Food and Agriculture Organization of the United Nations

Quest for novel feed resources

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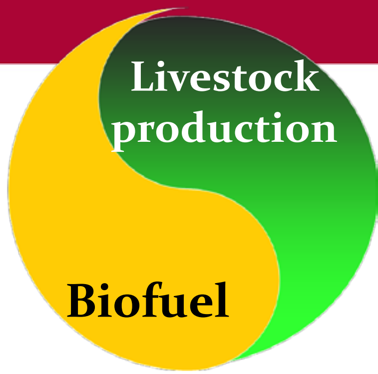
Outline of presentation



1. The quest for novel feed resources: why?

2. Co-products from bioethanol and biodiesel production

3. Unconventional feed resources

4. Future areas of research

5. Concluding remarks

Trends in use of feed concentrates & production

(Million tonnes)

	1980		2005	2007
	Use of concentra-tes	Production of meat, milk & eggs	Use of concentra-tes	Production of meat, milk & eggs
Developed	669	457	647	487
Developing	240	172	603	537

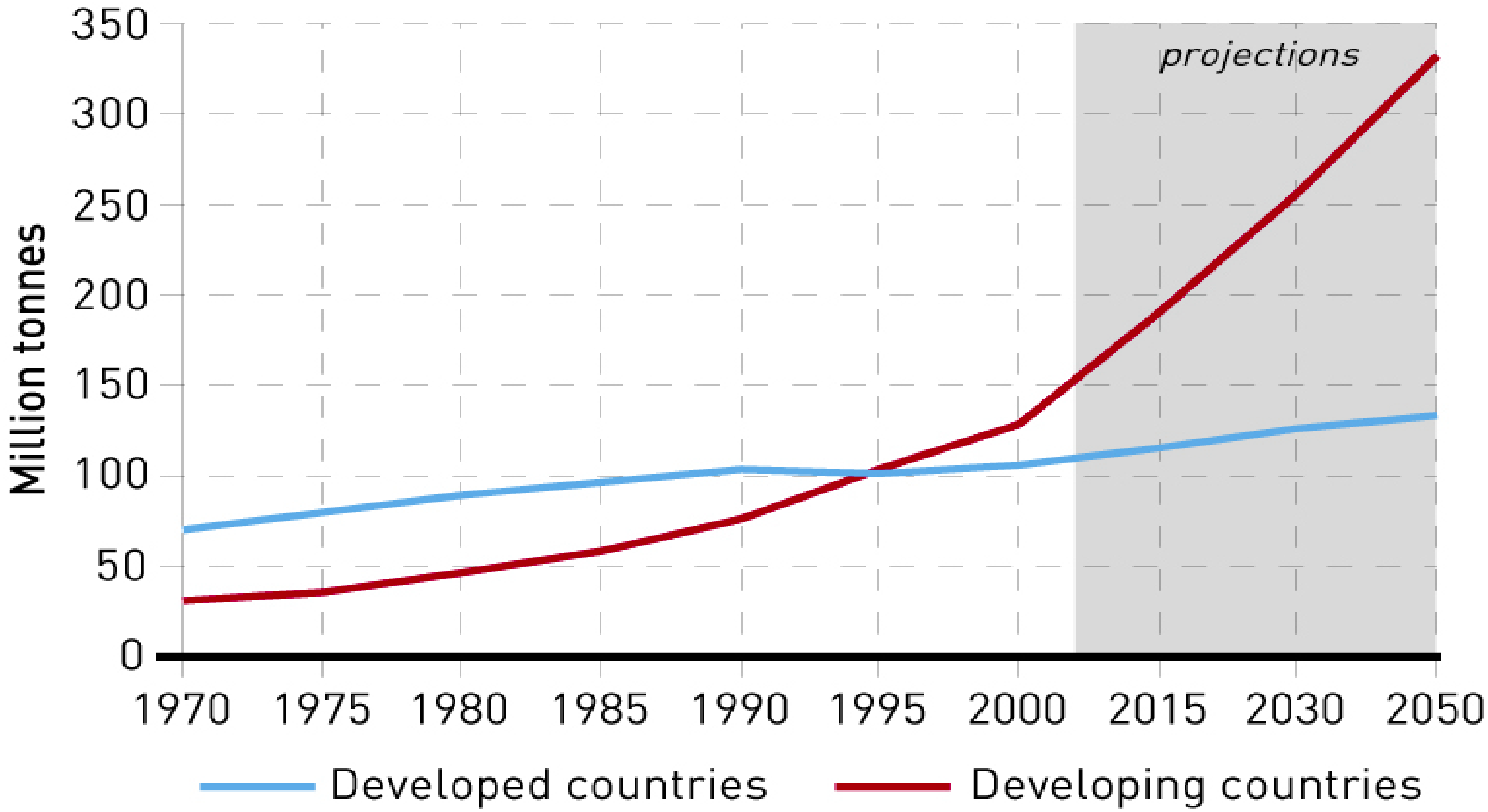
From SOFA 2009 Livestock in the balance

Use of cereals for animal feed by region/country

World	35%
EU	53%
Brazil	44%
Oceania	28%
N America	22%
India	4%

	1960	2007
China	7%	22%
Brazil	30%	44%

Meat Production



Additional grain required by 2050

1305 million tonnes of which:

- **553 million tonnes for livestock**
- **752 million tonnes for humans**

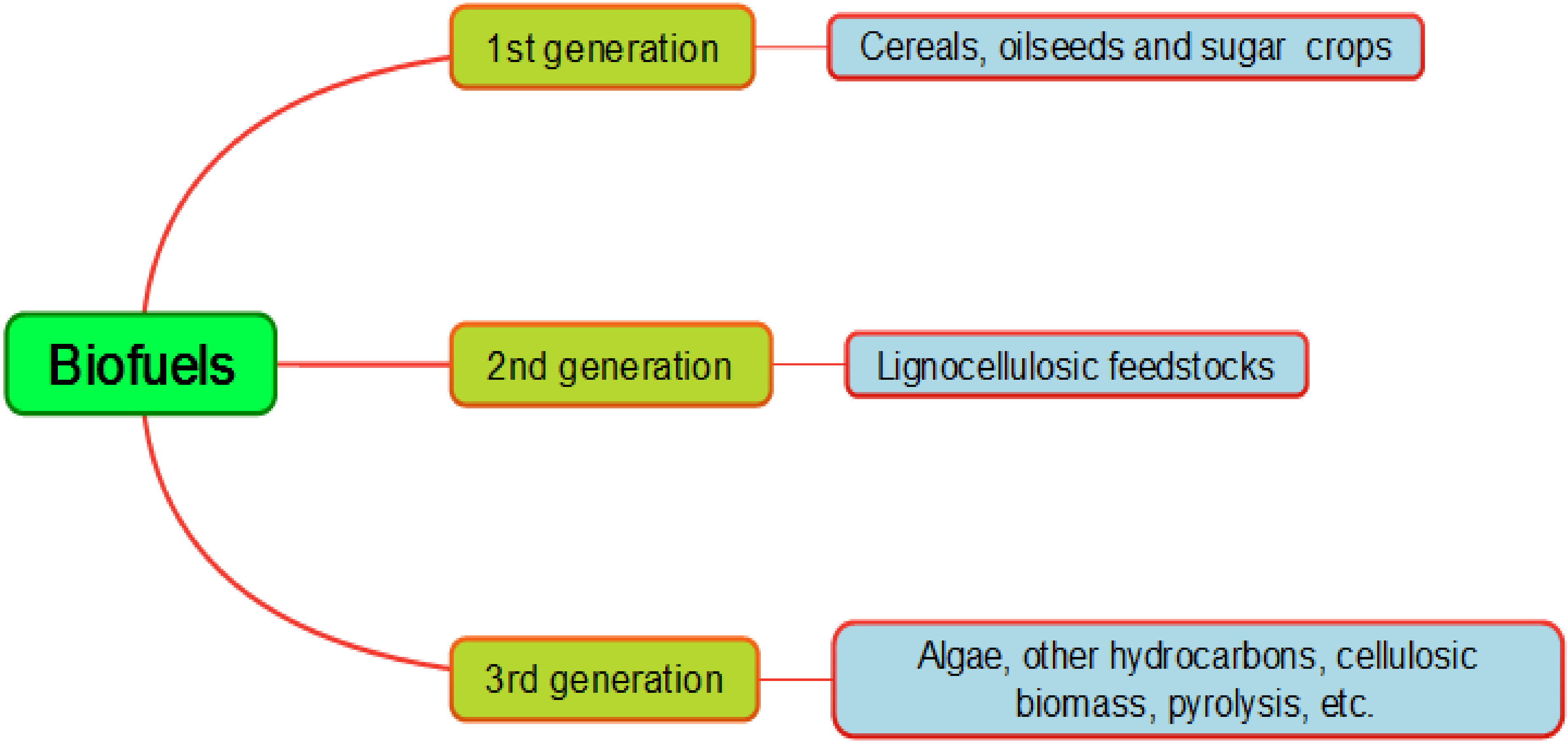
IAASTD 2009 using IFPRI economic models to generate predictions

