

Considerations on a Stepwise Data-Driven Innovation to Support Sustainable Dairy Transformation in smallholder dairies

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# Aim



Food and Agriculture Organization of the United Nations



Building on observations from the FAO Regional Forum on Innovations for Sustainable Livestock Transformation in Asia and the Pacific, we discuss a phased implementation strategy in progress in developing regions.

This approach focuses on **practical solutions** that evolve with **farmer capabilities** and **resources**.

### Figure 7.4. Milk production and yield in selected countries and regions



Note: The yield is calculated per milking animal (mainly cows but also buffaloes, camels, sheep and goats). Source: OECD/FAO (2023), "OECD-FAO Agricultural Outlook", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-outl-dataen.

StatLink and https://stat.link/pcnb83

Number of milk cows worldwide in 2024, by country (in 1,000 heads)



High number of cows in India ...

https://www.statista.com/statistics/869885/global-number-milk-cows-by-country/#:~:text=India%20is%20home%20to%20the,at%20about%2020%20million%20head.

How to help farmers to increase their productivity and improve if needed the composition of their milk ? Appropriate smart livestock farming ?



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https://www.era-susan.eu/content/farmsustainabl-enabling-smartlivestock-farming-technologies-environmental-sustainability

# Problem of Internet connection and coverage



# Do we need always internet connection ?

# Not available even if it can speed the process



Keep the motivation of farmers by giving direct outputs



1. Establishing Fundamental Data Practices

- 2. Introduction of appropriate Technological Intervention
- 3. Scaling up with advanced techonologies
- 4. Policy and Institutional Support

To start, take a simple example with high potential which minimizes the initial investment ...





1. Establishing Fundamental Data Practices



- Robust Animal Identification: ICAR can play a rule!
- Basic Record-Keeping Systems: Encourage farmers to maintain manual or digital records using low-cost tools (spreadsheets) of milk production
- Collaborate with local organizations to provide **hands-on demonstrations** of effective record-keeping techniques.



Motivation is improved when you have rapid results ...







- **Robust Animal Identification:** ICAR can play a rule!
- Basic Record-Keeping Systems: Encourage farmers to maintain manual or digital records using low-cost tools (spreadsheets) of milk production
- Collaborate with local organizations to provide **hands-on demonstrations** of effective record-keeping techniques.
- Improve the farmer's motivation :
  - Help farmers to develop basic data interpretation using on-site training to enhance decision-making regarding feeding, breeding, and disease management.
  - Use visualization (pictures, charts, graphs)





- **Robust Animal Identification:** ICAR can play a rule!
- Basic Record-Keeping Systems: Encourage farmers to maintain manual or digital records using low-cost tools (spreadsheets) of milk production
- Continue to collaborate with local organizations to provide **hands-on demonstrations** of effective record-keeping techniques.
- Improve the farmer's motivation :
  - Train farmers on **basic data interpretation using on-site training** to enhance decision-making regarding feeding, breeding, and disease management.
  - Use visualization (**charts, graphs**) to communicate trends of milk yield
- Community based data sharing :
  - Inform about the performances obtained by other farmers to exchange good practices.





1. Establishing Fundamental Data Practices



2. Introduction of appropriate Technological Intervention



- Farmers are motivated as already developed a first data acquisition
   we can go further
- Affordable precision Livestock farming :
  - Milk MIR spectrometry is an example

Milk composition is the mirror of the animal and its changes reflect its health status

Knowing its composition is therefore of interest















12

0

1076 cm<sup>-1</sup> : O-H C-C C-H

1157 cm-3: C-O-C 50 cm<sup>-1</sup>: C-O-

1500

1000

550 cm<sup>-1</sup> : C=N, N-H

2000

Wavenumbers (cm<sup>-1</sup>)

2500

© Grelet et al., 2015

1743 cm<sup>-1</sup> : CaO

- 2927 cm<sup>-1</sup> : -0

3000





- Farmers are motivated as already developed a first data acquisition
   we can go further
- Affordable precision Livestock farming :
  - Milk MIR spectrometry is an example
- Digital farm management tools
  - with and/or without internet connection
- Continue to increase the use of Artificial Insemination to increase genetic improvement



1. Establishing Fundamental Data Practices

2. Introduction of appropriate

**Technological Intervention** 



3. Scaling up with advanced techonologies



• IoT and smart farming?



Delaval filme
 A Delaval filme
 A de mouvement
 Assage sous un portique
 obot. L'imagerie 3D est
 aus forme d'une note
 Aporel. L'intérêt est
 re l'évolution du troupeau
 Jdapter les recommandations
entaires.

