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The total chain: What does it really cost?

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Proceeding costs of silage harvest: feed placement and removal of several alternatives

The discussion about the advantages of harvesting methods for ensiling is still on going. It's because the decision of using whether a chopper, a self-loading forage wagon or bales is shaped by many influences. Regional climatic conditions for harvesting and the structure of the agricultural area decide about the necessary power to harvest and to store the feed within the available time with minimal losses. The livestock owner has to consider work economics as well as animals requirements for quality and structure of fodder. Besides several alternatives for storing in bunker silos or bales, ensiling in bags is taken increasingly into consideration.

In the following a comparison of various methods will be presented, which will display the entire process from the cut to the feed trough. Reference point is the total costs, which are produced for each ton of dry matter in the various section of the process. The aim was to answer the questions what costs for the entire chain can be assumed and how the costs for various procedures of transport and storage differ. Whereas for the harvesting machinery private contractor wages can be employed, the investments for building measures of a bunker silo (silo panel, bunker silo each with two sloping walls) for a given tonnage have to be calculated. The tariffs for contractors can differ regionally, however they tend to be comparable. Using such a calculation, two different sizes of dairy cattle farms are considered: 150 livestock units (LS) (45 ha grass and 20 ha corn) and 250 livestock units (75 ha grass and 3 ha corn) (table 1). In total the farm with 150 LS plans with approximately 2,000 t of fresh mass and the one with 250 LS operating farm with approximately 3,300 t of fresh mass fodder.

Process of feed harvest

The costs for feed harvest will be equalized for all procedures. They amount approximately 6.50 €/t fresh matter (table 2). Using the forage harvester as service will cost on average 10.00 €/t incl. transport, whereas using the self-loading forage wagon will cost 8.50 €/t. The method with round bales incl. wrapping will cost as service on average 20.00 €, while costs for cubic bales (18.00 €) are slightly lower.

Conservation in silage bags

For ensiling, alternatives like silage bags, silo panel and bunker silo are available. For storing it in silage bags the material is processed with a silo press. The tariff for service is about 6.00 €/t without diesel (approx. 0.5 l/t) on average. Referring to the tonnages for a farm with 150 LS eight bags with a diameter of 2.70 m have to be calculated. The farm with 250 LS could choose a bigger bag-diameter of about 3 m. With a capacity of filling of approximately 4.5 t per running meter it would also be possible to achieve a high feed rate (table 3).

A larger bag-diameter reduces the space for storing the bags. The area should be accessible to allow a proper storage and a subsequent removal. A previous surfacing of the storage area depends on internal conditions and is not necessary in all cases. While planning the required space it should be considered that during the course of the year and the growing season, storage space will be released for subsequent maturating crops (corn silages). This may include savings of about 10% of the area, in this example.

On average the required space floor is about 1 m²/t.

Proceeding costs using the bunker silo

To evaluate the cost of storing in bunker silos or rather on panel silos, investment costs were cal-

Table 1: Data for storing grass and corn within a planed example

LS	150		250	
substrate	**grass**	**corn**	**grass**	**corn**
area (ha)	45	20	75	33
yield (t DM/ha)	10	12	10	12
tonnage (t DM/a)	**1.286**	**686**	**2.143**	**1.131**
amount (t DM/a)	**1.972**		**3.274**	

Table 2: Costs (€/t) for feed harvest of various harvesting methods (average values acc. CMU)

operation	forage harvester	self-loading forage wagon	round bales (RB)	cubic bales (CB)
cutting	3,50	3,50	3,50	3,50
turning	1,50	1,50	1,50	1,50
swating	1,50	1,50	1,50	1,50
recovery/	6,00	8,50		
pressing incl. wrapping for			20,00	18,00
RB/CB transport	4,00	-	8,00	8,00
amount (t DM/a)	**16,50**	**15,00**	**34,50[1)]**	**32,50[1)]**

[1)] without costs for storing

sources: private contractor and machinery syndicate – cost-rates 2008, charge for diesel is not considered

Table 3: Data for storing grass and maize in silage bags

LS	150			250		
substrate	grass	corn	amount	grass	corn	amount
bag Ø (m)	2,7			3,0		
bag length (m)	75			75		
storing amount (t/bag)	244	257		301	317	
filling capacity (t/running m)	3,6	3,8		4,4	4,7	
number of bags (n)	5,3	2,7	8	7,1	3,6	10,7
floor space required (m²)	2.200	1.500	3.700	3.000	1.800	4.800
real floor space (m²/t) [1)]			1,2			1,0

[1)] 5% existing floor spaces, 10% for grass and corn

culated over a period of 20 years as it is shown in table 4. In an edition of Neue Landwirtschaft these costs can be referred to in detail (Thaysen, NL 11/2007). The height of the silo is based as well on this assumption.

For compacting it has been assumed that it will take 2.5 min/t to ensure a maximum compression. The corporate tariff for compression is about 2.00 €/t. For covering the bunker with silo film and underlaying film with costs of 0.40 €/m² and an expenditure of time of 1.4 MPmin/m² were calculated.

The storage costs for a 150 LS farm will be between 6.90 and 7.30 €/t, for a 250 LS farm about 5.50 to 6.00 €/t. However, these costs are realized within a recovery period of 20 years. A planning horizon of 10 years instead of 20 years would increase the proceeding costs using a bunker silo of up to 19 €/t.

Feed removal

The costs for labour, machinery and diesel during extracting and feeding are shown in Table 5. Thereby a uniform dry matter (DM)-content of 35%, daily feeding twice a day 365 days and a standard density for both forms of ensiling was assumed.

Furthermore, a front-end loader with cutting clamp or bale grippers for lower performances and wheel loader with the related devices for higher performances was implied (table 5).

As shown by this example, for a 150 LS farm the costs for the removal out of the silo panel/bunker silo are about 5 €/t (with 250 LS the cost are < 4 €/t), for bale ensiling over 3 € and for ensiling in bags around 4 €/t.

Total costs

As illustrated by the chart all calculated and charged partial costs (transport, feed placement and removal) for each procedure and storage possibilities are subsumed comparatively as relative values to the procedure with a chopper in a bunker silo (=100). Using the bale procedure corn tonnages were considered as harvested with a chopper. With increasing farm size the costs for the procedures will decrease on average 4 €/t, except for ensiling in bags. While the

Table 4: Proceeding costs of storing grass and corn on a silo panel and in a bunker silo

type of silo	silo panel		bunker silo	
LS	**150**	**250**	**150**	**250**
tonnage (t/a)	**1.972**	**3.274**	**1.972**	**3.274**
constructions costs (€/m³) [1]	40	29	54	42
volume (m³)	3.034	5.037	2.465	4.093
investment costs (€)	121.354	146.071	133.110	171.885
recovery period (a)	***20***	***20***	***20***	***20***
depreciation	3,08	2,25	3,38	2,65
interest (6% ½ inv.)	1,85	1,35	2,03	1,58
compaction (2,5 min/t, 45 €/h)	1,88	1,88	1,88	1,88
film (0,40 €/m²)	0,30	0,25	0,29	0,22
silo covering, labour (€/t)	0,22	0,17	0,21	0,16
coating, maintenance (€/t)	0,18	0,11	0,18	0,12
amount (€/t)	7,50	6,00	7,95	6,60
risk assessment:				
recovery period (a)	***10***	***10***	***10***	***10***
amount (€/t)	**18,10**	**14,15**	**19,30**	**15,80**

[1] new agriculture 11/2007

Table 5: Costs of silage removal und feeding for several procedures and removal quantities/year[1]

removial quantity t / a	bunker silo / silo panel	bale silage	ensiling in bags
700	6,75	2,75	6,90
1.000	6,00	3,15	5,70
2.000	4,40	3,15	4,10
3.000	3,90	3,00	3,90

[1] sources: KTBL, 2008 personal note

bale procedure has the highest costs, storing in bags is relatively low priced due to a low quota of investment costs. The difference between using a self-loading forage wagon or a chopper are relatively small, however both processes are lower-priced using a silo panel than a bunker silo.

With the increases of costs, also dry matter (DM) and energy losses will be increasingly considered in economic terms. Losses of dry mass and energy are already created on the field (respiration and disintegration losses) and later during the fermentation due to a very slow pH-value reduction. In case of a too low level of DM-content (<30%) losses of silage liquor will occur.

Comparisons with the bunker silo show that sloping walls have to be preferred, because it could be confirmed the highest quality with the lowest losses using this type of procedure. The losses in the closed bag can be measured by using the so-called buried bag method. These bags are weighed during the feed placement and removal.

The quality of silages in bags has been investigated many times and is rated highly positive (table 6). Reasons for lowest losses during the fermentation result from a fast and safe closing of the bag and the absence of oxygen during the conservation process. In addition, quality is assured by a comparatively high feed rate. The consideration of these parameters will also reduce the costs in comparison with a bunker silo.

Reported losses in the bunker silo show a large range and they are depending on the substrate about 10% with good management. Here it has to be distinguished between inevitable and avoidable losses which result of mistakes in management. For instance, with costs for a corn silage of about 30 €/t losses of 1% would cause costs of 0.30 €/t. The lower losses in the bag contribute to the preference of this procedure.

Discussion and conclusion

Regarding to the machine costs, economies of scale by mechanization and utilization differences were not taken into account, they were calculated according to single private contractor-rates. Background is the increasing demand of service completion even at growing farms. Due to different conditions the result may vary.

Referring to the calculation, a uniform recovery period of 8 years for all buildings related to the particular procedures was implied. Although it is a relatively short period, it shows also that bunker silos often need a renovation after this time, which will produce additional costs.

Further evaluation criteria for selecting the procedures for transport, stock placement and removal are the impact on losses, fodder quality, availability of techniques and flexibility in investment decisions or business development.

For these criteria the methods are suited differently. However it could be shown that the process of conservation in bags is not the most expensive one, as it is often claimed. The reasons: the storage demand can be adjusted without constructional measurements.

Table 6: Losses during the fermentation in the bag (According to Steinhöfel et al. 1998)

silage comodity	dry matter content (%)	dry matter loss (%)
pre-wilted silage	31	4
silo corn	33	5
wet grain	25	1
press pulp	22	2

Besides, this method is suitable for all types of fodder, so that a high efficiency can be achieved. Amortization of this method can be realized in a very short time. Besides the high flexibility it can also meet the requirements for high performance.

In conclusion, by planning to build a silo plant it may be worthwhile to consider the method of ensiling in bags as an alternative.

