JERSEY CATTLE IN AFRICA

From the Breed's Documented Past to a Profit Index-Linked Future

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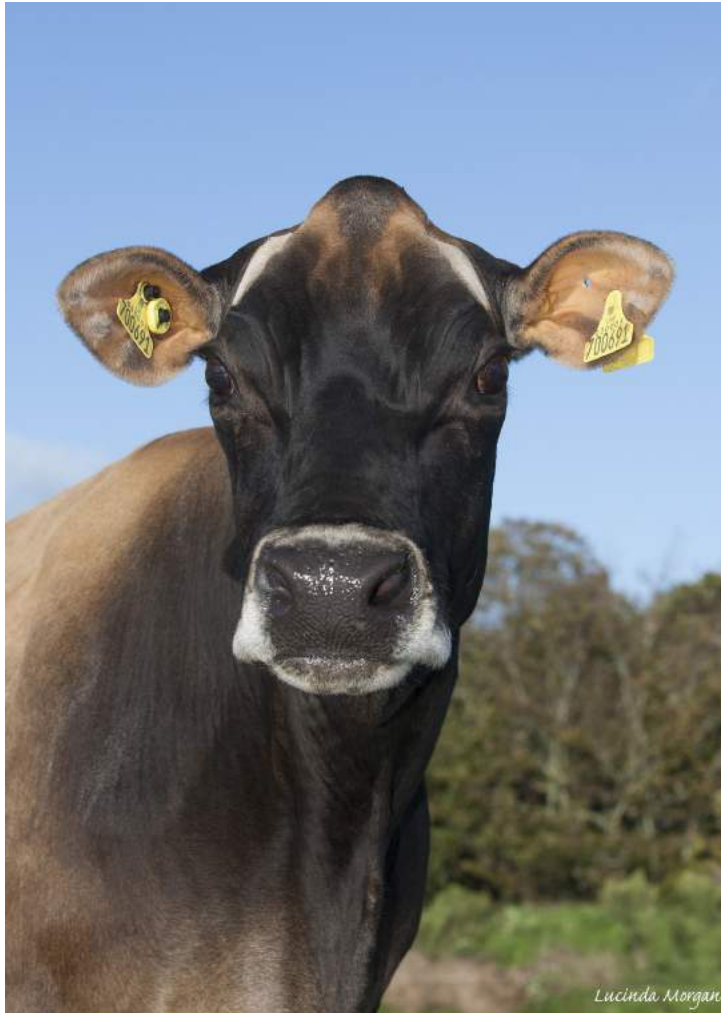
Now the second most numerous dairy breed on the planet, the global reach of the Jersey breed still has the Island of Jersey as it's fountainhead

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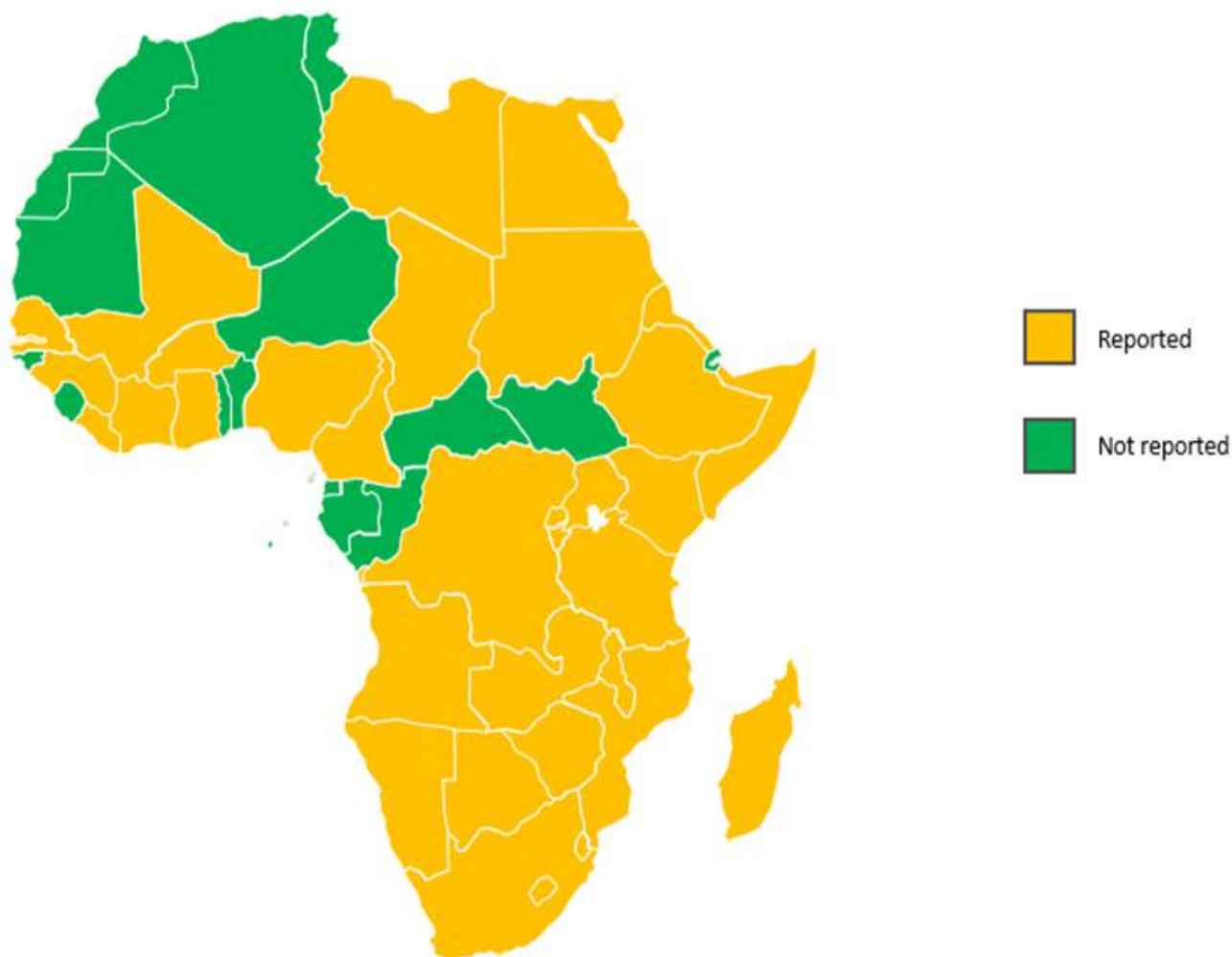
The Jersey African Forum welcomes the opportunity given by the authors to publish this report in early form as part of the 2021 AJF Virtual Conference.

The aim of this paper was to review the documented reports of the Jersey breed in Africa; and the suitability of the breed for a dairy profit index relevant for the future of Rwanda's dairy development programmes. We extended our review of available reports on the Jersey breed to various African countries to deliver on our main objective of providing relevant knowledge to support long term genetic improvement plans that could be customised to any targeted countries based on the productions systems, constraints, national policies and the local socio-economic development targets.

Through extensive research the authors have confirmed a presence for the Jersey breed across the majority of the continent of Africa, whether current or historic, as a pure breed or used in cross breeding programmes.

The RJAHS wishes to thank Jersey Overseas Aid for funding this important piece of work which can only advance the arguments for the Jersey breed to be considered by policy makers, dairy industry leaders, researchers, Non-Governmental Organisations and other stakeholders as a preferred breed for developing dairy across the continent of Africa today.

David Hambrook, Head of International Dairy for Development, RJAHS, Jersey

JERSEY CATTLE IN AFRICA:
From the Breed's Documented Past to a Profit Index-Linked Future

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SUMMARY

The paper reports on the prevalence and performance of the Jersey cattle breed in Africa, highlighting its geographic distribution and describing the reported performance and other related characteristics over a century, from the early 1900s to the present day. On the basis of key performance indicators and breed characteristics, this review will examine the suitability of Jersey cattle for increasing the volume and efficiency of milk production across the continent. Data relating to the Jersey cattle breed has been reported in at least 34 African countries, with our focus being on available material published between 1964 and 2020. A key parameter of any reference was a well-described consideration of the Jersey cattle breed (in pure from or crossbred with other exotic and/or indigenous breeds of various genetic compositions) with reported performance within a variety of production systems and agro-ecologies in Africa. The main focus was on key breed and performance parameters, including breed types and percentage of different breed types in specific environments, reproduction method and fertility (age at first calving (AFC) and calving interval); milk production (daily, annual/lactation and lifetime milk yields); survival and longevity; disease incidence; and production efficiency metrics such as: feed efficiency (milk unit per dry matter intake, DMI) and milk yield per unit of body weight (BW). The main performance descriptors identified from the reports were based on observations including (but not limited to) resilience under both abiotic (heat, nutrition) and biotic (incidences of pests and diseases) stressors, milk production, Body Weight (BW), nutrition and utilisation of feed resources. Results of the review showed that the smaller stature of the Jersey breed (and therefore lower maintenance requirements) means that it is better able than other exotic breeds to tolerate the production conditions (poor nutrition and feed quality, pests and diseases, heat stress, humidity, sub-optimum husbandry practices, animal welfare, etc) in the African small-scale dairy farming sector. Data on milk yield and survival showed that Jersey crosses with exotic and African indigenous breeds performed better than purebred cattle. Further analysis of the data provided strong evidence to support the suitability of the Jersey breed in crossbreeding with indigenous breeds for use in smallholder production systems. As an example of the progress made, over the past 16 years Rwandan farmers have explored various cattle breeds as the means to support a strategy for better and more efficient national milk production. Detailed analysis of the data collected demonstrated the suitability of the Jersey breed (small or moderately sized, resilient, docile, and offering better milk production) for a long-term strategy for growth and expansion of the dairy sector.

INTRODUCTION

The Jersey cattle breed originates from Jersey Island (a small British island found in the English Channel, close to the French coast), where Jersey cattle are still found today in purebred herds. It is the smallest of the common European dairy breeds and has been reported as a highly prized productive cow for centuries and as a distinct breed with a recorded history for nearly 200 years. Notwithstanding its origin on a small island, the Jersey breed has been exported to nearly all parts of the world for dairy development over the past century, and numerous benefits of the breed have been reported in the global dairy industry. The first reported introduction of the Jersey cattle to Africa dates back to the 1880s, nearly 140 years ago (Willis, 2012; Britannica, 2019). Over time, both formal and informal observations have been carried out relating to specific parameters/ traits and the overall performance of the Jersey breed. Some of these observations supported genetic improvement programmes through crossbreeding elite exotic animals with locally adapted or native breed cows and, more recently, have been used as the foundations for long-term genetic improvement programmes in Africa (Marshall et al., 2019). Other introductions of Jersey cattle to Africa have been opportunistic and not deliberately aligned with any national dairy improvement strategy. To further evaluate the use of the Jersey breed for dairy development in selected African countries (specifically Rwanda, Ethiopia and Malawi) it was necessary to create a knowledge base to guide development and deliver relevant interventions for genetic improvement that would transition into profitable, sustainable and efficient dairy production systems. To contribute to this knowledge generation, we reviewed the distribution of Jersey cattle, evaluated key performance and resilience indicators, and discussed the findings within the context of the Jersey being suitable for low-input smallholder dairy production systems in Africa.

African livestock contribute 30 to 40 percent of the agricultural Gross Domestic Product (AgGDP; FAO, 2019) and are a vital source of nutrients. Globally, livestock products (milk and meat and eggs) contribute about 13% of the world's calorie intake, yet, more importantly, serve as rich sources of protein and essential amino acids (FAO, 2009; 2018). Considerable research has been undertaken to improve the nutrition of some of the world's poorest people, with studies showing improved health, childhood growth and educational performance resulting from milk or meat supplementation and livestock ownership (Neumann et al., 2007; Randolph et al., 2007; Smith et al., 2012; Sibhatu et al., 2015). In Africa, livestock production must increase to meet the growing demands for milk, meat and eggs. Population growth and socio-economic development in Africa are driving important societal changes including increased disposable income, changes in nutritional and dietary needs and desires, and increased urbanisation that support the need for improved livestock production systems. Indeed, the FAO (Food and Agriculture Organisation of the United Nations) has estimated that global food supplies will have to increase by 60% in the next 30 years to support this demand (FAO, 2013a). As a result, livestock producers and food system stakeholders will have to make significant investments in key sectors of animal agriculture, including dairy.

One major challenge of livestock development in Africa and other low- and middle-income countries (LMICs) the need to sustainably close a productivity gap which, in terms of milk production per cow (productive efficiency) is currently about 10-fold below the levels routinely achieved in Europe (FAOSTAT, 2019). Total milk production in Europe is approximately 231,977,327 metric tonnes, which is five times greater than the total milk produced in Africa (48,073,729 metric tonne) (ibid). Another major challenge is the potential negative environmental impacts of live-

stock and increased use of resources for agricultural production. Although livestock may have positive or negative impacts on ecosystems, the immediate locality and the wider environment and atmosphere, media and policy-maker attention currently focuses largely on negative impacts. According to the FAO (2013b), the livestock sector contributes 14.5% of global greenhouse gas (GHG) emissions, potentially exacerbating climate change and environmental variability. This is exacerbated by the relatively greater proportions of methane (CH_4) and nitrous oxide (N_2O) in the total GHG emissions from ruminant livestock, both gases being considerably more potent drivers of global warming than carbon dioxide. Inevitably and very importantly, an improved livestock sector therefore plays a crucial role in mitigating GHG emissions (Rojas-Downing et al., 2017).

