depth reviews based on these key reproductive, growth characteristics, and indexes for KK cattle. Therefore, reproductive key parameters of KK cattle were reviewed with the aim of understanding the challenges on the production of KK cattle and to suggest possible strategies to alleviate those challenges.

Keywords: Growth, KK cattle, puberty, reproductive performance, semen quality

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E-mail addresses:
siraj_blri@yahoo.com (Mohammed Sirajul Islam)
nurhusien@upm.edu.my (Nurhusien Yimer Degu)
wahidh@upm.edu.my (Abd Wahid Haron)
jesse@upm.edu.my (Faez Firdaus Jesse Abdullah)
mark@upm.edu.my (Mark Hiew Wen Han)
wannorfitri@upm.edu.my (Wan-Nor Fitri)
* Corresponding author

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INTRODUCTION

Kedah-Kelantan (KK) cattle is an indigenous unique cattle breed in Malaysia. It is a well-adapted but slower growth performing local breed comprising 85% (593, 299 heads) of the total beef cattle population (Department of Veterinary Services [DVS], 2014). It is highly tolerant to extreme temperature and humidity. It is reared by traditional farming system with low quality feeds. Large genetic variations are found within KK cattle than the synthetic breeds. It is a great scope to improve the KK cattle through long term appropriate breeding effort. KK cattle are suitable for commercial beef production (Warzukni & Haron, 2010) which is playing a fundamental role for profitable beef production in Malaysia (Ariff et al., 2015; Thundathil et al., 2016).

Growth performance is one of the most important economic traits of beef cattle production. KK cows have been crossed with Brahman, Hereford, Angus, Shorthorn, Charolais, Limousin, and Semental Sire and so on for increasing their growth performance. Consequences, all animals crossed with KK cows have shown higher growth rate and body weight compared to KK straight bred cattle. On the contrary, KK cows crossing with different breeds affected the purity of Kedah-Kelantan cattle. Furthermore, genetic resource of Malaysian unique local beef cattle is declining as more emphasis has been given on crossing KK cows with different exotic beef breeds in order to increase beef production. Moreover, reduced survivability and fertility caused a decline in the profitability and sustainability of KK crossbred cattle in the tropical environment of Malaysia (Jamaludin et al., 2014). As a result, KK purebred cattle have been considered the natural heritage and unique natural animal genetic resouce for sustainable beef production in the country.

Better reproductive performance of breeding animals is the pre-requisite for efficient beef production. It can be said that bulls with good quality semen are the half of a cattle herd (Thundathil et al., 2016). Semen from one superior fertile bull can be used to thousands cows by exploiting that male genetic potentiality to a specific cattle population (Devkota et al., 2008). Approximately 40% lower fertility was observed in breeding bull that were not selected on the basis of their semen quality (Sofienaz et al., 2014). It has been reported that more than 90% KK cows reared by small-scale farmers are not bred by superior KK bulls. Furthermore, few practices of selective breeding program to improve the KK cattle population do exist based on the evaluation of bulls for their semen quality. Consequently, farmers are usually breeding their cows with poor quality KK bulls without proper breeding records which is a great challenge for KK cattle production (Ariff, et al., 2015; Johari & Jasmi, 2009).

Fertility is of primary economic consideration in the beef cattle industry. The importance of fertility, growth rate, and carcass quality has been correlated at the ratio of 10:2:1. KK cattle has higher fertility rate for producing a calf per year which is one of the most important traits of KK breed (A. W. M. Hafiz, 2019;

Clayton, 1983; Johari & Jasmi, 2009; M. A. R. Hafiz et al., 2009; Tan et al., 1985). Fertility was found as 46.3% to 52.5% in KK cattle reared by small-holder farmers at rural areas of Malaysia (Ariff et al., 2015). It is seen that, in terms of reproductive characteristics, especially fertility trait, KK cattle shows better performance than that of KK crossbred cattle in the country.

Selection of beef bulls for high quality semen is always much more important rather than a cow (Okere et al., 2014). Beef bulls are usually selected based on their growth performance, age, and weight at puberty, scrotal biometry, testosterone level and semen quality (Brito, 2014; Perumal, 2014; Sarsaifi et al., 2013). Body weight and scrotal circumference are commonly used to predict the semen producing efficiency of a breeding bull (Yimer et al., 2011). Recent studies revealed that beef bull selection on basis of scrotal circumference at growing stage was more reliable than adult stages (Gopinathan et al., 2018; Penitente-Filho et al., 2018). Therefore, reproductive key parameters of KK cattle with more emphasis on KK bulls have been reviewed with the aim of understanding the challenges on the production of KK cattle and to suggest possible strategies to alleviate those challenges.