#### tection du vélage

e capteur fixé sur la queue analyse son soulèvement et les mouvements de la vache (alternance des positions levée-couchée) qui indiquent l'imminence du vélage. Deux outils sont disponibles : Smart'Vel (Evolution) et Alert'Vel (ALB Innovation). L'information est transmise à une base et l'éleveur alerté par téléphone.

#### Détection du véloge

La sonde vaginale (Vel-Box de Génes Diffusion, Vel Phone de Médria) avertit de l'imminence d'un vélage. Elle est expulsée du vagin lors du vélage et une alerte est transmise par téléphone au sur l'ordinateur. La société New Deal a breveté un capteur (Happy Foaling) qui est implonté dans le vagin de la vache par chirurgie, avec une durée de vie de cing ans.

#### Capteurs sur matériel de traite

Alim. Santé Repro.

VELBOX

ALE WRITESTOP

#### Quantité et composition du lait

Les compteurs à lait en solle de traite et robots de traite apportent des informations en temps réel var la production et la conductivité. Jurnisseurs : Lely, GEA, Boumatic, 'milk, Delaval, SAC, Insentec. ogiciel DLM de Lely adapte matiquement la quantité de naté au robot à la réponse en lait.



La ceinture abdominale Agrimonitor de Databel détecte les contractions abdominales et utérines précédant le vélage. L'alerte est transmise vers le réseau téléphonique via un module de contrôle, selon deux modalités : vélage normal ou difficile.

Détection du vélage

200

Les boucles électroniques officielles (puces RFID) peuvent se substituer aux différents dispos, d'identification (collier, bracelet, bo, pour faire fonctionner les automates à la ferme : Dal, Dac, robots, portes de tri, compteur à lait... Ci-contre, le système Cowmanager de Select Sires comprend une puce pour l'identification, la prise de température et un accéléromètre pour la détection des chaleurs.

#### Ingestion, rumination

Identification électron

Le licol RumiWatch de Itin + Hoch mesure le nombre de bouchées, le temps d'ingestion, de rumination et d'abreuvement. A l'instar des auges individuelles avec peson intégré, cet équipement s'inscrit dans la logique d'une alimentation individuelle de précision.

#### Activité physique

Les colliers équipés d'un accéléromètre servent à la détection des chaleurs et permettent, grâce à la détection des mouvements de tête couplés au bruit de la rumination captée par microphone, d'analyser le comportement alimentaire (ingestion, rumination). Fournisseurs : Nedap, Médria, Evolution, Gènes Diffusion, Lely, Dairy Master, Milkline.

#### Température et pH du rumen



Le bolus Smaxtec de Sonders mesure en continu la température et le pH du rumen, et le Thermobolus de Médria, la température. La mesure du pH consiste à équiper des vaches sentinelles dans le troupeau pour contrôler le risque d'acidose.

#### Activité physique et position

Le bracelet à la patte sert à mesurer l'activité pour détec\* les chaleurs. Il permet l'ident\* au Dac, en salle de traite or Fournisseurs : Alimilk, Fu\* Nedap, GEA, Boumatic

https://www.eleveurlaitier.fr/dossier/descapteurs-au-service-de-lelevage-de-precision-1,0,549358506.html



100

Santé

Balance / topis de logette

Poids vif

1

BOUTOTO

Repro.

Santé

Posture Les capteurs de pression équipent la plate-forme StepMetrix de Boumatic pour détecter les boiteries. Le dispositif, fixé dans un couloir de retour de salle de traite, transmet les données à l'ordinateur. Les capteurs du matelas Smart Vibra Mat de Bioret indiquent si chaque vache fréquente normalement sa logette et les éventuelles variations de poids.

La balance automatique est proposée

de traite (GEA, Afimilk, Lely). Ces pesées

corporel, la baisse de la rumination

de pilotage du bilan énergétique.

par de nombreux constructeurs d'installation

régulières croisées avec les variations d'état

et la composition du lait offrent des éléments

.



- IoT and smart farming?
- Machine learning and Artificial Intelligence (AI) for dairy management?
- Blockchain for supply chain transparency?



1. Establishing Fundamental Data Practices



2. Introduction of appropriate Technological Intervention

3. Scaling up with advanced techonologies

4. Policy and Institutional

Support



- Subsidized technologies
- Access to cooperative funding mechanisms
- Expert advisory services
  - Continuous technical support also helps maintain equipment and ensures proper data management and interpretation.