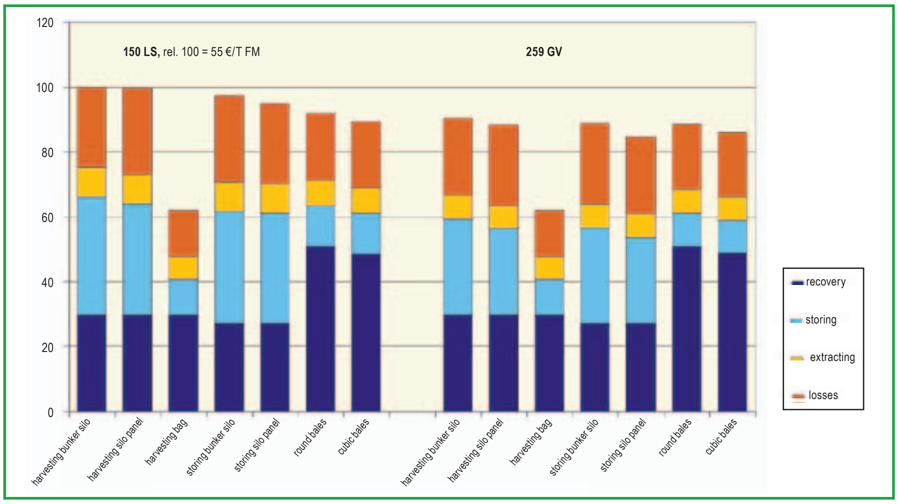

Figure 1: Recovery, stock placement and removal as well as losses of various procedures and storage possibilities comparatively as relative values to the procedure with a forage harvester in a bunker silo (n=100)

Storage of food grain in silage bags – a safe alternative to storage in warehouses

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The importance of short-term storage capacity for grain increases with the price fluctuations in the cereals market. In order to participate in price developments, conventional storage of grain is currently set, depending on the capacity and size of investment, with 100 to 250 €/t. Where as the costs for a 6-month storage at the agricultural trade are about 20 €/t. Supreme rule to avoid spoilage in cereal stocks is the protection against moisture and contaminations by birds, rodents, dogs and cats. In Germany, drying or cooling is used to conserve food grain but anaerobic storage largely hasn't been taken into consideration so far. The silage bag technology works on the principle of conservation through absence of oxygen and is characterized by low losses and high quality. Roughage and industrial by-products (press pulp) are ensilaged in silage bags according to this principle; even by conserving wet grain at 25% moisture content, lactic acid fermentation will take place under anaerobic conditions. The question of a practical experiment was, how quality parameters will be influenced during storage of food grain with storable dry matter content, in bags for 6 months.

A new system for ensiling in bags, the FARM BAGGER, enables along with rotor machines and rolling mills the storage of grain and other free flowing bulk goods in silage bags at comparatively lower capital investments.

Using this ensiling system in bags the material will be carried with an auger into a polyethylene bag with a diameter of 2.70 m (bag lengths up to 90 m). While filling them with the help of a grain wagon, performances of up to 300 tons/h

The harvested grain will be stored in a silage bag by using the Farm Bagger

can be achieved. Hence, also harvested fresh grain can be processed while combining.

Practical experiment

Therefore, Tarso wheat with a moisture content of 10, 9% was harvested by Budissa Agrarprodukte Preititz/Kleinbautzen GmbH with a yield of 87 dt/ha. With the crude protein content amounts 14.8 % TM, the starch content 67.2 % TM, a falling number of 407, a hectolitre-weight of 79.6 and a Zeleny sedimentation volume of 43.

75 tonnes of cereals were stored in 2 silage bags using the BUDISSA FARM BAGGER FT 900. The bags had a diameter of 9 ft (= Ø 2.70 m), the thickness of the bags was 215 µm. In bag 1 four valves were installed on each long side for the later regular sampling, bag 2 had only four valves on one side. Bag 2 should only be sampled after 6 months to exclude a possible change in quality by sampling. To determine the temperature profile in the bags eight data logger in bag 1 and four in bag 2 were inserted through the valves. The bags were covered with sandbags and a protective net against birds. A control batch remained in the warehouse where grain also had been stored after harvesting. Four data logger were inserted in this pile of wheat.

Sampling / analysis

While storing, after two and four weeks and after three and six months the control batch and wheat from bag 1 was sampled. In the following, samples were taken from all eight valves from two different heights: on one hand just below the surface and on the other hand at a depth of 1.20 m. From the control batch also eight samples were taken, four below the surface, four at a depth of 0.80 m.

Samples from bag 2 were included in the studies after 6 months of storage. In all forms of storing the temperature profile was determined during the storage. The following parameters of the samples were investigated: dry matter content, pH-value, starch and crude protein content as well as the quota of bacteria, yeasts and moulds. After six months an additional assessment of the germination characteristics was made by determining the germination potency and capacity.

Results given from the temperature profile

Nearly similar temperature profiles could be identified in both silage bags: a gradual descent of temperature and a reflection towards outside temperatures. The profiles suggest very low microbiological activities.

Results in relation of substances and microorganisms

In comparing the samples of all storage methods, the average chemical and microbial results are very similar.

The substances crude protein and starch detected before storing did not change their value,

also the pH-value were unchanged and there was no detected increase of the investigated groups of microorganisms. The contents of the investigated groups of germination are in range of reference values for ground grain products of the DGHM (2007).

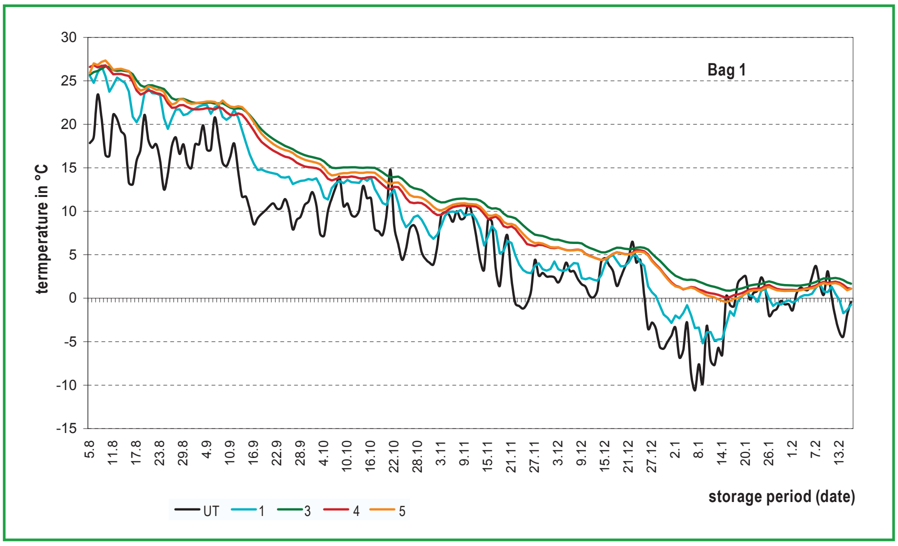

Figure 1: Temperature profile in the silage bag

Costs for grain storing in silage bags

The proceeding costs for using the farm bagger are made up of costs for machines, labour and bags. The investment costs depending on the equipment is at an average of 30,000 €. With an increasing efficiency machine costs will decrease, here comparing 5000 t and 30,000 t. A silage bag with a diameter of 2.70 m and a length of 75 m can store about 250 t. The figures show that a machine can be amortized with a low tonnage in a short period of time with costs of about 3 to 4 €/t.

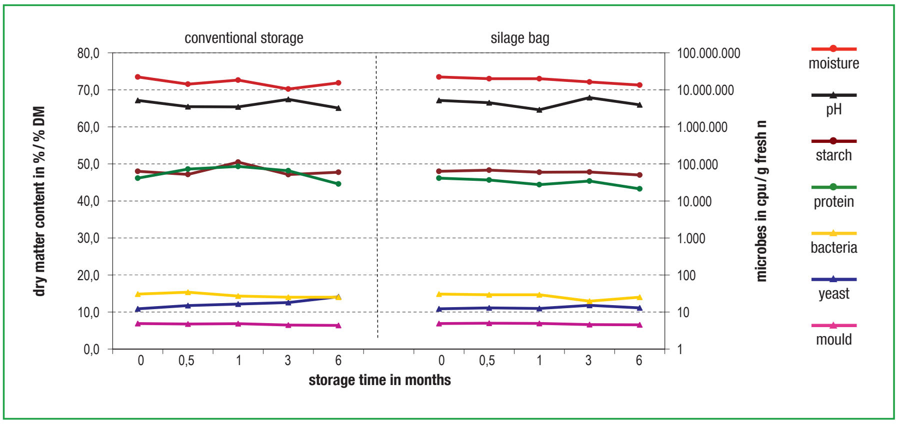

Figure 2: Chemical and microbiological parameters of wheat during the 6-months storing depending on the form of storage

Conclusion

To sum up, the practical experiment showed that wheat can be stored in silage bags for up to six months without losses in quality. The technology of extraction allows an effective take out and completes the process. Both in terms of labour economics as well as in quality and cost terms storing in silage bags is very well competitive with the conventional grain storage.

The protection of the bags and a suitable storage area are undismisable for the successful storage.

Where to put the grain maize?

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Dr. Udo Weber, Malschwitz, Germany

The question of increasing drying costs, particularly the drying of corn is a growing concern. Grain maize may be at most 4 to 5% more expensive in feeding than feeding barley. However, it has at the time of harvesting and water content of 60 to 75%. Also in an untainted and fresh state the grains possesses a high amount of micro-organisms. When the grain lives it can have up to 6 million bacteria, 40 thousand fungal spores and 50 thousand yeasts per corn grain without a problem. It is not until the cell walls give up their protection system, the grain possesses a humidity of more than 14% and the corn is surrounded by temperatures of more than 15°C, that the micro-organisms dissipate explosively the available energy into carbon dioxide, water and thermal energy. During tests, the temperature of freshly harvested corn with a humidity of 38% and a temperature at harvest of 20°C increased within 24 hours to more than 33°C. After 4 days in a pile, 51°C were provable. Besides an extreme loss of energy, the humidity increased by approximately 8%. After just a few days the corn had a very strong odour.

Drying is the most popular, most secure but most expensive form of conserving moist corn. The costs depend most of all on the water content. Further cost factors are the degree of spoilage, the transport distance and the necessity of a storage building. With reference to external drying, costs for backhaul to the farm are to be added. With a water content of 35%, costs for drying are about 30€ per ton of original substance (table 1). Referring to the chart, only absolute costs of drying are mentioned. Further costs, need to be taken into account as well.

