Sustainbeef

Transnational list of innovations aiming to reduce feed-food competition in beef production systems

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This research was made possible by funding from **SusAn**, an ERA-Net co-funded under European Union's Horizon 2020 research and innovation programme (www.era-SusAn.eu), under Grant Agreement n°696231

Table des matières

Introduction

The aim of this document is to list all the innovations identified by the partners to reduce feed-food competition in beef production systems.

This inventory should show the diversity of possibility to develop efficient and sustainable beef farming systems while focussing on limiting feed-food competition.

Several innovations have been identified through literature review, including grey literature, and interviews of experts.

List of innovations

Improving the use and management of grass and fodders

Ruminants are able to convert human-inedible fibrous plant materials into high quality animal products (Ertl et al., 2015). However, today's rations also contain substantial amounts of potentially human-edible feeds (e.g. cereals and legumes), which increases competition between animal feed and human food availability. One option would be to evolve towards beef farming systems based more on plant resources that are not edible by humans.

Efficient grazing

Beef cattle can eat grass and forages in their roughest state through grazing. This practice has been known for long but it can still be improved to adapt to the need of the farmers. Here are two innovations to take advantage of grasslands:

1. Cattle fattening on pastures

Innovation description	Fattening of large cattle (heifers and steers) through rotational grazing on multi-species grassland, with the ambition of adding value to cattle, via the local slaughterhouse. Grass is not harvested, stored or distributed. Taking place in breeders-fatteners systems.
Condition of application	• Combining grasses and legumes in grasslands to ensure a rich and balanced diet for the grazing animals • Start rotational grazing as soon as winter comes out (before having grass) • Having enough surfaces to adjust when grass height is not sufficient in the main paddocks
Objectification / Modelling of expected performances	• Reduced production costs (input, feed, meccanization, …) by 50% compared with classical diet • Gross margin increased by 40% • Reduce work load by ≈60% • Enhance animal welfare • Improve the impact on the environment (grassland and hedge conservation)
Barriers & drawbacks	• Need some time to learn the know-how : start with one or more sets of 6 animals before converting the whole system • Fence installation and maintenance (emergence of a new task) • Colour of the calves meat when grazing might not meet consumers demand • In dry areas, cannot always graze in summer due to the lack of grass • Risk of trampling, especially in wet areas? (Garnett, 2017)
Levers	• Acquire the necessary skills to set up this type of system by contacting neighbours who already practice it • Take the time to think about the installation of paths, water points, etc.

	• Early grazing (déprimage) to increase grass quality. Eating roughage in the early stages of its life increases the value potential of fodder. • Sell in short circuits can allow to take advantage of the added value associated with pasture finishing. (Alamome D. and Courty S., sd). • Or work on the image of the product to sell it in supermarkets. • Meets consumers' demand for environment-friendly beef farming systems (Alamome D. and Courty S., sd) • Making the period of birth coincide with the periods of grass growth to be able to fatten animals on pasture • Physiological ability of ruminants to regain in spring the weight that may have been lost during winter (compensatory growth) • Select adapted breed •
Advantages	• The grass growth of an associated meadow is more regular than that of pure ray-grass, leading to a better valorisation by cattle. • Better Ω3 : Ω6 ratio when grassfed than with concentrates
Innovation's region	• Western France (Vendée, Deux-Sèvres), Wallonia (CRA-W)
Reference and / or experts interviewed	• Liaigre T. and Gazeau M. (sd). Pourquoi, comment... Engraisser des bovins au pâturage, dossier Civam-Rad, 2 p. • Civam du Haut Bocage (2009). Pourquoi, comment... Engraisser ses bovins au pâturage, dossier Civam-Rad, 8 p. • Gazeau (2010). Le pâturage augmente la valeur ajoutée de l'engraissement des bovins. Etude réalisée chez des exploitants du Civam du Haut Bocage (Deux-Sèvres). Fourrages (2010) 202, 139-144 • Alamome D. and Courty S. (sd). Engraisser des bovins au pâturage : et si la viande poussait dans nos prés ? Agriculture Durable de Moyenne Montagne
Author	• L. Legein, CRA-W

2. Fast rotational grazing

Innovation description	This technique aims to optimize the overall management of the grazing system. By increasing the number of micro plots (less than 1 ha), it makes it possible to modify the speed of rotation of the animals in order to permanently respect the stage of development of the plants and to allow them to regrow as quickly and abundantly as possible, without drawing on their reserves.
Condition of application	Favourable climate for grass growth (eg : temperate ocean climate)

Modelling of expected performances	• Improved economic results
	  ○ Total investment of 1500 € (Crochet S., 2016)
	  ○ Decreased use of inputs : operating costs on the main forage area have been reduced by a factor of 3 (from 63€/ha in 2010 to 20€/ha in 2015) (Crochet S., 2016)
	  ○ Concentrates (cereals) in the Spring reduced by a factor 2 (Crochet S., 2016)
	• Less veterinary costs due to a reduction from 75 to 50% of corn silage during the winter, linked to a better exploitation of grasslands.

Barriers & drawbacks	• Increased initial workload for paddock and rotation organisation • (Re-)learning of grazing lines required (Leray et al., 2017) • "The apparent complexity of rotational grazing paralyzes farmers who need guidance and reassurance in their decision-making to take this step". (Leray et al., 2017)

	• The obstacles identified to the accessibility of plots for grazing of dairy cows are the distance and road crossing, and to a lesser extent the notions of soil bearing capacity and parcel fragmentation. (Possémé, 2017) • Veterinary costs can increase due to the verminosis diseases
Levers	• Favourable climate for grass growth • The will of the breeders in the implementation of this innovation is the first factor of success • No milking constraints in beef farming, distance between the farm and grassland is thus less of a problem • Get the cattle outside as soon as the bearing capacity of the meadows can support the weight of the hooves (Vergonjeanne, 2016) • Starting with natural grasslands, generally less sensitive to trampling than young grasslands. (Vergonjeanne, 2016)
Advantages	• Better grass valorisation • Long-term decrease in workload • Self-sufficiency
Innovation's region	• Department of Manche, Belgium (Wallonia)
Reference and / or experts interviewed	• Encyclopedia pratensis, s.d. 2 days/plot to better use grass, earl Meslin • Alexandre Lebrun • https://www.osez-agroecologie.org/carrie-paturage-tournant • Vergonjeanne 2016 : http://www.web-agri.fr/conduite-elevage/culture-fourrage/article/premier-tour-d-herbe-sortir-tot-pour-bien-gerer-la-pousse-1178-116493.html
Author	• L. Legein, CRA-W

Adapting animals to pastures

Besides grazing practices in itself, farmers can act on the animals to adapt them to pastures. It is best to choose animals that are suited for grazing. Furthermore, reproduction cycle can be aligned with grazing seasons.