BEEF CATTLE PRODUCTION IN MALAYSIA

The livestock industry plays a significant role in producing valuable animal protein for the human population of Malaysia (Kusriatmi et al., 2014). The livestock sector comprises beef cattle, buffalo, goat and sheep sub-sectors. Beef supply alone contributed 0.011% to the GDP and earned around RM 62 million in the agricultural sector in 2010 (Ariff et al., 2015). The KK cattle are the most important indigenous cattle in Malaysia. KK cattle are unique potential genetic resource for commercial beef production. The KK cattle are small-sized breed ranging in matured weight of 300 kg to 312 kg for male, and from 219 to 240 for female. In comparison, the mature weight of Brahman cattle from India is between 800 and 1100 kg but they were not profitable due to high mortality as well as poor reproductive performance. Malaysia needs to increase livestock production to meet up at least 50% of the local market needs. Presently, the local production of beef is only able to supply about 30% of the local consumption. In 2017, Malaysia produced 52,000 tonnes of beef worth RM 169 million and imported beef worthy of RM1.14 billion annually to meet the local demand of about 191, 000 tonnes (Loh, 2004). Therefore, KK beef cattle have been playing a significant role to meet up the growing demand of animal protein in Malaysia. However, KK cattle are normally reared in the subsistence farming system by smallholder farmers in Malaysia that makes KK cattle more sustainable in relation to climate change in the country. Role of three types of beef cattle breeds in Malaysia are as follows:

Exotic Beef Cattle Breeds

Malaysia has taken some initiatives to improve the beef production for fulfilling

the existing gap and growing demand of the beef of the country. Exotic beef breed importation is one of the most important efforts for accelerating the beef industry in the country. For that reason, Malaysia has imported more than 15 exotic breeds like Brahman, Branggus, Hereford, Aberdeen, Nelore, Angus, Droughmaster, Santa Gertudis, Bali, Shorthorn, Charolais, Limousin, Semental, and Chineese Yellow cattle from different regions of the world. However, most of the exotic breeds did not sustain in the Malaysian environment except a few breeds (Jamaludin et al., 2014; J. J. Abdullah, 1993; Johari & Jasmi, 2009). Breeds did not significantly contribute within 55 years of effort for the development of beef industry in Malaysia because of their poor reproductive performance and high mortality rate due to hot environment. Exotic breeds from various environmental conditions did not sustain in the tropical environment of Malaysia. Heat stress of this environment might have a direct effect on their production performance, fertility and survivability.

Crossbred Beef Cattle

Malaysia started the cross-breeding program in 1970 for increasing the production performance of KK cattle reported by Flint (1971). Initial crossbreeding program for beef production was started at UPM by crossing KK cows with Brahman and Hereford bulls (Flint, 1971). KK cows were crossed with more than fifteen exotic beef breeds for accelerating the beef industry in Malaysia (Ariff et al., 1993; Dahlan, 1985; A. W. M. Hafiz et al., 2014; Raymond, 2012). The Brakmas and Charoke synthetic cattle breeds were produced by 50% KK cows with 50% Brahman and 50% Charolais, respectively. All animals crossed with KK have shown higher growth rate and body weight in comparison to KK straight bred cattle. Crossbred cattle have low reproductive performance despite more growth efficiency (Abdulla et al., 2016). Furthermore, KK cows crossing with exotic breeds affected the purity of Kk cattle population. Moreover, survivability and fertility problem of KK crossbred cattle are acute in the hot environment of Malaysia (Jamaludin et al., 2014).

Indigenous Kedah-Kelantan (KK) Cattle (*Bos indicus*)

KK cattle are small sized Zebu type cattle with fatty hump and poorly developed dewlap. KK's are local beef breed like local Thai cattle and Yellow cattle of Southern China. KK's are mostly brown coat with solid body conformation along with reddish, black and grey spot. They have a broad and short head. Their neck is narrow and deep while their horns are short with variable size. The tail is long with switch about reaching the ground (around 70-78cm). They are highly fertile with strong mothering ability (Johari et al., 1994). They are well adapted to Malaysian tropical environment and mostly resistant to common diseases. KK cattle are considered as the natural animal genetic resource and it is called natural heritage and unique genetic resource of beef. They are reared with low quality feed

by rural small farmers through grazing and tethering system. Growth rate of KK is slow despite the type of the beef cattle. However, KK cattle are better for lean meat production in comparison to their crossbreds (Raymond & Hasan, 2012). Table 1 summarizes the key features, productive, and reproductive traits of KK cattle.

Advantages of Kedah-Kelantan Cattle over Exotic Breeds and Crossbreds in Malaysia

KK cattle are fully adapted with Malaysian environment of higher temperature, humidity, and rainfall. Despite this scope, Malaysia has to import about 80% of the total requirement of beef due to low production performance (Warzukni & Haron, 2010). Profitability and sustaianbility of livestock farming depends on the availability, cost and quality of raw ingredients for animal feeds. Feeds incur most part of production cost that involves about 70% to 80% cost of production in any livestock industry. Whereas, KK cattle mostly depends on locally available feedstuff on grazing lands with only some concentrate supplementation like palm kernel cake (PKC) and salt lick (Loh, 2004). The cost of animal feeds that contribute to the total cost of production is between 5.4% and 19.3% for both dairy and beef cattle production in Malaysia which is very low in comparison to the proportion of total production cost in other countries of the world. However, crossbred cattle need to be balanced ration with improved housing