Table 1: Overview of various conservation procedures

criteria	drying 1) (contract) (30 €/t)	harvestore 2) (own) (21 €/t)	acid preservation 5) (own, without crimp) (15 €/t)	ROmiLL 3) (contract, with bag) (13 €/t)	ROmiLL 3) (own, with bag) (10 €/t)
investment	-	175.000	5.000	-	70.000
capacity/a	unlimited	1.000	unlimited	unlimited	15.000
service life (risk)	-	15	5	-	3
€/year	29.700 4)	21.000	15.000	13.000	10.000
relativ	297	210	150	130	100
add.	22.000	12.000	7.000	3.000	0
expenditure	wo. processing, wo. add. transports, wo. storage	wo. expired stock, wo. less use	wo. processing, wo. building costs, wo. labour force	wo. costs/m², wo. additives, wo. add. use	wo. costs/m², wo. additives, wo. add. use

Sources:

wo. = without

1) Table acc. Budissa Getreidehandels- und Dienstleistungs GmbH Baschütz 2009

2) data acc. Budissa Agrar GmbH Kubschütz 2006 (Investition 2004)

3) data acc. BAG Budissa Agroservice GmbH und Lohnunternehmer 2006

4) calculation after 1% deduction of admissible admixture content

5) practice handbook Futterkonservierung 2006, page 119 (14 l/t propionic acid, 35% moisture, 6 months storage time) without subsidies!! 6% interest calculation

Alternatives for drying

Currently only the chemical conservation of corn or ensiling can be recommended as an alternative. The question of farmers remains: Is this form of conservation of corn really efficient?

The construction of tower silos for moist corn is chosen for pig fattening plants, because it allows a fully automatic daily feeding. However, according to cost calculations, for each ton of moist corn charges of at least 20€ are to be expected (table 1). But this only applies the silo is completely filled up every year. To have a storage capacity of 1,000 t, about 175,000 € have to be invested. The amortization is due to the long economic lifetime (at least 15 years) burdened with high interest costs and a high risk on the capital invested. The investor's demands for a short return of investment increase with an increasing risk.

A traditional popular method is the so-called acid conservation of moist whole grains, mostly under influence of air in a shed. For this method there are firm guidelines for the use of acid, which depends on the dry mass content and the planned period of storing. With a humidity of 35% and a 6 months storing period approximately 15 l per ton propionic acid are necessary, in order to guarantee an untainted storing by exposure to air. Every increase of the storing period leads to an increase of acid required.

The grain mostly is milled after storing, because for coarsely grinded corn the necessity for acid would rise, due to the bigger surface (by approximately 30%). The costs for the building and the high necessary safety precautions for the protection of the staff have to be taken into account.

Table 2: Procedural costs of the combined maize grinding and storage in silage bags (example ROmiLL CP 2)

	basic data	
investment	70.000 €	
costs for bag	275 €/bag	
bag content	120 t	
performance	30 - 40 t/h	
annual tonnage	5.000 t/year	
service life	5 years	
declining balance	10.000 €	
	costs	
	€/year	**€/t**
capital costs	12.000	2,4
return on investment (6% fo half the captial/year)	2.100	0,42
repairs, insuance (5% of purchase price/year	3.500	0,7
traktor (0,033 operating hours/t and 50 €/ operating hour incl. diesel)	8.333	1,67
wage (0,033 h/t und 15 €/h)	2.500	0,5
machine costs (total)	28.433	5,69
costs for bag	11.458	2,29
total costs 39.891	39.891	7,98

With a new system which could be a worthwhile alternative, the moist corn is milled and placed in a silage bag in one operation and an additive is applied at the same time. This has proved successful after initial examination. In "Köllitscher" tests, grain corn was ensilaged with approximately 33% humidity in silage bags.

The deterioration of nutritive value of grain prior to the ensiling process was surprisingly low. Only the sugar content reacted. It decreased by 50 to 65%, what had to be expected, due to the lactic acid fermentation. The loss of the dry mass was 8%, without adding additives. When adding additives the loss of the dry matter content was 6.8%.

The costs of the contracted labour for the production of the corn for feeding are about 13€ per ton. The costs of very high annual tonnages are approximately 10€ per ton.

A calculation of costs at a medium annual tonnage, as agricultural contractors can achieve, is shown by table 2. As mentioned for the other methods, several eventual positions are not taken into account in the survey of costs, but indicated on table 1. This could be the possible use of additive as well as the necessity of area for the bags. According to a recent research project (university Bonn 2005 to 2007), the application of ensilage additive can be minimized (2 to 3l/ton), because of the absolute exclusion of air. For this reason the yeasts and moulds of the crop can be contained and therefore when opening the bag the aerobic stability can be increased significantly.

Brand name Vodka made of moist corn in BUDISSA BAG bags

Dr. Udo Weber, BAG Budissa Agroservice GmbH, Malschwitz, Germany

Vodka Sobieski - There is scarcely anybody in Poland who does not know this brand. Under this name a lot of different products of vodka are produced and sold in the whole of Europe.

In a little village between Gniezno and Poznan (near the place of foundation of Poland), the two medieval polish cities, the production plant of this "national drink" is located. The production of this drink is subject to highest quality standards.

For 5 to 6 years moist corn has been stored, after initial tests, as whole grain in BUDISSA BAG bags without any additives, up to now with an annual rate of 5,000 to 6,000t a RT 6000 is used.

The main reason for this decision was an extreme reduction in costs, because a construction of a silo is not necessary. But most of all the expensive drying of grain corn, produced on own land, could be eliminated. That brings savings of at least 20 to 25€ per ton. Storage in bags costs only approximately 5€ per ton.

All tests and many years of experience proved: With moist corn there are neither lower ethanol yields nor a modified quality of alcohol compared to dried corn.

Since 2008 1,000 tons of dry rye, the main raw material for the alcohol production have been stored initially with the same machine in BUDISSA BAG bags. The expansion of the vodka production would have required the constructions of new silos. However this could be avoided by storing the rye in BUDISSA BAG bags without any problems, also for longer periods, under absolute exclusion of air in the bag.

With the help of the BUDISSA BAG technology further reductions of costs can contribute to a profitable production of vodka, in the future.

Secure storage of energy feedstock: Biomass in silage bags

Dr. Andrea Wagner and Dr. Udo Weber, Malschwitz, Germany

In recent years an increasing trend to conserve fodder in silage bags is noticeable. Also for the production of biogas the importance of this technology is growing. Reasons for this are mainly the high flexibility of the storage system, which allows the use of different forages as well as the possibility of adapting to changing basic conditions such as prices, climate and harvest situation.

After several academic examinations ensiling in silo bags results in high quality and low losses due to the early exclusion of air. In times of rising costs for the forage, the low losses in the bag contribute to a reduction of costs.

The project planning for the production of biogas is based on the evaluation of five major parameters: first of all the process technology, the time requirement, the area and plastic bags needed as well as the process costs. These criteria are explained on the example of different plant sizes (table 1).

Table 1: Amounts of substrat für different plant sizes

BHKW	kWel	75	150	250	350	500	1.000
maize silage	t FM/a	1.330	2.600	4.300	6.400	9.000	17.100
cattle manure	t FM/a	1.000	1.500	2.000	2.000	2.500	4.000
livestock	GV	50	75	100	100	125	200

Table 2: Silage quantities for different plant sizes (KWel)

bag diameter (m)		filling quantity [1]		number of bags [2] with plant perfomance electrical kilowatt output kW_{el}					
Ø	length	(t/running m)	(t/bag)	75	150	250	350	500	1.000
2,4	75	3	203	**7**	13	21	32	44	84
2,7	75	3,8	257	5	**10**	17	25	35	67
3,0	75	4,7	317	4	**8**	**14**	**20**	28	54
3,3	75	5,6	384	3	7	**11**	**17**	**23**	45
3,6	75	6,7	457	3	6	9	14	**20**	**37**

[1] storage density 0,6 t/m³

[2] anchor machine allows 150 m-bags and halves the number of bags

Industrial engineering

The bagging machine consists of 3 functional components; the feed table, the rotor and the tunnel with bag attachment. The pressure for compaction is indirectly created through the continuous input of the harvest material through the rotor into the bag, against the machine's breaking system. Similar to a bunker silo, the storage has to be adapted to the speed of the whole harvest chain. The technical performance of the currently used bagging machines in Ger-

Table 3: Feed rate calkulation for different plant sizes (kWel) (recommentation: 0,3 m/day in winter or 0,6 m/day in summer)

bag (m)		filling quantity [1]		feed rate a plant performance of installed electrical kilowatt output kW_{el}					
Ø	length	(t/running m)	(t/bag)	75	150	250	350	500	1.000
daily feed rate (t/d)				3,6	7,1	11,8	17,5	24,7	46,8
2,4	75	3	203	**1,2**	2,4	3,9	5,9	8,3	15,7
2,7	75	3,8	257	1	**1,9**	3,1	4,6	6,5	12,4
3	75	4,7	317	0,8	**1,5**	**2,5**	**3,8**	5,3	10
3,3	75	5,6	384	0,6	1,3	**2,1**	**3,1**	**4,4**	8,3
3,6	75	6,7	457	0,5	1,1	1,8	2,6	**3,7**	**7**

[1] storage density 0,6 t/m³

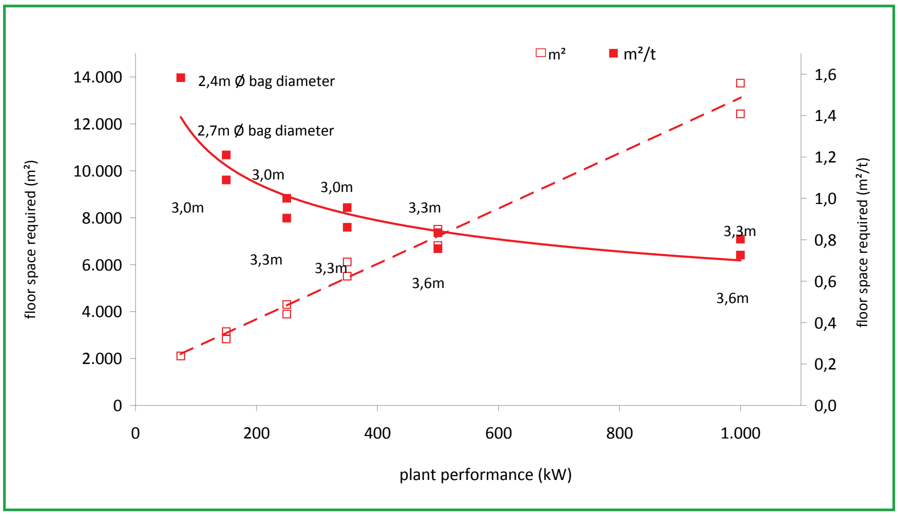

Figure 2: Floor space required depending on bag diameter considering various plant sizes (bag length 75 m)

many is up to 150t/h. With this performance a harvest of about 3ha/h is possible with this method and fits for all silage chains. One person is required to operate the machine and rear tipper trailer or self-loading forage wagons are required for filling the machine. After the filling, the bags are closed immediately and covered with protection nets. Comparing to the bunker silo neither time for covering with plastic film nor weighing down with sandbags is necessary. These work economic advantages have a great effect during the time pressure at harvest, and also at the point of extraction because the sheets and sandbags are easy to handle.

Necessity of area and plastic film

The costs for plastic film and area for the bags among other things depend on the number of bags needed for the amount of the forage. The number of bags depends on the amount which is stored and on the bag's diameter and length (table 2).