The African dairy sector

The dairy sector in Africa involves three forms of systems; extensive, semi-intensive and intensive, which are also classified according to the type and level of inputs: as low, medium and high, e.g. an extensive system = low inputs; intensive = high inputs, etc. Dairy breeds within these systems may be exotic, indigenous or a mixture: exotic breeds utilised in Africa are mainly Holstein-Friesian[1] Jersey and Ayrshire, with very few Guernsey, Brown-Swiss or Dairy Shorthorn cattle. Indigenous breeds mainly consist of Zebu breeds, e.g. Indian breeds, Ankole, Tuli, N'Dama, Boran Watusi, Nguni and others, which vary in use depending on the dairy systems and geographical region. The productivity of indigenous breeds is relatively low, ranging from a minimum of 0.5 litres to a maximum of 6 to 8 litres per day, depending on disease prevalence, climatic conditions, availability of feed and water, lactation cycle and parity of cows (Brown, 1959; Bester et al., 2001; Ngono et al., 2018). By contrast, exotic breeds could perform at much higher levels, but often do not exhibit their full genetic potential in African systems due to abiotic and biotic stresses and less than optimal management conditions.

Adoption of exotic/indigenous crossbreeding in livestock improvement programmes has been a primary intervention to increase milk production and enhance other performance characteristics. Over the past two decades, various initiatives have attempted (with varying levels of success) to improve dairy productivity in Africa by establishing centralised dairy improvement programmes with support from development agencies and government-led efforts. These include (but are not limited to) the International Fund for Agricultural Development (IFAD), the FAO of the United Nations, United States Agency for International Development (USAID), Bill and Melinda Gates Foundation (BMGF), Jersey Overseas Aid (JOA), Heifer International (HI), and Land O'Lakes Venture 37® (formerly Land O' Lakes International Development) (Makoni et al., 2013; Chagunda et al., 2015). Centralised dairy breeding programmes have the potential to contribute to genetic improvement of exotic, indigenous or crossbred animals using open or closed nucleus breeding herds and have shown productivity levels comparable to those seen under research conditions. However, there has been limited consideration of and research into farmers' perceptions of the resulting cat-

1. In their purebred form, Friesian and Holstein cattle are distinct breeds and separately recognised as such, with phenotypic characteristics that lead them to differ in adaptability and behavioural responses to climate and management systems the world over. Since the 1980's the genetic influence in these Black and White coloured 'exotic' cattle will be strongly biased towards the Holstein breed. However, even today and throughout Africa especially, these Black and White coloured cattle are commonly referred to as Friesians, which does not accurately reflect the genetics they carry. By referencing many other papers this review reports on Friesian, Holstein and their amalgamated and more commonly found form, Holstein-Friesian. For the purposes of this review, we have assumed any mention of Friesian or Holstein more likely references their combined Holstein-Friesian form.

tle, the key traits and characteristics of different breeds, and the alignment of the breeding pro-grammes with researchers' interests. Uncoordinated efforts have also led to inconsistent decisions on breed choices, leading to a poor match between the chosen dairy breeds and herd management systems in terms of optimum production and resilience (Bhuiyan, 2017; Alilo, 2019).

The East Africa dairy system can act as a point of reference for various genetic improvement inter-ventions facilitated by non-governmental organisations and agricultural funding agencies and in line with national livestock development strategies. East Africa is the leading milk-producing region in Africa, accounting for 68% of the continent's milk output (ILRI, 2013). The dairy sector is one of the fastest growing agricultural sub-sectors in Eastern African countries, which has generated sig-nificant economic returns and employment opportunities along dairy value chains (Makoni et al., 2013). Kenya and Tanzania are among the biggest dairy producers in Africa, but other countries, including Rwanda (MINAGRI, 2019) and Uganda (FAOSTAT, 2019), are on a trajectory for in-creased dairy production to meet the demand (DDA, 2021). Although Ethiopia has the largest dairy cattle population in Africa, productivity remains low (Getabalew et al., 2019). For sub-Saharan Africa (SSA) in general, cow milk production is predominant, followed by goat milk, sheep milk and camel milk (Bingi and Tondel, 2015). Despite the encouraging progress in the East Afri-can region, the success of centralised dairy breeding programmes has been variable due to a lack of targeted breeding objectives and strategies that are relevant to specific production systems (Ojango et al., 2019).

The challenges facing dairy producers in Africa are numerous, complex and vary depending on countries, regions and management systems (Njonge, 2017; Opoola et al., 2019). Key challenges include (but are not limited to):

1. Poor animal health and husbandry
2. Unsupportive dairy breeding policies and unstructured breeding programmes
3. Inadequate dairy infrastructure and facilities
4. Limited farmer access to reproductive technologies and relevant inputs (such as cattle health products, cattle feed, fodder seed, etc.)
5. A lack of animal data and performance recording for effective genetic and genomic evalua-tions
6. Poorly defined or non-existent dairy value chains.

These challenges are exacerbated by somewhat outdated views on breeding policy based on West-ern notions of more extreme purebred dairy exotic breeds as being the most suitable for dairying across the continent, with a focus on peak daily milk yield rather than lifetime or annual milk yield and without reference to the limitations placed on cattle performance by often inadequate feed re-sources.

Interventions to improve dairy production in Africa have been underpinned by advanced genetic improvement technologies and related innovations, including:

a. The development of national dairy platforms and policies to guide governmental efforts
b. Strategic guidance through policies and support for animal tracing and performance data re-cording for efficient and sustained genetic progress
c. Development of multi-stakeholder value chains and commercialisation of dairy products.

For example, national dairy master plans were developed for various countries including the Rwanda National Dairy Platform Strategy of 2013 and the Rwanda Livestock Master Plan of 2017 (Shapiro et al., 2017a); the Kenya Dairy Master Plan developed in 2010 (Bingi and Tondel, 2015); Tanzania's National Dairy Master Plan starting in 2016 (Michael et al., 2018); the Ethiopia Dairy Master Plan between 2015-2020 (Shapiro et al., 2017b) and the Uganda Dairy Master Plan implemented in 2000 (Balikowa, 2011). Other African countries are still in the process of developing national dairy master plans, and in the meantime, implement other countries' strategies in heterogeneous forms (Bingi and Tondel, 2015).

Importing various exotic dairy cattle breeds either as live animals or through use of semen for artificial Insemination (AI) (and to a lesser extent the use of Embryo Transfer) to support cross-breeding has been the main driver for dairy genetic improvement. The exotic breeds used vary considerably in BW, milk yield and milk composition, but almost as much variation in seen within specific breeds as between breeds. In terms of exotic breeds most commonly utilised in Africa, the Jersey breed ranks second following the Holstein-Friesian (Bland et al., 2015). Jersey cattle were first imported into Africa via South Africa in the 1880s and have since been introduced to the majority of African countries. Although no records are available to support the exact date of the first Jersey importation into South Africa, it is generally accepted that the first Jerseys were imported by Mr. Adrian van der Byl of Roodebloem Estate, Woodstock, Cape, from Jersey Island, in the early 1880s (Willis, 2012).

The aim of this paper was to review the documented reports of the Jersey breed in Africa; and the suitability of the breed for a dairy profit index relevant for the future of Rwanda's dairy development programmes. We extended our review of available reports on the Jersey breed to various African countries to deliver on our main objective of providing relevant knowledge to support long term genetic improvement plans that could be customised to any targeted countries based on the productions systems, constraints, national policies and the local socio-economic development targets.

Jersey cows at Zaza Farm, Rwanda. Zaza Farm is owned by SACPP (Sustainable Agriculture Community Partnership Program) ltd

Methodology

This review was conducted using online and public domain databases including Web of Knowledge® (https://login.webofknowledge.com/), Google Scholar® (https://scholar.google.co.uk/) and Pubmed® (https://www.ncbi.nlm.nih.gov/pubmed/). A systematic search strategy was employed using the following search terms: "Jersey", "Jersey performance in low- and middle-income countries (LMICs)", or "Jersey for low-input systems", in conjunction with the name of any African country (e.g. "Jersey breed performance in Mozambique"). The search was narrowed down to only include references that reported on the distribution, occurrence, breed characteristics, performance (particularly with regards to dairy production) and the search terms as mentioned above for Jersey cattle in Central, Eastern, Northern, Southern and Western Africa. Information from grey literature and archives were made available from the Royal Jersey Agricultural & Horticultural Society (RJAHS), Rwanda Agriculture and Animal Resources Development Board (RAB), Land O' Lakes Venture 37® and personal communications and experiences from key livestock scientists and development experts. Additional printed documents in the forms of reports and historic written journals with relevant information on Jersey cattle (including their crosses with indigenous cattle breeds and the recorded performances) were also consulted from the RJAHS, online articles, newspapers and manually curated by the authors. For comparison, other references with information on Jersey cattle within Asia and Latin America were also considered. Descriptive statistics were calculated with R programme (R core team, 2015) to determine traits such as milk yield, AFC, calving interval, reproductive methods (AI and natural service) and BW for Jersey cattle across different African countries.

Results

Based on our analyses of the published and other literature and other findings (from personal communications and named contacts in some countries), the Jersey breed was reported as being present (either currently or historically) in at least 34 African countries, either as purebred cattle or crossbred with exotic or indigenous dairy breeds occurring at different genetic levels (ranging from 10% to over 80% Jerseys crossed with exotic and indigenous dairy cattle). The countries reporting Jersey cattle present within their dairy populations (although across many different management systems) included: Angola, Botswana, Burkina Faso, Burundi, Cameroon, Chad, Cote d'Ivoire, Democratic Republic of the Congo, Egypt, Eritrea, E-Swatini, Ethiopia, Gambia, Guinea, Ghana, Lesotho, Kenya, Liberia, Libya, Madagascar, Malawi, Mozambique, Namibia, Nigeria, Rwanda, Senegal, Seychelles, Somalia, South Africa, Sudan, Tanzania, Uganda, Zambia and Zimbabwe. Highlights from selected countries for which detailed reports were available are outlined below. Appendix Figure 1 shows the African countries where the Jersey breed was reported as being present or historically recorded, based on the references consulted. It is however, highly probable that there are many more countries where Jersey cattle are likely to be present, just not reported as so in peer-reviewed literature – it would not be surprising if Jersey cattle, or at least Jersey genetics, existed in all African countries.

The proportion of Jersey cattle relative to other dairy breeds in Africa

Although Jersey cattle are reported in many countries within Africa, there is a paucity of information on the proportion of Jerseys relative to other dairy breeds. Some data does exist for more countries with well-established dairy industries. Although a somewhat dated estimate, Staal et al. (2001) reported that, in Kenya, 6.5% of dairy cattle were Jerseys, compared to 51% Holstein-Friesian, 23% Ayrshire, 13% Guernsey, 3.8% indigenous breeds, 1% Brown Swiss and 1.7% crossbreds (both exotic and indigenous breeds). Furthermore, Banga and Maiwashe (2013) reported that the dairy cattle population in South Africa comprised 60% Holstein-Friesian, 35% Jersey, 1.1% Ayrshire, 1% indigenous breeds, and 0.9% Guernsey, with a small proportion (1-2%) of Holstein-Friesian X Jersey crossbreds. This difference in cattle populations may reflect the relative intensification of dairy production in South Africa compared to other African countries. However, genetic parameters such as; estimates for desirable and heritable traits, genetic correlation, genomic diversity and population structure have also been reported for Brown-Swiss and some Indigenous breeds in South Africa (de Ponte Bouwer et al., 2013; Makina, 2015). The proportion of Jersey cattle within national dairy populations relative to other breeds, across African countries other than Kenya or South Africa were not readily available at the time of carrying out this review, with no cited or reported information available in public domains.

F1 Jersey x Ankole cattle at RAB Songa Station (2006)

This lack of clarity on the extent of the Jersey population by country is a challenge which could be addressed through improved data recording, monitoring and publication of Jersey cattle use in Africa's dairy management systems. However, documented production and reproduction performance traits for other dairy breeds exist (Table 1), with cited and documented average (±standard deviation) performances of the Jersey breed amongst other dairy breeds in Africa (Table 2). Table 2 shows favourable estimates demonstrating a Jersey and Jersey cross-breed advantage in pooled data analysed across the breeds for fertility traits such as; average number of completed lactations, age at first calving, first calving interval, average calving interval, number of inseminations per conception, feed efficiency and survival traits. Although pooled data for milk production and lifetime milk yield was not always most favourable in Jersey / Jersey-cross data compared to the Holstein-Friesian and Guernsey breeds, the data suggested that Jerseys and their crosses were more likely to be more fertile, survive longer and complete more lactations over their lifetime than the other dairy breeds in most African dairy systems.

