Innovative use of conventional and new technologies to unravel breed options for smallholder dairy production in Africa

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Africa occupies a large area of the World

**West Africa**

Countries: Gambia, Sierra Leone, Togo, Guinea, Mali, Senegal, Nigeria, Ghana, Niger, Cameroon, Gabon, Ivory Coast, Senegal, Burkina Faso, Guinea Bissau & Central African republic

**Southern Africa**

Countries: Zambia, Malawi, Mozambique, Zimbabwe, Botswana, Namibia, Angola, Swaziland, Madagascar, Lesotho, Mauritius & South Africa

**East and Central Africa**

Countries: Kenya, Tanzania, Uganda, Ethiopia, Rwanda, Burundi, DR Congo, Sudan, Somalia, Eritrea & Djibouti
- Africa hosts 310 million head of cattle (20.9% of the world cattle population)
- Africa produces 5.4% of the global milk from cattle (FAOSTAT, 2016)
- Up to 80% of the milk produced in Africa is by small-holder farmers
Smallholder dairy production systems

- Less than 10 head of cattle reared
- Land sizes less than 0.5 of an acre to 10 acres
Animals are the products of their genes, their environments and their gene-environment interactions.

\[ P = G + E + GE \]

<table>
<thead>
<tr>
<th><strong>P</strong> is the phenotype</th>
<th>The animal we see, its production etc.</th>
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Animals are also influenced by markets, institutions and policies

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- **P** is the phenotype: The animal we see, its production etc.
- **G** is the genotype: The genetic make up of the animal
- **E** is the environment: All factors (ambient conditions, health, nutrition, husbandry) except the genes of the animal
- **GE** is the interaction: Between the genes and the environment
What happened? Exotic genotypes were introduced into harsh production environments.

The graph shows the milk yield (l) for different production environments and genotypes:
- Indigenous
- X-bred
- Exotic

The graph indicates a significant difference in milk yield across production environments:
- Harsh: Indigenous and X-bred have similar low yields, while Exotic has a higher yield.
- Poor: X-bred has a higher yield compared to Indigenous and Exotic.
- Good: X-bred has the highest yield, significantly outperforming Indigenous and Exotic.

The graph also includes a red circle with the label "FAILED!" highlighting the poor performance of Indigenous and X-bred in the Harsh environment.
Improve management a little and change the genotype

![Graph showing yield in different production environments (Harsh, Poor, Good) for Indigenous, X-bred, and Exotic genotypes. The graph indicates significant improvement in yield in the Good production environment, especially for Exotic genotypes.]
Good management and different genotype

![Graph showing yield (L) vs. production environment (Harsh, Poor, Good) for Indigenous, X-bred, and Exotic genotypes.]

- **Yield (L)**
  - 0
  - 1000
  - 2000
  - 3000
  - 4000
  - 5000

- **Production environment**
  - Harsh
  - Poor
  - Good

- **Genotypes**
  - Indigenous
  - X-bred
  - Exotic
Why is change a challenge in Africa

- Production systems are mainly small-scale or pastoral, transaction costs are high
- Climate change!
- Limited resources, poverty, available feeds
- Endemic diseases
- Local Markets, skewed prices
- Poor Infrastructure
- Lack of feedback systems to inform management decisions
- Weak institutions
“You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete”

• Buckminster Fuller
Questions of interest in adapting genetic technologies

1. What genotypes perform well in smallholder systems
2. What delivery system(s) would best suit the identified genotype(s)
3. What Partnership(s) would be required to deliver the genotype(s)
4. Is there a business model and plan for delivery – ready to implement
A random sample of 2000 animals from 900 small holder farmers were selected from 7 sites in Kenya and Uganda.

Selected animals:
- Were genotyped using high density SNP technology to determine their breed composition.
- Their productivity was monitored over 2 years (March 2011 to March 2013).