The dilemma

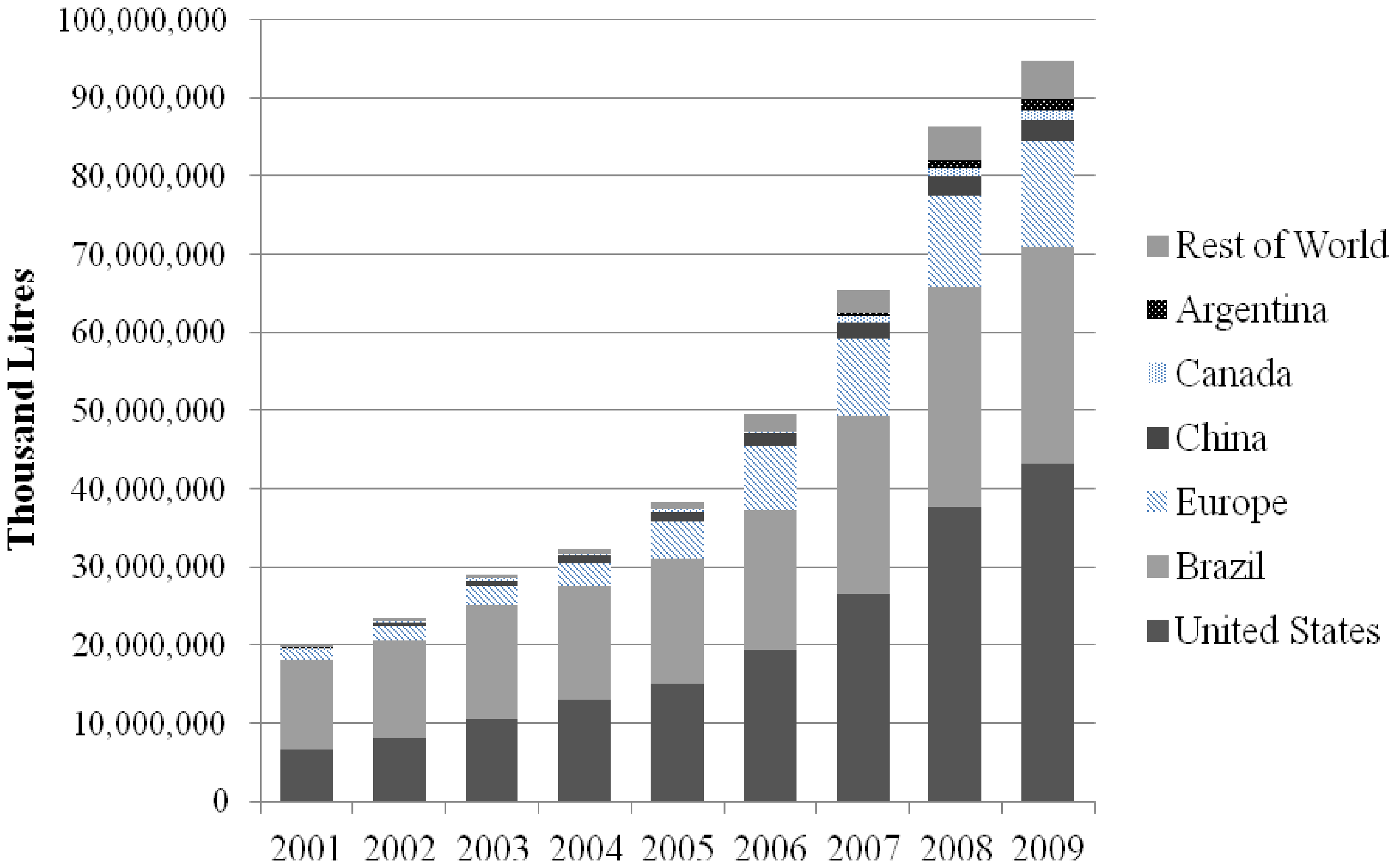
From where we will get feed?

- Growth in pig and poultry meat production putting great pressure on demand for grain
- Food-feed-fuel competition
- Decrease in arable land
- On-going global warming
- Increase in water shortage
- Challenge of feeding 9 billion people by 2050

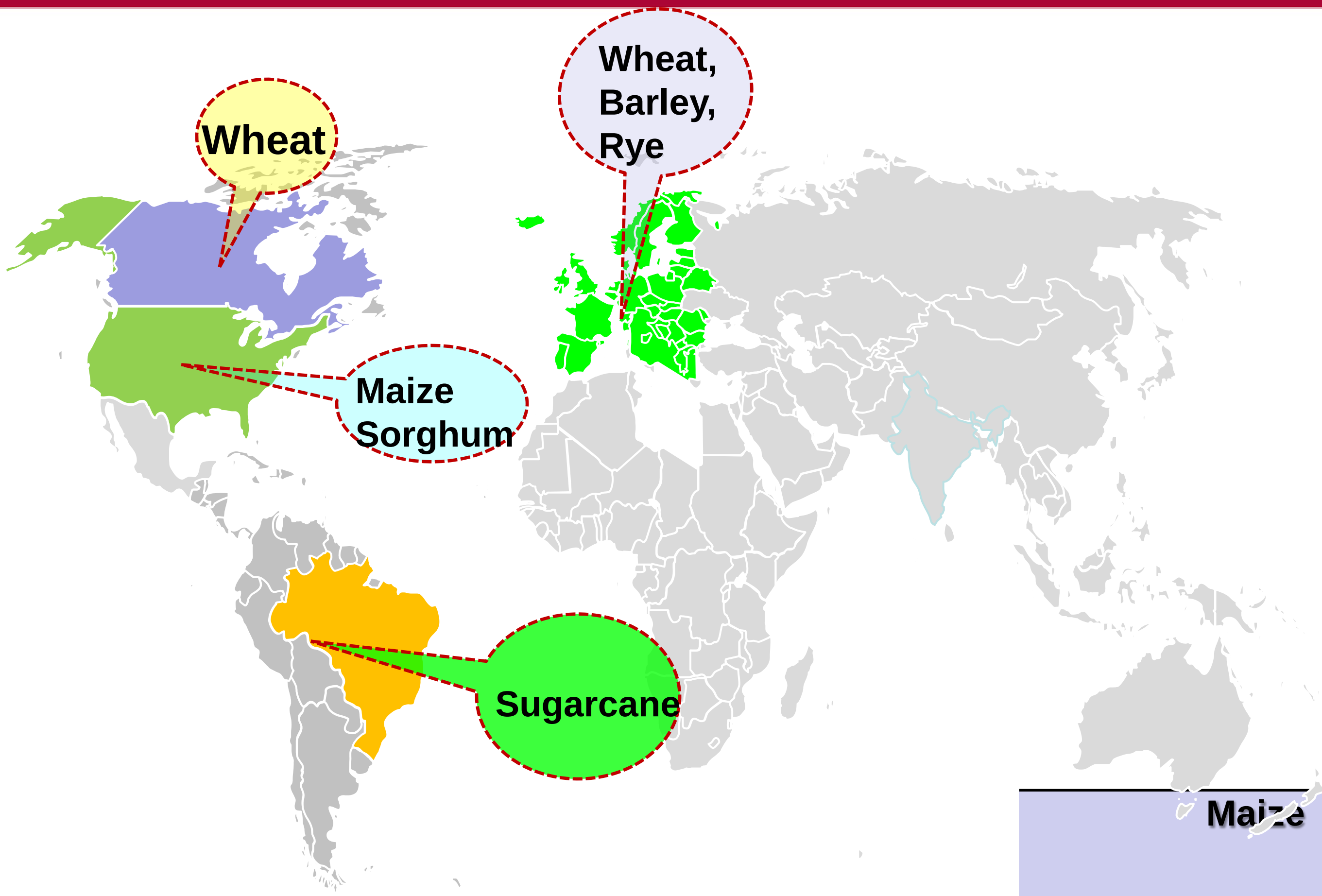
Biofuels : first, second and third generation



Bioethanol production: 5-fold increase



From what bioethanol is being produced?

