Biomassa-upstream stuurgroep

Memo: **Report[1] on BUS ticket no. A24**
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ADDED VALUE BY REFINING OF BIOMASS IN SOUTHERN AFRICA

Definition of the problem
In the mechanical refining of grass / weed a number of individual fractions can be separated, such as proteins, sugars and fibre. This process was invented by AVEBE and is still promoted by Johan Sanders (WUR). Protein components can be used for animal feed. The sugar-rich fraction can probably be converted to ethanol via fermentation. The fibre fraction could be used as raw material for products or as a solid fuel. Optionally, this fraction can also be converted to a liquid biofuel, e.g. via the Iogen route. AVEBE has developed the refining route to the pilot plant state and discontinued further development. This route might be an interesting option for small-scale application in developing countries.

Questions
1. What is the economic viability of the process? (should probably be addressed in a pre-study)
2. What does the future value chain look like?
3. What is the added value for the recovery of proteins / sugars and fibres?
4. What should a follow up project look like?
5. What are the ideas to finance a pre-study?
6. Which parties could be interested to take part in a consortium of a larger study?

1. Background
The shortage of fossil resources raises interest for renewable ones. This leads to rethinking of the classical production and processing methods towards closed loop processes that have minimal losses to the environment. Utilization for different purposes like feed and energy, show potential as both resources are saved and environmental benefits are gained. Fractionation of feedstuffs give better possibilities for precise dosing of animal feed-ratio's needed for optimal growth.
In Southern Africa, the animal production method is grazing from natural range. The available area per cattle unit varies from 2.7 ha in Zimbabwe to around 11 ha in most other countries. This indicates an underemployment of biomass present as pasture. The whole of southern Africa is also characterized by a long dry period resulting in feed shortages for cattle. Non-ruminant animals are low in number when compared to cattle due to high local prices for feedstock. This is the effect of low local production, indicated by the relatively low area of arable land.
Since several decades, leaves have been investigated as the source for proteins. Recently a pilot plant has been in operation in the Netherlands that fractionates grass and Lucerne leaves in three fractions: protein, fiber and juice that can be concentrated.
The possibility to extract protein from biomass for feeding non-ruminant animals, leaving sufficient protein in the cake to feed cattle during the dry period, with a potential to use residues for energy production, is worthwhile to investigate. The potential to produce more beef from both ruminants and non-ruminants will increase local economic development by the associated processing activities.

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Methodology

To investigate possibilities for more efficient utilization of biomass resources in southern Africa research will be done to:

1. Analyses of the different process cycles with quantification of mass flows for at least three different processes:
    a. Classical feeding of ruminant animals for beef and or milk production.
    b. Separating biomass in a watery, protein rich fraction and a press cake, containing still some protein. This will be our base case for further implementation.
    c. Full fractionalization of biomass through bio-refinery and splitting up in its main components.
2. Description of applicable technologies for above mentioned process cycles.
3. Inventory of biomass sources in different regions of Southern Africa, under natural and farming conditions.
4. Potential markets for products in Southern Africa.

Methods for biomass processing

Energy conservation is the main reasons to press grass for mechanical removal of moisture, in advance of a drying and palletizing process. This is done in grass drying factories in the Northern part of Europe (Andersen and Kiel 2000). In the Netherlands the Prograss consortium operated a pilot plant for bio-refining grass for protein, a sugar rich concentrate and fibers.

Grinding of grass, followed by pressing, produces leaf protein concentrate (LPC). From the juice, the protein is recovered by coagulation through heating the juice.

In Austria a process is developed in which a fermentation process is initiated, which is part of the ensiling process, called solid fermentation.

Availability of biomass

Tabel 1 shows that the area with permanent pasture and the low cattle density has a high potential to deliver biomass. This area is now extensively grown with grasses that do not meet the nutritional requirements of ruminants for maximum production. The main limitations are availability of green feed for at least half of the year in seasonally dry regions, and low nutritive value during most of the season of active growth. ('t Mannetje ,1981). So, both improved cattle production or biomass refining require nitrogen input either by means of fertilizers or leguminous crops

For a case for Western Province of Zambia it is possible to grow 18.5 ton DM per hectare during the rainy season from October to April, with adequate fertilization. (see Figure 1) The pasture is harvested in five cuttings with yields of 3.5 – 4.1 ton DM/ha/cutting. N-fertilizer efficiency is assumed to be 0.7. A protein content of 8% requires 340 kg N/ha/season, and a protein content of 15% requires 635 kg N/ha/season.