Table 1
Key features of Malaysian Kedah-Kelantan cattle production

Characteristics	Results	References
Breed	Tropical breed (*Bos indicus*)	Devendra and Choo (1975a); Devendra et al. (1975)
Origin	Malaysia	Devendra and Choo (1975a)
Coat colour	Mostly brown	Raymond (2012)
Rearing purpose	Subsistence farming	Johari and Jasmi (2009)
Feeding habit	Low quality feeds	Loh (2004)
Rearing system	Traditional	Jamaludin et al. (2014)
Adaptability	Fully adapted to Malaysia	Ariff et al. (2015)
Diseases resistance	High resistance against many diseases	Jamaludin et al. (2014)
Calf mortality (%)	5.50	Sivarajasingam (1984)
Mortality rate (%)	5-10	Mohamed et al. (2013)
Dressing percentage	45-55	Devendra and Choo (1975a)
	55.90	Dahlan et al. (1992)
Meat: Bone ratio	5.4:1	Devendra and Choo (1975a)
	3-7:1	Dahlan et al. (1992)
Calf production (no.)/year	One calf	Johari and Jasmi (2009)
Feed conversion ratio (FCR)	6.55	Ariff et al. (1993)
Average dry matter intake (kg)	3.03	Sukri and Idris (1982)

system whereas KK cattle needs traditional housing system with low quality feeds. KK cattle has higher fertility rate for producing a calf per year which is one of the most important trait of KK breed (Johari & Jasmi, 2009). Fertility was found to be 46.3% to 52.5% in KK cattle reared by small-holder farmers at rural areas of Malaysia (Ariff et al., 2015). So, it can be certainly said that in terms of reproductive characteristics, especially fertility trait of KK cattle shows the better performance than that of KK crossbreds. Fertility is a primary economic consideration in the beef cattle industry. The importance of fertility, growth rate, and carcass quality has been correlated at the ratio of 10:2:1. Higher genetic variations were found within Kedah-Kelantan cattle than the synthetic breeds. So, there is a great scope to improve the KK cattle through long term selective breeding program. KK cattle are suitable for commercial beef production in Malaysia (Johari et al., 1994), which is playing a fundamental role for profitable beef production in Malaysia (Jamaludin et al., 2014). On the other hand, crossbred cattle have lower fertility in comparison to KK cattle. KK cattle are strongly resistant against the most viral and bacterial diseases. They are also highly resistant against the most external and internal parasities. For that reason, only FMD and HS vaccines are given to KK cattle as disease prevention. Parasitic diseases are fully controlled by deworming of animals twice or sometimes once a year. No or minimum cost is required in bio-security measures to control and prevent any diseases in subsistence farming system. Furthermore, KK cattle can be reared by minimum cost for disease prevention and control measures because of their high resistance to diseases. Thus, KK cattle can contribute more and more for beef cattle production in Malaysia due to their well adaptability with progressive climate changes.

GROWTH PERFORMANCE OF KK CATTLE

Growth performance is one of the most important traits for beef production system. Growth performance is normally measured by body weight and average daily gain of an animal in a certain period of time. Body weight is the most essential tool to assess the reproductive efficiency and growth performance of breeding animals. It also helps to determine the correct amount of feed to be provided to animal thereby avoiding overfeeding or underfeeding. Body weight measurement is the most vital, easier, faster, and cheaper technique to take decision for breeding, feeding, and veterinary services of animals. Moreover, body weight helps to determine the age at puberty of male and female animals. Methods for body weight measurements are electronic scale, weight band and height, width, and heart girth. Electronic scale is a generally used device to determine the body weight of animal perfectly. Growth is frequently measured in body weight gain per unit of time. Growth is also defined as a progressive increase in size or weight of an animal in a specific time period (Bures & Barton, 2012). Growth can also be associated with accumulation

of nutrients in the body over the lifetime of an animal along with other factors like breed type, management, and environment. Growth performance in the peri-pubertal age is a good indicator of reproductive efficiency of bulls for artificial insemination program or natural services. Growth performance is directly related to breed, age, scrotal circumference, and testicular hormones (Lee et al., 2009; Silva et al., 2017). On the other hand, growth affects greatly the semen quality especially sperm motility, sperm concentration, and sperm morphology of beef bulls. For better understanding, meta-analysis was performed on body weight and average daily gain of KK bulls and cows by one sample *t*-test using SPSS computer program.

KK BULLS

Body weight and average daily gain (ADG) of KK bulls in different ages were summarized in Table 2. Table 3 showed the meta-data analysis on body weight and average daily gain of KK bulls in different ages. Mean birth weight of KK bull calves were found to be 15.28 kg with significant difference ($p<0.001$) among different researchers. Mean body weight of KK bulls were found to be 73.89kg and 102.25kg at 6 months and 12 months, respectively and differed significantly ($p<0.05$). Average daily gain was 0.291kg/day/bull of KK with a highly significance difference ($p<0.001$) which clearly showed the large variation on average daily gain by the finding of different researchers in different ages of KK bulls. This variation might be due to different location, period, and management. It indicates the further systematic research for better understanding of growth performance of KK bulls. However, body weight and growth performance are comparatively lower in KK bulls rather than other breed types like crossbreds, synthetic breeds, and exotic breeds.