3. Crossbreeding Salers x Angus for a better valorisation of grassland in mountain grazing systems:

Innovation description	Crossbreeding Salers cows (hardiness) with Angus bulls (early, grazing breed). The objective is to produce young bulls 12-15 months, not too heavy (300 kg carcass). This innovation relies on two important points : - Winter calvings (February-March) - A good grassland management Calves are grazing from May to October. Thereafter, they are fattened with high quality (2nd cut), wrapped grass and a low quantity of concentrates, if necessary.
Condition of application	• Mountain grazing suckler systems
Objectification / Modelling of expected performances	• Low consumption of concentrates • Good weight gain • Qualitative product
Barriers & drawbacks	In France, this products faces several reluctances from the livestock and meat value chain actors :

	- This product (light and young) does not comply with the sector expectations - The meat sector professionals are very attached to their traditional breeds. In France, the perception of quality is related to the breed
Levers	• Communication on the quality of this product • Creation of a label / adaptation of the sector
Advantages	• Grass valorisation • Short production cycle = lower feed consumption
Innovation's region	• France, Wales
Reference and / or experts interviewed	• Karine Vazeille (INRA) • From Salamix INRA Project : https://www6.inra.fr/comite_agriculture_biologique/Les-outils-de-recherche/Les-programmes-INRA-dedies-a-l-AB/Inra-AgriBio/AgriBio-4/SALAMIX
Author	• J. Balouzat, INRA

4. Spring calving for a better use of grass resources in low-input dairy systems:

Innovation description	This practice consists in making the cows calve before turning-out to pasture in order to synchronise the lactation curve with the grass growth. This starts from the observation that with the end of milk quotas, the competitiveness of mountain farms must be achieved through the maximum use of pastures, the reduction of inputs and quality products such as PDO cheeses.
Condition of application	• Mountain low-input dairy systems with grasslands
Objectification / Modelling of expected performances	•
Barriers & drawbacks	• poor reproduction performance • No spring grazing allowed in certain areas in order to preserve particular economic species
Levers	• Meets consumer expectations • To compensate for this low gestation rate, it was decided in the first year to extend the lactation of a few non-pregnant cows by about 10 months. • "If the economic performance is not favourable, the only way to maintain that type of pasture-based systems will be to switch to other breeds that reproduce easily even with low inputs, such as Jersey or Holstein-Friesian from Ireland or New-Zealand(Piccand et al. 2013)
Advantages	• Matches the high animal needs with high grass availability periods • Production of most milk at pasture, which requires less concentrate for a similar milk yield, as the feeding value of grazed swards is always higher than that of the corresponding preserved forage.
Innovation's region	• France (INRA), Denmark
• **Reference and / or experts interviewed**	• Dominique Pomiès, Anne Farruggia • Piccand, V., E. Cutullic, S. Meier, F. Schori, P.L. Kunz, J.R. Roche, and P. Thomet. 2013. "Production and Reproduction of Fleckvieh, Brown Swiss, and 2 Strains of Holstein-Friesian Cows in a Pasture-Based, Seasonal-Calving Dairy System." *Journal of Dairy Science* 96 (8): 5352–63. https://doi.org/10.3168/jds.2012-6444.

	• Pomiès, Dominique, F Fournier, and Anne Farruggia. 2016. "Extended Lactations to Overcome Reproduction Problems in Mountain Low-Input Dairy Systems." *Options Méditerranéennes*, no. 116: 75–79. • Botreau et al (2014). Towards an agroecological assessment of dairy systems: proposal for a set of criteria suited to mountain farming. Animal (2014), 8:8, pp 1349–1360 © The Animal Consortium 2014
Author	• J. Balouzat, INRA • L. Legein, CRAW

Improving forage quality

The quality and type of forage can also be an entry point to improve the use of grasslands resources. The species used can help provide a balanced diet while the conservation techniques will make it possible to benefit fully from the nutrients provided by the grassland.

5. Alfalfa and red clover as protein supplements in rations for young beef cattle

Innovation description	Feeding young Limousin and Charolais cattle with a flattened wheat-based diet distributed *ad libidum* to produce carcasses weighing 430 to 440 kg. They receive wrapped alfalfa or red clover as their only protein supply to replace soymeal.
Condition of application	• Crop-livestock systems • Harvest high quality fodder resources • Have sufficient area in cash crops to introduce legumes into the crop rotation
Objectification / Modelling of expected performances	• Reduced soil occupation by 50% (globally not locally)[1] • 40% reduction in food costs with legumes • Use of 7-8 ares/young cattle to produce legumes and extra-wheat • Increased farm's operating income of +13% and +11% when soymeal is replaced respectively by alfalfa and red clover for young cattle. (Guillaume, 2015)
Barriers & drawbacks	• Loss of margin in cash crops • More tender but less juicy and tasty meat than the reference meat (Charolais cows) • In Bastien et al. (2017), the downstream value chain actors interviewed had a negative image of the quality of young bovine meat • This type of meat is mainly export oriented to countries facing substantial crisis and downstream actors have doubts about the future of those markets
Levers	• The protein provided by legumes is very well valued by animals without digestive health problem : the fibre in alfalfa or clover is sufficient for the rumen to function properly • Carcasses with a same finishing status as those of cattle supplemented with soya meal • The inefficient utilisation of dietary forage protein could potentially be improved by decreasing the extent of protein degradation that occurs within the rumen, and polyphenol oxidase containing forages, such as red clover, could be a sustainable mechanism which contributes to achieving this (Hart et al., 2016) • Adapt to and convince local market
Advantages	• Significant protein self-sufficiency gain • Limit negative impacts linked to soybeans production (Hessle, 2017; FCRN, 2015)