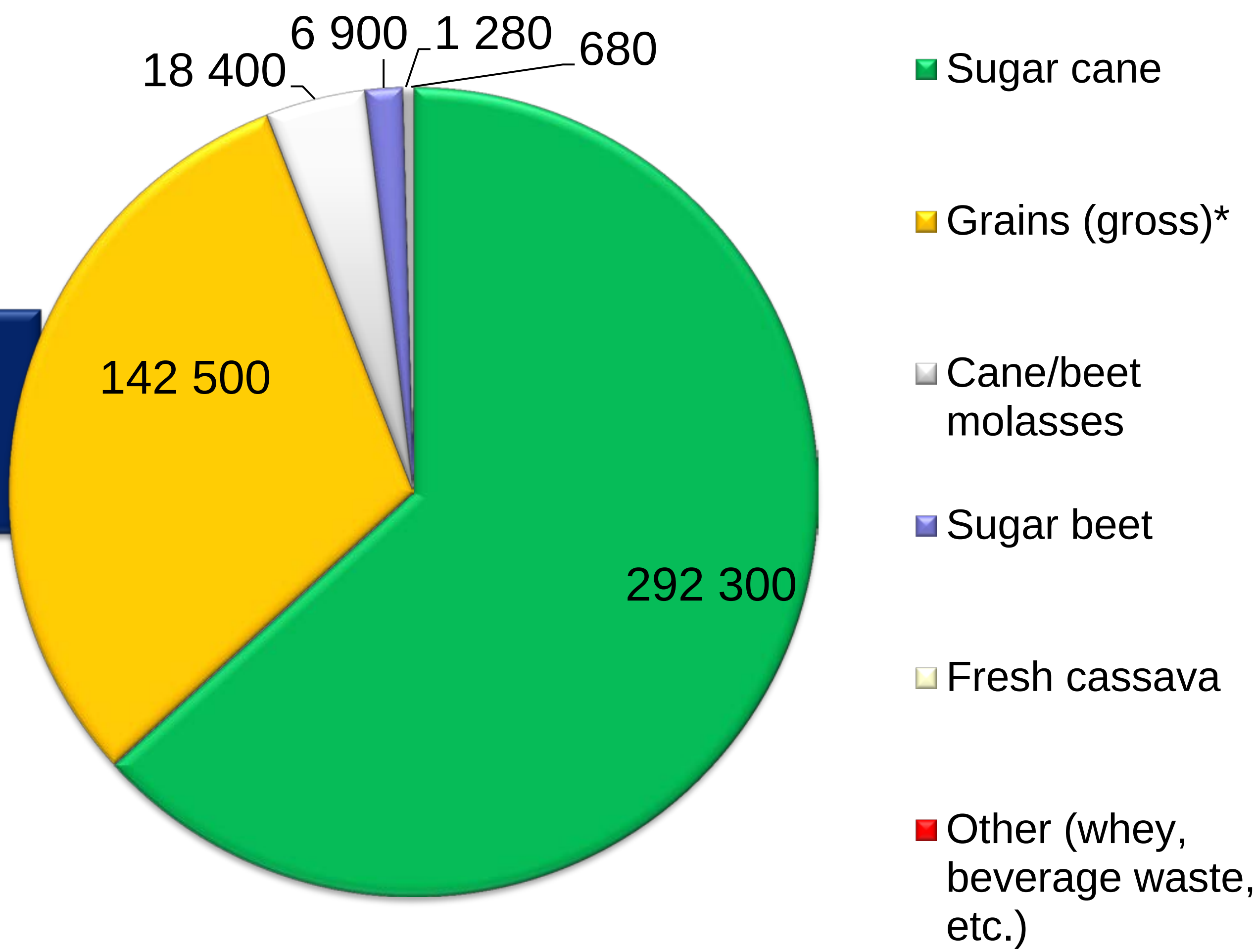


Number of plants

	Maize	Wheat	Other Grain	Total
USA	186	0	9	195
EU	9	9	8	26
CANADA	8	5	3	16

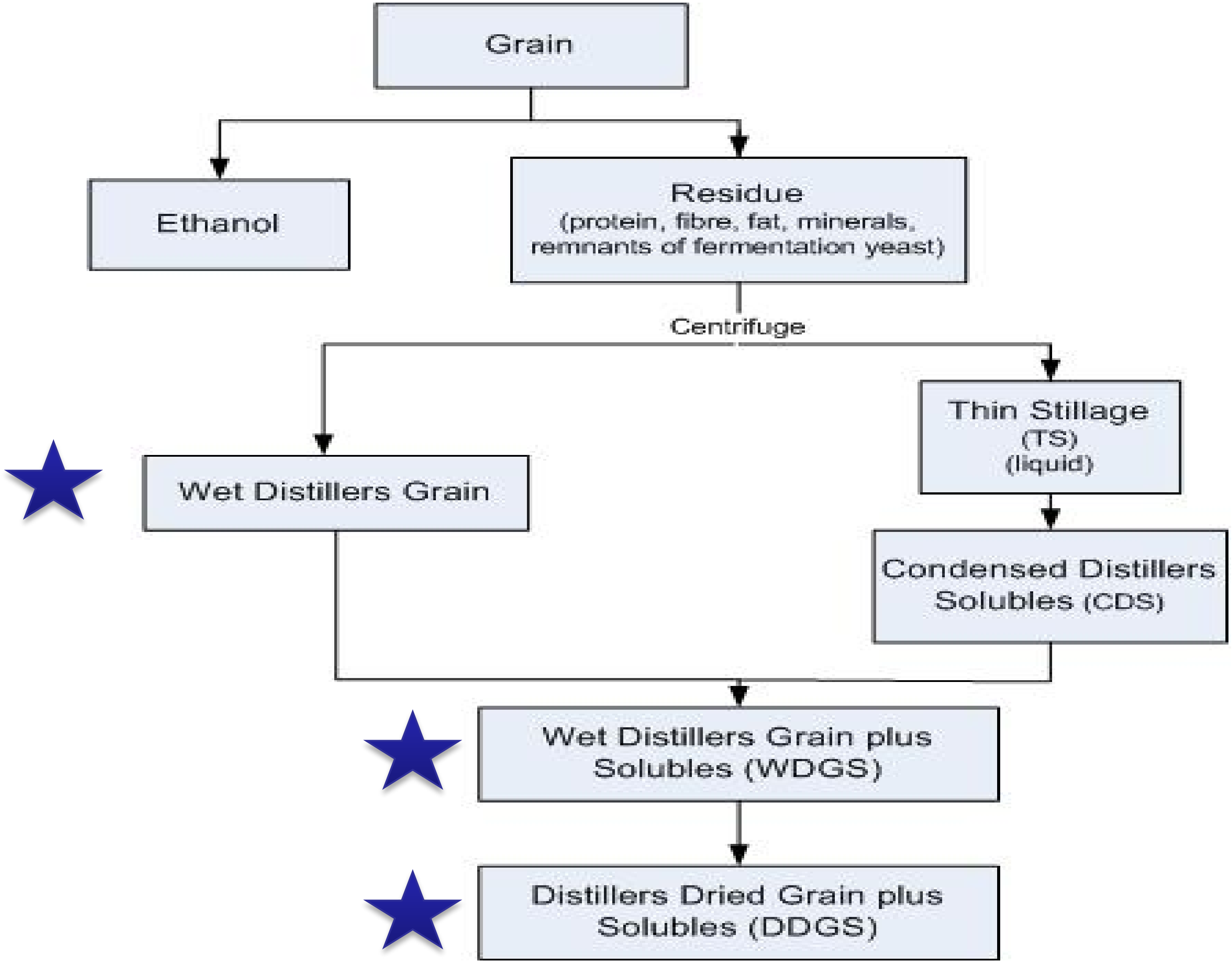
2010 world feedstock usage for fuel ethanol (thousand tonne)