Table 2
Body weight and average daily gain of KK bulls in different ages

Parameters	Results	References
Birth weight (kg)	15.80	Devendra et al. (1975)
	15.00	Sivarajasingam (1984)
	15.60	Dahlan (1985)
	14.00	Mak et al. (1986)
	17.50	Idris and Moin (2002)
	17.00	Johari and Jasmi (2009)
	14.31	M. A. R. Hafiz et al. (2009)
	13.97	Warzukni and Haron (2010)
	14.27	Sofienaz et al. (2014)
3 month weight (kg)	44.95	Sofienaz et al. (2014)
6 month weight (kg)	59.60	Devendra et al. (1975)
	79.50	Idris and Moin (2002)
	77.10	Dahlan (1985)

Table 2 *(continue)*

Parameters	Results	References
6 month weight (kg)	80.00	Johari and Jasmi (2009)
	70.02	M. A. R. Hafiz et al. (2009)
	67.55	Sofienaz et al. (2014)
12 month weight (kg)	95.50	Sivarajasingam (1984)
	100.80	Dahlan (1985)
	130.00	Johari and Jasmi (2009)
18 month weight (kg)	87.45	M. A. R. Hafiz et al. (2009)
	144.00	Dalhan (1985)
	120.41	M. A. R. Hafiz et al. (2009)
24 month weight (kg)	188.70	Dahlan (1985)
	156.19	M. A. R. Hafiz et al. (2009)
30 month weight (kg)	190.00	Johari and Jasmi (2009)
	217.40	Dahlan (1985)
Mature weight (kg)	214.50	Devendra et al. (1975)
	306.00	Sivarajasingam (1984)
ADG from 0 -3 month	0.324	Sofienaz et al. (2014)
ADG from 0-6month	0.296	Sivarajasingam (1984)
	0.341	Dahlan (1985)
ADG from 0-12 month	0.350	M. A. R. Hafiz et al. (2009)
	0.243	M. A. R. Hafiz et al. (2009)
ADG from 0-18 month	0.223	M. A. R. Hafiz et al. (2009)
	0.225	Mak et al. (1986)
ADG from 0-24 month	0.216	M. A. R. Hafiz et al. (2009)
ADG from 3 -6 month	0.252	Sofienaz et al. (2014)
ADG from 6-12 month	0.132	Dahlan (1985)
ADG from 6-24 month	0.339	Sivarajasingam (1984)
ADG from 12-18 month	0.239	Dahlan (1985)
	0.448	Budiono (1985)
ADG from 18-24 month	0.583	Mak et al. (1986)

Note. ADG = Average daily gain

Table 3
Meta-analysis of body weight and average daily gain of KK bulls in different ages

Parameters	Minimum	Maximum	Range	Mean ±SD	*p*-value
Birth weight (kg)	13.97	17.50	3.53	15.28±1.23	0.000
6 month weight (kg)	59.60	80.40	20.80	73.89±7.44	0.031
12 month weight (kg)	87.45	130.00	42.55	102.25±16.27	0.019
24 month weight (kg)	156.19	190.00	33.81	178.30±17.11	0.374
ADG(kg/day/animal)	0.12	0.58	0.46	0.291±0.11	0.000

Note. ADG = Average daily gain

KK COWS

Weight at birth, 3-month, 6-month, 12-month, 24-month, 26-month, 48-month, at maturity and their average daily gain from birth to 3 month, 6 month, 12 month, 18 month, 24 month, 3-6month, 6-12 month, 12-18 month, and 6-24 month of ages are illustrated in Table 4. The results of different researchers from 1975 to 2014 in various locations with traditional and improved management system are highlighted in this review. Table 5 summarizes the meta analysis of body weight and average daily gain of KK cows in different ages. Body weight at birth, 6-months and 12-months of ages were 14.30 kg, 65.43kg, and 92.06kg, respectively with significant difference (p<0.05). The average daily gain was 0.267kg/day/animal which was found highly significant difference (p<0.001) among the results of various previous researchers in different ages of KK cows.

Significant differences were obtained among the findings of various researchers for body weight and average daily gain in both the sex of KK cattle which clearly indicated the need of more attention for in depth research for further better understanding of the growth performance of KK cattle. More detailed research is needed on the body weight and growth performance of Kedah-Kelantan bulls before undertaking long term plan of selective breeding program to augment the KK cattle production in Malaysia.

Table 4
Body weight and average daily gain of KK cows in different ages

Parameters	Results	References
Birth weight (kg)	14.70	Devendra et al. (1975)
	15.12	Dahlan (1985)
	15.60	Liang et al. (1991)
	12.93	Warzukni and Haron (2010)
	13.95	M. A. R. Hafiz et al. (2009)
	13.50	Sofienaz et al. (2014)
3 month weight (kg)	45.40	Sofienaz et al. (2014)
6 month weight	74.90	Dahlan (1985)
	64.35	M. A. R. Hafiz et al. (2009)
	66.90	Sofienaz et al. (2014)
	55.60	Devendra et al. (1975)
	94.80	Dahlan (1985)
12 month weight (kg)	101.00	Ariff et al. (1993)
	80.37	M. A. R. Hafiz et al. (2009)
18 month weight (kg)	131.90	Dahlan (1985)
	111.90	M. A. R. Hafiz et al. (2009)
24month weight (kg)	195.60	Dahlan (1985)
	138.61	M. A. R. Hafiz et al. (2009)