[1] According to the Nordic Council of Ministers (2014), the yield of soymeal in South America is 2.05 t/ha. According to Guillaume (2015) the amount of soymeal needed for one young male in the NEOBIF experiment was 314 kg (gross), thus the area needed to produce soymeal for one young is 0.314 t / (2.05 t/ha) = 0.153 ha ≈ 15 ares. In contrast, the area needed to produce legumes and extra-wheat for one young is ≈ 7 to 8 ares

	• A meat production based on local feed and that is environmentally coherent can be attractive to citizens and consumers • Higher levels of omega 3 in meat from Limousin animals supplemented with legumes
Innovation's region	• France (Brittany)
Reference and / or experts interviewed	• Bastien et al. (2017). NEOBIF : Etude de nouveaux modes de production de viande bovine à partir de bovins mâles allaitants. Innovations Agronomiques 55 (2017), 71-84. • Guillaume A. (2015). L'engraissement de jeunes bovins avec des légumineuses. NEOBIF – satellite 3R 2015. • Nordic Council of Ministers (2014). Climate change and primary industries: Impacts, adaptation and mitigation in the Nordic countries. Nordisk Ministerråd : Nordisk Råd : [Eksp.] www.norden.org/order • Hart et al., 2016. The effects of PPO activity on the proteome of ingested red clover and implications for improving the nutrition of grazing cattle. Journal of Proteomics 141 (2016) 67–76
Author	• L. Legein, CRA-W

6. Hay dried in barn

Innovation description	The barn hay drying process is based on the harvesting of green hay, which is then dried in the barn using hot air ventilation. This ancient technique has been perfected over time and in recent years has become more and more popular in all breeding regions of France.
Condition of application	• Dairy farms with cows with a maximum production of 8000 L/year • All types of climates • Interest for cattle fattening remains to be explored
Modelling of expected performances	• At the beginning about 4 ha per 100 m^2 of ventilated surface can be harvested • A lactating dairy cow often consumes 18 to 20 kg/d of this product • The investment costs can vary from 50000€ to more than 300000€ depending on the required capacity, the existing buildings as well as the share of self-construction. However the operating costs (fan and claw) are relatively low (from 4 to 6 €/t MS of hay). In general, depreciation is carried out over a period of 10 to 15 years • Economic feeding: 22€ for forage and 65€ for concentrates/1000 l of milk (Encyclopedia Pratensis)
Barriers & drawbacks	• Requires a work organization very different from the schemes we are familiar with • Requires good technical skills • Substantial investment in buildings and equipment
Levers	• Popular in areas where corn growing is sometimes difficult and winters can be long and harsh • The choice of species and varieties will have a significant impact on the ease of drying • The phenological stage of the plants, their water content linked to fertilization as well as the proportion of stem will also have an impact on the drying aptitude. • Farmers concerned about the quality of the forage harvested • Milk valuation through artisanal cheese or under the PDO label
Advantages	• Technique that allows to maximize the feed value of the hay • Can be kept for a long time • Hay highly palatable and ingested in large quantities without waste by animals

	• Offers great flexibility in grassland management with the possibility of disengaging at any time a plot whose grazing stage is too advanced • Significantly reduce the purchase cost of protein feed • Healthier animals and lower veterinary costs
Innovation's region	• France, Belgique, Suisse, …
Reference and / or experts interviewed	• David Knoden "Le séchage du foin en grange : principes de base" • Encyclopedia Pratensis https://www.encyclopediapratensis.eu/product/inno4grass/gaecdelapouliniere/
Author	• L. Legein, CRA-W

Human-inedible fodder from cropping systems

Cropping systems, besides producing food products, can provide feed that are not in competition with human food. Those can be directly grazed or harvested as fodder. Furthermore, grasslands can be part of the rotation and, in return, cropping systems can benefit from the interaction with cattle.

7. Production of fodder through cover crops

Innovation description	Multiple cropping can provide additional fodder for livestock holdings. Those crops can be either grazed or ensiled. The cover crops are sown if the weather permits, just after the cereal harvest and are kept all winter long. They can also be sown as relay crop in the previous crop.
Condition of application	• Adapt to local conditions • Earliest possible establishment of the cover crop after the harvest of the previous crop • For sowing, fine surface preparation with rolling often guarantees good emergence. • The cover crops should also be destroyed at least two months before the plantation or sowing of the next crop
Objectification / Modelling of expected performances	• 60 € of seeds/ha for grazing mix • 3 tMS/ha for grazing
Barriers & drawbacks	• Be careful not to penalize the next culture (Chambre d'Agriculture Landes, s.d.) • The weather must allow it (Bourgeois, 2010) • Random yield in link to the weather at the end of summer and in autumn (Chambre d'Agriculture Landes, s.d.) • Mixture to be adapted to the needs of the animals but also of the cropping system • Not a "one size fits all" solution
Levers	• Could be very productive and palatable to livestock (Chambre d'Agriculture Landes, s.d.) • Direct sowing practices are possible (Bourgeois, 2010) • Complying with the obligation of the Nitrates Directive on autumnal soil cover (Chambre d'Agriculture Marne, 2011, Bourgeois, 2010). • Agronomic benefits (more specifically with direct sowing and/or reduced tillage) (Bourgeois, 2010) • The use of several species in combination makes it possible to limit the risk of failure related to climatic hazards (Bourgeois, 2010)
Advantages	• Save on stocks to be distributed in autumn

Innovation's region	• France, Belgium (travaux de Marc De Toffoli, CS Ovin de DiverIMPACTS, Thèse de Sophie Herremans, …)
Reference and / or experts interviewed	• Bourgeois S. (2010). Des couverts pâturés et des couverts récoltés. Technique d'élevage, alimentation. Réussir bovins viande, janvier 2010, n°167, pp 54 – 55. • Chambre d'Agriculture Landes (s.d.). Les intercultures à vocation fourragères, un intérêt à ne pas négliger. L'herbe un potentiel à valoriser. • Chambres d'Agriculture Aquitaine (2013). L'herbe… un potentiel à valoriser. • Chambre d'Agriculture Marne (2011). Des intercultures à utilisation fourragère.
Author	• L. Legein, CRA-W