Use of a leguminous crop is studies for the case of Mucuna. This crop can produce eight ton dry matter per hectare with a protein content of 22 percent, while binding its own nitrogen requirement. A growing period of 3.5 months allows to produce one grass cutting after the Mucuna is harvested. This grass can utilize the nitrogen left in the soil by the preceding Mucuna crop.

Mucuna contains a substance, L-Dopa, which is of toxic character and must be removed. Because heating plays an important role in L-Dopa removal, proposed processing might solve this issue.

Tabel 1. Land utilization and the number of animals in southern African countries.

	Angola	*Zambia*	*Mozambique*	*Namibië*	*Botswana*	*South Africa*	*Lesotho*	*Swaziland*	*Zimbabwe*
Total Land	*124,670*	*74,339*	*78,490*	*82,329*	*56,673*	*121,447*	*3,035*	*1,720*	*38,685*
Agricultural Area	*57,300*	*35,289*	*48,435*	*38,820*	*25,980*	*99,640*	*2,334*	*1,390*	*20,550*
Arable	*3,000*	*5,260*	*4,200*	*816*	*370*	*14,753*	*330*	*178*	*3,220*
Permanent crops	*300*	*29*	*235*	*4*	*3*	*959*	*4*	*12*	*130*
Permanent Pasture	*54,000*	*30,000*	*44,000*	*38,000*	*25,600*	*83,928*	*2,000*	*1,200*	*17,200*
Cattle (heads x 1000)	*4,150*	*2,600*	*1,320*	*2,509*	*1,700*	*13,600*	*540*	*580*	*5,753*
goats(x 1000)	*2,050*	*1,270*	*392*	*1,780*	*2,250*	*6,850*	*650*	*422*	*2,970*
sheep(x 1000)	*340*	*150*	*125*	*2,370*	*400*	*29,100*	*850*	*27*	*610*
Cattle unit(x 1000)[3]	*4,628*	*2.884*	*1.423*	*3.339*	*2.230*	*20.790*	*840*	*670*	*6.469*
Ha/cattle unit	*11.7*	*10.4*	*31*	*11.4*	*11.5*	*4.0*	*2.3*	*1.8*	*2.7*
Chickens (x 1000)	*6,800*	*30,000*	*28,000*	*2,600*	*4,000*	*120,000*	*1,800*	*3,200*	*22,000*
Pigs(x 1000)	*780*	*340*	*180*	*22*	*8*	*1,620*	*65*	*30*	*605*

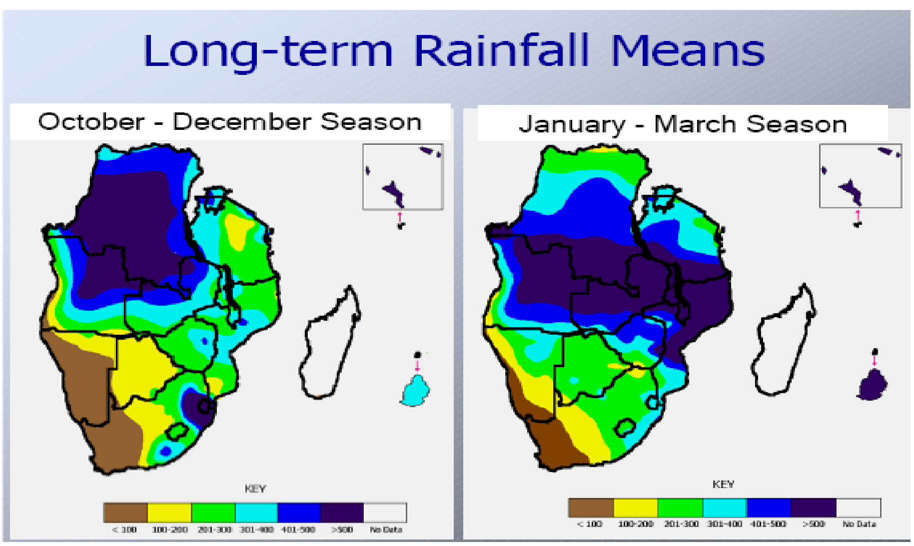

Figure 1. Rainfall distribution in southern Africa after SADC.

Crop residues are, seen the relative small acreages, not considered as a source for biomass.