New bagging machines draw during the filling an anchor through the bag. When the bag is completely filled the anchor is pulled out at the end of the bag. These anchor machines can fill bags with up to 150 m length. With a diameter of 3.60 m this means about 1,000 tons per bag.

With the diameter, the fill quantity of each running meter and the stored amount per bag increase. Particularly with regards to smaller biogas plants, the comparatively small ingate surface of the bag abets a high feed rate, which is absolute necessary for the quality assurance (table 3).

The decision for a diameter depends on the feed rate and particularly on the availability and the efficiency of the machine. For example, the technology for 3.3/3.6m of bag's diameter needs at least 20,000 tons/a.

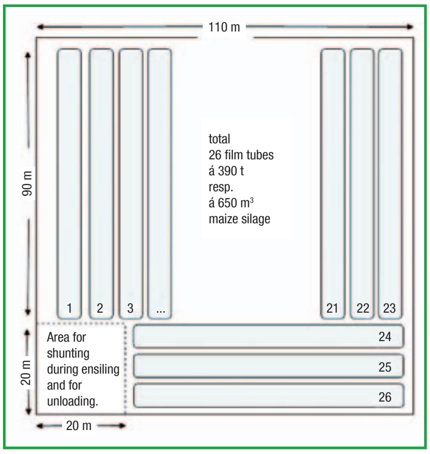

Figure 1: Outline of the area for the bags (10,000 tons maize silage; 10' bag diameter, 90 m length)

The floor space required consists of the space for the bags, the distance between the bags and the area to shunt when filling the machine and when extracting. An example for the order of the bags shows figure 1. According to the local conditions, an additional area of approximately 500 m² is needed, in order to make the work with the bags possible.

The areas should be accessible, in order to make an appropriate placing of the bags as well as the later extraction possible. A surface area of deposit depends on the local conditions and is not always needed. Several different alternatives are possible.

Surfaced areas should basically be provided for higher precipitation periods and non-surfaced areas for drier periods. When planning the size of the area, it should be considered that areas are cleared during the growing season (e.g. green rye, whole crop, silage, corn silage) and can be used again for the following substrate. This could safe up to 25 % of floor space.

The calculation example (figure 2) compares the absolute requirement of space for bags with relative value. In this example the area required was reduced by 15% through restocking. The area required increases with the size of the

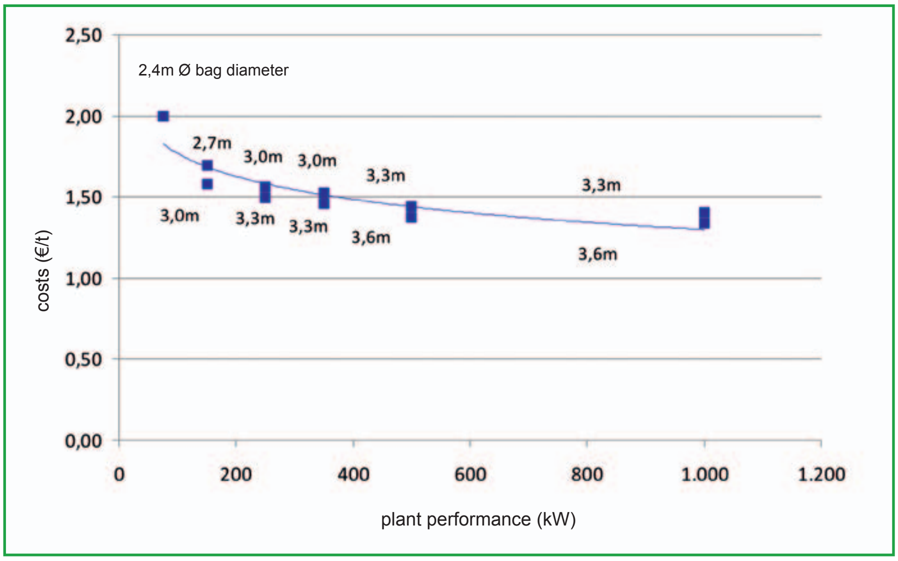

Figure 3: Film costs depending on the bag diameter for different plant sizes (75 m bag length)

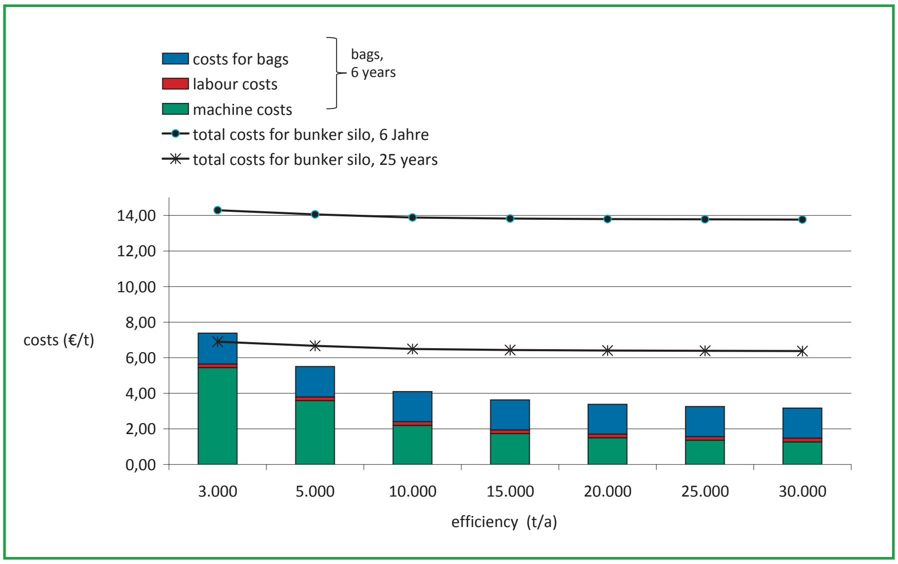

Figure 4: Process costs for bag technology (BUDISSA BAGGER RT 8000, depreciation period 6 years, interest rate 6% of half of the investment costs; 9' bag diameter, 75 m bag length; performance 100 t/h)

plant of up to 1.5 ha in the case of a 1 mw plant (storage of > 17,000 t corn). However, with regards to the total tonnage it decreases by 50% to 0.7 m²/ton. As a result, the costs for the area drop with the growing size of the plant and the bag size respectively.

By comparison, up to 0.85 ha are needed when planning a 4 meter high bunker silo. The relative floor space required is constant and compared to bags it is about 0.5 m²/t and average approximately the half of the required space for plastic bags. However, in case of small bunker silos and a low feed rate a height of less than 4m has to be assumed, which means an increase of the floor space required, in order to keep the feed rate, so that the difference of the required floor space between the silo bag and the bunker silo is smaller anyway. As well as with the floor space required also the costs for the plastic film per ton drop with growing plant performance and the recommended bag diameter (figure 3).

Whereas seven silo bags with a diameter of 2.4 m and a price of 1.99 €/t for storing 1,330 t corn (75kw) are required, these costs decrease with larger biogas plants that need 37 bags with a diameter of 3.6 m (1mw plant) down to 1.34 €/t. Tonnage, the difference, especially with big plants between bunker and bag concerning the costs is smaller. High demands are made on the quality of the plastic film due to the high mechanical load when at compression (tensile strength, elongation at break etc.). The demands are above the DLG-standard. The film thickness is at about 240 µm (according to the diameter of the bag). Film quality is more important than thickness.

Procedural costs

The following calculations are based on the use of the BUDISSA BAGGER RT 8000 for ensiling the required feed stock quantities.

When evaluating costs, first of all the depreciation period is important. Most investors in biogas plants answer that it should be not more than 6 years. On this basis the machine costs per ton for using the BUDISSSA BAG technology have been calculated. For calculating the investment costs (35 €/m³) for a bunker silo a period of 25 years as well as a period of 6 years (figure 4) were compared. The costs for a bunker silo with 4m height are based on the assumption that the compaction per ton is about 2.5 min. This value was set according to scientific investigations to ensure a maximum compaction. The compaction while using bunker silo is under discussion since the compaction performance isn't in accordance with the performance increase of today's forage harvesters. Quality deficiency are assessed increasingly and traced back to this fact. According to investigations made by the Chamber of Agriculture of Schleswig-Holstein over 80% of silages in bunker silos are under the recommended value. Similar results were observed in North Rhine-Westphalia. Technical recommendations for compacting concentrate on creating several silos with simultaneous ensiling and compacting or however, on intensifications of compaction by using e.g. vibrating rollers used for roadwork.

For covering the bunker silo with silo film and under-laying film costs of 0.40 €/m² and an expenditure of time of 1.4 MPmin/m² were calculated.

The costs for using the bagging technology decrease with increasing tonnages of down to 3.20 € at 25,000 to 30,000 t/a. Reasons are mainly based on the higher efficiency of the machine. By comparison, when using the bunker silo an increase in tonnages cause only minor cost savings, since the investment costs, the compaction effort and the film costs rise proportionally with every tonnage. In total, costs for a bunker silo are about 6.40 to 6.90 €/t which means even with 5.000 t/a the costs are higher than for ensiling in bags. A planning horizon of 6 years instead of 25 years would double the procedural costs while using the bunker silo.

Quality and losses

With the increase of costs, also dry matter (DM) and energy losses will be increasingly considered in economic terms. Losses of dry mass and energy are already created on the field (respiration and disintegration losses) and later during the fermentation due to a very slow pH-value reduction. In case of a too low level of DM-content (<30%) losses of silage liquor will occur.

Comparisons with the bunker silo show that sloping walls have to be preferred, because it could be confirmed the highest quality with the lowest losses using this type of procedure. The losses in the closed bag can be measured by using the so-called buried bag method. These bags are weighed during the feed placement and removal.

The quality of silages in bags has been investigated many times and is rated highly positive (table 4). Reasons for lowest losses during the fermentation result from a fast and safe closing of the bag and the absence of oxygen during the conservation process. In addition, quality is assured by a comparatively high feed rate. The consideration of these parameters will also reduce the costs in comparison with a bunker silo.

Table 4: Losses during the fermentation in the bag (according to Steinhöfel et al. 1998)

silage commodity	dry matter content (%)	dry matter loss (%)
pre-wilted silage	31	4
silo corn	33	5
wet grain	25	1
press pulp	22	2

Reported losses in the bunker silo show a large range and they are depending on the substrate about 10% with good management. Here it has to be distinguished between inevitable and avoidable losses which result of mistakes in management. For instance, with costs for a corn silage of about 30 €/t losses of 1% would cause costs of 0.30 €/t. The lower losses in the bag contribute to the preference of this procedure.

Flexibility is of great importance

To manage a biogas plant flexibility is of great importance. Prices for substrates influence the decision for the particular raw materials. Plants which are fed with grain had to be modified due to the developments in the grain market and the consequential high prices for grain. The changed sugar market regulations and the high yield of gas from sugar beets increase the demand for technical solutions for conserving the "biogas-beet".