8. Integrated crop-livestock systems

Innovation description	Production systems integrating crops and livestock have potential for providing additional ecosystem services from agriculture by capturing positive ecological interactions and avoiding negative environmental outcomes, while sustaining profitability by contrast with specialized systems. Cattle and crops interact throughout the rotation. Cattle feeding on forage crops, crop residues and/or cover crops.
Condition of application	• A diversity of systems depending on the ecoregions: crop rotations including grasslands, grazing cover crops in cash-crop rotations, crop residue grazing, direct sowing, dual-purpose cereal crops, and agro-forestry/silvopasture.
Objectification / Modelling of expected performances	• Increased crops performances and yields (from reduced insect, disease and weed pressures in sod-based crop rotations, from grazing cover crops and dual-purpose cereal crops) (Sulc and Franzluebbers, 2014) • Improved profitability ⇨ Compare integrated system with the sum of 2 specialized systems

Barriers & drawbacks	• Risk of cattle trampling leading to deterioration of soil physical properties and reduction of root growth and yield
	• Specialized crop producers have generally little interest in integrated crop-livestock systems due to:
	  ○ comfort with commodity support policies,
	  ○ managerial ease of crop only systems,
	  ○ and rising market prices for their products

Levers	• Management of crops with no tillage is considered to be a key tool in raising the productivity of integrated crop–livestock systems in the [Southeastern USA] region (Franzluebbers and Stuedemann, 2013)
	• Stocking pressure and amount of residue left is an important management tool in limiting the negative effects of grazing animals
	• Several technologies have greatly improved opportunities for producers to develop successful integrated crop-livestock systems:
	  ○ conservation tillage
	  ○ improved weed control practices
	  ○ fertilization
	  ○ improved plant genetics
	  ○ planting technologies
	• portable electric fencing and improved water systems (for cattle to drink?)

Advantages	• Crops provide forage for the livestock • Livestock apply the nutrient consumed back on the land through manure deposition Increases soil C accumulation and sequestration with manure recycling ⇨ Soil tilth, fertility and carbon (C) sequestration • Reduced feed costs (especially in the winter) • Reduced reliance on herbicides

	• Improved soil properties
Innovation's region	• USA
Reference and / or experts interviewed	• Sulc and Franzluebbers 2014 European Journal of Agronomy 57 (2014) 21 – 30 • Franzluebbers and Stuedemann 2013 European Journal of Agronomy 57 (2014) 62 – 70
Author	• L. Legein, CRA-W

Replacing concentrate with by-products of the industry

The food industry produces waste that has to be handled and can have an impact on the environment. However, part of them could contribute to replace – partly or totally – concentrate in competition with food production. Indeed there are by-products non-edible or not wanted by humans that can be converted by animals and can provide protein and energy.

New by-products

9. Oil seed cakes in animal feeding

Innovation description	Use by-products obtained by pressure extraction oil for human or energy use. They are obtained by the press of the fruits of some crops containing high levels of proteins and oils (e.i soybean or rape). The cakes obtained after pressing are profitable sources of amino acids and energy for different animal categories.
Condition of application	Choice of varieties which do not contain antinutritional substances (e.i. glucosinolates) or high levels of poly unsaturated fatty acids
Objectification / Modelling of expected performances	• Positive environment impacts • Cost reduction (e.g. replacing soybean meal by peanut, palm kernel or sunflower cakes in dairy cows' diet; Oliveira et al., 2016) • Improvement of the nutritional quality of milk by producing lower concentrations of saturated FAs and a higher proportion of unsaturated FAs (Oliveira et al., 2016) • Without compromising the production or nutritional composition of milk (Oliveira et al., 2016)
Barriers& drawbacks	• High content of unsaturated fatty acids, which are possible causes of reduction of milk production and of fat content or have negative effects on meat quality Short Shelf-life and difficult to be stored • Antinutrition substances • High levels of poly unsaturated fatty acids
Levers	• Proximity of productive areas where these crops are grown and processed. • Nowadays, greater consumer awareness of foods that contain micro components with beneficial effects on health and disease prevention (Oliveira et al., 2016).
Advantages	• Economic gain • Exploitation of these by-products. • Reduction of greenhouse gas emission as result of introduction of lipids in the diet • Improvement of meat quality and animal welfare. • Sunflower and palm kernel cakes demonstrated efficiency by increasing the concentrations of unsaturated FAs and bioactive compounds (CLA) that can slow the aging process, boost the immune system and protect against heart disease and certain cancers (Oliveira et al., 2016)
Innovation's region	• All areas where these by-products are produced

Reference and / or experts interviewed	• Moate P.J, Deighton M.H., Williams S.R.O., Pryce J.E., Hayes B.J., Jacobs J.L.,. Eckard R.J., Hanna M.C. and Wales W.J. Reducing the carbon footprint of Australian milk production by mitigation of enteric methane emissions. Animal Production Science, 2016, 56, 1017–1034. • Jóźwik A., Strzałkowska N., Markiewicz-Kęszycka M., Krzyżewski J., Lipińska P., Rutkowska J., Wróblewska B., Klusek J., Cooper R.G. Effects of replacing rapeseed cake with linseed cake in a corn-grass silage-based diet for milking cows. Animal Science Papers and Reports vol. 34 (2016) no. 2, 129-142. • Ariff, O.M., Sharifah, N.Y. and Hafidz, A.W. Status of beef industry of Malaysia Mal. J. Anim. Sci. 18(2): 1-21 (December 2015) • Keshary D.L., Kundu S.S., Chander D., Dinesh K. Fractionation and evaluation of carbohydrate and protein contento of some concentrate feeds for ruminants. Indian Journal of Animal Science, 2014, 31,4.
Author	G. Pirlo and M. Iacurto (CREA)