Description of process cycles

[3] 5 sheeps or goats in one cattle unit.

1.1 Grazing

The simplest process is feeding cattle by grazing. By good pasture management it is possible to supply cattle with good quality feed. This involves fertilizing to obtain a sufficient high protein content (minimal 8% DM basis) in combination with regular grazing or cutting to enforce young biomass. Grazing results in losses of about 30% due to trampling etc.

Measures must be taken to overcome the dry season. During the rainy season, part of the fields can be harvested and ensilaged for later use. A practical method is to use round balers with a foliage wrapper. The bales can be left in the field and opened when required during the dry season. As temperatures allow cattle to stay outdoors, this process does not involve transport and use of storage space.

Quantities

Our calculations are based on an average DM uptake of 7.5 kg/day/cattle unit with at least 8 % protein content (DM basis). The rainy season in Western Province of Zambia covers 155 days, which makes that with a harvesting efficiency of 70% by grazing, 90 hectare grass is required for grazing and 85 hectare for silage making to feed 1000 cattle units.

1.2 Biomass separation

Separation involves pressing fresh or ensiled biomass, which results in a protein rich effluent and a cake. Protein can be separated from the effluent after coagulation. The cake can be fed to cattle during the dry season, but should contain a protein level of at least 8% for adequate uptake.

Two sources of biomass are evaluated. i.e. grass and Mucuna with a protein content of respectively 15 and 22 percent on dry matter basis. The composition of both products, before and after pressing to a dry matter content of 50% is given in Tabel 2. It is assumed that 80% of the protein is soluble in water and that all soluble components are proportionally divided with the water over juice and cake.

Tabel 2. Composition of biomass sources grass and Mucuna and its products.

	Grass	Grass juice	Grass cake	Mucuna	Mucuna juice	Mucuna cake
Water	800	665	135	800	659	141
Protein	30	20	10	44	29	15
Sugar	30	25	5	10	8	2
Fat	20	17	3	10	8	2
Fiber	120	4	116	136	14	122
Total	**1000**	**680**	**320**	**1000**	**718**	**282**

The protein in the juice must be either chemically or thermal coagulated for successful separation. In respect of energy requirements, a chemical method is preferred. Separation is done by decanters, resulting in a paste of protein, some fiber, and fats with a total DM content of 45%. This paste can be fed to pigs as protein source in their feed, but direct conservation of this protein substrate is required, which can be done by lowering the pH to 4 or by drying. Energy wise, the former method is preferred.

When processing ensiled biomass during the dry season, a significant part of the produced cake can be directly fed to cattle. Overproduction of cake during the dry season and all production during the wet season should be ensiled for later use as feed.

Quantities

Based on the compositions given in table 2, a press capacity of 25 ton/hour wet biomass, plant operation of 3330 hours a year and the yields mentioned in paragraph 3, an area of around 410 hectares should be

grown with grass and harvested 5 times from December till April. This results in 83,270 ton wet biomass (20% DM) , ending up in 13,350 ton DM in the cake which contains 900 ton protein and 1598 ton protein in the paste. A protein poor effluent of 46,600 ton, containing 2000 ton sugar remains. (Sugar concentration largely depends on grass varieties)
Based on an uptake of 0.4 kg protein uptake a day, 12,876 pigs can be fed from the protein, while 8476 cattle units can be fed from the cake during the dry season. (This amount of cattle requires an additional 760 hectare for feeding during the wet season)

When a mixture of grass and Mucuna is used, on an area of 1,853 ha, 3 cuttings of grass and one cutting of 1368 ha Mucuna are realized. (part of the grass is grown after Mucuna). This biomass source produces 2135 ton protein as paste and 1130 ton in the cake. It is possible to feed 17,205 pigs and 7,800 cattle units.

1.3 Full fractionalization

For full fractionalization of biomass it is required that the biomass is crushed. Seen the large variety of processing steps and resulting products, this line is not worked out in detail.
Under the assumption that all protein will be separated and can be used as pig feed, it is possible to feed from the areas Mucuna and grass mentioned in paragraph 1.2 a number of 27,120 pigs.