The basic political conditions as well as the operational framework are not a rigor system over a long period of time. Finally, growth and harvest conditions influence the yield and storage capacities. Altogether, new findings on biogas generation will be made in the nearer future which could influence the choice of substrates as well.

There are six different bag diameters between 6.5' and 12' available on the market. Therefore filling amounts per metre of 2.00 tons to 7.50 tons can be realized. The choice of the right bag diameter depends on the daily feed rate. A smaller dairy farm could reach a high feed rate with a 8' bag where as a biogas plant (1 MW) could easily choose a 12' bag.

Preservation of sugar beets for biogas production

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Because of the high yield per hectare and a good fermentability a growing interest in sugar beets as a substrate for the biogas production can be noticed over the last 2 years. First practical experiences show a rapid gas generation and high specific gas yields. An optimum technology for storing and processing has not been found yet.

Sugar beets are only storable for a short length of time. Therefore conservation is necessary for a year-round availability. Furthermore they need to be cleaned and crushed before using them in the biogas plant. Stones have to be separated reliably, because there are no crushing devises that can deal with stones. Practically this can only be done in combination with the washing process. This means, that all beets freshly harvested or stored in a pile have to be washed before they go to the fermenter.

But how can the beets be conserved for the use in spring and summer and how should they be processed?

To find a practical solution for this question a cooperative experiment of several companies was launched in 2008. Aims of the trial were to find out whether to crush the beets first and than store them or vice versa. How to preserve the potential gas formation? How high is the gas yield of fresh and conserved beets?

To find answers on all these questions first pilot schemes with 215- litre barrels were launched. These barrels had a device to control the gas exchange and to drain the effluent.

Half of the barrels were opened at the end of March (after 4.5 months), the other half in August after 9 months. Evaluation criterions were the amount of effluent, fermentation losses during storage and during removal of the silage as well as the methane accumulation potential of fresh and preserved sugar beets.

WEISSBACH suggested calculating the methane accumulation potential by using the content of fermentable organic dry matter based on a chemical laboratory analyses.

The principle of conservation through ensiling is the total exclusion of oxygen. Sugar beets in a silo release after the death of tissue cells a high amount of nutritive effluent which should be essentially utilized. This would require storage containers that are gas and water tight.

With a storage density of only 230 kg dry matter per m³ these containers would be unaffordable.

Fortunately the practical trials showed that sugar beets can also be ensiled in large plastic bags, even without being crushed beforehand. Therefore plastic bags can be used as cost-effective and gas tight silos. They even are water tight as long as they are undamaged. Only a small undiscovered leakage can cause the loss of the whole effluent. To reduce the risk of losses through uncontrolled discharge of effluent the accruing amount should be kept as low as possible. As our experiment shows (figure 1) whole sugar beets emit significantly less effluent. This amount can be kept in the bags much easier and can be drained after a few weeks of storage.

The enormous value of the effluent is shown in numerous analyses of the organic dry matter content and the methane accumulation potential (table 1). Unlike other biomass plants the organic dry matter of sugar beets consists mostly of water soluble sugar. This is the reason why the effluent is as valuable as the rest

Table 1: Contents of organic dry matter (oDM) and methane accumulation potential

substrate	oDM-content	methane accumulation potential	
	g/kg FM	l/kg oDM	m³/t FM
sugar beets, fresh in november	231 (226…236)	361 (360…361)	83 (82…85)
sugar beets stored in a pile until march	221 (218…225)	363 (361…364)	80 (79…82)
silage stored until august	212 (198…231)	383 (357…403)	81 (77...86)
effluent, undiluted	199 (177…214)	385 (374…410)	77 (68...80)

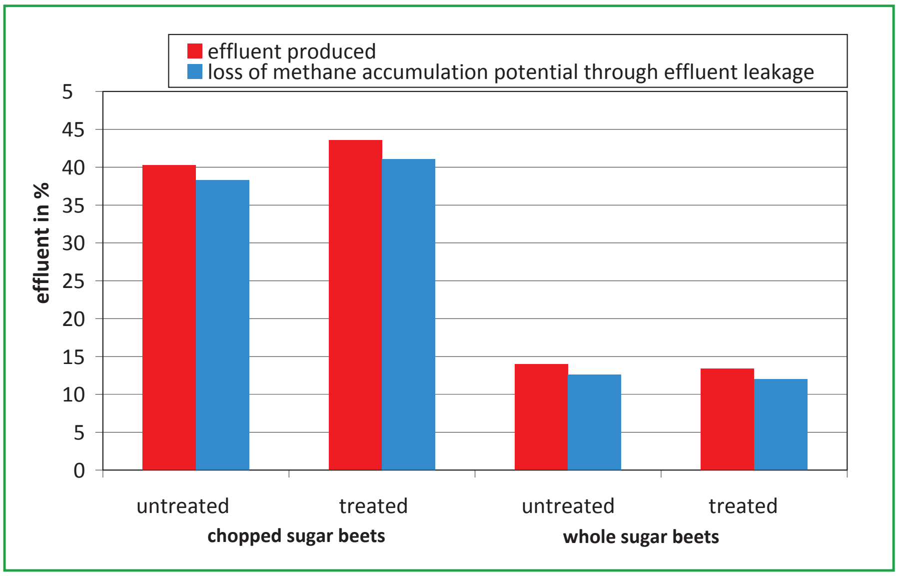

Figure 1: Effluent accrue and potential loss through effluent leakage after 9 months storage time

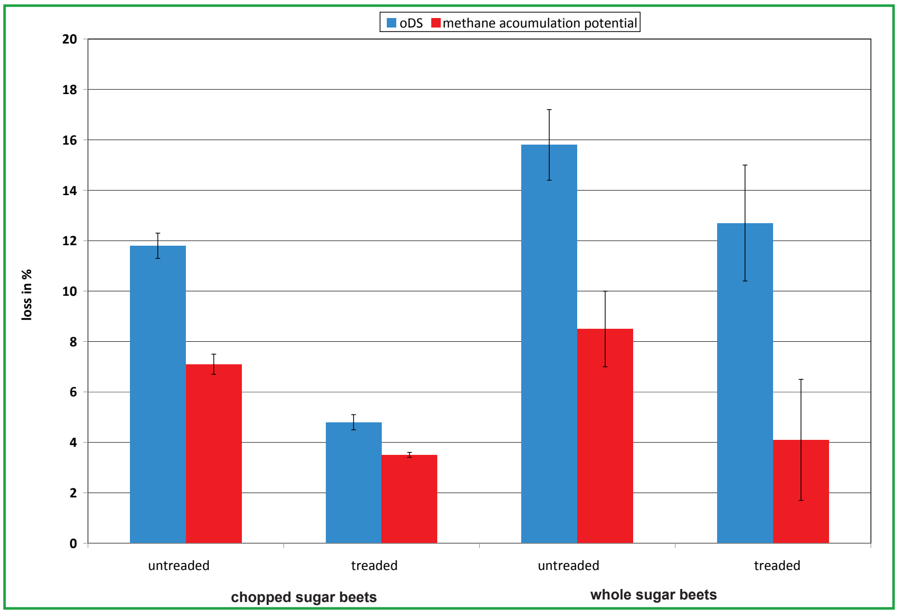

Figure 2: Losses though fermentation gas generation and remaining respiration with or without treatment of the sugar beets with KOFASIL®Stabil and 9 months of storage

Sugar beets after 4 months of storage in a plastic bag

of the beet silage. During ensiling the organic dry matter content of the silage decreases due to the fermentation gas generation. In the same process the specific potential gas formation per kg organic dry matter increases. This increase occurs, because the main fermentation product of sugar beet silage is alcohol.

Alcohol has more energy than sugar and therefore produces more methane. Based on the fresh matter, silage and effluent as well as fresh sugar beets produce the same quantity of methane.

It is also of great interest how much of the organic dry matter and methane accumulation potential is lost through the biological process in the silo. Even though the fermentation through yeast produces the high energetic metabolite alcohol, energy is used for this process. In spite of the good exclusion of oxygen there are still losses through rest respiration.

Therefore it was examined, if the microbial energy consumption could be reduced through using a chemical silage additive. For this purpose a liquid preparation with active agents

Storage of 320 tons of sugar beets (biogas plant in Algermissen, cooperative project with KWS)

that suppress yeast was used. The whole sugar beets were subjected to surface treatment with the additive. In the chopped beets the additive was admixed. The exact results of the fermentation losses are shown in figure 2.

It is obvious, that with ensiling whole sugar beets there are higher losses than with chopped beets. Reason for this is the volume of cavity between the beets, where oxygen is enclosed.

Processes of pressure balance between the volume of cavity and the atmosphere may also cause a small penetration of oxygen during a long storage period in the plastic bags.

The treatment with additives reduces the fermentation losses. The disadvantage of not chopping the beets with regards to these losses can be compensated with the use of the additive. The loss of methane accumulation potential with additive was independent of the chopping almost equal and at a very low level.

Another critical situation for the preservation of the methane accumulation potential can be the time during take out, after the ensiling of whole sugar beets. After opening the bag the carbon dioxide in the cavities can drain out easily and is replaced by inrushing air. This can cause reheating with high nutrient losses. To reduce these losses the bag should be emptied within a few days especially in the summer time. The use of the silage additive can lead to improvement in this case, because it slows down the reheating significantly.

This could be proven in stability tests. For this test a whole sugar beet out of the bag was mashed and tested under defined conditions on its aerobic stability. The results are shown in figure 3.

For this test the whole beets had to be chopped to be tested under the standardized conditions therefore the reheating sets in much earlier than in a plastic bag with whole beets. Nevertheless the test shows the differences in sensitivity towards air between different types of silage. It is evident, that through the treatment with a silage additive the reheating of the ensiled sugar beets is retarded significantly and therefore a slower feed rate can be realized without risking higher losses of methane accumulation potential.