Phenotypic characteristics of Jersey dairy cattle

Based on data from other parts of the world, on both references and other materials consulted, compared to other dairy breeds the Jersey breed is reported to be hardy, resilient and well-adapted to both a wide range of climatic and geographical conditions (Hilton and Briggs, 1980; Berry and Buckley, 2016) and, possibly more importantly, to a range of production systems. Morphologically, the Jersey breed appears in varied colours of dark brown to light brown, including strains that show white patches. The patches of white hair and lighter skin pigment (known as 'broken coloured') make these strains less well adapted for hotter climatic conditions due to greater susceptibility to certain cancers with increased sun exposure, and targeted breeding programmes tend to minimise the prevalence of these coloured cattle in the population. All Jersey cattle have a characteristic black muzzle, surrounded by a mealy coloured band of hair, plus almost always hard black hooves. These hard black hooves assist greatly in minimising incidence of locomotion issues, especially where cattle are kept on concrete or other hard surfaces or where feet stand in small enclosures for long periods of time predominantly due to low housing spaces, poorly managed surfaces, with heavy rains causing soil erosion and sloping into where these cattle are kept. Naturally inquisitive by nature, the breed's lack of timidity enables them to co-exist with much larger cattle, where they often dominate the social order. In a mixed herd, this allows them to obtain a greater share of feed and other resources (e.g. preferred sites for lying or first entry/exit from the milking parlour). Although this is not necessarily an advantage in African systems *per se,* it means that Jerseys may out-compete other breeds within the herd when resources are relatively scarce, as may occur in smallholder systems.

A East African smallholder farmer with her two cows, one a Holstein Friesian x and the other a near pure Jersey. The difference in size alone, passed down from these two breeds, is obvious, as is the impact on their maintenance requirements

Jerseys are the smallest of the common exotic dairy breeds, generally weighing between 380 and 450 kg, though more modern strains developed in the western hemisphere are larger, weighing up to 550 kg. The relatively lighter weight of Jersey cattle compared to many other breeds is again an advantage in African systems. Cattle require a certain quantity of nutrients each day simply to remain alive and maintain normal bodily functions (the "maintenance" requirement) – this requirement must be fulfilled before they can partition any extra nutrients into pregnancy, milk production or growth. A smaller animal needs less feed to maintain herself and is therefore more able to produce milk under conditions where feed resources may be limited, then her heavier counterparts. This also has environmental benefits as, per kg of milk produced, Jersey cattle have lower GHG emissions and require fewer total resources (Capper and Cady, 2012). An in-depth review of the impact of the Jersey breed in terms of its performance and adaptability in an African manage-

ment system, along with a genetic evaluation, was first carried out in Tanzania by Mahadevan and Hutchinson (1964). Given, however, that this paper is over 50 years old, a modern review would be of considerable value.

Milk nutrient content, daily milk yield, annual milk yield and lifetime milk yield

The lifetime productivity of Jersey cattle will vary considerable depending on genetic merit, production system feed availability and quality, health, and overall performance in different global regions. Although Jersey cows may produce less total milk on a daily basis than, for example, Holstein-Friesian cattle in European or North American systems, the increased milk solids content and resilience of the breed has significant impacts at the lifetime level, particularly in tropical or subtropical systems. For example, Krishanender et al. (2014) reported that lifetime productivity (whether measured as daily milk yield, annual milk yield or lifetime milk yield) was higher in pure and crossbred Jerseys than in other exotic or indigenous breeds in sub-temperate systems. Furthermore, Jersey cows have been reported to demonstrate significant increases in lifetime daily yield (Boothby et al., 2020), AFC and survival rates (Buckley et al., 2014) compared to Holstein-Friesians in UK production systems. The proportion of days in milk over the total lifetime and the herd life of Jersey cattle were also increased compared to Holstein-Friesian, Brown-Swiss and Guernsey breeds (P< 0.01) in a study published by Garcia-Peniche (2004) incorporating seven regions in the United States. With regards to Jersey crossbred cattle, Effa et al. (2013) reported a significant increase in the lifetime yield of F_1 offspring of Jersey x Boran cows (13,546.5 (± 812.3) litres) compared to F_1 Holstein-Friesian x Boran cows (12,816.7 (± 817.0) litres), although this study was conducted in Ethiopia and therefore does not necessarily represent all differences in the performance of all F_1 crossbred offspring across the globe. The estimates for productive life, herd life, and AFC were also reported as more favourable for F_1 Jersey x Boran crossbreds than in the F_1 Holstein-Friesian x Boran crossbreds (ibid). However, after the F_1 offspring, it is difficult to ascertain the genetic capacity and potential for milk yield and productivity of subsequent generations, as the Jersey genetics may be diluted out or affected by other breeds within the population.

Although significant yield increases have been seen for Holstein Friesian cattle over time in temperate zones, studies in other regions have shown differing results. For example, gradual and steady annual increases in total milk production in Jersey cows were greater than the increased observed in Holstein-Friesian cattle in the tropical region of Oman, with the highest daily milk yield occurring in the second and third lactation for Jersey cows and third and fourth lactations for Holstein-Friesian cows (Alqaisi et al., 2019). Similarly, Wangdi et al. (2014) reported a significant increase in daily milk yield for pure Jerseys and crossbreds relative to other exotic dairy and Asian indigenous dairy breeds raised in Bhutan in South Asia. Milk yields from Jersey cattle are in excess of 13 times their BW per lactation (David Clarke Livestock, 2021), a remarkable feat of efficiency given the increased milk fat and protein concentrations compared to other dairy breeds. For example, Bland et al. (2015) noted that Jersey milk contained 18% more protein, 25% more fat and 20% more calcium than milk produced from other dairy breeds. This increase in milk solids content contributed to the greater cheese yield per kg of Jersey milk (compared to Holstein-Friesian milk) cited by Capper and Cady (2012) and therefore to improved production efficiency and reduced environmental impacts in North American production systems. This is of obvious importance

from a food security and sustainability perspective within Low and Middle Income Countries (LMIC), as improving the nutritional status of some of the world's poorest people leads to myriad health, development and social benefits (FAO, GDP and IFCN, 2018).

Resistance to climate extremes is a key element of suitability for African production systems, with the most valuable cattle able to maintain productivity despite variation in temperature or humidity. A report by Phillips (2014) comparing heat stress responses in Jerseys and Holstein-Friesian dairy cows raised near the Mooi river of South Africa showed that, during the warmer months, Jersey cows exhibited a 5.35 litres/cow/month reduction in total milk production compared to 5.76 litres/cow/month in Holstein-Friesians, despite the higher genetic merit of the Holstein-Friesian cows. Moreover, the milk yield of Jersey cows in their 10th lactation was 6.6% higher than in their first lactation; whereas for Holsteins the milk yield was 14% less than that of their first lactations, showing a remarkable yield persistence and improvement over time.

Fertility traits and impact on age at first calving

Fertility and reproductive traits are crucial to the success of any dairy production system, not least because from a biological perspective, cows must produce a calf in order to lactate. From a lifecycle and efficiency point of view, as discussed earlier, the Jersey often has an advantage over larger breeds in terms of spending a greater proportion of her total life in lactation. This is facilitated by an earlier age at puberty, better detection of oestrus behaviour, an early AFC and an optimised calving interval, with a dry period that is suited to the herd and system. Traditionally, a 12-month calving interval has been considered to be ideal in many intensive dairy systems, yet in dairy systems where feed or forage is limited, there may occasionally be some benefits to extending lactation if this results in a successful conception and pregnancy. The bulk of the literature surveyed reported that purebred and crossbred Jersey cows reach puberty at an earlier age (Berry and Buckley, 2016), which may be a function of their smaller body size and therefore relatively higher body fat at a given age compared to larger-framed cattle. However, reproductive performance after puberty was also cited by Berry and Buckley (2016) as being improved in Jersey cattle, with higher pregnancy rates, an earlier AFC and a reduced calving interval compared to other exotic or indigenous breeds. Conception rates and the number of inseminations per conception were also cited as improved in Jersey cattle, compared to other dairy breeds – for example, Kasbergen (2013) reported that Jersey cows exhibited higher overall conception rate (CR) of 32% vs. 29% CR for Holstein cows raised in the hot and dry climate of California, USA.

The excellent fertility attributes of the Jersey breed increase profitability of annual and lifetime milk production, longevity and number of subsequent calvings, as well as decreasing the time and impact on-farm resources. Garcia-Peniche (2004) analysed fertility traits in Jersey cattle compared with other breeds in herds across multiple geographic and climatic regions of the USA and reported that in herds with a single breed of cattle, AFC in Jerseys averaged 784 (±97.5[2]) days, compared with 855 (±98.5) days for Brown Swiss and 814 (±95.7) days for Holsteins. In addition, the mean first calving interval in Jersey herds, measured in seven geographic regions, ranged from 390 (±5.1) days to 426 (±5.6) days, in comparison with a range across the same regions for Holstein herds of 409 (±3.4) days to 461 (±4.9) days.

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2. Standard Error

Evaluations of the performance of the Jersey breed in Africa by Opoola et al. (2020) also reported lower mean AFC in Jerseys compared with Holsteins in data from Kenya (909 days (± 31.44) for Jerseys vs 972 (± 3.93) for Holsteins) and from South Africa (861 days (± 1.21) for Jerseys vs 873 days (± 1.02) for Holsteins). In the same analysis, Jerseys also exhibited shorter mean calving intervals compared with Holsteins in both Kenya (457 days (± 28.77) for Jerseys, vs. 475 days (± 6.12) for Holsteins) and South Africa (405 days (± 0.88) for Jerseys vs 429 days (± 0.85) for Holsteins). Effa et al. (2013) in studying Jersey crossbreed performance in central Ethiopia found F1 Jersey x Boran showed a mean AFC of 38.8 months (± 0.6) compared to 44.02 months (± 0.7) in F1 Friesian x Boran crosses. Hunde et al. (2015) also observed a mean AFC of 29.9 months (± 0.17) in pure Jersey cattle studied over a 24-year period at a site in close proximity in the Central Highlands region to the site of the Effa et al. (2013) study. Mostert et al. (2010) also showed decreases in the annual calving interval in Jersey cows (0.50 days/year) compared to increases in Holstein-Friesians (1.25 days/year), Ayrshire (0.71 days/year) and Guernseys (0.57 days/year). These would be expected to improve overall productivity and are thought to have been due to the inclusion of calving intervals and AFC standards in the selection of bull dams implemented by the South African Jersey breed society (Jersey SA) since the early nineties in South Africa's dairy breeding programme (Mostert, 2010).

Survival and longevity

The literature reviewed within this study showed that, compared to other breeds, Jersey cattle had improved survival-related traits in terms of longevity, herd life, the number of completed lactations and total days in milk. The longevity of dairy cattle attracts a great deal of debate worldwide, as there is no "ideal" number of lactations for a cow to complete within her lifetime. The low number of lactations (1-3) completed by many cows in intensive systems attracts criticism, yet some researchers claim that keeping a cow for extended periods of time reduces the opportunity to make genetic gains. The decision of when to cull a cow is often based on economic factors. Therefore, a breed like the Jersey, which is able to maintain productivity and stay in the herd for longer than other breeds, is of obvious economic and environmental value, as well as mitigating consumer concerns about cows being culled at relatively young ages. This is particularly important in smallholder systems in Africa as these cows are often the main source of income, status and high-quality protein, therefore there are obvious economic, nutritional and social benefits to increased longevity. For example, Muller and Waal (2016) showed improved longevity and survival of first lactation cows to the fifth lactation at 34% for Jersey cows compared to 23% for Holstein cows bred in the Western Cape of South Africa.

The effect of breed on longevity is not confined to African systems: research from the USA by Garcia-Peniche (2004) compared multiple longevity traits in herds of different breeds across geographic regions and reported increased average days of completed lactation in purebred Jersey herds of 633 (±291) days vs. pure Brown-Swiss with 554 (±280.2) days and pure Holstein herds with 592 (280) days. Jerseys also averaged increased survival rates in the herd up to five years of age; 0.45% (±0.5) in pure Jersey herds vs 0.38 % (±0.49) in Holstein herds and 0.42% (±0.49) in Brown-Swiss herds.

Jersey crossbreds have also been demonstrated to perform favourably for longevity traits in tropical countries (Adaneye 1985; Gebregziabher and Mulugeta, 2006; Effa et al., 2013; Hunde et al.,

2015). In the tropical highlands of Ethiopia, F1 Jersey x Boran crosses studied for longevity traits by Effa et al. (2012) showed significantly longer mean total life (4270 days (± 135)), herd life (3108 days (± 147)) and productive life (2387 days (± 126)) when compared with F1 Friesian x Boran crosses with a mean total life of 4200 days (± 135), mean herd life of 2877 days (± 148), and mean productive life of 2145 days (±127). F1 Jersey x Boran crosses also showed higher mean lifetime milk yield in litres (13547 (± 812), compared to 12817 (± 817) for F1 Friesian x Boran), though mean total milk yield in terms of litres per day of total life was broadly comparable at 3.04 litres (± 0.2)[3] in F1 Jersey x Boran crosses vs. 3.00 litres (± 0.2)[4] in F1 Friesian x Boran crosses.

