Improving livestock productivity, nutrition security, and the environment through the food-not feed strategy

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Animal Production and Health Division, FAO, Rome

Outline

- **Context**
- **Enlarging feed resource base**
- **Strategies to efficiently utilize available feed resources**
- **Impact of food-not feeding strategy on efficiencies in multi-dimension**
- **Moving from ‘calorie security’ to nutrition security**
- **Concluding remarks**

Huge demand for animal feed

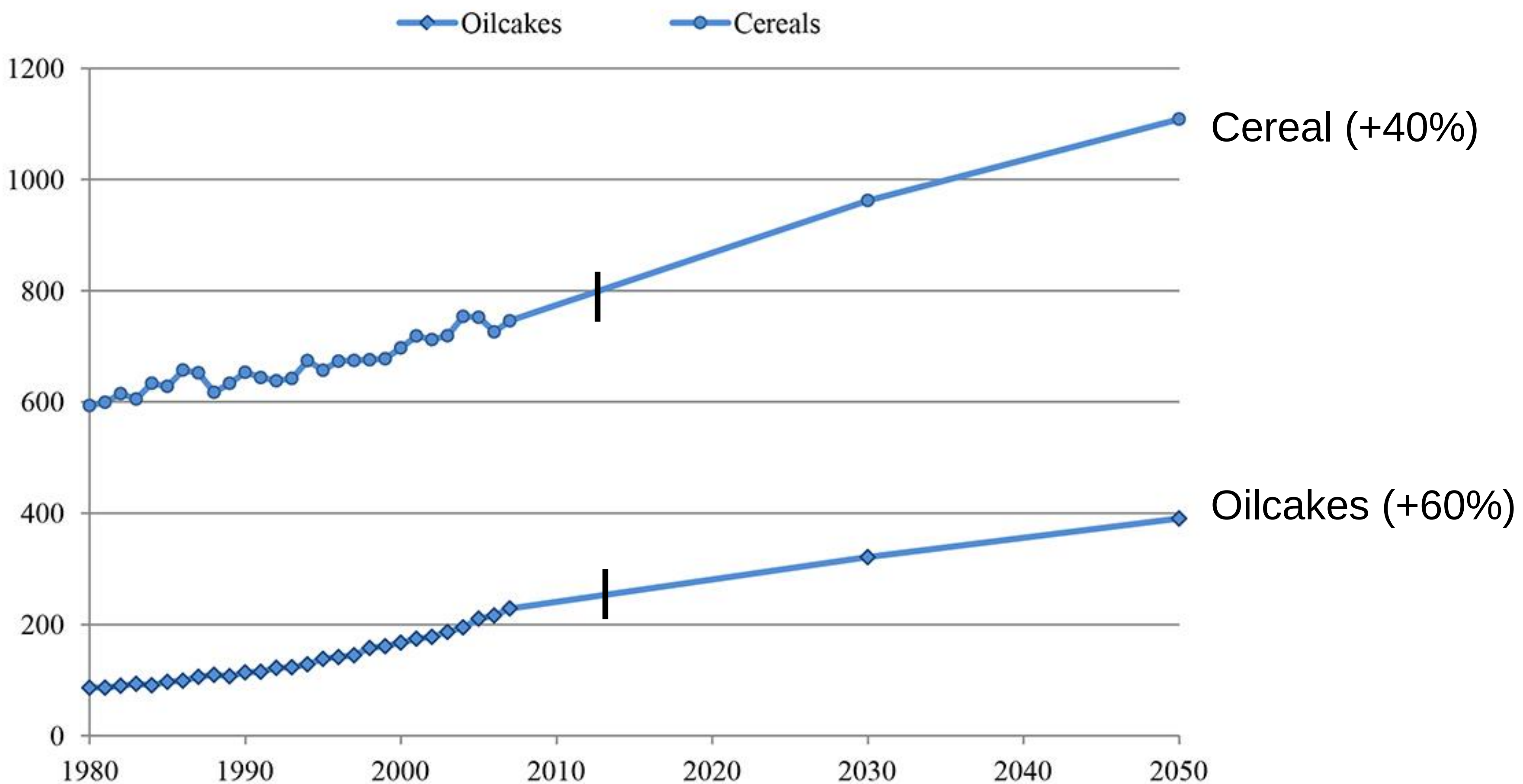
2050

An additional 443 million tonnes of maize production

60% for animal feeds (23% for biofuels)

Soybean production would need to increase nearly to
400 million tonnes (an increase by 80% of the present level)

Oilcakes and cereal use as feed



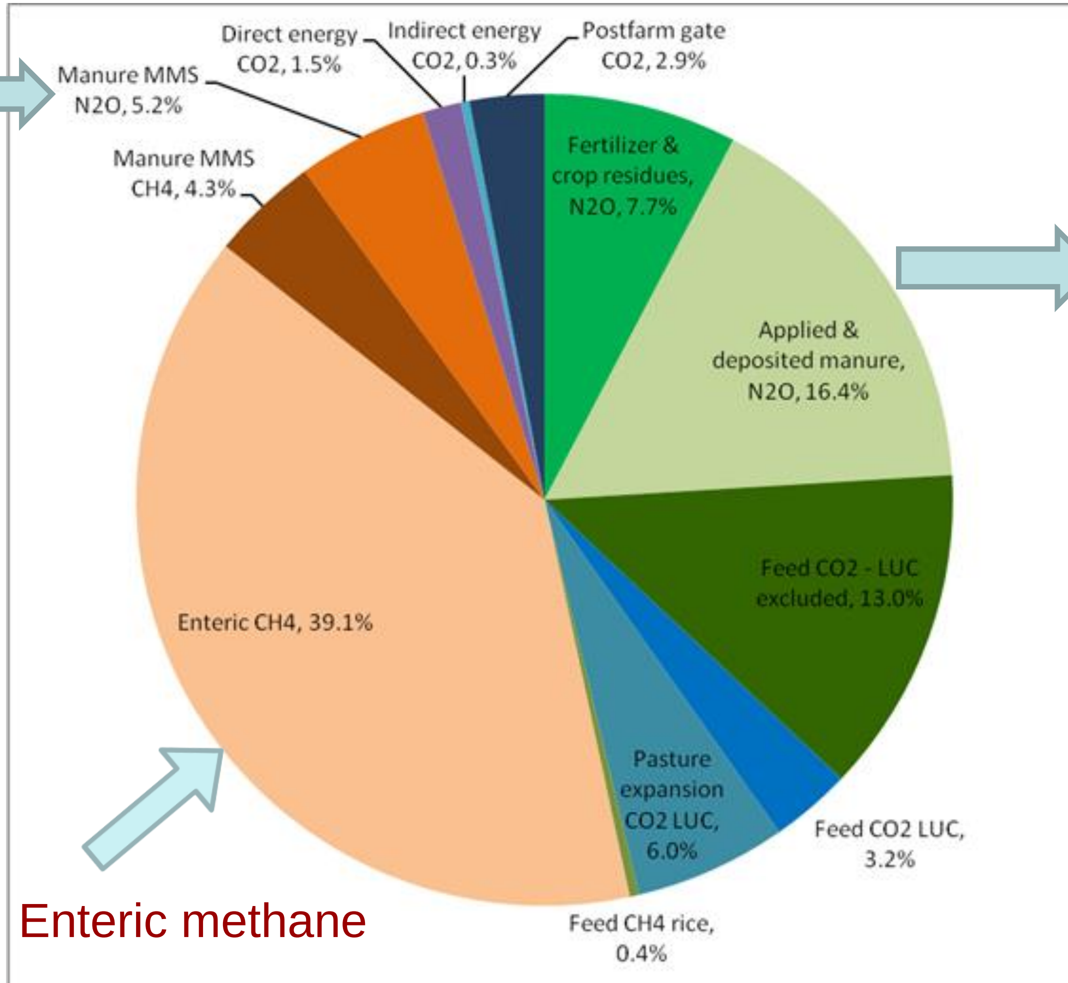
Historical data 1980-2007 from FAOSTAT; Projections: World feed use of Cereals: sum of the country feed projections; World projections of oilcakes feed use: world oilcakes production derived as joint products from the summation of the country production projection of oilcrops.

Feed and the environment (GHG)

Global GHG emissions from livestock supply chains (14.5%), by category of emissions

Feeding practices

70– 90% of Feed P to Manure



Enteric methane

Feed production and processing: 45 %

FAO (2013)

Severe shortage of good quality feed

Percent Feed balance as dry matter (DM), crude protein (CP) and metabolizable energy (ME) -- Ethiopia

Region	Feed balance, DM (%)	Feed balance, ME (%)	Feed balance, CP (%)
Tigray	-17.4	-50.9	-48.6
Afar	-35.1	-50.9	-48.1
Amhara	-9.6	-46.6	-43.2
Oromia	-4.0	-43.04	-41.6
Somali	+31.5	-3.4	+2.0
Benishangul -Gumuz	+173.9	+63.7	+92.9
SNNPR*	-34.2	-59.4	-53.7
Gambela	+284.3	+141.3	+164.9
Harari	-59.7	-74.3	-79.1
Dire Dawa	-50.6	-66.3	-72.5
TOTAL	**-9.4**	**-45.2**	**-42.3**

Extreme seasonal fluctuations affect feed distribution

Feed basket →

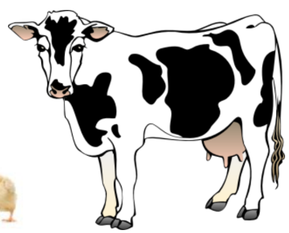
DM : Crop residues 46%, Pastures 60%
ME : Crop residues 42.5%, Pastures 52.8%
CP: Crop residues 32.4% Pastures 58.3%