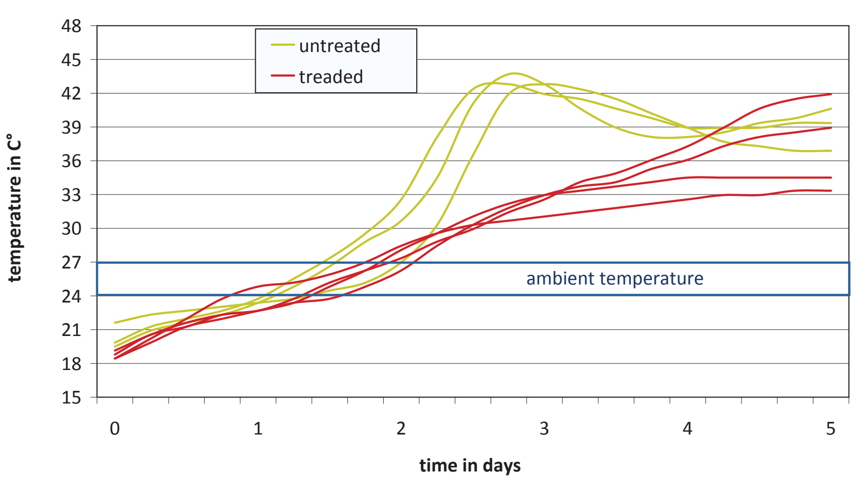

Figure 3: Influence of surface treatment of sugar beets with KOFASIL®STABIL on the heating of the silage with air access in the stability test

Conclusion

A stocking up sugar beets for longer than the month of March needs a minimal loss and cost-effective solution of conservation. One suitable possibility is the ensiling of washed and stone-free whole sugar beets in large plastic bags. An accurate effluent-management is essential for this process. All effluent has to be collected and exploited. The waiving of chopping the beets before ensiling reduces the effluent production considerably and makes it easier to handle the effluent. However it causes higher losses through fermentation, remaining respiration and a higher risk of reheating during the take out of the bag. Fermentation losses and secondary fermentation can be reduced effectively through surface treatment of whole sugar beets.

Technology: The storage of whole sugar beets in a plastic bag is done with a silo press for beets (BUDISSA PUSH BAGGER). It is filled over a charging hopper with telescopic loaders or overhead loading wagons. The beets are pushed with a push blade into the PE-bags with a diameter of 6,5' (PT 600) or 8' (PT 800). Amounts of up to 75 tons or 240 t per bag can be stored. That means 1,3 tons or 3,0 tons per metre respectively. The technical performance depending on the machine type is between 100 and 140 tons/hour. For take out a cutting clamp, front loader or other loading devices can be used. The necessary chopping can be done with an adapted roller mill, which is commonly used for moist grain. The storage costs for this flexible method are 4,50 – 6,00 EUR/ton.

Feeding of high-yielding cows with pressed beet pulp

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In recent years ensiling of press pulp was investigated again extensively. It has been proved that the conservation in silage bags, even over a long period of time (up to 18 months) represents the most cost-saving and low-loss procedure. This leads to the result that since its introduction in 1993/94 more than 1 million tonnes of press pulp across Europe have been stored in silage bags. Press pulp is successfully used to feed ruminant animals. Scientists of the National Institute for Agriculture in Iden analyzed the issue of what volume could be fed to high-yielding cows. Therefore, they carried out a feeding study with high-yielding cows (10,500 l milk performance).

Table 1: Comparison of different rations (PP: press pulp, CB: corn/barley) in feeding experiment (feeding proportions in % of DM)

feed	trial section 1		trial section 2	
	ration PP	ration CB	ration PP	ration CB
gras- and alfalfa silage	15,7	15,7	15,1	15,1
maize silage	24,4	35,7	19,8	34,1
hay, straw (1/2 : 1/2)	3,1	2,9	5,5	5
grinded husk silage and CCM	8	11	11,3	11,6
press pulp silage	20,8	-	26,4	-
barley, crushed	5,9	11	-	11,2
mixture of extraction meal	19,1	20,9	18,6	20
fat, glxcerine, minerals (1/3 : 1/3 : 1/3)	3	2,8	3,3	3
Values of contens				
dry matter (g/kg fresh matter)	384	465	381	494
energy (MJ NEL/kg DM)	7,2	7,2	7,3	7,2
raw fibre (g/kg DM)	165	146	173	151
starch and sugar (g/kg DM)	190	270	180	280
usable crude protein (g/kg DM)	168	169	169	169
ruminale N-balance (g/kg DM)	0,4	1,5	0	0,7

Table 2b: Costs and savings of feed by using press pulp

	costs		total net savings	
	€/t DM	€/ cow and day	€/ cow and day	€/ cow and day (300 lactation days)
21 kg press pulp	10	0,21	0,76	229
	20	0,42	0,55	166
	30	0,63	0,34	103

The aim was to compare the effects of rations with press pulp and corn and grain on the fresh and dry mass consumption and quantities of milk. In experiments up to 5 kg of dry matter (DM)-press pulp (21kg of fresh mass) were exchanged against grinded husk, barley and corn silage (Table 1).

Results

The results contradict claims that press pulp in the ration have a bad effect on structure. The investigations for both rations revealed

- the same level of milk performance
- the same content of fat and protein
- no health problems.

Table 2a: What was exchanged by using press pulp

exchanged by press pulp silage	costs	
	€/t DM	€/ cow and day
9,5 kg maize silage	35	0,33
1,7 kg grinded husk silage	100	0,17
1,6 kg barley	200	0,32
1,0 kg rapeseed/UDP	150	0,15
total		0,97

The feeding experiment confirms the recommendation of up to 22 kg press pulp silage per animal and day of high-yielding cows (DM about 5 kg/cow and day). In the case of press pulp rations the scientists could assess a higher fresh mass at a lower DM-intake while achieving the same milk yield. This shows an improvement in the DM-utilization by using press pulp. Considering the costs this results are of utmost importance. The use of the feed is greatly influenced by the price. In this connection, at the current grain and silage prices costs can be reduced significantly by using press pulp (Table 2a, 2b).

Using the conventional corn-grain-ration produces costs of 0.97 €/day, meanwhile costs for press pulp are about 0.21 €/day (for the same favourable stock price of 10 €/t) which leads to cost-savings of about 0.76 €/day. Even in the case of high costs with 30 €/t press pulp will be conducive to save costs.

As a result, press pulp represents definitely the most favourable feed concentrate at the moment with which it is also possible even with high-yielding cows to save on feed costs without adverse health effects.

Ensiling brewers' grains using the truck bagger

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Table 1: Nutrient contents of fresh brewer's grain (n=33)

	DM %	pH	crude ash g/kg DM	crude protein g/kg DM	crude fibre g/kg DM	crude fat g/kg DM	sugar g/kg DM	NEL MJ/kg DM
x	21,7	5,6	51,3	254,7	179,1	87,8	7,9	6,5
s	2,0	0,3	3,1	18,7	12,9	8,4	9,9	0,1

Brewers' grains are a protein-rich moist feed. Due to the low digestibility of organic substances they are used primarily for feeding cattle. Besides the high content of protein especially the rumens stability of the brewers' grains protein must be stressed out particularly (Table 1).

Fresh brewers' grains are, like other moist feed due to the high content of water, easily perishable.

Studies of brewers' grains taken from different breweries show, that brewers' grains leave the breweries mostly germfree, but still within one to two days during the exposure to air a deterioration process caused by moulds and yeast will take place (Figure 1).

If a fast feeding is not assured, the fresh brewers' grains should be ensiled as fast as possible after it arrives at the farm. For that open silage pits and horizontal silos have been used predominantly. So, when observing the general silage rules good silages can be achieved. Above all, cleanliness of the storage area and efficient work must be minded. Especially important is a quick and complete exclusion of air. Unfortunately, in practice this is not always observed. Hygiene standards are not respected and the silo stock is not closed speedy and hermetically enough. The result is spoiled silage and a turning away from ensiling brewers' grains anyway.

In 2004 the companies Beuker and RKW SE developed a new silage technology for wet brewers' grains - the so called truck bagging. The truck collecting the brewers' grains in the brewery is equipped with a special tunnel.

Thus, brewers' grains can be unloaded directly from the truck into the silage bag. This bag will be laid down and immediately hermetically closed. The trucker can do this all by himself and the farmer receives a complete silo of brewers' grains. This procedure assures a clean work and a fast exclusion of air which does not depend on the farmer's production process. In practice, truck bagging can be quickly established. In 2007 over 100,000 t of brewers' grains were ensiled in silage bags.

However, this relatively new technology requires a critical consideration of previous recommendations relating to the ensilage of brewers' grains. An extensive experiment is supposed to investigate this procedure in detail to derive recommendations for practice.

Microbial aspects

When leaving the brewery Brewers' grains have a temperature of about 60°C. Except of a few heat-resistant lactic acid bacteria all other germs are eliminated by the high temperatures during the procedures in the brewery. The risk of a following contamination with undesired germs is minimal using the truck bagging technology provided that the truck is clean. Without contacting the ground brewers' grains will end up directly from the truck in the silage bag which will be immediately closed hermetically after filling. The results of the experiments in table 2 confirm that with using this technology hygienic safe silages can be produced.

Silage liquor problem

Effluent which occurs during the ensiling of wet brewer's grain can not be compared to effluent that comes up through ensilaging of green forage. In fact it is connate water which accrues as process water after the lautering.

For the ensilage of brewers' grains in open silage pits or rather in a horizontal silo it is recommended to drain this silage liquor unhindered because a pond of silage liquor can have an adverse impact on the silage quality. Does this rule apply to the silage bag also?

To clarify this matter moist brewers' grains were ensiled in two silage bags by means of the truck bagger. One bag was laid down on a slightly tilted ground to provoke a silage liquor drain. Pipes on the bottom of the bag assured that the liquor was collected in a container. The second bag was laid down evenly and the silage liquor was kept in the bag. Using the fermentation-acid profile it could be concluded that the silage liquor can remain in the bag (Figure 2 and 3). A formation of butyric acid how it is described in other brewers' grain silages with problems with the silage liquor was not found in our investigation. This statement is important in terms of cross compliance. The silage liquor needn't to be drained permanently; it can remain in the bag until the extraction will take place.