Table 4 *(continue)*

Parameters	Results	References
30 month weight (kg)	212.80	Dahlan (1985)
36 month weight (kg)	175.80	Ariff et al. (1993)
48 month weight (kg)	197.40	Ariff et al. (1993)
Mature weight (kg)	227.80	Ariff et al. (1993)
	173.70	Devendra et al. (1975)
	234.50	Sivarajasingam (1984)
Rate of maturing	0.0523	Ariff et al. (1993)
ADG from 0-3month	0.310	J. J. Abdullah (1993)
	0.365	Sofienaz et al. (2014)
ADG from 0-6month	0.270	J. J. Abdullah (1993)
	0.332	Dahlan (1985)
	0.321	M. A. R. Hafiz et al. (2009)
ADG from 0-12 month	0.223	M. A. R. Hafiz et al. (2009)
ADG from 0-18 month	0.207	M. A. R. Hafiz et al. (2009)
ADG from 0-24 month	0.192	M. A. R. Hafiz et al. (2009)
ADG from 3 - 6 month	0.238	Sofienaz et al. (2014)
ADG from 6-12 month	0.410	Sukri and Idris (1982)
	0.109	Dahlan (1985)
ADG from 12-18 month	0.209	Dahlan (1985)
ADG from 6-24 month	0.294	Devendra and Choo (1975b)

Note. ADG = Average daily gain

Table 5
Meta-analysis of body weight and average daily gain of KK cows in different ages

Parameters	Minimum	Maximum	Range	Mean ± SD	*p*-value
Birth weight (kg)	12.93	15.60	2.67	14.30±1.01	0.016
6 month weight (kg)	55.60	74.90	19.30	65.43±7.95	0.007
12 month weight (kg)	80.37	101.00	20.63	92.06±10.58	0.047
Mature weight (kg)	173.70	234.50	60.80	212.00±33.33	0.148
ADG (kg/day/animal)	0.11	0.41	0.30	0.267±0.07	0.001

Note. ADG = Average daily gain

REPRODUCTIVE PERFORMANCE OF KK CATTLE

KK Bulls

Age at Puberty and Sexual Maturity of KK Bulls. Puberty is the age of first breeding potential, while sexual maturity is the age of maximum breeding potential of a breeding bull. It is basically defined as the period whenever the sexual organs of a bull are functionally developed for reproduction. Onset of puberty is typically demarcated when a bull can produce at least 50×10^6 sperm /ml with at least 10% progressive motility in the first ejaculation (Ismaya,

1987). Puberty is usually characterised by different male reproductive traits like age, body weight, scrotal circumference, hormone concentration, libido and semen quality (Barth, 2004; Menegassi et al., 2011). Growth performance, testosterone level, and age at puberty are positively correlated with good quality semen (Thundathil et al., 2016). Semen traits are commonly evaluated in every 30 days of interval from 8 month to about 16 months. Studies reported that age at puberty were 11, 10, 11, 9, and 8 months for Hereford, Angus, Red Poll and Brown Swiss respectively with a minimum of 50 x 10 spermatozoa/ml with at least 10% progressive motility (Argiris et al., 2018). It is clearly seen that different breeds of beef bulls are generally used for breeding ranging from 8-14 months. In addition, beef bulls routinely produce good quality semen within 3-4 months of age after attaining the age at puberty. About 33%, 60% bulls, and almost all bulls can produce good quality semen within the age of 12, 14, and 16 month of age, respectively (Argiris et al., 2018; Persson & Söderquist, 2005; Watson, 2000). Semen quality are gradually improved after attainment of age at puberty (about 10 months) and age at maturity (about 12 months) reported by Brito et al. (2012). Likewise, beef bulls within 12-15 months of age are normally considered for satisfactory semen quality approximately 50 days after puberty. Besides, age at puberty of KK bulls were more than 16 months with sperm concentration of $320x10^6$/ml and body weight 151.5 kg (Ismaya, 1987). Body weight during peri-pubertal age of bulls is a good indicator of early pubertal age. However, data are not available on peri-pubertal age of KK bulls to determine actual age of puberty and sexual maturity for selecting appropriate breeding bulls for commercial purpose to enhance the productivity of KK cattle in the country.

Scrotal Circumference. Scrotal circumference is the major key component of breeding soundness evaluation of breeding bulls. Scrotal circumference is a vital indicator of high quality semen production in young bulls (McGowan, 2018). Scrotal circumference is highly repeatable and heritable reproductive trait of male animal (Corbet et al., 2013). It is phenotypically and genetically correlated with reproductive traits of male especially sperm motility, morphology and concentration that greatly influence the bull fertility (Melis et al., 2010; Paterno et al., 2017). Moreover, scrotal circumference is also a good sign of puberty producing at least 50 million sperm with 10% or higher motility in an ejaculation. Thus, scrotal circumference (SC) has been considered a very useful reproductive tool for determining the age at puberty and is performed to improve the reproductive performance of beef cattle production (Silvio et al., 2019). Scrotal circumference is highly correlated with body weight, age with testis' weight linked fertility (Devkota et al., 2008; Waldner et al., 2010). Brito et al. (2003) reported that testicular diameter, testicular length, testicular volume along with scrotal circumference were an important part of breeding soundness evaluation of a breeding bull. The bulls with