Food-feed competition

2012–2013: 795 million tonnes cereals (1/3 total cereal) - animal feed

Of the total cereal use in livestock sector

34% 26% 26% 14%

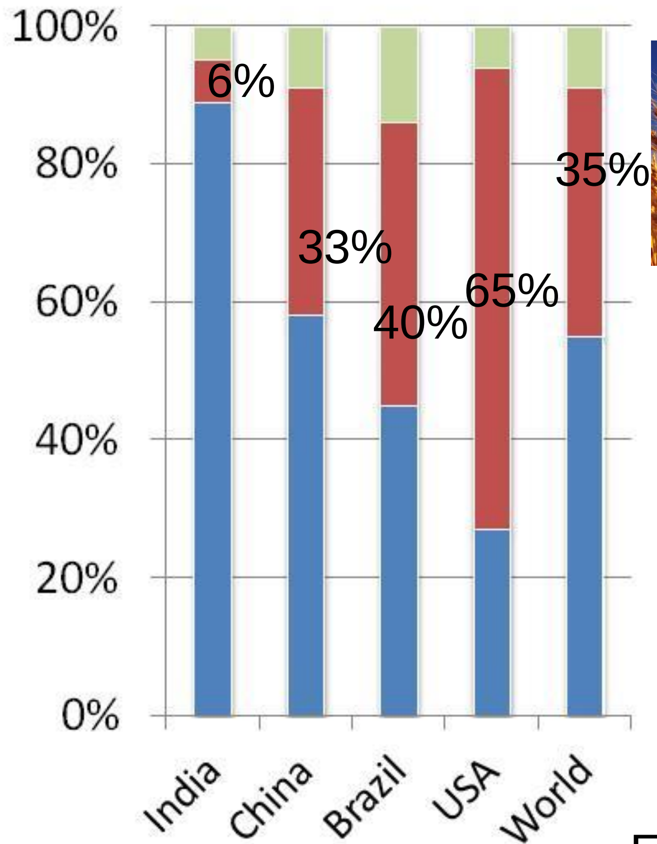
   

Cereal energy used for meat production, if fed directly

meet

Annual calorie need of 3.5 billion people

Nellemann et al. (2009), UNEP



EU: 53%

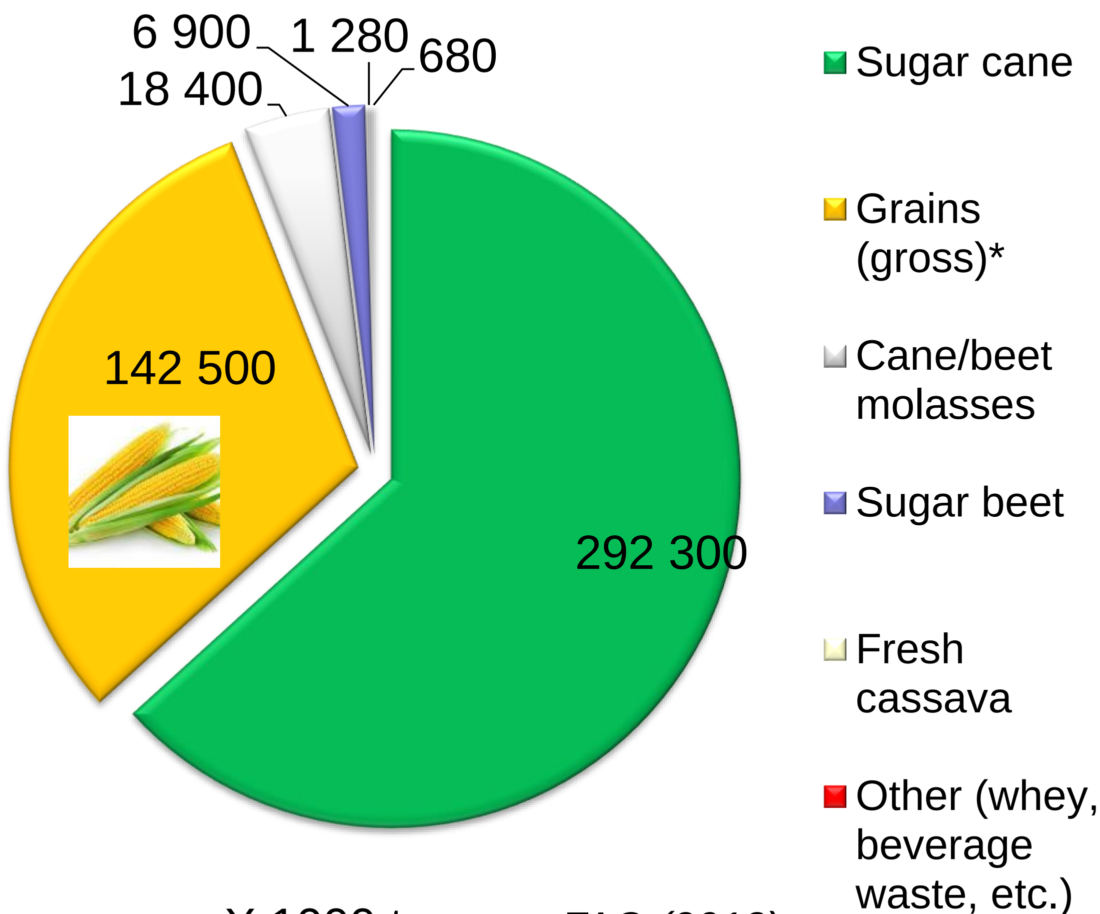
Fuel-feed competition

A continued rapid expansion of biofuel up to 2050

↓

Undernourished pre-school children

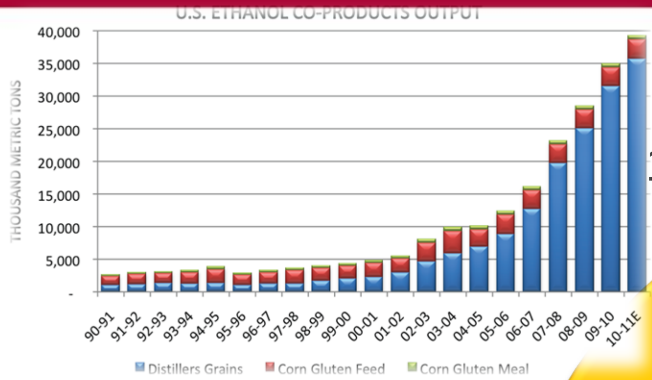
Africa and South Asia being 3 and 1.7 million higher than otherwise *FAO (2009)*

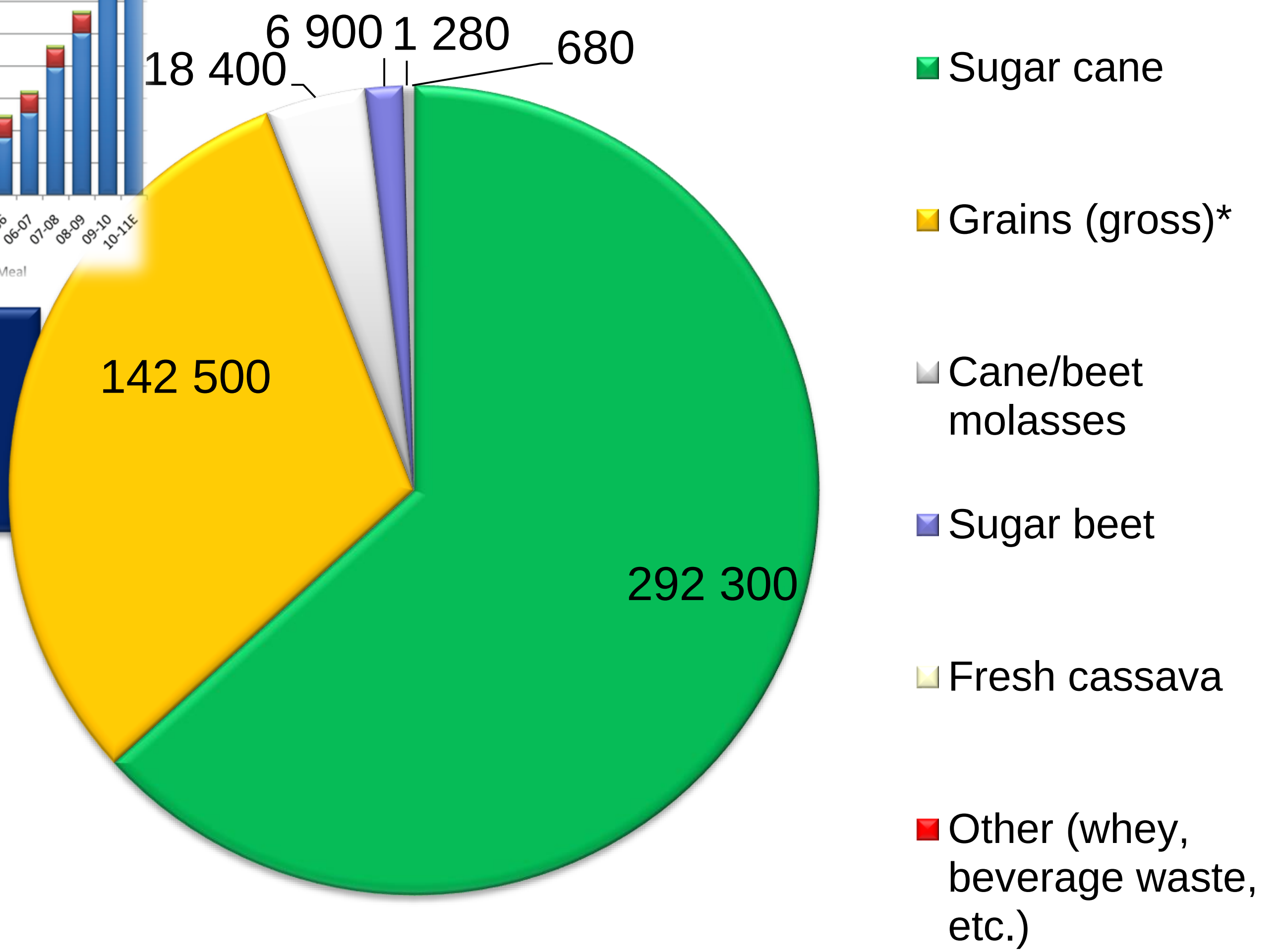


X 1000 tonnes *FAO (2013)*

Focus: Food-not Feed Resources

2010 world feedstock usage for fuel ethanol (thousand tonne)