Approximately 1/3 of grain used for fuel ethanol is protein-rich co-products

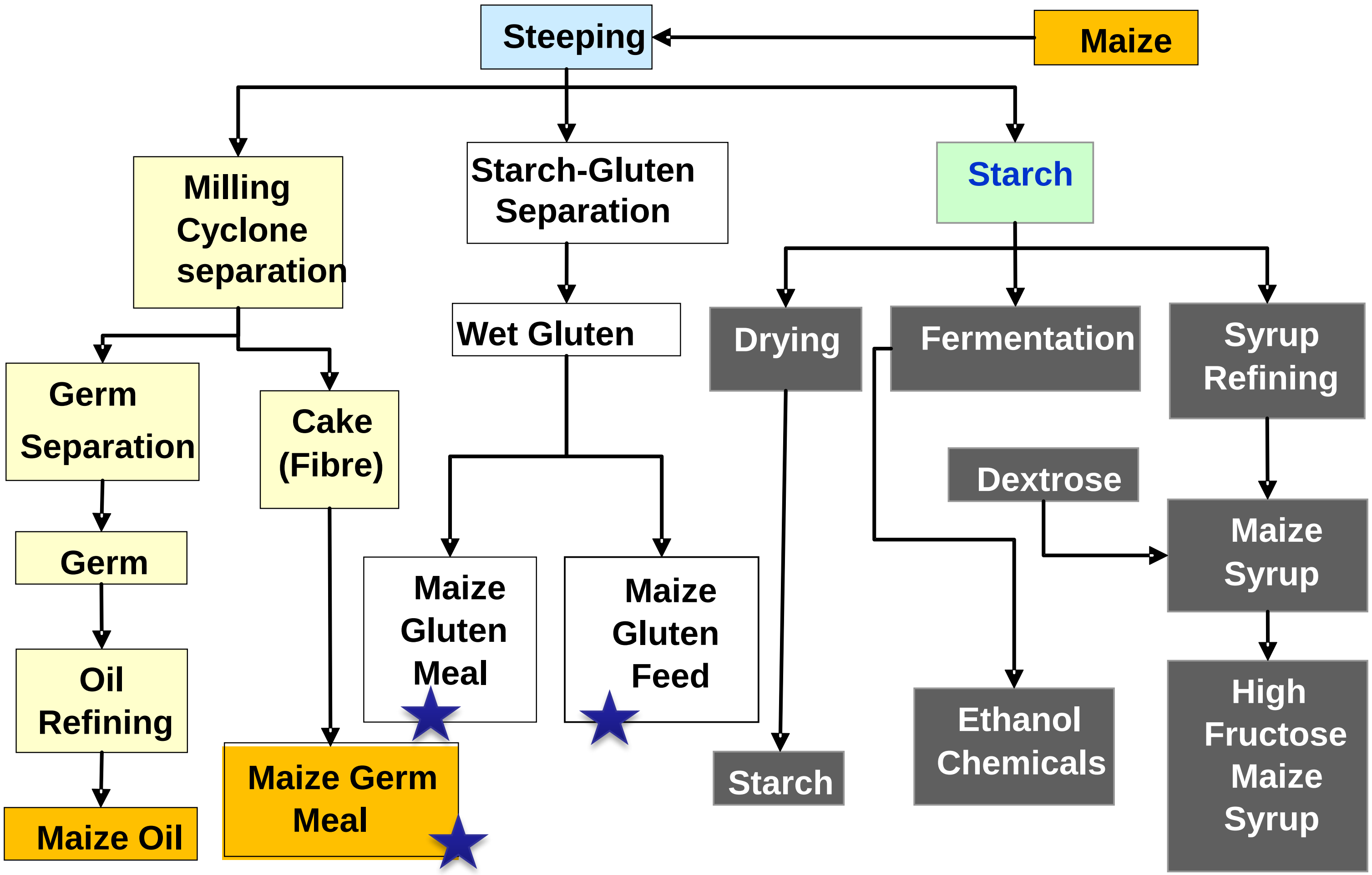


Source: F.O. Licht, 2011

Ethanol and co-product formation from grains

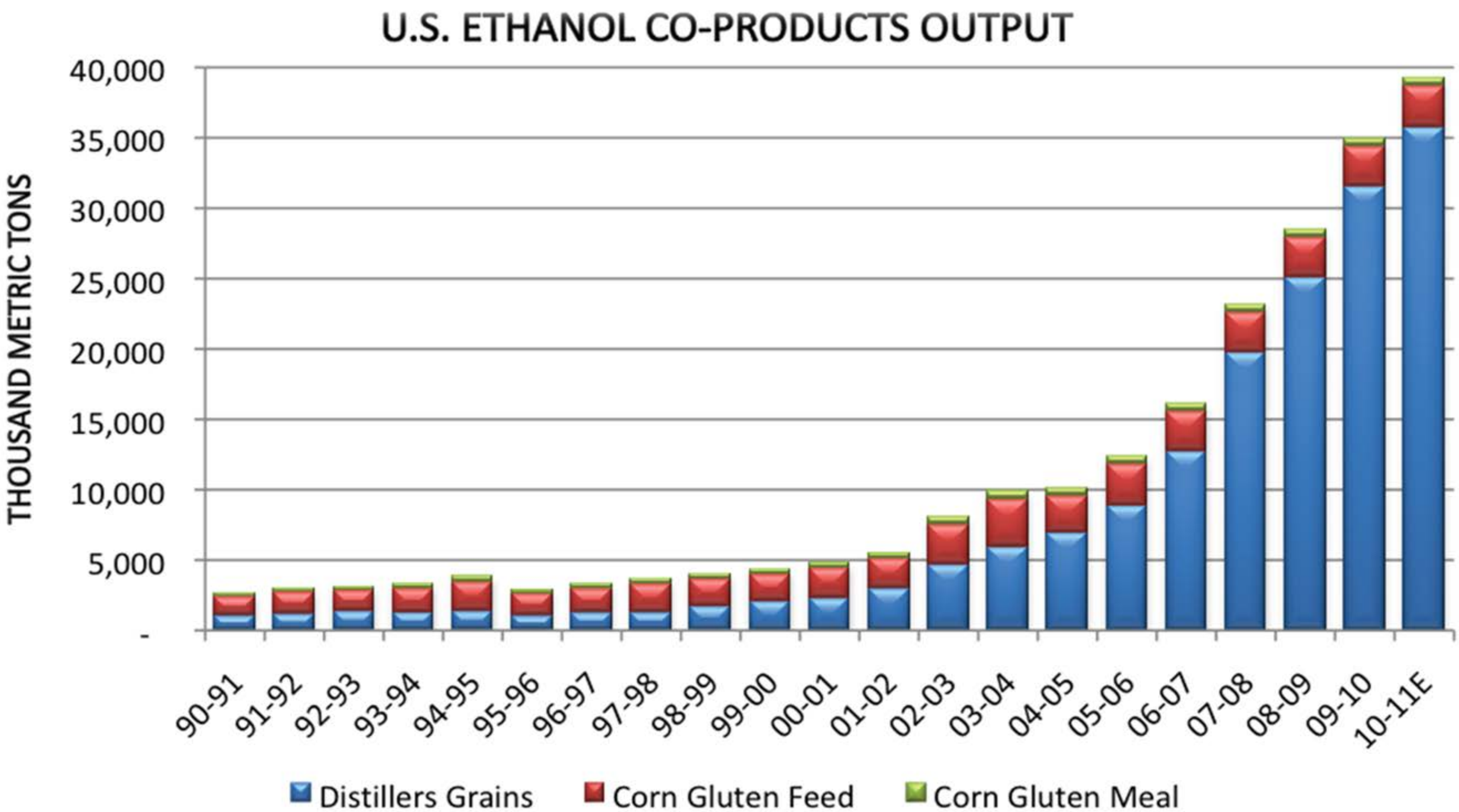


Wet-milling processes and co-products



SOURCE: Erickson *et al.*, 2005

Historical production of ethanol co-products

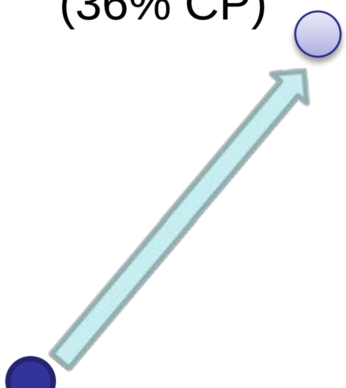


SOURCE: RFA, 2011

Properties of corn ethanol co-products

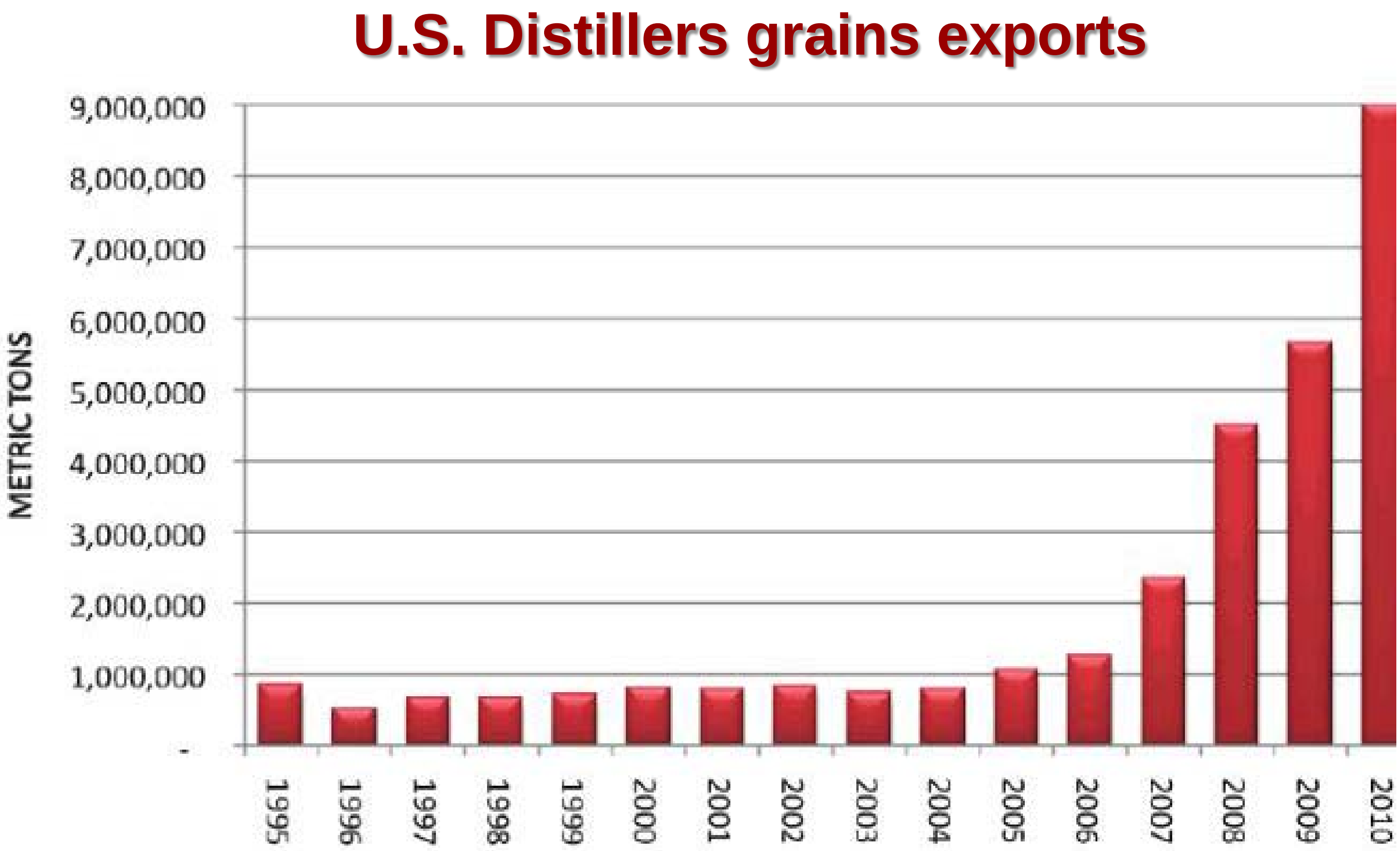
Animal feed/other co-products	Crude protein (%)	Fat (%)
Corn	8.3	3.9
Soy bean meal	45-50	1.4
DDGS	30.8	11.2
WDGS	36.0	15.0
d-DGS[1]	34.0	2.7
HP-DDG[2]	48.6	3.4
Corn gluten feed	23.8	3.5
Corn germ	17.2	19.1