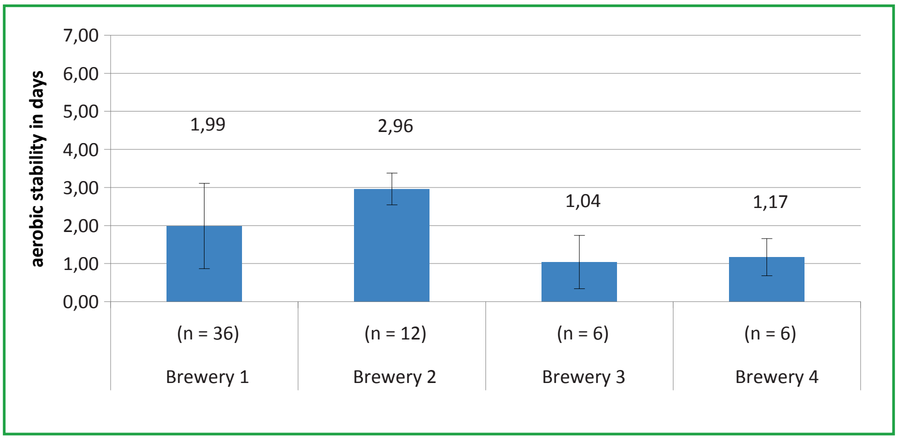

Figure 1: Aerobic stability of fresh brewer's grain out of different breweries

Table 2: Yeast and mould bacteria counts of brewer's grain

	summer trial (june–july 2006)			winter trial (february–march 2007)		
	sample size n	yeast CFU/g FM	moulds CFU/g FM	sample size n	yeast CFU/g FM	moulds CFU/g FM
brewery	6	0	0	3	0	0
ensiling	6	0	0	3	0	0
silage after 42 days	12	$1,3 \times 10^2$	0	6	$4,4 \times 10^4$	0

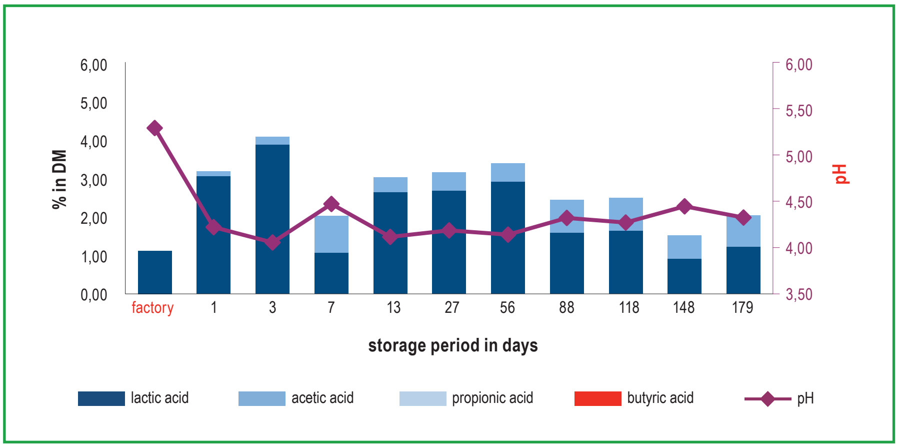

Figure 2: Fermentation acid pattern with effluent

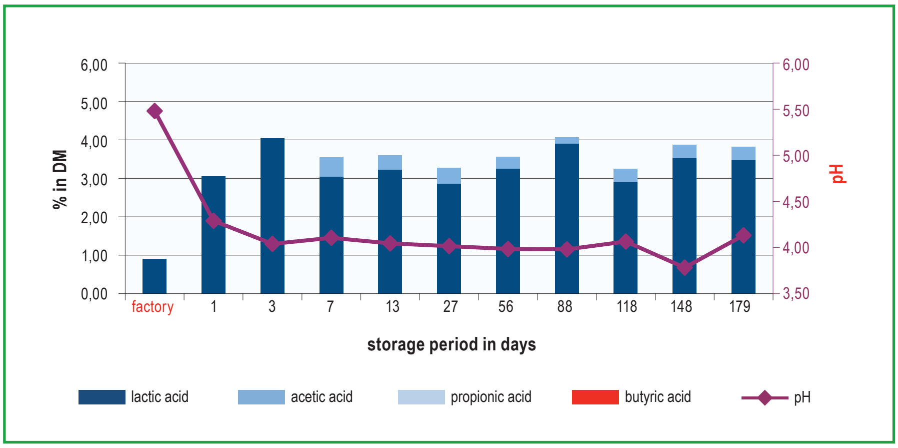

Figure 3: Fermentation acid pattern without effluent

Storage period

Coevally this investigation informs about the possible storage period of brewers' grains. It could be shown that under airtight conditions the quality of the brewers' grains silages even after 6 months of storage was very good. For open silage pits in the literature there is often a deterioration of the silage quality reported after 6 weeks. Defects may be caused during the ensiling process.

Opening the bag

Silages should only be opened when the main fermentation phase has ended. When using hot ensilaged by-products like brewers' grains or beet pulp the achievement of outdoor temperature level in the feedstock represents also a criterion. Thus, if the silo in the moment of opening is not yet cooled, undesired microbial processes take place.

Temperature measurements during the ensiling trials in summer and winter showed that the grain cooled down faster at low outdoor temperatures, but the span to achieve the outdoor temperature was comparable (fig. 3). Therefore, bags containing wet brewers' grains should be opened the earliest after two to three weeks. Against a too early opening argues the not - yet - compacted feed stock whereby the grains have not set yet and the gate won't be stable and fixed enough.

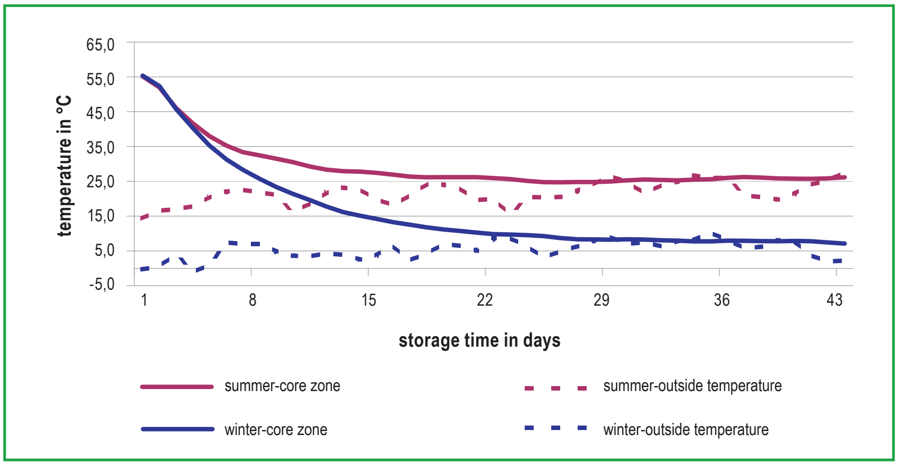

Figure 4: Temperature profile of brewer's grain

Loose parts will slip off and air can encroach deeper on the bag. If an insufficient feed occurs, deterioration is inevitable. After four weeks of storage the feed stock will be so compacted that during extraction a fixed and stable feed remains.

After opening the bag it must be minded that the aerobic stability of the brewers' grains silage only lingers one to two days.

It is well known that the stability to air of other silages can be increased through a longer anaerobic storage. This effect was not detected when using wet brewers' grains. The aerobic stability of silages of brewers' grains independent of the storage period was very low (Figure 4).

Conclusion

To sum up, when using the truck bagger wet grains can be ensiled successfully. The process minimizes the risk of contamination by yeasts and moulds. The observance of the main rules like clean working and fast exclusion of air is assured, regardless of the farm's production process. If an airtight storage by protection of the bags against damages is guaranteed, the silage may be stored for at least 6 months. Besides, silages liquor can remain in the bag and must pumped down not until the extraction. In case of a lower feed the bags should be opened soonest after four weeks.

The film quality of BUDISSA BAG-silage bags

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Only 15 years ago, the ensiling of fodder in bags still played a virtually insignificant role in agriculture. This applies to agricultural practices and also to applied research. Nowadays, in more than 20 European countries, 6 – 8 million tons of an extensive range of silage materials are compacted into bags. This development was accompanied by numerous scientific projects which resulted in a considerable increase in awareness.

The system is now well established and has been accepted. This can be justified on the one hand by the low investment costs per ton of silage and given the fact that silage bags pay for themselves quickly by the low investment risk. On the other hand and more importantly, bagging exhibits a range of advantages in terms of fermentation biology. As a reminder, there are no more aerobic filling phases, air is excluded quickly and more reliably, the cutting areas are reduced considerably and the losses compared to conventional processes in bunker silos are virtually halved. This has been proven not only for grass, alfalfa or silage maize but also for moist concentrates such as moist maize and moist cereals, compacted sugar-beet pulp, draff and compacted vinasse.

All previous scientific work concentrated in a one-sided manner on industrial measurements and on investigations into conservation success. Comparisons between different machines or between different films were scarcely made or made only on an empirical basis. Indeed, the film quality will have a considerable effect on the success of the process because the gas permeability or the UV stability of the expanded PE films contributes significantly to maintaining anaerobic storage conditions for example. Furthermore, the ratio of the film surface to the silage material is much narrower than it is in the case of high horizontal silos for example.

A thick film does not necessarily mean a good film

The first tests concerning the film-tube process in Germany were carried out back in the 1960s. At the time, the tubes were produced by the company Schleyer Polydress (subsequently BP Chemicals and nowadays RKW SE). These were bunker-silo films which were sealed at the base. Given that the tube-ensiling process failed to become established in Europe in the 1970s, there were no further developments in film quality. The patent for the process went to North America.

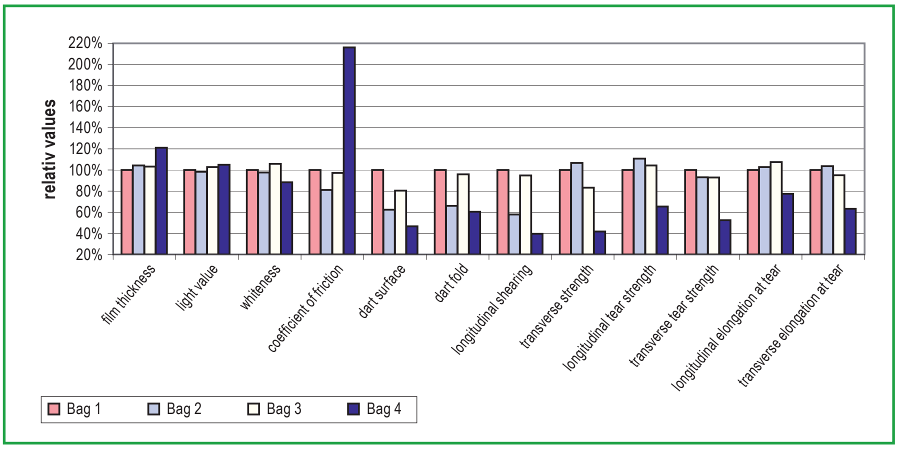

Figure 1: A relative comparison of selected parameters of 4 silo tube (Bag 1: Minimum standard of RKW AG 2009)

Only in 1993 did tube ensiling with the new tubes developed in the USA return to Europe. Logistics problems amid a growing market and the fluctuating price of plastics owing to oil prices later prompted European manufacturers to start producing tubes again. And also to develop them further. A great deal has been done since then. However, there was also a price to pay. Many tubes burst owing to inconsistent materials or owing to perforations during folding, not to mention the cases caused by the incorrect use of the presses. Any tube, regardless of how good it is, can be made to burst if machines are operated incorrectly.

Nowadays, tubes mainly comprise films which are white on the outside and black on the inside. The material is a mixture of different polyethylene raw materials such as low-density polyethylene (LD PE), linear low-density polyethylene (LLD PE) and metallocene-catalysed polyethylene (PE M). Furthermore, various additives such as colourings or additives to achieve UV stability are added. The mixtures of raw materials for silo tubes and bunker-silo films differ considerably owing to different quality requirements. Silo tubes, like bunker-silo films, are produced by extrusion in the blowing process and nowadays are mainly made up of three layers. However, whilst various quantities of recycled materials (production waste and secondary raw materials) are mainly used for bunker-silo films, only virgin materials, i.e. unused primary raw materials, are used for film tubes owing to the exacting quality requirements.