# Take home message









- Start simple and fix the pipeline focus on farmer needs
- Awareness campaigns, **farmer training** programs, and **cooperative support** networks to help farmers progress through each stage of this transformation.
- Standardized data collection and analysis protocols ensure that the data generated are reliable, comparable, and actionable across various contexts.
- Through coordinated efforts involving governments, research institutions, non-governmental organizations, and private stakeholders, the dairy sector can enhance productivity, efficiency, and economic stability, contributing to a resilient and sustainable agricultural landscape



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# Large-scale phenotyping in dairy sector using milk MIR spectra: Key factors affecting the quality of predictions

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Cluster	RPDcv	Relative RMSEcv	R <sup>2</sup> cv	Interpretation for application
1	> 6	<5%	> 0.97	Any application
2	4.2- <mark>6</mark>	<10%	0.94- 0.97	Quality control
3	3-4.2	<10%	0.89- 0.94	Quantitative screening
4	2-3	<25%	0.74– 0.89	Rough screening
5	1.5–2	<25%	0.55- 0.74	Allows to compare groups, discriminate high or low values
6	1.5–2	>25%	0.55- 0.74	Highly imprecise, can be used to detect extreme values
7	< <mark>1.</mark> 5		< 0.55	Not recommended

### From our experience ...

#### Table 1

Datasets used in the study.

Traits	N records	N	N countries	Sampling	References
Milk Fatty acide 30 models	1922	1822	7	2005 2015	Soveurt et al (20.40)
Milk Minerals, 5 models	1340	1340	4	2005-2015	Soveurt et al. [41]
Milk Lactoferrin	3906	3906	3	2005-2009	Soveurt et al. [42]
Methane emitted (CH4)	1089	299	7	2010-2019	Dehareng et al. [43] and Vanlierde et al. [18]
Milk Fresh Cheese Yield (FCY), Coagulation time r, Time when the curd is firm enough for cutting (k20)	283	283	1	2011-2014	Colinet et al. [44]
Milk Casein	996	*	1	2011-2014	Not published
Milk Acetone, β-hydroxybutyrate (BHB) and Citrate	566	346	3	2013-2014	Grelet et al. [45]
Blood BHB, Non-Esterified Fatty Acids (NEFA), Insulin Growth Factor I (IGF-I), Glucose	387	241	6	2014-2016	Grelet et al. [6]
Nitrogen efficiency (NUE), Nitrogen losses, Dry matter intake (DMI), Body weight	1034	129	3	2014-2015	Grelet et al. [14]
Milk Glucose free, Glucose-6-phosphate, Uric acid, Iso-citrate, Progesterone	2175	241	6	2014-2016	Not published

\*The casein model was constituted by 790 samples from individual cows and 206 samples from bulk tank.

Quantitative

Rough screening

Phenotype	Min	Max	Mean	SD	R <sup>2</sup> cv	Relative RMSEcv	RPDev	Cluster
Milk SAT FA(g/dL)	0.31	6.97	2.70	0.75	0.99	3%	10.22	1
Milk C18_1cis9 (g/dL)	0.08	2.69	0.76	0.29	0.95	8%	4.35	
Milk Casein (g/100 g)	1.61	4.05	2.66	0.34	0.95	3%	4.46	
Milk LCFA (g/dL)	0.19	4.79	1.59	0.52	0.95	7%	4.52	
Milk MCFA (g/dL)	0.22	5.48	2.00	0.60	0.97	5%	5.53	
Milk MONO FA (g/dL)	0.12	3.42	1.08	0.35	0.97	5%	5.83	2
Milk Tot18_1cis (g/dL)	0.09	2.77	0.82	0.31	0.95	8%	4.58	
Milk Total_C18_1 (g/dL)	0.10	2.98	0.94	0.33	0.96	7%	5.18	
Milk UNSAT (g/dL)	0.14	3.86	1.25	0.39	0.97	5%	5.75	
Milk C10 (g/dL)	0.02	0.32	0.11	0.04	0.91	9%	3.37	
Milk C12 (g/dL)	0.02	0.41	0.13	0.04	0.92	9%	3.62	
Milk C14 (g/dL)	0.05	1.20	0.45	0.13	0.93	7%	3.88	
Milk C16 (g/dL)	0.12	3.32	1.20	0.40	0.94	8%	4.18	
Milk C4 (g/dL)	0.01	0.23	0.10	0.03	0.93	8%	3.67	3
Milk C6 (g/dL)	0.01	0.16	0.07	0.02	0.91	9%	3.32	
Milk C8 (g/dL)	0.01	0.11	0.05	0.01	0.91	9%	3.29	
Milk Citrates (mmol/L)	3.88	16.12	9.04	2.21	0.89	8%	3.04	
Milk SCFA (g/dL)	0.05	0.80	0.35	0.10	0.93	7%	3.88	
Milk C17 (g/dL)	0.00	0.09	0.03	0.01	0.80	13%	2.24	
Milk C18 (g/dL)	0.05	1.32	0.40	0.15	0.84	14%	2.51	
Milk Calcium (mg/kg)	593	1743	1149	135	0.82	5%	2.34	
Milk Odd fatty acids (g/dL)	0.03	0.50	0.16	0.04	0.83	10%	2.41	4
Milk PUFA (g/dL)	0.02	0.53	0.16	0.05	0.77	13%	2.10	
Milk Total_Trans (g/dL)	0.02	0.75	0.16	0.08	0.80	19%	2.26	
Tot18 1trans (g/dL)	0.01	0.57	0.13	0.06	0.79	21%	2.17	