Ease of calving and calf mortality

Jersey heifers exhibit significant calving ease, require minimal assistance while calving, and have low calf mortality compared to other breeds (Dhakal et al., 2013). There is information suggesting that Jerseys are disease-resistant, thermo-tolerant and well adapted to challenges of the tropical environment, including limited water, sub-optimum nutrition, pests' infestation, vector-borne diseases, heat, and other issues. Additionally, Jersey cattle are known to adapt well to many types of climate, environment and management practices (Yoo et al., 2019).

Dhakal et al. (2013) observed improved ease of calving in pure Jersey, Jersey x Holstein and Holstein x Jersey crosses, and other Jersey crosses (>50% JJ) in comparison with pure Holsteins and other Holstein crosses (>50% HH), in a study based on a pasture-based system in the USA. Pure Jerseys required calving assistance in only 7.5% of births from primiparous cows and 3.4% of births from multiparous cows, with Jersey crosses (>50%) requiring assistance in 8.3% of births from primiparous cows and 5.6% of births from multiparous cows. In comparison, calving difficulties were more common in pure Holsteins (21.6% of births from primiparous cattle and 7.2% from multiparous), and in Holstein crosses (>50% HH) with 12.9% of primiparous births and 7.9% of multiparous births requiring assistance respectively. Crossing Jerseys directly with Holsteins also had a significant effect with assistance required in 8.8% (HJ) and 8.6% (JH) of births from primiparous cattle and 3.8% (HJ) and 4.8% (JH) of births in multiparous cattle. Calf mortality was also significantly lower in pure Jerseys (12.5% in primiparous cows and 5.6% in multiparous) compared with pure Holsteins (15.7% and 12.9% respectively). With reference to the tropical environment, it would therefore appear that the Jersey is a suitable breed to help reduce the impact of genotype-by-environment (or GxE) interactions exhibited by other exotic dairy breeds currently used for dairy production systems in Africa; genotype-by-environment being defined as when two different genotypes respond to environmental variation in different ways. Finally, the Jersey breed would appear to give the fastest returns and profit by five years of age and overall performance in fertility, survival and management traits analysed for Jersey than other exotic dairy breeds (Garcia -Peniche, 2004).

3. Not significant

4 . Not significant

Feed efficiency, milk per unit of bodyweight and milk per unit of dry matter intake

Jerseys are efficient at converting feed into milk, which means that Jersey cows can produce a significant volume of milk per kg of DMI. This is a major advantage in terms of overall dairy sustainability, as feed efficiency has been cited as one of the key determinants of GHG emissions and resource use (Thoma et al., 2013), as well as farm profitability. Carroll et al. (2006) reported that Jersey cows produced more fat corrected milk (FCM) and solids corrected milk (SCM) per kg of DMI than the Holstein and Brown-Swiss breeds.

Jersey cattle feeding on maize forage in Mozambique

This was due to the greater efficiency of milk fat production per unit of DMI within Jersey cattle. In addition, Sneddon et al. (2011) stated that feed conversion efficiency (FCE) estimates, measured as grams of milk solids (milk fat plus milk protein) per kilogram of DMI were also higher in Jersey (112g MS/kg DMI) than Holstein-Friesian cows (97 g MS/kg DMI). Sneddon et al. (2011) further showed that Jersey cows have significantly higher DMI per kilogram of BW compared to Holstein-Friesian and F_1 of Holstein-Friesian x Jersey cows (3.81, 3.23 and 3.64 g DMI/kg BW, respectively); a result echoed by Beecher at al. (2013). The small-framed Jersey has a lesser maintenance requirement than her larger-framed herd mates, therefore her increased feed intake per unit of BW means that she can partition a greater proportion of feed nutrients into milk production.

This is referred to as the "dilution of maintenance" effect, whereby, as milk yield increases, the maintenance nutrient requirement is spread over the greater volume of milk, and therefore the nutrient use per kg of milk is reduced. This has significant environmental consequences, as discussed later in this report.

The greater milk fat yield of Jersey cows also has been linked with improved heterosis for milk fat yield genes in Jersey crossbreds, compared with other dairy breeds. Improved heterosis for fat yield percentage has been reported for Jersey x Boran crossbreds (5.10±0.15%), by contrast to purebred Holstein-Friesian (4.77±0.03%) and Boran cattle (5.01±0.03%) under Ethiopian conditions (Hunde, 2019). This is an obvious advantage in terms of the role of milk nutritional composition in providing high-quality nutrition to smallholders and their families, but also in terms of commanding a greater price for milk sold for processing or consumption off-farm.

Environmental impacts and sustainability of the Jersey breed

Jersey cattle exhibit a number of positive attributes in terms of productivity and efficiency, yet for a truly sustainable future, dairy producers must ensure that they have an economically viable, environmentally responsible and socially acceptable system in place. Although there is no "one size fits all" dairy system or collection of management practices that will result in sustainability for all farmers, the better an individual cow or herd can perform, the more sustainable it is likely to be. In this context, sustainability means using fewer resources (feed, land, fertilisers, fossil fuels) and having a lower carbon footprint (kg of GHG) per kg of solids-corrected milk. This should also result in a relatively lower cost of production, which is obviously crucial for current and future economic viability, particularly in smallholder systems. Given that the concept of sustainability is a crucial discussion topic for all food systems stakeholders, any system that measures, benchmarks and demonstrates improved sustainability is also likely to gain greater social acceptability – the third and, in some ways, the most difficult pillar to achieve. This is an obvious challenge in LMIC, where smallholders often lack access to the technological resources or infrastructure to assess the sustainability of their operation. Facilitating ways to measure and benchmark sustainability metrics on smallholder operations is therefore an important knowledge gap, which warrants significant investment.

The sustainability of dairy systems has been investigated by multiple authors with regards to genetics, nutrition, management and farming system, yet the data relating to sustainability of specific cattle breeds is relatively lacking in the literature. The one exception is a paper by Capper and Cady (2012) which compared the environmental impacts of Jersey vs. Holstein cattle under typical U.S. management systems.

Supplying drinking water and other resources is a key sustainability consideration

The study, a modelling exercise using publicly available data, quantified the resource use and GHG emissions associated with producing the milk required to yield 500,000 t of cheese. Although Jersey cows had a lower daily milk yield than Holsteins (20.9 vs. 29.1 kg), the increased milk solids content and therefore cheese yield (8.0 kg milk per kg cheese for Jerseys, compared to 9.9 kg milk per kg cheese from Holstein milk), in combination with a lower mature bodyweight (454 *vs.* 680 kg), calving interval (13.7 *vs.* 14.1 mo), and age at first calving (25.3 *vs.* 26.1 months) coupled with improved longevity (3.00 *vs.* 2.54 lactations) meant that the Jersey cows had a greater productive efficiency than their Holstein counterparts. Consequently, per kg of cheese yield, feed use was reduced by 19.8%, land use by 18.9%, water use by 31.6%, and the GHG emissions were 20.5% lower when milk from Jersey cattle was used rather than Holsteins. Although it was not quantified within the paper, the reductions in resource use per kg of cheese would also be expected to improve economic viability of Jersey compared to Holstein systems. It could be argued that the difference between Jersey and Holsteins might be less pronounced in a U.S. intensive system than in some of the far more extensive African conditions described within this review, there

Jerseys on the move at Anglesea Farm, Zimbabwe

-fore differences in the impacts described by Capper and Cady (2012) might be greater under tropical or sub-tropical conditions. This underlines the potential suitability of Jersey cattle as a means to improve dairy sustainability across the globe.

At present, smallholder systems are significantly disadvantaged when GHG emissions are used as the sole metric of assessing sustainability, as global analyses have reported that regions containing a high proportion of smallholder farming systems have greater carbon footprints per kg or ton of milk, meat or eggs (FAO, 2010; MacLeod et al., 2013; Opio et al., 2013). The current global standard for assessing greenhouse gas emissions is prescribed by the Intergovernmental Panel on Climate Change (IPCC, 2019) using three different types of calculations (Tiers I, II and III) to assess GHG emissions, depending on data availability. Tier I require the most basic data (total livestock numbers multiplied by a default emissions factor per head) and is used in many LMICs because it is the easiest to apply. However, the default values used are based on intensive systems within developed regions, which cannot necessarily be applied to different systems or breeds (Leitner et al., 2021). More appropriate and accurate methane emissions factors must be calculated to be used on farms in LMICs, considering the efficiency and productivity benefits of Jersey cattle, in order to accurately assess the implications for GHG emissions for smallholders.

How the Jersey breed is contributing to dairy development across Africa: Highlights from selected countries

From the literature consulted, we grouped key dairy cattle performance characteristics reported in each country under the following areas to aid comparisons; a. Milk production (Milk nutrient value, daily milk yield, lifetime milk yield and annual milk yield); b. Fertility traits and AFC; c. Survival and longevity, d. Production efficiency (Feed efficiency, milk per unit BW and milk per unit DMI and e. Disease incidences. Findings on the performance of Jerseys across regions of Africa are summarised in the following sections.

Eastern Africa

Ethiopia: In addition to pure Jerseys, the performance of Jersey x Horro (local) and Jersey x Arsi (local) crossbreds have been reported in Ethiopia: Kebebe et al. (2011) showed that Jersey X Horro indigenous crosses raised in the sub-humid area of Bako, Ethiopia had slightly improved estimates of 1.97 for the number of services per conception (NSC) compared to an NSC of 2.0 for the local Horro breed. Similarly, Njubi et al. (1992) reported that environment and diverse management systems had a significant negative impact (P<0.01) on milk output and reproductive performance of purebred Jersey cattle but was still of minimal impact compared to the effects of environment and diverse management systems reported for other dairy breeds (Effa et al., 2013; Hunde, 2019). Demeke et al. (2003) reported more favourable heterosis estimates for fertility traits (P<0.05) in F_1 offspring of Jersey x Boran (AFC; 35.4 (±0.5) months, CI; 408.0 (±6.0) days, DD; 123.0 (±7.0) days and NSC; 1.31 (±0.04) than in the F_1 offspring of Friesian x Boran: AFC; 36.0 (±0.40) months, CI; 417.0 (±6.0) days, DD; 133.0 (±7.0) days and NSC; 1.49 (±0.04). The AFC was significantly lower and therefore more favourable across F_1 and F_2 Jersey crossbreds than in the Friesian crossbreds (P<0.05). Effa et al. (2013) also showed significantly longer herd-life for F_1 offspring of Jersey x Boran (3,107.53 days) as compared to F_1 offspring of Friesian x Boran (2,876.99 days); and noted in Holetta, Ethiopia, that the herd-life of ¾ Jersey x ¼ Boran crossbreds (2,717 days) was close to F_1 Friesian x Boran crossbred (2,877 days). Also, better estimates for AFC and CI were obtained for crossbreeds at different levels (15-75%) for Jersey x Arsi indigenous cattle than Friesian x Arsi crossbreds, both fed on a similar pasture feeding regime, as used in the central highlands of Ethiopia. Again, higher estimates were recorded for milk yield and cow BW in Jersey x Arsi crosses (Kiwuwa et al., 1983). Recent findings by Hunde (2019) reported improved heterosis for milk components and feed efficiency for Jersey x Boran crossbreds than in Holstein-Friesian x Boran crossbreds (P<0.05).

Kenya: The Jersey breed is one of the key breeds presently used for dairy production in Kenya (Odero-Waitituh, 2017) and employed as crossbreds with the Local East African Zebu (EAZ) cow (Omore et al., 1998; Kibiego et al., 2015). The average live weight of a pure Jersey cow in Kenya is about 350 Kg with a potential daily yield of 20 litres and 6.3% butterfat (Kangethe, 2020). The main method of reproduction for crossbreds is via artificial insemination (AI) (Odhiambo, 2016). These crossbreds are also known to be productive in terms of improved milk production, for example, Meyn & Wilkins (1974) reported improved lactation milk yield (kg) in Jersey x Sahiwal crosses (1583 (±381) kgs) vs pure Jersey cattle (1278 (±328) kgs) kept at a well-managed farm in high potential climatic conditions. In contrast, the same study reported that pure Holstein-Friesian cattle outperformed Holstein-Friesian x Sahiwal cross cattle in the same measure, though on a farm under more arid conditions.

Local Borena cattle are crossed with the Jersey to supply improved F1 cows for smallholder farmers in Project Mercy's development programme in Ethiopia

Rwanda[5]: The Rwandan cattle population was estimated at approximately 1.37 million head in 2019 (MINAGRI, 2020a) and estimated to be composed of indigenous breeds of Ankole, Inyambo and Inkungu (41%), exotic breeds (6%), and crossbreds of indigenous and exotics (51%) (Shapiro et al., 2017a). Jersey cattle were first introduced to Rwanda in the 1950s at the Station of INEAC (Institut National pour l'Etude Agronomique du Congo-Belge et Ruanda-Urundi) in Nyamiyaga, Nyanza, in the Southern province of the country. The herd later formed the base population of the Songa Research Station operated by the Rwanda Agriculture and Animal Resources Development Board (RAB; Rutinywa and Van Pee, 2016). It is believed that Jersey and Sahiwal cattle were the first exotic genetics to be imported to Rwanda, in an attempt to improve milk production in the indigenous cattle (Wilson, 2018). As an example, a personal communication from Dr Justin Zimulinda to the authors reported that farmers in Nyanza and nearby Huye District settlements of Songa were keeping Jersey cows from the 1960s onwards. Currently, the Jersey cow is common across Rwanda and highly valued amongst those aware of the breed for her adaptability to the local environment and scarce feed resources compared to other exotic (and high-resource-demanding) cows like the Holstein-Friesian, which is still the most common exotic and exotic-cross dairy cow in Rwanda (MINAGRI, 2019).