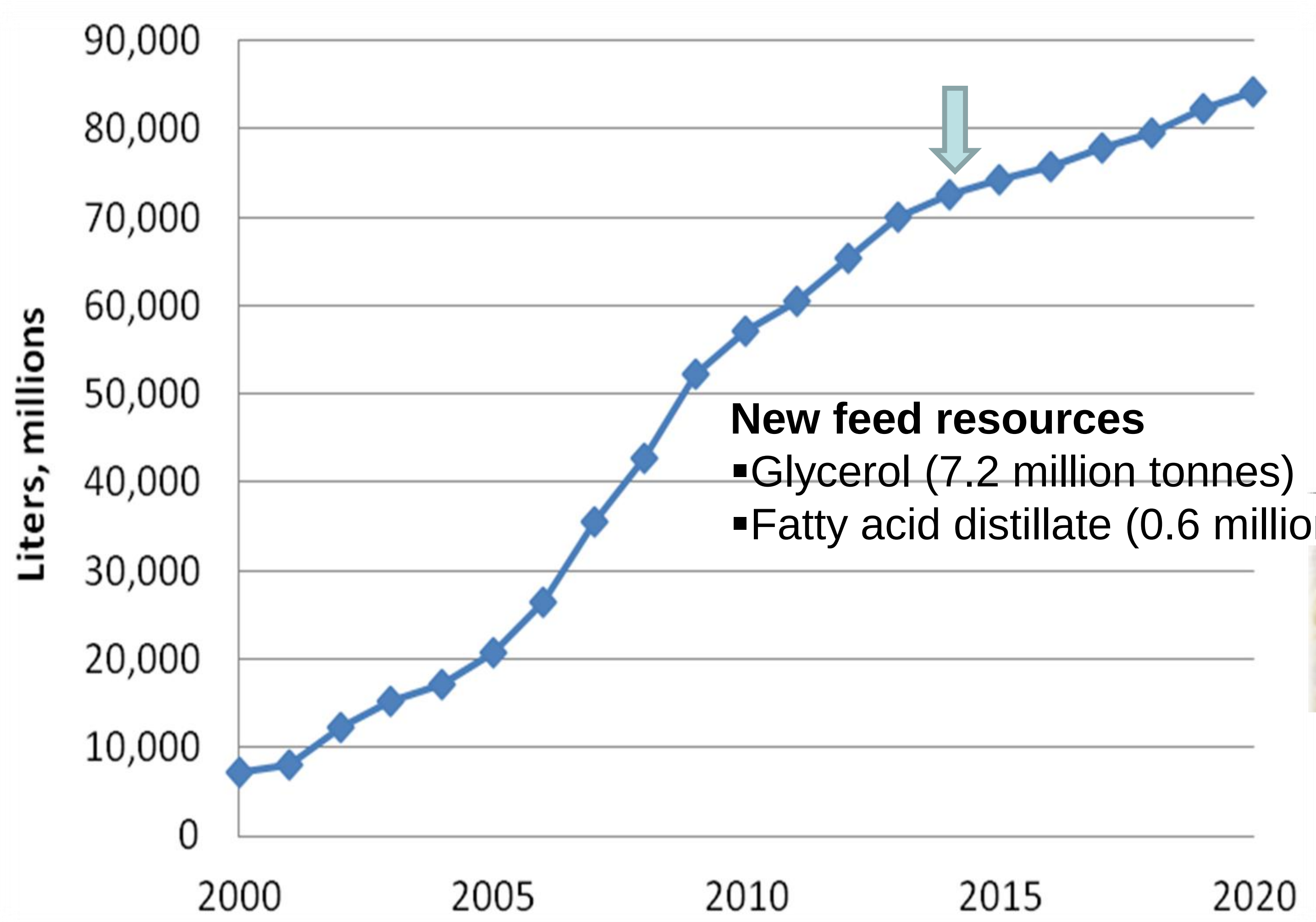


Approximately 1/3 of grain for fuel ethanol produces animal feed co-products

47.5 million tonnes

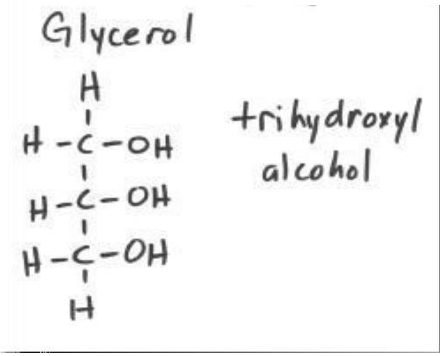
Source: F.O. Licht, 2011

Growth & anticipated world expansion of biodiesel production



New feed resources

- Glycerol (7.2 million tonnes)
- Fatty acid distillate (0.6 million tonnes)

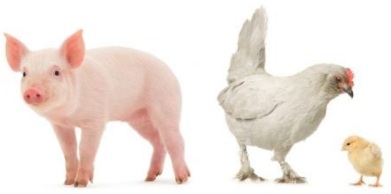


Source: National Biodiesel Board, 2008

Protein isolate for monogastrcs from ruminant feeds

- Palm kernel cake
- Pongamia seed cake
- Rapeseed cake
- Sunflower cake
- Camelina seed cake
- Green leuminous forages

Iso-electric pH → Protein isolate (80-90% CP)



Protein hydrolysate using green chemistry

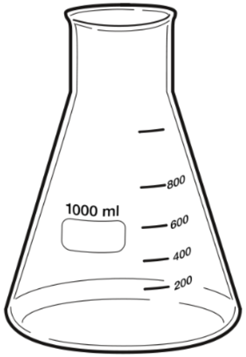
- **Pongamia seed**
- **Rapeseed**
- **Sunflower seed**
- **Camelina seed**
- **Jatropha kernels**

Enzyme assisted oil extraction

Oil

Hydrolysed proteins

Co-products of non-edible oil-based biodiesel industry



Scaling up of detoxification processes is needed

Seaweeds (macro-algae)

Brown algae	up to 14% CP
Red Algae	**up to 50% CP**
Green algae	up to 30% CP

Rich in bioactive compounds (enteric methane inhibitors)

Pre-biotics: alginates, mannitol, laminarin, fucoidan

Source of organic minerals

Seaweed polysaccharides have positive effect on reducing digestive infections in calves, prevent ketosis, boost immunity and reduce metabolic dis

- Future areas of work: Develop large scale production, harvesting and drying methods

Animal Feed Science and Technology 212 (2016) 1–17

Contents lists available at ScienceDirect

Animal Feed Science and Technology

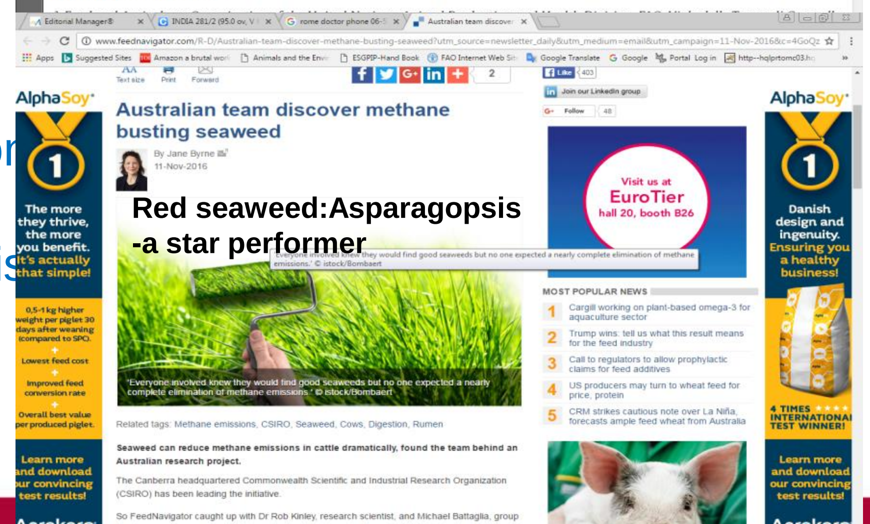
journal homepage: www.elsevier.com/locate/anifeedsci

ELSEVIER

Review article

Seaweeds for livestock diets: A review☆

Harinder P.S. Makkar[a,*], Gilles Tran[b], Valérie Heuzé[b], Sylvie Giger-Reverdin[c,d], Michel Lessire[e], François Lebas[f], Philippe Ankers[a]



www.feednavigator.com/R-D/Australian-team-discover-methane-busting-seaweed?utm_source=newsletter_daily&utm_medium=email&utm_campaign=11-Nov-2016&c=4GoQz

Australian team discover methane busting seaweed

By Jane Byrne

11-Nov-2016

Red seaweed:Asparagopsis -a star performer

'Everyone involved knew they would find good seaweeds but no one expected a nearly complete elimination of methane emissions.' © istock/Bombaert

Related tags: Methane emissions, CSIRO, Seaweed, Cows, Digestion, Rumen

Seaweed can reduce methane emissions in cattle dramatically, found the team behind an Australian research project.

The Canberra headquartered Commonwealth Scientific and Industrial Research Organization (CSIRO) has been leading the initiative.

So FeedNavigator caught up with Dr Rob Kinley, research scientist, and Michael Battaglia, group

MOST POPULAR NEWS

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2 Trump wins: tell us what this result means for the feed industry

3 Call to regulators to allow prophylactic claims for feed additives

4 US producers may turn to wheat feed for price, protein

5 CRM strikes cautious note over La Niña, forecasts ample feed wheat from Australia

Insect as feed for poultry, pigs and fish

Black Soldier Fly or *Hermetia illucens*

Maggots: larvae of the housefly *Musca domestica*

- **Protein quality is generally high, similar to other animal meat sources**
- **Protein content: ca 50%**
- **Fat content is variable, but in general a good source of essential polyunsaturated fatty acids**
- **A significant source of iron, zinc and vitamin A.**

G Model
ANIFEE-13121; No. of Pages 33

ARTICLE IN PRESS

Animal Feed Science and Technology xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Animal Feed Science and Technology

journal homepage: www.elsevier.com/locate/anifeedsci

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Review

State-of-the-art on use of insects as animal feed

Harinder P.S. Makkar[a,*], Gilles Tran[b], Valérie Heuzé[b], Philippe Ankers[a]

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ARTICLE INFO

Article history:
Received 25 January 2014
Received in revised form 1 July 2014
Accepted 20 July 2014
Available online xxx

ABSTRACT

A 60–70% increase in consumption of animal products is expected by 2050. This increase in the consumption will demand enormous resources, the feed being the most challenging because of the limited availability of natural resources, ongoing climatic changes and food–feed–fuel competition. The costs of conventional feed resources such as soymeal and

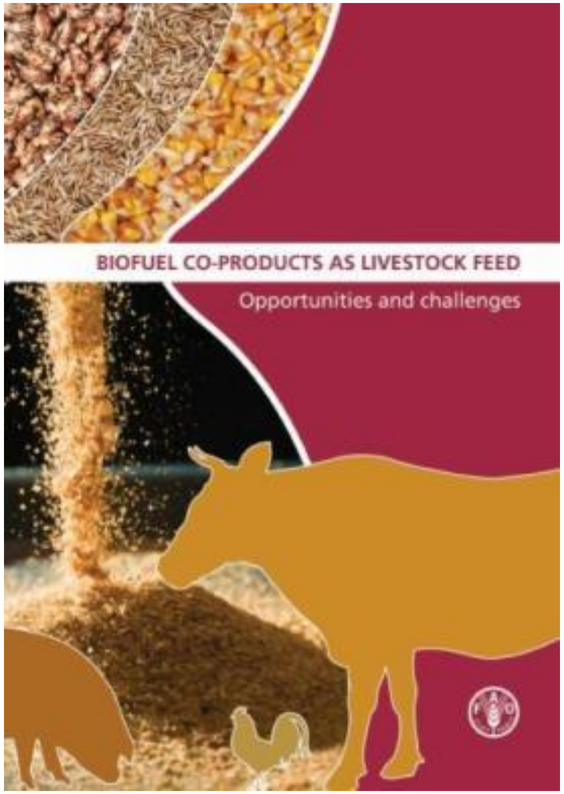
Challenges: Mass production at an industrial scale, safety issue and regulatory aspects

Source: Makkar et al (2014): AFST

Non-toxic Jatropha

Jatropha platyphylla (non-toxic)

Jatropha curcas (non-toxic)



Moringa – a novel feed resource

Dense cultivation
of *Moringa oleifera*

Yield	Yield (tons/ha/yr)	Concentration (% DM)
DM yield	126	
Protein	21.4	17.0
Sugar	12.6	10.0
Starch	10.0	7.9

20% leaf meal i.e. 25 tonnes; has 25% protein
Total protein yield/ha = **6.4 tonnes**

Vs.