Phenotype	Min	Max	Mean	SD	R <sup>2</sup> cv	Relative RMSEcv	RPDcv	Cluster
Cheese process r (s)	319	1653	906	231	0.58	16%	1.54	
Dry matter intake (kg/d)	8.8	36.2	19.9	4.5	0.71	12%	1.83	
Fresh cheese yield (g curd/100 g milk)	7.40	47.93	26.76	6.45	0.73	12%	1.91	
Methane emitted (g/d)	180	786	413	102	0.68	14%	1.79	
Milk C14_1 (g/dL)	0.00	0.15	0.04	0.02	0.68	21%	1.78	
Milk C16_1c (g/dL)	0.01	0.24	0.07	0.03	0.73	20%	1.91	
Milk C18_2c9c12 (g/dL)	0.00	0.17	0.06	0.02	0.72	19%	1.91	
Milk C18_3c9c12c15 (g/dL)	0.00	0.09	0.02	0.01	0.68	22%	1.77	
Milk isoanteiso FA (g/dL)	0.02	0.28	0.09	0.03	0.75	14%	2.00	23
Milk Magnesium (mg/kg)	61	157	100	13	0.72	7%	1.88	5
Milk omega3 (g/dL)	0.00	0.11	0.03	0.01	0.66	22%	1.73	
Milk omega6 (g/dL)	0.01	0.33	0.10	0.03	0.72	14%	1.89	
Milk Phosphorus (mg/kg)	509	1447	999	124	0.75	6%	1.99	
Milk Potassium (mg/kg)	819	1985	1524	147	0.55	6%	1.48	
Milk Tot18_2 (g/dL)	0.01	0.32	0.10	0.03	0.69	15%	1.79	
N efficiency (%)	9.8	81.7	36.9	10.3	0.71	15%	1.87	
N losses (kg/d)	0.04	0.81	0.31	0.11	0.65	20%	1.69	
Weight of cows(kg)	448	832	617	73	0.70	6%	1.83	
Blood BHB (mmol/L)	0.19	3.46	0.77	0.48	0.70	35%	1.81	
Blood IGF-I (mg/L)	13	436	107	71	0.61	42%	1.59	
Lactoferrin (mg/L)	7	1248	299	222	0.66	44%	1.71	6
Milk BHB (mmol/L)	0.05	1.60	0.22	0.17	0.75	46%	1.97	
Milk C18_2c9t11 (g/dL)	0.00	0.14	0.03	0.02	0.74	37%	1.95	

Phenotype	Min	Max	Mean	SD	R <sup>2</sup> cv	Relative RMSEcv	RPDcv	Cluster
Blood Glucose (mmol/L)	1.93	4.51	3.47	0.47	0.44	10%	1.33	
Blood NEFA (µekv/L)	26	1956	672	440	0.39	51%	1.28	
Cheese process k20 (s)	160	386	225	39	0.34	13%	1.24	
Milk Glucose Free (mmol/L)	0.00	0.69	0.24	0.11	0.50	32%	1.41	
Milk Glucose6Phosphate (mmol/L)	0.00	0.93	0.16	0.08	0.49	36%	1.40	7
Milk IsoCitrate (mmol/L)	0.02	2.90	0.17	0.10	0.11	55%	1.06	
Milk Natrium (mg/kg)	234	1273	356	91	0.44	15%	1.34	
Milk Progesterone (ng/ml)	0.50	22.44	5.22	2.74	0.08	50%	1.05	
Milk Uric Acid (µmol/L)	2.4	348.5	158.8	54.6	0.32	28%	1.22	