1 De-oiled DGS
2 High-protein dry distillers' grains



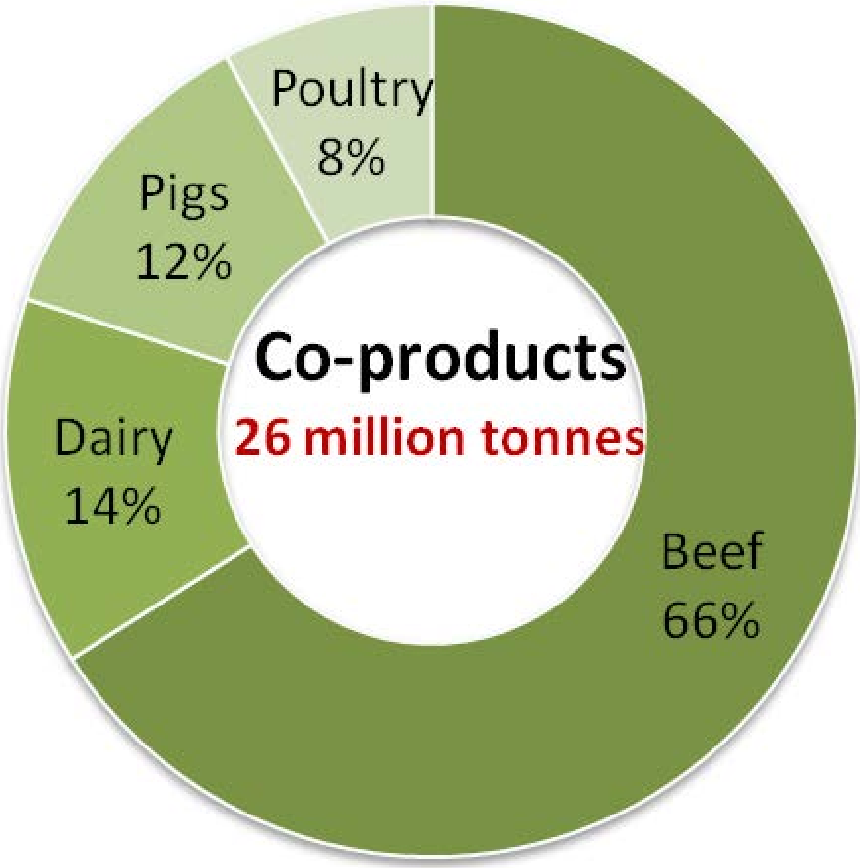
For normal inclusion levels of DDGS in animal diets, the limiting EAAs are *lysine and tryptophan for maize DDGS*, and *lysine and threonine for wheat DDGS.*

Exports of US DDGS



Shurson et al. 2012

Distillers grain use in the US



USA annual production

Composition changes (on a % DM basis) in typical beef feedlot diets before and after 2000 (USA)

Ingredient	Before 2000	Current with moderate maize price	Current with high maize price
Cracked and/or high moisture maize	75.0	52.0	44
Maize silage	15.0	15.0	-
Distillers Grain	-	25.0	45.0
Alfalfa hay	5.0	-	-
Grass hay	-	5.0	5.0
Maize stalks	-	-	3.0
Soybean meal, 44%	3.0	-	-
Urea	0.5	-	-
Vitamin-mineral mix	1.5	3.0	3.0

Shurson et al. 2012

Ingredient composition changes (% as-fed basis) in typical growing swine diets in the decades before and after 2000 (US)

Ingredient	Before 2000	At current maize, soybean meal and DDGS prices
Maize	70	53
Soybean meal	25	11
Canola meal	0	0
DDGS	0	30
Choice white grease	2	3
Other ingredients, vitamins, minerals, amino acids	3	3
Total	100	100

Shurson et al. 2012

Distillers grains in ruminant diets

- Corn co-products:
  - primarily as a source of dietary protein in feedlot diets
  - at high levels of grain replacement, fat & fibre contribute meaningful amounts of energy).

- WDGS has a feeding value 30–40% > maize at 10–40% of diet DM.

- Distillers grains are an excellent supplement for cattle on high-forage diets (because: high energy, protein and P contents).

- Reduced rumen degradability of crude protein and increased un-degraded protein increase.

- Maximum recommended levels of DG with solubles (on DM Basis):
  - pre-weaned calves 25%
  - growing heifers 30%
  - dry cows 15%
  - lactating dairy cows 20%

Distillers grains in pigs and poultry diets

- Growing pigs (2-3 wks after weaning): 30% of corn DDGS

- Gestating sows: 50% of DDGS.

- Lactating sows: 30 % DDGS

- With finishers: Necessary to withdraw DDGS 3 to 4 wks before slaughter
  (because high amount of PUFA in the corn oil
  -- reduce pork fat quality)

- Laying hens: DDGS (~15%)

- Broilers :>10% wheat DDGS reduce performance
  --NSP degrading enzymes needed to overcome adverse effects

Current, revised recommendations for maximum dietary inclusion rates of DDGS for various species of fish

Species	% DDGS	Comments
Catfish	Up to 30%	-
Trout	Up to 15%	Without synthetic lysine and methionine supplementation
Trout	Up to 22.5%	With synthetic lysine and methionine supplementation
Salmon	Up to 10%	-
Freshwater prawns	Up to 40%	Can replace some or all of the fishmeal in the diet
Shrimp	Up to 10%	Can replace an equivalent amount of fishmeal
Tilapia	Up to 20%	Without synthetic lysine and supplementation in high protein diets (40% CP)

HP-DDGS has also been tested

Safety issues

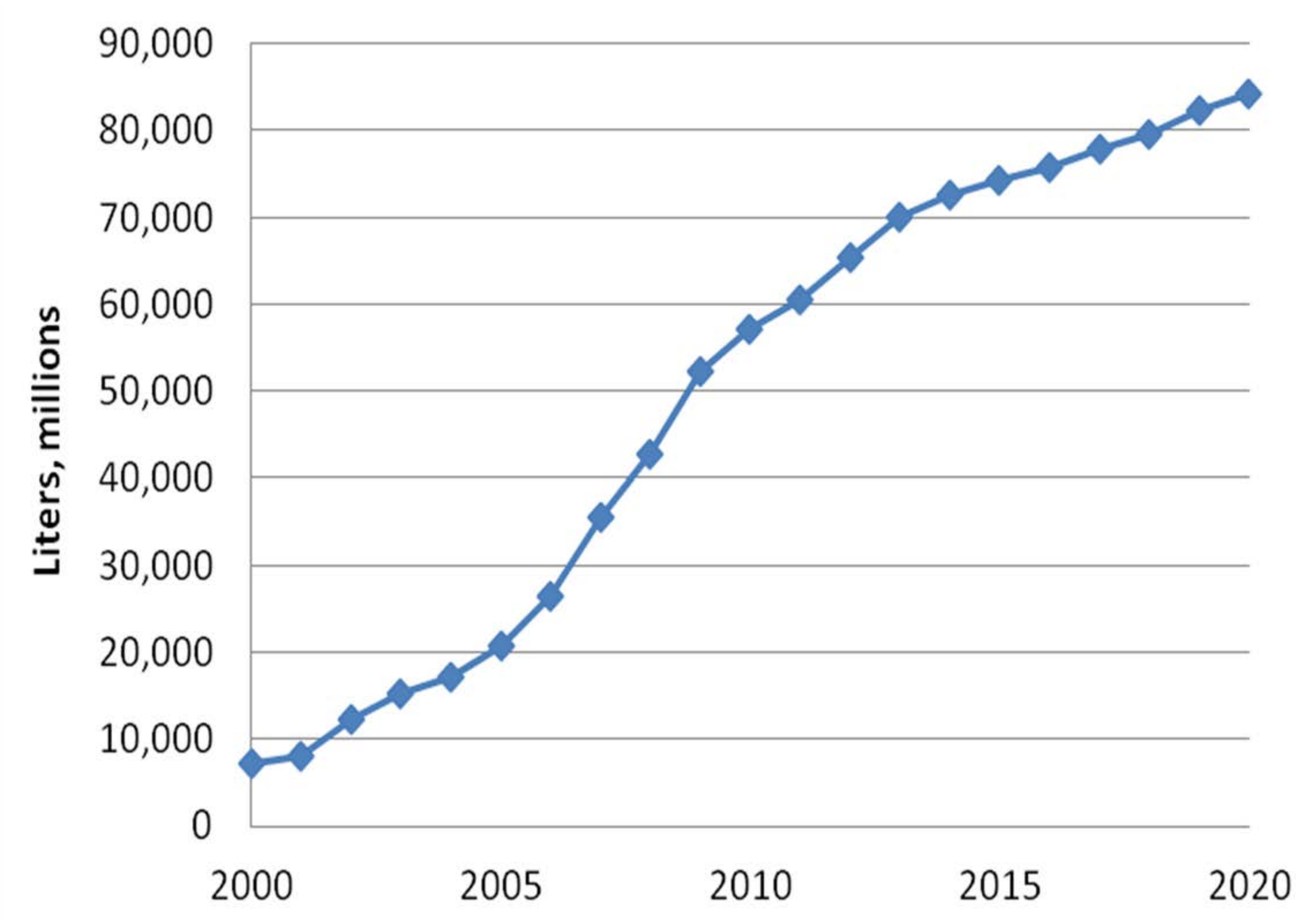
- Contamination resulting from the process: excess mycotoxins, antibiotics, pesticides, harmful bacteria (shedding of *E. coli* 0157:H7 in beeflot cattle),.
- Oil present in DDGS (maize oil has high PUFA) -- if oxidised, produce toxic aldehydes -- affecting pig health and performance, and meat quality.
- At high levels of S (0.47%) it inhibits oxidative processes in nervous tissue – leading to Polioencephalomalacia.
  (Distillers grains may be high in S (0.5–1.7 percent, DM basis)
- High S may decrease bio-availability of selenium and vitamin E