larger testes ejaculate more than bulls with smaller testes. Testicular size are positively related to body weight and age (Engelken, 2008). However, measurement of these parameters especially scrotal circumference has a great value on onset of puberty, total semen production, semen quality, pathological conditions of reproductive system, and the fertility or infertility status of breeding bulls (Menegassi et al., 2011). Moreover, testicular measurements have been utilized as the indicators for reproductive performance in the pre and post pubertal age of bulls (I. Ahmad et al., 2013). Scrotal circumference were 26.9cm, 33.5cm, 30.6 cm, 34.1 cm, and 32.2 cm for Nellore, Angus, Brangus, Hereford, and Brafard beef breeds with the age ranging 15-17 month (Silvio et al., 2019). Scrotal circumference performance of Kedah-Kelantan bulls with different age period were reported by different researchers that were summarized in Table 6. Mean scrotal circumference of Kedah-Kelantan purebred bulls in various age ranging from 24 month to more than 36 months were 22.5 cm to 36 cm which is lower than the standard beef breeds which may be due to smaller body size of KK cattle (Abdulla et al., 2016). Furthermore, mean scrotal circumference of Kedah-Kelantan straight bred bulls was found to be 22.5 cm whereas Senepol purebred beef bulls resemble to *Bos taurus* possessed 30.1 cm (Abdulla et al., 2016; M. I. Abdullah et al., 2010). However, scrotal circumference of KK bulls needs to measure for prediction of optimum age at puberty for further commercial use to have clear understanding of bull reproduction.

Table 6
Scrotal circumference of Kedah-Kelantan purebred bulls

Age (months)	Scrotal circumference (cm)	References
12	15.80	Ismaya (1987)
18	17.90	Ismaya (1987)
24	22.50	M. I. Abdullah et al. (2010)
	22.70	Ismaya (1987)
36	24.90	Ismaya (1987)
Above 36	36.00	Yimer et al. (2011)
	27.80	Ismaya (1987)

Testosterone Hormone (T) Production

Testosterone hormone (T) plays a vital role in the reproductive efficiency of bulls. Testosterone is essential for normal spermatogenesis and expression of secondary sexual traits (Okere et al., 2014). Testosterone is produced by Leydig cell of testicular parenchyma that tremendously affects the fertility and semen quality of bulls. Different values of T level in blood serum were found in different beef breeds with various ages. The minimum and maximum T level were 0.05 ng/ml and 2.96 ng/ml in blood serum respectively, in Simental beef bull (Melis et al., 2010). Hormonal changes at puberty are commonly caused by several mechanisms (Brito et al., 2012). It has been reported that pituitary gland becomes more responsive to GnRH at pubertal age (Harstine et al., 2018). As T concentration is always more at pubertal stage than pre-pubertal bulls (Stradaioli et al., 2017). Testosterone levels are normally lower in young bulls then gradually increases with the increasing

age of bulls (Byrne et al., 2017). The mean T concentrations of KK bulls were also reported with an increasing trend from peri-pubertal to pubertal age (Ismaya, 1987). The mean values of T were 0.42, 0.65, 1.38, and 3.01ng/ml in blood serum within the age of 12 months, 18 months, 24 months, and 36 months of KK bulls, respectively. However, T concentration in the KK bull from pre-pubertal age to old age needs to be thoroughly investigated to relate with libido, semen output, and its quality.

Semen Production and Quality

Semen volume varies between and within species, and breeds and even the same male during various time of collection (Kastelic & Thundathil, 2008; Penny, 2018; Thundathil et al., 2016). It may also vary with environmental condition, age of breed, body condition score, frequency of collection, exercise, teasing, nutritional status, season, and method of collection. In general, young bulls and those of smaller size within a species, produce smaller amount of semen. Table 7 represents the semen production and quality traits of KK bulls found by different researchers. Volume of semen means the total amount of semen produced in each ejaculation that is expressed in millilitres. The volume of semen is found to be 2 to 5.4ml per ejaculation in different ages of KK bulls. KK bull's semen is normally milky to whitish creamy colour with good wave pattern. Sperm concentration is measured as the concentration of spermatozoa in an ejaculation expressed in millions per millilitre (Suchocki & Szyda, 2015). Sperm motility means the ability of sperm to move progressively forward (Brito et al., 2003). Wave pattern or mass activity is a subjective score measured by a standard scale of 1-5 or 1-3 (Suchocki & Syzda, 2015). But Gredler et al. (2007) did not apply any scoring system for wave motion. However, more motility score is always desirable for quality semen. Forward swimming of sperm in a straight lines or large scales are called progressive motility (Utt, 2016). Motility and progressive motility both are scored in percentage in each ejaculation. At least 100 spermatozoa are counted for motile and non-motile sperm under microscope. Sperm

Table 7
Semen production and quality of Kedah-Kelantan bulls

Parameters	Results	References
Volume of semen (ml)	2.60 to 5.40	Ismaya (1987)
Sperm concentration ($\times 10^6$ sperm/ml)	1265.00	Yimer et. al. (2011)
	1167.00	M. I. Abdullah et. al. (2010)
	320 .00 to1018.00	Ismaya (1987)
Sperm motility (%)	67.00	Ashrafzadeh et al. (2013)
	67.00	Sauerweina et al. (2000)
	47.50 to 81.00	Ismaya (1987)
Live sperm (%)	78.30 to 82.50	Ismaya (1987)
	20.60 to 30.00	Ismaya (1987)

concentration, sperm motility and sperm morphology are essential parameters of evaluating the semen quality (Ashrafzadeh et al., 2013). Different researchers reported sperm concentration (320 to 2000 million/ml), sperm motility (47.5 to 82.50%) and abnormal sperm morphology (20 to 30%) in KK breeding bulls of different age period (Ismaya 1987; M. I. Abdullah et al., 2010; Yimer et al., 2011).