Field and SNP data was combined to determine which breed combinations perform best under different conditions.
Results
Breed composition from SNP assays

• Breed types identified in the populations were
  – **Exotic breeds**: Holstein-Friesian, Ayrshire, Guernsey, Jersey
  – **Indigenous breeds**: Zebu, Ankole, Nganda

• Animals were **highly admixed** with exotic breed composition ranging from 0% to 99%
Principal component analysis results based on 566k chip
Estimated proportions of exotic dairy breed alleles from SNP were used to categorize animals into 5 groups termed “% dairyness”; 0-20%, 21-35%, 36-60%, 61-87.5% and >87.5% exotic.
<table>
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<th>Breed groups derived from SNP analyses - Kenya</th>
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<tbody>
<tr>
<td><strong>Genotype combination for various % dairyness</strong></td>
</tr>
<tr>
<td>Breed type</td>
</tr>
<tr>
<td>Ayrshire</td>
</tr>
<tr>
<td>*Friesian</td>
</tr>
<tr>
<td>Guernsey-Jersey</td>
</tr>
<tr>
<td>Ayrshire-Friesian</td>
</tr>
<tr>
<td>Ayrshire-Guernsey</td>
</tr>
<tr>
<td>Friesian-Guernsey</td>
</tr>
<tr>
<td>Ayrshire-Friesian-Guernsey</td>
</tr>
<tr>
<td>Mixed</td>
</tr>
<tr>
<td>Zebu</td>
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</tbody>
</table>
Breed groups derived from SNP analyses - Uganda

<table>
<thead>
<tr>
<th>Breed type</th>
<th>&gt;87.5%</th>
<th>61-87.5%</th>
<th>36-60%</th>
<th>21-35%</th>
<th>&lt;20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friesian</td>
<td>FFF</td>
<td>FFFZ, FFZ</td>
<td>FFZZ, FF</td>
<td>FZZZ, FZZ</td>
<td>--</td>
</tr>
<tr>
<td>Holstein</td>
<td>--</td>
<td>HHZ</td>
<td>HZZ, HHZZ</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Holstein-Friesian</td>
<td>HHHF, FFH</td>
<td>FFHH, FHH</td>
<td>HHF, FHHZ, FFH</td>
<td>FHZZ, FHZ</td>
<td>--</td>
</tr>
<tr>
<td>Zebu</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>ZZZ</td>
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Milk yields were generally low, averaging 5.39±3.32 in Kenya and 5.62±3.45 in Uganda, with long lactations > 400 days.
Daily milk production for different dairy groups of animals within countries

Lactation curves for animals were generally flat with no evidence of a peak in early lactation.
Milk production by animals with different proportions of exotic genotypes (%dairyness)

High grade cattle only showed substantially better milk yields than other grades in the highest production environment.
There exists a huge yield gap in production by the same breed of dairy cattle in the different farming systems.

Figure 1: Realized lactation curves of improved (crossbred or higher) dairy cows achieved by different farmer types in Kenya.

- **Commercial/Intensive dairy farmers** - ~6,500 kg/lactation --- ~2% of farmers
- **Best smallholder farmers** - ~2,500 kg/lactation --- ~5% of farmers
- **Average smallholder farmers** - ~1,400 kg/lactation --- >90% of farmers

The gaps to be filled...
The lower than expected milk yields in the smallholder farming systems have profound implications for dairy extension and development programs and for businesses providing services to these farmers.

Given the larger size and maintenance requirements of high grade exotic cattle, lower grade exotics will be the most economically productive animals in the low and medium herd production levels.
Use of Technologies to effect change in Africa

Genotype adaptation to local agro-ecology
- Targeting of appropriate genotypes to the optimum agro-ecology
- Use of young bulls with a focus on production & adaptation
- Local feed/fodder resource use efficiency

Digital platforms for on-farm performance tracking
Decision-support and Farmer-to-Farmer performance benchmarking
Smart use records & genomics tools for selection and better AI service delivery

Accelerate on-farm genetic gains

Development of synthetic breeds
- “Africa needs to create dairy breeds that are best suited to local & emerging ecological conditions

Economically Relevant Traits
- Milk Yield/density
- Adaptability Indices
- Reproductive Performance
- Heat tolerance
- Survival rates
- Lactation persistency
- Mastitis incidences

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Concluding remarks

Genetic improvements have resulted in huge economic returns: - *Meat and Livestock Australia reported from 1963-2001, investment in genetic selection and crossbreeding resulted in net gain about $861 million*

Undergirding these improvements is the accurate evaluation of animals on which selection is based.

*Do we have enabling policies and appropriate policy frameworks in place to allow biotechnology and information technologies to effectively solve Africa’s food scarcity & safety problems?*
Acknowledgements

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Thank you

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