10. Use of dried stoned olive pomace

Innovation description	Use of by-products obtained from residue of olive oil production.
Condition of application	• Systems of growing and finishing cattle • Close to olive production sites?
Objectification / Modelling of expected performances	• High nutritional quality (Phenols and Antioxidant) because production process maintains antioxidant content. • Improved lipid stability ? => quality ? => price ?
Barriers& drawbacks	• Difficult to store • High drying costs • Limits in the use in the diet (no more than 14% of the concentrates)
Levers	• Close to areas where olive oil is produced • Use of by-product widely available in Italy but also Mediterranean region.
Advantages	• Exploitation of by-products that are potentially polluting for their high nutrient content • Potential improvement of meat quality
Innovation's region	• Mediterranean countries as Italy, Spain, Tunisia, France etc.
Reference and / or experts interviewed	Meo Zilio D., Bartocci S., Di Giovanni S., Servili M., Chiariotti A., Terramoccia S. 2014. Evaluation of dried stoned olive pomace as supplementation for lactating Holstein cattle: effect on milk production and quality. Animal Production Science Taticchi A., Bartocci S., Servili M., Di Giovanni S., Pauselli M., Mourvaki E., Meo Zilio D., Terramoccia S. 2017. Effect on quanti-quality milk and mozzarella cheese characteristics with further increasing the level of dried stoned olive pomace in diet for lactating buffalo. Asian-Australasian Journal Animal Science 30; 11: 1605-1611.
Author	G. Pirlo and M. Iacurto (CREA)

11. Whey in animal feeding

Innovation description	Use of a by-product obtained from cheese making. 2 examples: 1. Milk whey and "scotta" from a small cheese factory was monitored for acidification with or without inoculation with Lactobacillus helveticus. A mix of whey and scotta was administered to weaned calves.

	2. Silage produced from "sweet" liquid cheese whey, small grain straw and wheat middlings
Condition of application	• Systems of growing and finishing cattle

Objectification / Modelling of expected performances	• Reduced feed costs:
	  ○ The reduced cost from 3% to 6% for soybean and maize respectively
	  ○ From the literature it appears that whey can be given instead of water
	  ○ Reduction is related to tanker truck rent.
	• Water saving
	• Reduction of cheese factory waste disposal

Barriers& drawbacks	• Short shelf-life • Gradual introduction in the diet for acidosis disease risk
Levers	• Proximity of cheese factories • Use of by-product widely available in Italy. • Whey silage can be produced at any time of the year, farmers can thus adapt to availability
Advantages	• Economic gain • Alternative use of this by-product, that is commonly used in pig finishing. • Ensiling low-quality roughage such as straw with cheese whey has an effect on the physical structure of the straw making it more digestible.
Innovation's region	• All countries (Italy, USA).
Reference and / or experts interviewed	Di Giovanni S., Meo Zilio D., De Santis P., Vercasia B.M., Tripaldi C. 2017. Utilizzo di siero e scotta nell'alimentazione dei vitelli. L'informatore agrario 43/2017 Zobell Dale R and Burrel W.C. 2002. Producing Whey Silage for growing and finishing cattle. All Archived Publications. Paper 33. http://digitalcommons.usu.edu/extension_histall/33 UtahStateUniversity
Author	G. Pirlo and M. Iacurto (CREA)

Conservation of by-products

12. Local pulps and by-products in a single silo

Innovation description	By-products, fodder and cereals are mixed together in one single silo to produce balanced silage
Condition of application	• Systems including fattening of young cattle
Objectification / Modelling of expected performances	• Reduced costs of young cattle fattening (The gain on labour and material costs estimated at 32 euros per animal in Flamant et Lartisant (2016)) • Reduced working time (the time saved is on average 20 minutes per day in dairy systems)
Barriers & drawbacks	• Treasury advance can be large for silage confection • Mostly used for dairy cattle • Knowledge needed for proportions of by-products and technique of silage • Set up of silage takes time and requires organization
Levers	• Proximity of agri-food factories
Advantages	• Economic gain • Valorisation of local resources • Steady ration • Sugars provided by the by-products lead to fermentation and improved preservation • Simplification of the work at the year scale , once confection phase is over

	• Easier silage face management
Innovation's region	• France (North-East)
Reference and / or experts interviewed	• Bourgeois (2016) • Flamant et Lartisant (2016) • Lefebvre (2013) • Reibel (2014) • Pollen sarl (FR)
Author	• L. Legein, CRA-W

Limiting meat production to non-competitive feed

The two above approaches can be combined to achieve a meat production system that is not dependent on any human edible resources.

13. Principle of ecological leftovers applied to the Swedish context

Innovation description	Ecological resources are the constraining factor for livestock production. In other words, in this scenario, animals are fed with resources that are not fit for human consumption, such as grass from marginal land or by-products from crop production and food processing. Meat and milk are produced on grasslands and by-products. The remaining by-products are then allocated to the production on pigs and poultry (eggs and meat)
Condition of application	• Arable land should primarily be used for the production of plant-based food for humans • Livestock should be fed from biomass not suitable for or wanted by humans • Semi-natural grassland should be used for livestock production if grazing can be justified by reasons other than meat and milk production, e.g. biodiversity conservation, providing a livelihood for vulnerable populations, etc.
Objectification / Modelling of expected performances	• Reduce the share of land surface needed for European livestock systems to reach 50% or less of the utilised agricultural area (currently equivalent to 65% of the agricultural land according to Leip *et al* 2015). • Reduce the climate impact from production of the current Swedish human diet by 50% • The farm-level economic impact of a change in meat and dairy consumption would crucially depend on the type of new output found for the land released from livestock production (Westhoek et al., 2014) • The amount of food product yielded from food residue only is equivalent to 81 g pork/person/day in comparison with the 150 g of pork meat equivalent that has to be consumed to comply with the recommendation of 30 g of animal protein per day of the Health Council of the Netherlands. In the NL, the average consumption of animal proteins is 52 g/cap/day (meat, fish, milk and egg)
Barriers & drawbacks	• Grassland management need a high technicity in order to manage the variability of this resource and to connect it to animal needs • Such scenario will lead to a reduction of beef, poultry, pig meats production of 60 to 80 %. This requires changes in the current and well established consumption patterns. (Röös et al., 2016) • Requires some arable land for production of winter feeds in the Swedish context • Meat still plays a significant and important place in the diet of many people, and is associated with pleasure as well as various personal and social values, which presented potential barriers to reducing consumption.(Macdiarmid et al., 2016) • Food residues can also be used for providing renewable energy