Libido

Sexual aggressiveness or **s**exual behaviour is an important factor that highly influences the reproductive performance of bulls (Rehman et al., 2014). It depends mostly on breed, age of bull, genetic makeup and their environmental conditions (Beran et al., 2011; Galina et al., 2007; Kondracki et al., 2013; Petherick, 2005). The level of sexual aggressiveness or libido can directly affect the ejaculatory efficiency and the quality of semen in ejaculations (Levis & Reicks, 2005; Pound et al., 2002). Libido is typically defined as the lapsed time between exposure to stimuli and first service (Beran et al., 2011). It is a good parameter to predict the reproductive competence of bulls (M. Ahmad et al., 2005). Libido is also helpful to assess the soundness of bulls for selecting a suitable bull for artificial insemination program. Thus, bulls with higher libido can ensure optimum level of production with good quality semen during breeding seasons as well multiple ejaculations. There are many environmental factors affecting expression of libido of bull. It is difficult to draw specific conclusion about the libido and reproductive performance of bulls without studies involving females. However, as not enough work was done in this regard, it is difficult to draw any valid inference.

KK Cows

Results of reproductive traits of Kedah-Kelantan cow by different researchers are presented in Table 8. Reproductive performance is measured by the number of pregnant cows out of the total number of eligible cows to be pregnant of a cattle herd within one year. Calving interval, convention rate, conception rate are the most important reproductive characteristics of female animals for the efficient reproductive performance of bovine production. Estrous cycle is considered as the time between periods of estrous. The average of estrous cycles is almost similar in farm animals.

Puberty. Puberty can be defined when a heifer shows heat or estrous with ovulation first time. Heifers of exotic breeds normally reach puberty by 13-14 month of ages. Age at puberty of heifers is directly influenced by age, breed, body weight and environmental factors. Heifers can attain their puberty when they reach about 65-67% of their mature weight. The mean age at first estrous was 11 months of age for KK cows reported by Sivarajasingam (1984).

Conception Rate. High rate of conception is important for effective breeding program. The conception rate is defined as the percentage of services that result in conception. Age and weight at first conception were 18 months

to 28.60 month and 166 kg respectively, in KK cows revealed by various researchers. Age at first calving was 35.50 month to 38.20 month while weight at first calving was 250.70kg in KK cows.

Calving Interval. Calving interval (CI) is considered as the duration of time between two successive parturitions consisting the post -partum interval, conception length and the length of gestation. The range of calving interval was 12.10 to 13.20 month of age which is most prominent reproductive trait of KK cattle. Reproduction is the major factor influencing the efficiency beef cattle production. Optimum reproductive efficiency of beef cow mostly relies on the calving interval. On the other hand, calving interval is greatly depended on the postpartum interval from parturition to first estrous. Better reproductive efficiency were found in KK cows rather than Brangus, Bradford and Sahiwal against cystic ovarian diseases (COD) and abnormal ovarian cyclicity (AOC), which are the key factors

Table 8
Reproductive performances of Kedah-Kelantan cows

Parameters	Results	References
Mean age at first estrous (month)	11.00	Sivarajasingam (1984)
Age at first conception (month)	18.00	Sivarajasingam (1984)
Weight at first conception (kg)	166.00	Sivarajasingam (1984)
Mean age at conception (month)	28.60	Warzukni and Haron (2010)
Age at first calving (month)	35.50	Sivarajasingam (1984)
Age at first calving (month)	37.40	Johari et al. (1994)
Age at first calving (month)	38.20	Warzukni and Haron (2010)
Weight at first calving (kg)	250.70	J. J. Abdullah (1993)
First calving to conception (days)	81.00	Sivarajasingam (1984)
Calving to conception (days)	83.40	J. J. Abdullah (1993)
Calving to first breeding (days)	73.90	J. J. Abdullah (1993)
Calving to first ovulation (days)	66.30	J. J. Abdullah (1993)
Calving interval (month)	13.20	Sivarajasingam (1984)
Calving interval (month)	12.60	J. J. Abdullah (1993)
Calving interval (month)	12.10	Johari and Jasmi (2009)
Calving interval (month)	13.03	Warzukni and Haron (2010)
Number of services/conception	1.80	J. J. Abdullah (1993)
First service conception rate (%)	50.00	J. J. Abdullah (1993)
First service conception rate (%)	50.00	Johari et al. (1994)
Conception rate (%)	80-95	Sivarajasingam (1984)
Calving rate (%)	92.40	Johari et al. (1994)
	70-75	Mohamed et al. (2013)
Pregnancy rate (%)	84.20	J. J. Abdullah (1993)
Gestation length (days)	279.90	Liang et al. (1991)

of reproductive failures directly influencing the calving interval in cows (Yimer et al. 2010 & 2018).