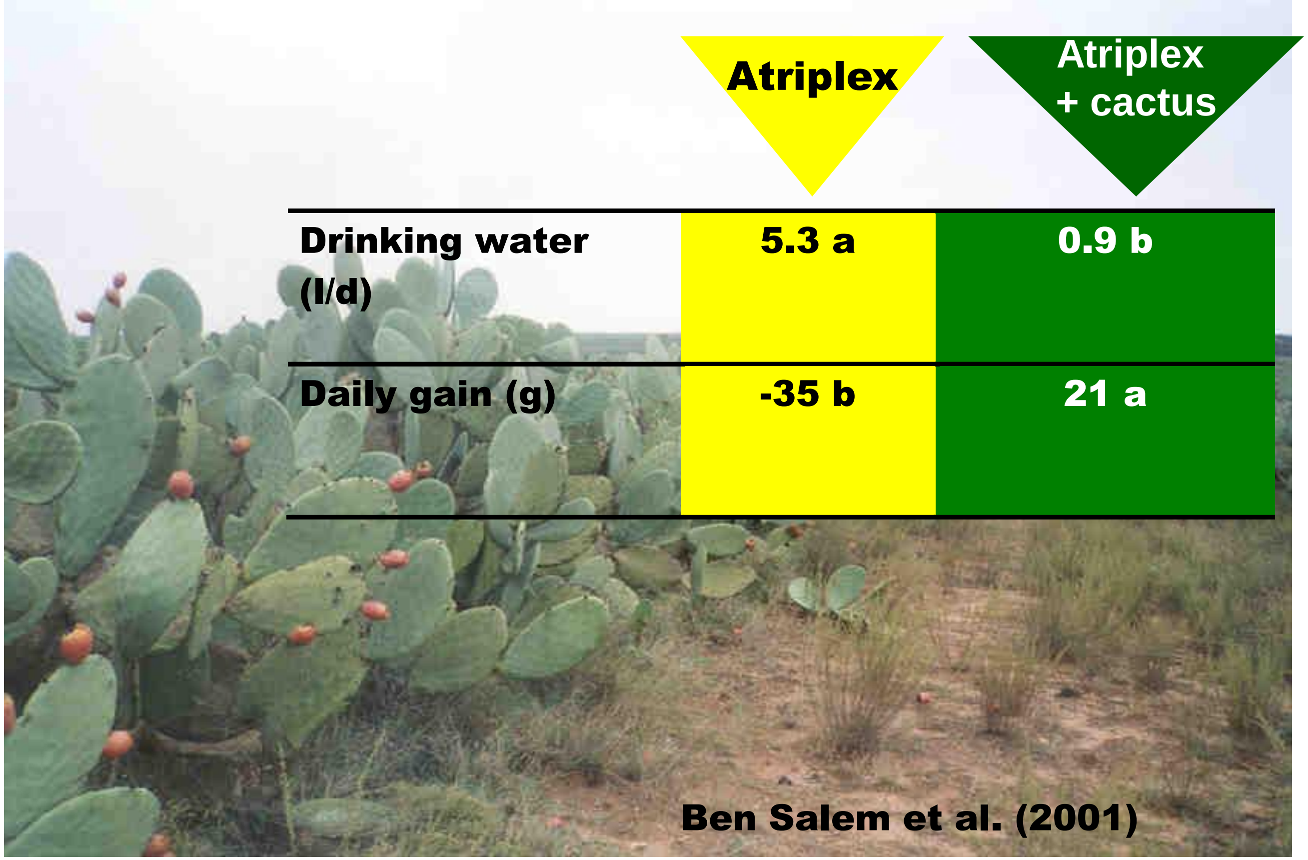
Soyabean

Soybean = 3.5 tonnes/ha
Protein = 35 %

Total protein yield/ha = **1.23 tonnes**

Cactus use as feed

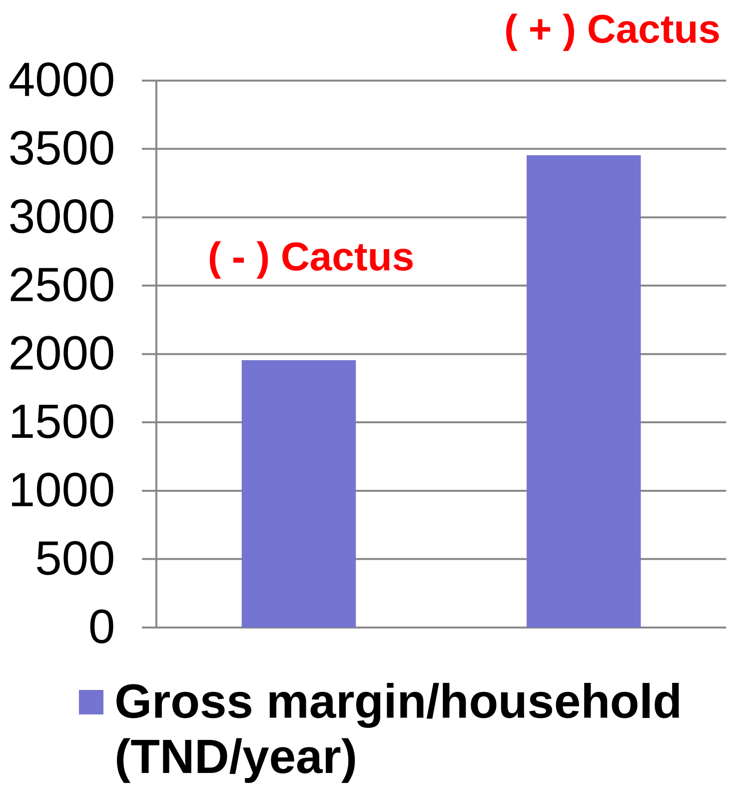
Complementary role of Atriplex and Cactus



	Atriplex	Atriplex + cactus
Drinking water (l/d)	5.3 a	0.9 b
Daily gain (g)	-35 b	21 a

Ben Salem et al. (2001)

Impact of Cactus on farmers' income



Net benefit/sheep increased with cactus incorporated in diet

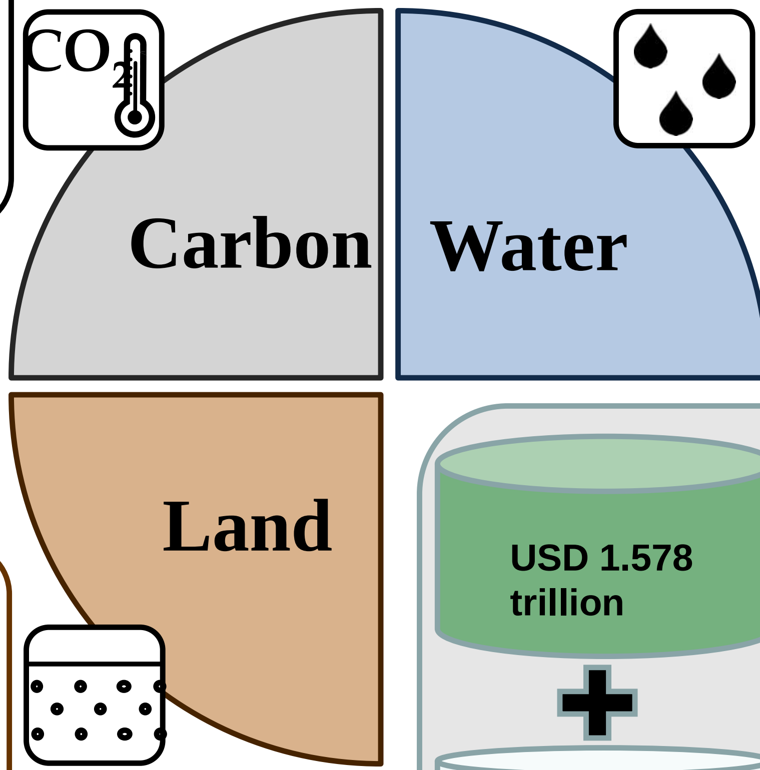
(26 sheep per household)

Daly & King (2014)

Footprint of food wastage (1.3-1.6 Gt/year)

3.3 Gt CO_2eq/year
=
3[rd] largest emitter,
if food wastage was a country

305 km^3/year
=
3 times lake Geneva



1.5 billion ha used to grow food that is wasted
=
30% of agricultural land

USD 1.578 trillion — Socio-environmental costs (under-estimate)

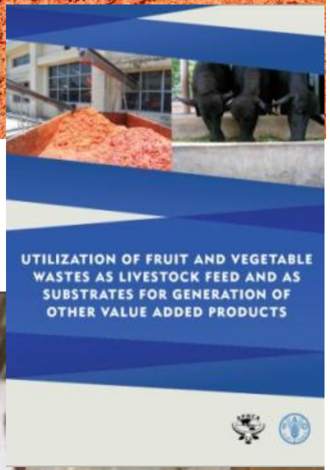
+

USD 1 055 billion — Economic costs (2012)

Full cost of Food Wastage

Source: FAO, 2013. Food Wastage Footprint: Impacts on Natural Resources

Fruit and Vegetable Wastes to Animal Feed



1.3-1.6 Gt (30% of total) Wasted per year

Insect rearing
Makkar et al. (2014)

Food processing sector (organized): Losses in Fruit & Vegetable (million tons)

India 1.81
China 32.0
USA 15

Silage production
Bakshi, Wadhwa and Makkar (2013)

Cultivate fodder production using spate/spread irrigation

Feed production is nutrition smart agriculture, especially in harsh conditions

Afar, Ethiopia

- Spate/spread irrigated fodder production:
  Biomass yield : 5-times than natural pasture
- Big potentials – in Kenya, Ethiopia, Somalia, Uganda

Use of spate irrigation for commercial fodder production in Somalia

Commercialization of fodder production has:

- Increased pastoralists' cash income
- Provided opportunity for women to sell fodder for income generation

Hydroponic fodder production

Low-cost systems might have niche where soil is poor, and availability of water and fodder is scarce