Bioethanol co-products – Vinasses

- Vinasse is produced from cassava, sugar cane, sweet potato, and sweet sorghum.
- Vinasse: preparation of multi-nutrient blocks – increase nutrient utilization & productivity of animals on low quality roughage diets

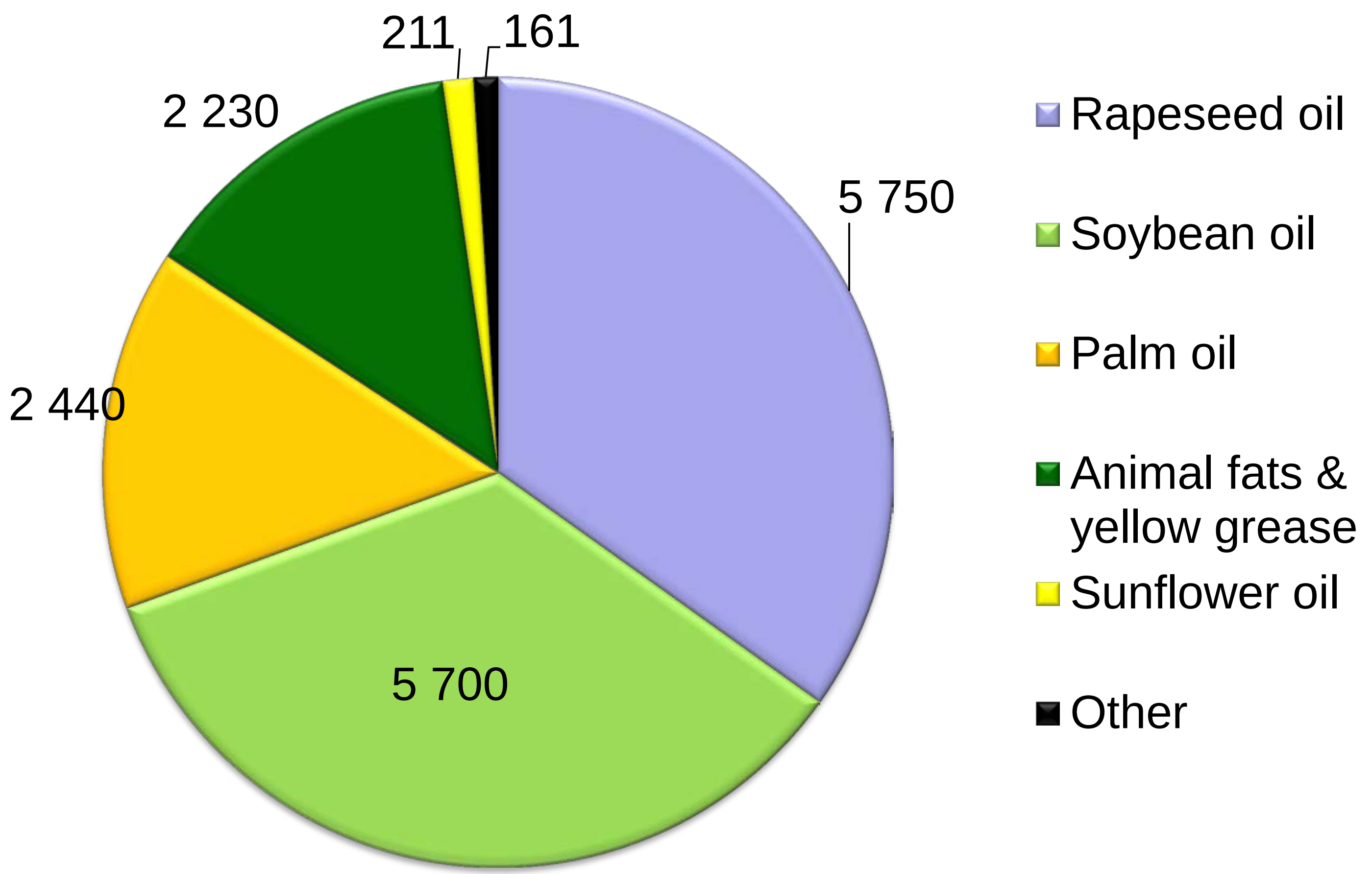
Multi-nutrient blocks

Growth and anticipated world expansion of biodiesel production



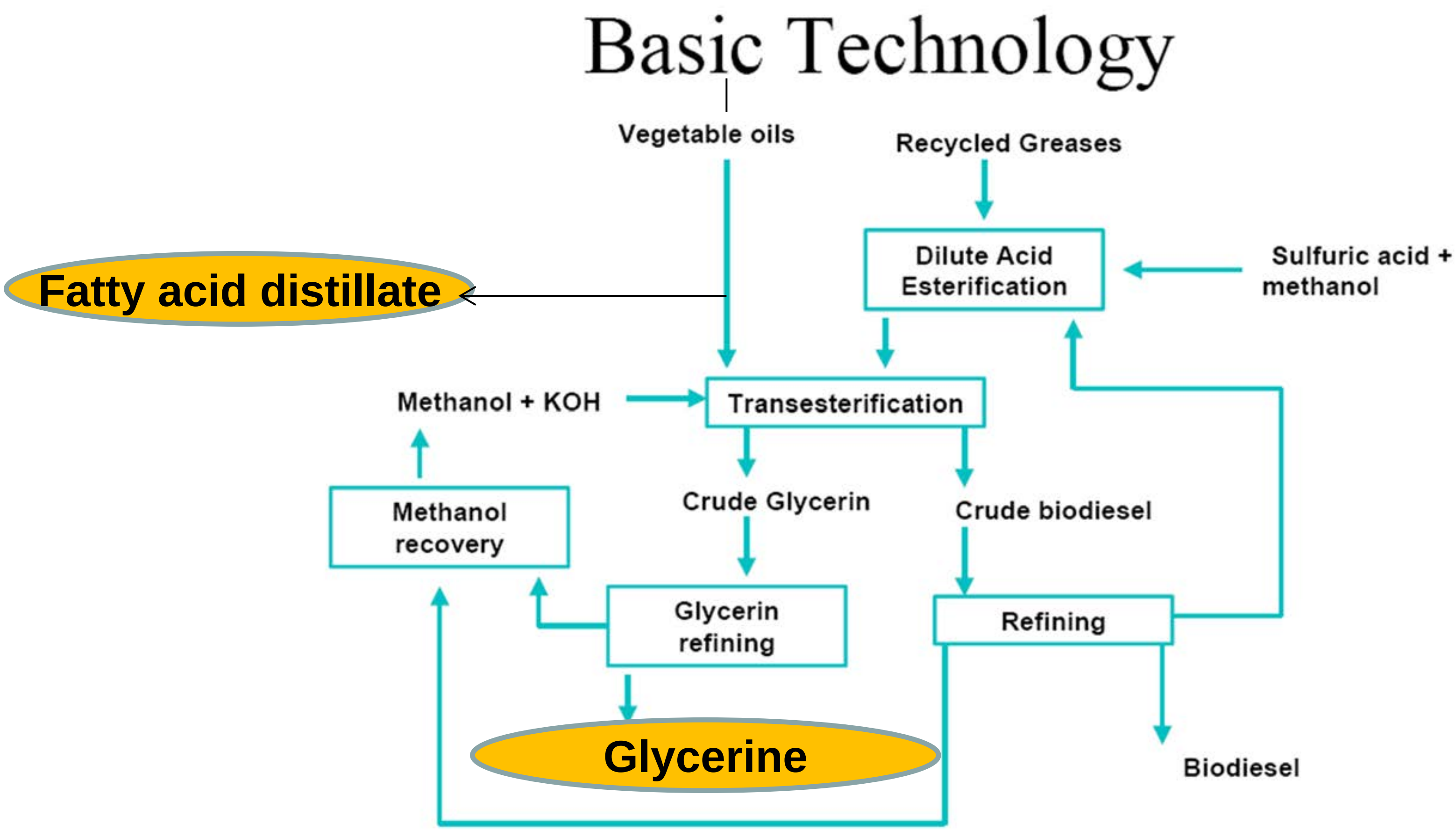
SOURCE: National Biodiesel Board, 2008

2010 world feedstock usage for biodiesel (thousand tonne)



Source: F.O. Licht, 2011

General biodiesel production process



Biodiesel co-products – Fatty acid distillate

- **Fatty acid distillate:** good **source of energy**.

- **Fatty acids distillate reacted with calcium oxide to develop a rumen-protected fat --- an effective way to protect fatty acids against ruminal biohydrogenation**

- **Augment the oleic, linoleic, α-linolenic and stearic acid content in the milk of dairy cows and reduce that of palmitic acid.**

Biodiesel co-products – Glycerol in ruminant diets

- Glycerol: 15% of the diet (recommended inclusion)
  - In dairy cow diets as an energy source (often shortly after calving)
  - or as a preventative for ketosis.
- In beef cattle, feed value of glycerine is greatest at $\leq$ 10%.