The Rwandan dairy industry has grown significantly in recent years with milk production rising from 372,619 metric tonnes in 2010 to 864,252 metric tonnes in 2019 (MINAGRI, 2020a) mainly due to increased use of bulls of the Jersey and Holstein-Friesian breeds through AI; distribution of female Holstein-Friesian and Jersey Crossbreds to smallholder farmers, as part of the Girinka[6] programme, and improved animal nutrition and husbandry practices. Rwanda is also seeking to in-

5. Expanded detail is provided in this section on Rwanda owing to the current interest and involvement of the authors in the development of the Rwandan dairy sector
6. Government of Rwanda dairy development initiative aimed at improving the livelihoods of poor families through sensitisation and training to dairy farming and the donation or 'passing on' of a dairy heifer within local communities. Translating from the local language of Kinyarwanda into

crease the number of Jersey breed cattle accessible for dairy cattle improvement projects, especially males for use at semen collection centres, and has been active in the use of bovine embryo technology. With comparison to previous data in recent years, MINAGRI reported a notable improvement in embryo transfer conception rates, from 25.49% in 2018 to 34% in 2020 (MINAGRI, 2020b).

As part of the Girinka programme, more than 1,200 Jersey cows and heifers have been imported since 2001 and eight Jersey bulls imported for semen production since 2007 (cattle import data, RAB). From 2008, more than 190,000 Jersey semen doses have been secured by RAB and used in AI across the country. In addition, owing to a long-term partnership between the Government of Rwanda and the Island of Jersey, close to 375,000 Jersey semen doses have been supplied to Rwanda since 2005 (RAB semen production and imports data; MINAGRI, 2020b). Currently, there are about 799,000 crossbred dairy cattle in Rwanda and it is projected that the number will increase to 1.17 million by 2022 representing an increase of 46%, while milk production is projected to grow from the 747 million litres of milk produced in 2017 to an estimated 2.2 billion litres by 2022, an 18.2% boost. The rise in both the number of dairy cattle and milk production volume is predicted to increase the contribution of the dairy value chain to the national gross product to about 55% (Mutesi, 2020).

The population of Rwanda's dairy cattle is diverse and the level of productivity is difficult to ascertain due to different levels of crossbreeding and the divergent management systems in which the animals are kept. In general, there are still no published or documented studies comparing different cattle genotypes in Rwanda as regards to their adaptability, milk production and quality, feed efficiency, grazing ability or cattle farming benefits to indicate which breeds or genotypes are more appropriate to specific production systems. A study on factors affecting growth traits of different cattle genotypes in Rwanda kept on a grazing system revealed that Jersey and Sahiwal breeds crossed with indigenous cattle were more resilient to environmental pressures as their weaning weights did not fluctuate across season nor in different years compared to Friesian and Brown Swiss crosses (Manzi et al., 2012). Recent studies by Chagunda et al. (2018) evaluated the genetic diversity and population structure of dairy cattle in Rwanda smallholder dairy farm systems. The results so far obtained and further studies could help in assessing the role of genotype in environmental interactions and demonstrate the gene flow of Jersey cattle genetics in the Rwanda cattle herd and the tropics.

Sudan: There are limited reports on other dairy breed activities but no publications available for the performance of the Jersey breed in Sudan. Exotic (Holstein-Friesian, Ayrshire and Guernsey) breeds were crossed through AI and natural mating with Butana females at the Ghurashi farm in North Sudan (Osman and Russell, 1974). Crossbreds (F$_1$) of 50% exotic and 50% local/indigenous genetic blood exhibited heterosis in terms of improved performance for milk yield, AFC and first calving interval (CI1) compared to the local stock (Osman and Russel, 1974; Cunningham and Syrstad, 1987), suggesting that these may confer sustainability advantages, although these publications are dated and more up-to-date analyses are required to draw firm conclusions.

Tanzania: In Tanzania, crossbreds obtained from backcrossing and line crossing of Tanzanian local Mpwapwa breed with Jersey, Ayrshire and Friesian breeds had a significant decrease in AFC, CI1 (first calving interval) and increased milk yield (MY) due to *Bos taurus* inheritance when compared to the pure Mpwapwa breed cattle (MacFarlane, 1971; Mkonyi, 1982). Shekimweri (1982) reported preliminary analysis for AFC, MY and CI1 of Sahiwal cows crossed with Jersey, Ayrshire and Friesian breeds via AI in Tanzania. Although 50% Friesian x 50% Sahiwal cows out-yielded the Jersey and Ayrshire crosses, the 50% Jersey x 50% Sahiwal crosses showed more favourable CI1 (398 (±24) days) than in 50% Ayrshire x 50%Sahiwal (423 (±27) days) and the poorest was in 50% Friesian x 50% Sahiwal (429 (±42) days). Mahadevan and Hutchison (1964) showed that crossbreds ranging from 25% to 75% *Bos taurus* inheritance produced twice as much milk as when bred from the East African Zebu Bull. The 50% *Bos taurus* group produced higher milk yield than 25% and 75% groups; and Friesian crosses out-yielded the Guernsey and Jersey crosses. However, Moyo and Mpofu (1998) showed that although the Jersey breed is lesser in terms of BW and milk quantity, they are more able to tolerate the production conditions and resource limitations in the small-scale sector. The Jersey F_{1s} have shown to be superior to purebreds for milk yield, survival and stayability in the herd than other exotic dairy breeds (Shekimweri 1982; Nouala et al., 2003). Amongst other crosses found in Tanzania, Jersey x Tanganyika Shorthorn Zebu (TSZ) can also be identified.

Jersey heifers grazing on maize stubble in Tanzania

Western and Central Africa

Cameroon: In the late 1980s Heifer Project International (HPI) and the Cameroonian government signed an agreement to support the importation of Jersey and Holstein-Friesian cattle and germplasm (HPI, 1999). Importation of exotic dairy cattle resulted in the development of more specialised dairy farming systems for the optimisation of milk yield among crossbreds. Crossbreds managed in the western highlands of Cameroon; produced from both natural mating and AI from European sires (Holstein-Friesian and Jersey) with indigenous cattle (Gudali, Red Fulani and White Fulani) exhibited more favourable reproductive traits amongst the Jersey crosses than for the Holstein-Friesian crosses (Djoko et al., 2003). As reported by Wilson (2018), HPI were supporting and training dairy farmers in practising a zero-grazing system as a means of reducing management and input costs incurred from feeds. However, dairy productivity remains low, with dairy practices being carried out on a small scale due to the effects of the environment (including high temperature, humidity, and presence of tick-borne and other diseases) on the genetic performance of the crossbreds.

Ivory Coast: In the Ivory Coast, crossbreeding between N'Dama and Jersey cattle started at the Centre de Recherches Zootechniques de Bingerville in 1962 and continued for 15 years (Charray et al., 1977). The objective of the crossbreeding research was to create a dairy breed adapted to the climatic conditions and husbandry in the country. However, no testing of the crossbreeding concept under farm conditions had been initiated when the programme was terminated due to financial problems in 1977. Letenneur (1978) explored the same data and reported on the performance of crossbreds from indigenous N'Dama cows produced via AI with the Jersey breed. Backcross to Jersey (75% Jersey x 25% N'Dama) produced 15% more milk than F_1 (50% Jersey x 50% N'Dama) but slightly lower fat content. Although milk yield increased with subsequent lactations, mortality was higher in cattle closer to pure-state Jersey, possibly as a result of lesser adaptability to the environment compared to N'Dama cattle or Jersey x N'Dama crossbred cattle in traits such as tick-resistance. There appears to be no documentation on the performance of the Jersey breed after the year 1978.

Nigeria: Fayeye et al. (2013) reported that although mean milk yield and milk protein was significantly higher in Holstein-Friesians than Jerseys (P<0.05) managed in the tropical climate of Nigeria, the Jersey breed had significantly higher (P<0.05) milk fat, solids-not-fat, total solids and lactose. In addition, two Nigerian indigenous dairy breeds; Sokoto Gudali and Bunaji (White Fulani) are reported to have excellent characteristics that could adapt well when crossed with exotic breeds, for improved manageability in smallholder input systems (Tawa and Rege, 1996; Mbap and Bawa, 2001).

The Gambia: The Gambia constitutes an ecological niche for tsetse flies (i.e. *Glossina morsitans submorsitans* and riverine *G. palpalis gambiensis*), therefore the use of crossbreds of exotic cattle with the N'Dama cattle that are naturally trypano-tolerant has been promoted, (Diack et al., 2005), rather than the use of pure exotics. Crosses found in the Gambia include Jersey x Holstein-Friesian and Jersey x Indigenous (N'Dama breed), with the use of Jerseys in crossbreeding programmes employed to improve milk production in the country. The mode of crossbreeding is to AI indigenous cows (i.e. N'Dama cows) using deep-frozen semen of European dairy breeds such as the Jersey or Holstein-Friesian (Diack et al., 2005). Previous findings of Nouala et al. (2003)

showed the significantly better performance of Holstein-Friesian (HF) x N'Dama (ND) and Jersey (J) x ND crossbreds than the indigenous N'Dama as a pure breed. Between the crosses, the HF x ND appeared superior for per day milk yield (5l/day), against the J x ND (4l/day), though when BW, as a measurement of feed requirement, is taken into consideration, both crosses produced 1l milk per day for the same unit of BW. The HF x ND, with an average weight of 365kgs, produced no more than the J x ND, at 292kgs, with both crosses producing 1 litre of milk per 73kgs of BW. The body condition score (BCS) for the HF x ND and J x ND crosses remained the same before supplementation (2.0) and changed equally to 2.5 after receiving food supplementation. Importantly, the Jersey crosses averaged a 33% longer productive life (four lactations) than Holstein-Friesian crosses (three lactations), a factor that would indicate the Jersey as being the more beneficial breed to cross with the N'Dama cattle in this environment.

The indigenous trypano-tolerant N'Dama breed has been crossed with both Jersey and Holstein-Friesian breeds in The Gambia

Southern Africa

Malawi: The awareness of dairy output and productivity as a means to meet the demand of the population is growing rapidly and is an increasing priority in Malawi (Akaichi and Revoredo-Giha, 2014; Baur et al., 2017). The Holstein-Friesian is the dominant exotic breed followed by the Jersey (Banda et al., 2012) whilst Chagunda et al. (2006) and Gazzarin et al. (2018) both report the presence of limited numbers of Ayrshires and Jerseys whilst indigenous breeds for dairy production include the Malawian Zebu. Approximately 90% of milk produced in Malawi is produced by smallholder farmers who manage crossbreds between indigenous and exotic breeds referenced above (Shire Highlands Milk Producers' Association (SHMPA) 2017). These crossbreds are reported to have better potential than their indigenous counterparts or pure exotic breeds in terms of productivity, reproductive performance, disease resilience, and overall manageability (Banda 1996; Mwale et al., 1999; Baur et al., 2017; Gazzarin et al., 2018). Banda (1996) indicated favourable and similar estimates for Jersey x Zebu crosses (CI; 377(±21) days, DO; 108 (±24) days; Total MY; 2703 (±238) litres; Lactation Length (LL); 336 (±25) days) than in Holstein-Friesian x Zebu (CI; 386 (±9) days, DO; 115 (±10) days, Total MY; 2709 (±109) litres, LL; 315(±15) days) managed under similar conditions. According to Nandolo (2015) and in contrast to other breeds used

for dairying in Malawi, pure Jersey cows managed in similar production systems exhibited considerable advantages in AFC (1,065 days) compared to Holstein-Friesian cows at 1,324 days (Watanabe et al. (2017). Nandolo (2015) also reported the following performance for Jersey cattle: CI (491 days); LL (307 days); lactation yield [LY] (2,704 kg) with repeatability estimates for CI (0.133(±0.364)), LL (0.422(±0.156)) and LY (0.271(±0.119)). SHMPA proactively promote the use of smaller Jersey breed genetics, in crossbred form, amongst their 12,000 farmer members. There is ongoing work in support of this programme, with breed composition data being collected and results to follow in the near future (SHMPA, 2020). Early indications imply that the use of the Jersey breed for crossbreeding purposes could be adopted more widely for dairying purposes in Malawi.