1.4 Nutrient balance

To compensate the 384 ton nitrogen removed from the fields as 2400 ton protein in the case with 882(=4409/5) ha grass, an amount of 573 tons of nitrogen must be supplied to the fields, as 70 percent efficiency of supplied nitrogen is used.
The pigs and cattle excrete 53 percent of the consumed protein, which results in 211 ton nitrogen in manure. When this manure is applied on the fields, an amount of 362 tons must be supplied as fertilizer.
In the case of a grass – Mucuna mixture, there is no need for N input in the leguminous Mucuna crop, and also not on 670 ha of grass grown after Mucuna. For the remaining grass an amount of 102 tons of Nitrogen are required. The excreted amount of 276 tons Nitrogen in manure is more then sufficient to compensate nitrogen removal. A good balance between the amount of grass and Mucuna should be looked after to prevent potential pollution problems.

1.5 Energy

A strong point in biorefining is the utilization for different purposes. Apart from a protein source, remaining sugars can be used as energy source.
Energy input is required by:

- Eventual fertilizer input, (68.41 MJ/kg) = 24,764GJ for grass, 0 for Mucuna grass mixture
- Fuel to drive agricultural machinery (31.3 l/ha for grass ad 35,700 kJ) = 4,928GJ and (38,6 l/ha mucuna) = 3,510GJ for the mucuna grass mixture
- Energy to drive the processing plant. 112,700 l diesel = 4,023,GJ

1.6 Technology to implement the processes

Harvesting involves:

- Cutting of the grass, for which preferably a mower conditioner is used, as this process breaks the leaves and stems so that separation is facilitated.
- Windrowing of grass for efficient collection
- Collection by means of a round baler. This is preferred above other systems as matching of transport on collecting is not critical. For silage making, the bales will be wrapped in a foil. An eventual alternative is the use of self loading wagons and silage in soil covered, horizontal silo's.

Tractors and agricultural machinery are required for harvesting and transport. Determination of optimal numbers requires optimization, taking seasonal constraints into account. In this study optimal efficiency for all types of machinery is assumed to estimate machinery cost for harvesting. This is set at $ 48.- /ha, from which $ 20.- ha is for fuel. (1 liter diesel = 1 $)

An open screw press does **pressing**. This requires relatively little power when compared to closed ones, but poorer extraction leaves the required amount protein in the cake.
The open screw press needs an investment of $ 60,000,- and results in hourly operating cost of $ 16,- from which half is fuel cost. (1$/liter)

Separation of the protein is by two decanters of 7.5 m3 each. This requires an investment of $ 200,000.- and $ 48,- /hr operating cost, from which also half is fuel cost. (1$/liter).

Financial aspects
In a grass-based system, the total expected cost is 354, 395 and 208 thousand dollars respectively for N fertilizer, machinery and processing. This results in a price of 383 $/ton protein.
In the grass Mucuna mixture these cost are 302 and 208 thousand dollar for machinery and equipment. There is no cost for N fertilizer. This results in a price of 150 $/ton protein.
This global calculation does not yet include labor cost, cost of housing and some farm operations like manure hauling, P and K fertilizers and the use of chemicals and storage space. This would require an extensive optimization routine to determine realistic quantities, which are out of the scope of this study. However optimization will also lead to lower cost as calculated yet.
Compared to a price of 450 $/ton protein from soybean meal, there is sufficient room in the price of the Mucuna grass mixture.
Products and potential markets
An important market is protein to supply both ruminants and non-ruminants with adequate levels. This market is an indirect one, as the main pull comes from beef and pig meat and chicken meat consumption. From Tabel 1 it can be concluded that for Zambia 20 processing units are required to cover feed requirement for the present number of pigs. This reflects the relative low pig meat production compared to beef. Cheaper protein sources have the potential to change this market, but it requires a market analyses in respect of acceptability.

Conclusions
There is a large land area in Southern Africa that can be used for biomass production. This can be realized by improving the present natural grass area to managed grasslands, but also by growing leguminous crops. Leguminous crops play a key role in reducing cost and energy as the input of fertilizers are the largest cost factor and energy input in a sole grass biomass production system.

Heating and drying are an important energy consumer, so chemical coagulation and conservation means are preferred methodologies.

Based on cost of the main components in the system, there is a good basis for a system based on a Mucuna and grass mixture as biomass source. With a more complete cost calculation to be performed, there are good opportunities to keep leaf protein competitive with sources from soybean meal.

Energy production from the sugar rich effluent requires input of additional sugars for economic operation. This can be achieved by adding cassava starch as a source. This can be a valuable combination with cassava as energy source in pig feed, as the energy content in protein paste is low.
Market preference for pig meat and poultry are an important factor in the scale of operation that can be reached in the different African countries.

Literature

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