Glycerine (similar to starch) has a deleterious effect on fibre digestion on high-grain diets.

Biodiesel co-products – Glycerol in pig & fish diets

- Glycerine contains energy similar to that of corn for pigs.

- If affordable, diet can contain glycerine up to:

  - Sow diets 9%
  - Weaners 6%
  - Finishers 15%

- Use of glycerin in fish diet is less clear, and further research needed

Oil palm co-products

Palm oil and palm kernel oil = ~30% of the total global production of oils & fats

Co-products	CP	ME (MJ/kg)
Palm kernel cake (PKC)	17.2	11.13

Limiting AA: Lys, met, try

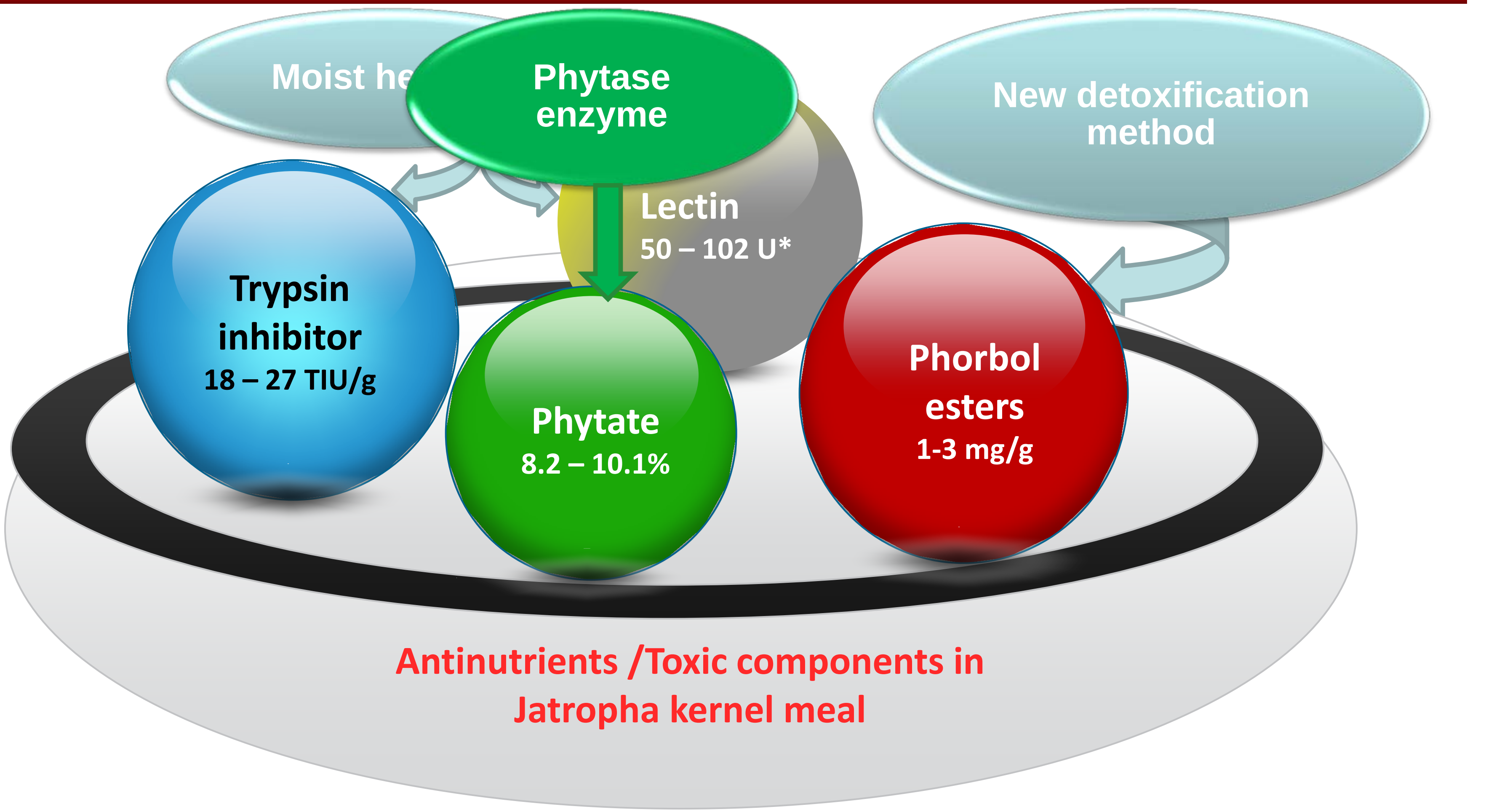
- a good energy and protein sources – ruminant
- Recommended levels of PKC feeding
  - Growing beef cattle: 30–80%
  - Goats: 20–50%
  - Lactating dairy cattle: 20–50%
  - Poultry and freshwater fish: < 10%

Jatropha curcas kernel meal

Kernel meal

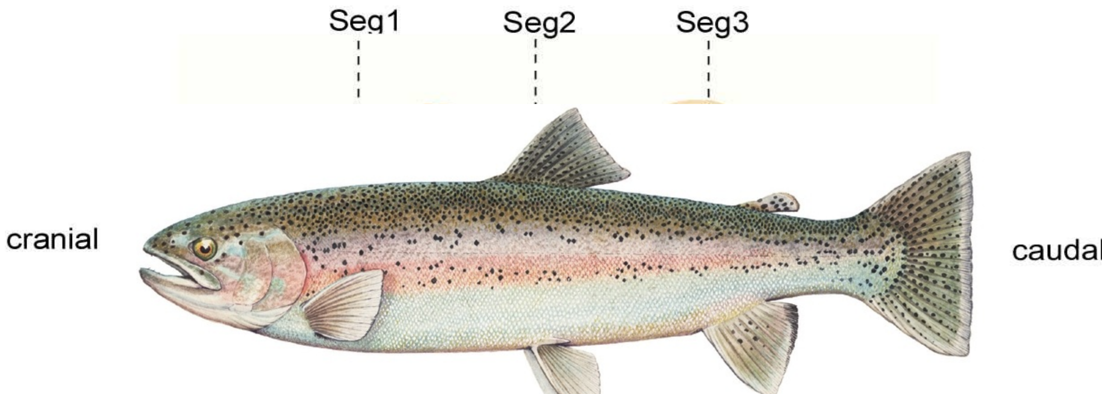
Kernel meal (58 % protein of 90% digestibility & excellent amino acid composition)

Antinutritional and toxic factors in Jatropha meal



U*: 1 mg of meal that produced haemagglutination per ml assay medium. (Source: Makkar and Becker, 2009)

Histopathological & biochemical studies



Biochemical parameters:
Normal range

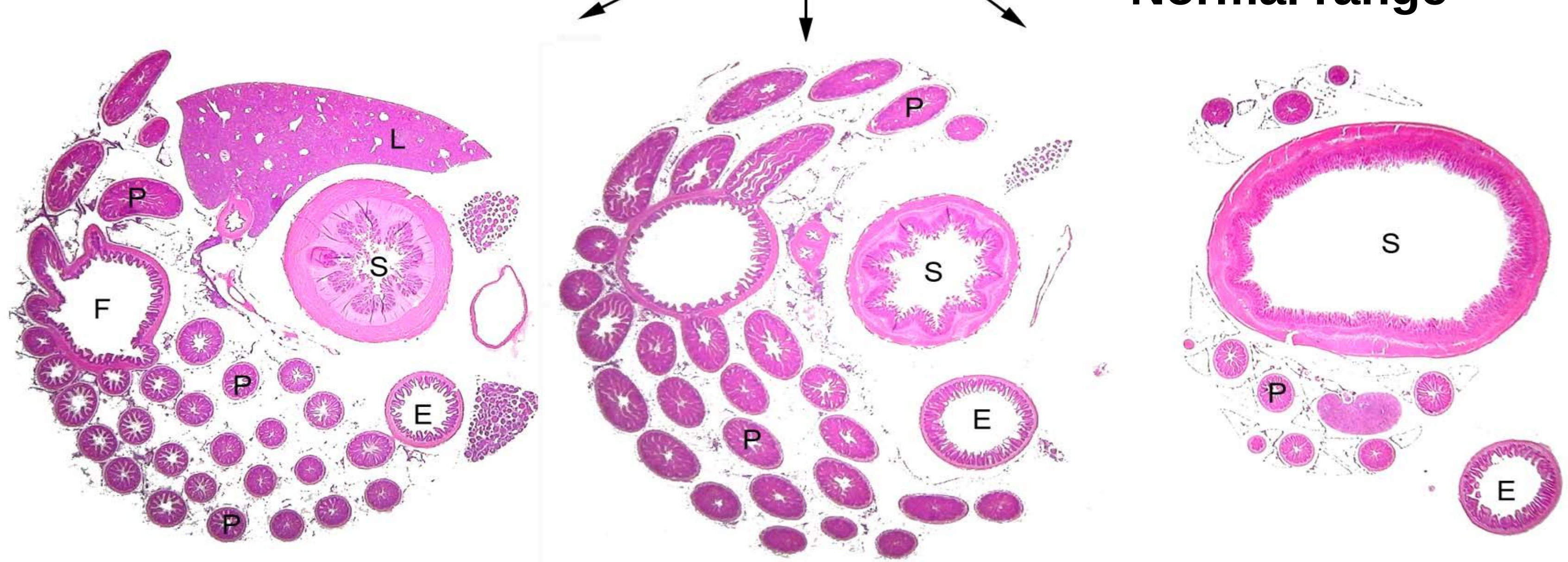


Fig. 3

Jatropha kernel meal in fish, pig and turkey diets

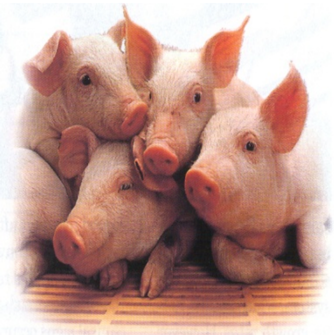
Common carp (*Cyprinus carpio* L.) diet:
Crude protein – 38% and lipid – 10%