Levers	• Need to produce more diversified crops in the rotation (grain legumes, oilseed crops and other food crops) to maintain the recommended intake of protein and fat in human diet despite reduced consumption of animal products and to increase cropping system resilience to pests, diseases and extreme weather events
	This will make new by-products available
	• Diet and eating habits are rapidly changing in our society (Röös *et al* 2016)
	• Identifying target transition pathways towards more plant-based diets (Schösler et al., 2012) to take into account the consumers' perception
	• Using efficient policy instruments influencing attitudes towards consumption of animal products: less but better meat with a promotion of beef meat that could have a very low feed-food competition level
	• Regionalized food systems emerging, influenced by policies
	• Product differentiation: added value for grassland based milk, what about grassland based beef meat ?
	• Limiting meat consumption vs. no consumption:
	  ○ Some vegetarian or vegan diet can have negative impacts on the environment
	  ○ Livestock products contains high rate of essential amino acids and micronutrients
	  ○ Social and environmental benefits of livestock systems
	• Improve the use of agricultural residues, agro-industrial by-products and waste materials to produce high-quality feedstuffs (Schader et al., 2015)

Advantages	• Reduced environmental impact ? • Reduce production costs? (see grazing and by-products innovations) • Direct impact on the reduction of feed-food competition • Handling waste (upgrade a low quality material into high quality foods)
Innovation's region	• Sweden, UK, NL, Be, …
Reference and / or experts interviewed	• Röös *et al* 2016 *Food Policy* **58** (2016) 1–13 • Adrian Leip *et al* 2015 *Environ. Res. Lett.* **10** 115004 • Schösler et al. 2012 Appetite 58 (2012) 39–47 • Westhoek et al. 2014 Global Environmental Change 26 (2014) 196 – 205 • Macdiarmid et al., 2016. Appetite 96 (2016) 487 – 493 • Schader C et al. 2015. Impacts of feeding less food-competing feedstuffs to livestock on global food system sustainability. J. R. Soc. Interface 12: 20150891. http://dx.doi.org/10.1098/rsif.2015.0891 • Elferink *et al.* 2008 *Journal of Cleaner Production* **16** (2008) 1227–1233
Author	• L. Legein, CRA-W

Insert alternative feed products in the cattle diet

Other type of resources, that are not plant-based, can potentially provide protein and energy. Indeed, the use of algae and insects in animal diet has been studied as response to feed-food competition and deforestation.

14. Use of insect meal as a source of protein in cattle diets

Innovation description	Insects are a great source of proteins and lipids, which could be used in livestock diet. Fed on any type of organic matter, they can be an efficient organic waste recycler thanks to their good conversion rate. (FAO)

	Despite a large number of edible insects, 2 species are commonly grown : the black soldier fly and the mealworm. They contain 55-60% of proteins and 15-35% lipids.
Condition of application	• Dairy and fattening units
Objectification / Modelling of expected performances	• Good digestibility and palatability • Little land and energy needed to produce • They could replace up to 25-100% of soymeal depending on the animal species (Makkar et al. 2014)
Barriers & drawbacks	• A regulatory issue: the use of insects meal is forbidden in ruminant production systems. The feeding sector is reluctant to its authorisation • Social acceptance • Scaling production • Deficient in calcium and certain amino-acids.
Levers	• Since July 2017, the use of insects meal has been authorised in aquaculture. Discussions should progress in pork and poultry production. It should open the door to ruminants.
Advantages	• A short non-seasonal production cycle, feasible anywhere • They can be a good means to value food and agriculture non-edible wastes
Innovation's region	• France (26 insect farms, 1st company : Ynsect, $37M raised), South Africa, Canada, USA…
Reference and / or experts interviewed	Expert interviewed : Gaëlle Maxin, INRA Makkar, Harinder P. S., Gilles Tran, Valérie Heuzé, and Philippe Ankers. 2014. "State-of-the-Art on Use of Insects as Animal Feed." *Animal Feed Science and Technology* 197 (November): 1–33. https://doi.org/10.1016/j.anifeedsci.2014.07.008.
Author	J. Balouzat (INRA)

15. Use of algae as a substitute for corn or soymeal in the grower and finisher cattle diets

Innovation description	Algae are a source of energy and protein, which can potentially be used as a substitute in concentrate-based diets. On a different scale, algae can also be used as a food supplement for their medicinal virtues. Algae can either come from specialised production units, or from the biodiesel industry, as a by-product.
Condition of application	• Dairy and fattening farms
Objectification / Modelling of expected performances	• Recent studies conducted in the USA have shown that algae can replace corn or soymeal at up to 45% of the diet (Dib 2012) (Emon et al. 2015). • Algae meal are supposed to have a positive effect on GHG emissions (Maia et al. 2016). • Used in dairy cattle systems, algae also contribute to increase the milk fat yields (Stamey et al. 2012).
Barriers & drawbacks	• A very prohibitive price : no large-scale production system yet • Further research on economics are needed • Limits regarding iodine, fluorine, arsenic and heavy metals content of algae • A high content of non-digestible fibres