The use of the Jersey breed as a sire of preference is encouraged within the Shire Highlands Milk Producers Association's smallholder farmer support programme

Mozambique: Indigenous breeds in Mozambique, mainly Sanga (hump-less) and Zebu (humped) types of cattle, are crossed with exotic breeds such as the Jersey, Holstein-Friesian and the more recently introduced Senepol breed; a composite but now fixed breed which is known to have the 'slick' gene – a key contributing genetic component for thermo-tolerance in the tropics. Dairy cattle, often of undefined genotypes, can be found across farms of differing sizes and management systems. Crossbreds identified include; Jersey x Senepol; New Zealand Friesian x Senepol, and Jersey x local beef or dairy breeds, among others. The crossbreds are used in both smallholder and commercial farms. Smallholder farmers practice zero-grazing, semi-zero grazing or extensive management systems with some inputs dependent on a farmers' capacity of finance and labour input while commercial farmers practice semi-intensive management systems (MERCADO baseline data, 2017). Both AI and natural mating are practiced at varying degrees depending on the financial capacity of farmers (Atkinson, 2011). Also, an open nucleus breeding (ONB) plan as part of dairy breeding strategy for Mozambique is being piloted at the Clifton Meadows farm within the country which intends to increase superior and well-adapted purebred genotypes through AI and MOET (Multiple Ovulation Embryo Transfer) and making offspring accessible for smallholder systems. The well-adapted tropical dairy genotypes resulting; High-grade Jersey milker cow (69% Jersey, 12% NZ-USA Holstein and 19% Senepol) and Clifton Meadows milk mas-

ter (75% Jersey and 25% Senepol) aim to enhance milk yield and volume, fertility, thermo-tolerance and forage utilisation and are currently being monitored by Land O' Lakes Venture37 in collaboration with the Government of Mozambique.

In Mozambique there is developing evidence that crossing the Jersey with the Senepol breed offers a more resilient cow for lower input systems than in using pure Jersey genetics alone

Average body or girth weight in smallholder farms and commercial farms in Mozambique are approximately 300 kg and 350 kg, respectively; the volume of milk output per cow per day during lactation ranges from 6 to 10 litres; the average number of days in lactation ranges from 267 to 361 days and average calving interval ranges from 467 and 491 days (Atkinson, 2011). The rates of tuberculosis and brucellosis have drastically decreased owing to efficient and effective testing conducted every six months among dairy herds (Tanner et al., 2014). In addition, annual campaigns for compulsory vaccinations against blackleg, anthrax, lumpy skin, and foot and mouth disease have been promoted among smallholder and commercial farmers (Cambaza, 2018). Future breeding plans to enhance productivity in Mozambique's dairy industry include exploring and leveraging on the advantages of the Senepol and Jersey breed through an *inter se* mating programme, where successive generations are bred back and forth across the two breeds. The crossbreds produced through *inter se* mating will aid in defining appropriate dairy breed genotypes that would be less capital intensive whilst adapted for less intensive systems currently practiced by smallholder farmers in Mozambique.

Namibia: Namibia has a strong livestock sector with a growing dairy industry, however, no detailed information on the Jersey breed could be located in this review. There is anecdotal evidence that the Jersey breed, in its pure or crossbred form, has been identified in some regions of Namibia and is currently used for dairy practices. Whilst not specifically relevant to the development or maintenance of the Jersey breed in the country, the dairy sector in Namibia is gradually growing but faces numerous challenges including arable land space, drought and irregular rainfalls for pasture production (Rothauge, 2001), diseases, market structure organisation (Rothauge, 2016), supply chain constraints and political issues (Hangara, 2017). Therefore, a structured and well-organised breeding policy, and economically viable cattle production system for smallholder farmers and access to financial credits or incentives, could enhance cattle productivity in Namibia where cattle are the main source of nutrition and revenue for smallholder farmers.

South Africa: South Africa has the largest population of Jersey cattle in Africa (Jersey Finance, 2020). More breeding and dairy management programmes have been established and reported on for European purebreds (Jersey and Holstein-Friesian) in South Africa than for their crossbreds with Indigenous cattle. Theron and Mostert (2009) reported differences between production and breeding potential of purebred Jerseys and Holsteins kept under different feeding regimes, including various uses of concentrates as well as mixed and pasture systems. The effect of feed and feeding regime on production traits in the Jersey breed is noticeable. The mean milk production (kg) observed on concentrate feeding was highest at 6385 (±1233), followed by mixed feeding at 5,155 (±955) and finally pasture feeding regimes at 474 (±1022). Average lactations were highest on mixed feeding regimes at 3.13 (±2.0) followed by pasture feeding at 3.09 (±1.9) and concentrate feeding at 2.90 (±1.7). Although average milk per lactation was predictably significantly higher in Holstein cattle (8,147±2,260 litres) than in Jersey cattle (5,347±1,156 litres), the average number of lactations was higher in the Jersey (3.2(±2.0)) than in Holsteins (2.9(±1.8)). This clearly shows the potential of the Jersey breed to persist and/or complete more lactations with the associated increase in calvings over the Holsteins, albeit at a lower yield per cow for the Jersey but with a similar volume of milk produced per land unit when considering the Jerseys' reduced per animal feed requirement.

South Africa has Africa's largest Jersey population with many large commercial herds

Zimbabwe: The Jersey breed is the second most commonly used exotic breed for dairy production in Zimbabwe after the Holstein-Friesian and is also used for crossbreeding with Zimbabwean Zebus (Missanjo et al., 2013). Reproduction is mainly via natural mating although AI is used in highly specialised dairy systems. There is no literature evaluating the performance of the Jersey as a crossbred with other breeds of cattle. Furthermore, there is a paucity of information on production traits of Jersey cattle in Zimbabwe as most research has mainly concentrated on the Holstein-Friesian breed (Kunaka and Makuza, 2005). However, a few researchers in Zimbabwe have estimated genetic parameters and phenotypic traits for both production and reproduction traits in purebred Jerseys (Banga, 1992; Missanjo et al., 2012; Missanjo et al., 2013). The estimates obtained were favourable towards the Jersey and could inform breeders of selection criteria for the development of an effective genetic improvement programme.

North Africa

Egypt: Reports from Egypt have been summarised from studies by Osman and Russell (1974), Fahmy et al. (1976) and Cunningham and Syrstad (1987). On average, the Jersey F_1 crossbreds studied calved at a considerably younger age (35.5 months), attained shorter calving interval (402 days) and produced more milk per lactation (2,020 litres) than the Boran at 43.6 months of first calving, 1,120 litres of milk per lactation and 396 days calving interval. Given that these reports are now extremely dated, more detailed up-to-date information would be useful in understanding the performance of Jersey cattle in this region.

Libya: RJAHS archive records report that Jersey cattle were exported to Libya from Jersey Island and the UK in considerable numbers in the 1980s, though no record of their presence or performance today was available in preparing this report.

Additional considerations for harnessing the potential of Jersey Cattle in Africa

One of the reasons for conducting this review was to explore the opportunity for the development of a simple decision support tool (a Dairy Profit Index) building on some of the key benefits of Jersey cattle as a critical contribution to profitable smallholder dairy systems in Africa. This review provides an assessment (albeit reliant in part on dated or less reliable information) on the impact of the Jersey breed based on available references up to 2020 and recorded performances up to 2018. Our assessment could be considered biased as it was viewed in the context of adopting exotic and indigenous cattle breeds for previous and future dairy development strategies in Africa. Although the Jersey breed is present and actively used in many African countries, there is still a paucity of data available. For instance, Namibia has a strong livestock development plan and an emerging dairy sector; however, data on production and reproduction performance remains very limited. Similarly, Mozambique has a growing dairy sector with various crosses between the Jersey breed and indigenous breeds but the data is not yet available from purposefully designed studies to assess and support genetic improvement.

In higher-income countries, e.g. Western Europe, the USA and Australia, the dairy sector has made considerable progress in adopting genetics that confer advantages in body size, adaptability, resilience, productivity and quality of dairy products from breeds such as Jerseys. Data suggests also that the potential economic benefit of the Jersey breed's efficiency is significant. A study by Oldenbroek (1986) showed that the Jersey breed appeared to have a higher efficiency than expected; possibly due to the higher yield and feed intake per unit of BW compared to other breeds. Furthermore, Kasbergen (2013) indicated that compared with the Holstein, Jersey cows were more economically efficient, generating more income per kg of milk, due to the higher milk components (average solids non-fat% of 9.42% versus 8.78%), higher pregnancy rate, feed efficiency and increased income over feed cost (~30%). The Jersey breed is able to convert low feed energy to an adequate milk volume and quality, which is especially important for smallholder farms that practice low-input dairy systems by default. Furthermore, Jersey cattle show increased resilience to tick and vector-borne diseases compared with other exotic breeds, potentially aiding smallholder farms to reduce veterinary and other maintenance costs, and enhancing the potential for Jersey-infused

cattle to serve as a triple-purpose breed (dairy, meat and/or draught purposes). The Jersey breed adapts well to the hot and dry environment with less of a compromise on milk performance and productivity, compared to other dairy breeds. The breed is also known to be cost-effective to manage and adapts well to a low-input system when compared to other exotic dairy breeds (Abin et al., 2018). Depending on the management system practiced, milk yield per unit of production input can be very cost-effective, providing an excellent source of nutrients for human consumption in addition to a potential source of income and revenue to meet smallholder farmers' financial commitments.

With the ever-increasing cost of feed and inputs, dairy farmers in climate-challenged regions of the world are beginning to think differently and explore opportunities to change cattle size and management systems to provide economic benefits. Similarly, these trends are fast growing in Africa with smallholder farmers moving towards rearing medium-sized breeds (e.g., Jerseys) to drive milk output while maintaining cattle fertility and longevity. Despite the abundance of other larger dairy breeds prevalent in Africa, the dairy sector still cannot meet the demand for dairy and dairy products. It is hypothesised that greater adoption of Jersey cattle in pure or crossbred form for dairying could help solve issues surrounding land size for dairying, land ownership, feed availability, community development and youth empowerment. In addition, it is proposed that an index mechanism or bio-economic model that factors profitability and sustainability of milk output that suits farmers' current resources in Africa could support in aiding such a transition.

The dairy sector in Africa is rapidly emerging or re-emerging in various forms in many countries on the continent, yet the two primary commercial breeds (Holstein-Friesian and Jersey) are currently not farmed in large numbers in purebred form outside of a few countries. The Jersey crossbreds have shown to be better adapted with a longer productive life than the Holstein-Friesian crossbreds (Okeyo, 2021). Therefore, it is important to explore the relevance of the characteristics of Jersey breed genetics for future dairy improvement strategies to ascertain what works best in terms of profit and revenue for the farmers, given the challenges of diverse production systems and climatic conditions.

The role of a Dairy Profit Index – selected examples

Most dairy and beef markets have indexes that are intended as tools to drive a farmer's profit by calculating breeding values, weightings for traits of economic importance, and ranking sires and cows within breeds. Various dairy profit indexes currently exist and are briefly described in the following paragraphs.

United Kingdom: The UK Profitable Lifetime Index (£PLI) is a within-breed genetic ranking index that accounts for production (34.4%), survival (15.1%), efficiency (11.8%), calving ability (1.6%), leg health (8.1%), udder health (13.7%) and fertility (15.3%; AHDB, April 2020). This index lays emphasis on promoting milk yield and maintaining milk quality for additional profit for UK dairy farmers with all year-round calving herds, and has two sub-indexes: the Spring Calving Index (£SCI) and the Autumn Calving Index (£ACI). The £SCI is an across-breed genetic ranking index designed for spring block calving herds and promotes more milk quality rather than volume. There is also a strong bias towards the promotion of improved fertility, which is seen as an essential characteristic of herds where the cattle need to calve and re-calve in following years, within a

tight time frame. The £ACI is a similar across-breed genetic ranking index designed for autumn block calving herds, where the more profitable herds may need to focus on the same traits, but with different weightings in the final index ranking.

The pie chart below shows the breakdown of the individual weightings of traits in the £SCI.
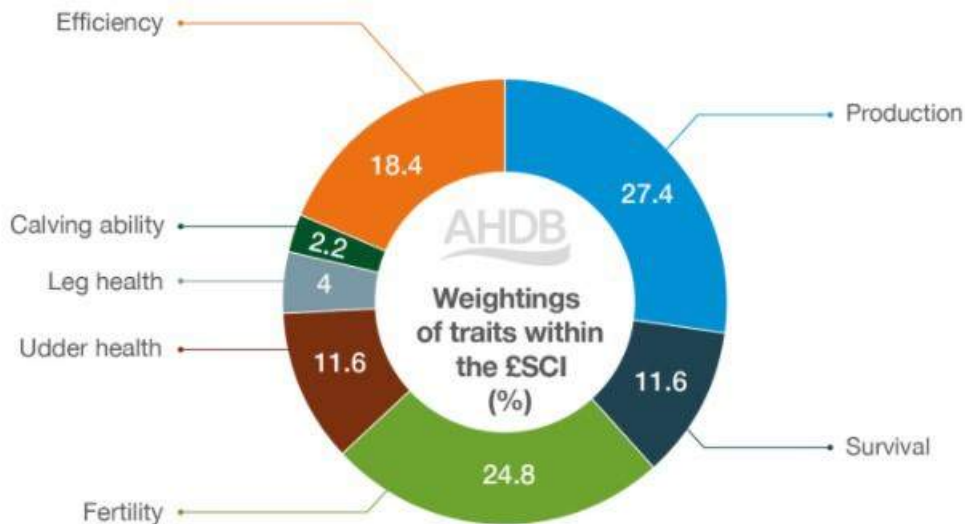
Pie chart showing the individual weightings of traits in the UK £SCI (Spring Calving Index) (Aug '21)

Canada: Canada's Lifetime Profit Index (LPI) accounts for 50% genetic plan (i.e. production), 30% durability and 20% health and fertility (CDN, 2021). The LPI formula for each breed is applied to bulls and cows in Canada that participate in national genetic evaluations for production and type trait. For foreign sires of the Holstein and Jersey breeds, which have available MACE (Multi-Trait Across-Country Evaluations) measures for production and type traits, the LPI for the respective breeds are used to compute MACE LPI (MLPI) values (CDN, 2009).