Re-emergence of single cell protein feeds after 25-30 years

KnipBio ups production

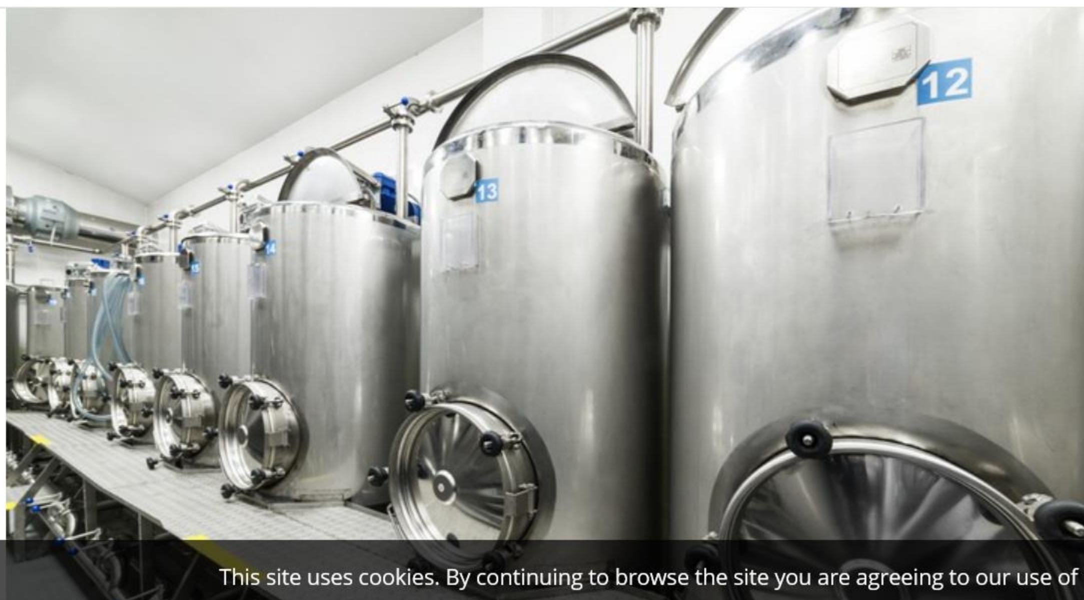
https://www.feednavigator.com/Article/2018/01/19/KnipBio-ups-production-of-single-cell-protein-feed-products-for-aquaculture?utm_

SPECIAL EDITION: ALTERNATIVE FEED PROTEINS

KnipBio ups production of single cell protein feed products for aquaculture

By Aerin Einstein-Curtis
19-Jan-2018 - Last updated on 19-Jan-2018 at 09:20 GMT

2 POST A COMMENT



Publication: 19 Jan 2018

Food Protein Vision 07 MAR 2018 Wed

ENG 17:32 19/01/2018

Towards making efficient use of available resources

Wide variation in efficiency of microbial protein production in rumen

g microbial protein/kg fermented organic matter in the rumen

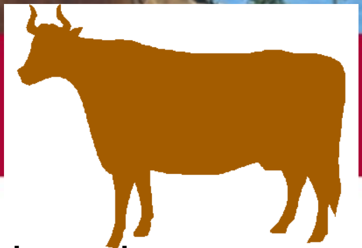
	Mean	Range
NRC (2001)	186	75 – 338
Lebzien & Voigt (1995)	188	63 – 313

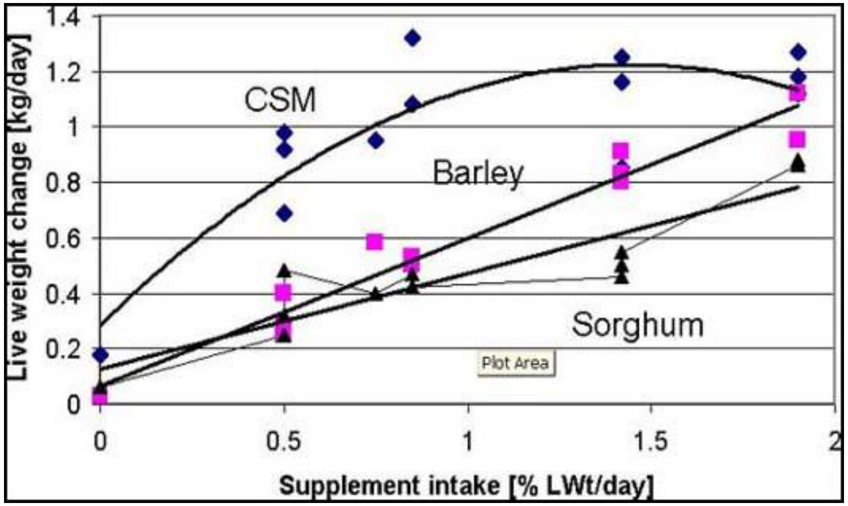
Almost 4-5 fold variation

Key to increase in ruminant productivity:

Optimization of the rumen

Human edible protein from roughage based feeding





Smart food-not feeding strategy: feeding of cotton seed meal (CSM) and not of barley and sorghum

5 kg straw :1 kg live weight gain

52.7 million tonnes of straw in Ethiopia

Produce 10.5 million tonnes of live animal annually (5 million tonnes of boneless meat = 1.31 million tonnes protein)
Adult protein consumption (WHO) = 60 g/d or 22 kg protein/year

Support 60 million people at 22 kg/year

LW of animal: 200 kg

0.5% of LW = 1 kg CSM/day

LW gain = 0.9 kg/day

FCR = 0.9/1 = 0.9

FCR in poultry and pigs

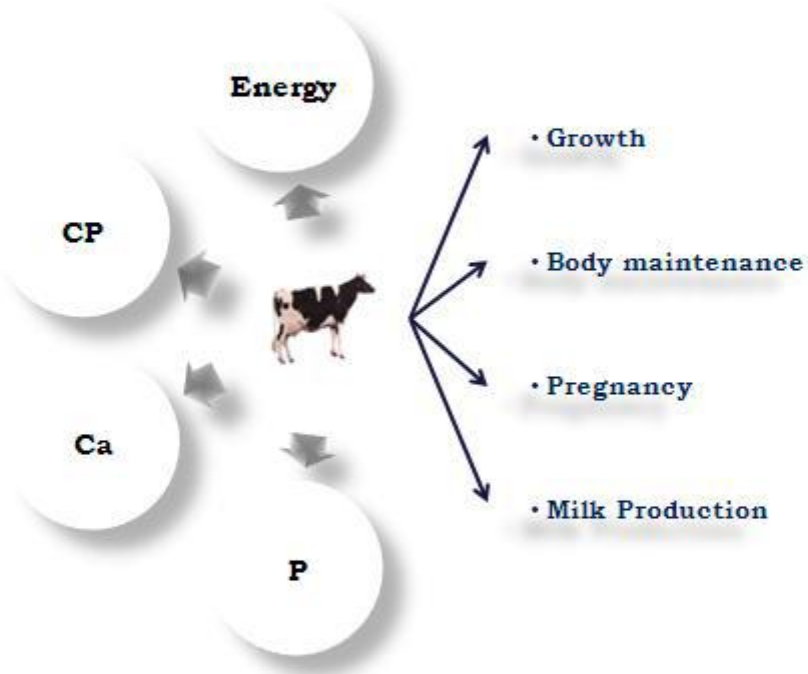
Grains: 2 kg/day

LW gain = 1 kg/day

FCR = 1/2 = 0.5

Smart Feeding Strategies -- Ration Balancing

Use the feed strategically, based on the physiological stage and production of the animal … Balanced feeding

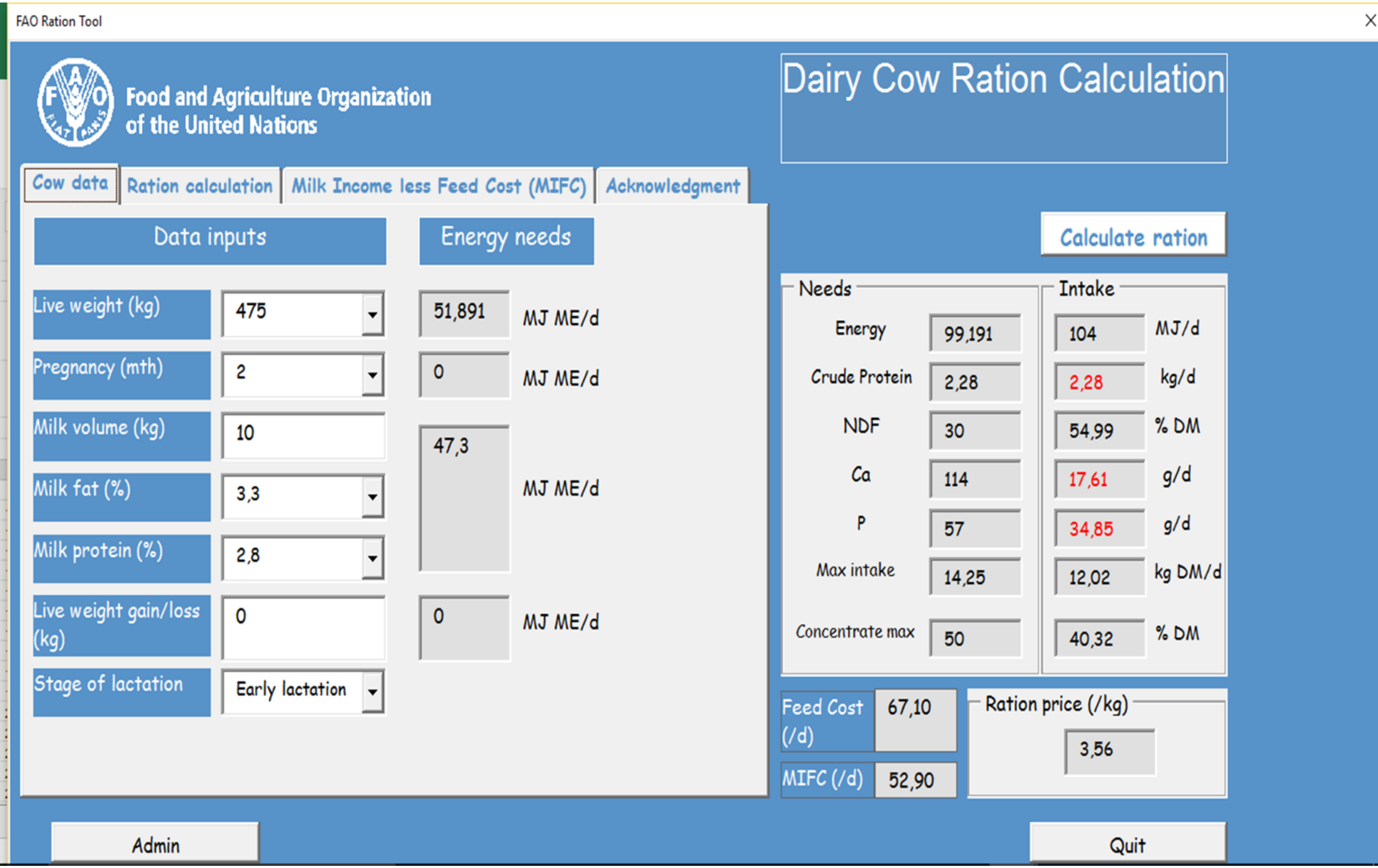


Slide credit: NDDB, India

Strategic use of anthelmintics

Use of mineral mixtures

Free of anti-nutritional factors


FAO Ration Tool
Food and Agriculture Organization of the United Nations
Dairy Cow Ration Calculation
Cow data
Ration calculation
Milk Income less Feed Cost (MIFC)
Acknowledgment
Data inputs
Energy needs
Live weight (kg)
475
51,891
MJ ME/d
Pregnancy (mth)
2
0
MJ ME/d
Milk volume (kg)
10
47,3
MJ ME/d
Milk fat (%)
3,3
Milk protein (%)
2,8
Live weight gain/loss (kg)
0
0
MJ ME/d
Stage of lactation
Early lactation
Calculate ration
Needs
Intake
Energy
99,191
104
MJ/d
Crude Protein
2,28
2,28
kg/d
NDF
30
54,99
% DM
Ca
114
17,61
g/d
P
57
34,85
g/d
Max intake
14,25
12,02
kg DM/d
Concentrate max
50
40,32
% DM
Feed Cost (/d)
67,10
MIFC (/d)
52,90
Ration price (/kg)
3,56
Admin
Quit