Rainbow trout (*Oncorhynchus mykiss*) diet:
Crude protein – 45% and lipid – 24%

Nile tilapia (*Oreochromis niloticus*):
Crude protein – 36% and lipid – 8%

White leg shrimp (*Pennaeus vannamei*):
Crude protein – 35% and lipid – 9%

50% replacement of fishmeal on protein basis



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50% replacement of soymeal on protein basis

Non-toxic Jatropha

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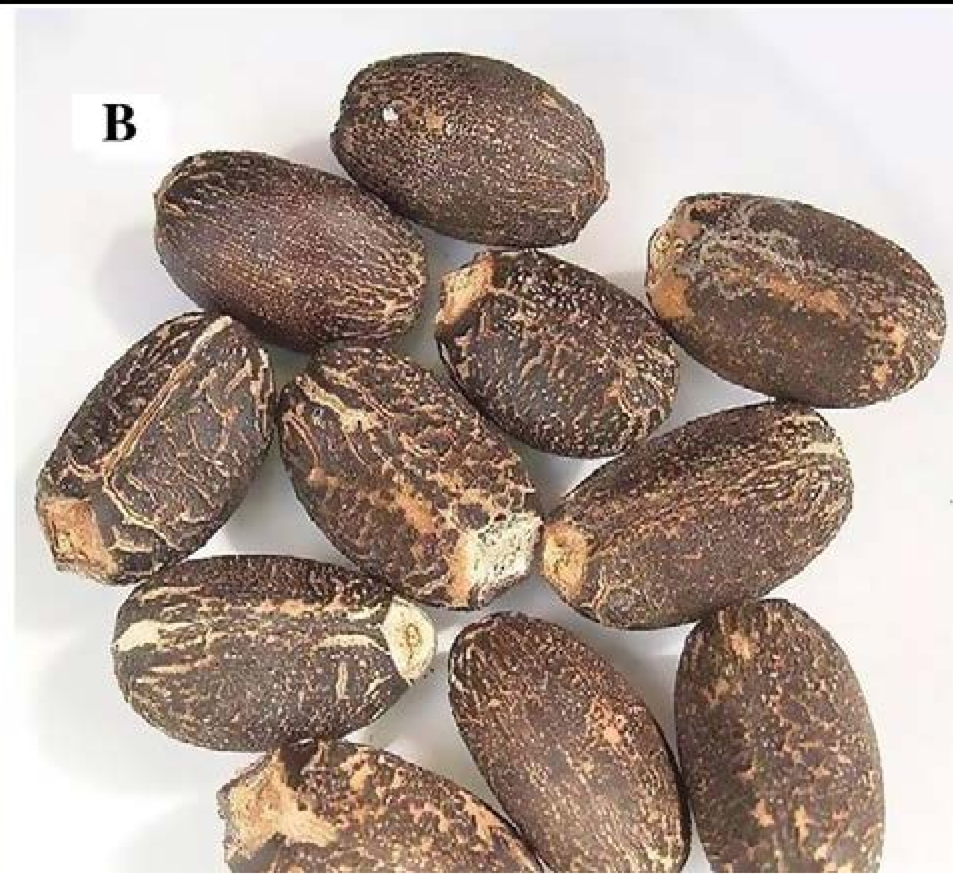

Jatropha platyphylla (non-toxic)

Jatropha curcas (non-toxic)

Biodiesel co-products – *Camelina sativa* meal

Camelina sativa or false flax - the *Brassica (Cruciferae)* family

- Crude protein: 36-40% (rich in EAA including lys & meth)
- Poultry (layer and broiler) diet : 10%
- When compared to control birds fed a corn-soy diet:
  - 8-10 fold increase in total omega-3 fatty acids and ±-linolenic acid
  - Omega-6: omega-3 fatty acid ratio in eggs -- Decreased
- Two large eggs from hens fed Camelina meal: provides over 300 mg omega-3 fatty acids to the human diet.

Co-products (meal/cake) of non-edible oil-based biodiesel industry

	Crude protein	Toxic compounds
Ricinus communis	27.1- 40	Ricin , ricinine (alkaloid), CB-1A (stable allergen)
Hevea brasiliensis	21.9	Cyanogenic glycosides (linamarin and lotaustralin), phytohaemagglutinin (antifertility factor)
Crambe abyssinica	46 – 58	Epi-progoitrin (thioglucoside)
Thevetia peruviana	42.8 – 47.5	Cardiac glycosides (thevetin A, thevebioside, gluco-peruvoside and acetylated monoside)
Azadirachta indica	45.0 – 49.4	Azadirachtin (tetranortriterpenoid antifeedant), isoprenoids and nimbidin (sulphurous compound)
Pongamia pinnata	24.2	Karanjinin (furano-flavonoid), antinutritional factors (phytates, tannins and protease inhibitors & glabrin)

Antinutritional and Toxic Factors

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

***Azadirachta indica* meal**

Water washed, methanol extraction, urea and alkali treatments of *Azadirachta indica* meal -- promising results in farm animals (up to 45% of concentrate for calves).

Scaling up of detoxification processes is needed

***Pongamia pinnata* meal**

Water-washed, alkali treated *Pongamia pinnata* meal: up to 13.5% of the concentrate in lamb diet.

Chemical composition of micro-algae

	Protein	Carbohydrate	Lipids	Nucleic acid
Anabaena cylindrical	43–56	25–30	4–7	Na
Aphanizomenon flos-aquae	62	23	3	Na
Scenedesmus obliqus	50–56	10–17	12–14	3–6
Scenedesmus quadricauda	47	na	1.9	na
Chlamydomonas rheihardii	48	17	21	na
Chlorella vulgaris	51–58	12–17	14–22	4–5
Chlorella pyrenoidosa	57	26	2	na
Spirogyra sp.	6–20	33–64	11–21	na
Dunaliella salina	57	32	6	na
Euglena gracilis	39–61	14–18	14–20	na
Prymnesium parvum	28–45	25–33	22–38	1–2
Tetraselmis maculate	52	15	3	na
Porphyridium cruentum	28–39	40–57	9–14	na
Spirulina platensis	46–63	8–14	4–9	2–5
Euglena gracilis	39–61	14–18	14–20	na

Good source of protein and energy

Amino acid profile of a few algae (g/100 g protein)

Source	Ile	Leu	Val	Lys	Phe	Tyr	Met	Cys	Try	Thr	Ala	Arg	Asp	Glu	Gly	His
Egg	6.6	8.8	7.2	5.3	5.8	4.2	3.2	2.3	1.7	5.0	Na	6.2	11.0	12.6	4.2	2.4
Soybean	5.3	7.7	5.3	6.4	5.0	3.7	1.3	1.9	1.4	4.0	5.0	7.4	1.3	19	4.5	2.6
Chlorella vulgaris	3.2	9.5	7.0	6.4	5.5	2.8	1.3	na	Na	5.3	9.4	6.9	9.3	13.7	6.3	2.0
Dunaliella bardawil	4.2	11.0	5.8	7.0	5.8	3.7	2.3	1.2	0.7	5.4	7.3	7.3	10.4	12.7	5.5	1.8
Spirulina platensis	6.7	9.8	7.1	4.8	5.3	5.3	2.5	0.9	0.3	6.2	9.5	7.3	11.8	10.3	5.7	2.2
Aphanizomenon flos-aquae	2.9	5.2	3.2	3.2	2.5	na	0.7	0.2	0.7	3.3	4.7	3.8	4.7	7.8	2.9	0.9

Compared with soymeal EAA reasonably good

Other Novel Feed Resources

Winter barley

Thornless cactus

Azola

Moringa oleifera

Decreasing food-feed competition using Moringa?

Intensive 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

6% leaf meal i.e. 7.56 tons = 25% protein
Total protein yield/ha = 1.9 tons

Soybean = 2 tons/ha & has 35% protein
Total protein yield/ha = 0.7 tons

Other Novel Feed Resources

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.

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

Major knowledge gaps and future research

- Need for standardisation of products from within a plant and between plants (distillers grains)
- Mass rearing of insects
- Evaluation of feeding value of biofuel co-products, insects and moringa – especially aquaculture
- Safety standards for use of co-products and of insects

FAO document: Biofuel co-products as livestock feed - Opportunities and challenges

http://www.fao.org/docrep/016/i3009e/i3009e.pdf

Concluding remarks

“ *An array of co-products of the bio-fuel industry, unconventional resources such as Moringa, Aquatic plants and Insect are good source of protein and energy and can replace soymeal and cereals such as maize in animal diets -- easing food-feed competition”*