Breeding. KK cows are normally bred by bulls through natural services. The number of services per conception was 1.80 in KK cows (J. J. Abdullah, 1993). First service conception rate was 50% reported (Johari et al., 1994) while calving rate 92.40% was found by Sivarajasingam (1984).

Calving interval of KK cows is about one year while conception rate is 85%-95% which are the prominent reproductive capability of KK cows. Due to lack of improved management and appropriate breeding techniques, the productivity of KK cows is comparatively low despite its high fertility and calf production ability of one calf in each year. However, published information on reproductive performance of KK cows based on systematic procedure of investigation is very limited.

CONCLUSION

KK cattle are small size and well-adapted local breed reared with traditional farming system with minimum feed costs. Large genetic variations are found within KK cattle than the synthetic breeds indicating a great scope to improve the KK cattle in future. Malaysia imported more than 15 foreign breeds from differents regions of the world. Unfortunately, most of the exotic breeds did not play any significant contribution within 55 years of effort for the development of beef industry in Malaysia due to their poor reproductive performance and high mortality rate. Simultaneously, crossing KK cows with the exotic beef breeds like Brahman, Hereford, Angus, Shorthorn, Friesian, Charolais, Limousin, and Semental, which caused genetic erosion and dilution of KK purity are the major challenges to maintain the original genomic characteristics of KK cattle.

Growth performance of an animal is the outmost important factor for economic beef production system. Monitoring growth performance is the most vital, easier, faster, and cheaper technique to take decision for breeding, feeding and veterinary services of animals. Moreover, it can be used as a means to determine the age at puberty and maturity of both cows and bulls. Based on the literature reviewed, it is apparent that the KK cattle have been found to be superior in terms of reproductive performances (Calving interval (CI) of about one year and a conception rate of 85%-95%) and semen quality but relatively lower growth performance compared to other cattle breeds such as crossbreds, synthetic breeds and exotic breeds. However, evidences have shown that growth performance of KK cattle can be enhanced. Based on the meta data analysis of KK cattle performance, a significantly wide variation among the findings of previous researchers for body weight and average daily gain in both sexes have been found; which implies presence of opportunities improvement in growth performance and the need of further research in sorting out the important factors that lead to superior production performance of the KK cattle. There is

lack of information on KK bulls based on scrotal biometry, semen quality, testosterone and libido at pre, puberty and post puberty ages for selecting appropriate breeding bulls. Scrotal circumference of KK bull was found to range from 22.5 to 36 cm for ages of 24 months to more than 36 months. Scrotal circumference is highly repeatable and heritable reproductive trait that needs to be measured for prediction of optimum age at puberty and maturity of KK bulls. Generally, though there may be several studies conducted on KK cattle, published information on reproductive performance of KK cows based on systematic researches is scarce. Therefore, any information pertinent to the production and reproduction performance and economics of the Malaysian indigenous KK cattle should be properly documented for further research and we believe that the current review will benefit in advancing further research and development work on KK cattle breeds and subsequently augmenting the staggering beef industry of Malaysia.

RECOMMENDATIONS FOR FUTURE RESEARCH

1. Special emphasis needs to be employed to well adapted indigenous KK cattle rather than exotic breeds or crossbreds with a view to protect the genetic erosion and dilution of KK cattle purity.
2. KK cattle are measured as the natural animal genetic resource and it can be considered "The Natural Heritage and Own Animal Genetic Resource of Malaysia" for sustainable and profitable beef production. So, long term plan for conservation and multiplication should be focused on priority basis to improve the KK cattle by the respective government institutes.
3. Genomic characterization of KK cattle based on common phenotypic traits must be considered as a top most priority work to determine the genetic potentiality through whole genome sequencing (WGS) for future research works.
4. More detailed research is needed on the body weight and growth performance of KK cattle under different rearing systems before undertaking the long term plan of selective breeding program to enhance the KK cattle production in Malaysia.
5. It can be strongly recommended that growth and reproductive performance KK cattle can be improved through appropriate and long term selective breeding program which may be the significant way for commercialization of KK cattle in this tropical region with progressive climate change situation.
6. Superior breeding bulls of Kedah-Kelantan can significantly contribute to develop the KK local beef cattle population. Bulls should examine from growing to post pubertal age considering all productive and reproductive parameters especially growth, reproductive traits, hormones, libido, age at puberty and maturity, and semen quality. Hence, very limited

in depth works so far have been done on Kedah-Kelantan breeding bull evaluation before. So, in-depth study based on the key reproductive traits of KK bulls would be given more emphasis for selecting the KK best breeding bulls to enhance the reproductive performance of KK cows.

7. Need to establish standard selection criteria for phenotypic characterization, breeding bull evaluation, age at puberty and maturity of KK cattle for taking the suitable steps for breeding, feeding and management.

Eventually, it can be recommended that KK cattle would be used for sustainable and economical beef production in Malaysia due to their adaptability behaviour with progressive climate changes by implementing selective breeding program.

CONFLICT OF INTEREST

None of the authors of this paper has any financial or personal relationship with other people or organizations that could inappropriately influence or bias the content of paper.

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