Effect of ration balancing (RB) on milk yield, milk fat & feeding cost in cows under field conditions from fourteen states (n=200000)

Parameter	Before RB	After RB	Change
Milk yield (kg/day)	8.10	8.40	+0.30
Milk fat (g/kg)	58.80	61.50	+2.7
Feeding cost per kg milk yield (Rs.)	10.09	8.47	-1.62
Increase in net daily income (Rs./animal)			+24.0

Effect of ration balancing on feed use efficiency & solid not fat (SNF)

Parameter	Cows (*n*=540)	
	Baseline	After RBP
FCM yield (kg/day)	8.04[c]	8.66[d]
Average DMI (kg/day)	14.55[c]	11.06[d]
FCM* yield (kg)/kg DMI	0.58[c]	0.78[d]
Average SNF % in milk	7.80	8.59 (+0.79)

Effect of ration balancing (RB) on N-utilization efficiency

Parameter		Cows (n=439)
Average CP intake (g/animal/day)	Before RB	1648[a]
	After RB	1232[b]
Average milk protein output (g/animal/day)	Before RB	322[a]
	After RB	335[b]
Dietary N secreted into milk (%)	Before RB	19.6[a]
	After RB	26.8[b]

Effect of feeding balanced ration on various parameters in cows (n=134)

Parameters	Before RB	After RB
Plasma IgG (mg/ml)	14.5[a]	22.1[b]
Plasma IgM (mg/ml)	2.7[c]	3.3[d]
Faecal eggs/g faeces	168[a]	81[b]

Effect of ration balancing (RB) on efficiency of microbial protein synthesis

Parameter	Cows (*n*=55)	
	Before RB	After RB
Microbial nitrogen yield (g CP/day)	724.1[a]	1004.4[b]
Efficiency of microbial protein synthesis (g MCP/kg DOM)	68.3[a]	93.3[b]

Balanced feeding & methane emission

Methane emission (g/day)		% reduction
Before RBP	After RBP	(n=61)
232.48 ± 5.93	199.60 ± 4.98	15.0

Carbon credit through reduction in methane

200,000 animals Ind. cattle (IC) : Crossbred (CB) : Buffalo (B) = 20 : 40 : 40

IC - 200 g CH_4/d; reduction 8%

CB - 300 g CH_4/d; reduction 12%

B - 320 g/d; reduction 12%

Total reduction CH_4/annum = 2346 tons

CO_2 equivalent = 53958 tons

220,000 US$ (one ton = US$ 5)

Garg and Makkar (2014)

Note: N_2O reduction not yet taken into account

Benefits of Ration Balancing Advisory Services

RBP

- Increases milk yield
- Increases fat & SNF% in milk
- Increases net daily income of milk producers
- Improves reproduction efficiency
- Increases microbial protein synthesis
- Reduces parasitic load
- Improves immune status
- Improves water foot print of milk
- Increases efficiency of vaccinations
- Reduces methane emission

Implementation of balanced feeding at smallholders level and strengthening the institutional support – extension network and capacity building – required

Reduce losses of feed resources

Loss of valuable resources

Air pollution

Loss in soil biodiversity

Making of densified total mixed ration blocks

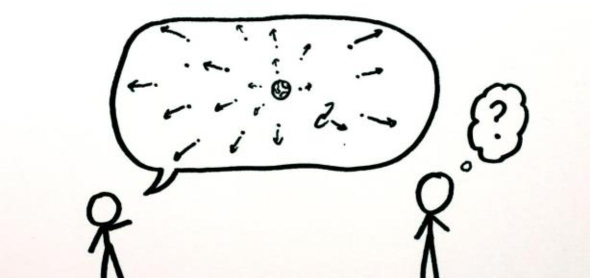
Forage
Wheat straw, paddy straw, sorghum stalks, Sugarcane tops, bagasse etc.

Concentrate
Oilseed cakes, urea, molasses or other energy sources,

Mixes
Vitamin mix, mineral mix, probiotics, additives, anti-oxidants, antitoxins, etc.

Machine for mixing of chopped straw and concentrate

Hydraulic press for making densified blocks



South-South partnerships

Advantages of Densified Straw-based Blocks

Less wastage, less chances of feed of selection

Higher productivity, a unique technology to deliver balanced diets

Easier and safer to transport & store

Good feed for emergency situations

Easier to feed by farmers, saves time

Setting up of National Feed Grid & Fodder Banks possible.

Can discourage straw burning

Urea-molassess block variants

Use of UMMB and its impact in some Asian countries

Country	UMMB produced (kg/yr)	Extra income/cow/day from milk
China	90 000	~ Yuan 2
Indonesia	120 000	~ Rupiah 500
Myanmar	45 000	~ Kyat 50
Sri Lanka	20 000	~ Rupee 25
Thailand	80 000	~Bhat 3 - 6
Vietnam	900 00	~ Dong 5 000- 10 000

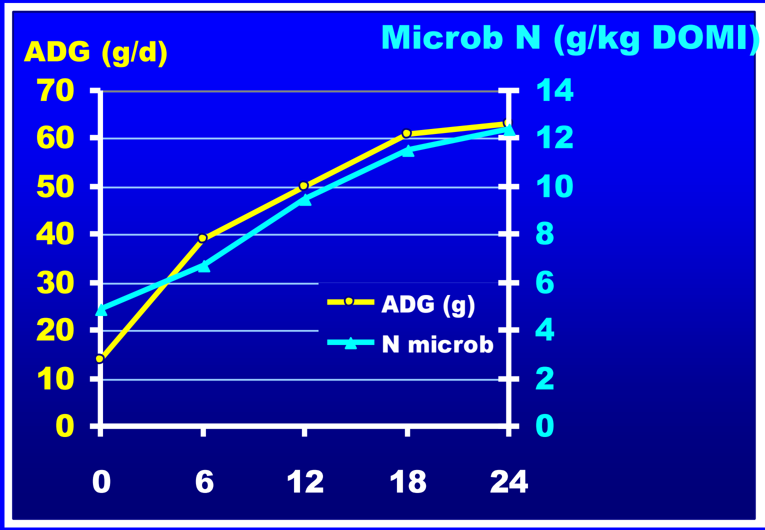
Cactus & mulberry fruits as substitute for molassess

Impact in

Asian countries: http://www.iaea.org/programmes/nafa/d3/mtc/ras035-report.pdf
African countries: http://www.iaea.org/programmes/nafa/d3/mtc/cairo-nov2000.pdf

Blocks containing polyethylene glycol….*Tunisia*

For diet based on *Acacia cyanophylla* leaf (CT 5 – 7 %) fed to Barbarine lambs (BW 29 kg)



% PEG in feed blocks

	PEG in feed blocks (%)				
	0	6	12	18	24
OM Dig. (%)	33.3	39.5	40.3	43.2	51.2
CP Dig. (%)	43.5	50.9	54.9	55.1	57.2

Blocks containing P, Se and forage seeds

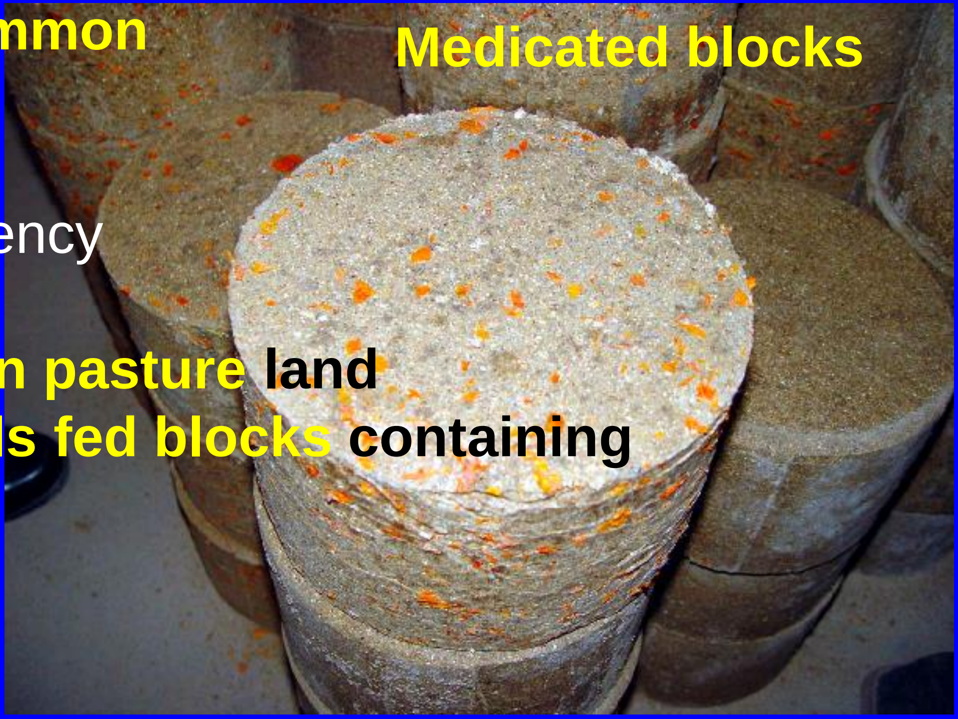
Heifers (grazing) in well-drained savannahs [Venezuela]

Phosphorus deficiency is common
[3 % di-ammonium phosphate in block]

Cattle in Jiang [China; near inner Mongolia)
where selenium deficiency is common

-- Increase in weight gain
-- Increase in reproductive efficiency

Forage seeds can be dispersed in pasture land through faeces of grazing animals fed blocks containing forage seeds



Blocks containing fenbendazole (FBZ, 0.5g/kg block) – anti-nematode block supplementation…1

Cattle [Vietnam/ Thailand/India/Malaysia/Australia]

– Decrease in parasitic load. Zero faecal egg counts

– Increase in body weight gain, milk production

– improvement in health and hair coat

Blocks containing pine apple leaves – anti-nematode block supplementation…2

Heifers [Vietnam/Philippines] (pine apple leaves 150 g/kg block)
– Decrease in faecal egg counts -- equally effective as fenbendazole