Australia: The Australian Profit Index (API), a prototype of the Balanced Performance Index (BPI) is a profit-based production index that accounts for nine traits such as milk, fat and protein yields, live weight, somatic cell count, fertility, survival, temperament and milking speed (Valentine et al., 2000). The updated API backed by strong science and in line with the farmer trait preferences currently includes an economically weighted measure (the economic index) and two alternative indexes where relative emphasis on fertility and fitness (compared to protein) is increased (Pryce et al., 2004).

Netherlands: The Dutch milk product index, also known as the total merit index of the Netherlands and Flanders (NVI), places emphasis on production (40%), longevity and health (35%) and type (25%). Below the NVI are various trait contributions with the Net Profit Index for milk production (INET)) at 29%, longevity (12%), udder health (12%), fertility (16%), udder (5%), feet and legs (9%), calving ease (5%), claw health (7%) and saved feed cost (8%).

United States: The Net Merit Index (NM$) of the USA ranks dairy animals based on their combined genetic merit for economically important traits for production (45%), health (40%) and type (15%). The NM$ index is driven by the type of heritable trait and management to drive substantial genetic progress. For instance, NM$ index includes the Dairy Wellness (DWP$) index for production (34%), health (56%) and conformation (10%) where more significant weight is upon health than the Total Production Index (TPI) which weights 46% on Production, 28% on Health and 26% on Conformation (Table 3). Therefore, what DWP$ adds to health, it sacrifices on production and conformation. Similarly, the Lifetime Profit Index (LPI$) puts more weight emphasis on production (51%), 34% durability/longevity and 15% on health and fertility.

France: The Index Economique Laitier (INEL) index of France, also known as the economic dairy yield index, puts more emphasis on production (50%) than fertility, somatic cell count, longevity and morphology/conformation (each at 12.5%). The INEL ensures that dairy quality, productivity and profitability are increased by focusing on minimising costs of veterinary bills, breeding and reproduction costs.

South Africa: The two main dairy indexes used for selection of dairy traits of economic importance in South Africa are the; Jersey SAINET and Holstein Breeding Value Index (BVI) (Banga, 2009, PhD thesis). The Jersey SAINET is a South African index (Taurus Jersey, 2007) that favours production and linear-type traits. The index is further divided into three sub-indexes where major emphasis is on production index (55%) (i.e. protein, butterfat and milk yield), 10% functional udder index (udder depth and width, somatic cell score and teat length and placement) and 35% functional type index (body, feet and leg conformation). The South African Holstein Breeding value index (BVI) is a production-type index, favouring high protein and butterfat producing cows, with large framed and extremely angular bodies, and, tightly attached udders. The BVI weights 52% on production, 45% on functional type trait and 3% on udder health (somatic cell score and udder health) (Taurus Holstein, 2007) (Table 3). However, the Jersey and Holstein indexes are not widely adopted within the country's dairy sector due to a lack of consensus on the appropriate dairy traits of economic importance for inclusion in dairy breeding goals. The authors of this report recognise that in countries where there may be multiple management systems, it is often difficult to create a single index which supports all systems. In large part it is this recognition that enables us to focus this section of the review on the development of a simple dairy profit index that primarily focuses on the development of dairy in a smallholder system environment.

Scandinavia: The NTM (Nordic Total Merit Index), a Scandinavian index, is one of the most progressive breeding value systems in the global dairy industry, combining 90 different sub-indexes into 15 different genetic traits that are heritable through mating bulls with cows. The Jersey breed NTM lays emphasis on health and reproduction (45%), production efficiency (40%) and conformation and workability (15%) (Viking Genetics 2021). The aim is to develop cattle's genetic and financial potential to achieve higher profitability and functionality of the herd by breeding new generations of cows with higher capability e.g. for milk production and resistance to diseases. The index also focuses heavily on management and health traits as it draws on the extensive dataset for these traits collected on Scandinavian dairy farms by law.
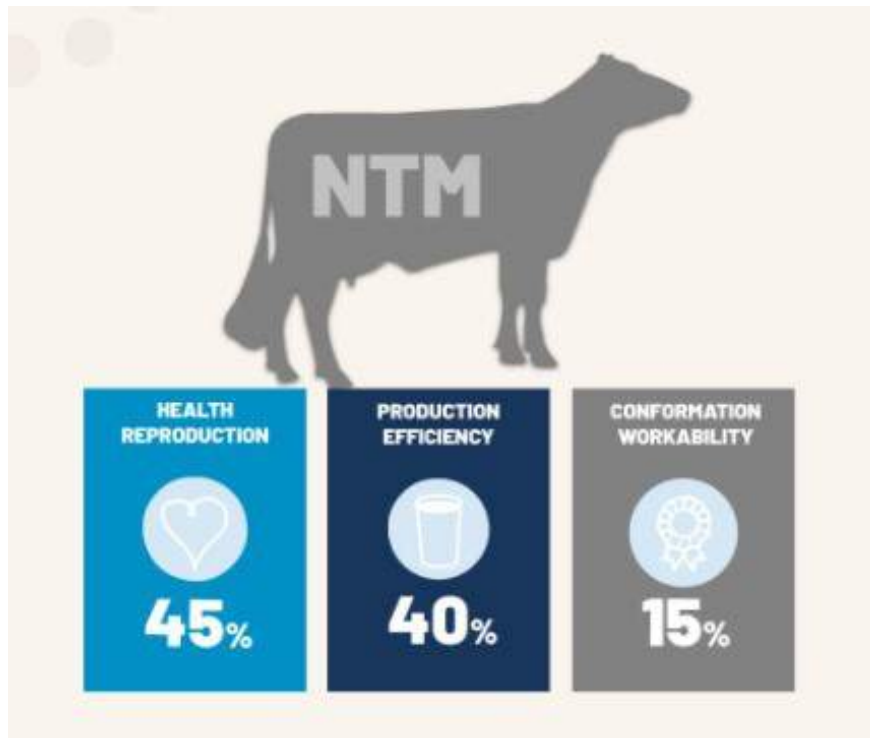
The Nordic Total Merit index is promoted as the most complete dairy index in the world, drawing on 90 individual traits through 3 composite elements

New Zealand: The New Zealand Index, also known as Breeding Worth is an index that accounts weights 24% on milk fat, 17% on protein, 13% on milk volume, 11% on live weight, 13% on fertility, 6% on somatic cell score, 9% on residual survival and 7% on body condition score (Dairy New Zealand 2021). The National Breeding Objective (NBO) in New Zealand aims to selectively breed for dairy cows that convert feed into farm profit. The Breeding Worth index ranks bulls and cows according to their genetic merit in compliance with the NBO. The index also accounts for milk production, feeding efficiency and grazing ability, robustness, minimal heifer replacement, survival of dairy cows and sires for future genetic breeding strategies. Therefore, the Breeding Worth Index's high focus on fertility, milking ability and production per Kg live weight are potentially of great relevance to the implementation of a proposed dairy (suitability) profit index for Africa. The coordinated and comprehensive data recording and genetic evaluation system in New Zealand is one of the critical factors that has increased the economic efficiency and viability of genetic improvement in the dairy industry. Therefore, the New Zealand Dairy Profit Index could be relevant and applicable to the development of an index mechanism for countries in Africa.

In addition, New Zealand has sampled many globally connected strains of dairy cattle, from the black and white Holstein and Friesian breeds, to the red and white Scandinavian and Ayrshire breeds to many of the key Jersey populations, in North America and Europe, as well as the Sahiwal breed native to Asia. All these breeds are more frequently now found in Africa and the tropics. Banga (2009) proposed that a single breeding objective on the basis of multiple-trait selection for South Africa's major dairy breeds would be useful across the different production and economic payment systems. However, considerable progress is required to enhance this breeding objective as well as facilitate its wide adoption within-country and other countries in Africa.
Crossbreeding is predominantly used for dairy production in both New Zealand and Africa whereby the genetic evaluation system analyses all breeds together so that the breeding values and profitability of crossbreds and purebreds can be referenced and compared directly across all breed geno-

types. A typical example of an across-breed sire index is the UK's Spring Calving Index which places heavy reliance on grazed grass as a requirement for spring feeding systems in conjunction with reducing maintenance costs and improving fertility, production, feed efficiency, conformation, survival and longevity. In addition, the generally less-intensive nature of dairy farm management practices in New Zealand has resulted in dairy cows that could be more suitable to Africa's milk production systems. In New Zealand, the majority of the dairy cattle get little cereal grains or other supplementary feed stuff similar to many smallholder dairy systems in Africa. However, commercial dairying in South Africa, where developed dairying is strong, often utilises high cereal grain feed (TMR – Total Mixed Ration) systems and as such differs from New Zealand where cattle have to produce as much milk as possible primarily from grass based on seasonal growth patterns, and then optimise their productivity, whilst their inherent enhanced fertility advantage better enables them to secure a pregnancy to calve again within the tight re-calving pattern required (Lopez-Villalobos and Garrick, 2006). For instance, a typical New Zealand type of dairy cow is more feed efficient in a characteristic New Zealand-type system; where she uses 50% of her feed intake to maintain her body condition and still produce her calf replacement, and 50% of the feed is used for milk production. However, a dairy cow of the Northern hemisphere may produce twice as much milk but about 65-75% of feed intake is used for milk production.

Hand pick highly ranked sires from our Alpha™ bull list to meet your breeding criteria, including Once-a-Day, High Input and A2.

My bulls	AB Code	Name ⌄	gBW($) / REL ⌄
Add	317025	MAXWELL GOLDIE MATAI S2J	306/84
Add	317023	SHEPHERDS LT FLINT ET S3J	342/87
Add	117068	MEANDER SB ARROW-ET S2F	286/85
Add	112032	JACLES BOY JAKS S2F	207/97

The New Zealand BW (Breeding Worth0 scheme allows bulls of different breed and crosses to be compared like for like, under the countries predominantly extensive dairy management system. In this example the bulls Matai and Flint ET are predominantly of Jersey genetics (S2J & S3J) whilst Arrow ET AND Oaks are predominantly Friesian (S2F)

Drawing again on the New Zealand example, New Zealand-type dairy cattle, whether pure or crossbred, have been developed over many generations to suit a very specific management system. This system has led to a cow that is small or moderate in size, matures earlier and has inherently higher fertility characteristics than dairy cattle in other populations. This pasture-based cow produces her first calf at 22-25 months, in line with the strict seasonal calving pattern, which may differ from dairy cattle found in other systems. (Blackwell et al., 2010; Gardner, 2017). A proposed (all-breed type) index for Africa that draws elements from the New Zealand type index, East Africa index and the UK's spring calving index to include increased weightings for fertility, calving ease, reduced condition loss and replacement costs, and disease resistance to mastitis would be an initial step, with an index that could then be modified as more information is recorded and included. An index in Africa could enhance the financial value returns of animals for a cost-effective breeding programme whereby these animals are ranked in a way that farmers can choose the appropriate cow of choice to fit the diverse management systems that are currently practiced in Africa.

In selected African countries, several researchers have previously performed genetic evaluation (Dube et al., 2009; Missanjo et al., 2013; Madilindi et al., 2019; Opoola et al., 2020) and most recently, genomic evaluations on the Jersey breed (Chagunda et al., 2018). Parameter estimations for milk yield, AFC, calving interval, feed efficiency, adaptability and disease resilience have been determined using preliminary methods or statistical procedures such as least squares mean, generalised or mixed linear models, and residual maximum likelihood ratios using both statistical and genetic software programmes (Nouala et al., 2003; Dube et al., 2009; Missanjo et al., 2013; Ojango et al., 2019). The estimations of these parameters for the aforementioned traits from performance data records provides opportunities to monitor genetic progress over a time period as well as optimise the implementation of sustainable breeding programmes using information available for the breed (Asimwe and Kifaro, 2007; Mostert et al., 2010; Makina, 2015; Opoola et al., 2020).

Development of dairy profit indexes applicable to African production systems

A proposed dairy profit index (DPI) that factors genetic traits of economic importance and alleviating current challenges faced by the African dairy sector will help maximise dairy productivity and improve efficiency of breeding plans for increased profits to dairy farmers. The East Africa dairy profit index developed by Animal Breeding East Africa Ltd (personal communications, ABEA Ltd, 2021) that draws elements from the New Zealand's Breeding Worth index is a good starting point for developing individual country indexes. The index developed for each country may be different in terms of monetary currency, sire breeding values, input and output costs but these would be similar in terms of the criteria and components used across the countries in Africa.