Levers	• Industrial processes (high volumes and standardised product) are being developed (in France : Olmix, Ceva, Inalve ; in Australia : University of Queensland) • In the bioethanol industry, volumes are higher and prices can be more competitive
Advantages	• Medicinal virtues • Quickness to produce • Valorisation of a by-product
Innovation's region	• USA, France, Australia
Reference and / or experts interviewed	Expert interviewed : Gaëlle Maxin, INRA Dib, Marco. 2012. "Chlorella Sp.: Lipid Extracted Algae Utilization of Algae Biodiesel Co-Products as an Alternative Protein Feed in Animal Production." PhD Thesis, Colorado State University. Emon, Van, M. L, D. D. Loy, and S. L. Hansen. 2015. "Determining the Preference, in Vitro Digestibility, in Situ Disappearance, and Grower Period Performance of Steers Fed a Novel Algae Meal Derived from Heterotrophic Microalgae." *Journal of Animal Science* 93 (6): 3121–29. https://doi.org/10.2527/jas.2014-8654. Maia, Margarida R. G., António J. M. Fonseca, Hugo M. Oliveira, Carla Mendonça, and Ana R. J. Cabrita. 2016. "The Potential Role of Seaweeds in the Natural Manipulation of Rumen Fermentation and Methane Production." *Scientific Reports* 6 (August): 32321. https://doi.org/10.1038/srep32321. Stamey, J. A., D. M. Shepherd, M. J. de Veth, and B. A. Corl. 2012. "Use of Algae or Algal Oil Rich in N-3 Fatty Acids as a Feed Supplement for Dairy Cattle." *Journal of Dairy Science* 95 (9): 5269–75. https://doi.org/10.3168/jds.2012-5412.
Author	J. Balouzat (INRA)

Act on feed efficiency

A more sustainable beef production can be achieved through a better feed conversion by the animal and a precise management of the ration.

16. Genomic selection for food efficiency in beef cattle

Innovation description	Select animals based on genomic prediction conducted as the association between genotypic data and measures of feed efficiency (FCR, RFI) or component traits (DMI, ADG)
Condition of application	• Follow animals from birth to slaughter • Systems including females for renewal
Objectification / Modelling of expected performances	• Decreased feed costs • Reduced feed consumption • Positive environment impact
Barriers & drawbacks	• Feed intake difficult to obtain and expensive to measure • Phenotypes expensive to measure ⇒ superior animals chosen for trials

	⇒ bias • Large reference population needed • Deterioration of other criteria
Levers	• Augmentation of genomic information at national level • Genomic as a tool to complement selection techniques • Routine collection of identified feed efficiency factors from herds • Construction of a reference population • Provide robust measure of feed efficiency • Determining the objective of the selection and defining the efficiency sought
Advantages	• Potential for great returns in the beef industry
Innovation's region	• USA • France
Reference and / or experts interviewed	• Schweer and Anderson (2016) • Fischer et al. (2015) • BEEF Alim 2020 (FR)

17. Precision livestock feeding

Innovation description	In recent years new information technologies have been developed to help in monitoring accurately many components of livestock systems, such as animals (e.g. feed intake, diet selection, digestive activity, metabolic parameters and productive level), animal products, feeds and the environment. Precision Livestock Farming is defined as "the use of information and communication technologies for improved control of fine-scale animal and physical resource variability to optimize economic, social, and environmental dairy farm performance" (Eastwood et al., 2012).
Condition of application	• Adopters need to have sufficient skills and competences to manage precision agriculture/livestock tools and sufficient financial resources to purchase it. (Pierpaoli et al. 2013) • Farmers intending to intensify production in the future are more likely to adopt those technologies (Sheep farmers; Lima et al. 2018)
Objectification / Modelling of expected performances	• Increased production efficiency and profitability • Reduced environmental impact • Improved product quality and safety • Improved animal health and well-being • Reduced GHG emissions • Increased feed efficiency and productivity
Barriers & drawbacks	• High investment costs • Difficult to be applied in small farms • Increased complexity of the systems inhibits easy adoption and makes calculations as to the financial benefits uncertain (Bartzanas et al. 2017) • Lack of support mechanisms, knowledge transfer and a consistent service offering for farmers (Bartzanas et al. 2017) • Lack of co-ordination between researchers, developers, market and farmers (Bartzanas et al. 2017)

Levers	• Develop a service sector that will be able to: (Banhazi et al. 2012 in Bartzanas et al. 2017)
	  ○ Take care of technology components,
	  ○ Interpret data captured by sensors,
	  ○ Formulate and send simple, relevant advice to farmers on a regular basis,
	  ○ Involve users in technology developments

	• In-field demonstrations, free trials, support services related to the use of new technologies, as they promote the perception that the use of a technology is easy (Precision Agriculture; Pierpaoli et al. 2013) • Developing low-performance (easy-to-use and low-cost) tools but useful enough to provide a benefit to the farmer in order to spread the technology among farmers (Pierpaoli et al. 2013)
Advantages	• Input and yield optimisation (Bartzanas et al. 2017) • optimising feed quality and digestibility, and animal health and husbandry (Wathes et al., 2008 in Bartzanas et al. 2017)
Innovation's region	• Europe, UK, Italy, North America
Reference and / or experts interviewed	• Pulina et al., 2017. Sustainable ruminant production to help feed the planet. Ital. J. Anim. Sci., 16: 140-171. • Abeni and Galli, 2016. Condizioni per lo sviluppo della zootecnia di precisione. L'Informatore Agrario, 38: 33-36. • Bartzanas et al. 2017 • Pierpaoli et al. 2013 • Lima et al. 2018
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Optimizing existing agro systems

Another possibility is to act indirectly on feed-food competition by optimizing and transforming the existing systems. For example, the rearing phase, the final purpose of the animal or land use can be improved.

18. Genomic selection : measuring and favouring the dairy production of suckler cows

Innovation description	A better milk production from the mother leads to a better weight gain of the young calf. Selecting suckler cows on their 1. total milk production and 2. persistency of lactation is a potential solution to reduce feed purchased while increasing weight at weaning.
Condition of application	• Herbageous suckler system (cow-calf)
Objectification / Modelling of expected performances	• "Throughout lactation, the average weight gain is 60 g/liter of extra milk drunk, i.e. a gain in live weight of 70 kg for a lactation of 2 300 kg compared to a lactation of 1 200 kg." (Sepchat, D'Hour, and Agabriel 2015) • The milk production of the suckler cow is resilient to dietary intake variation (of the mother), especially for multiparous cows and at the beginning of the lactation. This implies that variations in the mother' diet during lactation should not affect its milk production, and thus the weight gain of the calf. • Experiments on Salers calves showed that calves receiving 860 kg of extra milk from months 3 to 9 grow similarly to calves consuming 460 kg of concentrates. (Brouard, Devun, and Agabriel 2014)
Barriers & drawbacks	• Difficulties to measure the milk production of suckler cows (weighing of the calves before and after each feeding) • Milk production and weight gain are negatively correlated: females with high dairy potential are less heavy.