Cattle [Bangladesh] (pine apple fresh leaves 1.6 g/kg LW = 200 mg dried leaves/kg LW)
– Fecal egg count reduction % at 7, 14, 21 day post-treatment:
Leaves, 76, 82, 96; Albendazole 100, 87, 98)

Chopping of forages

Reduce wastage

Increase intake

Increase in feed nutrient use efficiency

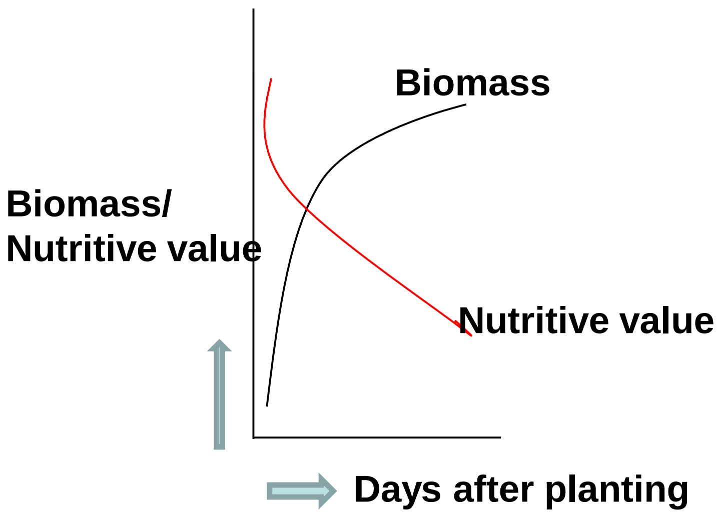
Increase in productivity

Need to promote use of ‘chaff-cutters’

Smart feeding: strategically use of available feed resources

An example: Use of fodder when CP and/or digestible organic matter /ha highest

Provision of the information to farmers of 'the window' having maximum CP and DOM



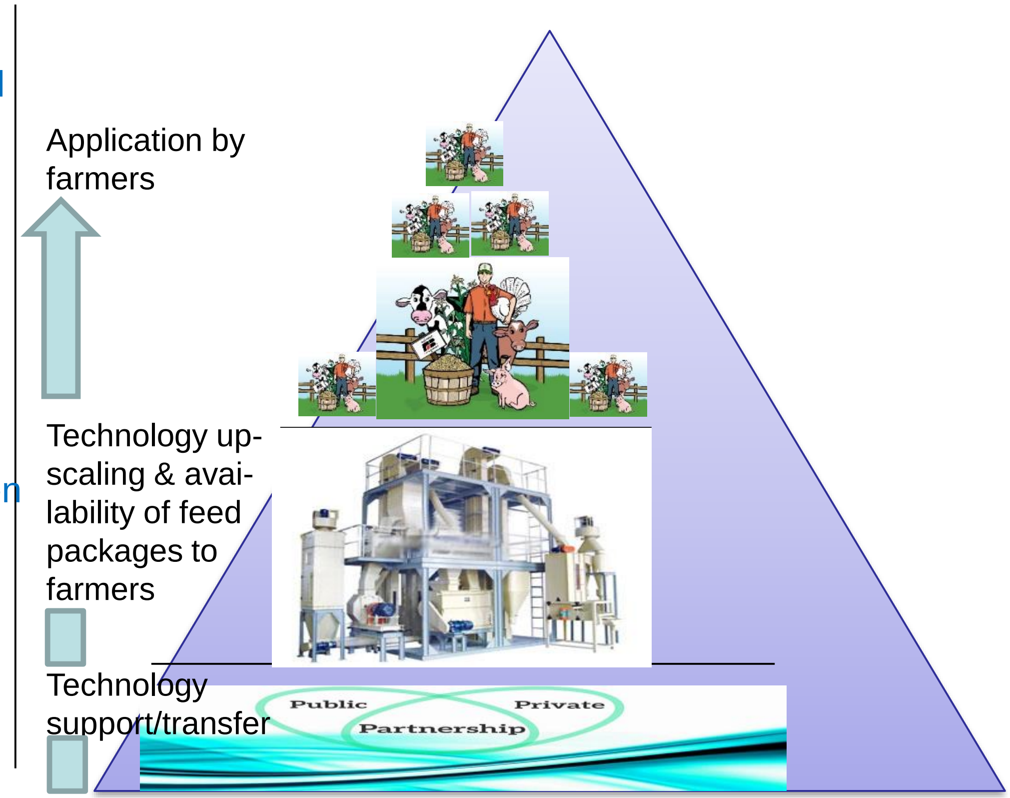
Days after planting?
Colour of leaves
Portable NIRS

ARCh_NET

PHAZIR

Overarching principles for successful technology adoption

Business model development

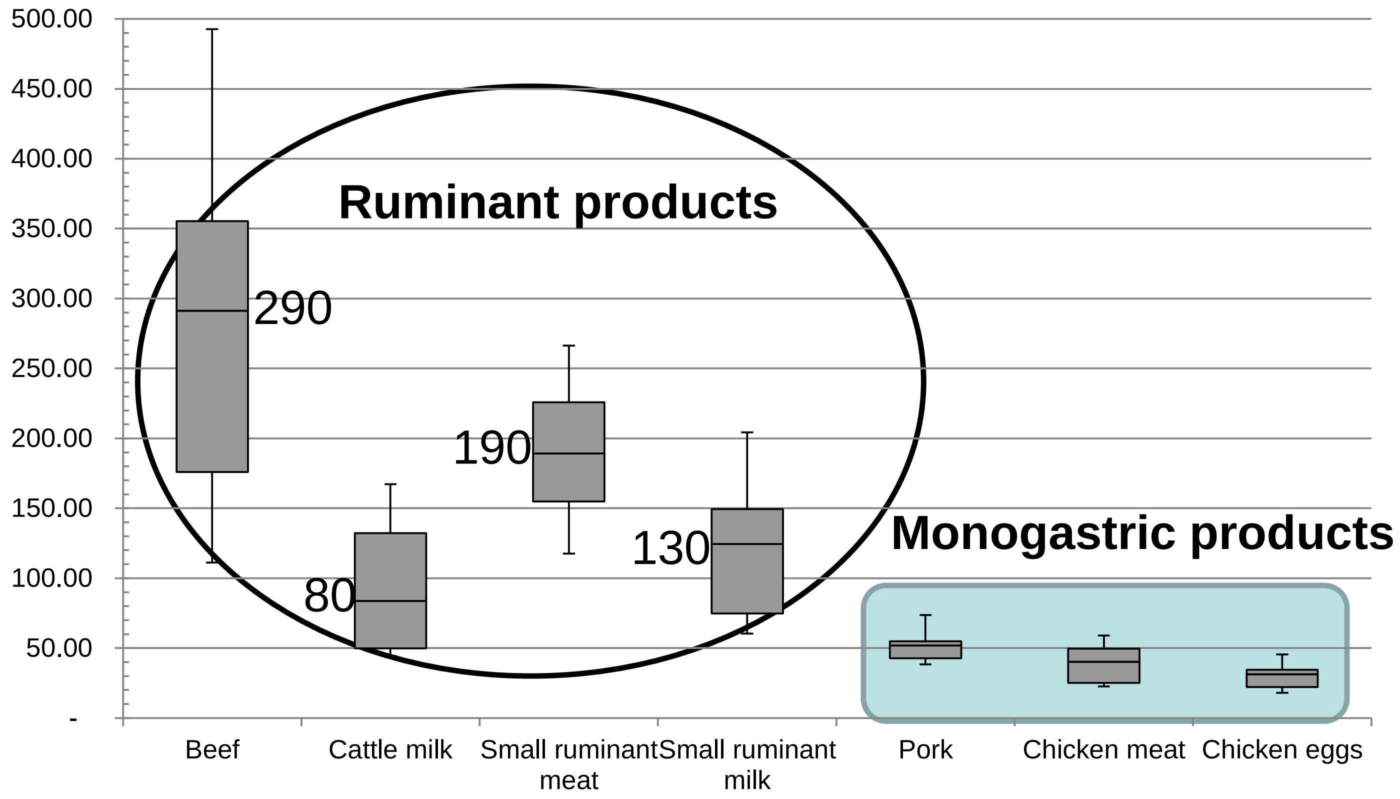


Food-not feed strategy & efficiency in multi-dimensions

Estimated global emission intensities (Ei)

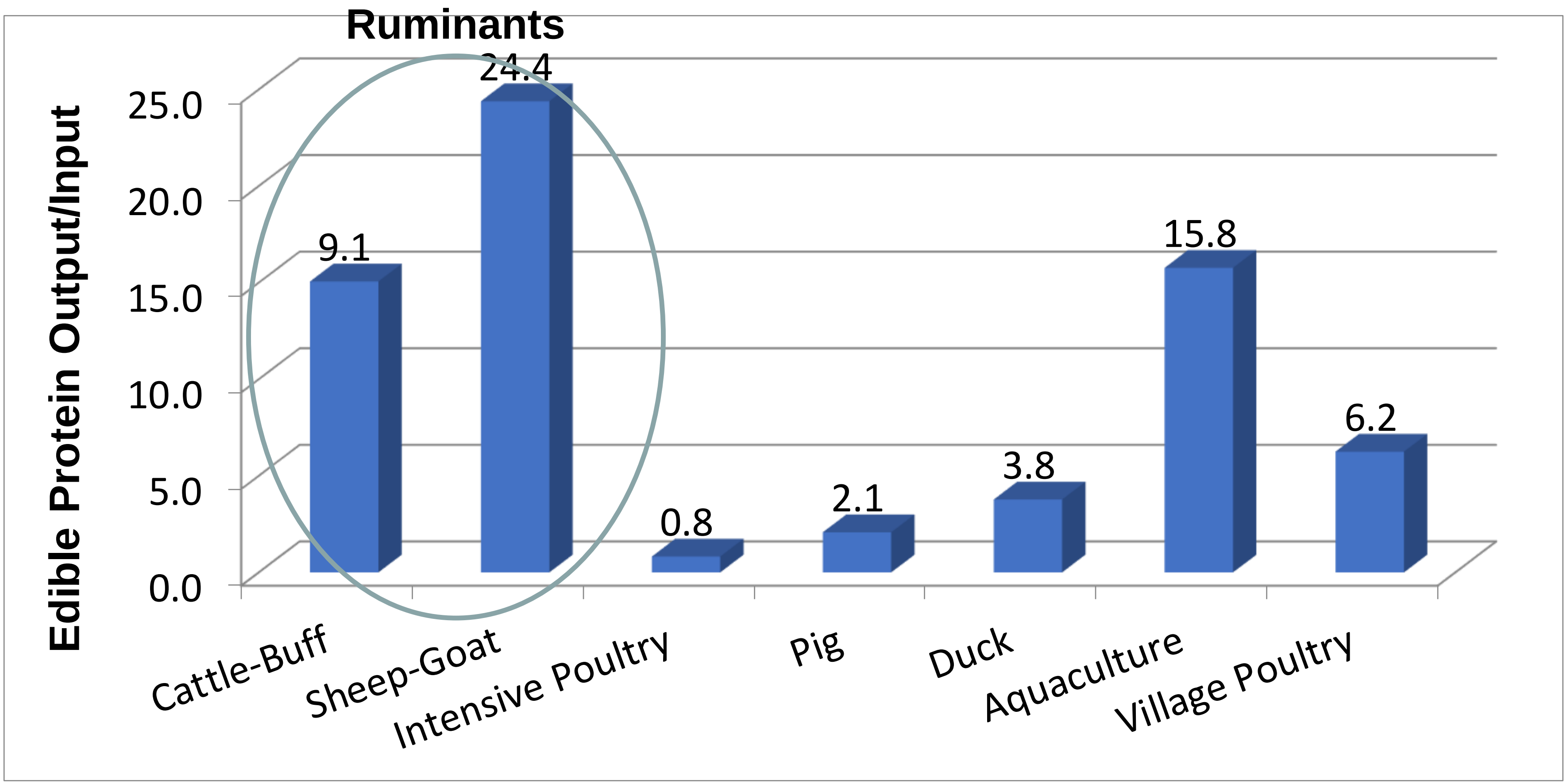
Livestock commodities

kg CO_2-eq per kg protein



FAO 2013

Human edible protein output-input ratio



Mean based on data from India, Pakistan, Bangladesh, Thailand, Bhutan, Mongolia (FAO, 2016).