A proposal for a Rwandan DPI should include economic weightings for measurable traits for milk yield, fertility, growth and survival, feed efficiency conversion rate, herd health and disease resistance, longevity and conformation whereby estimated breeding values (EBVs) and genomic breeding values (GEBVs) have been pre-determined for genomic selection of desirable bulls and cows for future breeding plans and strategies. The traits measured should include:

1. Production - daily milk yield, total days in milk, lifetime milk yield and annual milk yield

2. Fertility - both cow and bull traits such as AFC, calving ease, calving interval, non-return rate, body condition score during gestation and lactation, milk yield around insemination, days from calving following insemination, number of inseminations per conception and days open.

3. Growth and survival - longevity, cow/herd life and stayability in the herd.

4. Health - number of health interventions, incidence of mastitis, lameness and vector-borne diseases.

5. Conformation – Liveweight, body condition score, reduced culling rates

6. Feed efficiency - kg of DMI per kg of milk produced and milk yield per BW are crucial components that would help maximise dairy productivity especially where land space and ownership is one of the major constraints facing smallholder farming systems, as is the case in Rwanda. Therefore, the Jersey breed could be a suitable breed of choice in its pure or crossbred form, being known to be an efficient feed converter, which would help in maximising dairy output for Rwanda.

The prevalence of other dairy indexes employed globally could streamline the concept of developing a selection index for a suitable dairy breed for Africa (or Rwanda as an example) that could optimise milk yield and fertility without sacrificing on body weight (Table 3). Table 3 shows some of the dairy profit indexes of relevance to the proposed index for Rwanda. Most of the traits have proportions assigned as regards to performance, fertility, and conformation and also include health traits. The proposed index will select for bulls and cows by breed that have both performance (phenotype) data records as well as genotype information for milk yield, fertility and body size already accounted for by growth. The application of both the phenotype and genotype information is relevant for derivation of genomic estimated breeding values (GEBVs) for these bulls and cows. In addition, ranking procedures that include economic weights for input costs, management and the EBV and GEBVs for the components that make up milk yield, fertility and body size in relation to growth could provide initial information for the proposed DPI for Rwanda. The derived GEBVs will guide in selecting breeding candidates and ranking bulls with favourable traits for derivation of Single Nucleotide Polymorphism (SNP) keys for future genomic selection in Rwanda and Africa as a whole. The DPI at its first inception is expected to be an open-ended index whereby more traits of economic importance will be included (in conjunction with aforementioned traits) as the dairy sector emerges and migrates towards genomic profiling of top ranking bulls and cows to monitor breeding progress. However, more information on key traits to drive the future of the dairy sector would be included as relevant breeding information is obtained.

Conclusions and perspectives

This review highlights the impact, performance and prevalence of the Jersey breed in African countries. Although there is a paucity of detailed historical information about the Jersey breed in some African countries, the performance of the Jersey breed where it has been found or currently resides clearly shows the potential of exploring the widening of the breed's influence in Africa's dairy production systems. Therefore, whilst building a reference population for genomic selection of all exotic breeds currently used for dairy production in Africa could help drive productivity and profit for smallholder farmers, a reference population that links small or moderately sized cows like the Jersey breed, to traits of economic importance, could help inform future breeding goals for smallholder farmers in developing countries especially.

To our knowledge, this paper is the first review of the Jersey cow in Africa and provides an initial view of an exotic breed that has over time demonstrated its suitability and worth, through the gradual intensification of livestock development in Africa, though the data gap remains a challenge in many countries. There are increasing opportunities for breed assessment and recording of Jersey performance data for future dairy improvement and, in parallel, there is an urgent need for sustainable and economically viable data collection systems to underpin long-term improvement in management and breeding. Such systems should not be dependent on individual grant-funded or research projects being executed but need to involve both government and private partnerships and must provide decision support systems to farmers to improve livestock management in addition to improved genetics. It is encouraging, however, to note that livestock data collection and technical support has been a key driver for the past five years in the development of animal agriculture in Africa.

In addition to the more focused data collection and genomic sampling that has commenced in Rwanda (led by the RJAHS, CTLGH, RAB, and others), other dairy programmes both in Rwanda (e.g., the Rwanda Dairy Development Project) and elsewhere (e.g., the African Dairy Genetic Gains (ADGG) platform) have established innovative systems with long-term objectives including data collection on dairy performance. More data will further support long-term genetic improvement, based on well-established and measurable genetic potential of described breeds, synthetic breeds or crosses. This will also offer the opportunity to establish a set of markers for genomic selection and breeding values that are associated with economically and environmentally important traits for specific ecologies and production systems.

The indexes that are currently in use in developed regions are relatively complex and would be largely unworkable, for immediate application, throughout much of Africa. They require considerable and sustainable data collection, which is unlikely to happen in smallholder East African production systems at the present time. However, with the African dairy sector progressing towards a more sustainable system of production, through adequate performance data recording to monitoring genetic progress, there would be a possibility of developing a simple dairy profit index, tailored to Africa's smallholder farmers to maximise their management inputs and dairy productivity.

In addition, a dairy profit index that best defines profitability as seen in major global dairy markets could help the dairy sector in Africa because:

a) Such an index would help in enhancing the availability and utilisation of a system for the selection of bulls for use in the African smallholder dairy system.

b) The index will help evolve a comprehensive characterisation and comparison of dairy systems within countries and regions.

c) An additional benefit, probably a new innovation in many African countries, is that it would help rank bulls according to their suitability as a donor of imported germplasm, avoiding the use of inappropriate genetics, as well as positively influencing selection of bulls identified for germplasm production in other regions.

d) It will also enhance the availability and utilisation of genetic profiles of dairy cattle in general and cattle of specific breeds within countries, to help guide future breeding policies.

Similarly, and in pursuance of these aims, the RJAHS is collaborating with RAB to ensure smallholder farmers in Rwanda have access to what are anecdotally considered to be the more appropriate Jersey phenotypes for the country's smallholder systems. In addition, livestock data will be tracked and traced from farm to an online database system, where uniform performance data recording will promote and monitor genetic progress. This is being further supported by the genomic profiling of Rwanda's current dairy cattle genetics.

We anticipate that these efforts will contribute to dairy cattle that are both more profitable and more intrinsically suited to the environment in which they are being asked to perform. For Rwanda these socio-environmental factors include a cow that often needs to be managed and handled by the female in the household; that will need to survive climatic, disease and other health challenges; produce a nutrient rich foodstuff (milk or dairy products) from limited forage-based feed resources, and maintain sufficient body condition to rebreed and carry a calf.

A well-structured approach to future dairy cattle breeding policy that is developed around economically important dairy traits in the profit index, where animals with improved appropriate genetic merit are recognised, and financial returns are optimised, is the recommended route to improving dairy farming sustainability for smallholder farmers. This is a target that we should all strive for, while recognising that the Jersey breed is likely to hold the key to solving a number of these challenges.

ACKNOWLEDGEMENTS

Index of References:

A full list of references will be made available on https://africanjerseyforum.com

Table 1: Evaluation types identified within this report, where performance and attributes for Jersey breed in Africa are reviewed

Traits	Breeds & Admixture composition	Trait estimates	Data type	Evaluation type
Breed composition; JER, HOF, DSH, GUE, AYR with indigenous breeds (EAZ, Mpwapwa, Horro, Boran, Sahiwal, White Fulani, Red Sindhi, Ankole, etc.)	*Bos taurus* to *Bos indicus* blood levels	12.5%; 25%; 50%; 75%; 85% and <85%	Production and fertility data	Preliminary analysis; REML; ANOVA
Reproduction method; Artificial insemination (AI), natural mating		<90% AI ; < 10% natural mating with exotic bull stud	Production and fertility data	Preliminary analysis
Body weight (kg)		350-420 kg	Production and fertility data	Descriptive statistics
305 Day Milk yield (litres)	Exotic, indigenous & crossbreds	1,683 - 5,000	Production and fertility data	Descriptive statistics; Genetic analyses
Calving interval (days)		474	Production and fertility data	Descriptive statistics; Genetic analyses
Age at first calving (months)		29 – 38	Production and fertility data	Descriptive statistics Genetic analyses
Feed efficiency		<JER & JER crosses	Production, fertility and feed consumption data	Descriptive statistics; ANOVA
Character and temperament	-	-	-	-
Disease		<JER & JER crosses	Production and fertility data	Descriptive statistics
Adaptability		<JER & JER crosses	Production and fertility data	Descriptive statistics; Genetic analyses
Lifespan/longevity	Exotic, indigenous & crossbreds	<JER & JER crosses		Preliminary analysis

Breeds: JER (Jersey); HOF (Holstein-Friesian); AYR (Ayrshire); BSW (Brown Swiss); DSH (Dairy Shorthorn); GUE (Guernsey); SAH (Sahiwal).

Table 2: Cited and documented average (+/-standard deviation) performance of Jersey breed amongst other dairy breeds in Africa

Traits	Dairy breeds							Reference(s)
	JER	HOF	AYR	BSW	DSH	GUE	SAH	
305-day MY (litres)	4,666.10±940.14	6,147.24±2,131.26	3,564.73±1,482.634	-	2,020	5,143±252.20	893.01±245.13	Nicklov 2003, Meyn and Wilkins, 1974; Cunningham and Syrstad, 1987
1st MY (litres)	4,113.32±1,123.13	5,267.75±1,879.124	1,842.13±784.945	3,148.50		3,247.16±779.22	-	Meyn and Wilkins, 1974; Cunningham and Syrstad, 1987; Djoko et al., 2003; Opoola et al., 2020; Gertenbach, Chenyambuga and Mseleko, 2009
Ave no. lactation completed	3.16±0.097	2.8	-	-	-		-	Theron and Mostert, 2009; Chenyambuga and Mseleko, 2009
Calving to 1st heat interval (days)	80	69±3.00	-	-	-	-	-	Kebebe et al., 2011
Gestation length (days)	283	281.50±0.71	-	-	-	-	-	Kebebe et al., 2011
Days open	123	142.54±32.51		-	-	-	-	Mulangila 1997; Kebebe et al., 2011; Asimwe and Kifaro, 2007; Chenyambuga and Mseleko, 2009
AFC (days)	934.88±28.03	1,028.91±168.57	1,049.54±130.04	-	1,085.8±189.26	1,043.51±133.74	1,169.21±14.48	Njubi et al., 1992; Mulangila 1997; Wakhungu et al., 2006; Opoola et al., 2020
1st CI (days)	410.01±21.42	466±3.30	404			393	-	Mostert et al., 2010; Opoola et al., 2020
CI (days)	401.25±57.47	468.25±18.268	417.61±11.53	-	436-452	396.5	493.00±5.01	Kanuka and Greve (2000); Mostert et al., 2010; Nandolo, (2015); Opoola et al., 2020
Survival (%)	34	23	90.00±7.00	-	-	-	92.00±2.00	Wakhungu et al., 2006; Phillips, 2014; Muller and Waal, 2016
N°. of insemination per conception	1.94±0.04	1.96±0.04	2.167±0.624	-	-	-	-	Kebebe et al., 2011
Feed efficiency (grams/litre)	272	258	-	-	-	-	-	Phillips 2014
Longevity (%)	34	23	16.51±1.50	-	-	-	-	Phillips 2014

Breeds: JER (Jersey); HOF (Holstein-Friesian); AYR (Ayrshire); BSW (Brown Swiss); DSH (Dairy Shorthorn); GUE (Guernsey); SAH (Sahiwal), CI (Calving Interval); AFC (Age at 1st calving), MY (Milk Yield).

Table 3: International indices with proportion of relevant traits (%) to the proposed dairy profit index for Rwanda

Index type	Production	Fertility	Body weight /Growth	Survival/ longevity /stayability	Efficiency	Calving ability	Leg health	Udder health	Conformation			Milk fat	Milk protein	Milk volume	BCS	SCS
									Udder	Feet and legs	Claw health					
ABEA index			10	11												
Canadian LPI$	51	7.5		34			7.5					24	17	13	7	6
Ethiopia index																
New Zealand's BW			11	9								24	17	13	7	6
£PLI	34.4	15.3		15.1	11.8	1.6	8.1	13.7								
£SCI																
£ACI																
Dutch milk product index	40			35				25								
INET	29	16		12	8			12	5	9	7					
NMI of USA	45															
DWP$ of NMI																
INEL of France	50	12.5		12.5						12.5						
TPI of NMI																
Taurus Jersey																
Taurus Holstein																
Jersey SAINET	55								10	35						
Holstein BVI	52							3	45							
Scandinavian NTM	40	22.5							22.5	15						
Tanzania index	50														50	

£PLI (UK profitable lifetime index); £ACI (autumn calving index); £SCI (spring calving index); Canadian LPI$ (Canadian lifetime profit index); INET (net profit index for milk production); Net merit index (NMI) of USA; Holstein BVI (breeding value index); New Zealand's breeding worth (BW); Scandinavian NTM (Nordic total merit).