Levers	• To increase the cows lifetime performance, for having more lactations per cow
Advantages	• Less food purchased for weanlings • Expected economic gain, since the calves are heavier: with winter calvings, the quality of the grass in spring satisfies the nutritious requirements of the cow during her lactation. This allows the cow to maximise its lactation, the calf to grow fast, and the farmer to save money on the feed purchases.
Innovation's region	• France
Reference and / or experts interviewed	Anne Farruggia (INRA) Bernard Sepchat (INRA) Brouard, S., J. Devun, and J. Agabriel. 2014. "Guide de L'alimentation Du Troupeau Bovin Allaintant." *Institut de L'elevage (Idele), Ed Technipel, Paris, France. Cerca Con Google*. Sepchat, Bernard, Pascal D'Hour, and Jacques Agabriel. 2015. "Production Laitière Des Vaches Allaitantes: Caractérisation et Étude Des Principaux Facteurs de Variation." *Recontre Des. Rech. Sur Les. Ruminants* 22 (5–6): 329–332.
Author	• J. Balouzat, INRA

19. Terminal crossbreeding with beef breed, on dairy herd, for commercial beef production

Innovation description	Inseminating dairy cows with semen from beef bulls breed to produce calves for meat production
Condition of application	• Dairy farms
Objectification / Modelling of expected performances	• Increased income, generated by meat in dairy farms (due to a better conformation of the calve, crossbred calves can be sold about 200€ more than dairy calves) • Cross-breeding calves have higher slaughter yield and feed efficiency than dairy calves, while maintaining an easy calving according to Servais (2012)
Barriers & drawbacks	• More Caesarean sections on primiparous cows (if Belgian Blue is used as beef breed) than on multiparous ones • Belgian value chain oriented towards double-muscled type ⇒ crossbred calves not well valorised • Calf market rather fluctuating ⇒ increase in the supply of cross-breed veal may result in a fall in the selling price • Need to maintain herd of pure beef type breed • Need to have cows with a good fertility in order to insure replacement rate • High cost of sexed semen • Contractualisation with downstream companies to valorise the meat.
Levers	• Focusing genetic investments on cows with good potential and keep low genetic value multiparous dairy cows for crossbreeding • Sexed semen : ○ "Female" semen of dairy breed on the best dairy cows to ensure the genetic quality of the herd and the replacement rate with a minimum number of cows;

	○ "Male" semen of beef breed on multiparous dairy cows of lower genetic value. These calves have a higher value and the difference in selling price offsets the cost of the sexed doses. • Optimized bulls choice for easy calving
Advantages	• Heterosis or hybrid vigor • Potential for lowering global warming potential (GWP) of dairy-based systems while enhancing beef quality (De Vries et al. (2015) • Higher growth rate than dairy-bred calves (De Vries et al. (2015)
Innovation's region	• Belgium (Wallonia) • OECD countries (USA, UK, Ireland, Switzerland, Sweden, Australia, UE) • France (Bretagne)
Reference and / or experts interviewed	• Servais, L. (2012). Croisement terminal sur race Holstein, une source de revenu sous-exploitée. Wallonie Elevage, n°1 janvier 2012, pp 22-26 • De Vries M., van Middelaar C.E., de Boer I.J.M. (2015). Comparing environmental impacts of beef production systems: A review of life cycle assessments. Livestock Science 178 (2015) 279–288. • Chambre d'agriculture Bretagne (s.d.). Atelier n°1 : Combien j'élève de génisses ? Rendez-vous techniques bovins.
Author	• L. Legein, CRA-W

20. Agroforestry to reduce feed-food competition in cattle systems

Innovation description	To incorporate trees and hedges on the plots, in particular on/around the grasslands. Trees provide several agro-environmental services. They can be noble trees, fruit trees or fodder trees. They can contribute to the reduction of feed-food competition on two aspects : - Planted on non-arable land or around arable plots, they are a non-competitive source of feed during shortages, and they can help the grasslands to be more productive - They are a solution to produce food on non-arable land (fruit trees in grasslands)
Condition of application	• Every systems with agricultural land
Objectification / Modelling of expected performances	• Better animal welfare (Since animal health is directly dependent on their welfare, this can have a positive impact on animal production and reduce veterinary costs (Dritz, 2012)) • sales of wood/fruits • Trees and hedges are an extra fodder resource during shortages = less feed purchased
Barriers & drawbacks	• Planting trees is a long-term project with late economic benefits • Hedges and trees ranges are a constraint for mechanisation • Reduction of the cultivated area • The use of phytosanitary products on fruit trees can be a problem for animals pasturing below • Technical constraints for protecting young trees from wildlife and livestock • Lack of knowledge about feed potential
Levers	• Wide ranges of trees, which allow the passing of machinery • Use of an appropriate equipment

	• A high up-front investment is required. First results come many years after. Trees and hedges need maintenance time. • With organic farming systems, there is not the phytosanitary problem (Coulon, Pointereau, and Meiffren 2005)
Advantages	• To diversify forage resources • To contribute to fodder autonomy and cattle welfare (by providing shade or a shelter from wind and rain) • To mitigate climate change • To enhance biodiversity and to mitigate water supply • To prevent from soil erosion (not relevant on permanent grassland) • To strengthen the financial capital of the farm
Innovation's region	• Mediterranean countries, Europe…
Reference and / or experts interviewed	• Anne Farruggia INRA • Xavier Coquil INRA Emile et al. (2017). "Les arbres, une resource fourragère au pâturage pour des bovins laitiers ? », Fourrages (2017) 230, 155-160. Coulon, Frédéric, Philippe Pointereau, and Isabelle Meiffren. 2005. *Le pré-verger: pour une agriculture durable*. Toulouse: Solagro. Project AgForward : http://agforward.eu/index.php/fr/agroforestry-in-europe.html
Author	• J. Balouzat, INRA