Addressing an efficiency dilemma – examples

How different units of efficiency can affect the conclusions

One lactation

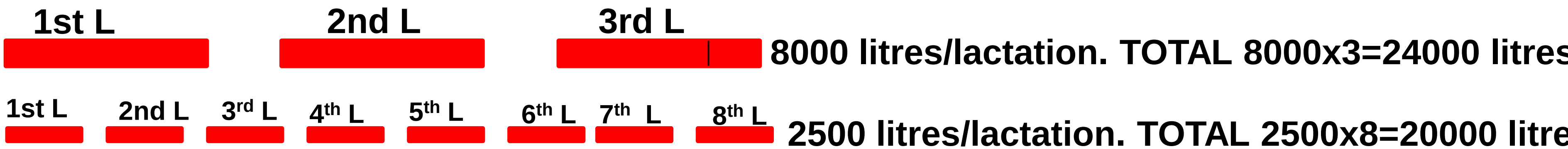
	Emission intensity (kg CO_2 eq./kg milk), at farm gate	
India, smallholder dairy	2.07 (C), 3.73 (B)(lactation, feed prod.)	Garg et al. (2016)
Kenya, smallholder dairy	2.0 – 4.2	Opio/FAO et al. 2014)
Swedish dairy farm	0.90–1.04	van der Werf et al., 2009
French dairy farm	1.04	van der Werf et al., 2009
W. Europe	1.47 (herd basis & feed prod.)	FAO (2013)
North America	1.33 (herd basis & feed prod.)	FAO (2013)

	Human edible protein output/human edible protein input	
India/BGD/PAK, milk	9.1	FAO (2015)
Jordan, milk	0.60	Hawileh, 2015
USA, milk	1.81	Baldwin, 1984; CAST, 1999)
UK, milk	1.41	Wilkinson, 2011
Netherlands, milk	4.38	Dijkstra, unpublished

Addressing an efficiency dilemma -- Productive life?

Efficiency should be based on productive life of livestock

Lactation = L

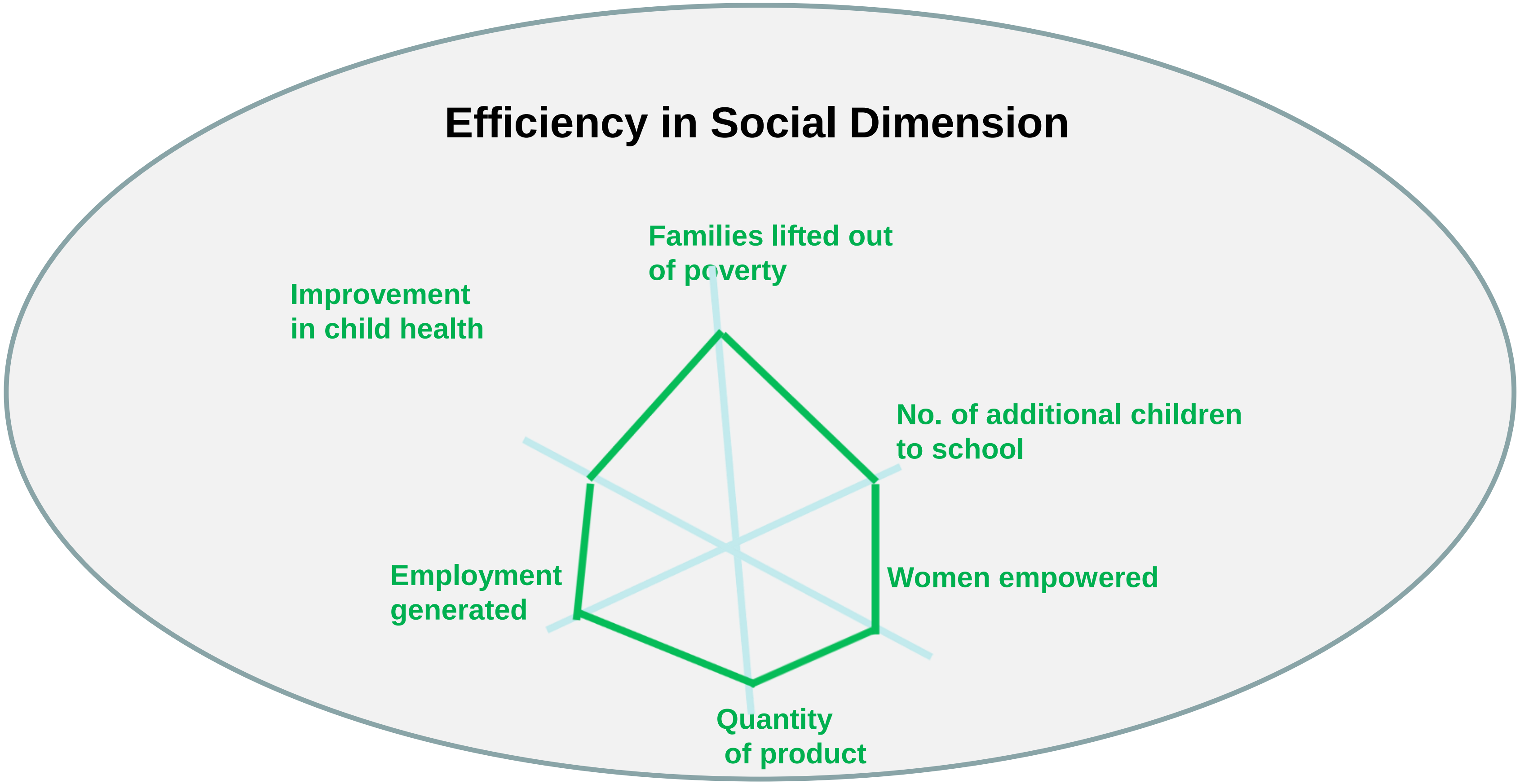


	GHG emissions [kg CO2-eq/kg FPCM] (Based on lifetime milk yield)	
Fleckvieh cows, dual purpose (27 farms)	0.90 – 1.26	Zehetmeier et al. (2014)
Holstein–Friesian cows Dairy cows (26 farms)	0.79 – 1.20	
India, Cows	1.0 (after ration balancing)	
India, Buffaloes*	1.48 (after ration balancing)	

NDDB: Garg et al. (2016)

Addressing an efficiency dilemma

We need to think of efficiency in multiple dimensions



Weekly consumption of a family in

Sub Sharan Africa

Germany

- **Billions of dollar of loss due to children malnutrition**
- **2 billion people globally mal-nourished -- various forms of micronutrient deficiencies**
- **40–60% of children in developing countries: impaired mental development**
- **One-fifth of total maternal deaths each year**

Moving the agenda beyond calorie security – livestock has a key role

- **Livestock are key for nutrition security (26 – 30 % protein)**
- **A major source of Vitamin B12 supply**

Diet	% Daily Nutrient Requirement				
	Vit A	Vit C	Folate	Zn	Fe
Rice + Carrot	100	<10	<10	20	<10
Rice + Carrot + Orange + Lentil	100	110	100	30	20
Rice + Carrot + Orange + Lentil + Meat	170	150	110	110	100

Highest health burdens of the "hidden hunger" : Vit. A, Zn, Fe, folate deficiencies

Rationalization of consumption of animal products

Average consumption of protein of animal origin (without fish): 24 g/capita/d

Lowest (Burundi) 1.7 g/capita/d — Total protein intake 42.5g/capita/da

Maximum (USA) 69 g/capita/d — Total protein intake 120 g/capita/d

Converge to

20 g protein of animal origin
= 7.3 kg protein/capita/annum = *ca* 52 kg of meat equivalent

Rationalization of consumption of animal products

- Decrease use of natural resources
- Sustainability to LPS
- Improve human health

For further discussion, see: Makkar (2017), Animal. DOI 10.1017/S175173111700324X

Take home messages...1/2

**Several food-not feed resources -- available and
A number of such novel feed resources -- will be available**

Several smart feeding strategies -- available to efficiently utilize available feed resources

Opportunities exist to convert food waste and loss to animal feed and to learn from East Asian countries

Think efficiency in multi-dimension -- taking efficiency units in all three-P dimensions – to present LPS in the right perspective.

Take home messages...2/2

In addition to improving efficiency of animal food production, addressing:

- **the consumption,**
- **distribution and**
- **affordability of animal products**

would be some important steps towards sustainable food production systems

Research and innovations towards:

- **use of human-inedible feeds without compromising animal production -- catalytic to the implementation of food-not feeding strategy**

Conclusions and Way Forward

Several food-not feed resources are available and a number of such novel feed resource will be available in the future. Research is required to increase availability of human inedible feed resources

Several smart feeding strategies are available to efficiently utilize available feed resources

Opportunities exist to convert food waste and loss to animal feed and to learn from East Asian countries

We need to think efficiency in multi-dimension (taking efficiency units in all three-P dimensions), so that LPS can be presented in the right perspective.

In addition to improving efficiency of animal food production, addressing the consumption, distribution and affordability of animal products would be some important steps towards sustainable food production systems of the future

Research and innovations towards use of human inedible feeds without compromising animal production would be catalytic to the implementation of food-not feeding strategy and its associated benefits to the environment and nutrition security.

Thanks for your attention

Acknowledgement: Dr. Garg, NDDB for providing slides on Ration Balancing approach