Unlike bunker-silo films for which DLG (German Agricultural Society) testing guidelines exist, there are currently no objective criteria for users to assess the quality of silo tubes. As a result, the thickness of the film is often used as a yardstick for the quality and gas permeability of the films. This may be entirely correct for bunker-silo films.

However, as demonstrated in Figure 1 in a practical example, the thickness of the film is a somewhat unsuitable parameter for a silo tube. Compared to bunker-silo films, totally different quality parameters are important and there are considerably more of these quality parameters. The diagram shows a number of the most important technical parameters for describing tube-film quality. The data are shown in the form of relative figures in order to provide a better overview.

It becomes clear that, in terms of the significant technical quality parameters, Tube No. 4 which is approximately 20% thicker does not come close to achieving the values of the standard tube which have proven necessary over the course of the development of the tube grades. Furthermore, the diagram shows that considerable differences in other parameters may nevertheless exist in films of virtually the same thickness (Tubes 1 to 3). The film thickness therefore cannot be used as the criterion. However, for the farmer, the problem remains that it is currently difficult to assess the film quality in any other way other than by using the thickness specified by the manufacturer. It appears all the more important to specify the objectively important criteria for users.

Technical film quality depends on a number of factors

Compared to bunker silos with side walls, the film surface of a film tube in proportion to the silo content is relatively large. Furthermore, owing to the compaction process of the silo press, there are high mechanical loads caused by compressive forces and tensile forces which barely occur in bunker-silofilms. As a result, the parameters elongation at tear, tear strength, shearing and drop impact take on a particularly great importance for silo tubes. Table 1 provides an overview of the DLG testing standards used when issuing the DLG seal of quality for a 200 µm thick bunker-silo film. In addition, for the purposes of comparison, minimum internal quality standards for a silo tube with a diameter of 2.70 m are contrasted. Considerable differences in the minimum requirements can be seen. Whilst a silo film with the specified technical properties can, as a rule, reliably protect silage for a year if used correctly, a silo tube must have considerably higher technical values owing to the specific requirement profile. The table also demonstrates that individual parameters such as dart drop impact and shearing do not represent test attributes for silo films but probably do play a role in assessing quality of the tube.

The first scientific model investigations into the temperature dependence of the load-bearing capability of silo tubes in various tube zones have recently become available. These models take into account the expansion of the silo tubes upon filling which is insignificant in the case of bunker-silo films (ATTILA et al. 2005). Colour (measured using light value and whiteness) plays a considerably more important role in silo tubes than it does in bunker-silo films. In summer, the tubes warm up and, as a result, expand. Lower whiteness can lead to increased warming and can cause the tube to tear owing to the high tensile and compressive forces. The coefficient of friction is also of great importance in film tubes. If it is too high, several film folds could slip from the tunnel very suddenly. The user must then make considerable additional efforts to push the film back onto the tunnel.

The UV stability of the film against the destructive effects of the sun's rays is usually underestimated. Even if one assumes that silos on average do not lie for more than 12 months, it is too risky to make this assumption for silo tubes. The highest standards provide stabilisation in Central Europe for 24 months and for a minimum of 18 months (NB: the intensity of the solar radiation depends on the location) which makes the film more expensive. Given that tubes, unlike bunker silos, are subjected to strong tensile and compressive forces, an early degeneration of the film can have a more dramatic effect and cause the tube to burst. The gas permeability of a film is strongly dependent on its thickness. Given that quality silo tubes with better raw materials are generally always thicker than 200 µm and that their gas permeability consequently exceeds the DLG test standards, this issue does not primarily apply. It may be appropriate to investigate any dependence on the expansion of

Table 1: DLG testing standards for silo film up to 200µm (DLG 1996, MOSCH 2002) and minimum internal standards for a 2.70 m film tube (WEBER and MEISE 2005)

parameter	unit	DLG standard	minimum standard	remarks
		bunker silo film	2,70 m bag	
raw materials-partially recycled		possible	none	
film thickness	µm	200	215	
deviation-nominal thickness	%	± 5	none	
deviation-individual values	%	± 15	± 12	
tear strength	N/mm²	> 17	> 23	
elongation at tear	%	> 400	> 750	
shearing	g	-	> 1800	
dart drop	g	-	> 800	method B
gas permeability	cm^3O_2/m^2	< 250	< 200	in 24 h
UV persistance	months	acc. to manufacturer	24	with 100 KLY

the silo tubes. However, such tests are still not yet available.

Film quality and technology ensure silage quality

The influence of film thickness and film colour on silage quality and losses is frequently discussed. Scientific tests with various film thicknesses (90 µm to 200 µm) and colours (white, black, green) revealed scarcely measurable influences on the silage quality of grass and maize in modelled bunker silos, not even directly under the film surface (SNELL et al. 2003). However, the temperature of the film surface and the silage lying directly beneath it was clearly dependent on the thickness and the colour of the film. In alfalfa round bales, a clear influence of the number of film layers (stretch film) on the silage quality was found, which indicates the minimum requirements for the film thickness (KELLER et al. 1997). It also becomes clear that methodical differences in tests of this type should be examined. However, the optimisation of thickness remains both an economic and an ecological issue.

Ultimately, reference is made to the peculiarities and specialist knowledge related to tube-ensiling technology which can be passed on only by qualified and trained members of staff and which must be constantly applied. This relates above all to the selection of the technology and the use of this technology when filling the tubes, the protection of the tubes during storage and the correct opening of the tubes and removal of the fodder. Management and detailed knowledge also play an important role in tube ensiling and must currently be expanded constantly.

Conclusion

Fodder conservation using film tubes

is being increasingly used throughout Europe, regardless of the size and structure of the operation. In contrast to bunker-silo films (DLG test standards), there are currently no minimum standards or assessment criteria for tube-film quality. The thickness of a film is only one criterion which, when considered in isolation, can lead to inaccurate assessments of film quality. The effects of different film-tube qualities on the silage quality should not be underestimated here. This should lead to demands to carry out comparative goods testing on the films in silo tubes in order to enable the farmer to make sound decisions when purchasing the tubes. Small differences in the prices of the films often make a difference of only around 0.1 to 0.3% based on the value of the fodder stored in the tube. Indeed, depending on the size of the tube and the type of fodder, fodder with a value of up to 100,000 EURO can be stored in a tube.

Composting in plastic bags – BUDISSA BAG technology in Sweden

Due to the waste recycling and management law biological waste has to be composted (conversion into organic fertilizer) or fermented, a landfill is not allowed.

The principle of composting is the decomposition of organic materials through micro-organisms under supply of oxygen.

In Scandinavia (Sweden, Denmark, Norway) the company COMPONORDIC SYSTEM uses the BUDISSA BAG technology (PUSH BAGGER PT 600/ PT 800) since 2001 on different composting sites. In comparison to the windrowing system the closed system has the advantage of less odour emission and also the costs are of great importance.

Technology and process regulation

With this method the bagger is filled over the filling hopper with the material (front loader) which is pushed into the bag afterwards. A high porosity of the material supports the composting process. Different from the conventional ensiling in plastic bags additional perforated aeration pipes (Ø 90 mm) are placed in the bag through aeration channels (PT 600 one aeration pipe/ bag, PT 800 two pipes). With an aeration blower and additional installed valves the composting process is regulated over the temperature. It is measured in the bag every hour on different positions in two different depths

The technical performance of this method depending on the material is 40-60 t/h (PT 600) and 80-140 t/h (PT 800). The compost bags are offered with 6.5' and 8' diameter. The bag length can be varied for both sizes and is in average 60 m.

Admixture of structural material

Composting in plastic bags is shown with the examples of two different composting sites in Sweden:

- Rangsell: On an area of 35 ha 7000 t/year are composted in plastic bags
- Composting site in Södertelje with approximately 16.000 t/year

The organic wastes (bio waste from households, sewage sludge, green property and waste wood) are separated from the normal residual waste in sorting sites. Afterwards it is mixed with structural material (wood chops, < 10% moisture) to raise the dry matter content and the porosity. The content of structural material (30 %) as well as the particle size depends on the material properties of the waste (Table 1).

The homogeneity of the mixture influences the progress of the conversion process.

The bags are placed on an asphalted ground with a slope of 3°. The aeration systems are installed at the upper end of the bag. Effluent is collected in channels. The cycle period depends on the moisture content of the materials and is in average 8-14 weeks. During this period the aeration first is slowly intensified with an automatic timer (maximum reached 3.-10.week) and afterwards lowered (from week 11).

Table 1: Table 1: Parameter for composting with the BUDISSA BAG plastic bag system

moisture content:	low (30%)	high (65%)
C/N	10	40
pH	5,5	8,5
O_2-content	5%	20%
particle size	5 cm	25 cm
composting period		
composting in plastic bags	8 weeks	20 weeks
further processing after bag opening	4 weeks	12 months

Process costs of the composting in plastic bags

The process costs include costs for floor space, machine costs, aeration costs and costs for bags (Table 2).

The floor space required depends on the cycle period. With periods of 10 weeks 5 cycles per year are possible where the area can be reused. Therefore a floor space requirement for bags of 0.2-0.3 m²/t can be calculated. The cost for surface pavement for bags are between 0.30 and 0.70 €/t.

The machine costs are calculated depending on the annual tonnage. With more than 5000 t/ year the PT 800 is recommended because of the larger bags and therefore less space requirement and higher technical performance (120 t/h in the example).

Besides the machine costs there are also costs for the aeration systems (one system for 2 bags). The plastic costs are generated from the storage quantities per bag and the tonnage per year.

A higher efficiency of the machine reduces the costs down to 5.30 €/t. Additional costs can accrue through the admixture of structural material and the sterilisation and purification of the waste.

Table 2: Costs of composting in plastic bags

machinetype		PT 600		PT 800	
bag diameter	m	1.95		2.40	
bag length	m	60		75	
tonnage	t/a	2,500	5,000	10,000	20,000
retention period	weeks	10 weeks		10 weeks	
storage quantity	**t/bag**	**100**		**200**	
number of bags per year	n	25	50	50	100
number of bags per cycle	n	2.5	5	5	10
area					
floor space required	m²/t	0.3		0.2	
area costs (20 €/m²)	€/t	0.7	0.5	0.3	0.3
machine costs					
investment	€	47,000	47,000	75,000	75,000
service life	a	6	6	6	6
depreciation	€/t	3.88	1.94	1.5	0.75
interest rate	€/t	0.58	0.29	0.23	0.11
operating costs					
(tractor, diesel, wage, repairs)	€/t	1.17	1.17	0.91	0.91
ventilation system	€/t	0.26	0.26	0.13	0.13
costs for bags	€/t	3.05	3.05	1.85	1.85
aeration pipes	€/t	1.26	1.26	1.26	1.26
turn over	€/t	0.33	0.33	0.33	0.33
total	**€/t**	**10.53**	**8.30**	**6.21**	**5.34**